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Inelastic Seismic Response Of Reinforced Concrete Buildings With Floor Diaphragm Openings

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SCHOOL OF ENGINEERING AND APPLIED SCIENCE

DEPARTMENT OF MECHANICAL ENGINEERING

AND MATERIAL SCIENCE

INELASTIC SEISMIC RESPONSE OF REINFORCED CONCRETE BUILDINGS WITH FLOOR DIAPHRAGM OPENINGS

By

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Prepared under the direction of Professors
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ABSTRACT

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Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls. Furthermore, they play a key role in distributing earthquake-induced loads to the lateral load resisting systems by diaphragm action. In reinforced concrete buildings, the in-plane flexibility of the floor diaphragms is often ignored for simplicity in practical design (i.e., the floor systems are frequently treated as perfectly rigid diaphragms). In recent building standards (ASCE-7, 2005), it is acknowledged that this assumption can result in considerable errors when predicting the seismic response of reinforced concrete buildings with diaphragm plan aspect ratio of 3:1 or greater. However, the influence of floor diaphragm openings (typically for the purpose of stairways, shafts, or other architectural features) has not been considered. In order to investigate the influence of diaphragm openings on the seismic response of reinforced concrete buildings; several 3-story reinforced concrete buildings are designed as a Building Frame System according to the International Building Code (2006). Each building is assumed to be in the Saint Louis, Missouri area, and it's analyzed using IDARC2, a non-commercial program capable of conducting nonlinear analysis of RC buildings with rigid, elastic, or inelastic floor diaphragms, under both static lateral loads (pushover) and dynamic ground motions (time-history), where a suite of three well-known earthquakes is scaled to model moderate ground motions in the Saint Louis region. The comprehensive analytical study conducted involves placing different opening sizes (none, 11%, 15% and 22% of total floor area) in various floor plan locations with respect to the location of the shear walls (located at end frames or at the interior frames), where three types of floor diaphragm models (rigid, elastic, and inelastic) are assumed. Building floor plan aspect ratios of 3:1 and 4:1 are investigated.

IDARC2 is enhanced by modifying the fiber model (strain compatibility) computation routine involved in obtaining the idealized moment-curvature curves of floor slabs with openings (symmetric and nonsymmetric). Also, a new option is added so that the user can over-ride IDARC2 idealized moment-curvature curves for slabs with openings and by defining their own. The results are then presented and discussed. It is concluded that in order to capture the seismic response of reinforced concrete buildings with floor diaphragm openings accurately; it is necessary to use an inelastic diaphragm model for floor diaphragm aspect ratio of 3:1 or greater. Thus, using a rigid diaphragm assumption, as specified by ASCE7-05 for buildings concrete floor diaphragms with aspect ratio of 3:1, and elastic diaphragm assumption, as allowed by ASCE7-05 for floor diaphragm with aspect ratio of 4:1, can result in significant underestimations of the lateral loads resisted by the interior building frames and building maximum frame displacements, particularly when the diaphragm openings are located in the middle two-thirds of the building plan. The base shear redistribution due to inelastic slab deformations increases the load subjected to the interior frames significantly. Hence, the influence of inelastic inplane diaphragm deformations due to floor openings cannot be overlooked in such buildings. Simple design recommendation is given for determining proper diaphragm chord reinforcement to prevent in-plane floor slab yielding when openings are present.

This dissertation is dedicated to my parents, wife, son and nieces. But most importantly my only brother, who taught me from childhood, that I can do anything I want.

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Mohamed T. AL HARASH, P.E., S.E.

Chapter 1

Introduction

Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls. Furthermore, they play a key role in distributing lateral loads by exhibiting diaphragm-like behavior. Hence, the structural behavior of horizontal diaphragms such as floors and roofs is often considered similar to that of an I-beam, where the flanges and the web resist bending and shear, respectively. Because floors systems (horizontal diaphragms) are typically deep beams with short spans, they have very high inplane stiffness and strength in comparison with other types of structural components and are often considered to be infinitely rigid in building structures if they were reinforced concrete (RC).

Cast-in-place concrete and concrete filled metal decks are normally considered rigid diaphragms unless their plan aspect ratio is greater than 3:1 (ASCE 7-05, [7]). The concept of rigid floor diaphragms for building type structures was introduced nearly 40 years ago as a means to simplify the solution process. In the case of rigid floor diaphragms, the floor plate is assumed to translate in plan and rotate about a vertical axis as a rigid body, the basic assumption being that there are no in-plane deformations in the floor plate. For diaphragms assumed to be infinitely stiff (rigid), the force distribution depends only on the relative stiffness between the vertical resisting elements. Another type of diaphragm is flexible diaphragm. These diaphragms are usually made of either plywood or un-topped light gage metal deck, where the lateral force distribution to the vertical resisting elements is based on tributary areas.

Openings in diaphragms for purposes of stairways, shafts, and other architectural applications cause stress concentration around these discontinuities. These openings can also reduce the stiffness of the diaphragm unless adequate reinforcement is provided. Diaphragms with openings are usually designed without stress calculations and are considered to be adequate ignoring any opening effects.

Past research [41, 42] has indicated that the distribution of lateral seismic forces is greatly affected by in-plane deformation of the floor diaphragms in rectangular buildings with end shear walls and moment resisting interior frames. This is particularly true when significant cracking and yielding occurs in the floor-slab system. Also, experimental and analytical investigations at the University of New York at Buffalo and Lehigh University [51] have clearly shown that cracking and even in-plane yielding of RC floor systems can be expected to occur in low-rise rectangular buildings with end shear walls and moment resisting interior frames when the plan aspect ratio exceeds 3:1. In these types of buildings, the collapse can occur after failure of the interior columns due to excessive strength and ductility demands caused by the in-plane behavior of floor diaphragms.

The collapse of Taiyo Fisheries Plant in Japan (a three story RC frame building with end walls) was observed to have followed this type of failure. The failure of the interior columns in the middle of the building was considered to be the cause of the collapse of the central portion of the structure although the end walls remained standing.

In this research effort all three types of diaphragms (elastic, inelastic and rigid) will be addressed in order to fully evaluate the effect of in-elastic diaphragm deformations on the seismic response of buildings with frames and shear walls. The inelastic dynamic response of the buildings will be evaluated using an enhanced computer program; IDARC2 [56], using a suite of earthquakes as the input ground motion. This program uses macro-modeling schemes to account for in-plane deformations due to shear and flexure in the diaphragm while considering stiffness deterioration, strength degradation, and bond-slip/pinching of the reinforced concrete beams, columns, shear walls and slabs due to inelastic cyclic loadings caused by the ground motion.

1.1 Motivation and Objectives

Although numerous publications have dealt with the behavior and design of concrete diaphragms, it is clear that there are several issues that have not yet been resolved.

Openings in diaphragms are often unavoidable and their presence can significantly modify the behavior of the diaphragm. At present, and in many cases the designer assumes that the diaphragm is a rigid element, totally ignoring in-plane deformations – an assumption that can lead to erroneous results. Nor is it satisfactory to assume that the diaphragm acts as a continuous elastic beam over the shear walls and frames running in the transverse direction for low-rise rectangular buildings with longer floor aspect ratios (greater than 3:1 ratio) without accounting for in-plane nonlinear deformation of the diaphragms. It is possible that the lateral load distribution of diaphragm inertia forces to the vertical frame elements may be compromised in a manner yielding an outcome contrary to what is assumed. This issue is considered vitally important, as it is the least understood subject in this area, since there is no quantification of the error in diaphragm and frame shears as a result of ignoring openings. Therefore, a systematic study of a set of carefully devised scenarios covering a spectrum of typical configurations is crucial where diaphragm in-plane deformations are incorporated in the analysis in order to capture the “real” behavior of the structural members as opposed to the “assumed” one.

Even though a total collapse of the diaphragm is unlikely to be the first major event in the failure of a building, a deterioration of its stiffness may result in a shift in the lateral loads distribution to the load carrying vertical elements causing some members to be overloaded resulting in a failure at that locality, thus jeopardizing the safety of the building structure and compromising the expected diaphragm action.

The proposed research will investigate the aforementioned issues in depth and will offer pertinent insights and better understanding of the structural behavior and design of RC buildings with floor diaphragm openings when subjected to strong ground motion.

The main goal of this research effort is to gain in-depth understanding of inelastic seismic response of rectangular RC buildings with diaphragms with openings through the following objectives:

1. To enhance IDARC2 [56] -developed in 1988- to account for RC buildings with diaphragm openings. Special attention will be given to the algorithms used in obtaining the in-plane idealized moment-curvature curves from the current fiber model.

2. To investigate the influence of estimated hysteretic parameters for slabs with openings.

3. To investigate the applicability of rigid floor assumption (neglecting their in-plane deformations) to modeling of floor diaphragms with openings of various sizes placed in symmetric and asymmetric plan locations. Also, to investigate the influence of floor diaphragms on the distribution of lateral loads among the frames and shear walls considering the floors' inelastic-in-plane deformations. This will result in establishing a criterion as to when floor diaphragm openings in earthquake resistance design of RC rectangular buildings with shear walls can be ignored.

Hence, by using a suite of actual earthquake accelerations as ground motion input for the dynamic analysis, the true behavior of the diaphragm will be better captured, which will lead to a deeper understanding of diaphragm behavior during a seismic event in RC buildings with flexible (elastic and inelastic) diaphragms with openings. It will also provide a timely and enhanced computational tool for the research community to use.

1.2 Organization and Outline

This dissertation is divided into seven chapters, followed by an Appendix. Chapter 1 gives a short background on the shortcoming and assumptions used by the structural engineering community in regards to rigid or elastic diaphragms with openings. It also covers the motivation behind this research effort, followed by the objectives.

Chapter 2 sheds light on all the previous literature to-date about diaphragms. Diaphragms of all types are looked into, plywood, reinforced concrete and metal decks.

Chapter 3 outlines the theory and assumptions governing the analysis, starting with the individual elements' model, followed by the global approach, including period determination, and the inelastic dynamic analysis.

Chapter 4 presents the different diaphragm models, design parameters and the building scenarios investigated. It also presents the proposed IDARC2 [56] enhancement to account for diaphragms with openings.

Chapter 5 will furnish the results of the analytical investigation described in Chapter 4 regarding the seismic response of the proposed buildings with diaphragms' openings including the influence of the estimated hysteretic parameters of slab elements.

Chapter 6 provides the discussion of all obtained results, and in Chapter 7, a summary of the findings, important conclusions, and suggestions for future research needs are presented. Appendix A contains the accepted doctoral proposal, followed by all published papers pertaining to this research and a sample IDARC2 [56] input and output file. Finally, quoted references are listed, followed by the Vita.

1.3 Major Research Contributions

The major research contributions of this research effort can be summarized as follows:

1. Enhanced/modified IDARC2 [56] source code so that (i) the fiber model module and the corresponding procedure used to obtain the idealized in-plane moment-curvature curves for slab elements with openings (with symmetrical cross-sections) is conducted accurately; and (ii) to provide the user with the capability to define the idealized moment-curvature curve for any type of slab elements (i.e., with or without openings, and having a symmetric or asymmetric cross section).

2. Investigated the influence of openings in floor diaphragms on the inelastic seismic response of reinforced concrete buildings including inelastic in-plane diaphragm deformations and subsequent redistribution of the lateral loads to frames and shear walls.

3. Examined the influence of the estimated slab hysteretic parameters involved in the analytical study floor diaphragms with openings.

4. Identified the limitations of the current building codes in the context of reinforced concrete slab diaphragms when openings are present, and provided analysis/design suggestions to practicing structural engineers on addressing this deficiency in the building codes.

Chapter 2

Literature Review

In this chapter, available literature to date will be reviewed and addressed by area. Although there has been a lot of work done in the area of diaphragms - ranging from analysis assumptions to design recommendations - none provide in-depth understanding of the seismic response of reinforced concrete (RC) buildings with floor diaphragm openings. Nor any research was done in order to provide simplified guidelines for analysis and design of such buildings as desired by the structural engineering community. In the present study, the applicability of rigid, elastic and inelastic floor diaphragm models for RC buildings with floor openings is investigated and some suggested design recommendations are provided.

2.1 National Building Codes Criteria

International Building Code (IBC) 2006 [28], Section 1616.5.1, requires the diaphragm with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50 percent of the gross enclosed diaphragm area, or change in effective diaphragm stiffness of more than 50 percent from one story to the next, to be considered as irregular in plan. For structures with this diaphragm discontinuity, the code prescribes an increase of 25 percent in the design forces determined for connections of diaphragms to vertical elements and to collectors, and for connections of collectors to the vertical elements. The code does not ascribe any criteria pertaining to the diaphragm design itself.

As for the area of steel design, American Institute of Steel Construction (AISC) Steel Design Guide No.2 [5] shows some insight into designing steel beams with web openings. Unfortunately, it cannot be extrapolated to concrete diaphragms, since its theory is calibrated using experimental results for steel beams only.

However, in the area of concrete design, American Concrete Institute (ACI) Building Code, ACI 318-08 [2], Section 11.11.6, addresses the effect of an opening on slabs in local terms. It restricts opening size in column strips and limits the allowable maximum openings size in middle strips. The interrupted reinforcement by an opening must be placed at one-half on each side of the opening. ACI 318-08 [2] does not address the overall effect of an opening on the floor. This reinforcement replacement criterion has no restriction on the opening size as long as it is within the prescribed column and middle strips requirement.

ASCE 7-05 [7], Section 12.3.1.2, and the Guide to the Design of Diaphragms [60] permits diaphragms of concrete slabs or concrete filled metal decks with span-to-depth ratios of 3:1 or less in structures that have no horizontal plan irregularities to be idealized as rigid, otherwise, the structural analysis shall explicitly include consideration of the stiffness of the diaphragm without explaining how.

2.2 Structural Concrete Members with Web Openings

In the field of concrete beams with web openings, Nasser et al. [49], Mansur et al. [47] and Abdalla & Kennedy [1] shed light on how an opening in rectangular RC or pre-stressed beams affects stress distributions and capacity of a concrete beam. Unfortunately, the theory provided was calibrated against available experimental results with no proof that it can be extended to include other configurations. Kato et al. [39], Taylor et al. [63] and Daisuke et al. [19], investigated the design of RC shear walls with one opening. Again, the results were only applicable to the pertinent cases.

Other studies were conducted in the area of concrete panels, in particular in the area of buckling. Swartz & Rosebraugh [61], Aghayere & MacGregor [4], and Park & Kim [52] addressed buckling of concrete plates under combined in-plane and transverse loads.

Since concrete diaphragms can be considered as concrete plates with beams as web stiffeners, this buckling approach does not address openings.

2.3 Seismic Behavior/Design of RC Buildings with Flexible Diaphragms

Other available literature is in the area of seismic behavior of RC buildings are summarized in this section. ACI Committee 442 [3] provided a summary of available methods to date for designing buildings to resist lateral loads. Although the report provided a compact reference, it did not touch upon openings and their effects on diaphragm design. Aktan & Nelson [6] simulated real-life seismic response of RC structures by experimentally testing scaled down prototypes of two existing buildings. Despite the fact that the proposed analytical models accurately simulated two existing buildings, diaphragm opening effects were not incorporated.

Button et al. [15] investigated the influence of floor diaphragm flexibility on three different types of buildings; large plan aspect ratio, three-winged (Y-shaped) and separate towered. Regardless of the insight given into how lateral force distribution differs from rigid to flexible diaphragms, openings were not considered. Basu [11,12], Jain [30, 31, 32, 33, 34, 35] and Tao [62] had analyzed different types of structures ranging from V-shaped, Y-shaped to long and narrow buildings. Though these studies proved to be conducive to understanding the dynamics of such structures, they did not address the effects of diaphragm openings.

Kunnath et al. [41] developed a modeling scheme for the inelastic response of floor diaphragms, and Reinhorn et al. [56] and Panahshahi et al. [51] verified it, using shake-table testing for two single-story RC, 1:6 scaled model structures, nonetheless, opening effects were not incorporated in the model and the proposed model's ability to account for in-plane diaphragm deformations, confirmed the possibility of building collapse, as a result of diaphragm yielding for low rise (one-, two-, and three-story) rectangular buildings with end shear walls and building plan aspect ratio greater than 3:1. Nakashima et al. [48] analyzed a seven story RC building using linear and non-linear analysis concluding that the inclusion of diaphragm flexibility did not significantly change the actual period of the structure and the maximum total base shear. Effects of diaphragm openings were not part of that analysis.

As for the domain of diaphragm performance-based design, Anderson et al. [8] developed analytical models using commercial computer programs, SAP 2000 [17] and ETABS [18] to evaluate the seismic performance of low-rise buildings with concrete walls and flexible diaphragms. Again, openings were not part of the models devised. Barron & Hueste [10] evaluated the impact of diaphragm flexibility on the structural response of four buildings having 2:1 and 3:1 plan aspect ratios and were three and five stories in height, respectively. The building diaphragms did not yield and the buildings in question did not have diaphragm openings. Hueste & Bai [27] analyzed a prototype five-story RC frame office building designed for the mid-1980s code requirements in the Central United States. Recommending an addition of shearwalls and RC columns jackets led to decrease in the probability of exceeding the life safety (LS) limit state. Unfortunately, retrofitting recommendations were specific to this structure only and no diaphragm opening effects were looked into.

Kunnath et al. [42] developed an analytical modeling scheme to assess the damageability of RC buildings experiencing inelastic behavior under earthquake loads. The results of the response analysis, expressed as damage indices, did not give any regard to diaphragm openings. Jeong & ElNashai [36] proposed a three-dimensional seismic assessment methodology for plan-irregular buildings. The analysis showed that plan-irregular structures suffer high levels of earthquake damage due to torsional effects. The analysis also proved that normal damage monitoring approaches might be inaccurate and even unconservative. However, the assessment did not account for diaphragm openings.

Ju & Lin [37] and Moeini [46] investigated the difference between rigid floor and flexible floor analyses of buildings, using the finite element method to analyze buildings with and without shear walls. An error formula was generated to estimate the error in column forces for buildings with plan symmetric arrangement of shear walls under the rigid floor assumption. Although 520 models were generated, none dealt with diaphragm openings.

Kim & White [40] proposed a linear static methodology applicable only to buildings with flexible diaphragms. The procedure is based on the assumption that diaphragm stiffness is small compared to the stiffness of the walls, and that flexible diaphragms within a building structure tend to respond independently of one another. Although the proposed approach gave insight into the limitations of current building codes, it did not deal with diaphragm opening effects.

Other related research addresses the consequence of assuming a rigid floor on lateral force distribution. Roper & Iding [58] briefly examined the appropriateness of assuming that floor diaphragms are perfectly rigid in their plane. Two models were used, the first was for a cruciform-shape building and the second was for a rectangular building. Both models showed discrepancy between rigid and flexible floor diaphragm lateral force distribution. In particular, when shear walls exhibit an abrupt change in stiffness. Still, effects of openings on lateral force distribution were not explored. Tokoro et al. [65] replicated an existing instrumented three story building using ETABS [18] and compared the model's diaphragm drift to the code allowable drift and judged the structure to be within the code's given drift limit; without considering any diaphragm opening effects.

Saffarini & Qudaimat [59] analytically investigated thirty-seven buildings, establishing diaphragm lateral deflection and inter-story shears as a comparison criterion between rigid and flexible diaphragms assumptions. The analysis showed considerable difference in the diaphragms' deflections and shears. The investigation briefly addressed opening effects as part of other parameters being studied. It was concluded that an opening definitely decreased the floor stiffness, and hence increased the inadequacy of the rigid floor assumption. Easterling & Porter [24] presented the results of an experimental research program in which thirty-two full-size composite (steel-deck and reinforced concrete floor slabs) diaphragms were loaded to failure. The research major contribution was the development of a better design approach for composite floor systems and stressing the importance of deformed bars reinforcing to improve ductility and control cracking associated with concrete failure around headed studs. The recommendations were only pertinent to the cantilevered diaphragms tested and no opening effects were examined.

Lastly, in the area of precast concrete and parking structures, Rodriguez et al. [57] compared ASCE 7-05 [7] seismic forces to generated shake table forces for a particular systems in question without investigating openings. Lee & Kuchma [43] and Wan et al. [67] looked into precast concrete diaphragm parking structures accounting for the ramp cavity and diaphragm connections but ignoring slab out-of-plane property and its effects.

2.4 Behavior/Design of Plywood and Light Gage Steel Diaphragms

Different agencies and research groups have investigated analysis techniques and behavior of diaphragms. American Plywood Association (APA) research report 138 [64] has devised an approximate method for obtaining shear stresses at any point within plywood diaphragms and around openings.

The analysis assumes that a plywood diaphragm with openings behaves similar to a Vierendeel Truss. Chord elements between shear webs of the Vierendeel Truss are assumed to have points of contraflexure at their mid-lengths. Diaphragm segments outside the openings are analyzed first, and then segments around the openings analyzed second assuming no openings are present. The procedure is carried-out again with the openings considered. Finally the net change in chord forces due to openings is achieved by superimposing both results. This methodology though intuitive and does satisfy equilibrium conditions, is not altogether reliable. Faherty & Williamson [25] clearly stated that this method is a simple analytical approach with no experimental verification. Kamiya & Itani [38] investigated the APA method by horizontally test-loading three plywood-sheathed floor diaphragms designed to the same load. The tests conducted yielded diaphragm shear and deflection equations instead of the lengthy APA method for those three diaphragms; there was no indication on how their effort can be extended to include other configurations.

Philips et al. [54] studied how walls transverse to the loading direction in wood-framed buildings share lateral loads. The study shows that such interaction between transverse walls and plywood-sheathed diaphragms can go up as high as 25 percent; the percentage decreased with increasing applied load and no opening effects were investigated. Gebremedhin & Price [26] examined how plywood sheathed diaphragms distributed lateral loads to frames. Opening effects were looked at in a manner only to state that for walls with openings, the stiffness decrease is not linear with the opening size. For a 25 percent loss in frame area, the wall stiffness decreased by 17 percent and for a 50 percent loss in frame area the stiffness of the same wall decreased by 64 percent.

Carney [16] provided a bibliography on wood and plywood diaphragms research going back as far as the 1920's and virtually none addressed diaphragm openings. Peralta et al. [53] experimentally investigated in-plane behavior of existing wood floor and roof diaphragms in un-reinforced masonry buildings consistent with elements and connection details typical for pre-1950 construction. The outcome was design curves defining the relationship between the applied lateral force and the diaphragm mid-span displacement. Opening effects on diaphragm stiffness were not addressed either.

Itani & Cheung [29] introduced a finite element model to analyze the non-linear load-deflection behavior of sheathed wood diaphragms. The model is general and is in good agreement with experimental measurements. Nonetheless it is does not deal with openings and how to extend the developed model to account for them. Pudd & Fonseca [55] developed a new state-of-the-art analytical model for sheathing-to-framing connections in wood shear walls and diaphragms. Although the new model is unlike previous analytical models, being suitable for both monotonic and cyclic analysis, it did not account for the effects of openings on neither shear walls nor diaphragms.

Degenkolb [22] investigated pitched and curved timber diaphragms emphasizing that boundary stresses exist at any break in the sheathing plane and should be provided in the design of an efficient diaphragm - no opening effects were considered. Bower [13] published plywood deflection formulas under lateral loading, stating that they can be modified to apply to any diaphragm shape or loading pattern without giving examples.

Westphal & Panahshahi [66] used three-dimensional finite element models to obtain in-plane deformations of wood roof diaphragms and story drift due to seismic load for buildings with plan aspect ratio ranging from 1.2 to 1.6. The results obtained show that the predicted diaphragm deflections by the International Building Code (IBC) [28] are conservative. However, effects of openings on this conclusion were not investigated.

As for the area of light gage steel deck (or metal decks), Nilson [50] set the benchmark for all future experimental work in metal diaphragms. Although the full-scale tests were extensive, with emphasis on shear strengths and diaphragm deflections, openings effects were never addressed. Bryan & El-Dakhakhni [14] further developed Nilson [50] work to a more general theory for determining stiffness and strength of light gage metal deck. Nonetheless the theory developed did not account for diaphragm openings. Easley [23] focused on the buckling aspect of corrugated metal shear diaphragms. It was concluded that for most applications, buckling occurs when the number of fasteners is plenty so that localized failure at the fasteners does not occur. However, opening effects on diaphragm buckling were not looked into.

Davies [20, 21] developed a method to replace a metal deck diaphragm by a series of frame elements connected by springs. This method can also be extended to account for openings. A major disadvantage of this method is that results obtained are purely linear. Atrek & Nilson [9] established a non-linear analysis method for light gage steel decks. Results resembled closely available experimental data, nonetheless openings were not addressed and no insight was given on how to extend this method to cover diaphragms other than the tested ones.

Luttrell [44, 45] suggested a method to obtain shear stress distribution around an opening in metal deck diaphragms. The method developed would ratio the shear distribution around the opening by the percentage of diaphragm length lost parallel to the loading direction. A linear increase in shear concentration may be acceptable for metal decks but no evidence confirms that this method can be applied to concrete diaphragms.

Chapter 3

Theory and Modeling Used in IDARC2

Computer modeling has proven to be not only fast, but also a reliable means for structural analysis and assessment. With numerical modeling being used extensively in structural investigations as a more economical approach to expensive laboratory testing, a non-linear structural analysis program will be used for this research, namely IDARC2 [56], a non-commercial program that is available for the research community interested in the further development of diaphragm analysis and design. Main concepts used in IDARC2 [56] are highlighted here. Part of this research effort will be dedicated to enhancing IDARC2 [56] by obtaining the nonlinear flexural properties of slabs with openings as well allowing user-specified diaphragm properties. With these improvements incorporated -Chapter 4, Section 3- the enhanced IDARC2 will provide an effective nonlinear modeling tool for obtaining the seismic response of RC buildings carrying diaphragms with openings.

3.1 IDARC2 Component Framework and Modeling

A typical reinforced concrete building is modeled by IDARC2 [56] using the following six element types: 1) beams, 2) columns, 3) shear walls, 4) floor slabs (elastic, inelastic, and rigid), 5) edge columns and 6) transverse beams as shown in a discretized section in Figure: 3-1.

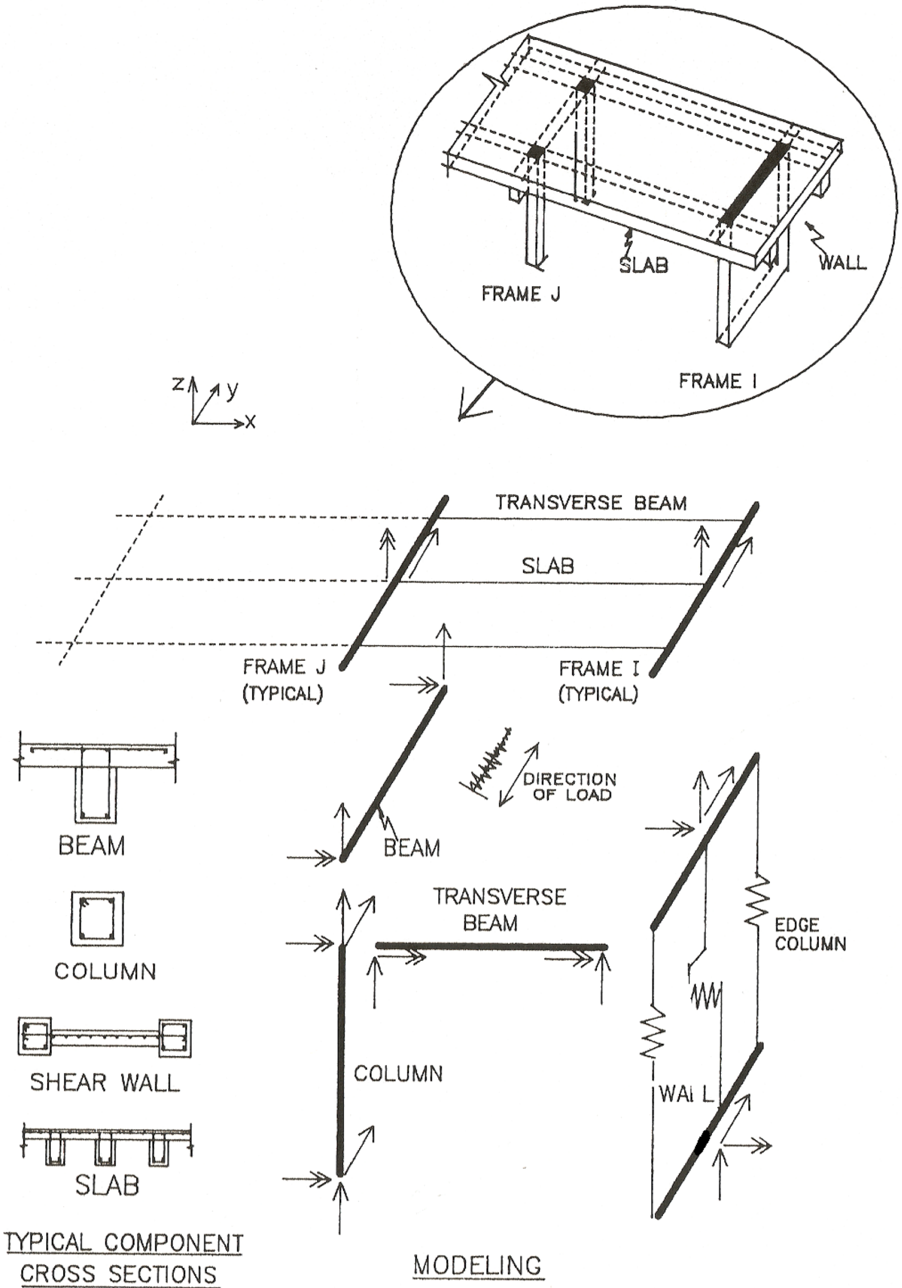


Figure 3-1: Typical Structure and Component Modeling [42]

3.2 Structural Elements Modeling

For the purpose of dynamic analysis, floor and frames masses are lumped at the floor level. While the beams and columns are modeled as continuous equivalent shear-flexure springs. The floor slabs and shear walls are modeled using a pair of shear and flexure springs connected in series. Inelastic axial springs are used to model edge column elements separately. Transverse elements are connected and modeled using elastic linear and rotational springs - contributing to the stiffness of the building – will have an effect on both the vertical and rotational deformation of the shear walls and the main beams.

Distributed Flexibility Model (DFM) – In order to account for the spread of plasticity at member's ends; a distributed flexibility approach is used for modeling the inelastic behavior of beams, columns, floor slabs and shear walls. In Figure 3-2, the flexibility factor, 1/EI, is linearly distributed along the member's length between the point of contraflexure and the two critical sections at the ends. Throughout the analysis, the flexural factors at the critical sections are monitored in order to update the inelastic behavior of the components during the load history. The inelastic distributed flexibility model is illustrated in Figure 3-2.

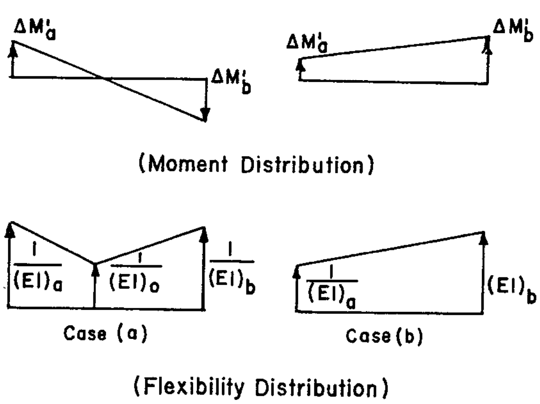


Figure 3-2: Distributed Flexibility Model [42]

3.3 Flexible Floor Slab Diaphragm Models

A comparison can be made between the diaphragm action in floor slabs and the action of shear walls placed in a horizontal position. Hence, if a slab is modeled as a horizontal shear wall, its response to in-plane loading would be captured accurately. A major difference arises; however, while the response of shear walls to vertical loads is planar tension or compression, the behavior of floor slabs to vertical loads is out-of-plane bending, resulting in a more complicated response. This response to out-of-plane bending is adapted on the basis of available experimental results [41].

A typical floor slab element connecting two parallel frames is shown in Figure 3-3. Two degrees of freedom (DOF) per node are assumed: an in-plane rotation, θ, and a lateral translation, u.

Linear variation of flexibility is assumed in deriving the flexibility matrix for all component of the building, with the exception of transverse beams.

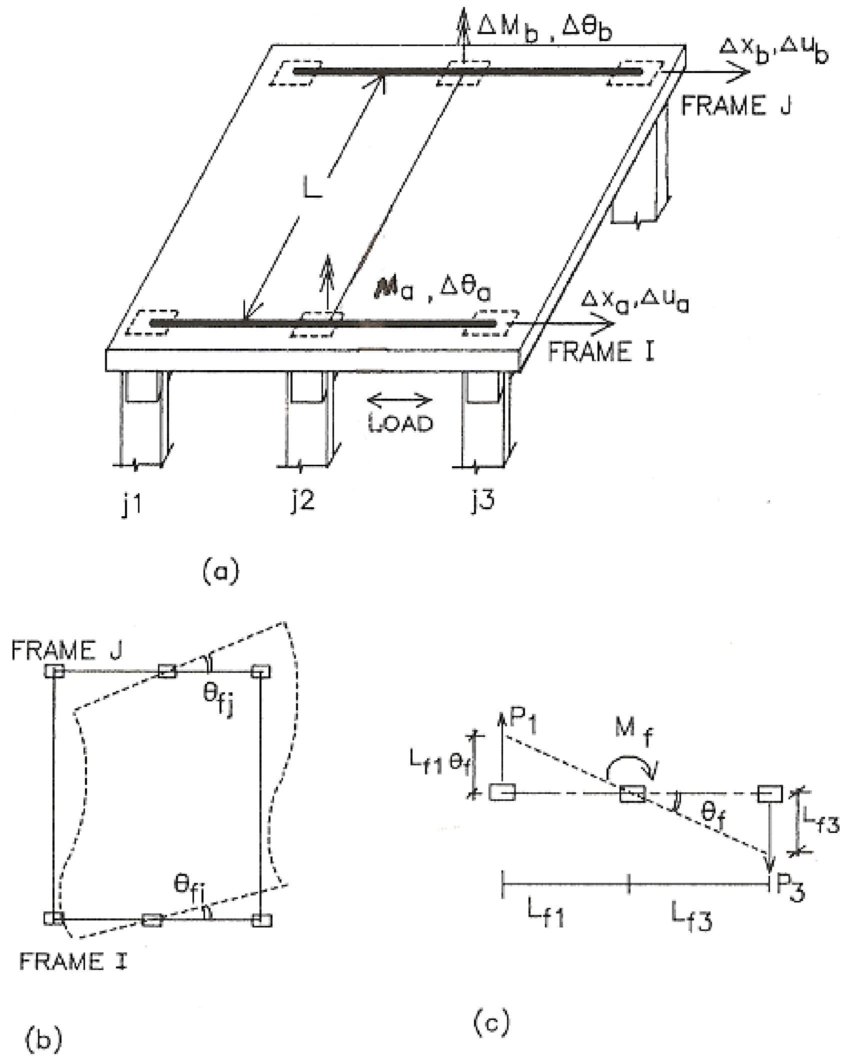


Figure 3-3: Details of Slab Modeling [42]

The incremental moment-rotation relationship is established from the integration of the M/EI diagram. Two possibilities arise, depending upon the location of the point of contraflexure (Figure 3-2).

Hence:

$$\begin{Bmatrix} \Delta\theta_a \\ \Delta\theta_b \end{Bmatrix} = \left[f_s \right] \begin{Bmatrix} \Delta M_a \\ \Delta M_b \end{Bmatrix} \qquad \text{[Eq. 3-1]}$$

where the flexibility matrix $[f_s]$ is given by:

$$[f_s] = L\begin{Bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{Bmatrix}$$ [Eq. 3-2]

For the case where the contra-flexure point lies within the element (case a):

$$f_{11} = \frac{1}{12(EI)_a}(6\alpha - 4\alpha^2 + \alpha^3) + \frac{1}{12(EI)_b}(1 - 3\alpha + 3\alpha^2 - \alpha^3) + \frac{1}{12(EI)_o}(3 - 3\alpha + \alpha^2)$$ [Eq.3-3]

$$f_{12} = f_{21} = \frac{1}{12(EI)_a}(-2\alpha^2 + \alpha^3) + \frac{1}{12(EI)_b}(-1 + \alpha + \alpha^2 - \alpha^3) + \frac{1}{12(EI)_o}(-1 - \alpha + \alpha^2)$$ [Eq.3-4]

$$f_{22} = \frac{1}{12(EI)_a}\alpha^3 + \frac{1}{12(EI)_b}(3 - \alpha - \alpha^2 - \alpha^3) + \frac{1}{12(EI)_o}(1 + \alpha + \alpha^2)$$ [Eq.3-5]

and for the case where the contra-flexure point lies outside the element (case b):

$$f_{11} = \frac{1}{4(EI)_a} + \frac{1}{12(EI)_b}$$ [Eq.3-6]

$$f_{12} = f_{21} = -\frac{1}{12(EI)_a} - \frac{1}{12(EI)_b}$$ [Eq.3-7]

$$f_{22} = \frac{1}{12(EI)_a} + \frac{1}{4(EI)_b}$$ [Eq.3-8]

where:

$$\alpha = \frac{\Delta M_a}{\Delta M_a + \Delta M_b} \qquad \text{[Eq.3-9]}$$

The inclusion of the inelastic shear spring in series with the flexural spring necessitates the following modification of the flexibility matrix,

$$[fs] = L\begin{Bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{Bmatrix} + \frac{1}{GA^*L}\begin{Bmatrix} 1 & -1 \\ -1 & 1 \end{Bmatrix} \qquad \text{[Eq.3-10]}$$

where G is the shear modulus, A^* is the effective shear area, and L is the length of the member under consideration. For slabs and shear walls, A^* is significant and cannot be ignored as in the case of beams or columns. Thus, for inelastic slab elements, Eq. 3-1 is rewritten as:

$$\begin{Bmatrix} \Delta\theta_a \\ \Delta\theta_b \end{Bmatrix} = [fs]\begin{Bmatrix} \Delta M_a \\ \Delta M_b \end{Bmatrix} \qquad \text{[Eq.3-11]}$$

3.4 Stiffness Matrix Development

The M-θ relationship has an inverse form of the flexibility relation of Eq.3-11:

$$\begin{pmatrix} \Delta M_a \\ \Delta M_b \end{pmatrix} = [k'] \begin{pmatrix} \Delta\theta_a \\ \Delta\theta_b \end{pmatrix} \qquad \text{[Eq.3-12]}$$

where $[k']$ is the inverted flexibility matrix.

From force-equilibrium:

$$\begin{pmatrix} \Delta X_a \\ \Delta M_a \\ \Delta X_b \\ \Delta M_b \end{pmatrix} = [R_s] \begin{pmatrix} \Delta M_a \\ \Delta M_b \end{pmatrix} \qquad \text{[Eq.3-13]}$$

where:

$$[R_s] = \begin{pmatrix} \left(\frac{-1}{L}\right) & \left(\frac{-1}{L}\right) \\ 1 & 0 \\ \left(\frac{1}{L}\right) & \left(\frac{1}{L}\right) \\ 0 & 1 \end{pmatrix} \qquad \text{[Eq.3-14]}$$

Hence, the stiffness equation for slab element is:

$$\begin{pmatrix} \Delta X_a \\ \Delta M_a \\ \Delta X_b \\ \Delta M_b \end{pmatrix} = [K_s] \begin{pmatrix} \Delta \upsilon_a \\ \Delta \theta_a \\ \Delta \upsilon_b \\ \Delta \theta_b \end{pmatrix} \qquad \text{[Eq.3-15]}$$

where the element stiffness matrix can be obtained by:

$$[K_s] = [R_s][k'][R_s]^T \qquad \text{[Eq.3-16]}$$

3.5 Frame Torsion Modeling

Any floor system that experiences twisting due to differential movement of slab edges undergoes inplane bending (Figure 3-3b). The relative stiffness of the horizontal to vertical structural systems affects the torsional resistance of the frames and the in-plane rotation of the slabs. In general, the effect of frames in restraining the floor slab system from in-plane rotation is very small and could be ignored.

Also, shear walls arranged perpendicular to the lateral loading direction could result in sizeable floor slab rotational restraint. This behavior must be incorporated in the structural analysis. Modeling of torsional restraint is accomplished in IDARC2 in the following manner:

A rotation of the slab system is assumed to take place about the center of the frame axis. For a rotation θ_f about the center, the frame moment M_f is given by:

$$M_f = k_f \theta_f \qquad \text{[Eq.3-17]}$$

The restraint provided by the columns due to the lateral deflection shown in Figure 3-3c is evaluated as:

$$P_i = 3\left(\frac{EI}{h^3}\right)_{fi} l_{fi}\theta_f \qquad \text{[Eq.3-18]}$$

where EI and h, refer to the flexural rigidity and height of the element respectively.

The stiffness coefficient is then determined for a unit rotation taking into account the total moment about the center of the frame axis:

$$k_f = \sum P_i l_{fi} \qquad \text{[Eq.3-19]}$$

where P_i is obtained from Eq.3-18 by setting $\theta_f = 1$.

3.6 Beam-Column Elements

With the beam-column elements forming a vertical plane in the direction of loading, they are modeled as simple flexural springs, with shear-deformation effects coupled by means of an equivalent spring. A typical element with rigid panel zones is show in Figure 3-4. The inclusion of rigid zones necessitates a transformation of the flexibility matrix as follows:

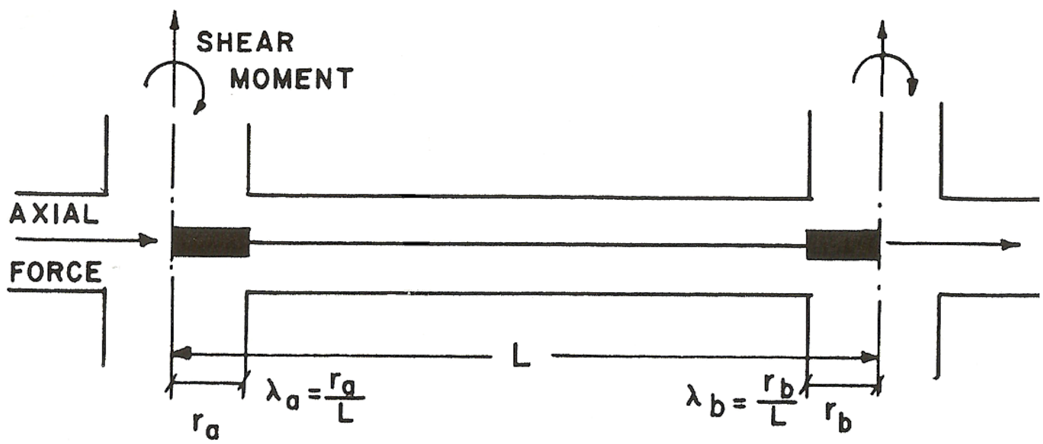


Figure 3-4: Typical Beam-Column Element with Degrees of Freedom [42]

$$[\bar{k}] = [B][k^{'}][B]^{T}$$ [Eq.3-20]

where:

$$[B] = \frac{1}{1-\lambda_a-\lambda_b}\begin{pmatrix} 1-\lambda_b & \lambda_a \\ \lambda_b & 1-\lambda_a \end{pmatrix}$$ [Eq.3-21]

3.7 Shear Walls and Edge Columns

The modeling of a shear wall element is similar to a floor slab except for the incorporation of edge columns at the wall boundaries (if they exist) and the addition of axial effects. The edge columns may be included only for strength computations for setting up envelope curves. The bending deformation of the wall element to be caused by the vertical movements of the boundary columns is allowed by the ability to treat each wall as an equivalent column with inelastic axial springs at the edges.

3.8 Transverse Beams

Each transverse T-beam is modeled using elastic springs with one vertical and one rotational (torsional) degree-of-freedom to incorporate the effects of transverse elements on the inplane response of the main frames, as shown in Figure 3-1. There are two types of transverse elements. First, are beams that connect to shear walls and the other are beams that connect to the main beams in the direction of loading. Contributions arising from the direct stiffness of these springs are added to the corresponding terms in the overall structure stiffness matrix. The purpose of modeling transverse beams in this manner is to account for their restraining behavior.

3.9 Fundamental Natural Period

The building structural system's fundamental natural frequency is calculated using the Rayleigh quotient method. The general form of the Rayleigh quotient is found by equating the maximum potential energy to the kinetic energy of the structural system:

$$\omega^2 = \frac{\{\psi^T\}[K]\{\psi\}}{\{\psi^T\}[M]\{\psi\}} \qquad \text{[Eq.3-22]}$$

Where [K] and [M] are the stiffness and mass matrix of the system, respectively, ω is the fundamental frequency, and $\{\psi\}$ is the shape vector of fundamental mode of vibration of the system. An inverse triangular lateral load is applied to the structure, and the magnitude of the base of the triangle is obtained from the distribution of floor weights to respective frames using the tributary area concept

Therefore, the application of Eq.3-22 is direct and in a discretized form, for a multi-story building, this may be written as:

$$\omega^2 = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} k_{ij}\Delta u_{ij}^2}{\sum_{i=1}^{N} m_i u_i^2} \qquad \text{[Eq.3-23]}$$

where N is the number of stories; M is the number of frames; u is the deflection; Δu is the relative story drift; and i & j refer to the story and frame number, respectively.

3.10 Three-Parameter Hysteretic Model

For the inelastic analysis, a proper selection of hysteretic models for the constituent components is one of the critical factors in successfully predicting the dynamic response under strong earthquake motions. A three-parameter hysteretic model is used in the inelastic dynamic analysis to duplicate the various aspects of reinforced concrete behavior under inelastic loading.

Through the combination of a tri-linear envelope and the three parameters, referred to as α, β, and γ, a variety of hysteretic properties can be achieved. The main characteristics represented by these three parameters are stiffness degradation, strength deterioration and pinching or bond slip, respectively (Figure 3-5). The stiffness degradation factor α specifies the degree of reduction in the unloading stiffness and the reduction in area enclosed by the hysteresis loops for consecutive loading cycles. The pinching factor γ reduces the stiffness of the reloading paths as well as the area of the hysteresis loops and the amount of dissipated energy. The strength deterioration factor β is the ratio computed as the amount of incremental damage caused by the increase of the maximum response divided by the normalized incremental hysteresis energy.

Appropriate combinations of α, β, and γ given in Table 3-1 below are used to achieve the hysteretic behavior observed in the experimental tests of typical reinforced concrete members.

Table 3-1: Hysteretic Parameters Used in Dynamic Analysis

Element	Stiffness Degradation Coefficient, α	Bond-Slippage Coefficient, γ	Strength Deterioration Coefficient, β	Post-Yielding Stiffness Ratio
Beam	4.00	0.80	0.01	0.015
Column	2.00	0.80	0.01	0.015
Wall Bending	3.50	1.00	0.15	0.015
Wall Shear	0.10	1.00	0.15	0.015
Slab Bending	2.50	0.80	0.15	0.015
Slab Shear	0.10	0.80	0.15	0.015

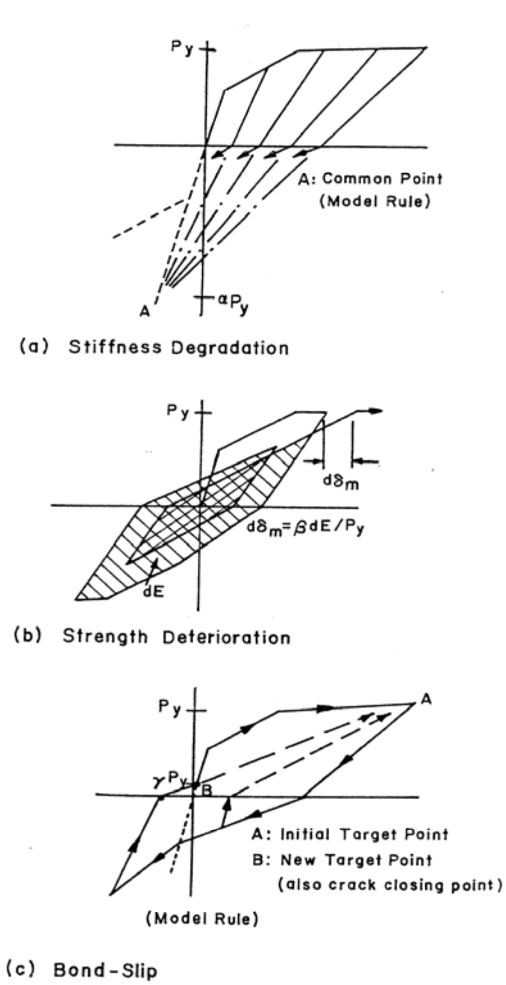


Figure 3-5: Three-Parameter Hysteretic Model [42]

3.11 Inelastic Static (Pushover) and Dynamic Analysis

After IDARC2 [56] initially determines the internal member forces due to gravity loads applied, by solving the following equilibrium equation:

$$[K]\{\Delta u\} = \{\Delta F\} \qquad \text{[Eq.3-24]}$$

where:

[K] = Assembled global stiffness matrix,

{Δu} = Required solution vector of incremental nodal displacement,

{ΔF} = Incremental load vector.

it proceeds with pushover (inelastic static) analysis and subsequently inelastic dynamic analysis. Then, the lateral load that is computed from the base shear coefficient using the following expression:

$$f_j = \frac{W_j h_j}{\sum_{i=1}^{n} W_i h} W_t^* \qquad \text{[Eq.3-25]}$$

is applied as an inverted triangular load applied to the building at every story, where:

Subscript j = Story level under consideration,

W = Floor weight,

h = Height of corresponding story from the base of the building,

W_t* = Factored total weight of the building,

n = Total number of stories.

IDARC2 [56] step-by-step dynamic response analysis involves the solution of the following equation of motion;

$$M\ddot{y} + C\dot{y} + Ky = F \qquad \text{[Eq.3-26]}$$

where:

F = Vector of effective loads resulting from earthquake ground motion,
M = Lumped mass matrix,
C = Damping matrix,
K = Stiffness matrix,
y = Relative displacement of the structure with respect to the ground, $\dot{y}$ is the relative speed and $\ddot{y}$ is the relative acceleration.

Expressing Eq.3-26 in an incremental format yields:

$$M\Delta\ddot{y}_i + C\Delta\dot{y}_i + K_i y_i = \Delta F_i \qquad \text{[Eq.3-27]}$$

The Newark Beta method is used to determine the solution of Eq.3-25. Using a constant average acceleration, the following equations are used to obtain incremental velocity and incremental displacement:

$$\Delta\dot{y}_i = \ddot{y}_i \Delta t + \frac{1}{2}\Delta\ddot{y}_i \Delta t^2 \qquad \text{[Eq.3-28]}$$

and,

$$\Delta y_i = \dot{y}_i \Delta t + \frac{1}{2}\ddot{y}_i \Delta t^2 + \frac{1}{4}\Delta\ddot{y}_i \Delta t^2 \qquad \text{[Eq.3-29]}$$

The solution of Eq.3-29 for $\Delta\ddot{y}_i$ and its substitution into Eq. 3-28 results in:

$$\Delta\ddot{y}_i = \frac{4}{\Delta t^2}\Delta y_i - \frac{4}{\Delta t}\dot{y}_i - 2\ddot{y}_i \qquad \text{[Eq.3-30]}$$

$$\Delta\dot{y}_i = \frac{2}{\Delta t}\Delta\dot{y}_i - 2\dot{y}_i \qquad \text{[Eq.3-31]}$$

The substitution of Eqs.3-30 and 3-31 into the incremental equation of motion, Eq.3-27 results in an equation to calculate the incremental displacement Δy_i namely:

$$K_i^e \Delta y_i = \Delta F_i^e \qquad \text{[Eq.3-32]}$$

where K_i^e and ΔF_i^e are defined as the effective stiffness matrix and incremental force vector, respectively. This method is unconditionally stable, and it yields accurate results when a small time interval (Δt) of 0.005 sec. or smaller is used in the dynamic analysis.

The numerical methodology involved in this research will involve studying the effects of various parameters of interest. Those parameters are:

- Floor rigidity type; namely, rigid, elastic or inelastic.
- Three parameters (α, β, γ) used in the slab hysteretic model for diaphragms with openings.
- Lateral member supports location; namely frames and shear walls.
- Opening size and locations.
- Floor-plan aspect ratio.

Chapter 4

Analytical Investigations of RC Buildings with Diaphragm Openings

In this research, 20 buildings where investigated, namely A1-9, B1-7, C1, D1, P1 and P2. All buildings were 3-story; 39 ft high (i.e., 13 ft story height) reinforced concrete buildings. All elements were designed and detailed to meet ACI 318-08 [2] and IBC 2006 [28] prescribed forces. The lateral force resisting system in both directions consists of “Building Frame System” in which ordinary shear walls will resist the entire seismic load while ordinary moment resisting frames will carry gravity loads. The equivalent lateral forces generated were based on a site class C, seismic design category (SDC) C and seismic use group I.

4.1 Geometry and Design

The structure’s plan was either twelve 20 ft bays in length (240 ft total) and three 20 ft bays in depth (60 ft total) – 4:1 plan aspect ratio, or nine 20 ft bays in length (180 ft total) and three 20 ft bays in depth (60 ft total) – 3:1 plan aspect ratio. Two symmetrically placed shear walls locations were investigated, at the ends (ESW) or in the middle (ISW). In all the cases investigated, 8 in. thick shear walls were placed at every floor level. The columns were 14 in. x 14 in. and the girders were 14 in. x 24 in. As for the floor slab diaphragm, it is a one-way 5 in. slab spanning across the frames with intermediate 14 in. x 14 in. supporting beams, i.e., 10 ft slab span.

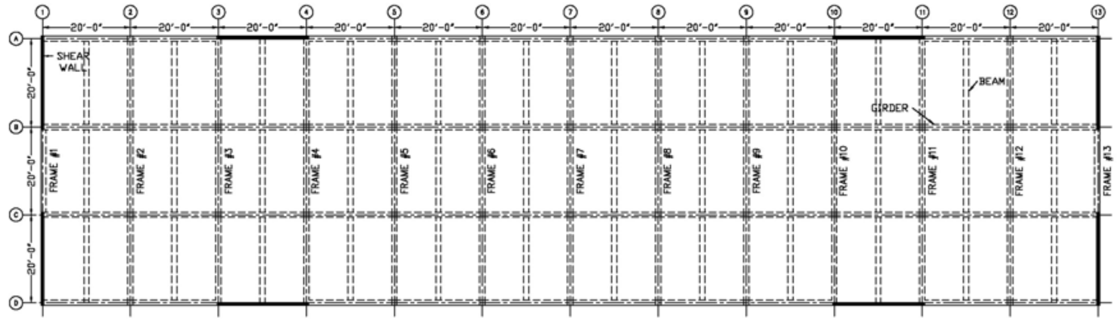


Figure 4-1: Building A1 Diaphragm Plan

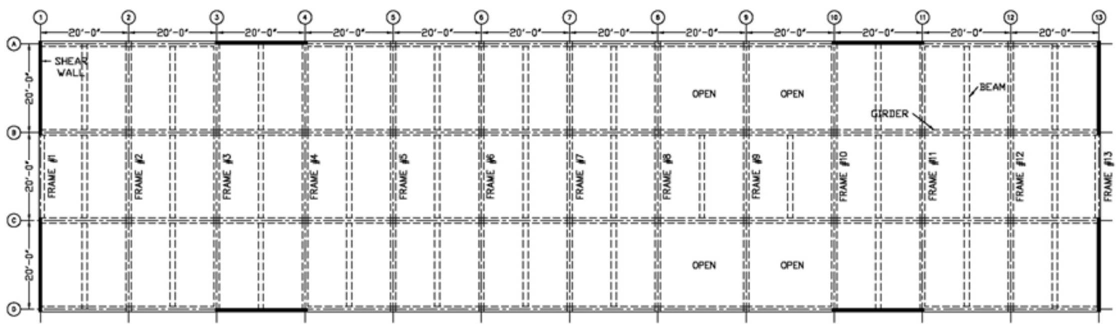


Figure 4-2: Building A2 Diaphragm Plan

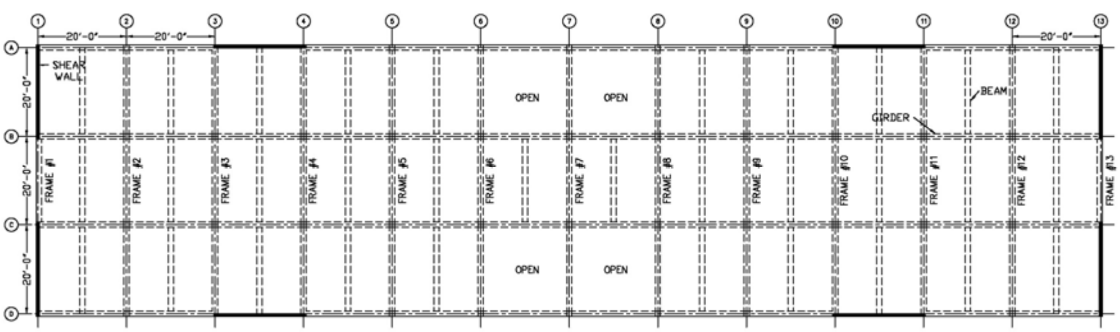


Figure 4-3: Building A3 Diaphragm Plan

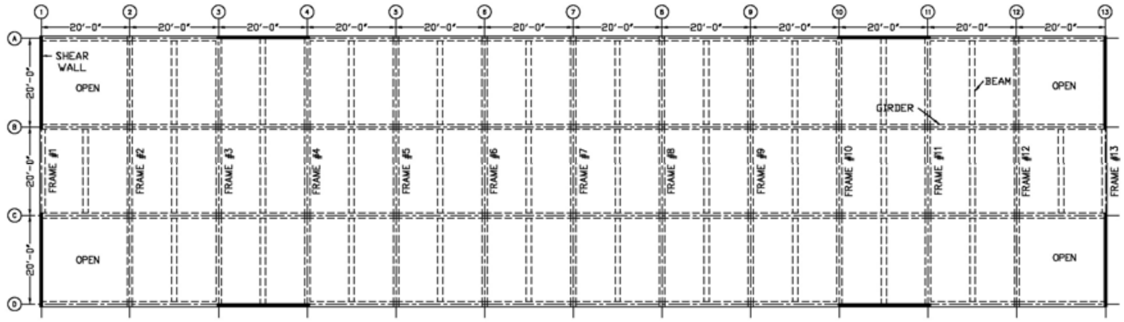


Figure 4-4: Building A4 Diaphragm Plan

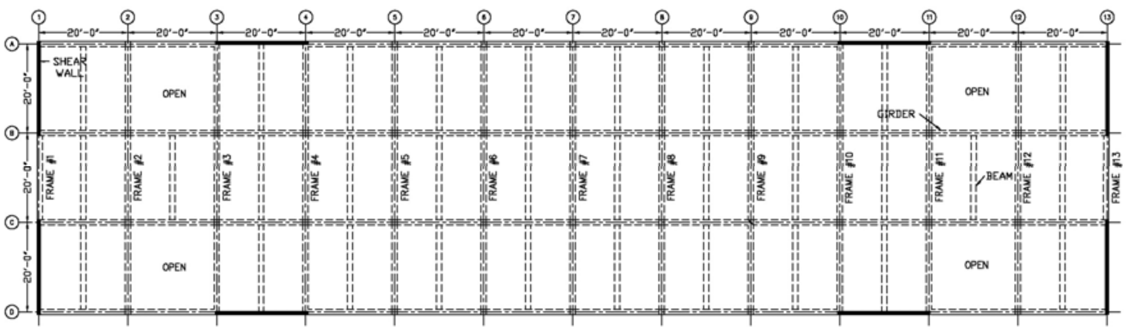


Figure 4-5: Building A5 Diaphragm Plan

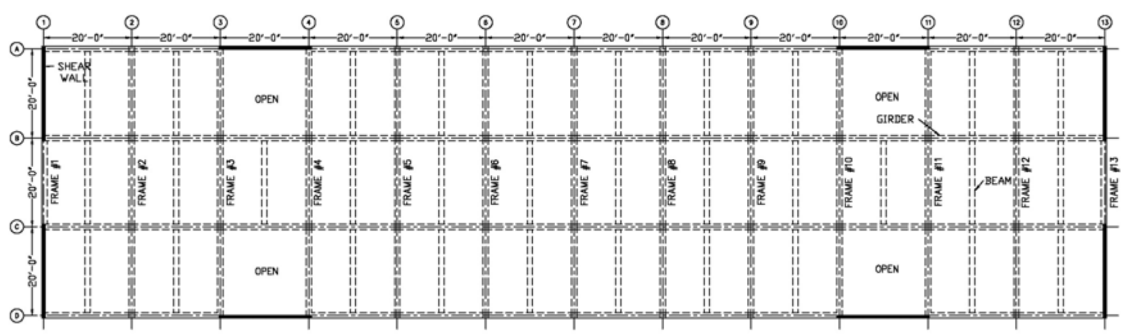


Figure 4-6: Building A6 Diaphragm Plan

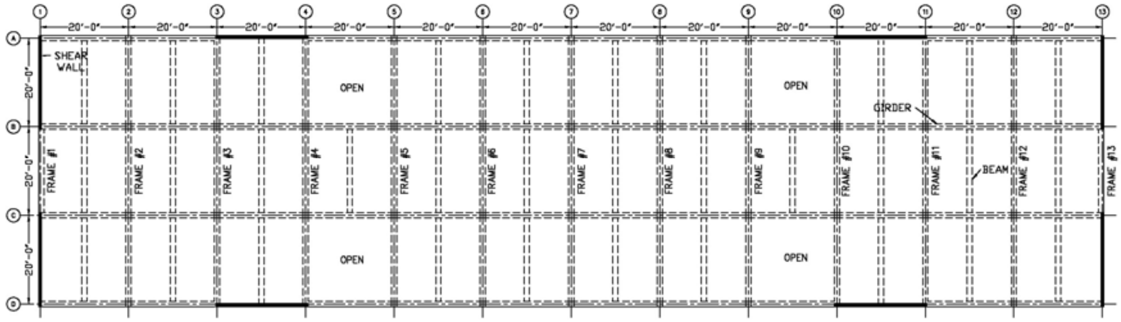


Figure 4-7: Building A7 Diaphragm Plan

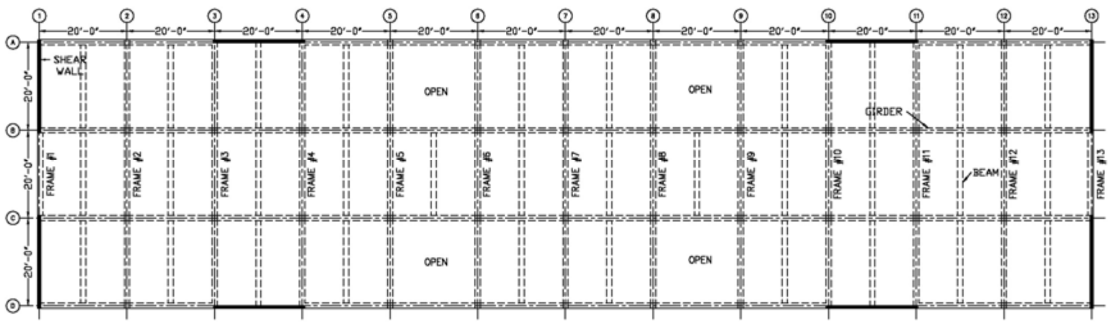


Figure 4-8: Building A8 Diaphragm Plan

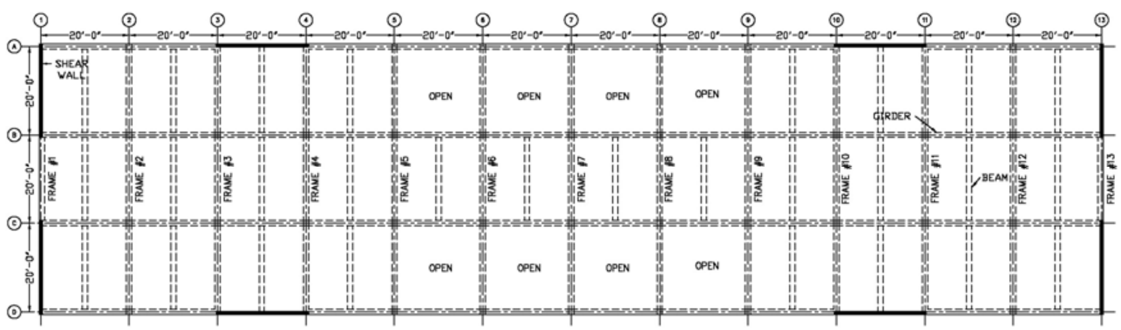


Figure 4-9: Building A9 Diaphragm Plan

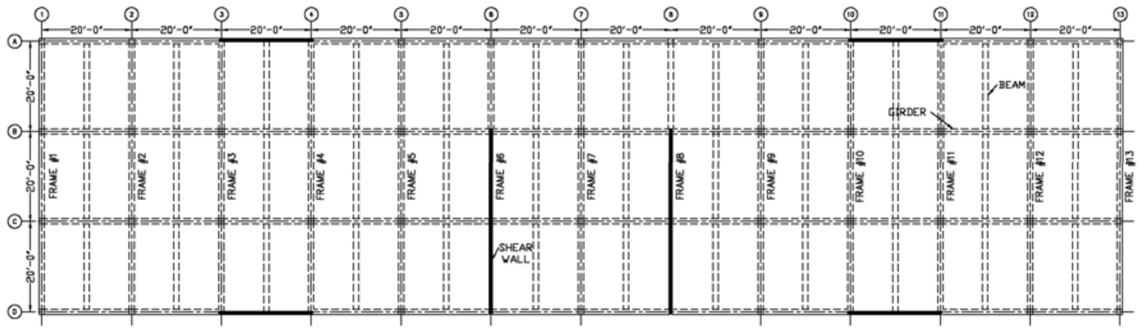


Figure 4-10: Building B1 Diaphragm Plan

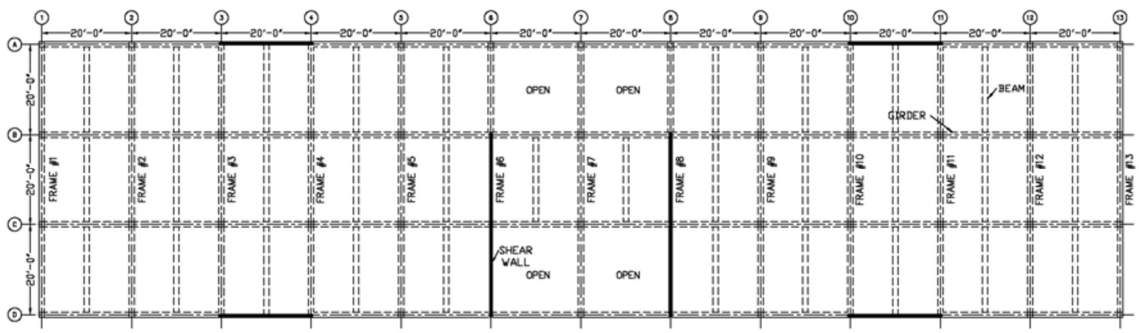


Figure 4-11: Building B2 Diaphragm Plan

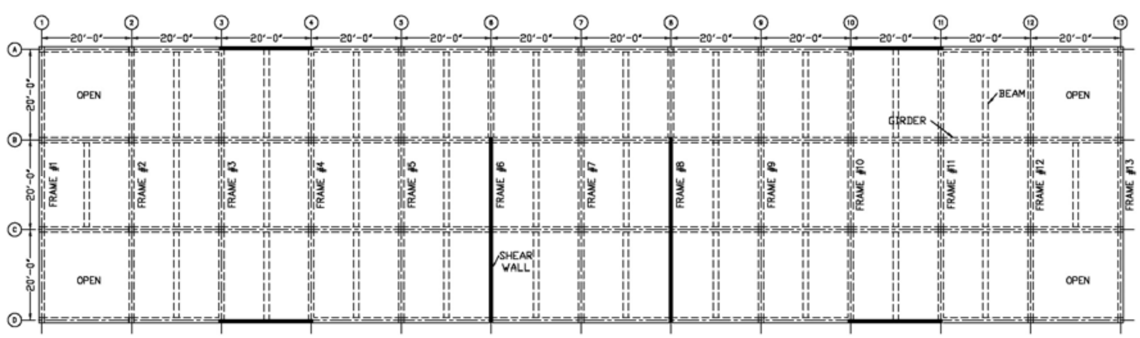


Figure 4-12: Building B3 Diaphragm Plan

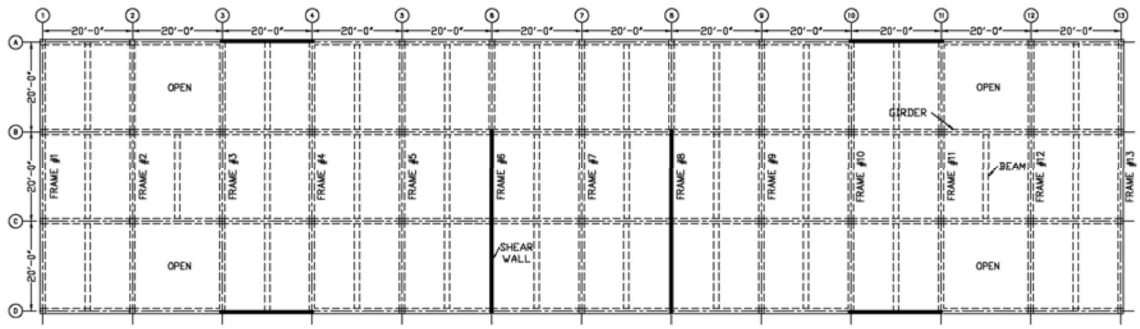


Figure 4-13: Building B4 Diaphragm Plan

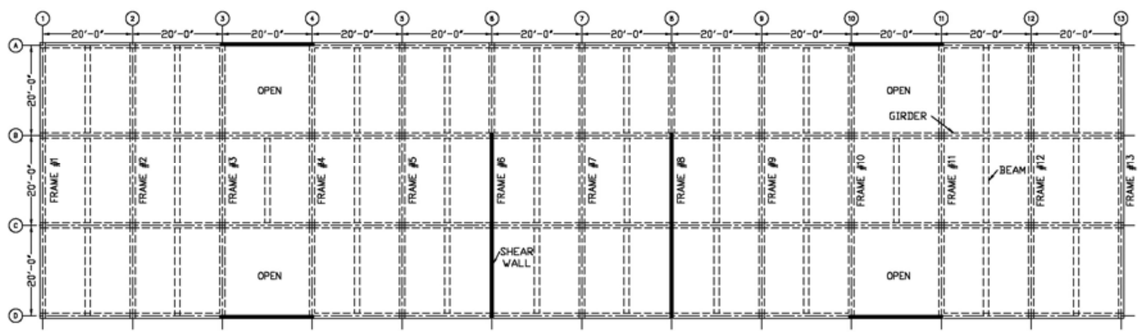


Figure 4-14: Building B5 Diaphragm Plan

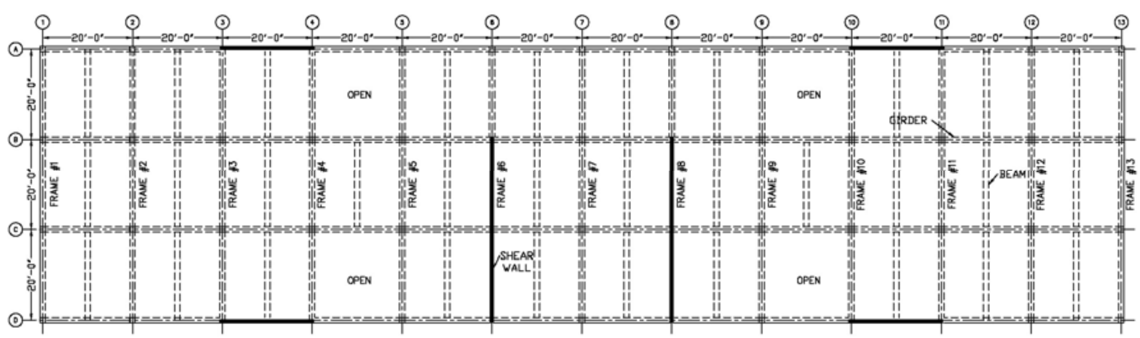


Figure 4-15: Building B6 Diaphragm Plan

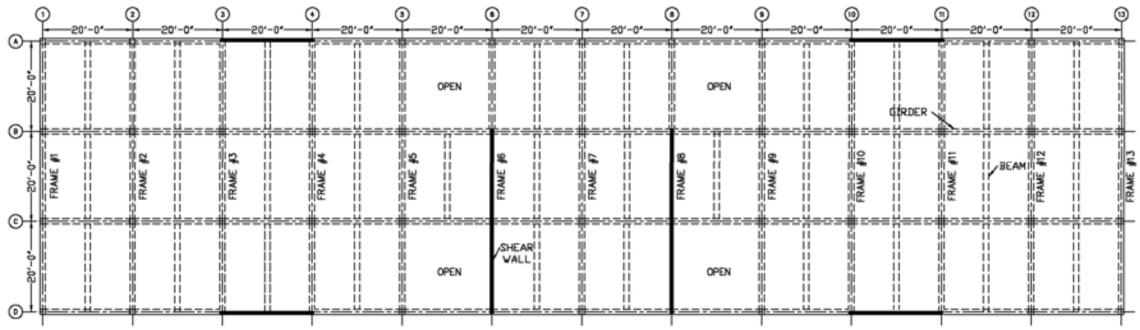


Figure 4-16: Building B7 Diaphragm Plan

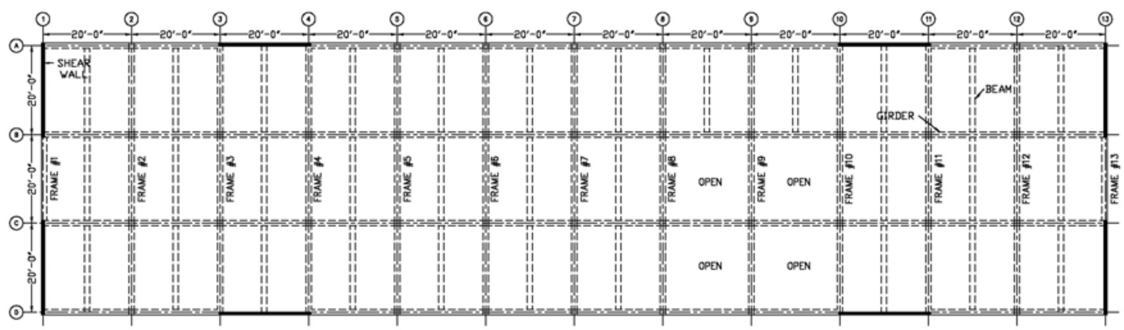


Figure 4-17: Building P1 Diaphragm Plan

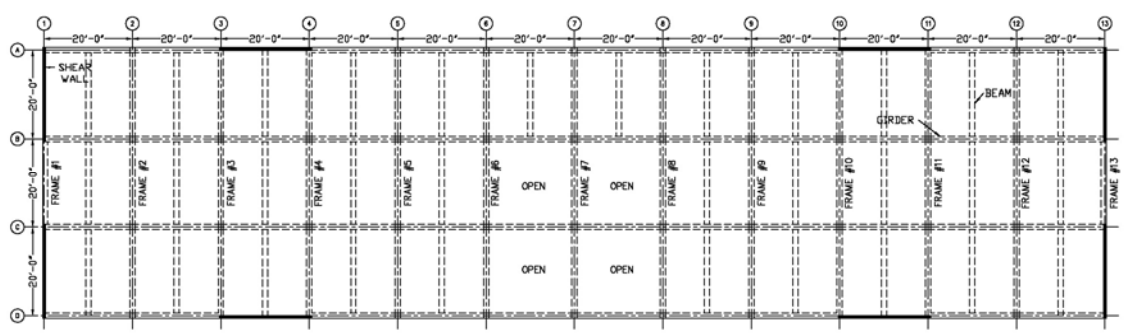


Figure 4-18: Building P2 Diaphragm Plan

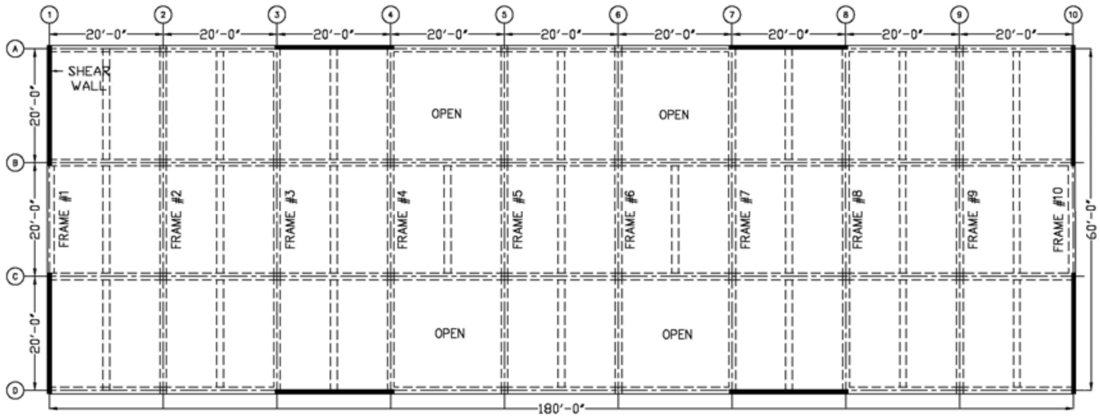


Figure 4-19: Building C1 Diaphragm Plan

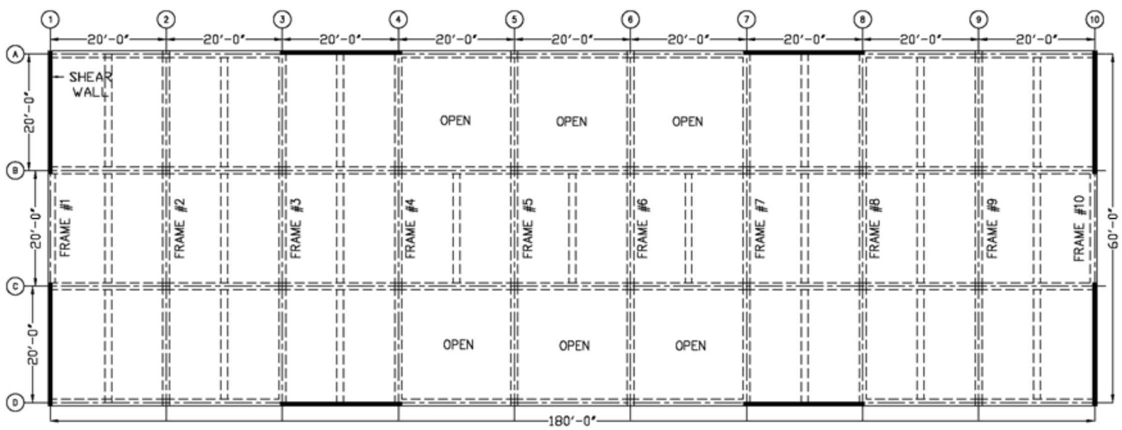


Figure 4-20: Building D1 Diaphragm Plan

All buildings were assumed to be in Saint Louis, Missouri, and hence are designed and detailed accordingly with the seismic parameters shown in Table 4-1. Figure 4-21 shows the spectral acceleration that was developed from IBC [28] for the site. The enlarged portion of the initial part of the spectrum (Fig.4-22) shows that the "flat" region where both $T_{N\text{-}S}$ and $T_{E\text{-}W}$ lay. Hence the seismic coefficient, C_s will not be affected and will remain at 8.9%.

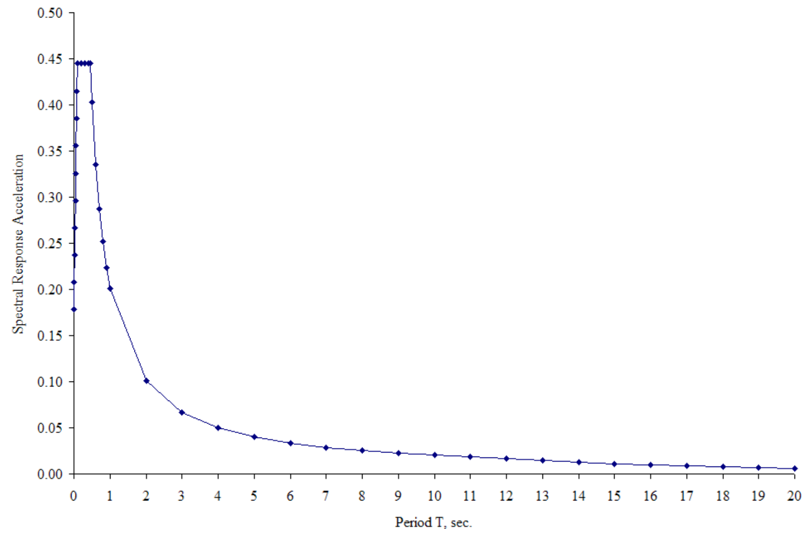


Figure 4-21: IBC 2006 [28] Site Specific Acceleration Response Spectra

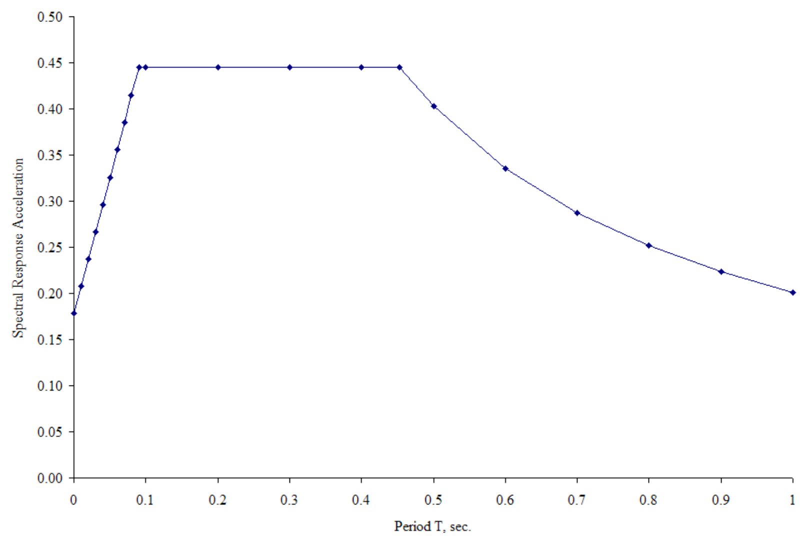


Figure 4-22: Flat Region of IBC 2006 [28] Site Specific Acceleration Response Spectra

All elements were designed using concrete compressive strength of 4000 psi and grade 60 reinforcing steel with an applied uniform live load of 50 psf and super imposed dead load of 20 psf. Members' structural reinforcing details are given in Table 4-2.

Table 4-1: Seismic Parameters per IBC 2006 [28]

Parameter	Value
Short Period Acceleration, S_s	0.57
Long Period Acceleration, S_l	0.19
Short Period Site Coefficient, Fa	1.17
Long Period Site Coefficient, Fv	1.59
Short Period Spectral Response Acceleration Parameter, S_{DS}	0.45
Long Period Spectral Response Acceleration Parameter, S_{Dl}	0.20
Response Modification Factor, $R_{N\text{-}S}$ & $R_{E\text{-}W}$	5.00
Over-strength Factor, $\Omega_{o,\ N\text{-}S}$ & $\Omega_{o,\ E\text{-}W}$	2.50
Deflection Amplification Factor, $C_{d,\ N\text{-}S}$ & $C_{d,\ E\text{-}W}$	4.50
Fundamental Period of Structure, $T_{a,\ N\text{-}S}$	0.31 sec.
Fundamental Period of Structure, $T_{a,\ E\text{-}W}$	0.31 sec.
Base Shear Seismic Coefficient, Cs	8.9 %

Table 4-2: Reinforced Concrete Elements Details per ACI 318-08 [2]

Element Type	Element Size	Steel Reinforcing
Slab	5 in.	#3 @ 12 in. one-way
Columns	14 in. x 14 in.	8-#6 verticals w/#3 @ 6 in. ties
Walls	8 in.	#6 @ 12 in. each way vertical & horizontal
Girders	14 in. x 24 in	3-#5 top & bottom w/#3 @ 10 in. stirrups – next to solid slab. 2-#5 top & bottom w/#3 @ 10 in. stirrups – next to open slab.
Beams	14 in. x 14 in.	6-#5 top & bottom w/#3 @ 6 in. stirrups

4.2 Parameters Investigated

The following parameters influencing floor diaphragms behavior are investigated in this research:

i. Diaphragm aspect ratio,
ii. Floor opening location,
iii. Shear wall locations,
iv. Hysteretic parameters,
v. Diaphragm models (rigid, elastic and inelastic), and
vi. Ground motions.

4.2.1 Diaphragm Aspect Ratio

The diaphragms' aspect ratio of 3:1 and 4:1 were chosen to investigate the applicability of various floor diaphragm type assumptions (i.e., rigid, elastic, inelastic). For example, rigid diaphragm assumption is not only a common industry practice but also a code requirement in ASCE 7-05 [7] section 12.3.1.2 for buildings with diaphragm aspect ratio of 3:1 or less; however, the effect of diaphragm openings is ignored in such buildings.

4.2.2 Floor Opening Locations

Several scenarios of diaphragm opening locations are investigated: openings at the building ends (more vulnerable to shear yielding and less to flexural yielding in buildings with end shear walls), quarter points, third points and in the center (more vulnerable to flexural yielding), where different floor diaphragm area losses are studied, 11%, 15% and 22%. Also, diaphragm openings locations placed symmetrically and non-symmetrically placed in the building (with respect to the centerline of the building plan as well as diaphragm cross-section) are investigated.

4.2.3 Shear Wall Locations

Shear walls are used as the main lateral force resisting system in N-S and E-W directions. In this research 8 in. thick ordinary concrete shear walls are used in two locations, at the ends and at the mid-region of the buildings and their effect on lateral load distribution and displacement examined.

4.2.4 Idealized Inplane Trilinear Moment-Curvature Curves

Flexural behavior of slabs is established using fiber model analysis. In this analysis, the entire cross section is divided into a number of smaller sections. Each section is then further discretized into fibers for the monotonic inelastic analysis. At the start of the analysis, a displacement controlled loading is applied in small increments. The purpose of this analysis is to set up a trilinear envelope that defines slab cracking and yielding. This was done in the past by idealizing in-plane tri-linear moment-curvature curves to fit the experimental envelope with the presence of out-of-plane loads for floor slabs without openings [42 and 51] as shown in Figures 4-25 and 4-26, where M_{cr}/M_{yield} of 1/3 is used. In the present study, due to lack of available experimental results for floor slabs with openings, a sensitivity study is conducted where the effect of M_{cr}/M_{yield} ranging from 1/4 to 1/2 is investigated.

4.2.5 Hysteretic Parameters

Strength deterioration under cyclic loading in nonlinear dynamic analysis is achieved through three parameter hysteretic model where a combination of hysteretic properties referred to as α, β, and γ, and the idealized trilinear envelopes. The stiffness degradation factor α specifies the degree of reduction in the unloading stiffness and the reduction in area enclosed by the hysteresis loops for consecutive loading cycles. The pinching factor γ reduces the stiffness of the reloading paths as well as the area of the hysteresis loops and the amount of dissipated energy. The strength deterioration factor β is the ratio computed as the amount of incremental damage caused by the increase of the maximum response divided by the normalized incremental hysteresis energy.

The value of these parameters have been obtained through experimental observation and engineering judgment for floor slab diaphragms without openings in the past [42 and 51]. In this current study, the effects of these three hysteretic parameters on dynamic analysis are investigated as part of a sensitivity study . The hysteretic parameters are changed as follows: 1.25α, α, 0.75α; 1.25γ, γ, 0.75γ; 1.25β, β, 0.75β where the average values of these parameters were used as the base values for all other cases analyzed.

4.2.6 Diaphragm Models (Rigid, Elastic, and Inelastic)

All three types of diaphragms models are investigated: rigid, elastic and inelastic. In the case of rigid floor diaphragms, the diaphragm is assumed to translate in plan and rotate about a vertical axis as a rigid body with the basic assumption being that there are no in-plane deformations in the slab-beam floor system. Hence, the force distribution in the vertical lateral load resisting frames depends only on the relative stiffness between these frames. When using elastic diaphragm model, the in-plane linear elastic shear and flexural springs are used in series (i.e., in-plane yielding is not allowed). In the case of an inelastic diaphragm model, nonlinear flexural spring (based on the idealized tri-linear moment-curvature models explained in Section 4.2.4) are connected with inelastic shear spring in series. Thus, deformations of the floor diaphragms after yielding of the inelastic springs provide a more accurate prediction of the force distribution in the vertical lateral load resisting frames.

4.2.7 Ground Motions

Since there are no available records of any severe earthquakes for the Saint Louis area, earthquakes were chosen with a period close to that of the building in question. Three earthquakes were selected as shown in Table 4-3 and their peak ground accelerations (PGA) were scaled down to represent the value expected at a site in the Saint Louis area based on the IBC 2006 [28] value of 0.27g. Of particular interest is the Loma Prieta (1989). It was selected since its dominant period of 0.34 seconds is close to $T_{a,\ N\text{-}S}$ of 0.31 seconds. This selection was made to maximize any resonance that may take place during an earthquake. Since Loma Prieta's PGA was recorded as 0.41g, thus, it was scaled down by a factor of 0.27/0.41 or 66% as its acceleration history is shown in Figure 4-23. Fast Fourier Transform (FFT) for this earthquake record shows the dominant frequency occurs at 2.95 Hz (Figure 4-24), which is equivalent to a dominant period of 0.34 sec.

Table 4-3: Earthquakes Characteristics Used in Dynamic Analysis

Earthquake	**PGA, g**	**T_g, sec.**	**Scale**
Loma Prieta - Corralitos - 1989	0.41	0.34 sec.	0.659
San Fernando - Pacoima -1971	1.15	0.40 sec.	0.235
Parkfield - Cholane -1966	0.48	0.40 sec.	0.563

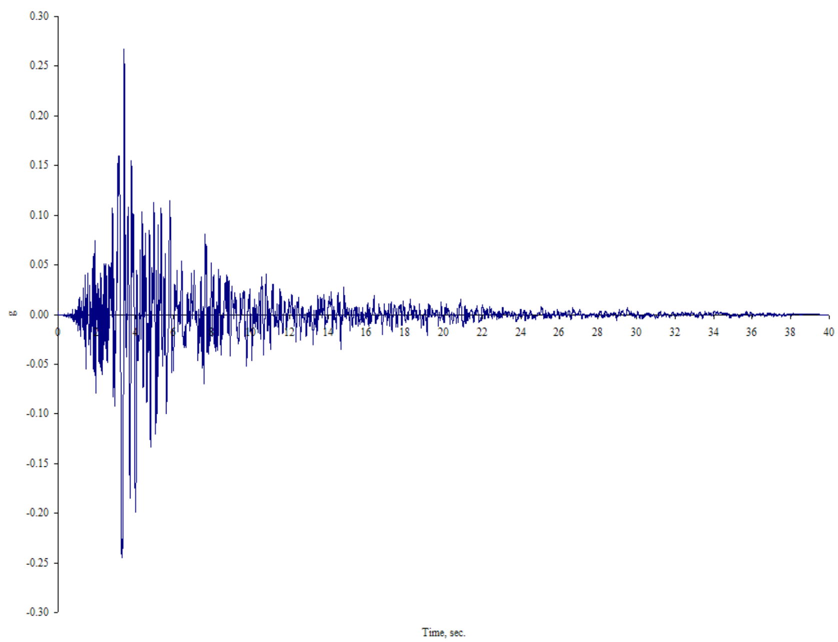


Figure 4-23: Scaled Loma Prieta Acceleration Time History

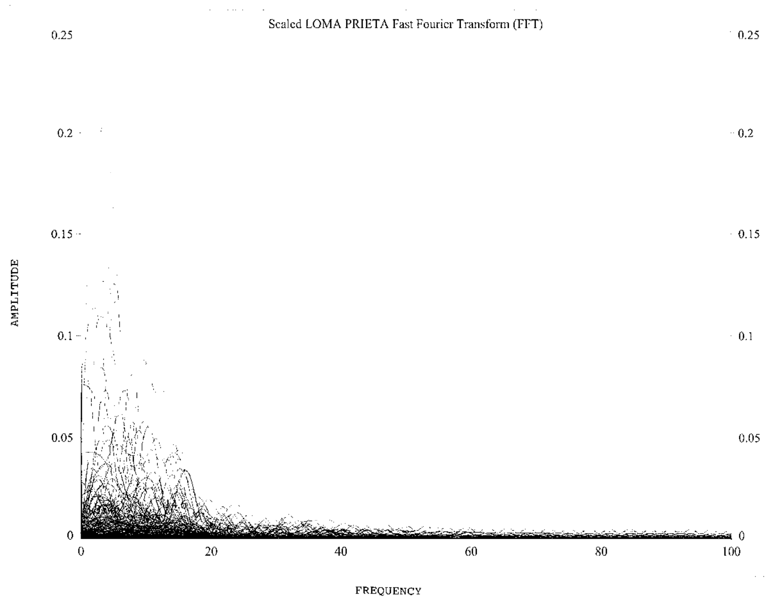


Figure 4-24: Scaled Loma Prieta Fast Fourier Transform (FFT)

4.3 Modification of IDARC2 for Slab Elements with Openings

IDARC2 [56] is a program that was developed to conduct inelastic static and seismic simulations of rectangular plan structures with inelastic diaphragms with symmetrical floor cross-sections. The proposed analytical enhancements listed in the following sections, will contribute to the state-of-the-art and practice in structural engineering. It will also provide an enhanced computational tool for both the research and practicing community to use.

4.3.1 Moment-curvature Idealization from Fiber Model Procedure

The original idealization approach in IDARC2 [56] was applicable to the building profile tested on the shake table where the floor system consisted of a single bay in the testing direction with symmetrical floor cross-section [51]. It was calibrated to reflect the behavior of the test building investigated. The tri-linear idealization envelope of the moment curvature curves was accurate for such buildings [42, 51 & 56].

In the enhanced approach presented in this study, the program is modified so that it would use the yielding curvature corresponding to the smaller of the curvature of the moment-curvature slope of 0.05 of the initial slope obtained from the theoretical fiber model or six times the cracking curvature (as shown in tests [56]), and its corresponding yielding moment on the theoretical moment-curvature curve is used to establish the theoretical yielding criteria. Then, for idealization of nominally reinforced slabs, where the theoretical fiber model cracking moment is typically larger than this yield moment, the idealized yield moment is set equal to the theoretical cracking moment. For heavily reinforced slabs where the theoretical fiber model cracking moment is typically smaller than the theoretical yielding moment, the idealized yield moment is taken as the average of the theoretical yielding moment and the theoretical cracking moment (this will represent the strength loss due to the presence of out-of plane loads, which is confirmed with laboratory testing [48]).

Regarding the trilinear idealization of the moment curvature curve, the variation from the initial stiffness slope is taken to be one-third of the idealized slab yielding strength when vertical loads (out-of-plane) loads are applied (as it was observed in test results [48]). Figures 4-25 and 4-26 show typical moment-curvature plots for such floor systems. The fitted enhanced idealized trilinear moment-curvature curve envelope will accurately account for the behavior of floor slab diaphragms under both inplane and out-of-plane loads. A post-yielding stiffness of 0.0025 (EI_o) is used to prevent numerical instabilities within the flexibility matrix computation used in the enhanced program.

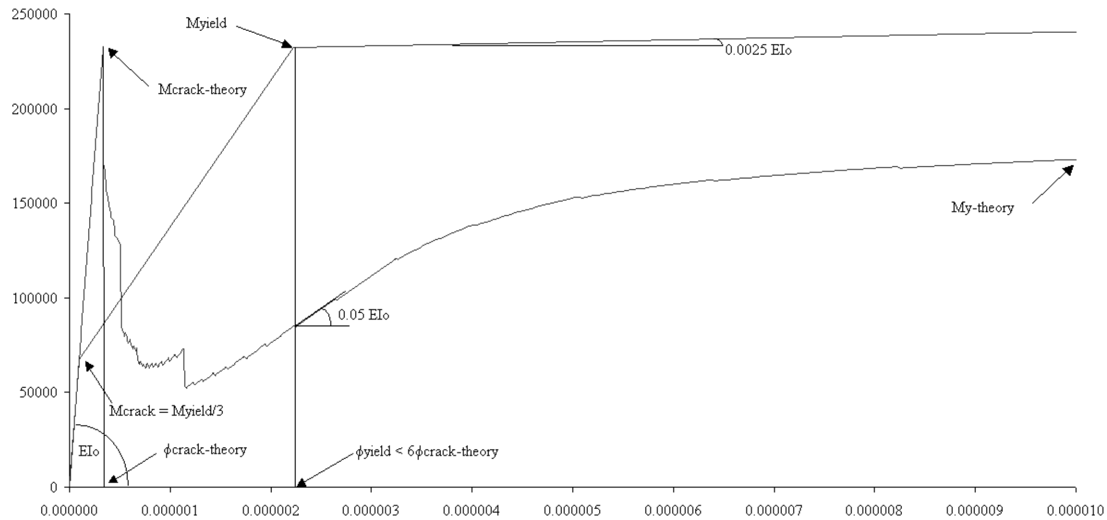


Figure 4-25: Idealized Moment-Curvature Envelope Curve - Nominally Reinforced Slabs

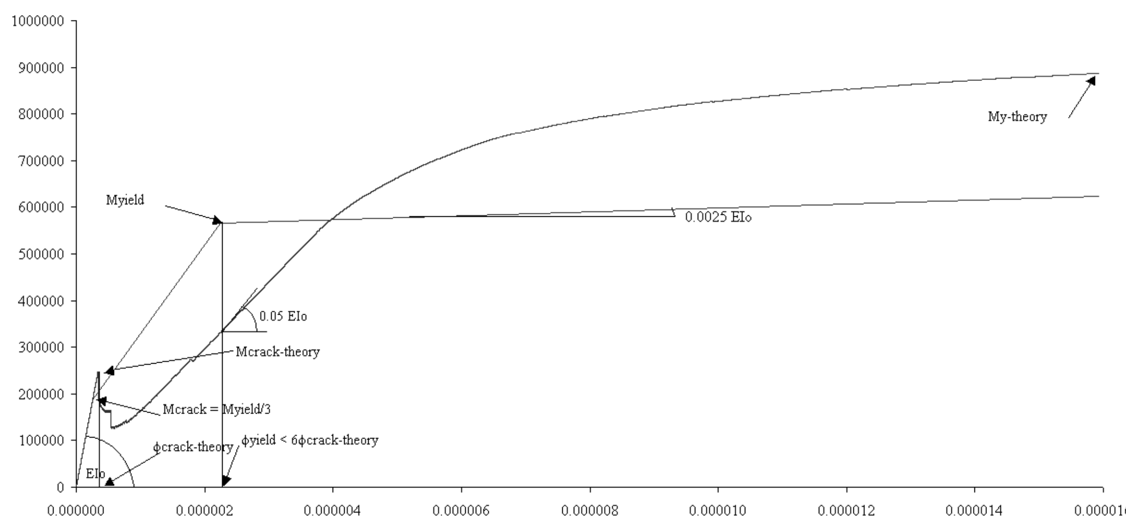


Figure 4-26: Idealized Moment-Curvature Envelope Curve - Heavily Reinforced Slabs

4.3.2 User Defined Idealized Moment-Curvature Curves

IDARC2 [56] had no means to account for unsymmetrical trilinear moment-curvature properties. This was satisfactory for the type of building tested in its original development [42, 51 & 56]. This shortcoming particularly limits analysis of buildings with diaphragm openings placed non-symmetrically with respect to centerline of diaphragm cross-section. This limitation has been overcome by modifying the program so that it can accept user-defined idealized moment-curvature curves for unsymmetrical floor diaphragm cross-sections.

Unsymmetrical trilinear moment-curvature properties can be input in the enhanced IDARC2 version by allowing all of the following parameters to be recognized:

- Positive and negative cracking moments, M^{+}_{cr} & M^{-}_{cr}.
- Positive and negative yield moments, M^{+}_{y} & M^{-}_{y}.
- Positive and negative yield curvature, ϕ^{+}_{y} & ϕ^{-}_{y}.
- Initial flexural stiffness, EI_o.
- Post-positive flexural stiffness - 0.0025 EI_o minimum.
- Post-negative flexural stiffness - 0.0025 EI_o minimum.

Figure 4-27 shows case P1 and P2 open slab section unsymmetrical user-input trilinear moment-curvature curve.

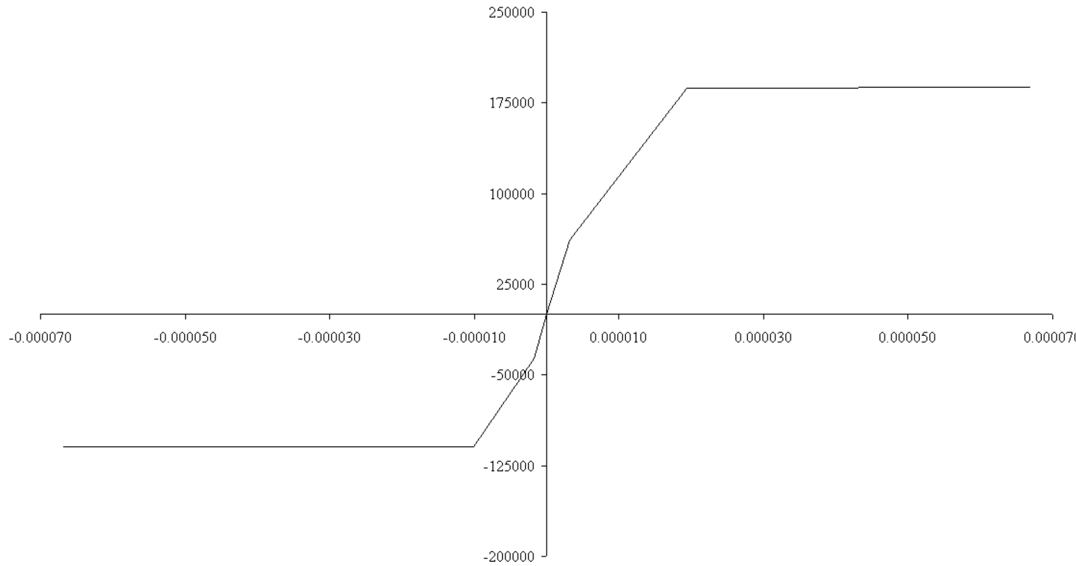


Figure 4-27: Case P1/P2 Open Slab Unsymm. Trilinear Moment-Curvature Curve

4.3.3 Shear Spring Limitation

As mentioned earlier, in-plane behavior of a typical floor slab element is modeled by inelastic flexural and shear springs connected in series (Sections 3.3). This is analogous to behavior of a deep beam, except the effect of out-of-plane loading is also considered. This approach will ensure that if a shear-type failure is to occur, it is captured and taken into account. Also, in the enhanced program, trilinear shear force-deformation properties can be user-input by specifying the following properties;

- Cracking shear force.
- Yielding shear force.
- Initial shear stiffness.
- Post-yielding shear stiffness.
- Yield shear deformation.

However, based on the analytical and parametric investigation conducted in this research, it is observed that the in-plane diaphragm shear forces obtained from dynamic analysis fall below the in-plane shear capacity of the concrete slab-beam system i.e., the largest shear force observed on any slab element with or without openings did not exceed the shear capacity of that slab element. Therefore, use of an elastic shear spring (with GA as the spring constant) connected in series with inelastic flexural would be adequate for capturing the inelastic seismic behavior of reinforced concrete buildings with diaphragm openings. Thus, user defined idealized values of extremely large magnitude for cracking and yielding shear forces would be appropriate in modeling the inelastic behavior of the floors slab as a combined inelastic flexural spring and elastic spring connected in series.

Chapter 5

Analytical Study Results

In this chapter, results obtained from the pushover (inelastic static) analysis, inelastic dynamic analysis, and the corresponding sensitivity studies are presented.

Table 5-1 presents all the different scenarios investigated. There are 20 buildings in total, A1-A9, B1-B7, P1, P2, C1 and D1. For the analytical study (as explained in Section 4.2), several parameters are investigated: plan aspect ratio, floor opening locations, shear wall locations, diaphragm models, and ground motions (in total, 120 cases). Also, a sensitivity study was conducted on a base reference case where the effect of the location of the initial slope change location in the idealized tri-linear moment-curvature curve and the changing of magnitudes of the three hysteretic parameters on dynamic response of the buildings are investigated (8 additional cases). In total, results of 129 cases are analyzed using the enhanced IDARC2 program.

Table 5-1: All Scenarios Investigated*

Group A1 [0%]	**Group A2 [11%]**	**Group A3 [11%]**	**Group A4 [11%]**
1A1-4:1-ESW-Solid-IE-LP	1A2-4:1-ESW-(8&9-T&B)-IE-LP	1A3-4:1-ESW-(6&7-T&B)-IE-LP	1A4-4:1-ESW-(1&12-T&B)-IE-LP
2A1-4:1-ESW-Solid-EL-LP	2A2-4:1-ESW-(8&9-T&B)-EL-LP	2A3-4:1-ESW-(6&7-T&B)-EL-LP	2A4-4:1-ESW-(1&12-T&B)-IE-SF
3A1-4:1-ESW-Solid-RD-LP	3A2-4:1-ESW-(8&9-T&B)-RD-LP	3A3-4:1-ESW-(6&7-T&B)-RD-LP	3A4-4:1-ESW-(1&12-T&B)-IE-PF
4A1-4:1-ESW-Solid-IE-SF	4A2-4:1-ESW-(8&9-T&B)-IE-SF	4A3-4:1-ESW-(6&7-T&B)-IE-SF	**Group A5 [11%]**
5A1-4:1-ESW-Solid-EL-SF	5A2-4:1-ESW-(8&9-T&B)-EL-SF	5A3-4:1-ESW-(6&7-T&B)-EL-SF	1A5-4:1-ESW-(2&11-T&B)-IE-LP
6A1-4:1-ESW-Solid-RD-SF	6A2-4:1-ESW-(8&9-T&B)-RD-SF	6A3-4:1-ESW-(6&7-T&B)-RD-SF	2A5-4:1-ESW-(2&11-T&B)-IE-SF
7A1-4:1-ESW-Solid-IE-PF	7A2-4:1-ESW-(8&9-T&B)-IE-PF	7A3-4:1-ESW-(6&7-T&B)-IE-PF	3A5-4:1-ESW-(2&11-T&B)-IE-PF
8A1-4:1-ESW-Solid-EL-PF	8A2-4:1-ESW-(8&9-T&B)-EL-PF	8A3-4:1-ESW-(6&7-T&B)-EL-PF	**Group A6 [11%]**
9A1-4:1-ESW-Solid-RD-PF	9A2-4:1-ESW-(8&9-T&B)-RD-PF	9A3-4:1-ESW-(6&7-T&B)-RD-PF	1A6-4:1-ESW-(3&10-T&B)-IE-LP
Group P1 [11%] - USER	**Group P2 [11%] - USER**	**Group A9 [22%]**	2A6-4:1-ESW-(3&10-T&B)-IE-SF
1P1-4:1-ESW-(8&9-M&B)-IE-LP	1P2-4:1-ESW-(6&7-M&B)-IE-LP	1A9-4:1-ESW-(5 6 7 8-T&B)-IE-LP	3A6-4:1-ESW-(3&10-T&B)-IE-PF
2P1-4:1-ESW-(8&9-M&B)-EL-LP	2P2-4:1-ESW-(6&7-M&B)-EL-LP	2A9-4:1-ESW-(5 6 7 8-T&B)-EL-LP	**Group A7 [11%]**
3P1-4:1-ESW-(8&9-M&B)-RD-LP	3P2-4:1-ESW-(6&7-M&B)-RD-LP	3A9-4:1-ESW-(5 6 7 8-T&B)-RD-LP	1A7-4:1-ESW-(4&9-T&B)-IE-LP
4P1-4:1-ESW-(8&9-M&B)-IE-SF	4P2-4:1-ESW-(6&7-M&B)-IE-SF	4A9-4:1-ESW-(5 6 7 8-T&B)-IE-SF	2A7-4:1-ESW-(4&9-T&B)-IE-SF
5P1-4:1-ESW-(8&9-M&B)-EL-SF	5P2-4:1-ESW-(6&7-M&B)-EL-SF	5A9-4:1-ESW-(5 6 7 8-T&B)-EL-SF	3A7-4:1-ESW-(4&9-T&B)-IE-PF
6P1-4:1-ESW-(8&9-M&B)-RD-SF	6P2-4:1-ESW-(6&7-M&B)-RD-SF	6A9-4:1-ESW-(5 6 7 8-T&B)-RD-SF	**Group A8 [11%]**
7P1-4:1-ESW-(8&9-M&B)-IE-PF	7P2-4:1-ESW-(6&7-M&B)-IE-PF	7A9-4:1-ESW-(5 6 7 8-T&B)-IE-PF	1A8-4:1-ESW-(5&8-T&B)-IE-LP
8P1-4:1-ESW-(8&9-M&B)-EL-PF	8P2-4:1-ESW-(6&7-M&B)-EL-PF	8A9-4:1-ESW-(5 6 7 8-T&B)-EL-PF	2A8-4:1-ESW-(5&8-T&B)-IE-SF
9P1-4:1-ESW-(8&9-M&B)-RD-PF	9P2-4:1-ESW-(6&7-M&B)-RD-PF	9A9-4:1-ESW-(5 6 7 8-T&B)-RD-PF	3A8-4:1-ESW-(5&8-T&B)-IE-PF
Group B1 [0%]	**Group B2 [11%]**	**Group B3 [11%]**	
1B1-4:1-ISW-Solid-IE-LP	1B2-4:1-ISW-(6&7-T&B)-IE-LP	1B3-4:1-ISW-(1&12-T&B)-IE-LP	
2B1-4:1-ISW-Solid-EL-LP	2B2-4:1-ISW-(6&7-T&B)-EL-LP	2B3-4:1-ISW-(1&11-T&B)-IE-SF	
3B1-4:1-ISW-Solid-RD-LP	3B2-4:1-ISW-(6&7-T&B)-RD-LP	3B3-4:1-ISW-(1&12-T&B)-IE-PF	
4B1-4:1-ISW-Solid-IE-SF	4B2-4:1-ISW-(6&7-T&B)-IE-SF	**Group B4 [11%]**	
5B1-4:1-ISW-Solid-EL-SF	5B2-4:1-ISW-(6&7-T&B)-EL-SF	1B4-4:1-ISW-(2&11-T&B)-IE-LP	
6B1-4:1-ISW-Solid-RD-SF	6B2-4:1-ISW-(6&7-T&B)-RD-SF	2B4-4:1-ISW-(2&11-T&B)-IE-SF	
7B1-4:1-ISW-Solid-IE-PF	7B2-4:1-ISW-(6&7-T&B)-IE-PF	3B4-4:1-ISW-(2&11-T&B)-IE-PF	
8B1-4:1-ISW-Solid-EL-PF	8B2-4:1-ISW-(6&7-T&B)-EL-PF	**Group B5 [11%]**	
9B1-4:1-ISW-Solid-RD-PF	9B2-4:1-ISW-(6&7-T&B)-RD-PF	1B5-4:1-ISW-(3&10-T&B)-IE-LP	
Group C1 [15%]	**Group D1 [22%]**	2B5-4:1-ISW-(3&10-T&B)-IE-SF	
1C1-3:1-ESW-(4&6-T&B)-IE-LP	1D1-3:1-ESW-(4 5 6-T&B)-IE-LP	3B5-4:1-ISW-(3&10-T&B)-IE-PF	
2C1-3:1-ESW-(4&6-T&B)-EL-LP	2D1-3:1-ESW-(4 5 6-T&B)-EL-LP	**Group B6 [11%]**	
3C1-3:1-ESW-(4&6-T&B)-RD-LP	3D1-3:1-ESW-(4 5 6-T&B)-RD-LP	1B6-4:1-ISW-(4&9-T&B)-IE-LP	
4C1-3:1-ESW-(4&6-T&B)-IE-SF	4D1-3:1-ESW-(4 5 6-T&B)-IE-SF	2B6-4:1-ISW-(4&9-T&B)-IE-SF	
5C1-3:1-ESW-(4&6-T&B)-EL-SF	5D1-3:1-ESW-(4 5 6-T&B)-EL-SF	3B6-4:1-ISW-(4&9-T&B)-IE-PF	
6C1-3:1-ESW-(4&6-T&B)-RD-SF	6D1-3:1-ESW-(4 5 6-T&B)-RD-SF	**Group B7 [11%]**	
7C1-3:1-ESW-(4&6-T&B)-IE-PF	7D1-3:1-ESW-(4 5 6-T&B)-IE-PF	1B7-4:1-ISW-(5&8-T&B)-IE-LP	
8C1-3:1-ESW-(4&6-T&B)-EL-PF	8D1-3:1-ESW-(4 5 6-T&B)-EL-PF	2B7-4:1-ISW-(5&8-T&B)-IE-SF	
9C1-3:1-ESW-(4&6-T&B)-RD-PF	9D1-3:1-ESW-(4 5 6-T&B)-RD-PF	3B7-4:1-ISW-(5&8-T&B)-IE-PF	

* Definition of terms and notations used:

First number used in the building scenario name is the scenario's number (e.g., 9 scenarios are considered for Building A1)
4:1 or 3:1 = Diaphragm plan aspect ratio.
Shear wall frame locations: ESW = End shear wall, ISW = Intermediate shear wall
Floor panel opening locations are given within parentheses: bay numbers are followed by M = Middle panel, T = Top, B = Bottom
Diaphragm model used: IE = Inelastic, El = Elastic, Rd = Rigid
Scaled earthquake used: LP = Loma Prieta, SF = San Fernando, PF = Parkfield (as given in Table 4-3)
Percentages given are the diaphragm plan area reduction due to openings

5.1 Pushover Analysis Results

The results of inelastic static analysis of all 20 buildings subjected to a lateral load with inverted triangular distribution due to amplification of floor accelerations with increasing height from the base of the building (i.e., pushover analysis) are presented in tabular format in Table 5-2 and then graphical format in Figures 5-1 thru 5-20. The Inelastic diaphragm model option of IDARC2 [56] is selected where simplified idealized bi-linear moment-curvature curves for all nonlinear elements are used. It is observed that the overall nonlinear response of the buildings is mainly dominated by the yielding of the shear wall elements at the base of building and then the top story slab elements, hence their yielding sequence is presented in Table 5-2, followed by the graphical presentation of the lateral load normalized by the building weight (i.e., the base shear coefficient) versus the maximum building lateral displacement (lateral drift in % of building height) of the most critical frame pertaining to the building investigated.

Table 5-2: Results of Building Pushover Analysis: Wall and Slab Yield Sequence

Scenario	Base Shear Coefficient	
	Wall Yielding	Slab Yielding
1A1-4:1-ESW-Solid-IE	0.180	0.420
1A2-4:1-ESW-(8&9-T&B)-IE	0.170	0.250
1A3-4:1-ESW-(6&7-T&B)-IE	0.180	0.240
1A4-4:1-ESW-(1&12-T&B)-IE	0.170	0.380
1A5-4:1-ESW-(2&11-T&B)-IE	0.180	0.390
1A6-4:1-ESW-(3&10-T&B)-IE	0.180	0.320
1A7-4:1-ESW-(4&9-T&B)-IE	0.180	0.260
1A8-4:1-ESW-(5&8-T&B)-IE	0.180	0.240
1A9-4:1-ESW-(5 6 7 8-T&B)-IE	0.190	0.280
1B1-4:1-ISW-Solid-IE	0.170	0.490
1B2-4:1-ISW-(6&7-T&B)-IE	0.200	0.300
1B3-4:1-ISW-(1&12-T&B)-IE	0.190	0.540
1B4-4:1-ISW-(2&11-T&B)-IE	0.220	-
1B5-4:1-ISW-(3&10-T&B)-IE	0.230	0.630
1B6-4:1-ISW-(4&9-T&B)-IE	0.230	0.520
1B7-4:1-ISW-(5&8-T&B)-IE	0.220	0.310
1P1-4:1-ESW-(8&9-M&B)-IE	0.170	0.170
1P2-4:1-ESW-(6&7-M&B)-IE	0.170	0.170
1C1-3:1-ESW-(4&6-T&B)-IE	0.230	0.530
1D1-3:1-ESW-(4 5 6-T&B)-IE	0.240	0.590

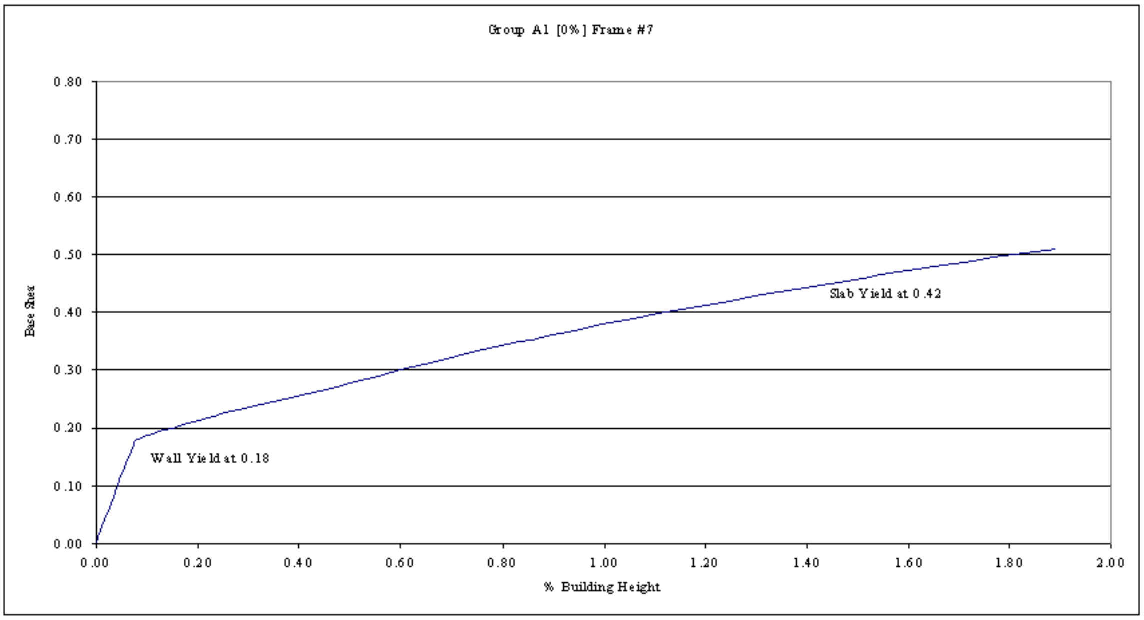


Figure 5-1: Pushover Results for Building 1A1 (Lateral load-vs-Drift at Frame 7)

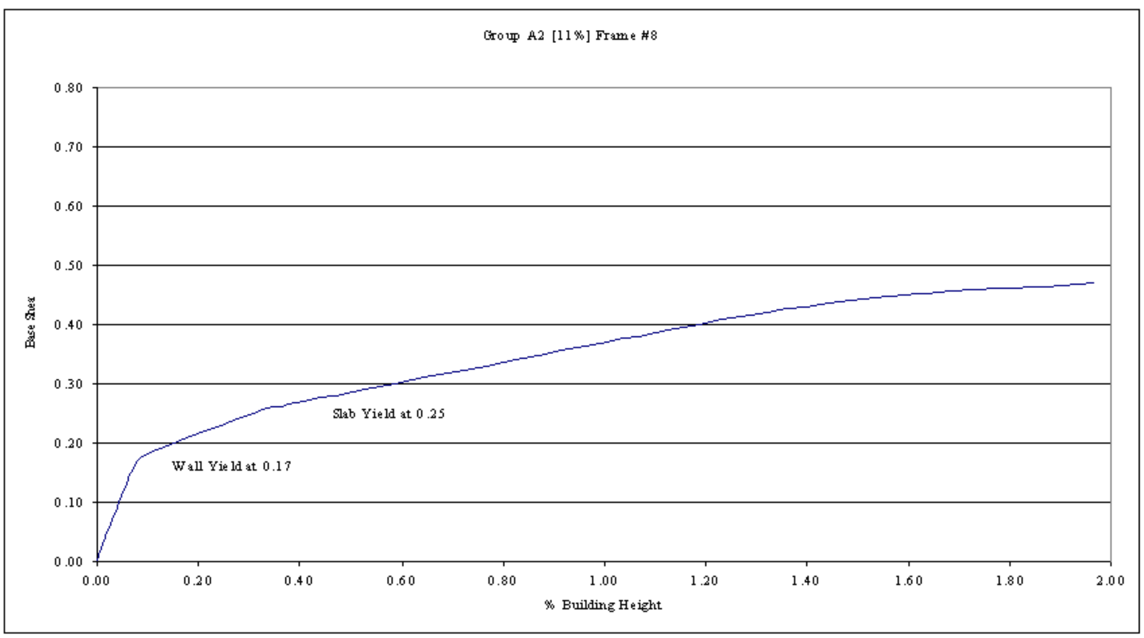


Figure 5-2: Pushover Results for Building 1A2 (Lateral load-vs-Drift at Frame 8)

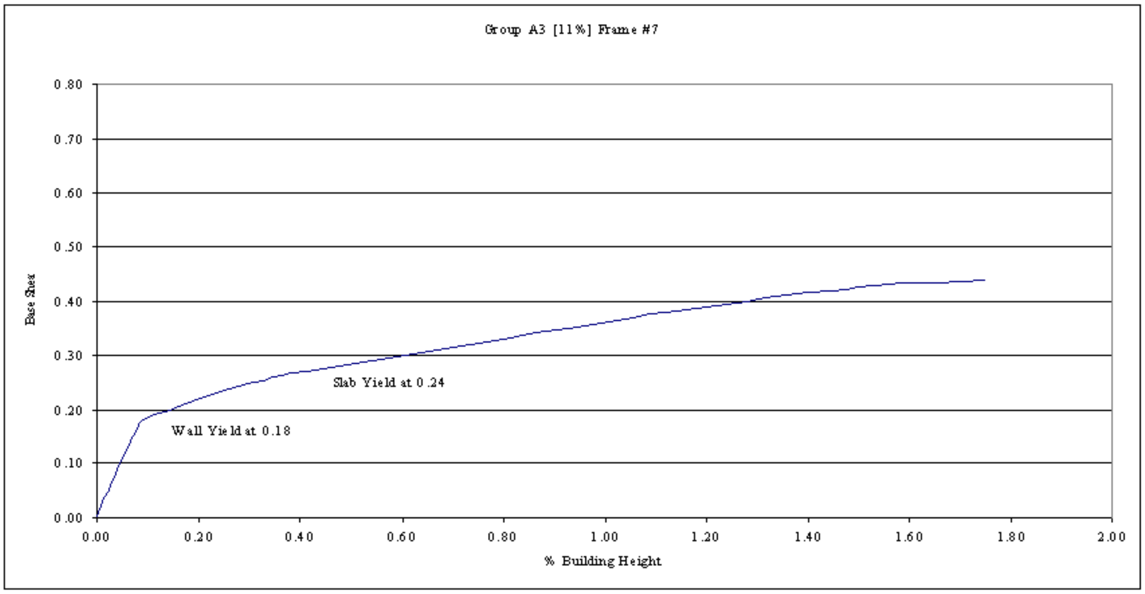


Figure 5-3: Pushover Results for Building 1A3 (Lateral load-vs-Drift at Frame 7)

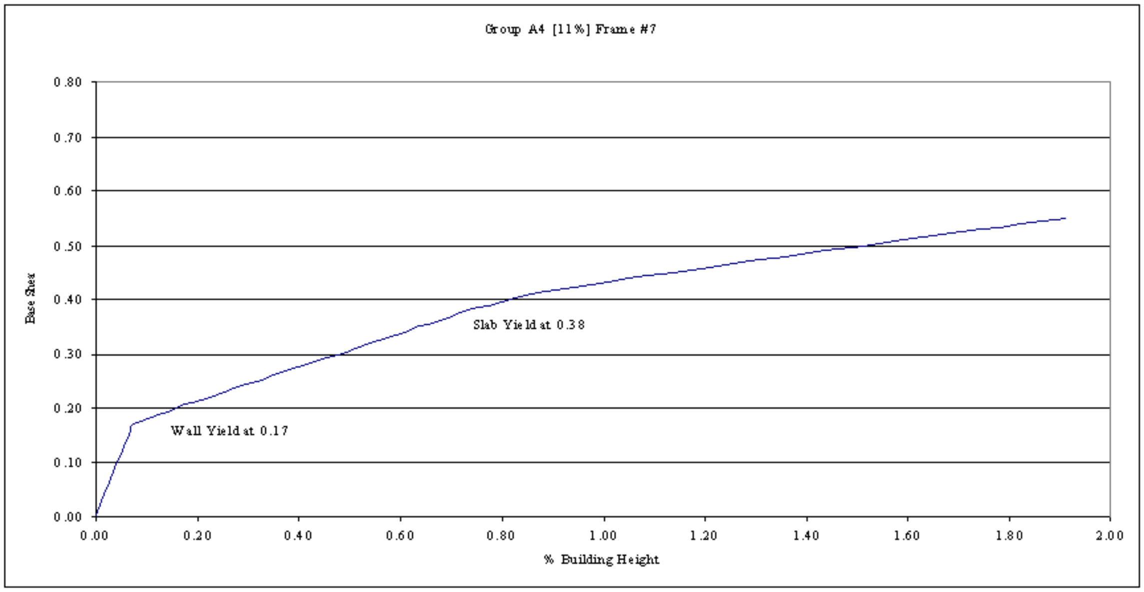


Figure 5-4: Pushover Results for Building 1A4 (Lateral load-vs-Drift at Frame 7)

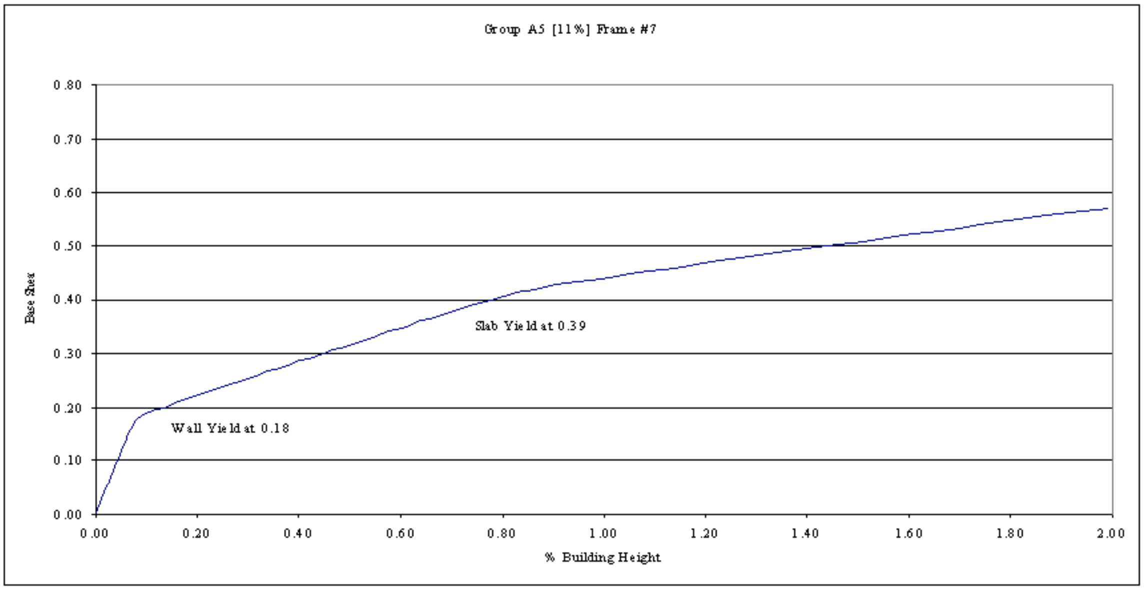


Figure 5-5: Pushover Results for Building 1A5 (Lateral load-vs-Drift at Frame 7)

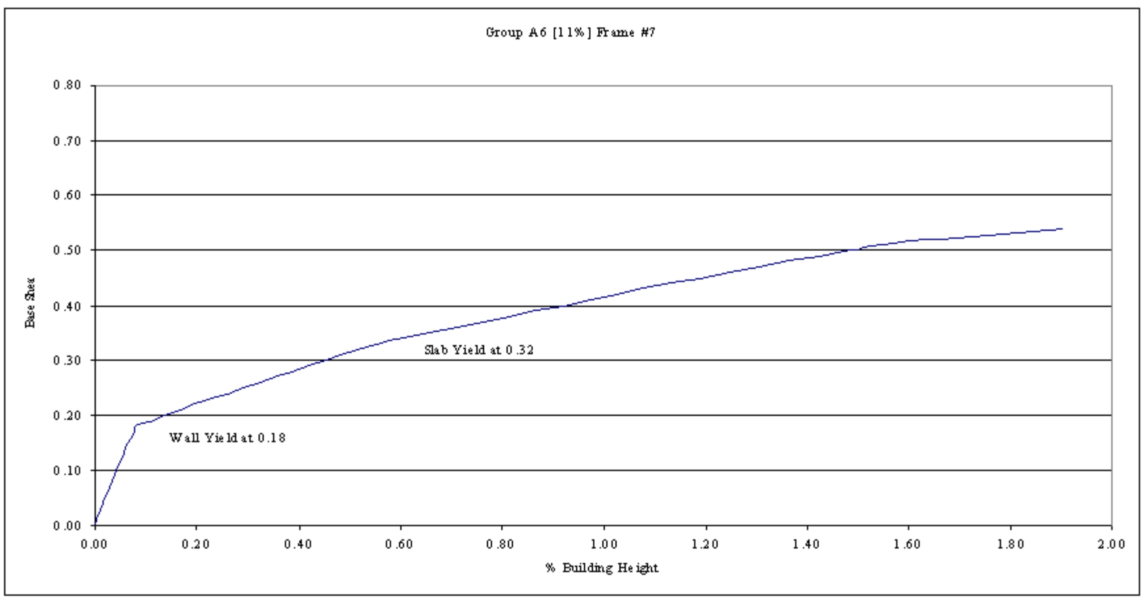


Figure 5-6: Pushover Results for Building 1A6 (Lateral load-vs-Drift at Frame 7)

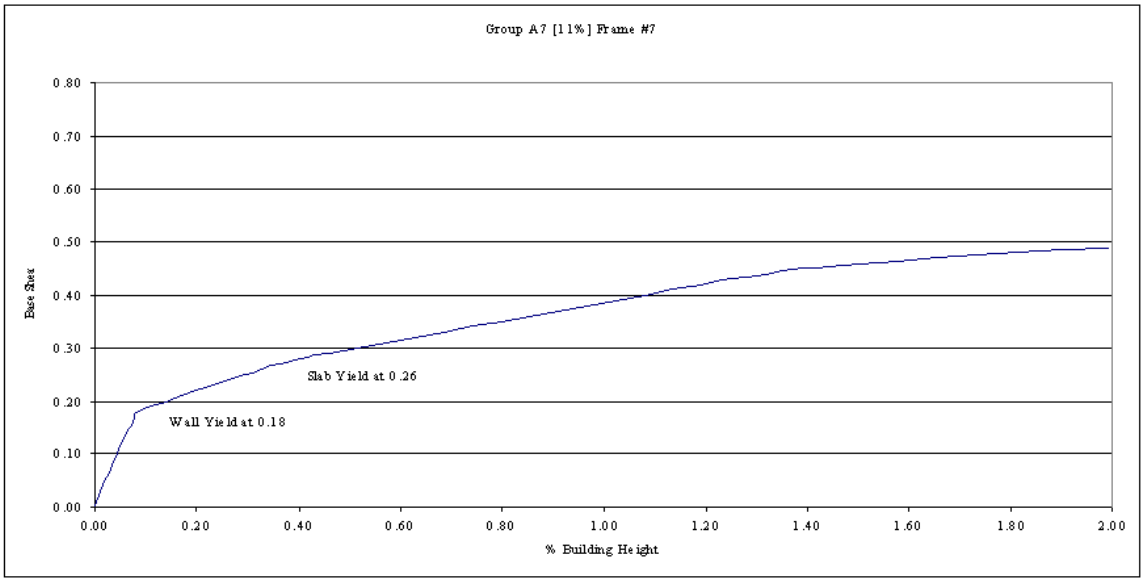


Figure 5-7: Pushover Results for Building 1A7 (Lateral load-vs-Drift at Frame 7)

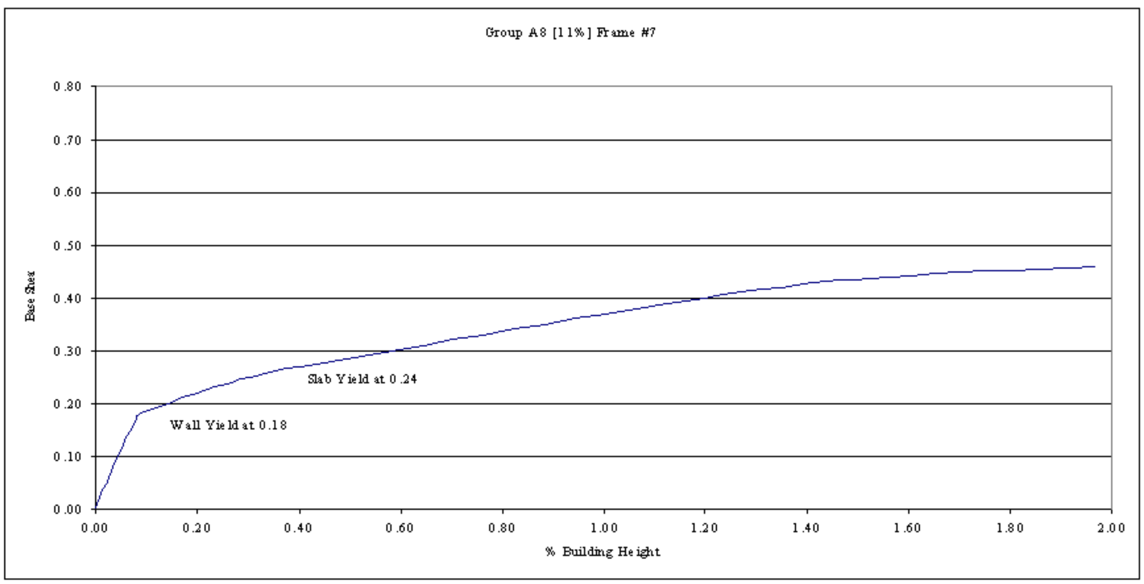


Figure 5-8: Pushover Results for Building 1A8 (Lateral load-vs-Drift at Frame 7)

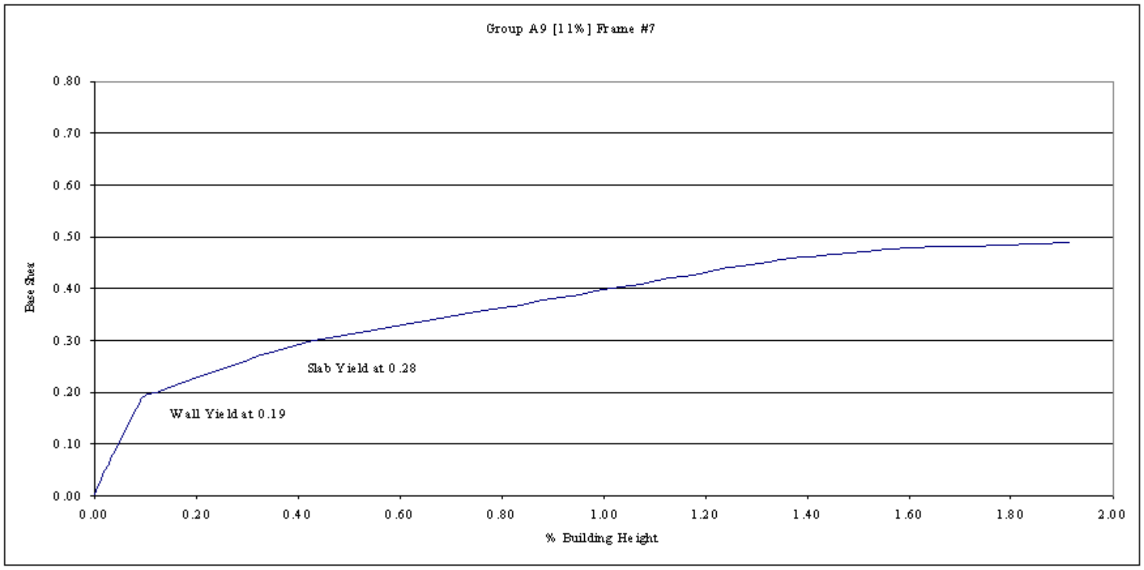


Figure 5-9: Pushover Results for Building 1A9 (Lateral load-vs-Drift at Frame 7)

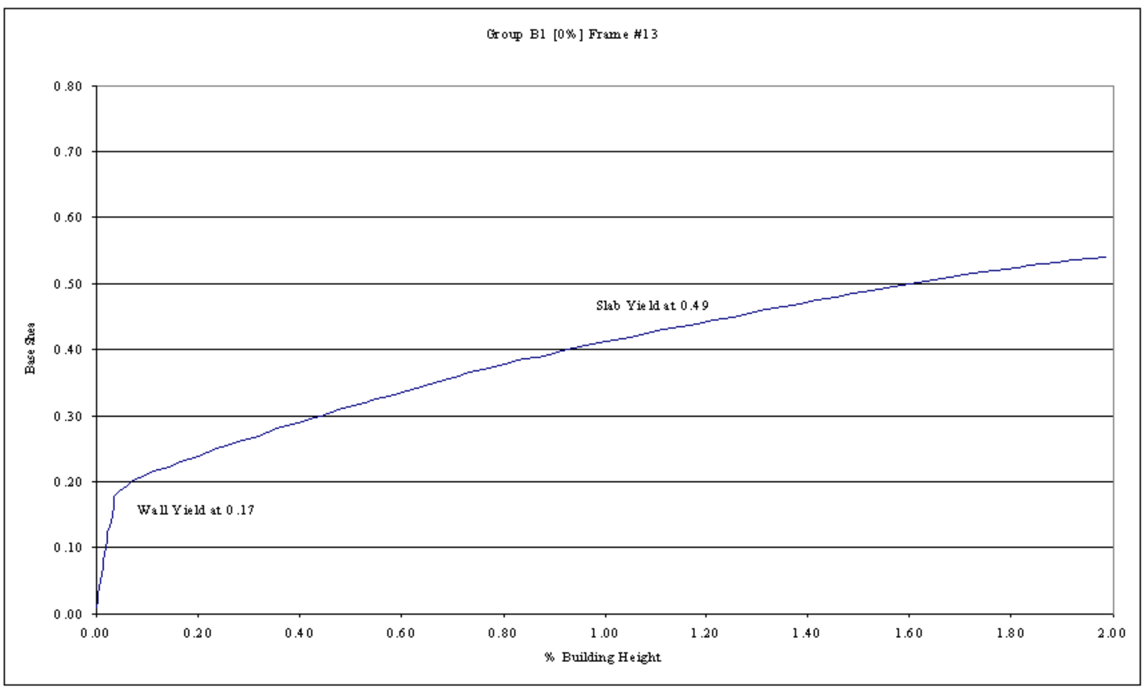


Figure 5-10: Pushover Results for Building 1B1 (Lateral load-vs-Drift at Frame 13)

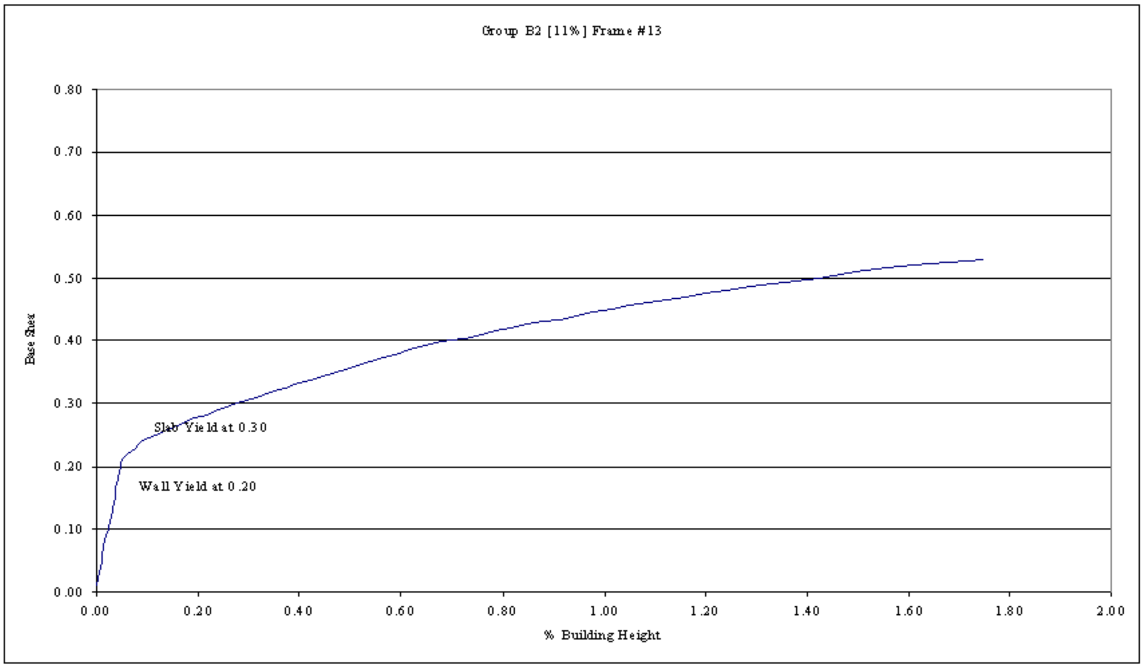


Figure 5-11: Pushover Results for Building 1B2 (Lateral load-vs-Drift at Frame 13)

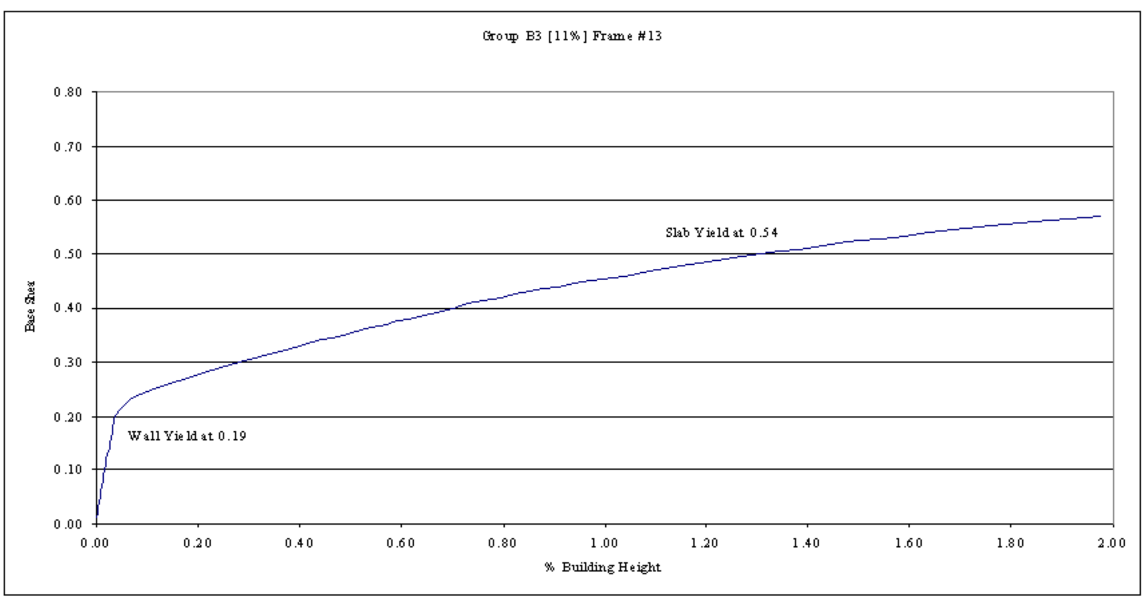


Figure 5-12: Pushover Results for Building 1B3 (Lateral load-vs-Drift at Frame 13)

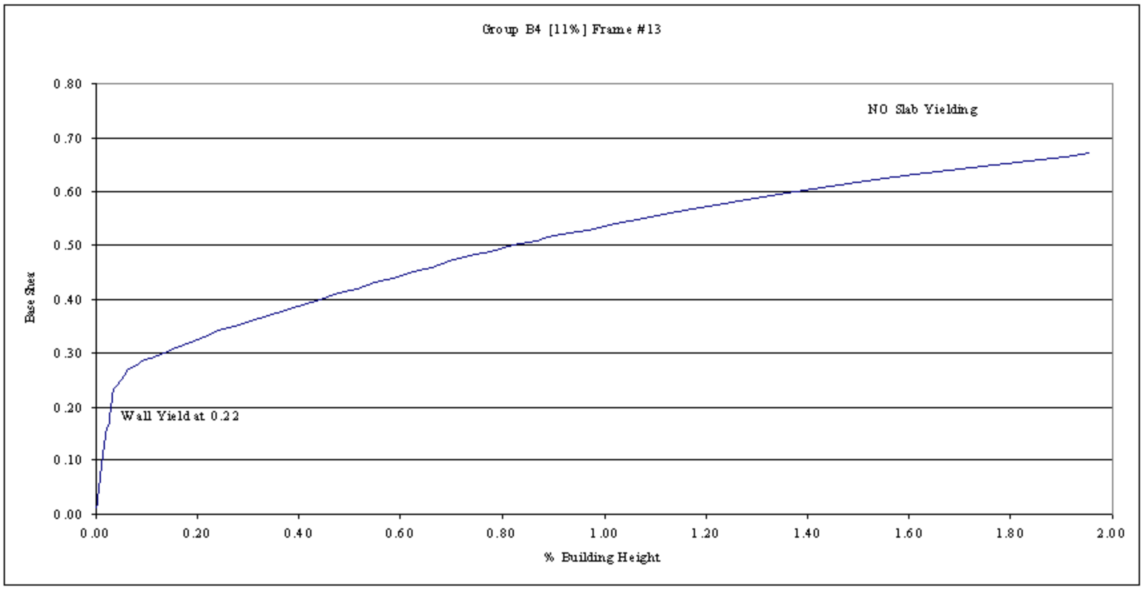


Figure 5-13: Pushover Results for Building 1B4 (Lateral load-vs-Drift at Frame 13)

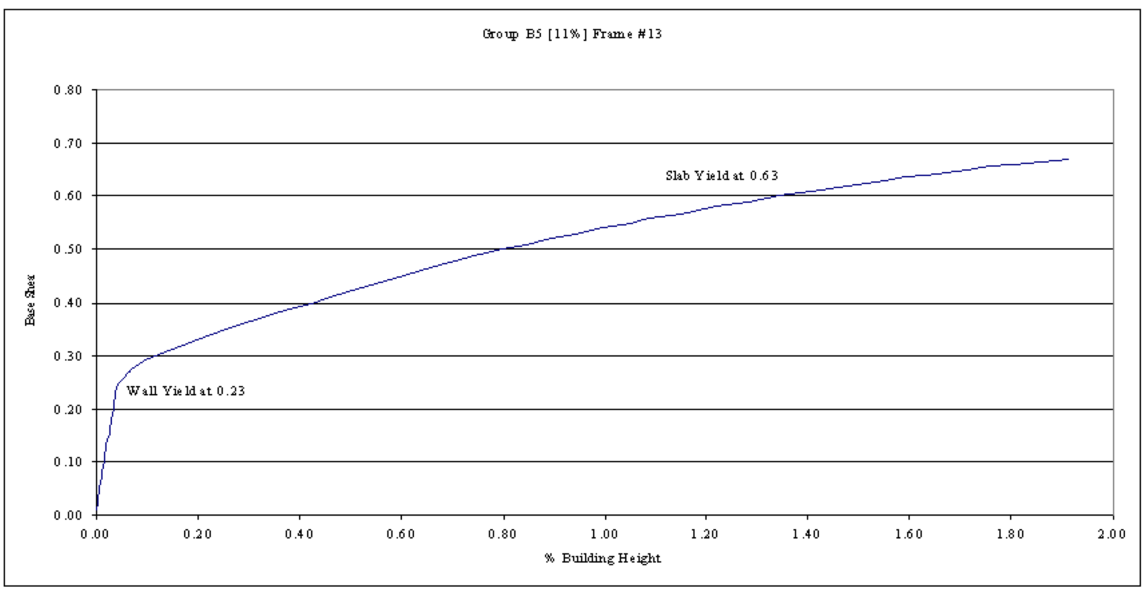


Figure 5-14: Pushover Results for Building 1B5 (Lateral load-vs-Drift at Frame 13)

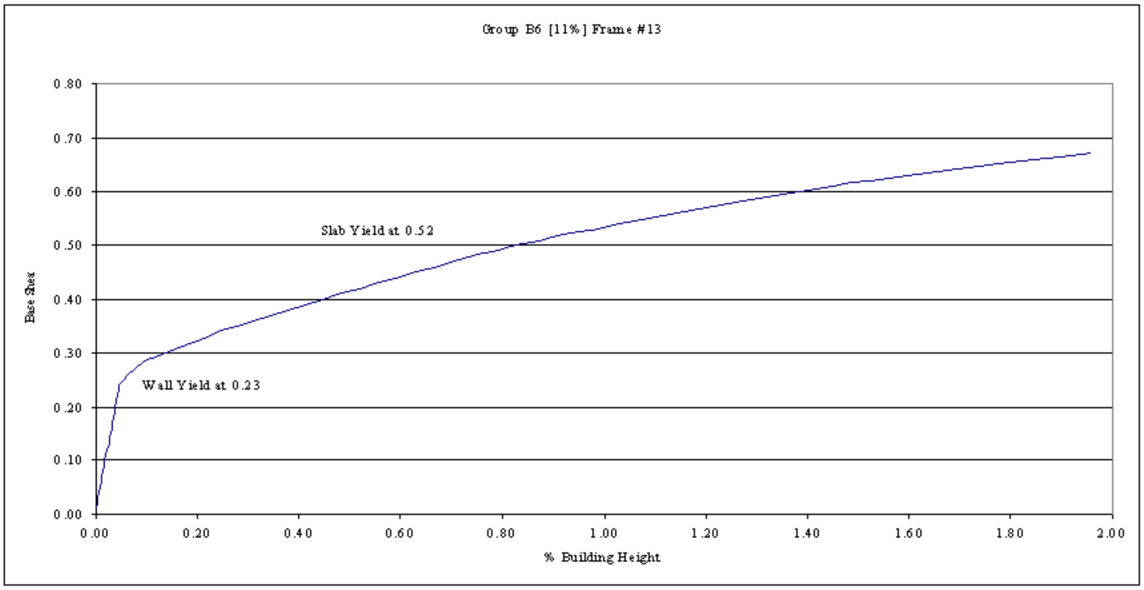


Figure 5-15: Pushover Results for Building 1B6 (Lateral load-vs-Drift at Frame 13)

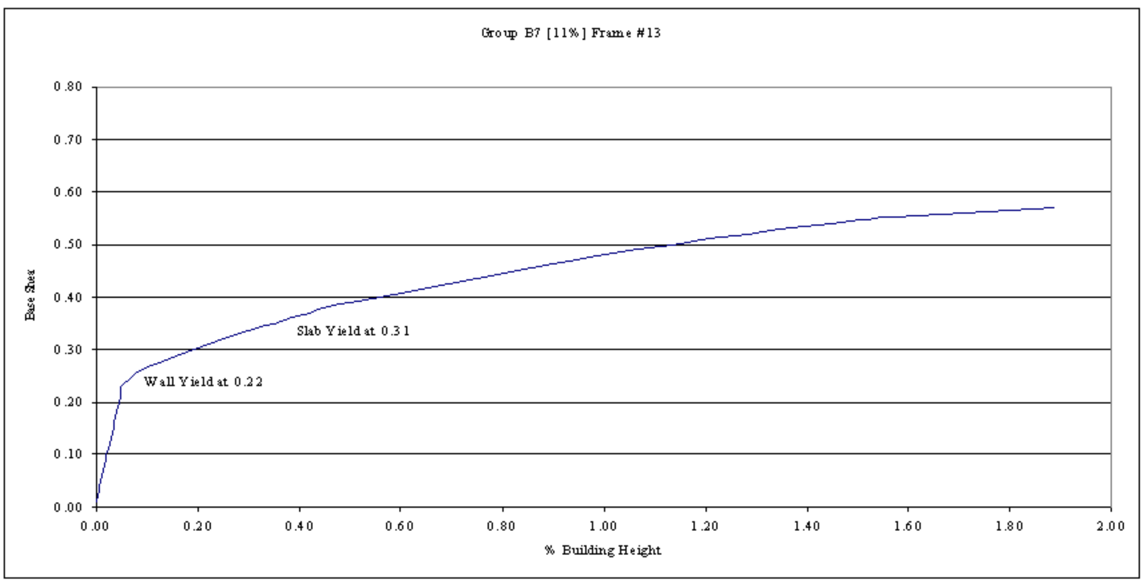


Figure 5-16: Pushover Results for Building 1B7 (Lateral load-vs-Drift at Frame 13)

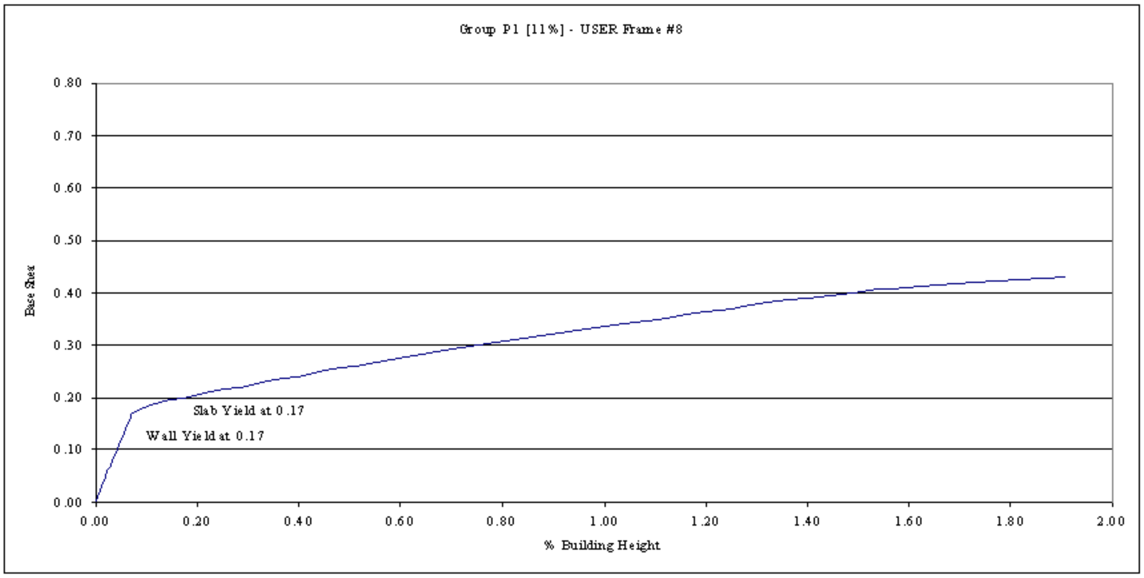


Figure 5-17: Pushover Results for Building 1P1 (Lateral load-vs-Drift at Frame 8)

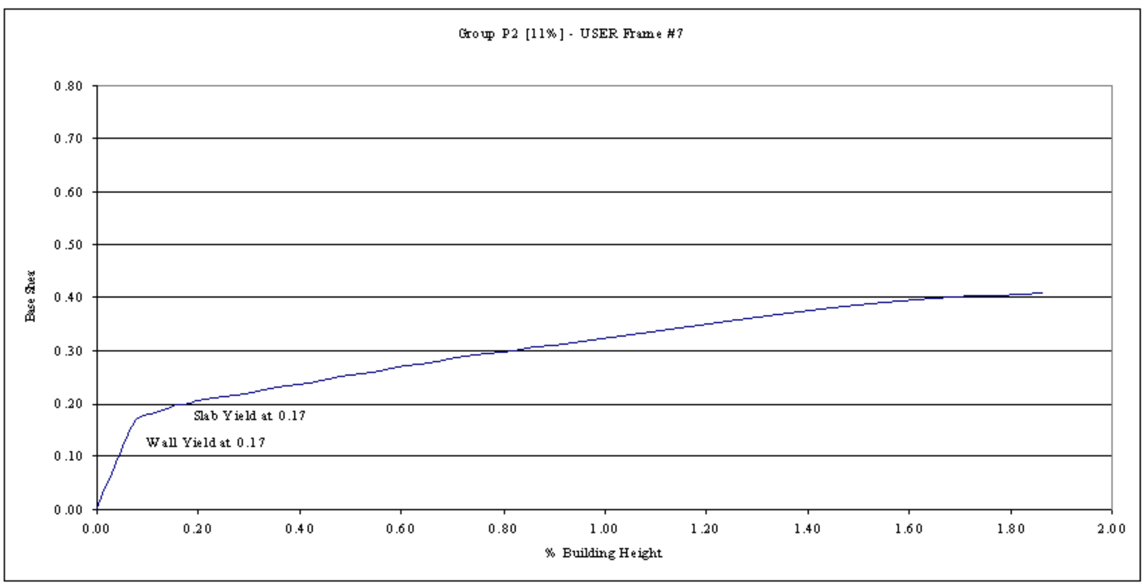


Figure 5-18: Pushover Results for Building 1P2 (Lateral load-vs-Drift at Frame 7)

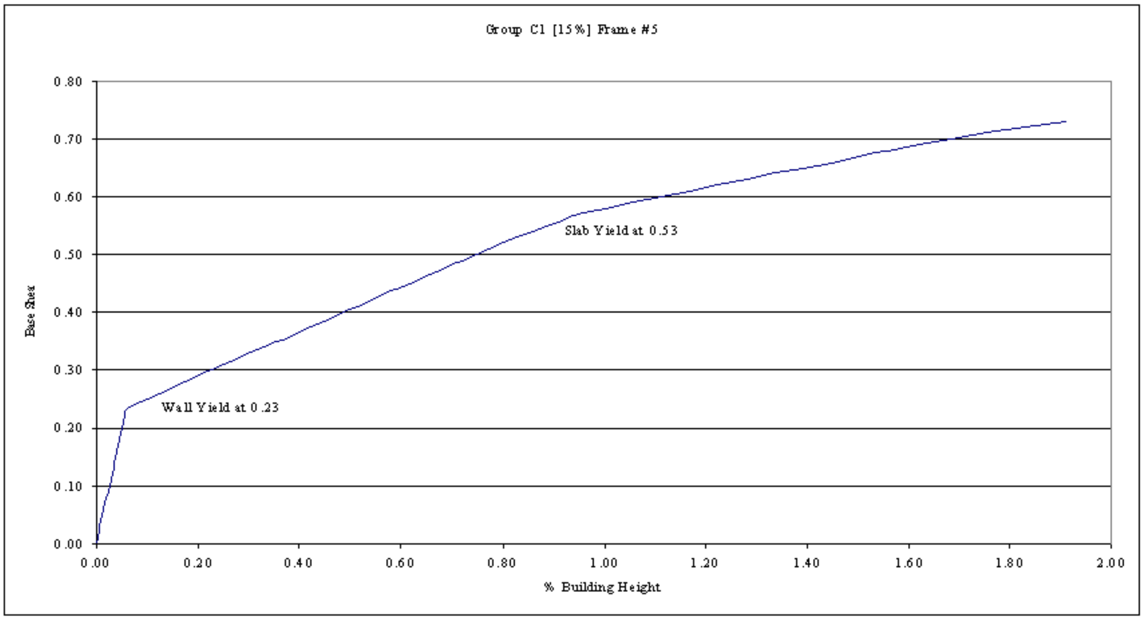


Figure 5-19: Pushover Results for Building 1C1 (Lateral load-vs-Drift at Frame 5)

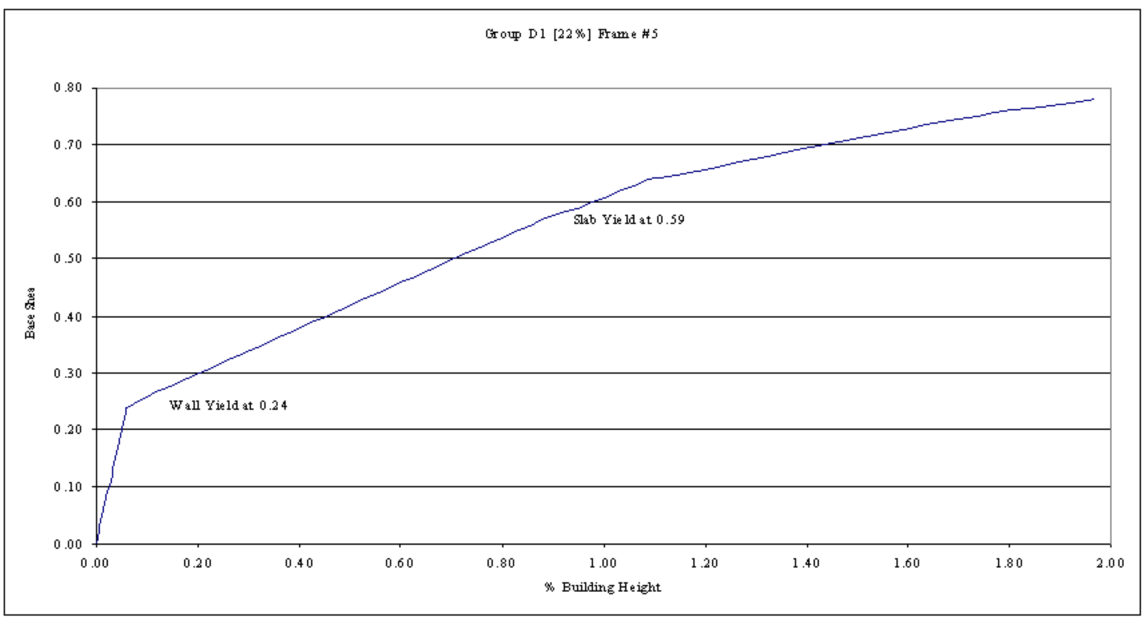


Figure 5-20: Pushover Results for Building 1D1 (Lateral load-vs-Drift at Frame 5)

In building 1A1 where the plan aspect ratio is 4:1 and the shear walls are at the ends and the floor diaphragms have no openings (see Fig. 4-1), and they behave as deep beams with end supports, the shear wall elements at the base of building yielded first at base shear coefficient of 0.180 and the slab elements at middle of the third floor diaphragm yielded at a much higher (133% higher) base shear coefficient of 0.420 (Figure 5-1). As for building 1A2, keeping the end shear walls and the aspect ratio the same, however, openings are introduced non-symmetrically (with respect to the plan of the building) at bays 8 and 9 (see Figure 4-2), the wall elements yielded first at base shear coefficient of 0.170, followed by the slab elements at 47% higher base shear coefficient of 0.250 (Figure 5-2). Similar yielding pattern is observed in building 1A3, where the end shear walls and a diaphragm aspect ratio of 4:1 is maintained, but openings are interjected in the middle bays of the building symmetrically, the wall elements yielded first at base shear coefficient of 0.180, followed by the slab elements at 33% higher base shear coefficient of 0.240 (Figure 5-3). In building 1A4 – where the openings are moved towards the ends - the shear wall elements at the base of building yielded first at base shear coefficient of 0.170 and the slab elements at middle of the third floor diaphragm yielded at a much higher (124% higher) base shear coefficient of 0.380 (Figure 5-4). While in building 1A5, the shear wall elements at the base of building yielded first at base shear coefficient of 0.180 and the slab elements at middle of the third floor diaphragm yielded at a much higher (116% higher) base shear coefficient of 0.390 (Figure 5-5). However, building 1A6, the shear wall elements at the base of building yielded first at base shear coefficient of 0.180 and the slab elements at middle of the third floor diaphragm yielded at a higher (78% higher) base shear coefficient of 0.320 (Figure 5-6). For building 1A7, the shear wall elements at the base of building yielded first at base shear coefficient of 0.180 and the slab elements at middle of the third floor diaphragm yielded at a higher (44% higher) base shear coefficient of 0.260 (Figure 5-7). Then again in building 1A8, the shear wall elements at the base of building yielded first at base shear coefficient of 0.180 and the slab elements at middle of the third floor diaphragm yielded at a higher (33% higher) base shear coefficient of 0.240 (Figure 5-8).

Compared to building 1A8, building 1A9 where the plan aspect ratio is 4:1 and the shear walls are at the ends and the floor diaphragms have 8 openings – twice as in building 1A8 - the shear wall elements at the base of building yielded first at base shear coefficient of 0.190 – within 5% of 1A8 - and the slab elements at middle of the third floor diaphragm yielded at 47% higher base shear coefficient of 0.280 (Figure 5-9). Similarly, for building 1B1 where the plan aspect ratio is also 4:1, however, the shear walls were shifted to the interior frames - floor diaphragms behaving as deep cantilever beams - the walls at the base of the building yielded first at base shear coefficient of 0.170 – 11% lower than in building 1A1 - and the slabs at the middle bays of the third floor yielded at a higher (188% higher) base shear coefficient of 0.490 – 17% higher than in building 1A1 - (Figure 5-10). As for building 1B2, where the openings are introduced symmetrically in the middle bays of the building, the walls yielded first at base shear coefficient of 0.200 and the slab elements with openings yielded at a higher (50% higher) base shear coefficient of 0.300 (Figure 5-11). For building 1B3 where openings are moved to the ends of the building, the walls yielded first at base shear coefficient of 0.190 and the middle bay slab yielded at a higher (84% higher) base shear coefficient of 0.540 (Figure 5-12). But for building 1B4 the walls yielded first at base shear coefficient of 0.220 and none of the slab elements yielded when the building was subjected to a lateral drift of 2% of the building height (Figure 5-13). As for building 1B5 the walls yielded first at base shear coefficient of 0.230 and the slab yielded next at a higher (74% higher) base shear coefficient of 0.630 (Figure 5-14). While for building 1B6 the walls yielded first at base shear coefficient of 0.230 and the slab yielded next at a higher (126% higher) base shear coefficient of 0.520 (Figure 5-15). Finally, for building 1B7, the wall yielded at base shear coefficient of 0.220, followed by the yielding of the slab with opening at a base shear coefficient of 0.310 - 41% higher - (Figure 5-16).

For buildings 1P1 and 1P2 with end shear walls and diaphragm plan aspect ratio of 4:1, at bays 8 and 9 (Figure 4-17) and bays 6 and 9 (Figure 4-18) respectively, the 11% floor openings are placed non-symmetrically with respect to the centerline of the floor diaphragm cross-section. Hence causing the slab and the shear wall to yield simultaneously at a base shear coefficient of 0.170 (Figures 5-17 & 5-18).

For buildings 1C1 and 1D1 where the diaphragm plan aspect ratio is 3:1 and the shear walls are located at the ends, the effects of reducing the floor area by 15% and 22%, respectively, by placing the slab openings symmetrically in the floor diaphragms were investigated (Figures 4-19 and 4-20). For building 1C1, the walls yielded first at a base shear coefficient of 0.230 and the slabs yielded at a 130% higher base shear coefficient of 0.530 (Figure 5-19). For building 1D1, the wall yielded first at base shear coefficient of 0.240 and the slab yielded again at a 130% higher base shear coefficient of 0.590 (Figure 5-20).

5.2 Dynamic Analysis Outcome

The outcomes gathered for the inelastic dynamic analysis of all 129 scenarios investigated for all 20 building groups considered are presented in tabular and graphical format in this section. A rundown of all the inelastic dynamic summary results for every scenario is presented in Table 5-3, where the total building base shear and its distribution to the beam-column frames and shear wall frames, henceforth are referred to as the frames and shear walls, are given in absolute values and percentages of the total building base shear along with the buildings periods. Subsequently, Figures 5-21 to 5-32 show the shear distribution across frames.

Table 5-3: Inelastic Dynamic Analysis Result Summary

Scenario	Base Shear, k	% Walls Shear	% Frames Shear	Walls Shear, k	Frames Shear, k	Period, T, sec.
Group A1 [0%]						
1A1-4:1-ESW-Solid-IE-LP	1599.60	71.38	28.62	1141.80	457.80	0.286
2A1-4:1-ESW-Solid-EL-LP	1732.60	73.47	26.53	1272.90	459.70	0.286
3A1-4:1-ESW-Solid-RD-LP	1708.80	77.38	22.62	1322.20	386.60	0.247
4A1-4:1-ESW-Solid-IE-SF	863.31	74.57	25.43	643.80	219.51	0.286
5A1-4:1-ESW-Solid-EL-SF	959.66	76.40	23.60	733.20	226.46	0.286
6A1-4:1-ESW-Solid-RD-SF	902.66	79.97	20.03	721.90	180.76	0.247
7A1-4:1-ESW-Solid-IE-PF	930.50	76.35	23.65	710.40	220.10	0.286
8A1-4:1-ESW-Solid-EL-PF	1024.60	77.03	22.97	789.20	235.40	0.286
9A1-4:1-ESW-Solid-RD-PF	1129.30	81.32	18.68	918.30	211.00	0.247
Group A2 [11%]						
1A2-4:1-ESW-(8&9-T&B)-IE-LP	1533.80	69.07	30.93	1059.40	474.40	0.284
2A2-4:1-ESW-(8&9-T&B)-EL-LP	1737.40	72.82	27.18	1265.20	472.20	0.284
3A2-4:1-ESW-(8&9-T&B)-RD-LP	1700.00	78.10	21.90	1327.70	372.30	0.237
4A2-4:1-ESW-(8&9-T&B)-IE-SF	771.99	72.25	27.75	557.80	214.19	0.284
5A2-4:1-ESW-(8&9-T&B)-EL-SF	891.16	75.01	24.99	668.50	222.66	0.284
6A2-4:1-ESW-(8&9-T&B)-RD-SF	860.74	80.34	19.66	691.50	169.24	0.237
7A2-4:1-ESW-(8&9-T&B)-IE-PF	867.22	73.33	26.67	635.90	231.32	0.284
8A2-4:1-ESW-(8&9-T&B)-EL-PF	911.84	76.72	23.28	699.60	212.24	0.284
9A2-4:1-ESW-(8&9-T&B)-RD-PF	972.64	80.40	19.60	782.00	190.64	0.237
Group A3 [11%]						
1A3-4:1-ESW-(6&7-T&B)-IE-LP	1545.50	69.14	30.86	1068.60	476.90	0.285
2A3-4:1-ESW-(6&7-T&B)-EL-LP	1800.50	73.88	26.12	1330.20	470.30	0.285
3A3-4:1-ESW-(6&7-T&B)-RD-LP	1593.00	77.90	22.10	1241.00	352.00	0.237
4A3-4:1-ESW-(6&7-T&B)-IE-SF	724.33	70.82	29.18	513.00	211.33	0.285
5A3-4:1-ESW-(6&7-T&B)-EL-SF	891.04	74.47	25.53	663.60	227.44	0.285
6A3-4:1-ESW-(6&7-T&B)-RD-SF	874.08	79.65	20.35	696.20	177.88	0.237
7A3-4:1-ESW-(6&7-T&B)-IE-PF	893.87	76.14	23.86	680.60	213.27	0.285
8A3-4:1-ESW-(6&7-T&B)-EL-PF	952.99	77.71	22.29	740.60	212.39	0.285
9A3-4:1-ESW-(6&7-T&B)-RD-PF	1074.40	81.65	18.35	877.20	197.20	0.237
Group A4 [11%]						
1A4-4:1-ESW-(1&12-T&B)-IE-LP	1586.80	69.66	30.34	1105.40	481.40	0.280
2A4-4:1-ESW-(1&12-T&B)-IE-SF	798.22	73.71	26.29	588.40	209.82	0.280
3A4-4:1-ESW-(1&12-T&B)-IE-PF	858.46	64.70	35.30	555.40	303.06	0.280

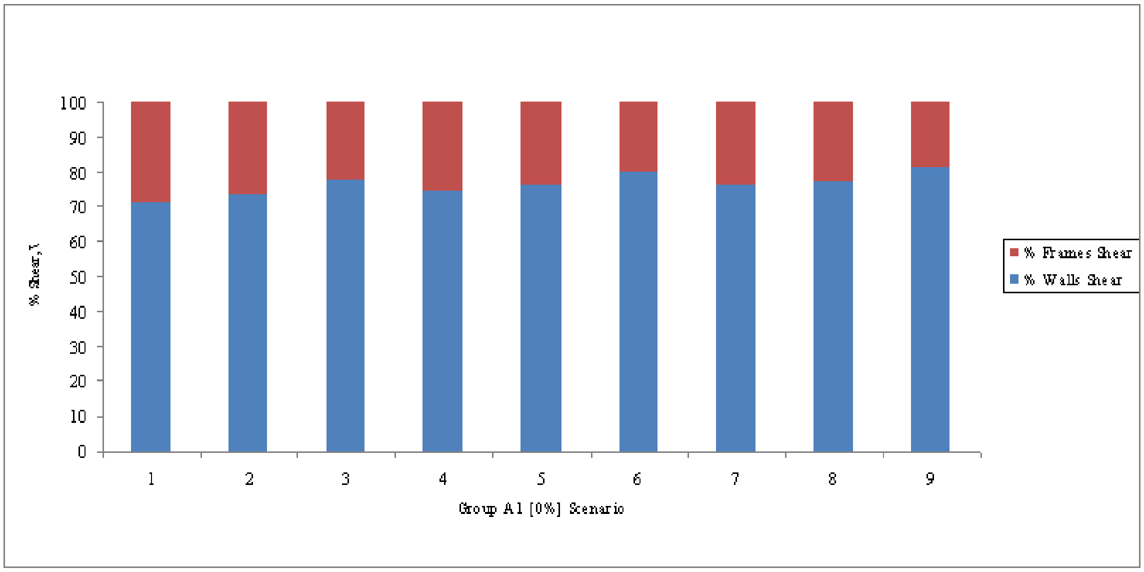
Table 5-3 (Cont'd): Inelastic Dynamic Analysis Result Summary

Scenario	Base Shear, k	% Walls Shear	% Frames Shear	Walls Shear, k	Frames Shear, k	Period, T, sec.
Group A5 [11%]						
1A5-4:1-ESW-(2&11-T&B)-IE-LP	1578.10	70.64	29.36	1114.80	463.30	0.281
2A5-4:1-ESW-(2&11-T&B)-IE-SF	811.02	73.98	26.02	600.00	211.02	0.281
3A5-4:1-ESW-(2&11-T&B)-IE-PF	851.64	65.26	34.74	555.80	295.84	0.281
Group A6 [11%]						
1A6-4:1-ESW-(3&10-T&B)-IE-LP	1553.40	69.72	30.28	1083.10	470.30	0.282
2A6-4:1-ESW-(3&10-T&B)-IE-SF	801.63	73.59	26.41	589.90	211.73	0.282
3A6-4:1-ESW-(3&10-T&B)-IE-PF	853.66	64.73	35.27	552.60	301.06	0.282
Group A7 [11%]						
1A7-4:1-ESW-(4&9-T&B)-IE-LP	1570.80	69.68	30.32	1094.60	476.20	0.284
2A7-4:1-ESW-(4&9-T&B)-IE-SF	763.36	72.10	27.90	550.40	212.96	0.284
3A7-4:1-ESW-(4&9-T&B)-IE-PF	875.43	74.34	25.66	650.80	224.63	0.284
Group A8 [11%]						
1A8-4:1-ESW-(5&8-T&B)-IE-LP	1571.60	69.81	30.19	1097.20	474.40	0.285
2A8-4:1-ESW-(5&8-T&B)-IE-SF	779.82	72.71	27.29	567.00	212.82	0.285
3A8-4:1-ESW-(5&8-T&B)-IE-PF	917.08	74.58	25.42	684.00	233.08	0.285
Group A9 [22%]						
1A9-4:1-ESW-(5 6 7 8-T&B)-IE-LP	1541.10	69.15	30.85	1065.60	475.50	0.282
2A9-4:1-ESW-(5 6 7 8-T&B)-EL-LP	1699.80	72.02	27.98	1224.20	475.60	0.282
3A9-4:1-ESW-(5 6 7 8-T&B)-RD-LP	1630.70	79.74	20.26	1300.40	330.30	0.229
4A9-4:1-ESW-(5 6 7 8-T&B)-IE-SF	751.10	75.68	24.32	568.40	182.70	0.282
5A9-4:1-ESW-(5 6 7 8-T&B)-EL-SF	862.63	73.89	26.11	637.40	225.23	0.282
6A9-4:1-ESW-(5 6 7 8-T&B)-RD-SF	853.67	80.80	19.20	689.80	163.87	0.229
7A9-4:1-ESW-(5 6 7 8-T&B)-IE-PF	943.36	72.70	27.30	685.80	257.56	0.282
8A9-4:1-ESW-(5 6 7 8-T&B)-EL-PF	906.39	69.77	30.23	632.40	273.99	0.282
9A9-4:1-ESW-(5 6 7 8-T&B)-RD-PF	1096.90	81.78	18.22	897.00	199.90	0.229
Group B1 [0%]						
1B1-4:1-ISW-Solid-IE-LP	1594.43	78.74	21.26	1255.40	339.03	0.190
2B1-4:1-ISW-Solid-EL-LP	1601.99	80.36	19.64	1287.40	314.59	0.190
3B1-4:1-ISW-Solid-RD-LP	1703.91	83.87	16.13	1429.00	274.91	0.162
4B1-4:1-ISW-Solid-IE-SF	983.64	82.04	17.96	807.00	176.64	0.190
5B1-4:1-ISW-Solid-EL-SF	1000.21	87.36	12.64	873.80	126.41	0.190
6B1-4:1-ISW-Solid-RD-SF	923.25	83.70	16.30	772.80	150.45	0.162
7B1-4:1-ISW-Solid-IE-PF	1145.60	81.54	18.46	934.10	211.50	0.190
8B1-4:1-ISW-Solid-EL-PF	1204.96	83.67	16.33	1008.20	196.76	0.190
9B1-4:1-ISW-Solid-RD-PF	1527.92	86.90	13.10	1327.70	200.22	0.162
Group B2 [11%]						
1B2-4:1-ISW-(6&7-T&B)-IE-LP	1539.77	73.29	26.71	1128.50	411.27	0.200
2B2-4:1-ISW-(6&7-T&B)-EL-LP	1642.49	77.90	22.10	1279.50	362.99	0.200
3B2-4:1-ISW-(6&7-T&B)-RD-LP	1624.02	82.76	17.24	1344.10	279.92	0.156
4B2-4:1-ISW-(6&7-T&B)-IE-SF	873.87	77.03	22.97	673.10	200.77	0.200
5B2-4:1-ISW-(6&7-T&B)-EL-SF	1076.19	78.23	21.77	841.90	234.29	0.200
6B2-4:1-ISW-(6&7-T&B)-RD-SF	813.56	79.58	20.42	647.40	166.16	0.156
7B2-4:1-ISW-(6&7-T&B)-IE-PF	929.33	75.41	24.59	700.80	228.53	0.200
8B2-4:1-ISW-(6&7-T&B)-EL-PF	1051.34	79.48	20.52	835.60	215.74	0.200
9B2-4:1-ISW-(6&7-T&B)-RD-PF	1404.37	84.51	15.49	1186.80	217.57	0.156
Group B3 [11%]						
1B3-4:1-ISW-(1&12-T&B)-IE-LP	1611.43	79.44	20.56	1280.20	331.23	0.183
2B3-4:1-ISW-(1&12-T&B)-IE-SF	917.45	79.86	20.14	732.70	184.75	0.183
3B3-4:1-ISW-(1&12-T&B)-IE-PF	1202.34	79.05	20.95	950.50	251.84	0.183
Group B4 [11%]						
1B4-4:1-ISW-(2&11-T&B)-IE-LP	1502.44	80.05	19.95	1202.70	299.74	0.166
2B4-4:1-ISW-(2&11-T&B)-IE-SF	759.32	75.00	25.00	569.50	189.82	0.166
3B4-4:1-ISW-(2&11-T&B)-IE-PF	1277.28	79.11	20.89	1010.40	266.88	0.166

Table 5-3 (Cont'd): Inelastic Dynamic Analysis Result Summary

Scenario	Base Shear, k	% Walls Shear	% Frames Shear	Walls Shear, k	Frames Shear, k	Period, T, sec.
Group B5 [11%]						
1B5-4:1-ISW-(3&10-T&B)-IE-LP	1443.86	78.89	21.11	1139.00	304.86	0.172
2B5-4:1-ISW-(3&10-T&B)-IE-SF	755.02	75.93	24.07	573.30	181.72	0.172
3B5-4:1-ISW-(3&10-T&B)-IE-PF	1191.76	80.04	19.96	953.90	237.86	0.172
Group B6 [11%]						
1B6-4:1-ISW-(4&9-T&B)-IE-LP	1419.11	76.22	23.78	1081.70	337.41	0.180
2B6-4:1-ISW-(4&9-T&B)-IE-SF	911.92	78.38	21.62	714.80	197.12	0.180
3B6-4:1-ISW-(4&9-T&B)-IE-PF	976.33	76.17	23.83	743.70	232.63	0.180
Group B7 [11%]						
1B7-4:1-ISW-(5&8-T&B)-IE-LP	1432.98	73.98	26.02	1060.10	372.88	0.191
2B7-4:1-ISW-(5&8-T&B)-IE-SF	838.55	76.42	23.58	640.80	197.75	0.191
3B7-4:1-ISW-(5&8-T&B)-IE-PF	783.49	71.16	28.84	557.50	225.99	0.191
Group P1 [11%] - USER						
1P1-4:1-ESW-(8&9-M&B)-IE-LP	1568.40	70.72	29.28	1109.10	459.30	0.279
2P1-4:1-ESW-(8&9-M&B)-EL-LP	1803.80	75.12	24.88	1355.10	448.70	0.279
3P1-4:1-ESW-(8&9-M&B)-RD-LP	1739.70	79.48	20.52	1382.80	356.90	0.237
4P1-4:1-ESW-(8&9-M&B)-IE-SF	794.52	70.12	29.88	557.10	237.42	0.279
5P1-4:1-ESW-(8&9-M&B)-EL-SF	894.59	76.44	23.56	683.80	210.79	0.279
6P1-4:1-ESW-(8&9-M&B)-RD-SF	914.74	80.86	19.14	739.70	175.04	0.238
7P1-4:1-ESW-(8&9-M&B)-IE-PF	859.64	72.07	27.93	619.50	240.14	0.279
8P1-4:1-ESW-(8&9-M&B)-EL-PF	909.63	76.51	23.49	696.00	213.63	0.279
9P1-4:1-ESW-(8&9-M&B)-RD-PF	972.52	80.38	19.62	781.70	190.82	0.237
Group P2 [11%] - USER						
1P2-4:1-ESW-(6&7-M&B)-IE-LP	1508.70	69.97	30.03	1055.60	453.10	0.279
2P2-4:1-ESW-(6&7-M&B)-EL-LP	1775.50	74.68	25.32	1326.00	449.50	0.279
3P2-4:1-ESW-(6&7-M&B)-RD-LP	1631.20	78.70	21.30	1283.70	347.50	0.236
4P2-4:1-ESW-(6&7-M&B)-IE-SF	780.06	69.46	30.54	541.80	238.26	0.279
5P2-4:1-ESW-(6&7-M&B)-EL-SF	871.86	74.21	25.79	647.00	224.86	0.279
6P2-4:1-ESW-(6&7-M&B)-RD-SF	941.94	80.88	19.12	761.80	180.14	0.236
7P2-4:1-ESW-(6&7-M&B)-IE-PF	916.95	69.29	30.71	635.40	281.55	0.279
8P2-4:1-ESW-(6&7-M&B)-EL-PF	944.42	71.42	28.58	674.50	269.92	0.279
9P2-4:1-ESW-(6&7-M&B)-RD-PF	1071.30	80.87	19.13	866.40	204.90	0.236
Group C1 [15%]						
1C1-3:1-ESW-(4&6-T&B)-IE-LP	1297.00	81.49	18.51	1056.90	240.10	0.229
2C1-3:1-ESW-(4&6-T&B)-EL-LP	1305.80	82.36	17.64	1075.40	230.40	0.229
3C1-3:1-ESW-(4&6-T&B)-RD-LP	1424.60	93.07	6.93	1325.90	98.70	0.209
4C1-3:1-ESW-(4&6-T&B)-IE-SF	771.08	80.86	19.14	623.50	147.58	0.229
5C1-3:1-ESW-(4&6-T&B)-EL-SF	773.08	81.07	18.93	626.70	146.38	0.229
6C1-3:1-ESW-(4&6-T&B)-RD-SF	704.29	85.55	14.45	602.50	101.79	0.209
7C1-3:1-ESW-(4&6-T&B)-IE-PF	899.00	79.00	21.00	710.20	188.80	0.229
8C1-3:1-ESW-(4&6-T&B)-EL-PF	942.18	79.26	20.74	746.80	195.38	0.229
9C1-3:1-ESW-(4&6-T&B)-RD-PF	866.90	97.29	2.71	843.40	23.50	0.209
Group D1 [22%]						
1D1-3:1-ESW-(4 5 6-T&B)-IE-LP	1292.80	81.54	18.46	1054.10	238.70	0.226
2D1-3:1-ESW-(4 5 6-T&B)-EL-LP	1306.40	82.56	17.44	1078.50	227.90	0.226
3D1-3:1-ESW-(4 5 6-T&B)-RD-LP	1435.10	92.78	7.22	1331.50	103.60	0.204
4D1-3:1-ESW-(4 5 6-T&B)-IE-SF	745.09	80.14	19.86	597.10	147.99	0.226
5D1-3:1-ESW-(4 5 6-T&B)-EL-SF	745.51	80.23	19.77	598.10	147.41	0.226
6D1-3:1-ESW-(4 5 6-T&B)-RD-SF	740.94	85.82	14.18	635.90	105.04	0.204
7D1-3:1-ESW-(4 5 6-T&B)-IE-PF	866.03	77.65	22.35	672.50	193.53	0.226
8D1-3:1-ESW-(4 5 6-T&B)-EL-PF	907.03	79.16	20.84	718.00	189.03	0.226
9D1-3:1-ESW-(4 5 6-T&B)-RD-PF	841.14	97.38	2.62	819.10	22.04	0.204

In the Figures 5-21 through 5-32, the first graph on the top represents the base shear distribution amongst the shear wall frames and the moment frames in percent per scenario, i.e. 1 through 9, while the second graph on the bottom represents the base shear distribution in absolute values with the first bar (blue) as the total building base shear, the second bar (red) as the shear wall frames base shear, and the third bar (green) as the moment frame base shear – per scenario, i.e. 1 through 9.



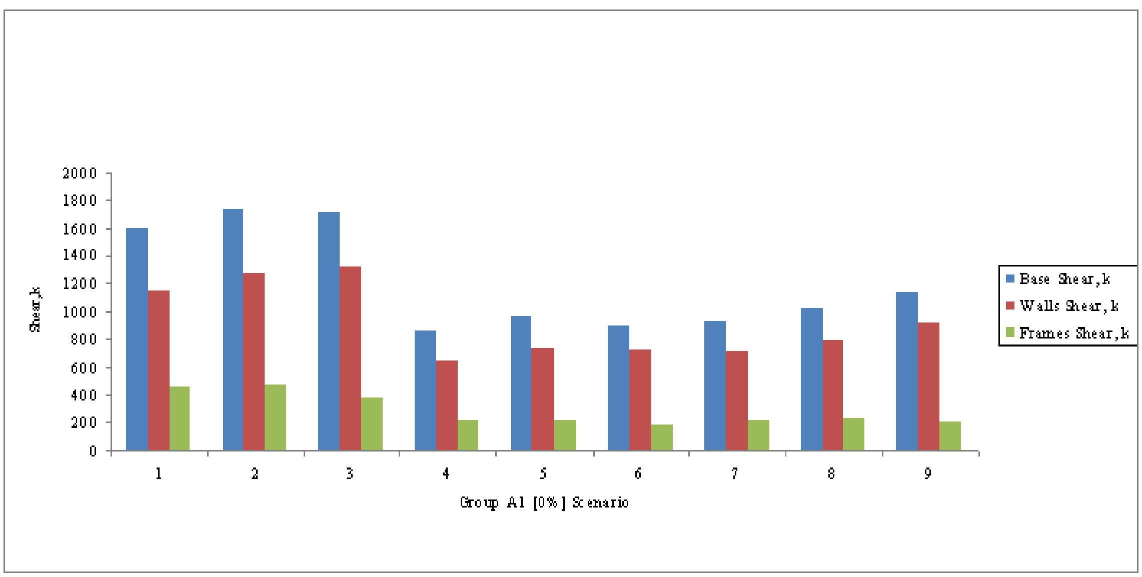


Figure 5-21: Building A1 [0%] Shear Distribution vs. Scenario Number

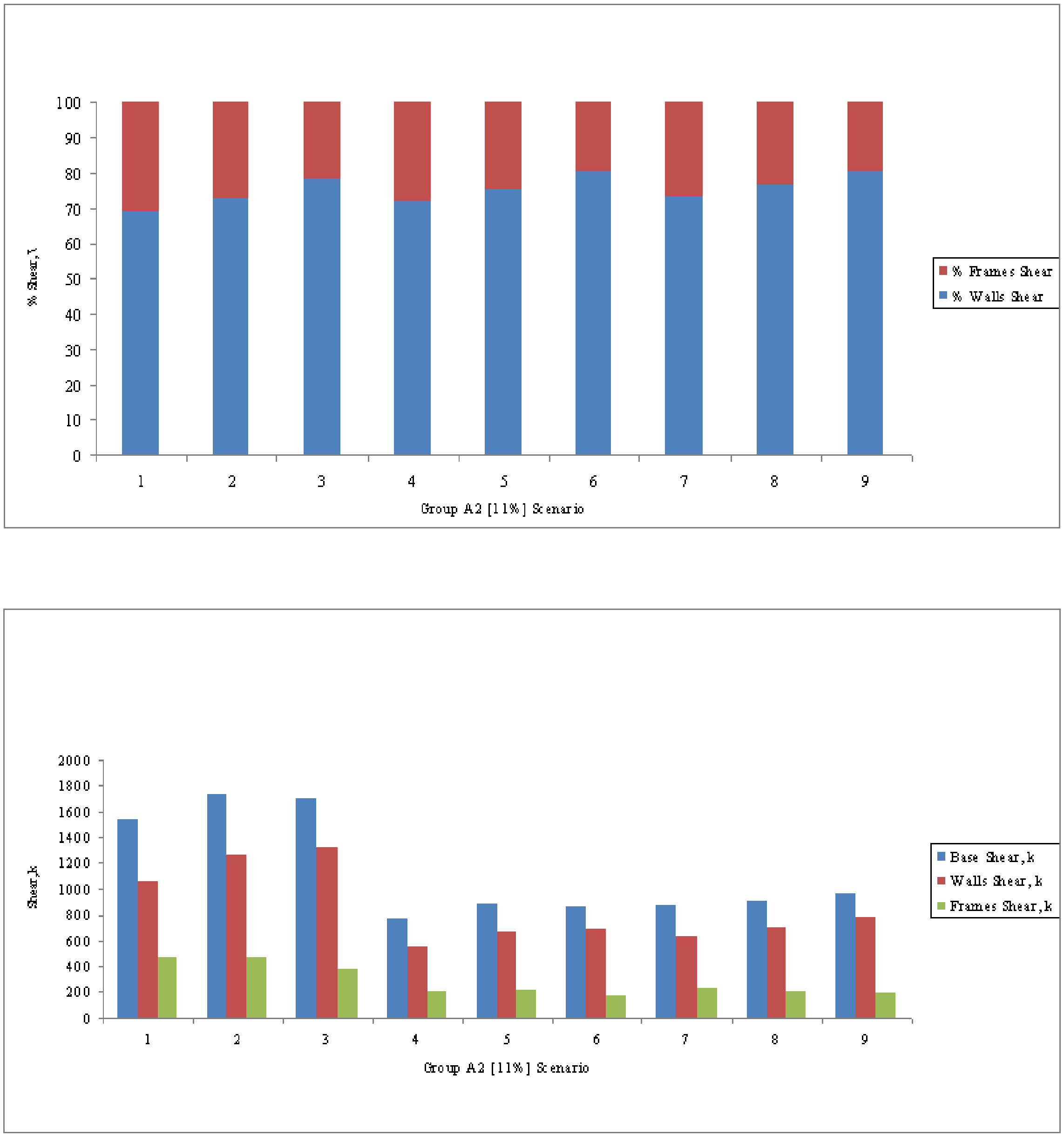
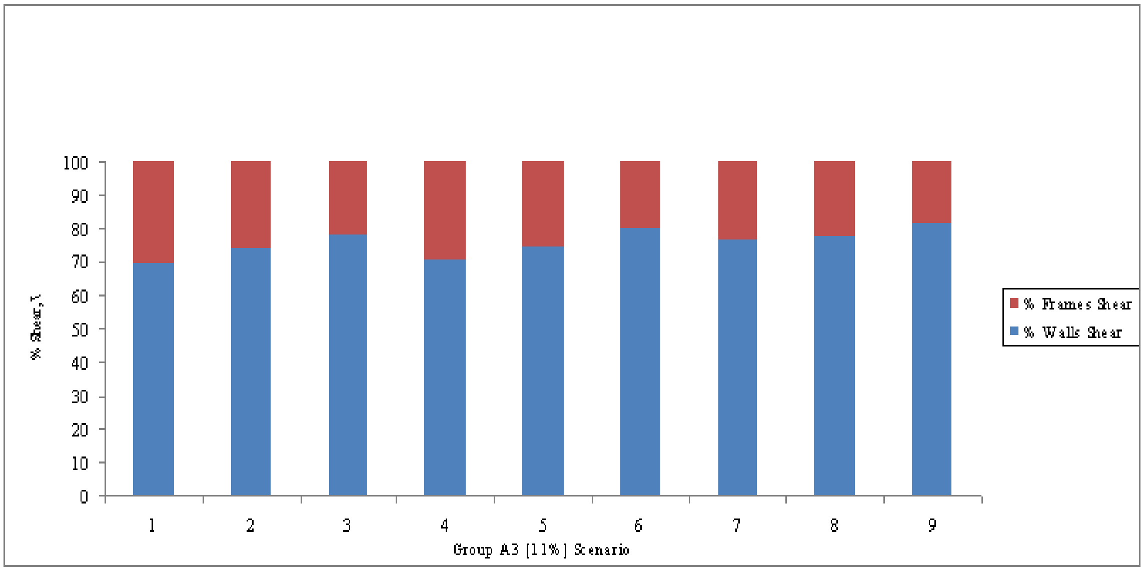


Figure 5-22: Building A2 [11%] Shear Distribution vs. Scenario Number



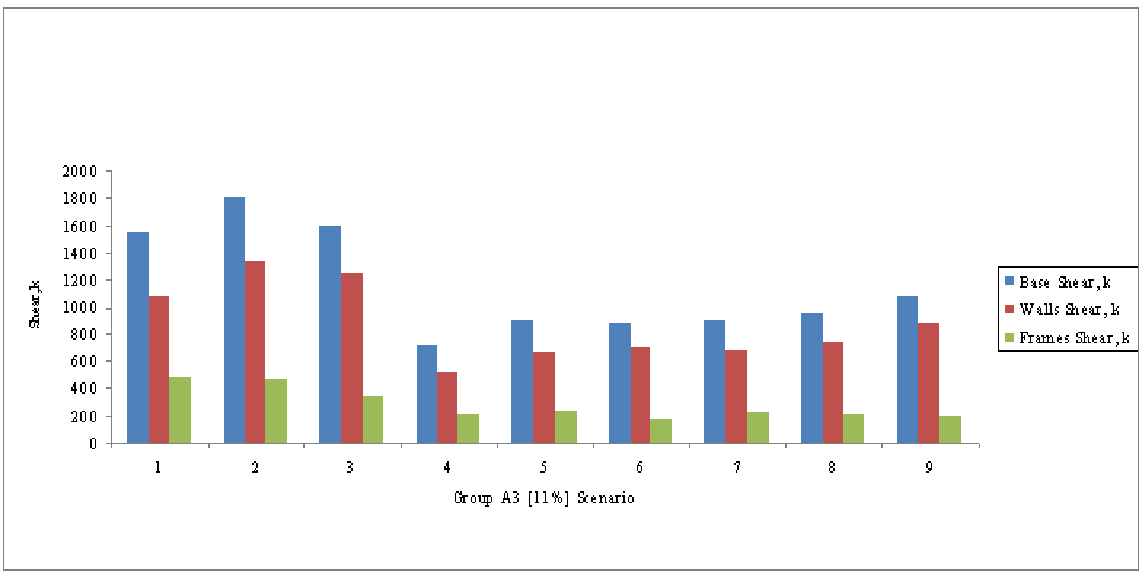
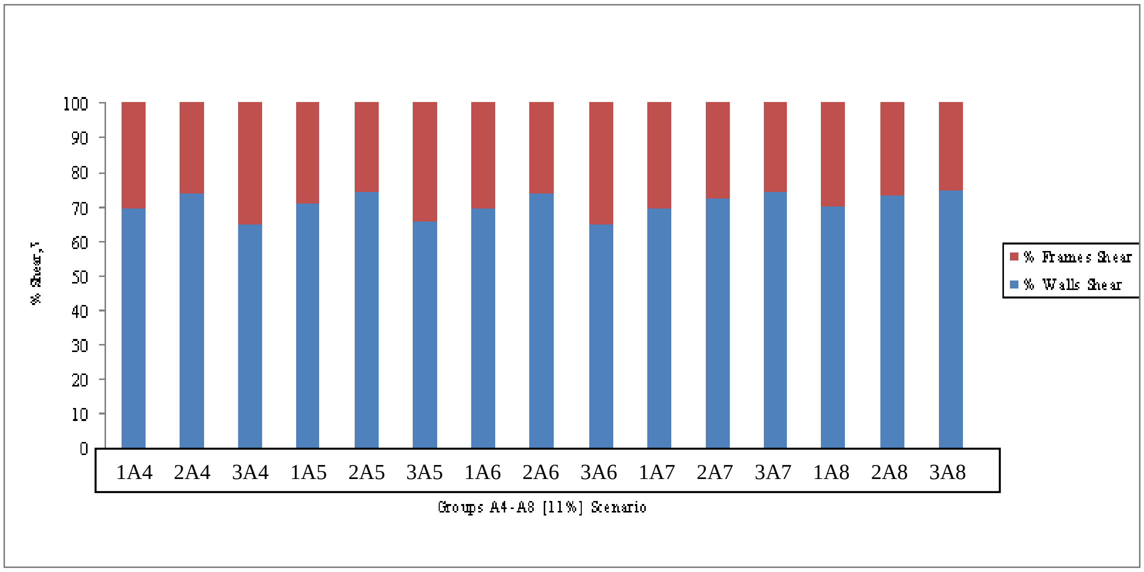


Figure 5-23: Building A3 [11%] Shear Distribution vs. Scenario Number



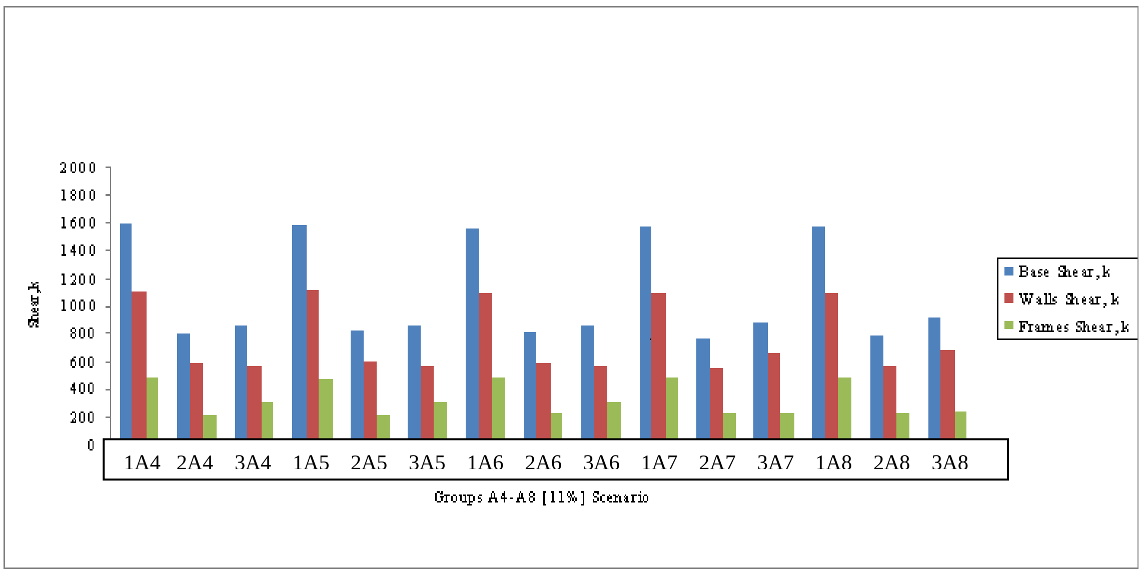
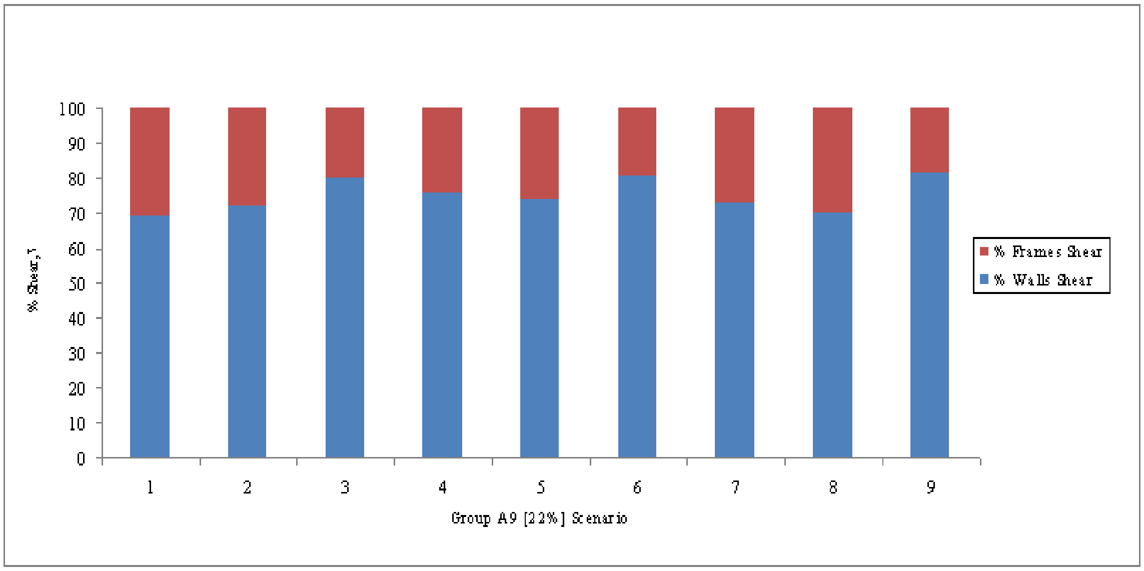


Figure 5-24: Building A4 – A8 [11%] Shear Distribution vs. Scenario Number



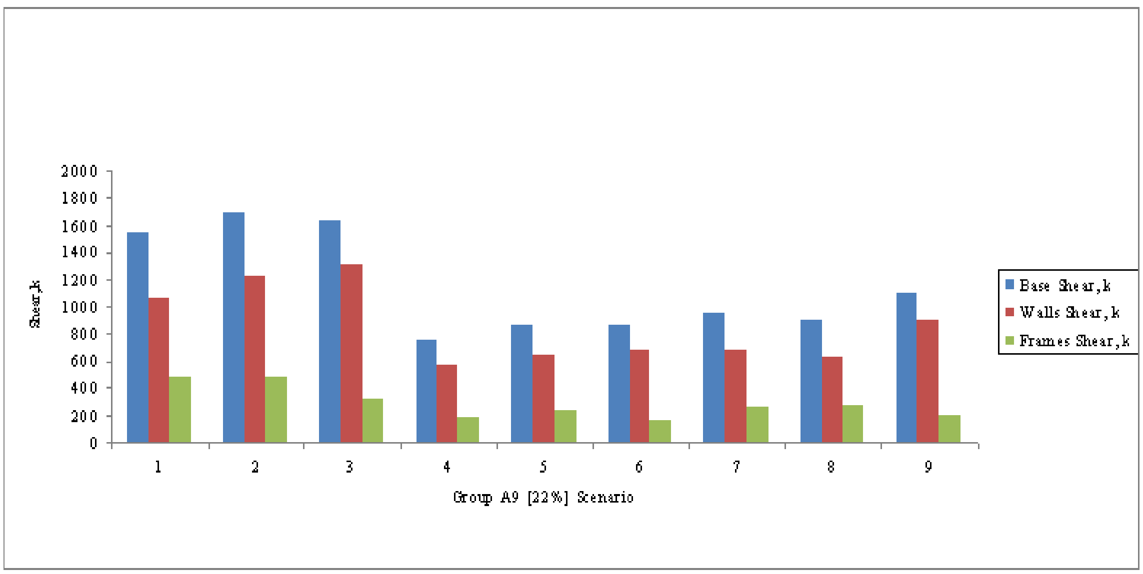
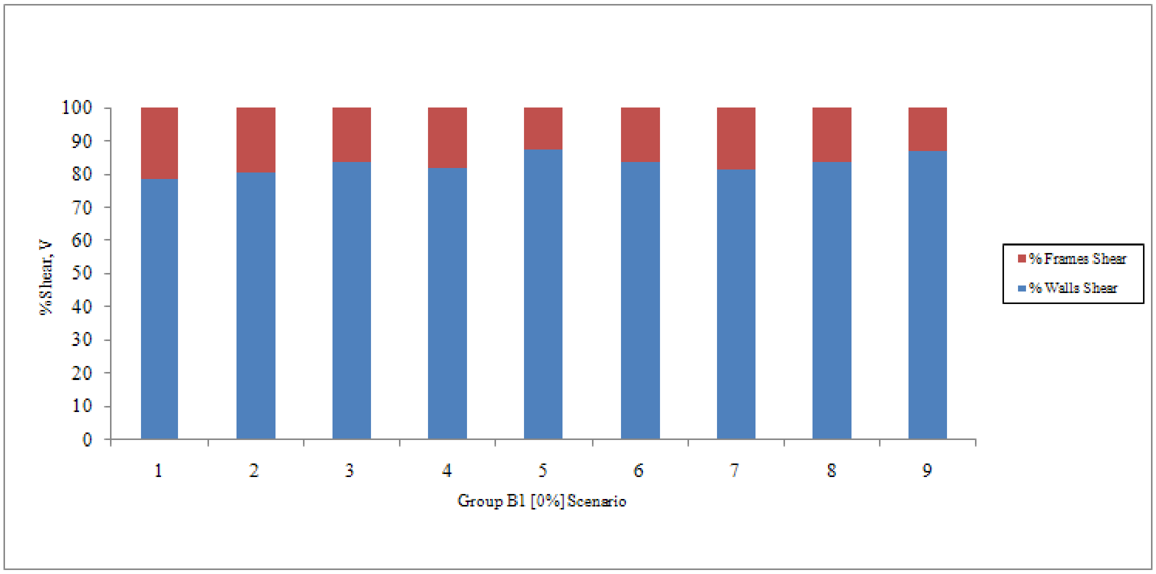


Figure 5-25: Building A9 [22%] Shear Distribution vs. Scenario Number



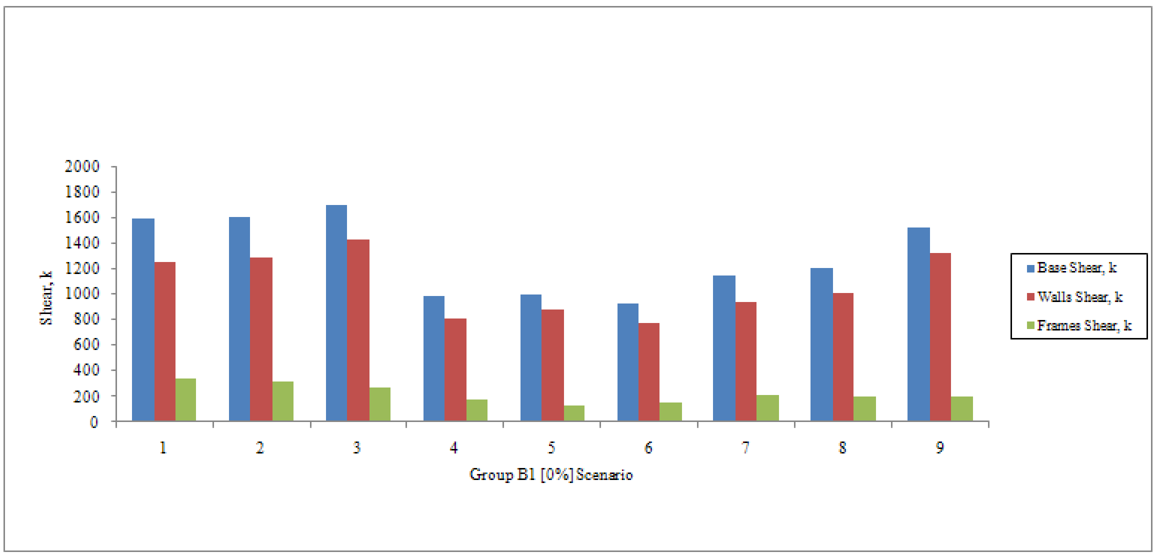
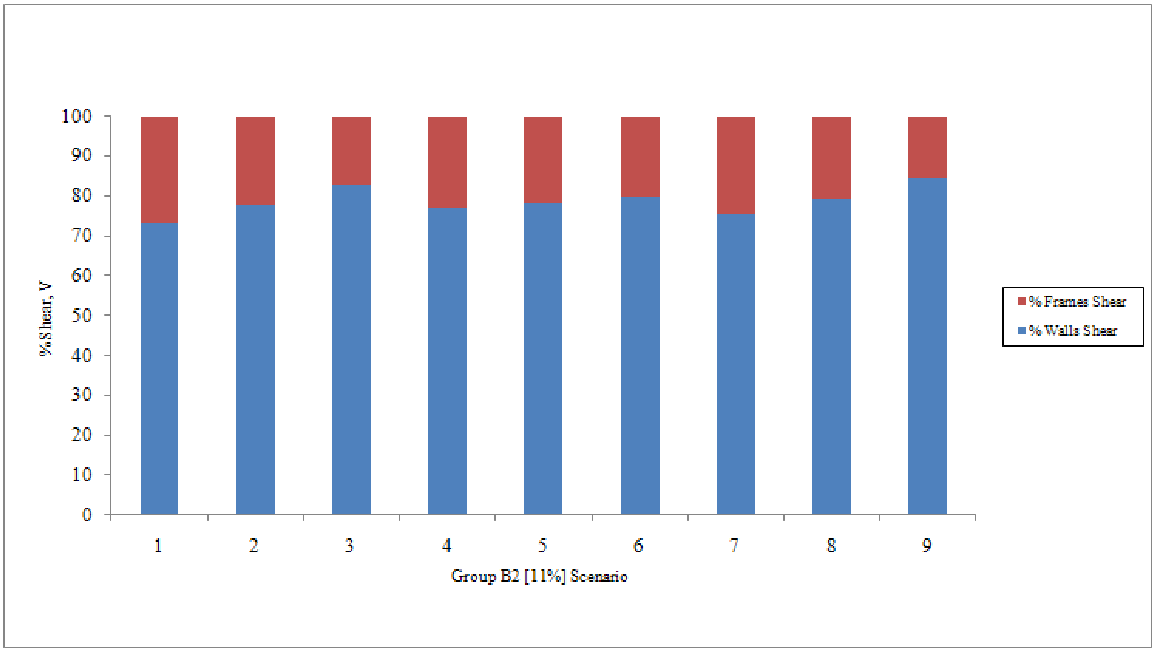


Figure 5-26: Building B1 [0%] Shear Distribution vs. Scenario Number



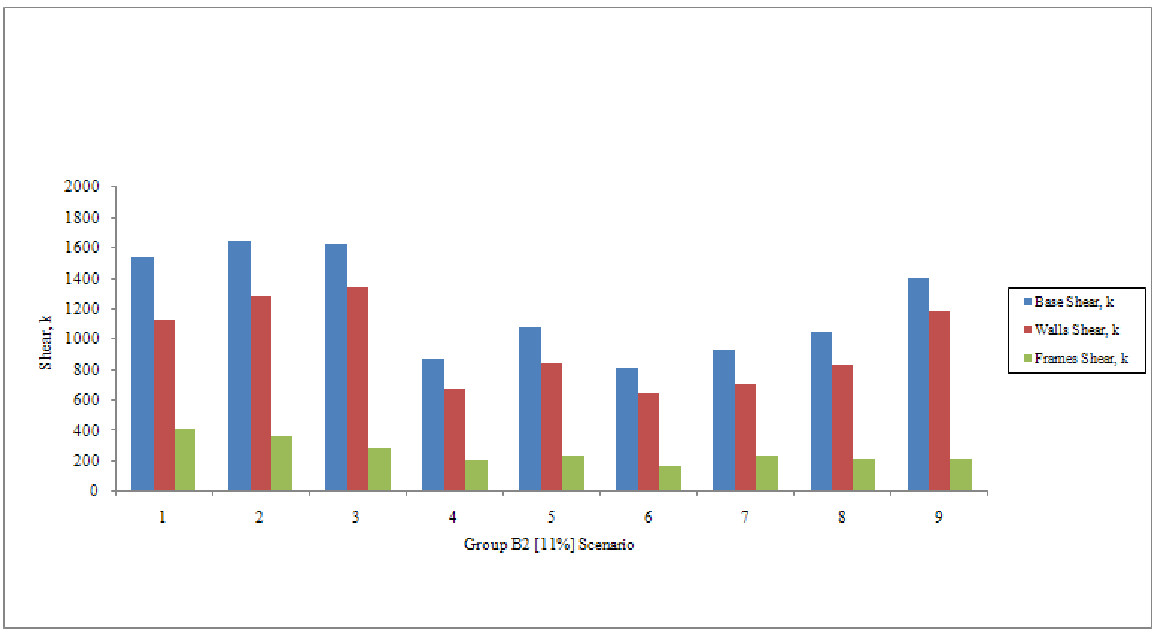
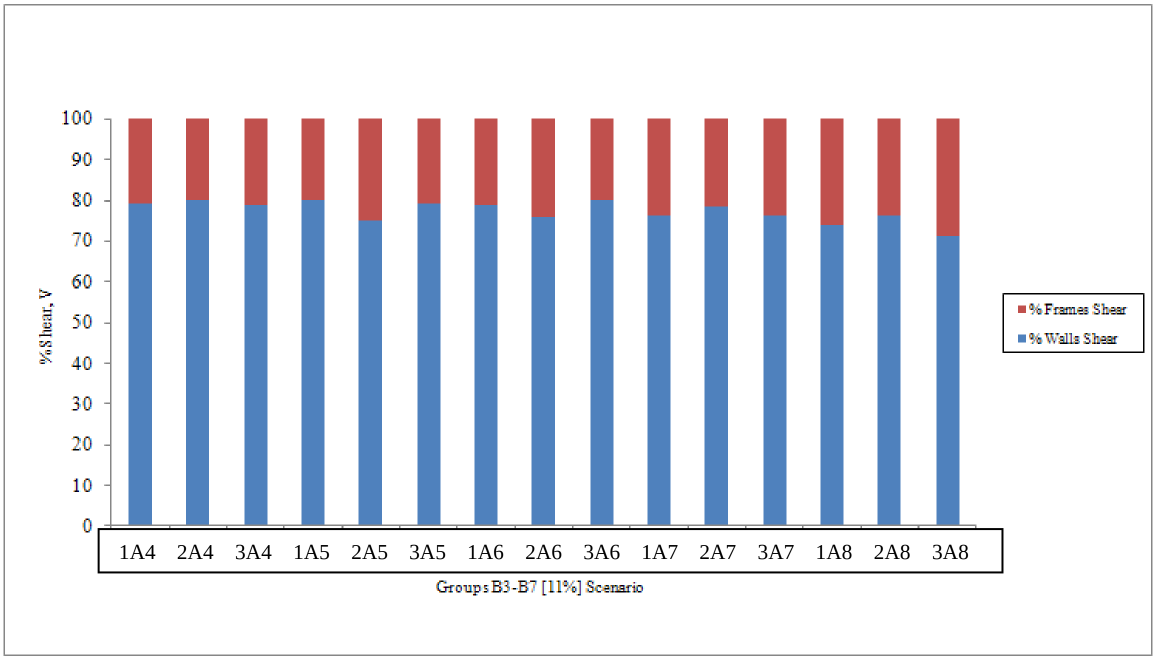


Figure 5-27: Building B2 [11%] Shear Distribution vs. Scenario Number



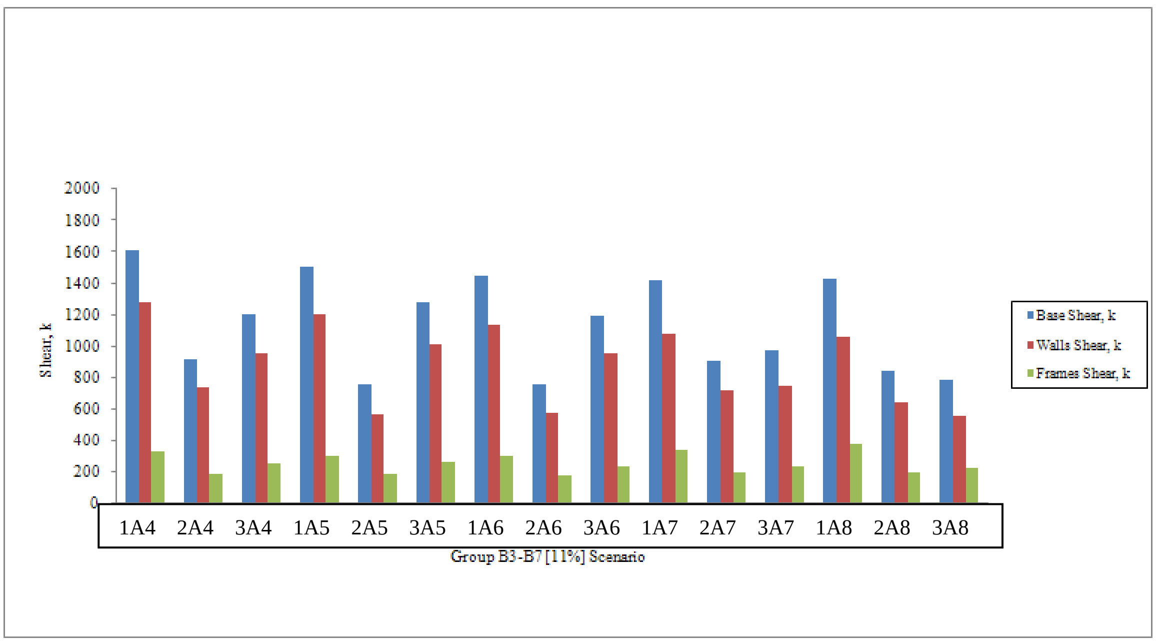
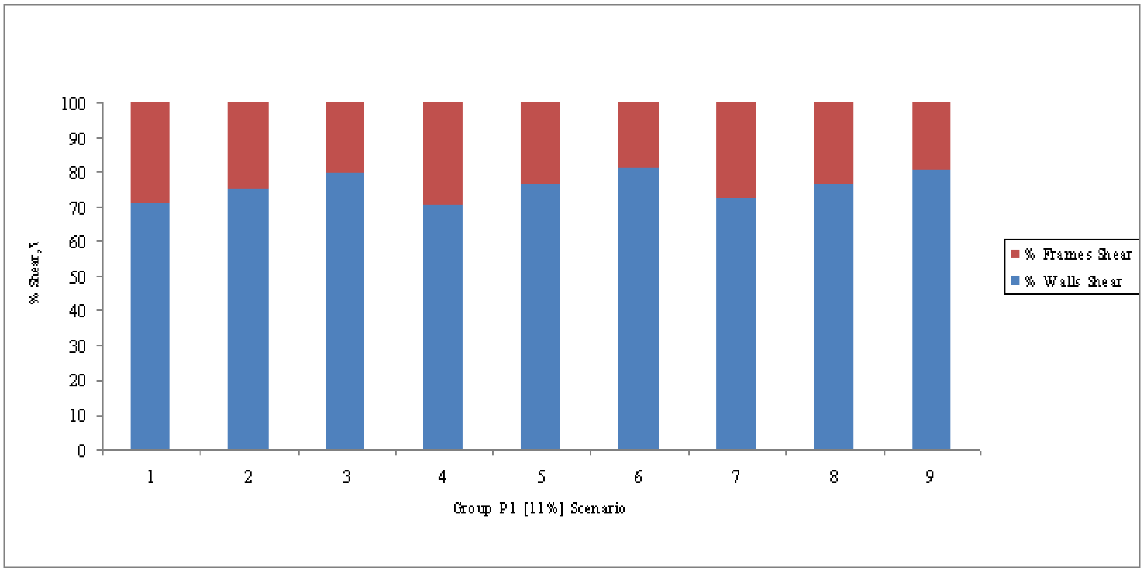


Figure 5-28: Building B3 –B7 [11%] Shear Distribution vs. Scenario Number



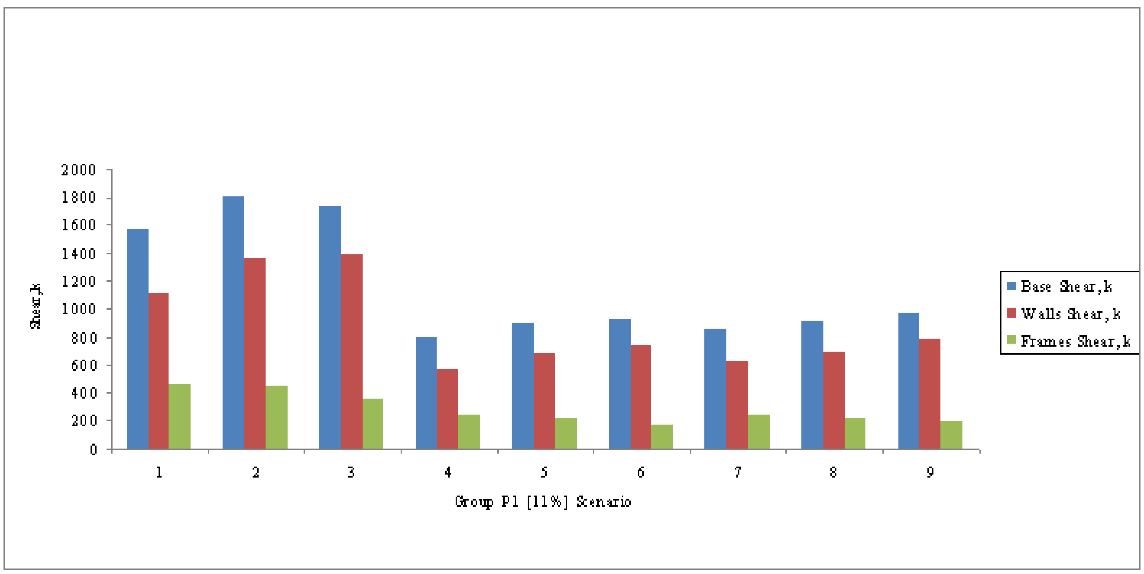
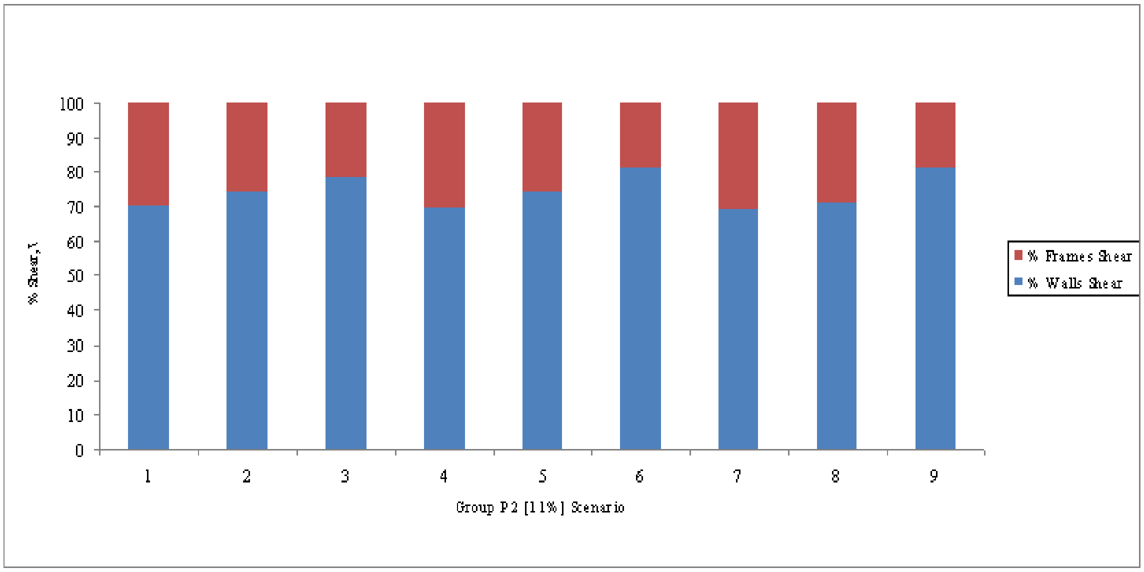


Figure 5-29: Building P1 [11%] Shear Distribution vs. Scenario Number



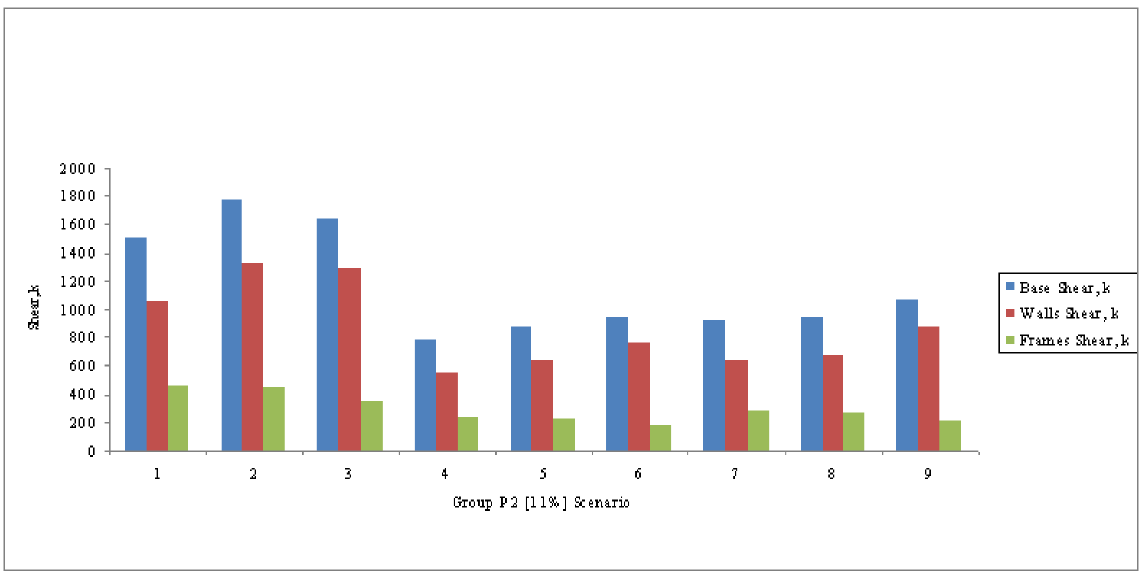
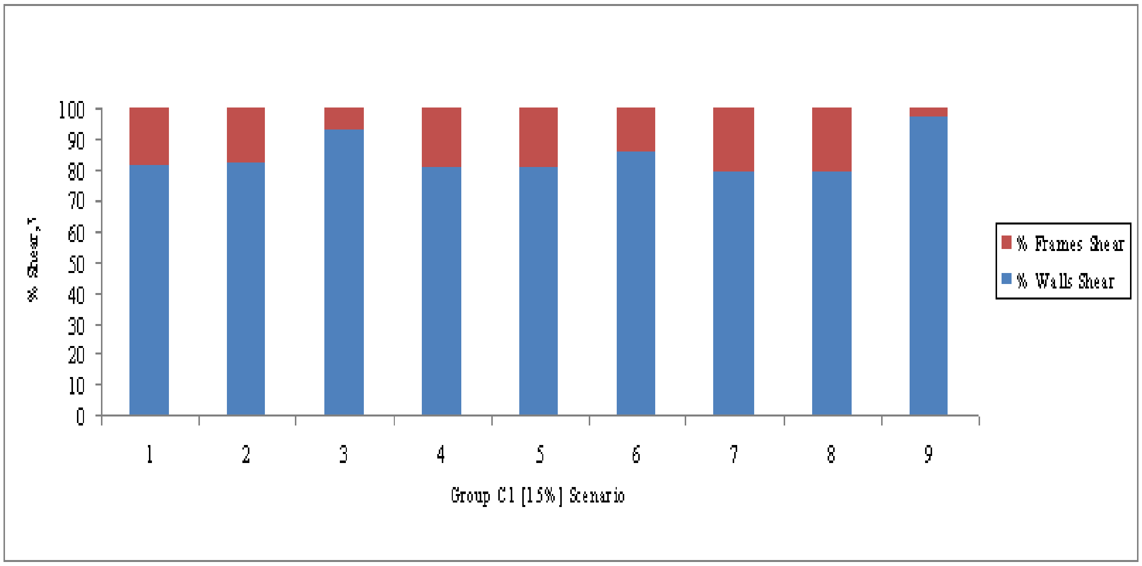


Figure 5-30: Building P2 [11%] Shear Distribution vs. Scenario Number



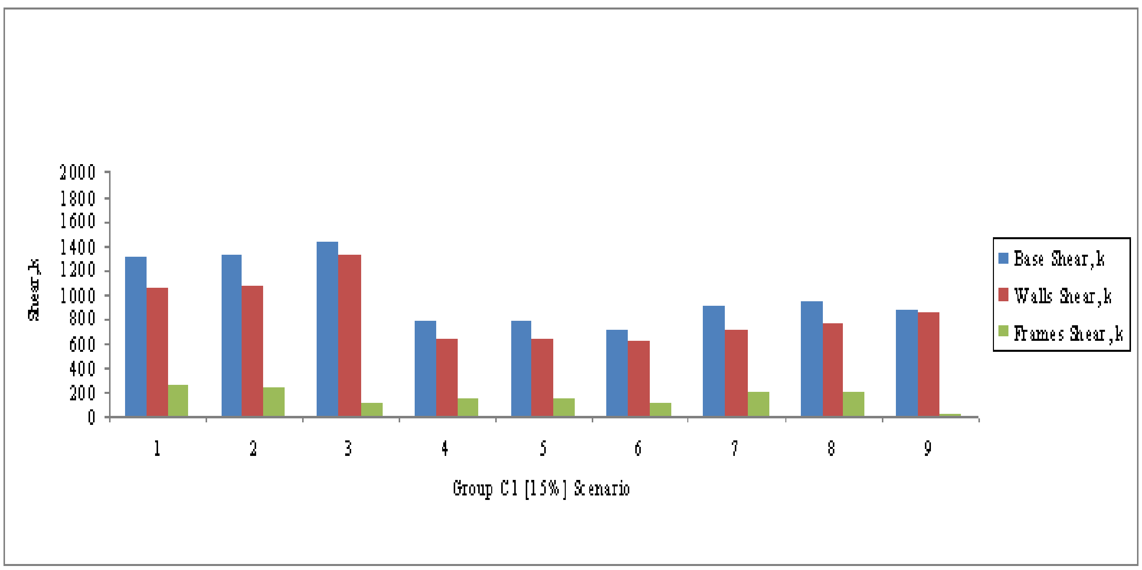
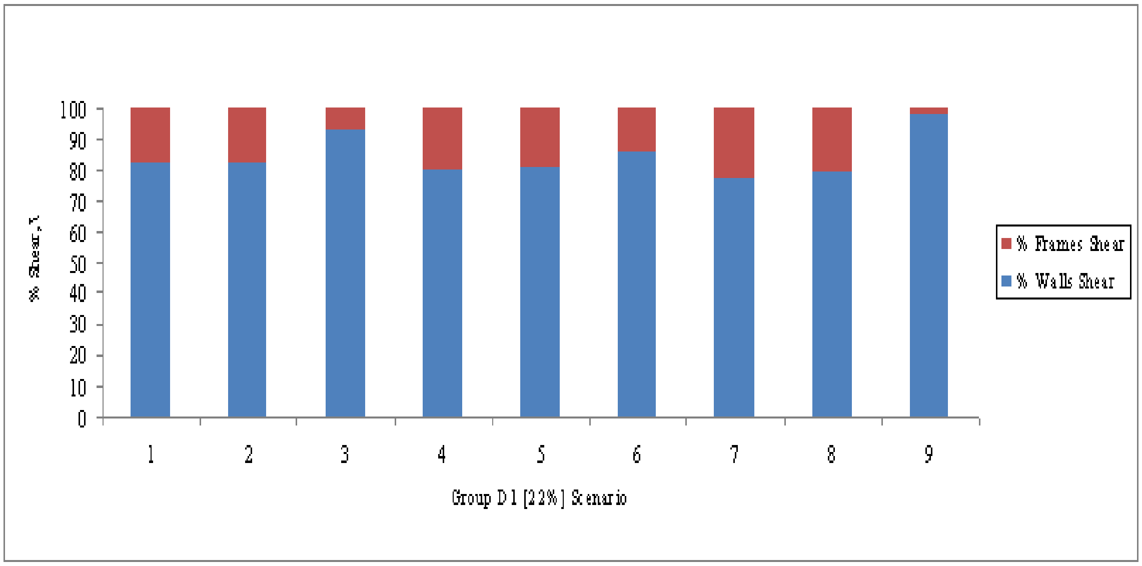


Figure 5-31: Building C1 [15%] Shear Distribution vs. Scenario Number



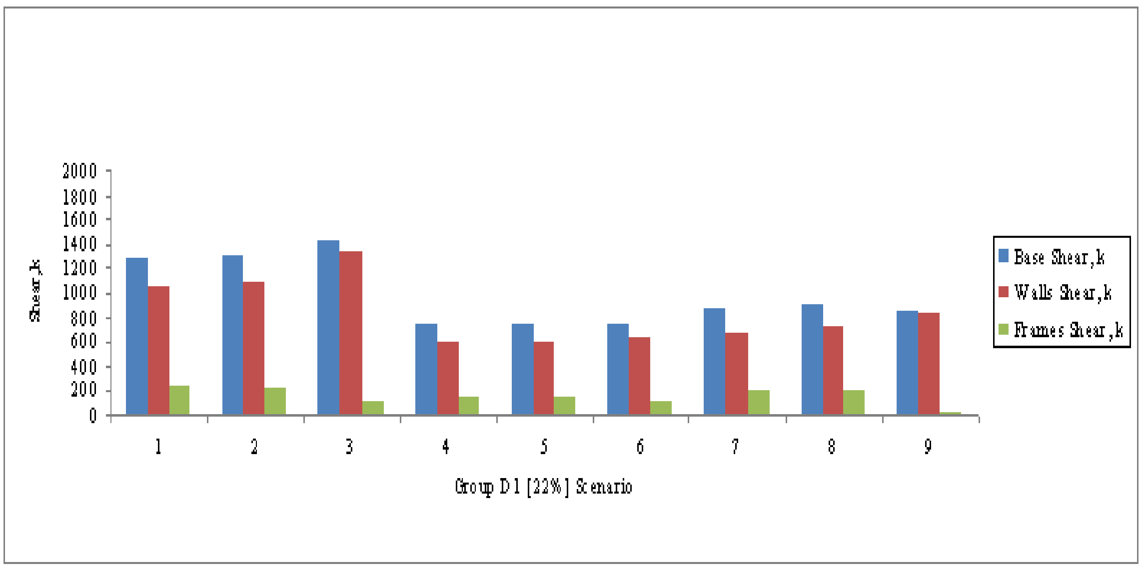


Figure 5-32: Building D1 [22%] Shear Distribution vs. Scenario Number

All buildings were investigated using the three different earthquakes. For building group A1 [0%] – without openings -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 29% of the base shear for the inelastic, about 27% for the elastic case and about 23% for the rigid case. While with the scaled San Fernando earthquake, frames took about 25% of the base shear for the inelastic, about 24% for the elastic case and about 20% for the rigid cases. As for the scaled Parkfield earthquake, frames took about 24% of the base shear for the inelastic case, about 23% for the elastic case and about 19% for the rigid case. It is observed that the frames are subjected to the largest lateral loads (457.80 kips, which is about 29% of the total lateral load) in the first scenario where inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake. This is mainly due to the fact that the dominant period of the earthquake (0.34 sec.) was closest to the fundamental period of the building (0.31 sec.) and the floor diaphragms experienced the largest in-plane deformations. It is also noteworthy that using the rigid diaphragm yields a higher total base shear of the building, but it also results in decreased load demand on the frames since diaphragms are not allowed to deform.

As for building group A2 [11%] – openings placed at bays 8 & 9 unsymmetrical with respect to building plan centerline -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 31% of the base shear for the inelastic case, about 27% for the elastic case and about 22% for the rigid case. While with the scaled San Fernando earthquake, frames took about 28% of the base shear for the inelastic case, about 25% for the elastic case and about 20% for the rigid case. As for the scaled Parkfield earthquake, frames took about 27% of the base shear for the inelastic case, about 23% for the elastic case and about 20% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (474.40 kips, which is about 31% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where both, walls and slab elements have yielded..

As for building group A3 [11%] – openings placed symmetrically at bays 6 & 7 with respect to building plan centerline -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 31% of the base shear for the inelastic case, about 26%

for the elastic case and about 22% for the rigid case. While with the scaled San Fernando earthquake, frames took about 29% of the base shear for the inelastic case, about 26% for the elastic case and about 20% for the rigid case. As for the scaled Parkfield earthquake, frames took about 24% of the base shear for the inelastic case, about 22% for the elastic case and about 18% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (476.90 kips, which is about 31% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where the slabs and walls have yielded.

As for building groups A4 to A8 [11%], the scaled Loma Prieta earthquake yielded the highest frame shear in all cases where frames took about 30% of the base shear for the inelastic case. As for the scaled San Fernando earthquake, frames took about 26% of the base shear for the inelastic cases. As for the scaled Parkfield earthquake, frames took about 35% of the base shear for the inelastic case. Lastly, when walls yielded under the Loma Prieta earthquake, the frames were subjected to the largest lateral load of 481.4 kips.

As for building group A9 [22%] – openings placed symmetrically at bays 5, 6, 7 &8 with respect to building plan centerline -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 31% of the base shear for the inelastic case, about 28% for the elastic case and about 20% for the rigid case. While with the scaled San Fernando earthquake, frames took about 24% of the base shear for the inelastic case, about 26% for the elastic case and about 19% for the rigid case. As for the scaled Parkfield earthquake, frames took about 27% of the base shear for the inelastic case, about 30% for the elastic case and about 18% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (475.50 kips, which is about 31% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where both the slab and wall elements have yielded.

As for building group B1 [0%] –without openings -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 21% of the base shear for the inelastic case, about 20% for the elastic case and about 16% for the rigid case. While with the scaled San Fernando earthquake, frames took about 18% of the base shear for the inelastic case, about 13% for the elastic case and about 16% for the rigid case. As for the scaled Parkfield earthquake, frames took about 18% of the base shear for the inelastic case, about 16% for the elastic case and about 13% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (339.03 kips, which is about 21% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where the walls yielded at the building base.

As for building group B2 [11%] – openings placed at bays 6 & 7 symmetrically -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 27% of the base shear for the inelastic case, about 22% for the elastic case and about 17% for the rigid case. While with the scaled San Fernando earthquake, frames took about 23% of the base shear for the inelastic case, about 22% for the elastic case and about 20% for the rigid case. As for the scaled Parkfield earthquake, frames took about 25% of the base shear for the inelastic case, about 21% for the elastic case and about 15% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (411.27 kips, which is about 27% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where both the slab and wall elements have yielded.

As for building groups B3 to B7 [11%], the scaled Loma Prieta earthquake yielded the highest frame shear in all cases where frames took about 26% of the base shear for the inelastic case. As for the scaled San Fernando earthquake, frames took about 25% of the base shear for the inelastic cases. As for the scaled Parkfield earthquake, frames took about 29% of the base shear for the inelastic case at most and about 21% of the base shear at the least. The frames were subjected to the largest lateral load (372.9 kips) when building B7 was subjected to the scaled Loma Prieta earthquake, where both the slab and wall elements have yielded.

As for building group P1 [11%] – openings placed at bays 8 & 9 unsymmetrically -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 30% of the base shear for the inelastic case, about 25% for the elastic case and about 21% for the rigid case. While with the scaled San Fernando earthquake, frames took about 30% of the base shear for the inelastic case, about 24% for the elastic case and about 19% for the rigid case. As for the scaled Parkfield earthquake, frames took about 28% of the base shear for the inelastic case, about 23% for the elastic case and about 20% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (459.30 kips, which is about 30% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where both the slab and wall elements have yielded.

As for building group P2 [11%] – openings placed at bays 6 & 7 unsymmetrically -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 30% of the base shear for the inelastic case, about 25% for the elastic case and about 21% for the rigid case. While with the scaled San Fernando earthquake, frames took about 31% of the base shear for the inelastic case, about 26% for the elastic case and about 19% for the rigid case. As for the scaled Parkfield earthquake, frames took about 31% of the base shear for the inelastic case, about 29% for the elastic case and about 19% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (453.10 kips, which is about 30% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where both the slab and wall elements have yielded.

As for building group C1 [15%] – openings placed at bays 4 & 6 symmetrically -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 19% of the base shear for the inelastic case, about 18% for the elastic case and about 7% for the rigid case. While with the scaled San Fernando earthquake, frames took about 19% of the base shear for the inelastic case, about 19% for the elastic case and about 15% for the rigid case. As for the scaled Parkfield earthquake, frames took about 21% of the base shear for the inelastic case, about 21% for the elastic case and about 3% for the rigid case. It is observed that the frames are subjected to the largest lateral loads (240.10 kips, which is about 19% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake. However, these frame loads were significantly less than the ones in building groups, A, B and P since the building plan aspect ratio is 3:1, and the slab elements did not yield.

As for building group D1 [22%] – openings placed at bays 4, 5 & 6 symmetrically -, with scaled Loma Prieta earthquake used as the input dynamic load, frames took about 18% of the base shear for the inelastic case, about 17% for the elastic case and about 7% for the rigid case. While with the scaled San Fernando earthquake, frames took about 20% of the base shear for the inelastic case, about 20% for the elastic case and about 14% for the rigid case. As for the scaled Parkfield earthquake, frames took about 22% of the base shear for the inelastic case, about 21% for the elastic case and about 3% for the rigid case. It is again observed that the frames are subjected to the largest lateral loads (238.70 kips, which is about 18% of the total lateral load) in the first scenario when inelastic slab model is used in conjunction with the scaled Loma Prieta earthquake, where only the walls have yielded.

With regards to building periods, it is of note to mention that for building groups A1 [0%], A2 [11%], A3 [11%], A9 [22%], B1 [0%], B2 [11%], P1 [11%], P2 [11%], C1 [15%] and D1 [22%] the building period was 10%-15% higher when the rigid slab model is used, as compared to elastic and inelastic models, due to the higher building overall stiffness.

As for building groups A4 [11%], A5 [11%], A6 [11%], A7 [11%], A8 [11%], the periods were not a function of the location and size of floor openings, however, with group B3 [11%], B4 [11%], B5 [11%], B6 [11%] and B7 [11%], the periods changed from 0.166 sec. in the case of building group B4 to 0.191 sec. in the case of building group B7 (15% difference), indicating that moving the openings to the mid-region of the building, decreases the building stiffness by more than 30% as reflected in Table 5-4.

Table 5-4: Inelastic Dynamic Analysis Building Frame Displacements Summary

Case	Bldg. Max. Top Displ., in.	Diaph. Max. Inplane Defl., in.
Group A1 [0%]		
1A1-4:1-ESW-Solid-IE-LP	1.2040	0.5920
2A1-4:1-ESW-Solid-EL-LP	1.1180	0.1830
3A1-4:1-ESW-Solid-RD-LP	0.8234	0.0291
4A1-4:1-ESW-Solid-IE-SF	0.3422	0.1906
5A1-4:1-ESW-Solid-EL-SF	0.3237	0.1468
6A1-4:1-ESW-Solid-RD-SF	0.2329	0.0154
7A1-4:1-ESW-Solid-IE-PF	0.3943	0.2636
8A1-4:1-ESW-Solid-EL-PF	0.3776	0.1927
9A1-4:1-ESW-Solid-RD-PF	0.2564	0.0235
Group A2 [11%]		
1A2-4:1-ESW-(8&9-T&B)-IE-LP	1.3230	1.0612
2A2-4:1-ESW-(8&9-T&B)-EL-LP	1.0610	0.2312
3A2-4:1-ESW-(8&9-T&B)-RD-LP	0.7500	0.0812
4A2-4:1-ESW-(8&9-T&B)-IE-SF	0.3243	0.2175
5A2-4:1-ESW-(8&9-T&B)-EL-SF	0.3195	0.1938
6A2-4:1-ESW-(8&9-T&B)-RD-SF	0.2186	0.0322
7A2-4:1-ESW-(8&9-T&B)-IE-PF	0.4102	0.2791
8A2-4:1-ESW-(8&9-T&B)-EL-PF	0.3933	0.2328
9A2-4:1-ESW-(8&9-T&B)-RD-PF	0.2436	0.0400
Group A3 [11%]		
1A3-4:1-ESW-(6&7-T&B)-IE-LP	1.2740	0.8264
2A3-4:1-ESW-(6&7-T&B)-EL-LP	1.0660	0.2230
3A3-4:1-ESW-(6&7-T&B)-RD-LP	0.7190	0.0194
4A3-4:1-ESW-(6&7-T&B)-IE-SF	0.3528	0.2669
5A3-4:1-ESW-(6&7-T&B)-EL-SF	0.3411	0.2016
6A3-4:1-ESW-(6&7-T&B)-RD-SF	0.2165	0.0128
7A3-4:1-ESW-(6&7-T&B)-IE-PF	0.4396	0.3005
8A3-4:1-ESW-(6&7-T&B)-EL-PF	0.4099	0.2488
9A3-4:1-ESW-(6&7-T&B)-RD-PF	0.2314	0.0226
Group A4 [11%]		
1A4-4:1-ESW-(1&12-T&B)-IE-LP	1.0530	0.3583
2A4-4:1-ESW-(1&12-T&B)-IE-SF	0.3109	0.1636
3A4-4:1-ESW-(1&12-T&B)-IE-PF	0.4083	0.2795

Table 5-4 (Cont'd): Inelastic Dynamic Analysis Building Frame Displacements Summary

Group A5 [11%]		
1A5-4:1-ESW-(2&11-T&B)-IE-LP	1.0870	0.5491
2A5-4:1-ESW-(2&11-T&B)-IE-SF	0.3134	0.1714
3A5-4:1-ESW-(2&11-T&B)-IE-PF	0.3840	0.2666
Group A6 [11%]		
1A6-4:1-ESW-(3&10-T&B)-IE-LP	1.0760	0.5128
2A6-4:1-ESW-(3&10-T&B)-IE-SF	0.3176	0.1953
3A6-4:1-ESW-(3&10-T&B)-IE-PF	0.3918	0.2703
Group A7 [11%]		
1A7-4:1-ESW-(4&9-T&B)-IE-LP	1.2370	0.8853
2A7-4:1-ESW-(4&9-T&B)-IE-SF	0.3253	0.2148
3A7-4:1-ESW-(4&9-T&B)-IE-PF	0.3886	0.2651
Group A8 [11%]		
1A8-4:1-ESW-(5&8-T&B)-IE-LP	1.2260	0.8150
2A8-4:1-ESW-(5&8-T&B)-IE-SF	0.3281	0.2342
3A8-4:1-ESW-(5&8-T&B)-IE-PF	0.4090	0.2727
Group A9 [22%]		
1A9-4:1-ESW-(5 6 7 8-T&B)-IE-LP	1.1970	0.7775
2A9-4:1-ESW-(5 6 7 8-T&B)-EL-LP	1.0560	0.2394
3A9-4:1-ESW-(5 6 7 8-T&B)-RD-LP	0.5962	0.0126
4A9-4:1-ESW-(5 6 7 8-T&B)-IE-SF	0.3494	0.2650
5A9-4:1-ESW-(5 6 7 8-T&B)-EL-SF	0.3571	0.2313
6A9-4:1-ESW-(5 6 7 8-T&B)-RD-SF	0.1986	0.0106
7A9-4:1-ESW-(5 6 7 8-T&B)-IE-PF	0.4044	0.3829
8A9-4:1-ESW-(5 6 7 8-T&B)-EL-PF	0.3921	0.2294
9A9-4:1-ESW-(5 6 7 8-T&B)-RD-PF	0.2107	0.0138
Group B1 [0%]		
1B1-4:1-ISW-Solid-IE-LP	0.5964	0.2302
2B1-4:1-ISW-Solid-EL-LP	0.5719	0.1256
3B1-4:1-ISW-Solid-RD-LP	0.4750	0.0228
4B1-4:1-ISW-Solid-IE-SF	0.1055	0.0414
5B1-4:1-ISW-Solid-EL-SF	0.0982	0.0283
6B1-4:1-ISW-Solid-RD-SF	0.0617	0.0086
7B1-4:1-ISW-Solid-IE-PF	0.2466	0.1718
8B1-4:1-ISW-Solid-EL-PF	0.2231	0.1175
9B1-4:1-ISW-Solid-RD-PF	0.2263	0.0213

Table 5-4 (Cont'd): Inelastic Dynamic Analysis Building Frame Displacements Summary

Group B2 [11%]		
1B2-4:1-ISW-(6&7-T&B)-IE-LP	0.6730	0.4054
2B2-4:1-ISW-(6&7-T&B)-EL-LP	0.4933	0.1173
3B2-4:1-ISW-(6&7-T&B)-RD-LP	0.4333	0.0266
4B2-4:1-ISW-(6&7-T&B)-IE-SF	0.1405	0.0944
5B2-4:1-ISW-(6&7-T&B)-EL-SF	0.2656	0.2034
6B2-4:1-ISW-(6&7-T&B)-RD-SF	0.0565	0.0080
7B2-4:1-ISW-(6&7-T&B)-IE-PF	1.0110	0.9270
8B2-4:1-ISW-(6&7-T&B)-EL-PF	0.0729	0.1841
9B2-4:1-ISW-(6&7-T&B)-RD-PF	0.2172	0.0256
Group B3 [11%]		
1B3-4:1-ISW-(1&12-T&B)-IE-LP	0.5040	0.1960
2B3-4:1-ISW-(1&11-T&B)-IE-SF	0.0582	0.0997
3B3-4:1-ISW-(1&12-T&B)-IE-PF	0.2173	0.1225
Group B4 [11%]		
1B4-4:1-ISW-(2&11-T&B)-IE-LP	0.4053	0.1358
2B4-4:1-ISW-(2&11-T&B)-IE-SF	0.0399	0.0656
3B4-4:1-ISW-(2&11-T&B)-IE-PF	0.2766	0.1606
Group B5 [11%]		
1B5-4:1-ISW-(3&10-T&B)-IE-LP	0.4746	0.2300
2B5-4:1-ISW-(3&10-T&B)-IE-SF	0.0430	0.0976
3B5-4:1-ISW-(3&10-T&B)-IE-PF	0.2150	0.1378
Group B6 [11%]		
1B6-4:1-ISW-(4&9-T&B)-IE-LP	0.5348	0.3404
2B6-4:1-ISW-(4&9-T&B)-IE-SF	0.0490	0.1278
3B6-4:1-ISW-(4&9-T&B)-IE-PF	0.0745	0.1267
Group B7 [11%]		
1B7-4:1-ISW-(5&8-T&B)-IE-LP	0.5003	0.2960
2B7-4:1-ISW-(5&8-T&B)-IE-SF	0.0462	0.1461
3B7-4:1-ISW-(5&8-T&B)-IE-PF	0.0557	0.2000

Table 5-4 (Cont'd): Inelastic Dynamic Analysis Building Frame Displacements Summary

Group P1 [11%] - USER		
1P1-4:1-ESW-(8&9-M&B)-IE-LP	1.2410	0.8939
2P1-4:1-ESW-(8&9-M&B)-EL-LP	1.0450	0.3120
3P1-4:1-ESW-(8&9-M&B)-RD-LP	0.7402	0.0744
4P1-4:1-ESW-(8&9-M&B)-IE-SF	0.3926	0.2788
5P1-4:1-ESW-(8&9-M&B)-EL-SF	0.3371	0.1612
6P1-4:1-ESW-(8&9-M&B)-RD-SF	0.2423	0.0358
7P1-4:1-ESW-(8&9-M&B)-IE-PF	0.3774	0.2367
8P1-4:1-ESW-(8&9-M&B)-EL-PF	0.3773	0.2105
9P1-4:1-ESW-(8&9-M&B)-RD-PF	0.2437	0.0401
Group P2 [11%] - USER		
1P2-4:1-ESW-(6&7-M&B)-IE-LP	1.2920	0.8253
2P2-4:1-ESW-(6&7-M&B)-EL-LP	1.0510	0.2226
3P2-4:1-ESW-(6&7-M&B)-RD-LP	0.7252	0.0222
4P2-4:1-ESW-(6&7-M&B)-IE-SF	0.4326	0.3260
5P2-4:1-ESW-(6&7-M&B)-EL-SF	0.3413	0.1571
6P2-4:1-ESW-(6&7-M&B)-RD-SF	0.2366	0.0150
7P2-4:1-ESW-(6&7-M&B)-IE-PF	0.3928	0.3521
8P2-4:1-ESW-(6&7-M&B)-EL-PF	0.3840	0.2177
9P2-4:1-ESW-(6&7-M&B)-RD-PF	0.2323	0.0227
Group C1 [15%]		
1C1-3:1-ESW-(4&6-T&B)-IE-LP	0.6649	0.2627
2C1-3:1-ESW-(4&6-T&B)-EL-LP	0.601	0.1775
3C1-3:1-ESW-(4&6-T&B)-RD-LP	0.4768	0.023
4C1-3:1-ESW-(4&6-T&B)-IE-SF	0.2241	0.0725
5C1-3:1-ESW-(4&6-T&B)-EL-SF	0.2236	0.0705
6C1-3:1-ESW-(4&6-T&B)-RD-SF	0.1586	0.0085
7C1-3:1-ESW-(4&6-T&B)-IE-PF	0.2722	0.1273
8C1-3:1-ESW-(4&6-T&B)-EL-PF	0.262	0.1048
9C1-3:1-ESW-(4&6-T&B)-RD-PF	0.2123	0.0199
Group D1 [22%]		
1D1-3:1-ESW-(4 5 6-T&B)-IE-LP	0.5912	0.191
2D1-3:1-ESW-(4 5 6-T&B)-EL-LP	0.5783	0.1723
3D1-3:1-ESW-(4 5 6-T&B)-RD-LP	0.427	0.0308
4D1-3:1-ESW-(4 5 6-T&B)-IE-SF	0.2227	0.0743
5D1-3:1-ESW-(4 5 6-T&B)-EL-SF	0.2224	0.0733
6D1-3:1-ESW-(4 5 6-T&B)-RD-SF	0.1443	0.0065
7D1-3:1-ESW-(4 5 6-T&B)-IE-PF	0.2659	0.1183
8D1-3:1-ESW-(4 5 6-T&B)-EL-PF	0.2548	0.0962
9D1-3:1-ESW-(4 5 6-T&B)-RD-PF	0.2168	0.0145

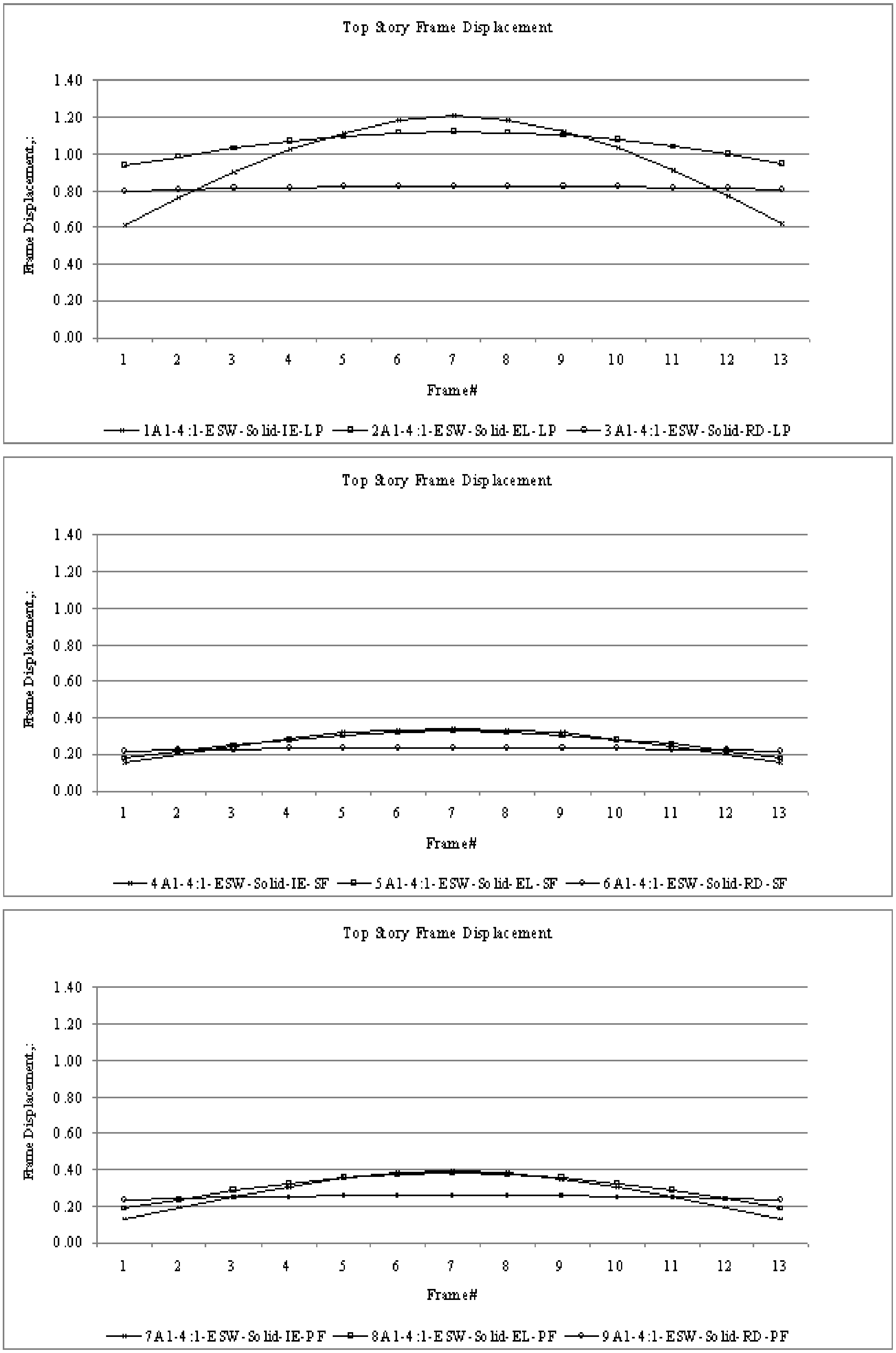


Figure 5-33: Building A1 [0%] Top Story max. Frame Deflection vs. Frame Numbers

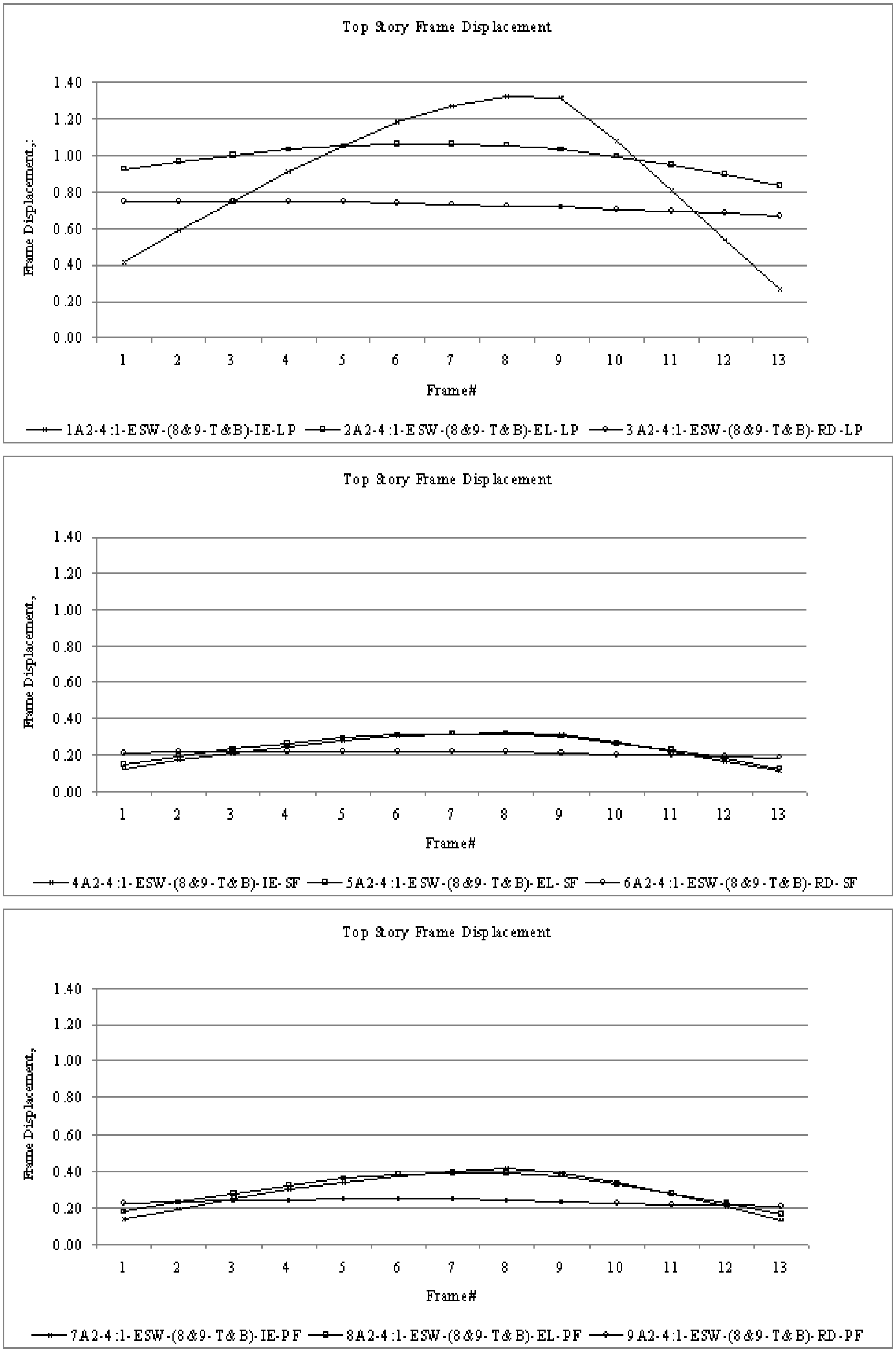


Figure 5-34: Building A2 [11%] Top Story max. Frame Deflection vs. Frame Numbers

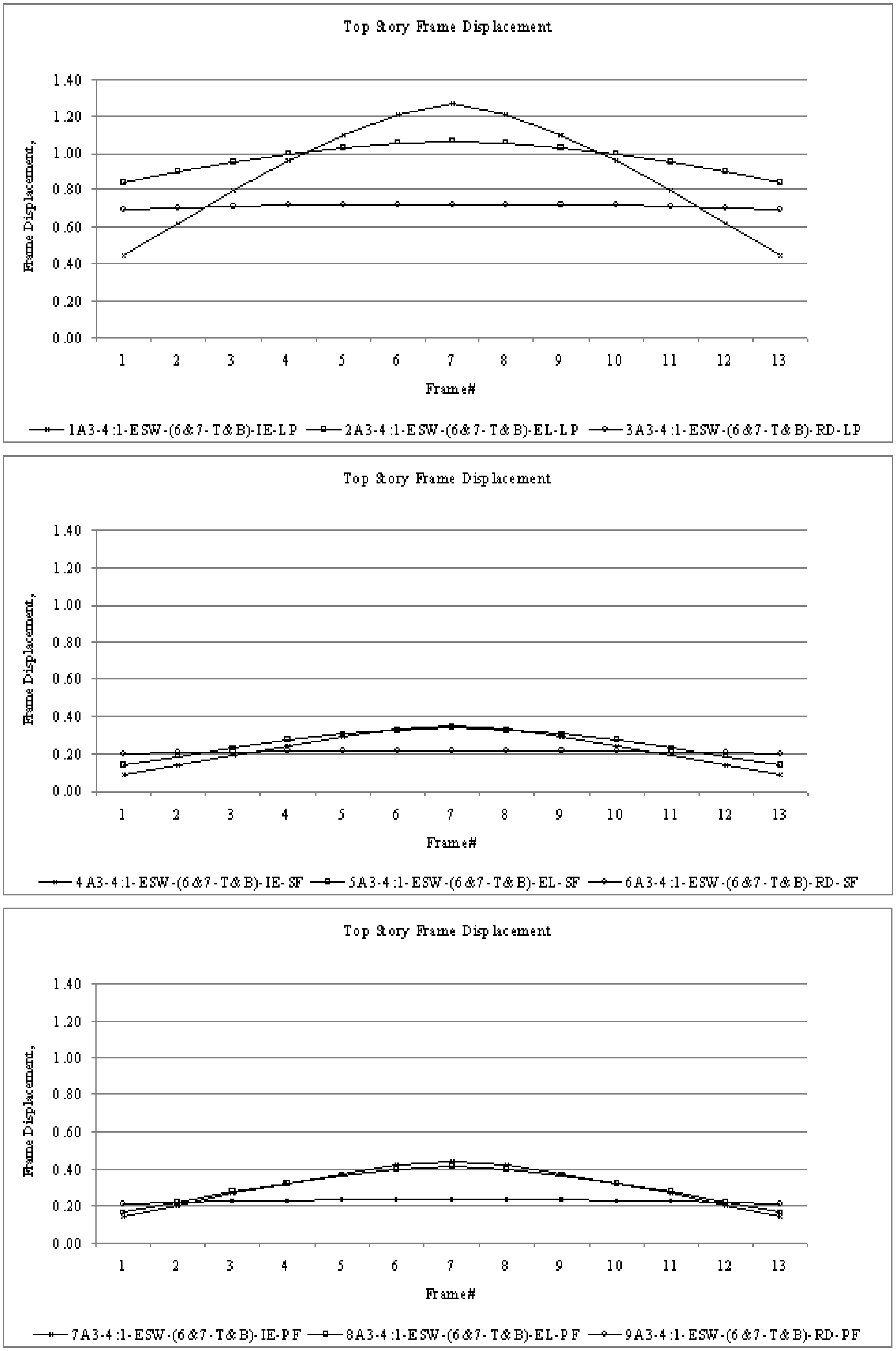


Figure 5-35: Building A3 [11%] Top Story max. Frame Deflection vs. Frame Numbers

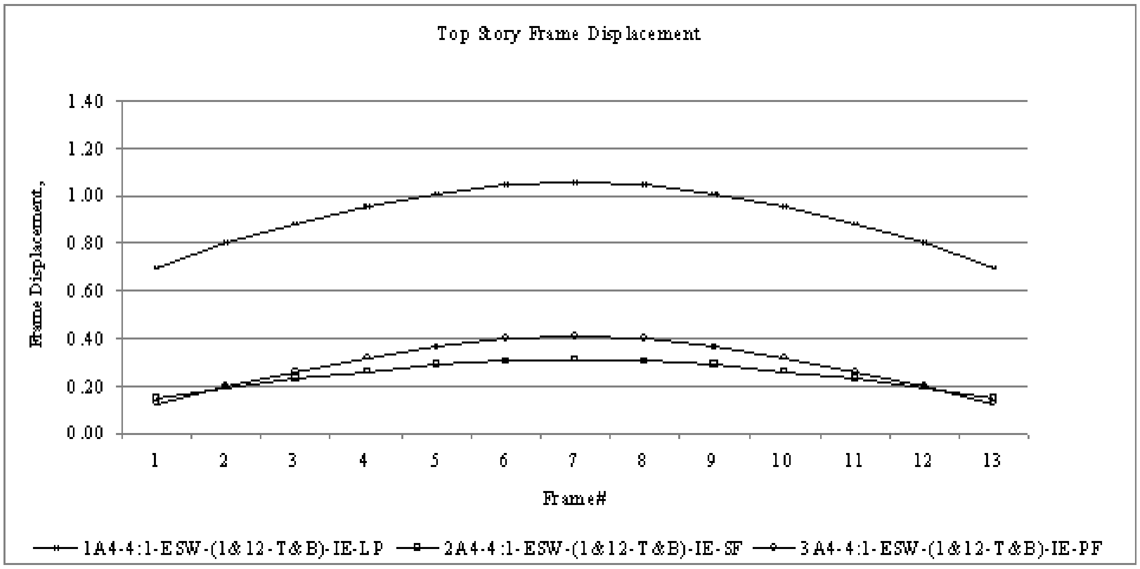


Figure 5-36: Building A4 [11%] Top Story max. Frame Deflection vs. Frame Numbers

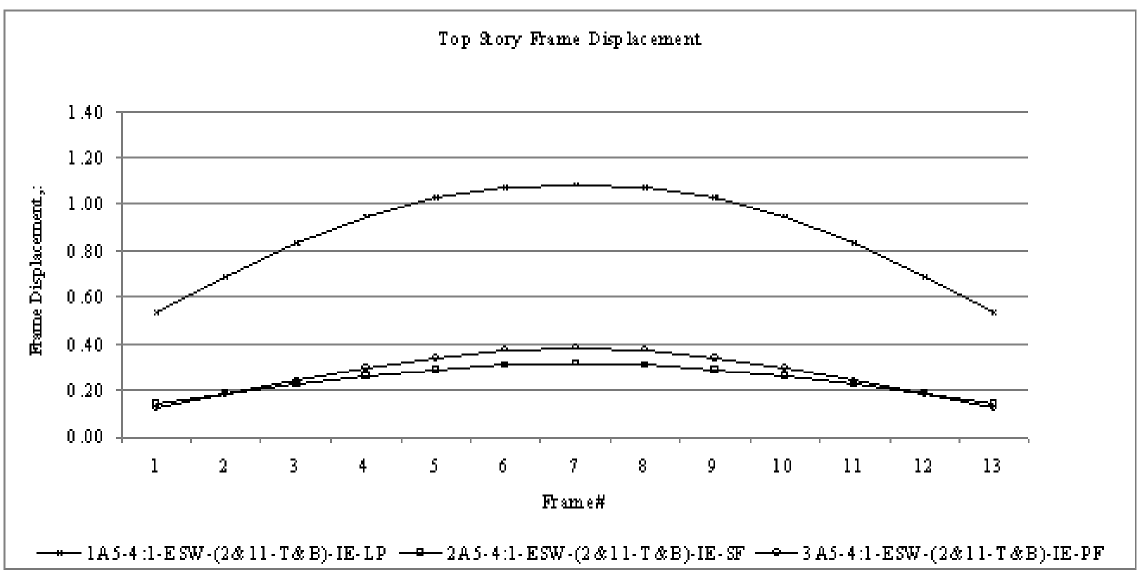


Figure 5-37: Building A5 [11%] Top Story max. Frame Deflection vs. Frame Numbers

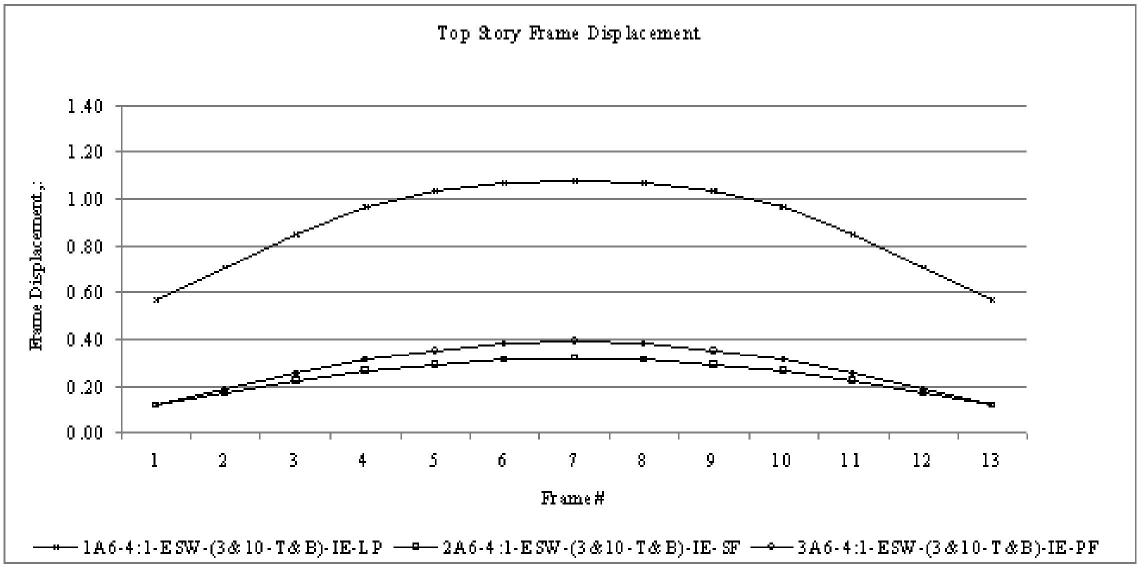


Figure 5-38: Building A6 [11%] Top Story max. Frame Deflection vs. Frame Numbers

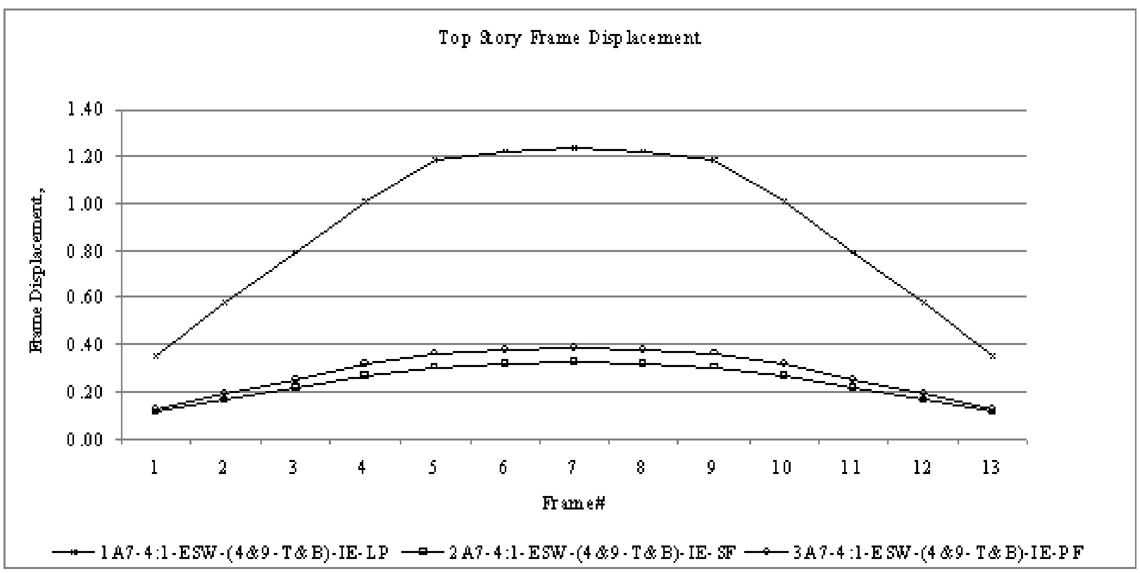


Figure 5-39: Building A7 [11%] Top Story max. Frame Deflection vs. Frame Numbers

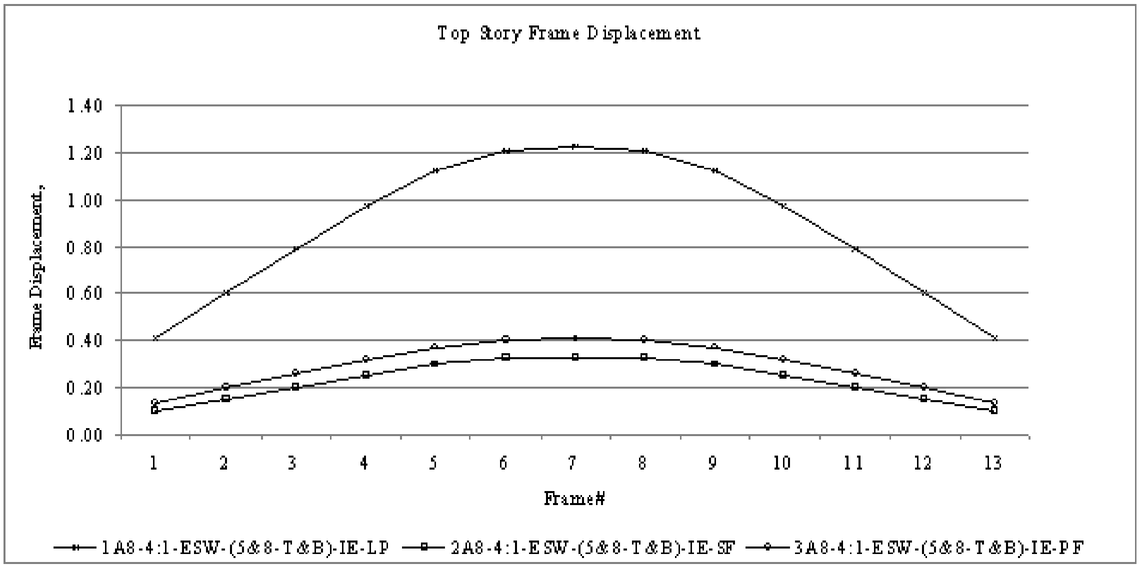


Figure 5-40: Building A8 [11%] Top Story max. Frame Deflection vs. Frame Numbers

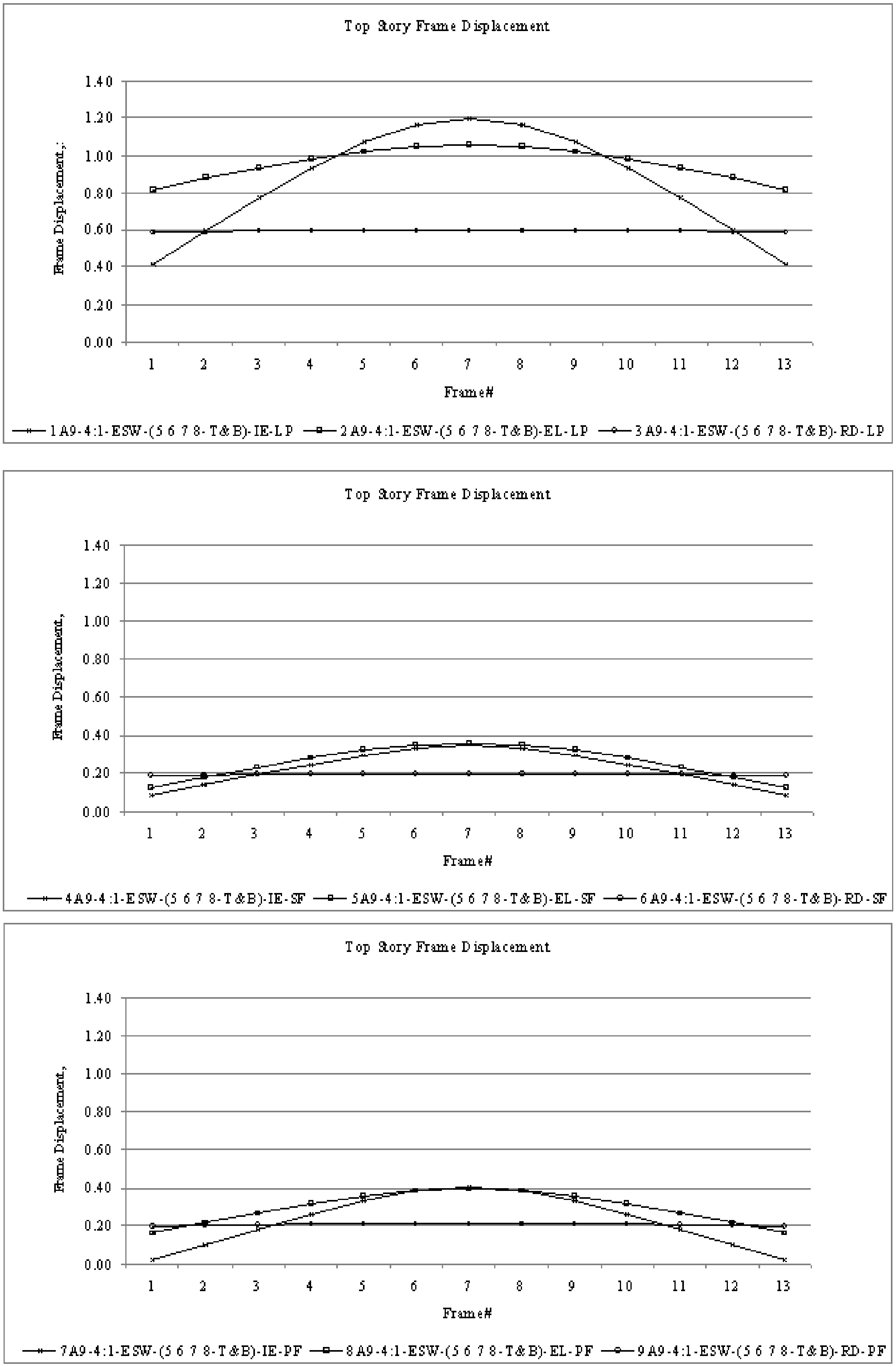
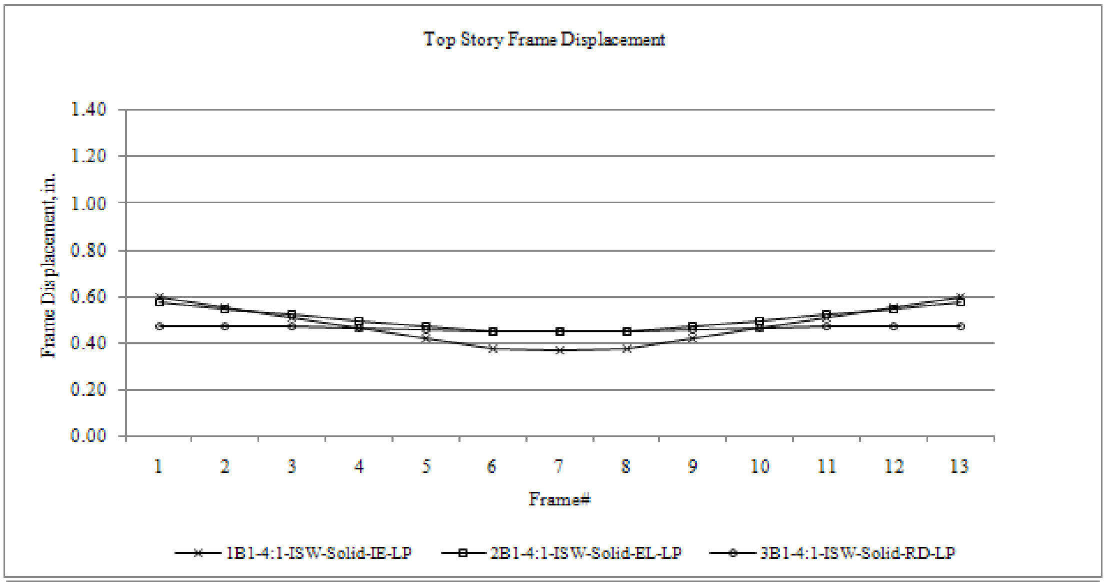
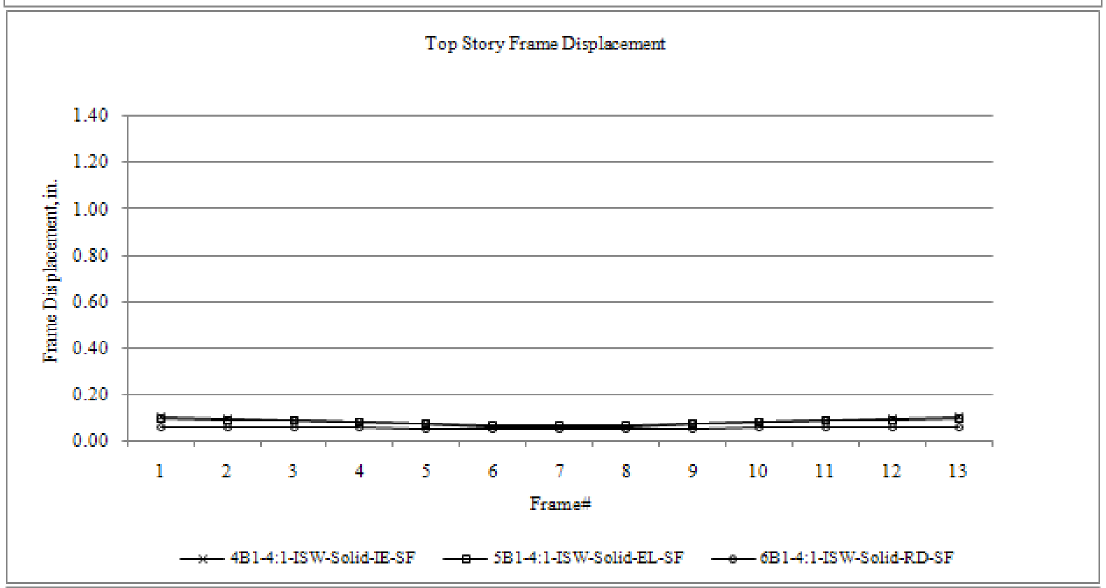


Figure 5-41: Building A9 [22%] Top Story max. Frame Deflection vs. Frame Numbers





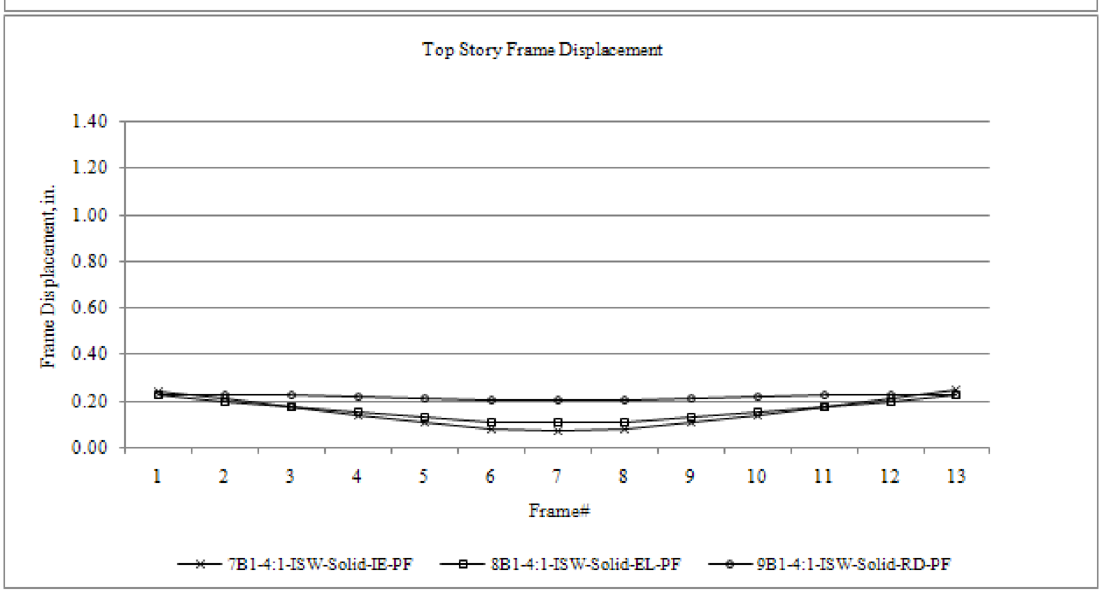


Figure 5-42: Building B1 [0%] Top Story max. Frame Deflection vs. Frame Numbers

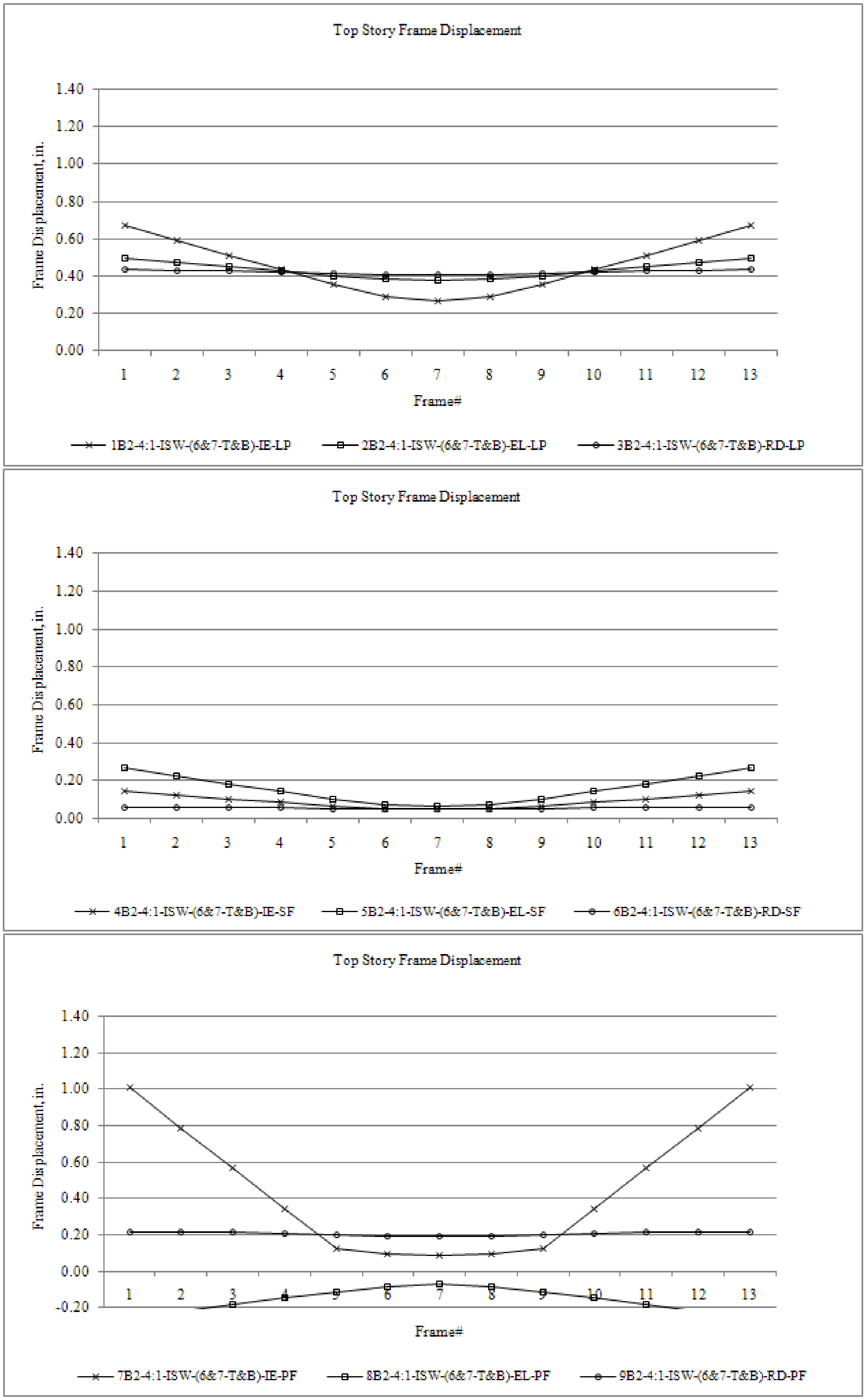


Figure 5-43: Building B2 [11%] Top Story max. Frame Deflection vs. Frame Numbers

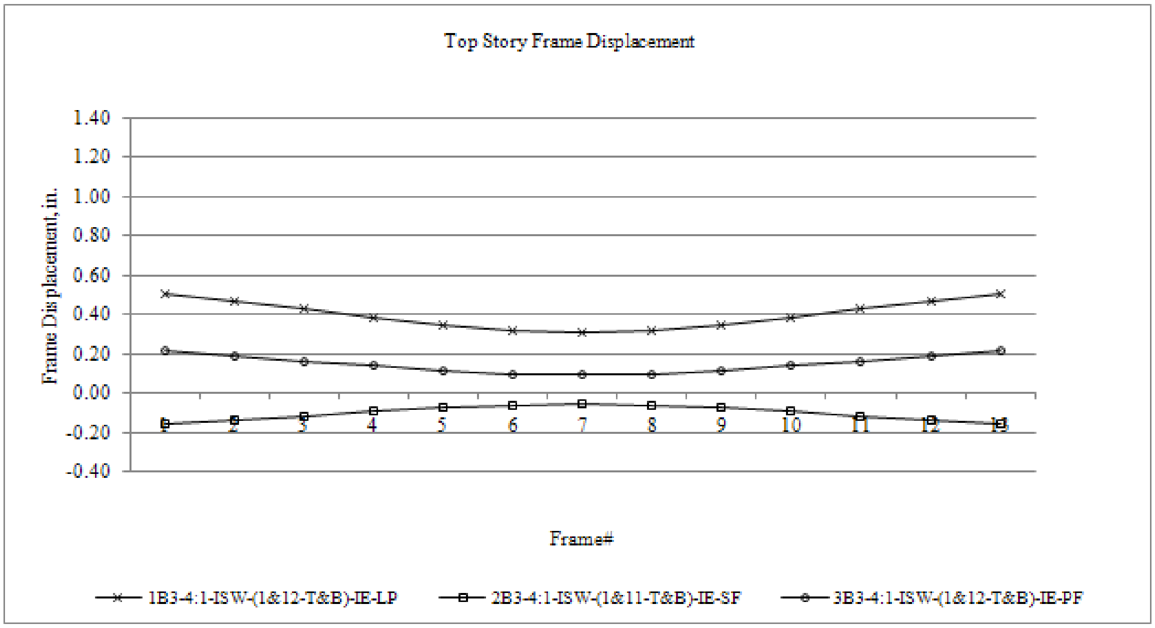


Figure 5-44: Building B3 [11%] Top Story max. Frame Deflection vs. Frame Numbers

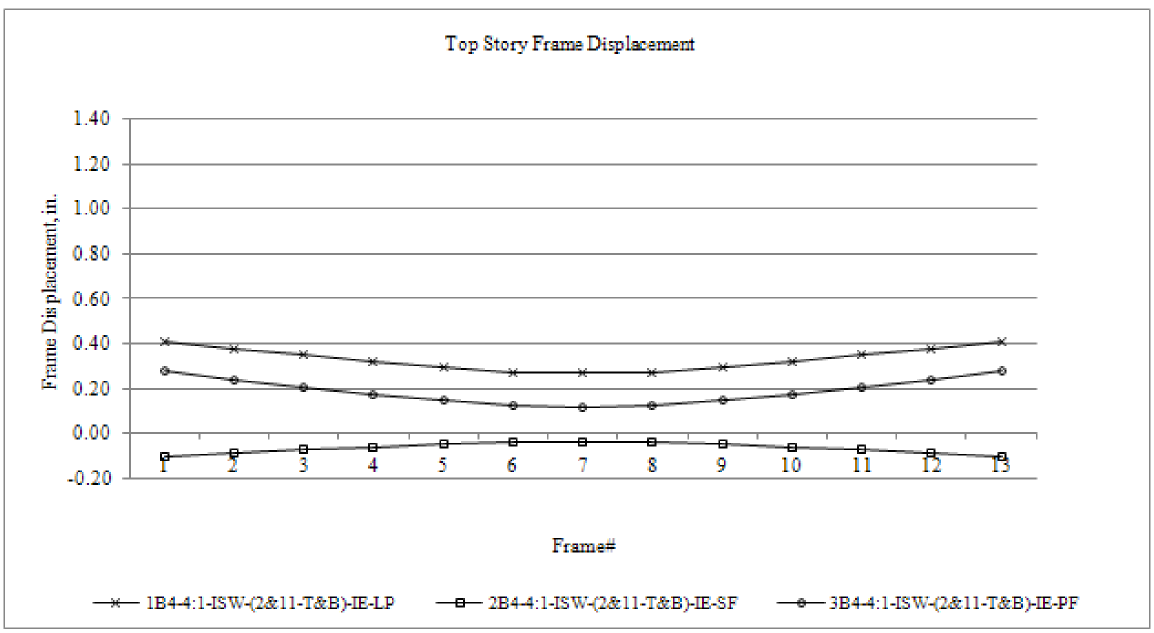


Figure 5-45: Building B4 [11%] Top Story max. Frame Deflection vs. Frame Numbers

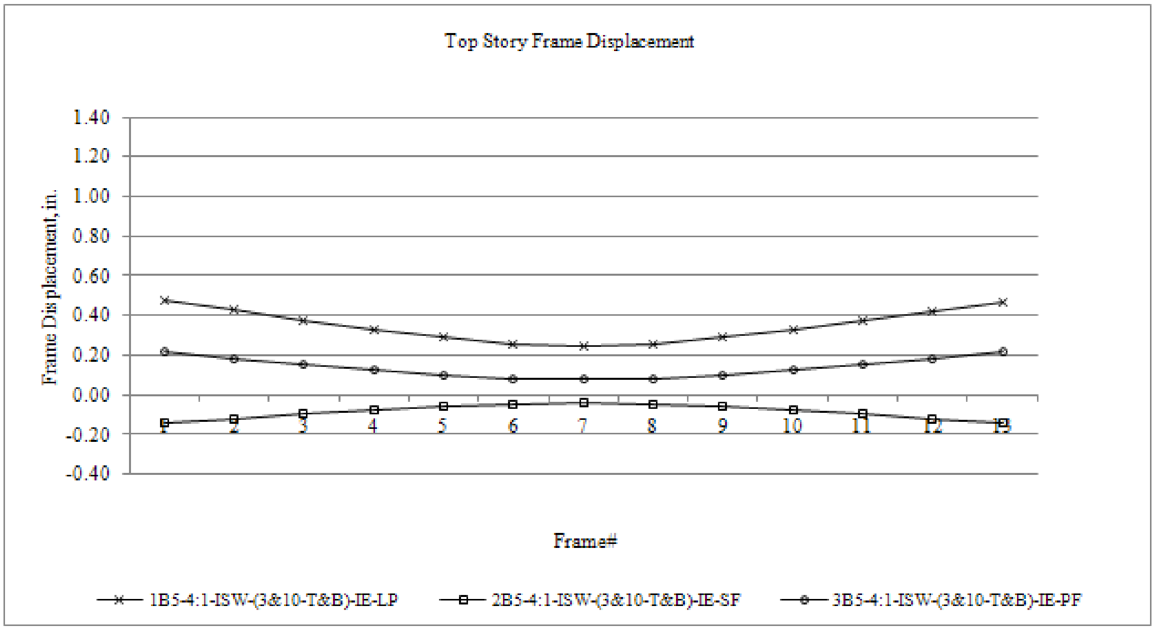


Figure 5-46: Building B5 [11%] Top Story max. Frame Deflection vs. Frame Numbers

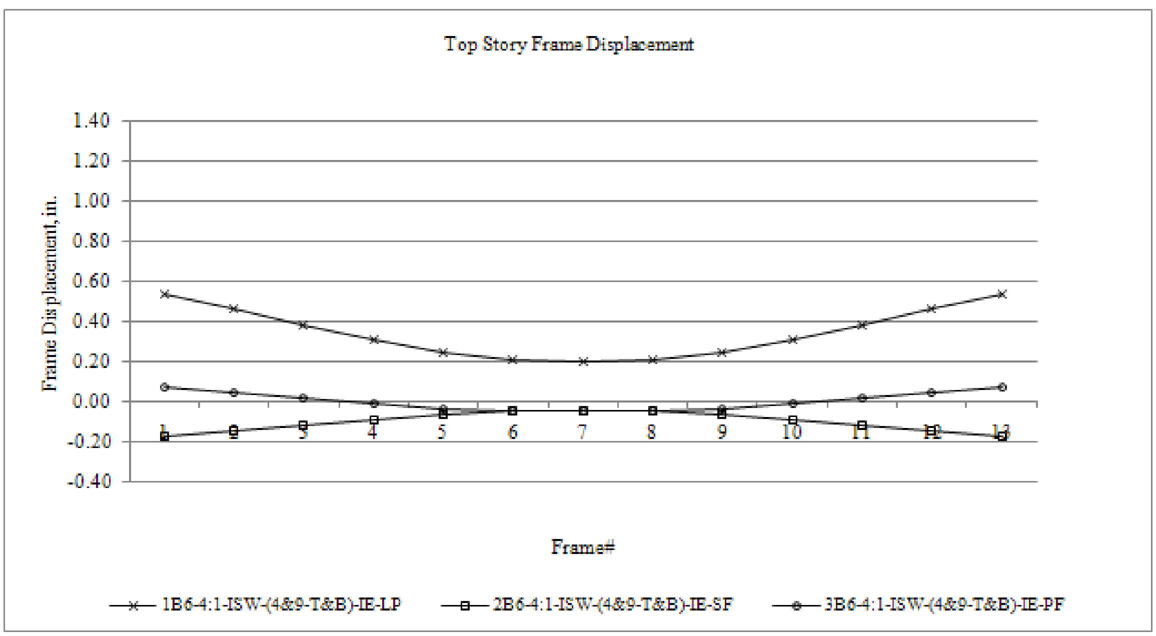


Figure 5-47: Building B6 [11%] Top Story max. Frame Deflection vs. Frame Numbers

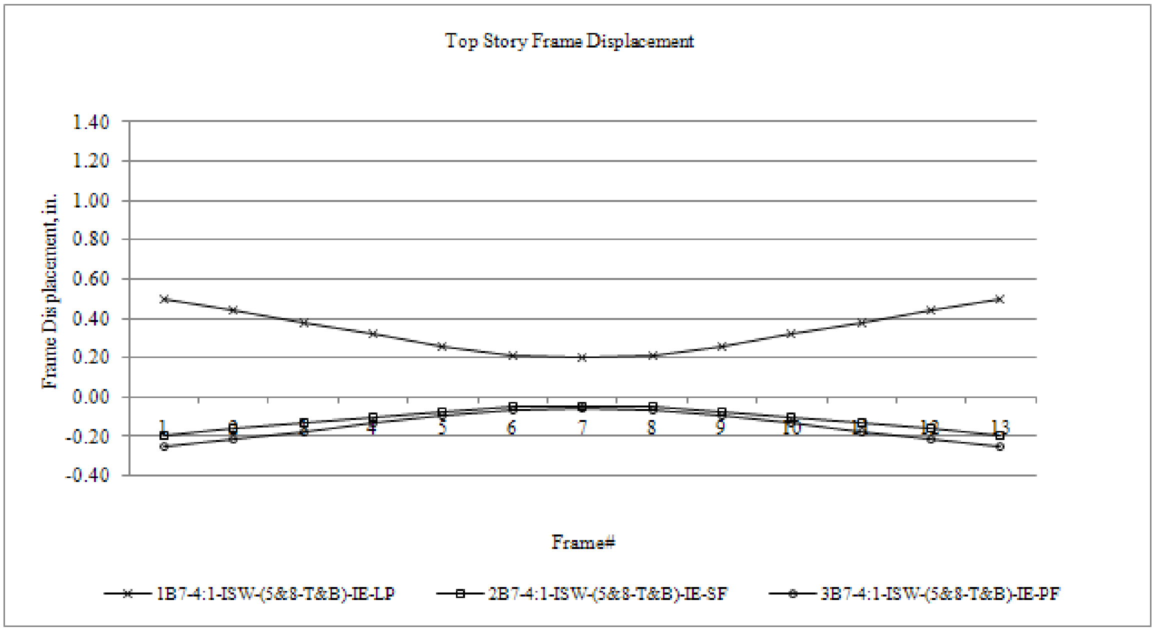


Figure 5-48: Building B7 [11%] Top Story max. Frame Deflection vs. Frame Numbers

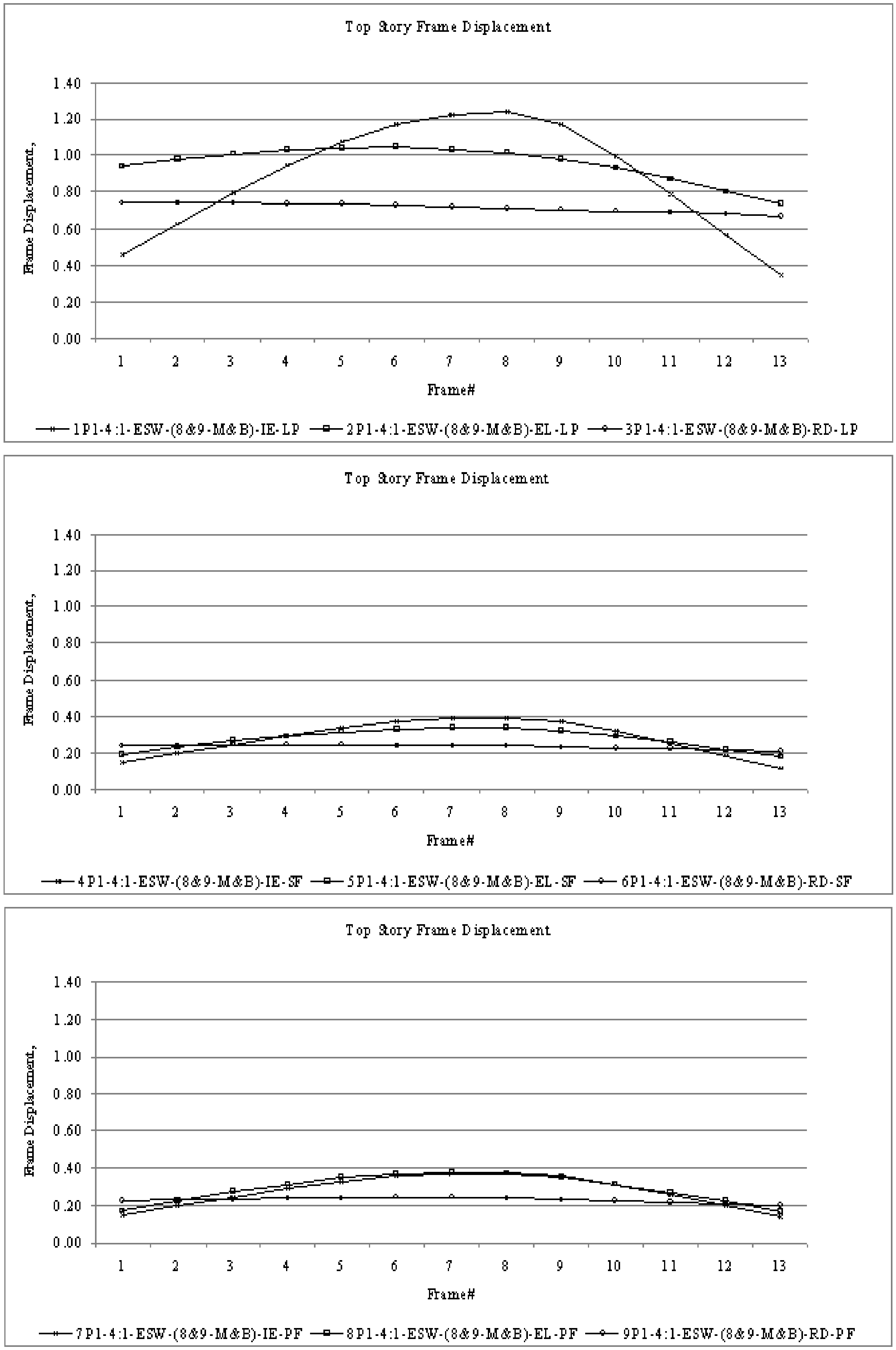


Figure 5-49: Building P1 [11%] Top Story max. Frame Deflection vs. Frame Numbers

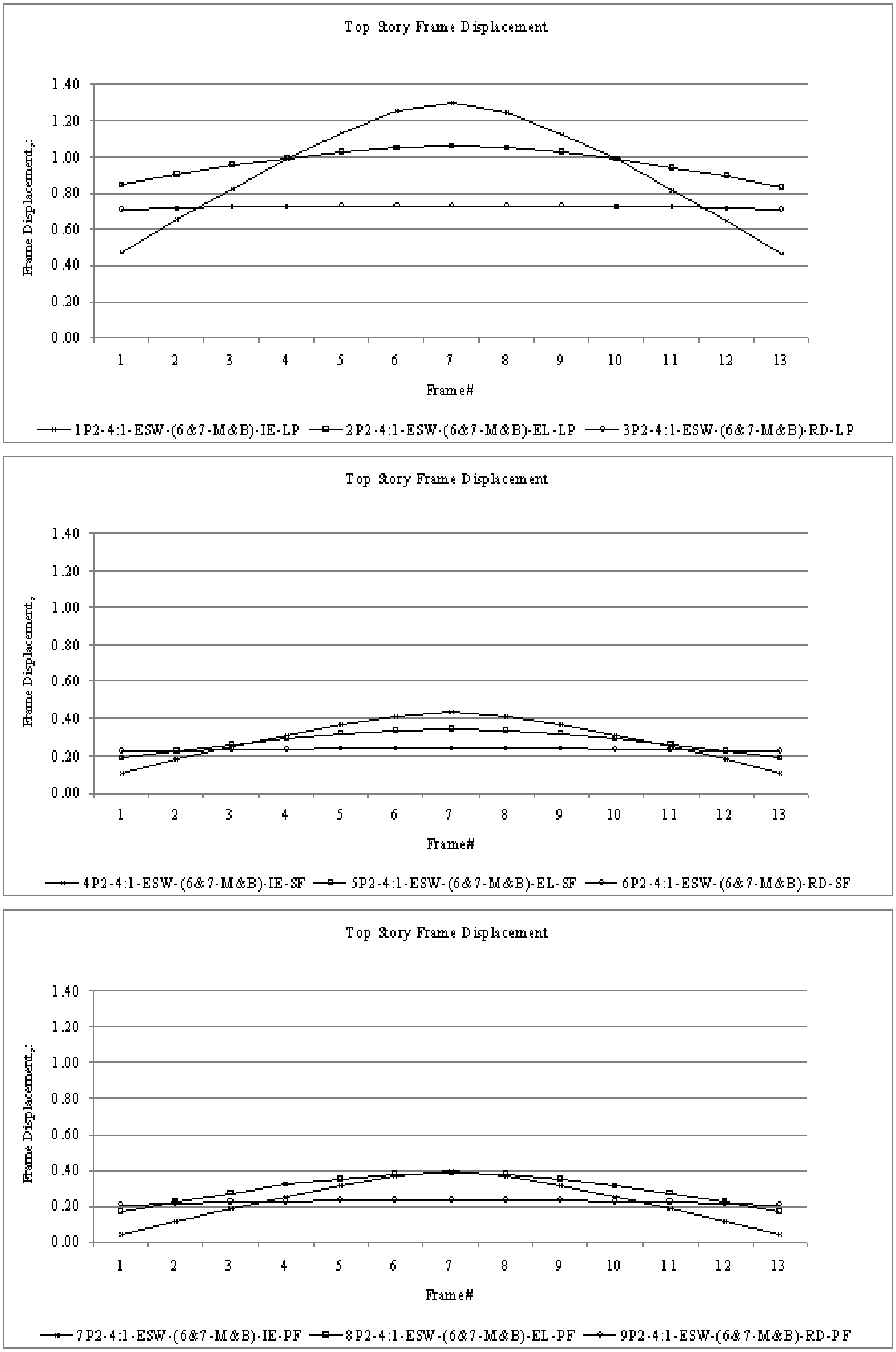


Figure 5-50: Building P2 [11%] Top Story max. Frame Deflection vs. Frame Numbers

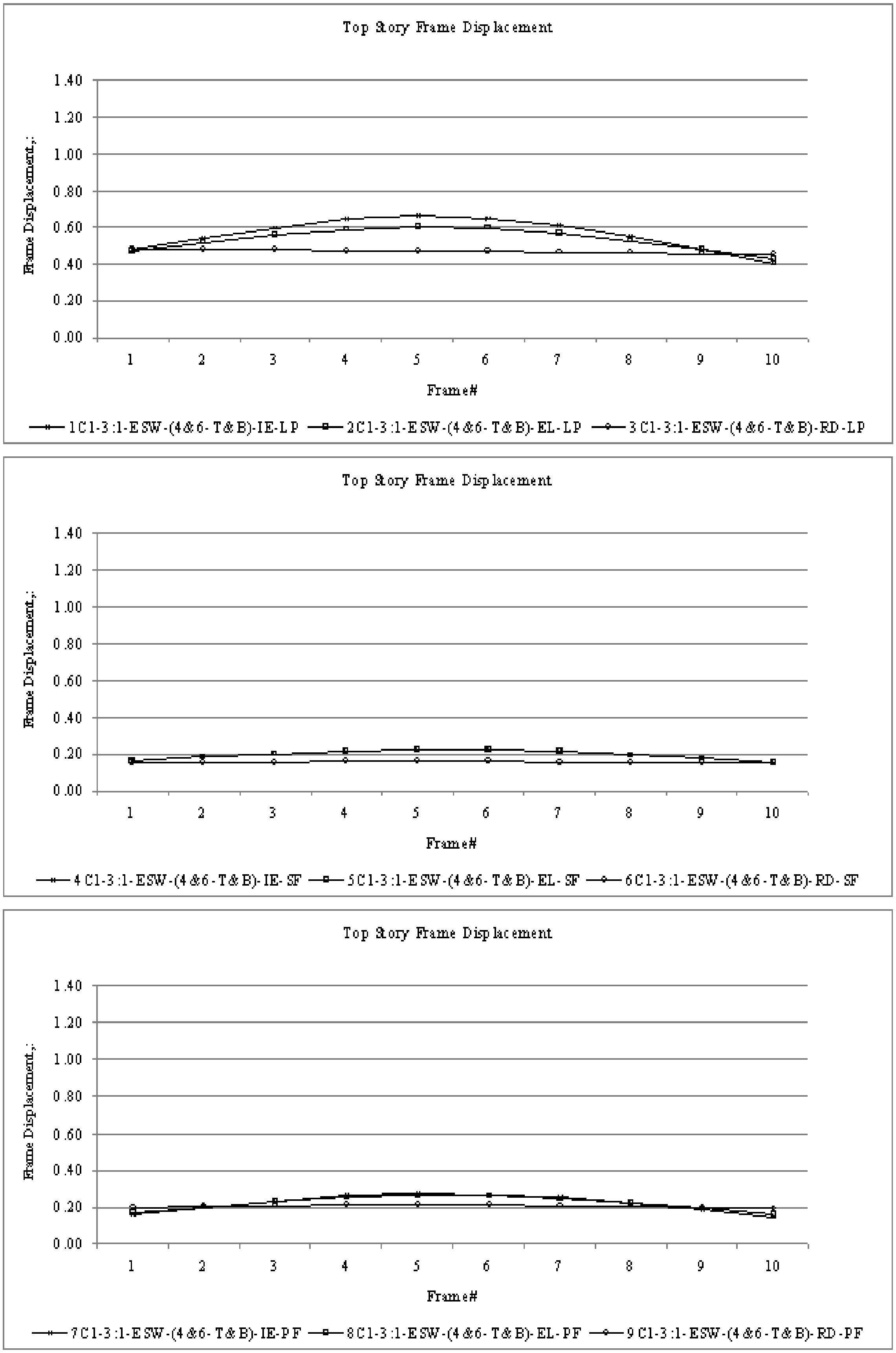


Figure 5-51: Buildings C1 [15%] Top Story max. Frame Deflection vs. Frame Numbers

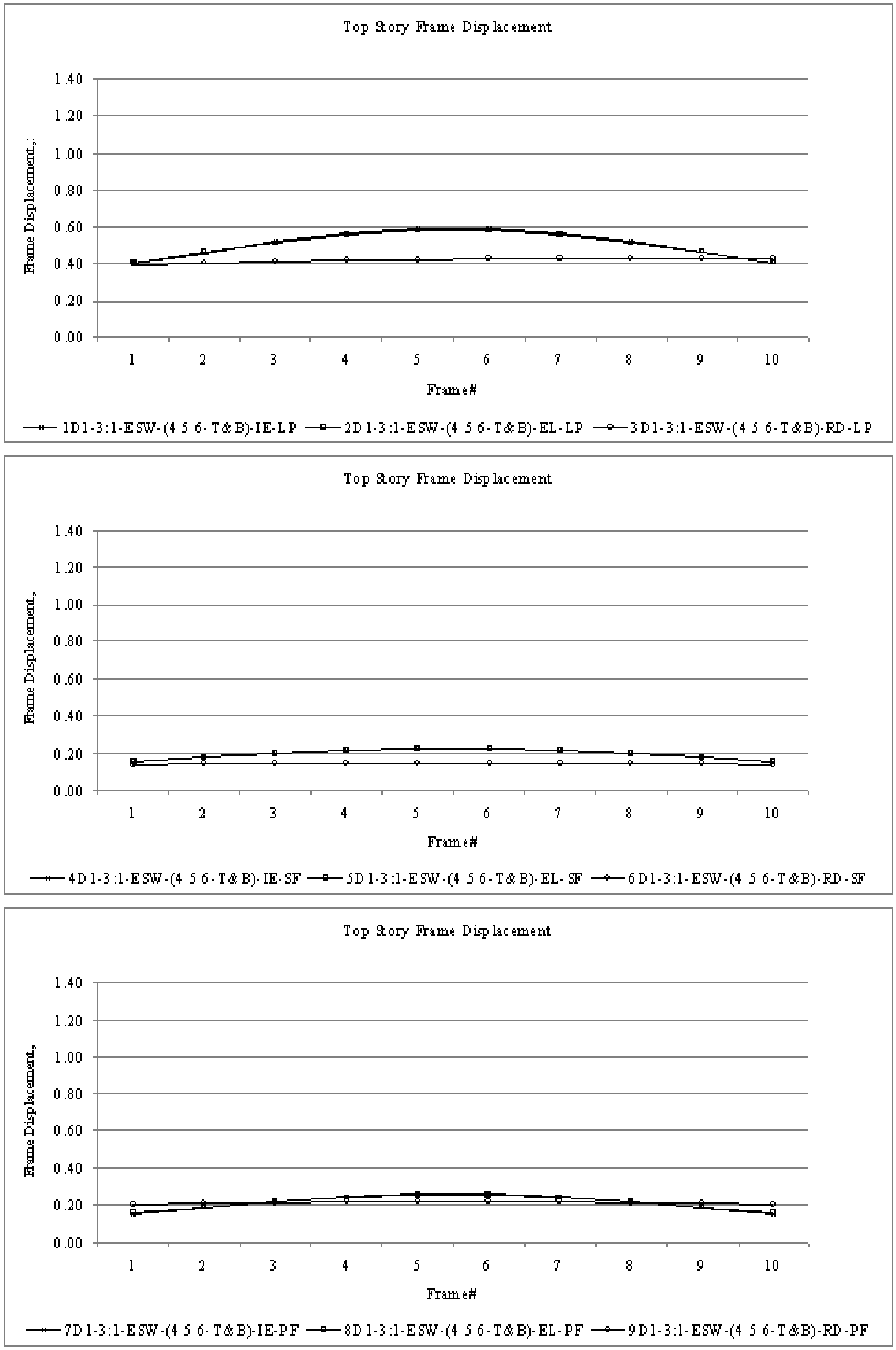


Figure 5-52: Buildings D1 [22%] Top Story max. Frame Deflection vs. Frame Numbers

Building frame maximum displacements and maximum diaphragm inplane deflections occurred at the top story in all buildings investigated when either elastic or inelastic slab models are used, imposing a higher ductility demand on the interior frames. Table 5-4, presented these displacements for all cases studied. It is evident that Loma Prieta earthquake had caused the maximum frame displacements and maximum diaphragm inplane deflection when using the inelastic diaphragm assumption.

5.3 Sensitivity Study Findings

As mentioned previously, a three-parameter hysteretic model is used in the inelastic dynamic analysis to duplicate the various aspects of reinforced concrete behavior under inelastic dynamic loading. These three-parameter hysteretic variables as mentioned earlier are referred to as α, β, and γ. The effects of stiffness degradation (through α), strength deterioration (through β), and bond-slip pinching (through γ) on the hysteretic behavior of the reinforced slab element was investigated through different combinations

Combination of the varying hysteretic properties and changing the shape of the idealized trilinear moment-curvature envelopes were investigated as part of a sensitivity analysis for the base case 1A3-4:1-ESW-(6&7-T&B)-IE-LP. This reference case was chosen because it gave one of the highest frame displacements due to extensive inplane yielding of the floor diaphragm compared to other cases examined, and it is symmetric in plan and section. The sensitivity analysis commenced by increasing the stiffness degradation factor α, 25% and then decreasing it to 75% the base value. Similarly, the pinching factor γ is increased by 25% and then reduced to 75% the base value. Finally, the strength deterioration factor β is increased by 25% and then reduced to 75% the base value.

Regarding the trilinear idealization for moment-curvature, several approximations are reported by testing results for diaphragms without openings where the variation from the initial location for change of slope is taken to be one-third of the slab yield strength when vertical loads (out-of-plane) loads are applied [48]. This variation of the apparent cracking is changed from one-third to one-fourth to one-half the yielding moment. Also, a bilinear idealization for the moment-curvature envelope was included by setting the cracking moment to equal the yielding moment.

Thus, the sensitivity analysis required IDARC2 [56] source code modification to implement the different moment-curvature envelope idealizations. All the sensitivity study results are presented herein in Table 5-5.

Table 5-5: Sensitivity Study Analysis Results Summary

Scenario	Base Shear, k	%V to Walls	%V to Frames	V to Frames, k	Bldg. Max. Top Displ., in.
1A3-4:1-ESW-(6&7-T&B)-IE-LP	1545.51	69.14	30.86	476.90	1.274
1.25α	1554.10	69.60	30.40	472.50	1.265
0.75α	1580.50	69.75	30.25	478.10	1.277
1.25γ	1542.90	69.22	30.78	474.90	1.302
0.75γ	1553.50	69.44	30.56	474.70	1.298
1.25β	1580.60	69.88	30.12	476.00	1.277
0.75β	1546.50	69.14	30.86	477.30	1.251
0.25My	1487.10	68.48	31.52	468.70	1.567
0.50My	1644.40	70.80	29.20	480.20	1.187
1.00My	1778.40	73.53	26.47	470.80	1.104

It is apparent that the maximum top story frame displacement and building base shear did not change significantly (less than 4% and 3% respectively). Also, the base shear distribution to the interior frames had changed by no more than 3%.

Subsequent to the modification in the hysteretic parameters, a variation of the cracking moment from one-quarter My to one-half My to My, i.e. bilinear idealization, was also examined. Hence, it was noticed that the maximum top story frame displacement changed by more than 23 % for the smallest cracking moment (0.25My).

However, the building base shears and the base shear distribution to the interior frames were within 6% and 5% of the reference case, respectively, with the exception of the case using the bilinear idealization assumption, where the total building base shear was overestimated by 15% and the distribution to the interior frames was underestimated by 15%.

These results clearly show the inadequacy of using a bilinear moment-curvature assumption for the floor diaphragm, and the need for future verification of the actual location of cracking moment using the idealized trilinear curve.

Chapter 6

Analytical Study Discussion

This research effort portrays a comprehensive picture of the in-plane behavior of reinforced concrete floor slab diaphragms subjected to different earthquake loadings, and the effects of their characteristics on the overall building seismic response, in particular diaphragms with openings. In this chapter, a summary of all the findings of the inelastic (pushover) analysis, inelastic dynamic (time-history) analysis and sensitivity study are discussed, and design guidelines of reinforced concrete buildings with diaphragm openings are presented.

6.1 Pushover Analysis

This section will discuss the key observations relating to the pushover analysis for all diaphragm scenarios investigated. For building groups A1 thru A9 where the floor diaphragm plan aspect ratio is 4:1 with end shear walls, the yield sequence is shear walls followed by slab yielding. Again, for building groups B1, thru B7 where the floor diaphragm plan aspect ratio is 4:1 with intermediate shear walls, the yield sequence is also shear walls followed by slab yielding.

Interestingly, for building groups P1 and P2 where the floor diaphragm plan aspect ratio is 4:1 with end shear walls, the yield sequence is simultaneous, i.e. shear walls and slab yield at the same time at a base shear coefficient of 0.170. This synchronized yielding is due to the presence of openings in the bottom two bays of the slab cross-section as compared to being symmetrically placed, i.e. top and bottom. Thus, the slab yielding moments for open sections is reduced by 25% (from 136560 kip-in to 109370 kip-in).

Finally, for cases C1 and D1, with end shear walls and diaphragm plan aspect ratio of 3:1, the yield sequence is shear wall yielding followed by the slab yielding.

From the preceding inelastic pushover results presented and discussed; it is evident that the dominant yield failure mode is first shear walls and then slabs. This is the preferred sequence, since slab diaphragms are not typically detailed for ductile behavior. Table 6-1 shows a pushover summary for all the cases investigated, showing the value for slab displacement when slab yielding occurs and also when wall yielding takes place, hence, illustrating how yielding of either one elements (slab or wall) influences the overall response of the buildings.

Table 6-1: Pushover Analysis Slab Displacement Summary at Slab and Wall Yielding

Scenario	At Slab Yielding			Slab Yielding Coeff. / Wall Yielding Coeff.	At Wall Yielding		
	Wall Drift, %H	Frame Drift, %H	Slab Displ., in.		Wall Drift, %H	Frame Drift, %H	Slab Displ., in.
1A1-4:1-ESW-Solid-IE	1.188	1.248	0.282	2.333	0.0409	0.0772	0.1699
1A2-4:1-ESW-(8&9-T&B)-IE	0.282	0.312	0.141	1.471	0.0372	0.0783	0.1923
1A3-4:1-ESW-(6&7-T&B)-IE	0.212	0.268	0.265	1.333	0.0387	0.0848	0.2157
1A4-4:1-ESW-(1&12-T&B)-IE	0.663	0.733	0.332	2.235	0.0363	0.0748	0.1802
1A5-4:1-ESW-(2&11-T&B)-IE	0.663	0.736	0.342	2.167	0.0386	0.0794	0.1909
1A6-4:1-ESW-(3&10-T&B)-IE	0.453	0.516	0.294	1.778	0.0386	0.0804	0.1956
1A7-4:1-ESW-(4&9-T&B)-IE	0.272	0.327	0.257	1.444	0.0386	0.0824	0.2050
1A8-4:1-ESW-(5&8-T&B)-IE	0.211	0.265	0.252	1.333	0.0385	0.0845	0.2153
1A9-4:1-ESW-(5 6 7 8-T&B)-IE	0.285	0.356	0.330	1.474	0.0380	0.0936	0.2602
1B1-4:1-ISW-Solid-IE	1.561	1.569	0.039	2.882	0.0146	0.0364	0.1020
1B2-4:1-ISW-(6&7-T&B)-IE	0.275	0.309	0.160	1.500	0.0146	0.0500	0.1657
1B3-4:1-ISW-(1&12-T&B)-IE	1.700	1.697	0.012	2.842	0.0151	0.0347	0.0917
1B4-4:1-ISW-(2&11-T&B)-IE	1.939	1.943	0.016	-	0.0147	0.0324	0.0828
1B5-4:1-ISW-(3&10-T&B)-IE	1.603	1.618	0.074	2.739	0.0153	0.0391	0.1114
1B6-4:1-ISW-(4&9-T&B)-IE	0.991	1.026	0.163	2.261	0.0153	0.0453	0.1404
1B7-4:1-ISW-(5&8-T&B)-IE	0.212	0.247	0.165	1.409	0.0149	0.0506	0.1671
1P1-4:1-ESW-(8&9-M&B)-IE	0.037	0.074	0.172	1.000	0.0373	0.0740	0.1718
1P2-4:1-ESW-(6&7-M&B)-IE	0.036	0.075	0.182	1.000	0.0364	0.0752	0.1816
1C1-3:1-ESW-(4&6-T&B)-IE	0.777	1.004	1.062	2.304	0.0383	0.0598	0.1006
1D1-3:1-ESW-(4 5 6-T&B)-IE	0.856	1.169	1.465	2.458	0.0382	0.0619	0.1109

6.2 Dynamic Response of Buildings

This section will discuss the key findings related to the inelastic dynamic analysis of all the building scenarios examined. Yielding of the floor diaphragm slabs is reached when the slab yields due to either inplane bending or shear yielding. However, from the dynamic analyses; the slab shear forces were smaller than what is required to yield the diaphragm in shear, hence, diaphragms yielded flexurally. The largest slab diaphragm inplane bending moments occurred at the mid-span for cases with end shear walls and at the walls for cases with intermediate shear walls. The discussion herein will revolve around the major parameters investigated, namely; the diaphragm plan aspect ratio, influence of floor openings size and location, wall locations, slab diaphragm models and earthquake type, concluded by an error index estimate for frame displacements.

<u>Diaphragm Plan Aspect Ratio</u> – Two ratios were examined; 3:1 (groups C and D) and 4:1 (groups A, B and P). Clearly, there was no slab yielding in the 3:1 cases. This is due to the fact that the shear walls have yielded at significantly lower lateral loads (see Table 6-1).. However, the influence of inplane diaphragm deformation is noticeable due to slab in-plane cracking, resulting in the frame shear re-distribution of 81% to end walls and 9% to interior frames, which is considerably different from the values (93% and 7%) obtained using the rigid slab assumption, as specified by ASCE7-05 [7].

Also, for the 4:1 case, for the solid cases, i.e. A1 and B1, the solid slab did not yield but the walls did. But in the remaining 4:1 cases where openings were present, the slab yielded when openings were in the middle third of the diaphragm plan as noticed in cases A2, A3, A6, A7, A8, A9,B2, B6, B7, P1 and P2.

<u>Diaphragm Opening Size (% are of the floor plan) and Location</u> – Examined diaphragm openings sizes varied from 0% to 22% of the floor plan area, and they were placed within various bays in the floor plan either symmetrically or non symmetrically with respect to the floor plan's centerline axis in both directions (see Figures 4-1 through 4-20). Based on assessment of dynamic analysis results (i.e., frame displacements, slab deformations, frame shear redistributions and in-plane diaphragm displacement) the following observations were made with respect to the slab inplane behavior;

1. Slab yielding occurred when openings were placed at bays in the middle two-thirds of the floor plan in building groups A and P, and middle half of the floor plan in building group B.

2. The influence of diaphragm yielding on the seismic response of buildings is more prominent when openings are placed non-symmetrically with respect to the floor plan centerline axis in the N-S direction (cases A2 & P1) and in the E-W direction (cases P1 & P2).

3. It is noted that when the slab cross-section becomes non-symmetric due to openings, the yield capacity of the slab is significantly lower than the symmetrical case, thus, its influence become more pronounced. Case P2 resulted in the highest base shear frame redistribution (30%) due to slab yielding.

4. When the openings were placed at the end bays of the building with end walls, it is noted that high percentage of base shear was gained by the interior frame using the scaled Parkfield earthquake when neither slabs nor walls had yielded. Careful examination of the dynamic results indicate that for this particular case, the inner frames vibrated in and out-of-phase with respect to the end frames due to significant reduction in the end bay slab stiffness caused by openings, resulting in a higher percentage of the earthquake load in the inner frame. However, the total shear force in these frames was considerably less than the other cases since the walls and slabs had not yielded, as observed in cases 3A4 and 3A5.

<u>Shear wall Location</u> – For shear walls placed symmetrically either at the ends or in the middle of the building; their effect on base shear distribution between shear walls and frames was generally similar amongst the two different shear wall layouts for a given earthquake type.

<u>Slab Diaphragm Models</u> – For all three floor diaphragm types investigated (inelastic, elastic and rigid), the frame shear is shown to be much higher in the inelastic floor slab diaphragm model than the elastic case, and the least for the rigid model. This difference is more evident for buildings with plan aspect ratio of 4:1 than it is for 3:1. Since shear walls are designed to take the entire base shear, nonetheless, the use of elastic or rigid diaphragm models undervalues the base shear forces taken by the interior frames.

Additionally, the effects of energy dissipation due to slab cracking and hysteretic action in the inelastic model, and hence, longer period, resulted in lower base shear compared to the elastic or rigid slab models. Henceforth, it is evident from the frame displacement results that the maximum displacement occurred at the top story and also under the inelastic floor diaphragm assumption, which allows for inplane slab cracking and yielding. This generally results in additional earthquake loads carried by the interior frames.

<u>Types of Scaled Earthquakes</u> – Three different scaled earthquakes were used, namely, Loma Prieta, San Fernando and Parkfield. Loma Prieta, yielded the highest building base shears and frame displacements. However, as explained earlier, Parkfield's dynamic results in cases 3A4 and 3A5 had exhibited an out-of-phase dynamic behavior between the end frames and the interior frames where the interior frames took the highest share of total building base (35%).

<u>Maximum Building Frame Displacement Error Index</u> – An error index relating the maximum interior frame inelastic displacement to the ASCE 7-05 [7] prescribed inelastic frame displacements, which is obtained by multiplying the elastic frame displacement by C_d of 4.5 to account for the inelastic behavior of the building. Hence, for buildings with plan aspect ratio of 4:1 with end walls, an error Index for the top story maximum inelastic displacement relative to the code prescribed one is given by:

$$Error \cdot Index = \frac{\left(\Delta_{Top \cdot Level \cdot Interior \cdot Frame \cdot Maximum \cdot Inelastic \cdot Displacement} - \Delta_{ASCE7-05}\right)}{\Delta_{ASCE7-05}} \qquad \text{[Eq.6-1]}$$

Table 6-3 illustrates that the error index varies from a minimum of about 16% up to a high of 56%, when 11% floor openings are placed non-symmetrically with respect to both axis of the building. It is evident that the building code [28] clearly underestimates the inelastic displacements. Hence for this reason, it is recommended that the Deflection Amplification Factor, C_d, for this type of structure as defined in IBC 2006 [28] be increased from the prescribed value of 4.5 to 1.56 x 4.5= 7.0, conservatively, if yielding of the slab diaphragms was to be allowed. Also, as it was pointed out in the previous section, the interior frames should be designed to resist at least 30% of total lateral load (case P2). These design recommendations are typically prohibitive, and thus more practical recommendation are provided in Section 6.4, to insure that slab diaphragm yielding does not occur in such buildings.

Table 6-2: Error Index for all Inelastic Building Cases Investigated

Scenario	Bldg. Max. ASCE7-05 Top Displ., in.	Bldg. Max. Dynamic Top Displ., in.	Error Index, %
1A1-4:1-ESW-Solid-IE	0.80	1.204	49.77
1A2-4:1-ESW-(8&9-T&B)-IE	0.86	1.323	53.25
1A3-4:1-ESW-(6&7-T&B)-IE	0.88	1.274	44.28
1A4-4:1-ESW-(1&12-T&B)-IE	0.82	1.053	27.68
1A5-4:1-ESW-(2&11-T&B)-IE	0.83	1.087	31.47
1A6-4:1-ESW-(3&10-T&B)-IE	0.84	1.076	28.52
1A7-4:1-ESW-(4&9-T&B)-IE	0.86	1.237	44.17
1A8-4:1-ESW-(5&8-T&B)-IE	0.88	1.226	39.33
1A9-4:1-ESW-(5 6 7 8-T&B)-IE	0.92	1.197	29.64
1B1-4:1-ISW-Solid-IE	0.40	0.596	48.61
1B2-4:1-ISW-(6&7-T&B)-IE	0.47	0.673	43.62
1B3-4:1-ISW-(1&12-T&B)-IE	0.34	0.504	47.23
1B4-4:1-ISW-(2&11-T&B)-IE	0.28	0.405	46.83
1B5-4:1-ISW-(3&10-T&B)-IE	0.32	0.475	48.95
1B6-4:1-ISW-(4&9-T&B)-IE	0.37	0.535	44.87
1B7-4:1-ISW-(5&8-T&B)-IE	0.43	0.500	16.05
1P1-4:1-ESW-(8&9-M&B)-IE	0.82	1.241	52.10
1P2-4:1-ESW-(6&7-M&B)-IE	0.83	1.292	55.83
1C1-3:1-ESW-(4&6-T&B)-IE	0.49	0.665	36.44
1D1-3:1-ESW-(4 5 6-T&B)-IE	0.48	0.591	22.29

6.3 Sensitivity Study

As stated previously, a three-parameter hysteretic model along with an idealized trilinear moment-curvature envelope of the slabs were used in the inelastic dynamic analysis to duplicate the various aspects of reinforced concrete behavior under inelastic dynamic loading. Figure 6-1 shows a typical time history plot for the top story slab element in bay 8 in building case 1P1-4:1-ESW-(8&9-M&B)-IE-LP to illustrate the hysteretic loops in slab with unsymmetrically placed openings. It is observed that the slab element is only subjected to two cycles of inelastic loading. Hence, the impact of changing the hysteretic parameters, α, β, γ will not have a remarkable effect on the floor slab diaphragm inelastic deformation outcome.

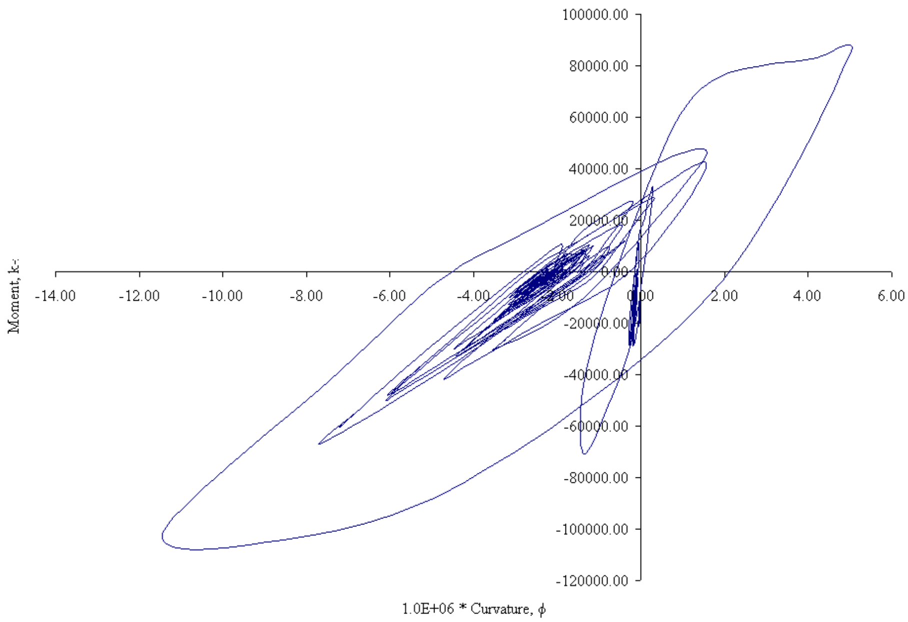


Figure 6-1: Moment-Curvature time history for 1P1-4:1-ESW-(8&9-M&B)-IE-LP

When using the idealized trilinear moment curvature envelopes, the overall change in the base shear distribution amongst the frames and shear walls was only 5% and 6% respectively. However, frame displacements where different by 23% because of larger inplane slab deformation due to the early cracking moment of ¼ My. This will have an impact on architectural detailing of exterior components like glass facades and stone claddings and must be accounted for in design.

Also, using a bilinear approximation for moment-curvature properties of slabs is not acceptable as the maximum top story frame displacement is underestimated by more than 15%, and the base shear distribution to the interior frames is again underestimated by more than 14%, both unconservatively.

6.4 Suggested Design Recommendations

Based on the extensive analytical results obtained herein, it is very interesting to point out that for all the cases evaluated in this study, the walls yielded first and then the slab as reflected in Table 5-2.

Since all the buildings in question are in the Saint Louis area, and referencing Figure 4-22, they all fall in the "flat region" of IBC 2006 [28] site-specific acceleration response spectra. Hence, for all buildings studied, the building code design base shear coefficient, C_s, is 8.9% as shown in Table 4-1.

Also, since the building periods calculated using Rayleigh's method were all less than 0.5 sec. (Table 5-3), the exponent related to the structure period, k, is taken to be unity. Thus, from IBC 2006 [28], the base shear seismic coefficient, C_{vx} is:

$$C_{vx} = \frac{W_x h_x^k}{\sum W_i h_i^k}$$, where k = 1.0 [Eq.6-2]

and $h_1 = h$, $h_2 = 2*h$ and $h_3 = 3*h$, and h is typical story height, hence, the following algorithm is formulated;

at the first story, $C_1 = 1/6$ or $F_1 = \frac{V}{6}$ [Eq. 6-3]

at the second story, $C_2 = 1/3$ or $F_2 = \frac{V}{3}$ [Eq. 6-4]

and at the roof $C_3 = 1/2$ or $F_3 = \frac{V}{2}$ [Eq. 6-5]

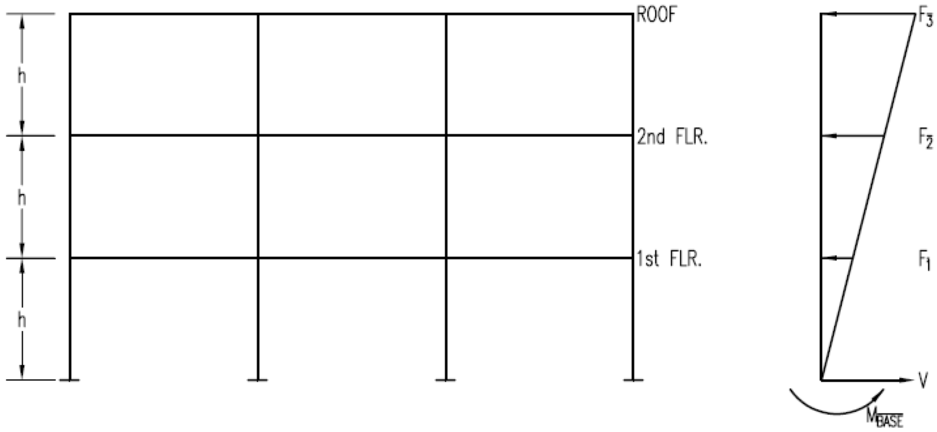


Figure 6-2: Seismic Force Distribution per IBC 2006 [28]

Since all floor weights are approximately equal and taking the overturning moments at the base, per Figure 6-3;

$$M_{Base} = \frac{3Vh}{2} + \frac{2Vh}{3} + \frac{Vh}{6} = 2.33\,Vh \qquad \text{[Eq. 6-6]}$$

Using elastic wall and slab deformations (given in Table 6-1) and ASCE 7-05 [7] section 12.3 diaphragm type classification based on diaphragm inplane deformations being less or greater than 2 times the average wall displacements, as defined in Figure 6-3, the floor diaphragm behavior in these buildings range between stiff (elastic) to flexible, as shown in Table 6-3.

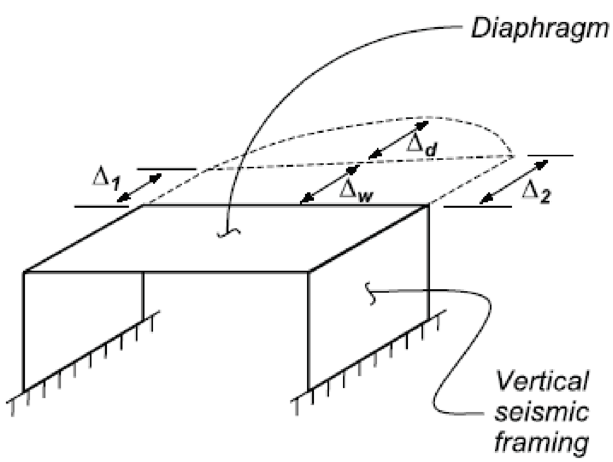


Figure 6-3: Diaphragm and Wall Displacement Terminology [7]

Table 6-3: ASCE 7-05 [7] Diaphragm Type Classification

Scenario	Diaph. Type
1A1-4:1-ESW-Solid-IE	STIFF
1A2-4:1-ESW-(8&9-T&B)-IE	STIFF
1A3-4:1-ESW-(6&7-T&B)-IE	STIFF
1A4-4:1-ESW-(1&12-T&B)-IE	STIFF
1A5-4:1-ESW-(2&11-T&B)-IE	STIFF
1A6-4:1-ESW-(3&10-T&B)-IE	STIFF
1A7-4:1-ESW-(4&9-T&B)-IE	STIFF
1A8-4:1-ESW-(5&8-T&B)-IE	STIFF
1A9-4:1-ESW-(5 6 7 8-T&B)-IE	STIFF
1B1-4:1-ISW-Solid-IE	STIFF
1B2-4:1-ISW-(6&7-T&B)-IE	FLEXIBLE
1B3-4:1-ISW-(1&12-T&B)-IE	STIFF
1B4-4:1-ISW-(2&11-T&B)-IE	STIFF
1B5-4:1-ISW-(3&10-T&B)-IE	STIFF
1B6-4:1-ISW-(4&9-T&B)-IE	STIFF
1B7-4:1-ISW-(5&8-T&B)-IE	FLEXIBLE
1P1-4:1-ESW-(8&9-M&B)-IE	STIFF
1P2-4:1-ESW-(6&7-M&B)-IE	STIFF
1C1-3:1-ESW-(4&6-T&B)-IE	STIFF
1D1-3:1-ESW-(4 5 6-T&B)-IE	STIFF

With the maximum occurring load at the top story for the buildings assumed to be a parabolic load distribution per FEMA 356 [68] as shown in Figure 6-4, applied over the full span of the diaphragm from end shear wall to end shear wall, L, with x being the distance from the center line of the diaphragm, and w_3 is the inertial load per unit length of the floor diaphragm, hence;

$$w_3 = \frac{1.5F_3}{L}\left[1-\left(\frac{2x}{L}\right)^2\right] \quad \text{[Eq. 6-7]}$$

Similarly, the interior frame resistance is considered to vary parabolically over the length of the building as shown in Figure 6-4 with interior frames taking an average of 30% of the lateral load.

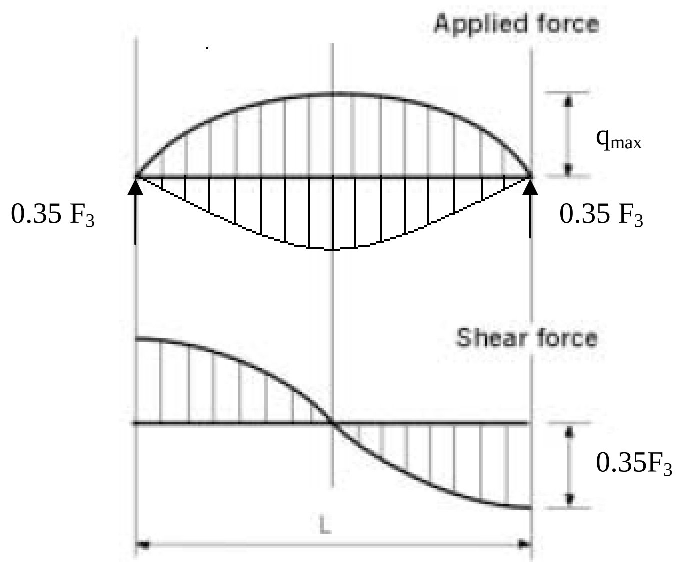


Figure 6-4: Top Floor Diaphragm Load per FEMA 356 [68]

Henceforth, the maximum inplane slab moment assuming a conservative simple-span and ignoring end shear walls torsional stiffness, can be obtained by calculating the area under the shear diagram in Figure 6-4 as such;

$$M_{Slab(max)} = \frac{3}{4}(0.35F_3)\left(\frac{L}{2}\right) = 0.13125F_3L = 0.065625VL = \frac{VL}{15.24} \qquad \text{[Eq. 6-8]}$$

With the careful examination of the inelastic static (pushover) analysis and dynamic (time history) analysis of buildings with plan ratio of 4:1 with end walls; it is noted that to prevent inplane slab floor diaphragm flexural yielding (according to time history analysis results), the ratio of the base shear coefficient corresponding to the initial yielding of the floor diaphragm (at the top story), 0.39, to the base shear coefficient corresponding to the initial yielding of the shear walls (at the base of the building), 0.18, should be at least 2.17 (based on the results of building 1A5). Thus, the slab moment capacity should be increased by combining the above factor times that of the value given in Equation 6-8 as such;

$$M_{Slab\,(max)} = 2.17 \times \frac{VL}{15.24} = 0.143VL \qquad \text{[Eq. 6-9]}$$

Combining Equation 6-9 with Equation 6-6, slab moment capacity can also be written in terms of design over-turning moment at the base of structure:

$$M_{Slab(max)} = 0.061 M_{Base} \frac{L}{h} \qquad \text{[Eq. 6-10]}$$

Thus, it is recommended that if the provided inplane diaphragm moment capacity at the critical slab section - as it was based on fiber model idealization moment capacities observed in the buildings studied and as closely estimated by using inplane cracking moment computed based on the plain concrete cross-section as specified by Equation 9.9 of the ACI 318-08 [2] - is less than the required moment given by Equation 6-10 or 6-11, then the diaphragm chords should be reinforced as follows;

$$M_{Slab(max)} = 1.13 M_{Base} \qquad \text{[Eq. 6-11]}$$

Again, by closely examining all the results obtained from the dynamic analysis for all the building cases where the slab diaphragm had yielded due to the applied earthquakes; building case 1A5-4:1-ESW-(2&11-T&B)-IE had resulted in the largest difference amongst all the A-Group between it's wall yielding base shear coefficient of 0.18 and slab yielding base shear coefficient, 0.39. Thus, this case was taken as the starting point for a series of dynamic runs, where the slab diaphragm reinforcing was increased incrementally until the slab yielded no more. Hence; for buildings were analysis bring to light cracking in floor slabs reinforced for nominal gravity loads, chords should be reinforced so as eliminate slab yielding assuming a plain concrete slab as follows;

$$A_s = \frac{M_{Slab(max)}}{f_y \cdot D} \qquad \text{[Eq. 6-12]}$$

Where A_S is the area of chord reinforcement required to prevent floor slab diaphragms from yielding, and D is the diaphragm over all depth.

Chapter 7

Summary and Conclusions

There is a significant void in published literature on the subject of analysis and behavior of reinforced concrete floor slab diaphragms with openings. All the cases investigated in this research effort gave insight into the influence of diaphragm deformation assumptions (inelastic, elastic and rigid) on the nonlinear seismic response of buildings with floor slab openings. IDARC2 [56], a program that was developed to conduct inelastic static and seismic simulations of rectangular plan structures with inelastic diaphragms, is enhanced to account properly for floor openings (symmetric or non-symmetric). Summary and conclusions of this study along with the suggestions for future research work are presented in this chapter.

7.1 Summary

Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls. Furthermore, they take a major part in distributing earthquake-induced loads to the lateral load resisting systems by diaphragm action. In reinforced concrete buildings, inplane floor diaphragms deformations are often ignored for simplicity in practical design (i.e., the floor systems are frequently treated as perfectly rigid diaphragms). Past research, which is acknowledged in recent building standards, has shown that this assumption can result in considerable error when predicting seismic response of reinforced concrete buildings when diaphragm plan aspect ratio is greater than 3:1 [41 & 7]. However, the influence of floor diaphragm openings (typically for the purpose of stairways, shafts, and other architectural applications) has not been considered. In order to investigate the influence of diaphragm openings on the seismic response of reinforced concrete buildings, 3-story reinforced concrete buildings are designed as a Building Frame System with either end or interior shear walls to resist 100% of the earthquake load according to the International Building Code [28] in the Saint Louis, Missouri, and they are analyzed with and without floor openings located at different locations. The inelastic behavior of all the buildings is investigated under both static lateral loads (pushover) and dynamic ground motions (time-history), where a suite of three well-known earthquakes is scaled to model moderate ground motions in the Saint Louis region. The findings were presented in this research effort and discussed.

7.2 Conclusions

The findings of this research along with recommendations may be cataloged as follows:

1. Results of pushover analysis indicate that end shear walls yield prior to floor diaphragms in the building with solid floor slabs is the preferred yield sequence and the same should be observed in building with diaphragm openings.

2. The proposed analytical enhancements to IDARC2 [56] program is achieved for inelastic floor slab diaphragms with openings where appropriate trilinear moment-curvature idealization algorithms are used. Also, the enhanced program is now fully capable to analyzing unsymmetrical floor slab diaphragm thru user-defined floor slab diaphragm properties.

3. By examining the inelastic seismic response of the reinforced concrete buildings - with and without floor diaphragm openings - it is evident that current design practices in ASCE 7-05 [7] and IBC 2006 [28] of disregarding diaphragm inplane inelastic deformations for diaphragms with plan aspect ratio of 3:1 (by specifying the use of rigid diaphragm assumption) and with floor diaphragm plan aspect ratio of 4:1 (by allowing the use of elastic diaphragm assumption) is an inappropriate representation of the diaphragm's true behavior. Hence, the influence of inelastic inplane diaphragm deformations due to floor openings cannot be overlooked in

such buildings, particularly when the diaphragm openings are located in the middle two-thirds of the building.

4. Results of dynamic analysis show that combined effects of inelastic floor diaphragm deformation with shear wall yielding shifts the base shear to the frames by up to 30%.

5. From dynamic analysis, it is observed that the inplane yielding of floor diaphragm is controlled by flexure and not shear.

6. The shears taken by interior frames is much higher in the inelastic floor slab diaphragm model than the elastic case, and more prominent for the rigid model. Thus, the rigid floor assumption significantly underestimates the base shear of the frames.

7. The maximum building frame displacement occurred at the top story under the inelastic floor diaphragm assumption.

8. The maximum frame inelastic displacement was compared to the ASCE 7-05 [7] predicted value, which is obtained by multiplying the elastic frame displacement by the Displacement Amplification Factor (C_d) to account for the inelastic behavior of the building. It is observed that the ASCE 7-05 underestimates the building frame displacement by up to 56% when floor diaphragms yield.

9. The effect of shear walls location (either at the end frames or at interior frames) on base shear redistribution due to yielding of floor diaphragms was minimal.

10. The sensitivity study of the three-parameter hysteretic model used in IDARC2 [56] to account for the stiffness degradation (α), the pinching factor (γ), and the strength deterioration (β) indicates that variations of these parameters by ± 25% resulting in insignificant (less than 4%) change in the dynamic results.

11. The sensitivity study of the idealized tri-linear moment curvature used for the diaphragms was conducted by changing the variation of the cracking moment from the initial stiffness slope of one-third the yielding moment (as specified in IDARC2 [56] for solid slabs) to 0.25, 0.5 and 1.0 of the yielding moment (i.e., bilinear idealization). It was noticed that for the smallest cracking moment (0.25My) used, the maximum top story frame displacement changed the most (by 23%), indicating the occurrence of the largest inplane diaphragm deformation, however, the frame base shear distribution changed only by 5%.

12. Using bilinear idealization for moment curvature envelope of slabs is found to be unacceptable since it resulted in the total building base shear being overestimated by 15%, shear distribution to the interior frames being underestimated by 15%, and maximum frame displacement being underestimated by 14%.

13. To capture the proper dynamic response of buildings with diaphragm opening at bays adjacent to the end shear walls, special care should be given to the modeling of diaphragm deformations so that the potential out-of-phase vibration of end frames and interior frames (due to significant reduction of slab stiffness near end walls) is properly captured by the dynamic analysis.

14. Simplified design recommendation were provided for the proper amount of reinforcing steel to be used in chord members of floor diaphragms to prevent diaphragm yielding in such buildings.

7.3 Suggestions for Future Research

To extend the scope limitations of this study, the following additional research is suggested for proper understanding of inelastic seismic response of reinforced concrete buildings with floor diaphragm openings.

1. Further investigation is needed on buildings located in more severe seismic regions in the country where diaphragm slabs may be subjected to a larger number of inelastic cyclic loadings.

2. More accurate moment-curvature envelopes are needed for diaphragms with openings, where slab cracking moments are properly estimated by using combined experimental and computational methods.

3. Inplane behavior due to heavy out-of-plane loading should be examined closely, as the intensity of the vertical load may be very well alter the inplane behavior of the floor slab diaphragm.

Appendix A

Accepted Proposal

Inelastic Seismic Response of RC Buildings with Floor Diaphragm Openings

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Senior Structural Engineer
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Washington University in St.Louis

November 2007

A Doctoral Proposal submitted to the Department of Civil Engineering at Washington University in Saint Louis Saint Louis, Missouri, USA

Forward

Following the doctoral proposal defense presentation on Thursday May 12th, 2005, the doctoral committee comprising:

- Kevin Z. Truman, Ph.D., Chairman and Doctoral Supervisor,
- Thomas G. Harmon, Ph.D.,
- Philips L. Gould, Ph.D.,
- Shirley J. Dyke, Ph.D.,
- Srinivasan Sridharan, Ph.D.,
- Hiroaki Mukai, Ph.D.

collectively had suggestions to better define the research scope. Hence the proposal document was thoroughly reworked incorporating all the committee's valuable suggestions. The suggestions may be summarized as:

- Exploring other published literature venues on diaphragms (Dr. Gould).
- Make the research scope more precise, delineating the essential issues associated with diaphragms-frames interaction (Dr. Harmon).
- Identifying the critical parameters of the problem and quantify their relative influence on the diaphragms-frames interaction (Dr. Dyke).
- Other committee members had technical and textual corrections.

Dr. Gould suggested looking for more publications related to diaphragms; thirty seven new references were obtained from PEER (Pacific Earthquake Engineering Research Center), ACI (American Concrete Institute) Structural Journal, 8th and 13th WCEE (World Conference on Earthquake Engineering), Engineering Structures Magazine, ASCE (American Society of Civil Engineers) Structural and Mechanics Journals, Mid-America Earthquake Center and MCEER (Multidisciplinary Center for Earthquake Engineering Research Information Center). A complete literature review is found in Chapter 3.

Dr. Harmon suggested narrowing down the scope of work to only rectangular reinforced concrete (RC) buildings and investigating the applicability of the rigid-floor assumption beyond the elastic range. He also suggested not using SAP 2000 [15] or ETABS [16], because of their inability to capture post-elastic behavior of concrete. Hence, IDACR2 [1] will be used instead.

The overall objectives are now defined as:

1. To develop a simplified methodology for the inelastic analysis of RC buildings with frames, shear walls and diaphragms with openings. This methodology utilizes a local-global approach. This approach will combine detailed local finite element analyses of diaphragms with openings using ABAQUS [58] and calibrated inelastic hysteretic parameters for cyclic response. A simplified and well-tested inelastic nonlinear (static and dynamic) global analysis program, IDARC [1] (Inelastic Dynamic Analysis of Reinforced Concrete Structures) is selected for the global analysis in the present work. In this approach, response to cyclic loading is encapsulated in terms of three hysteretic parameters, α, β and γ. These parameters will be calibrated for diaphragms with openings by using available detailed experimental results [59]. Hence,

objective 1 can be viewed as enhancing IDARC [2] for the analysis of diaphragms with openings. The enhancement shall include changing the current tedious test-input format to a user-friendly visual-based one.[1] Using the newly enhanced analysis tool in calculating the flexural and shear properties of slabs with openings; objectives 2 and 3 will be carried out.

2. To investigate the influence of openings in floor diaphragms on the lateral load distribution to frames and shear walls considering diaphragms' in-plane inelastic deformations, so that a criterion can be established to judge under what conditions such openings need to be specifically considered in a global earthquake resistant design.

3. To investigate whether ductility demands for RC buildings dictated by current building codes [3, 25] are adequate in the context of diaphragm inelastic in-plane deformations when openings are present and to propose appropriate design guidelines to ensure adequate performance during an earthquake.

Dr. Dyke suggested identifying the parameters that will be studied. Virtually all parameters influencing diaphragms behavior will be investigated in this research. In particular;

i. In-plane floor diaphragm models used in inelastic seismic response analysis. (i.e. rigid, elastic and inelastic);
ii. Lateral frame and shear wall stiffness and their locations;
iii. Floor diaphragm opening size and location;
iv. Floor plan aspect ratio.

While most of this research effort will be conducted on symmetric representative models, effects of plan asymmetry will also be examined on small, more typical models.

Regarding objectives (2) and (3); preliminary detailed analyses have been conducted on a typical 3-D 3 story low-rise building using IDARC2 [1]. Interesting new findings are reported in chapter 5 entitled "Methodology and Preliminary Investigations", clearly exhibiting current building codes [3, 25] shortcomings.

With the above suggestions and remarks accounted for, the proposed research will have a more definitive scope that complies with the Doctoral Committee requirements.

[1] The source code for IDARC2 [1] has been provided by Dr. Nader Panahshahi of Southern Illinois University Edwardsville and Dr. Sashi Kunnath of the University of California at Davis. See Appendix B for their supporting letters.

1. Introduction

Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls. Furthermore, they play a key role in distributing lateral loads by exhibiting diaphragm-like behavior. For that, the structural behavior of horizontal diaphragms such as floors and roofs is often considered similar to that of an I-beam, where the flanges and the web resist bending and shear, respectively. Because floors systems (horizontal diaphragms) are typically deep beams with short spans, they have very high stiffness and strength in comparison with other types of structural components and are often considered to be infinitely rigid in reinforced concrete buildings.

Cast-in-place concrete and concrete filled metal decks are normally considered rigid diaphragms. The concept of rigid floor diaphragms for building type structures was introduced nearly 40 years ago as a means to simplify the solution process. In the case of rigid floor diaphragms, the floor plate is assumed to translate in plan and rotate about a vertical axis as a rigid body, the basic assumption being that there are no in-plane deformations in the floor plate. The disadvantage of such an assumption is that the solution will not produce any information on the diaphragm shear stresses or recover any axial forces in horizontal members that lie in the plane of the floors. However, this assumption has serious limitations for buildings with flexible diaphragms. For diaphragms assumed to be infinitely stiff (rigid), the force distribution depends only on the relative stiffness between the vertical resisting elements. With the recent advances in numerical methods and computer technology the reasons that justified the use of rigid floor diaphragm models may no longer be valid. Therefore, it is maybe important in some cases that floor systems be modeled as an inelastic diaphragm so that diaphragm deformations are included in the analysis. These deformations are important not only for the evaluation of the diaphragm shear stresses but also to capture axial forces in members in the plane of the diaphragm. Another type of diaphragm is the flexible diaphragm. Flexible diaphragms are usually made of either plywood or light gage metal deck. For flexible diaphragms, diaphragm shears and moments are typically obtained by familiar procedures for continuous beams or by tributary area method.

Openings in diaphragms for purposes of stairways, shafts, and other architectural applications cause stress concentration around these discontinuities. These openings can also reduce the stiffness and strength of the diaphragm unless adequate reinforcement is provided. Diaphragms with openings are usually designed without stress calculations and are considered to be adequate ignoring any opening effects.

Past research has indicated that the distribution of lateral seismic forces is greatly affected by in-plane deformation of the floor diaphragms in rectangular buildings with end shear walls and moment resisting interior frames [38]. This is particularly true when significant cracking and yielding occurs in the floor-slab system. Also, experimental and analytical investigations at the University of New York at Buffalo and Lehigh University have clearly shown that cracking and even in-plane yielding of RC floor systems can be expected to occur in low-rise rectangular buildings with end shear walls and moment resisting interior frames where the plan aspect ratio exceeds 3 [38, 46]. In these types of buildings, the collapse can occur after failure of the interior columns due to excessive strength and ductility demands caused by in-plane behavior of floor diaphragms.

The collapse of Taiyo Fisheries Plant in Japan (a three story RC frame building with end walls) was observed to have followed this type of failure. The failure of the interior columns in the middle of the building was considered to be the cause of the collapse of the central portion of the structure although the end walls remained standing [57].

In this research effort all three types of diaphragms (elastic, inelastic and rigid) will be addressed in order to fully evaluate the effect of in-elastic diaphragm deformations on the seismic performance of buildings with frames and shear walls. The inelastic dynamic response of the buildings will be evaluated using an enhanced computer program (IDARC2 [1]) using a suite of earthquakes as the input ground motion. This program uses macro-modeling schemes to account for in-plane deformations due to shear and flexure in the diaphragm while considering stiffness deterioration and strength degradation of the reinforced concrete beams, columns, shear walls and slabs due to inelastic cyclic loadings caused by the ground motion.

2. Motivation

Although numerous publications dealt with the behavior and design of diaphragms, it is clear that there are several issues that have not yet been resolved.

Openings in diaphragms are often unavoidable and their presence can significantly modify the behavior of the diaphragm. At present and in many cases the designer assumes that the diaphragm is a rigid element, totally ignoring in-plane deformations – an assumption that can lead to erroneous results [33, 36]. Nor is it satisfactory to assume that the diaphragm acts as a continuous elastic beam over the intermediate shear walls and frames running in the transverse direction for low-rise rectangular buildings with longer floor aspect ratio [36, 46]. It is possible that the effectiveness of the diaphragm can be compromised in a manner yielding an outcome contrary to what is assumed. This issue is considered vitally important, as it is the least understood subject in this area, since there is no quantification of the error in diaphragm shears and frame members as a result of ignoring openings. Therefore, a systematic study of a set of carefully devised scenarios covering a spectrum of typical configurations used in practice is crucial where diaphragm in-plane deformations are incorporated in the analysis in order to capture the “real” behavior of the structural members as opposed to the “assumed” one.

Even though a total collapse of the diaphragm is unlikely to be the first major event in the failure of a building, a deterioration of its stiffness may result in a shift in the lateral loads distribution to the load carrying vertical elements causing some members to be overloaded resulting in a failure at that locality, thus jeopardizing the safety of the building structure and compromising the expected diaphragm action. Focusing attention on the progressive damage of diaphragms alone, one may anticipate a continuously evolving pattern of load distribution until failure occurs at the location of one of the load carrying members to the diaphragm.

The proposed research will investigate the aforementioned issues in depth and will be able to offer pertinent insights and better understanding of the structural behavior and design of RC buildings with floor diaphragm openings when subjected to strong ground motion.

3. Literature Review

Complete review and evaluation of all available literature to date is presented and addressed by area in Appendix B.

4. Objectives

The main goal of this research effort is to gain in-depth understanding of diaphragm behavior in seismic response of rectangular RC buildings through the following objectives:

1. To enhance IDARC2 [1] (developed in 1988) to account for RC buildings with diaphragm openings. Special attention will be given to the algorithms and mechanics principles governing the in-plane behavior of diaphragms and enhancement of the current global model along with estimated hysteretic parameters for slabs with openings. The calibration of the hysteretic parameters to reflect diaphragm with openings will be carried out thru a more detailed local analysis using ABAQUS [58] and available test results for shear walls with openings [59]. Simultaneously, IDARC2 [1] will be upgraded from its current text based-input pre-processing state to a more user-friendly visual based application. IDARC2 [1] source code (in FORTRAN) is made available thru Dr. Nader Panahshahi at Southern Illinois University Edwardsville – SIUE, and Dr. Sashi Kunnath of the University of California at Davis – UCD (see Appendix C for their supporting letters).

2. To investigate the applicability of rigid floor assumption (neglecting their in-plane deformations) to modeling of floor diaphragms with openings of various sizes placed in symmetric and asymmetric plan locations. Also, to investigate the influence of floor diaphragms on the distribution of lateral loads among the frames and shear walls with consideration of floors' inelastic-in-plane deformations. This will result in establishing a criterion as to when floor diaphragm openings in earthquake resistance design of RC rectangular buildings with shear walls can be ignored.

3. To determine appropriate design guidelines for RC buildings with significant inelastic in-plane diaphragm deformation to ensure that slab, frame, shear wall ductility demands due to seismic loads are within the building codes [3, 25] acceptable range and to provide the reinforcement detailing required to ensure adequate performance due to seismic loading.

The preliminary investigation presented in the next chapter has clearly demonstrated that floor diaphragms ductility demands are exceeded during an earthquake and using rigid diaphragm models is unacceptable for buildings with shear walls.

Hence, by using a suite of actual earthquake accelerations as ground motion input for the dynamic analysis, the true behavior of the diaphragm will be better captured, which will lead to a deeper understanding of diaphragm behavior and will result in valuable design recommendations for the seismic design of RC buildings with flexible (elastic and inelastic) diaphragms with openings. It will also provide a timely and enhanced computational tool for the research community to use.

5. Methodology and Preliminary Investigation

Computer modeling has proven to be not only fast, but also a reliable means for structural analysis and assessment. With numerical modeling being used extensively in structural investigations as a more economical approach to expensive laboratory testing, a three-dimensional non-linear analysis program will be used for this research, namely IDARC2 [1]. IDARC2 [1] is a non-commercial program that is available exclusively for the research community interested in the further development of diaphragm analysis and design. Part of this research effort will be dedicated to enhance IDARC2 [1] fiber models to obtain the shear and flexural properties of slabs with openings. Furthermore, finite element simulations will be carried-out to calibrate the macro-model in-order to estimate the hysteretic parameters (α, β, γ) for slabs with openings. With the above improvements incorporated, coupled with a user-friendly data-input pre-processor, IDARC2 [1] will provide simplified modeling for RC buildings with walls, frames and diaphragms with openings.

5.1 IDARC2 [1] Component Framework and Modeling

A typical reinforced concrete building is modeled by IDARC2 [1] using the following six element types: 1) Beams, 2) Columns, 3) Shear Walls, 4) Flexible (Elastic and Inelastic) or Rigid Floor Slabs, 5) Edge Columns and 6) Transverse Beams as shown below in a discretized section:

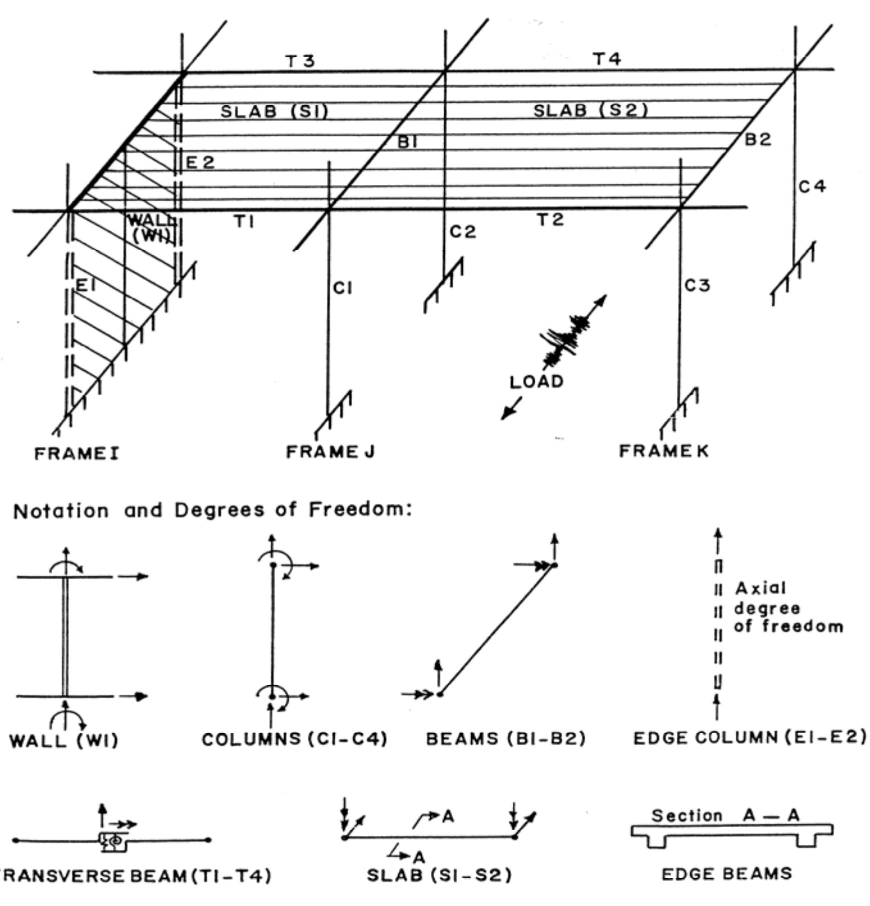

Figure 5-1: Typical Structure and Component Modeling [1]

5.1.1 Modeling of Structural Systems

Floor and frames masses are lumped at the floor level. Beams and columns are modeled as continuous equivalent shear-flexure springs. Floor slabs and shear walls are modeled using a pair of shear and flexure springs connected in series. Edge column elements can be modeled separately using inelastic axial springs. Transverse elements that contribute to the stiffness of the building are assumed to have an effect on both the vertical and rotational deformation of the shear walls or main beams to which they are connected and are modeled using elastic linear and rotational springs.

Distributed Flexibility Model (DFM) – The inelastic single-component model used in the analysis of beams, columns, floor slabs and shear walls uses a distributed flexibility approach. The flexibility factor, 1/EI, in this model is linearly distributed along the member between the two critical sections at the ends and the point of contraflexure. The flexural factors at the critical sections are monitored throughout the analysis to keep the inelastic behavior of the components during the load history; an elastic property is given to the section at the contraflexure point. The inelastic distributed flexibility model used in the analysis of beams, columns, walls and slabs is illustrated below as:

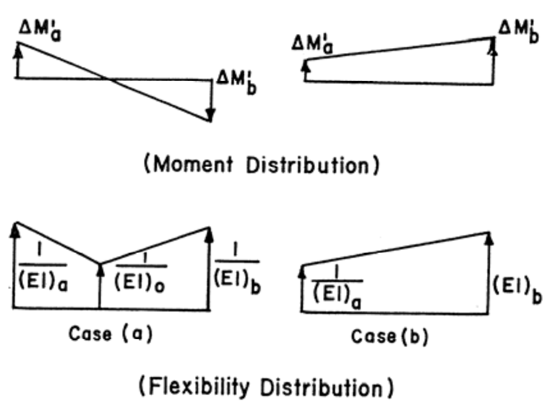

Figure 5-2: Distributed Flexibility Model [1]

5.1.2 Flexible Floor Slabs Models – Diaphragm action in floor slabs can be compared to the action of shear walls placed in a horizontal position. Hence, if a slab is modeled exactly as a shear wall in the horizontal plane, its response to in-plane loading must be reasonably adequate. However, a major difference arises: while the response of shear walls to vertical loads is in-plane compression/tension, the response of floor slabs to vertical loads is primarily one of out-of-plane bending leading to a more complex three-dimensional response.

A typical floor slab element connecting two parallel frames is shown in Figure 5-3. Two degrees of freedom (DOF) per node are assumed: an in-plane rotation, θ and a lateral translation, u. A linear variation of flexibility is assumed in deriving the flexibility matrix.

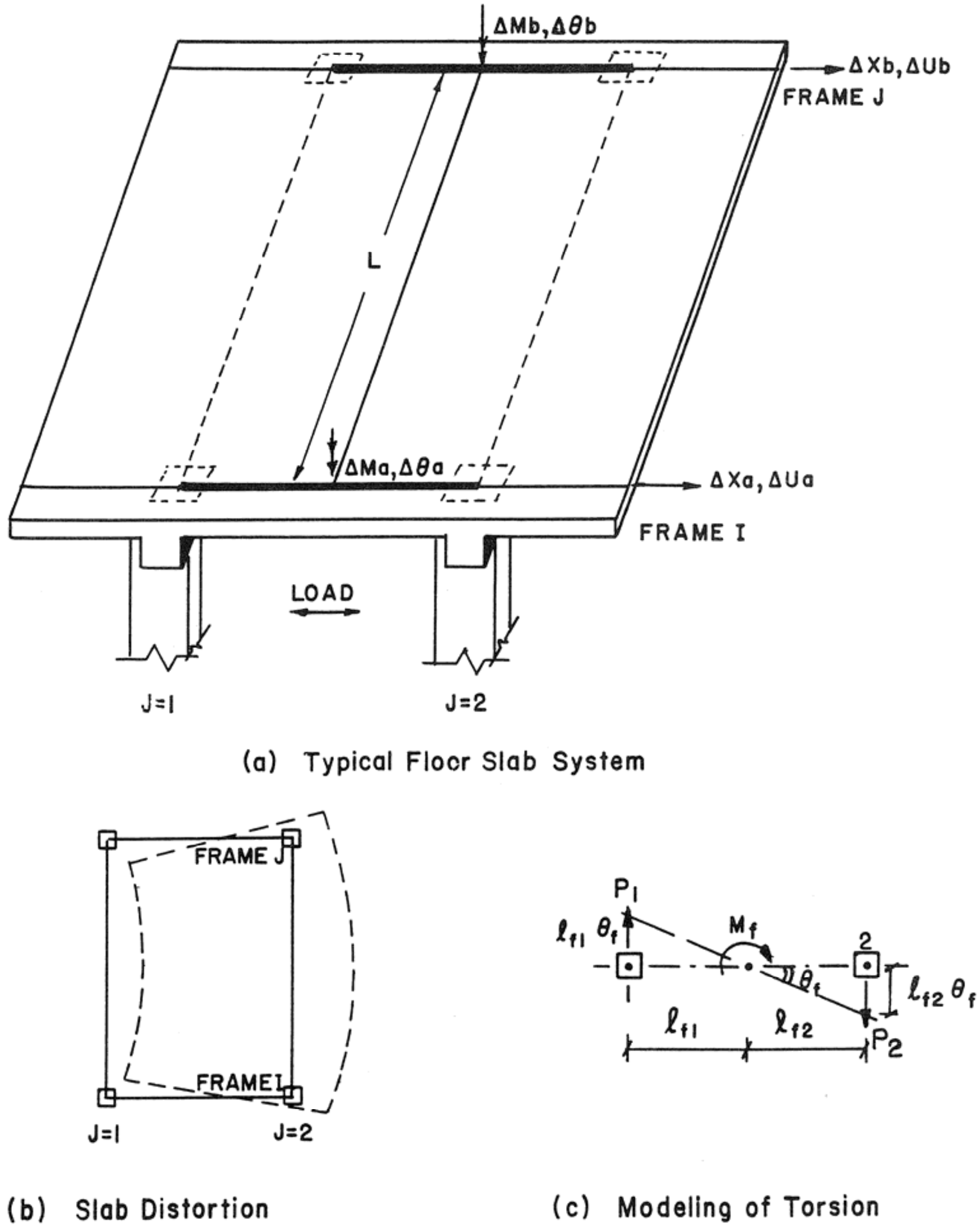

Figure 5-3: Details of Slab Modeling [1]

The incremental moment-rotation relationship is established from the integration of the M/EI diagram. Two possibilities arise, depending upon the location of the point of contraflexure (Figure 5-2).

Hence:

$$\begin{Bmatrix} \Delta\theta_a \\ \Delta\theta_b \end{Bmatrix} = [k] \begin{Bmatrix} \Delta M_a \\ \Delta M_b \end{Bmatrix} \qquad \text{[Eq. 5-1]}$$

where the flexibility matrix $[k]$ is given by:

$$[k]=L\begin{Bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{Bmatrix}+\frac{1}{GA^{*}L}\begin{Bmatrix} 1 & -1 \\ -1 & 1 \end{Bmatrix} \quad \text{[Eq. 5-2]}$$

and G is the shear modulus, A^{*} is the effective shear area, and L is the length of the member under consideration. For slabs and shear walls, A^{*} is significant and cannot be ignored as in the case of beams or columns.

For the case where the contra-flexure point lies within the element (case a):

$$f_{11}=\frac{1}{12(EI)_a}(6\alpha-4\alpha^2+\alpha^3)+\frac{1}{12(EI)_b}(1-3\alpha+3\alpha^2-\alpha^3)+\frac{1}{12(EI)_o}(3-3\alpha+\alpha^2) \quad \text{[Eq.5-3]}$$

$$f_{12}=f_{21}=\frac{1}{12(EI)_a}(-2\alpha^2+\alpha^3)+\frac{1}{12(EI)_b}(-1+\alpha+\alpha^2-\alpha^3)+\frac{1}{12(EI)_o}(-1-\alpha+\alpha^2) \quad \text{[Eq.5-4]}$$

$$f_{22}=\frac{1}{12(EI)_a}\alpha^3+\frac{1}{12(EI)_b}(3-\alpha-\alpha^2-\alpha^3)+\frac{1}{12(EI)_o}(1+\alpha+\alpha^2) \quad \text{[Eq.5-5]}$$

and for the case where the contra-flexure point lies outside the element (case b):

$$f_{11}=\frac{1}{4(EI)_a}+\frac{1}{12(EI)_b} \quad \text{[Eq.5-6]}$$

$$f_{12}=f_{21}=-\frac{1}{12(EI)_a}-\frac{1}{12(EI)_b} \quad \text{[Eq.5-7]}$$

$$f_{22}=\frac{1}{12(EI)_a}+\frac{1}{4(EI)_b} \quad \text{[Eq.5-8]}$$

where:

$$\alpha=\frac{\Delta M_a}{\Delta M_a+\Delta M_b} \quad \text{[Eq.5-9]}$$

5.1.3 Development of the Stiffness Matrix

The M-θ relationships has an inverse form of the flexibility relation of Eq.5-1:

$$\begin{pmatrix}\Delta M_a \\ \Delta M_b\end{pmatrix} = [k^{'}]\begin{pmatrix}\Delta\theta_a \\ \Delta\theta_b\end{pmatrix} \qquad \text{[Eq.5-10]}$$

where $[k^{'}]$ is the inverted flexibility matrix.

From force-equilibrium:

$$\begin{pmatrix}\Delta X_a \\ \Delta M_a \\ \Delta X_b \\ \Delta M_b\end{pmatrix} = [R_s]\begin{pmatrix}\Delta M_a \\ \Delta M_b\end{pmatrix} \qquad \text{[Eq.5-11]}$$

where:

$$[R_s] = \begin{pmatrix}\left(\frac{-1}{L}\right) & \left(\frac{-1}{L}\right) \\ 1 & 0 \\ \left(\frac{1}{L}\right) & \left(\frac{1}{L}\right) \\ 0 & 1\end{pmatrix} \qquad \text{[Eq.5-12]}$$

Hence, the stiffness equation for slab element is:

$$\begin{pmatrix}\Delta X_a \\ \Delta M_a \\ \Delta X_b \\ \Delta M_b\end{pmatrix} = [K_s]\begin{pmatrix}\Delta\upsilon_a \\ \Delta\theta_a \\ \Delta\upsilon_b \\ \Delta\theta_b\end{pmatrix} \qquad \text{[Eq.5-13]}$$

where: $[K_s] = [R_s][k^{'}][R_s]^T$, is the element stiffness matrix. [Eq.5-14]

5.1.4 Modeling of Frame Torsion

Any floor slab system that undergoes in-plane bending also experiences twisting due to differential movement of the slab edges (Figure 5-3). The effect of the torsional resistance of the frames on the in-plane rotation of the slabs depends on the relative stiffness of the horizontal and vertical structural systems. Generally the effect of frames in restraining the floor slab system from in-plane rotation is negligible and can be ignored.

However, the influence of solid shear walls arranged in the perpendicular direction to the lateral loading can result in considerable rotational restraint for the floor slab which needs to be included in the analysis [46]. Modeling of torsional restraint is achieved in IDARC2 [1] in the following manner:

A rotation of the slab system is assumed to take place about the center of the frame axis. For a rotation θ_f about the center, the frame moment M_f is given by:

$$M_f = k_f \theta_f \qquad \text{[Eq.5-15]}$$

The restraint provided by the columns due to the lateral deflection shown in Figure 5-3c is evaluated as:

$$P_i = 3\left(\frac{EI}{h^3}\right)_i l_i \theta_f \qquad \text{[Eq.5-16]}$$

where EI and h refer to the flexural rigidity and height of the vertical element.

The stiffness coefficient is then determined for a unit rotation taking into account the total moment about the center of the frame axis:

$$k_f = \sum P_i l_i \qquad \text{[Eq.5-17]}$$

where P_i is obtained from Eq.5-16 by setting $\theta_f = 1$.

5.1.5 Beam-Column Elements

Main beam-column elements form a vertical plane in the direction of loading. They are modeled as simple flexural springs in which shear-deformation effects have been coupled by means of equivalent spring. A typical element with rigid panel zones is show in Figure 5-4. The inclusion of rigid zones necessitates a transformation of the flexibility matrix as follows:

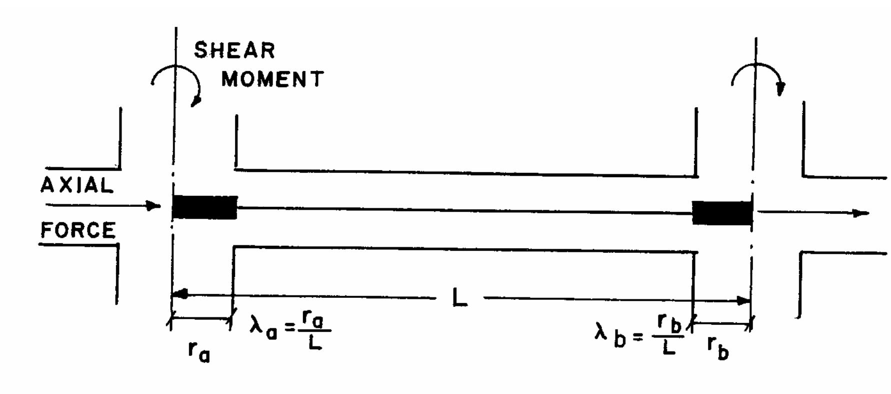

Figure 5-4: Typical Beam-Column Element with Degrees of Freedom [1]

$$[\bar{k}] = [B][k^{'}][B]^T \quad \text{[Eq.5-18]}$$

where:

$$[B] = \frac{1}{1-\lambda_a-\lambda_b}\begin{pmatrix} 1-\lambda_b & \lambda_a \\ \lambda_b & 1-\lambda_a \end{pmatrix} \quad \text{[Eq.5-19]}$$

5.1.6 Shear Walls

The modeling of shear wall elements is similar to that for floor slabs except (1) the inclusion of axial effects and (2) the incorporation of edge columns at the ends of the wall. Walls may, however, be modeled with or without edge columns. Alternatively, the edge columns may be included only for strength computations in setting up envelope curves. The ability to treat each wall as an equivalent column with inelastic axial springs at the edges allows for bending deformation of the wall element to be caused by the vertical movements of the boundary columns.

5.1.7 Edge Columns and Transverse Beams

To incorporate the effects of transverse elements on the in-plane response of the main frames, each transverse T-beam is modeled using elastic springs with one vertical and one rotational (torsional) degree-of-freedom as shown in Figure 5-1. Transverse elements are basically of two types: beams that connect to shear walls, and beams connected to the main beams in the direction of loading. Direct stiffness contributions arising from these springs are simply added to corresponding terms in the overall structure stiffness matrix. The purpose of modeling transverse beams in this fashion is to account for their restraining actions due to two effects, should they become significant: (a) the axial movement of vertical elements, especially edge columns in shear walls, (b) flexural-torsional coupling with main elements.

5.1.8 Fundamental Natural Period

The fundamental natural frequency of the structural system is established using the Rayleigh quotient. The general form of the Rayleigh quotient by equating the maximum potential and kinetic energies of the system:

$$\omega^2 = \frac{\{\psi^T\}[K]\{\psi\}}{\{\psi^T\}[M]\{\psi\}} \quad \text{[Eq.5-20]}$$

Where [K] and [M] are the stiffness and mass matrix of the system, respectively, ω is the fundamental frequency, and $\{\psi\}$ is the shape vector of fundamental mode of vibration of the system. The structure is loaded laterally in an inverse triangular form. The magnitude of the base of the triangle is obtained from the distribution of floor weights to respective frames using the tributary area concept. The deflected shape of the structure using this load pattern is assumed to be similar to the first mode shape.

Therefore, the application of Eq.5-20 is direct. In discrete form, for a multi-story building, this may be written as:

$$\omega^2 = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} k_{ij}\Delta u_{ij}^2}{\sum_{i=1}^{N} m_i u_i^2} \qquad \text{[Eq.5-21]}$$

where N is the number of stories; M is the number of frames; u is the deflection; Δu is the relative story drift; and i & j refer to the story and frame number, respectively.

5.1.9 Three-Parameter Hysteretic Model

For the inelastic analysis, a proper selection of hysteretic models for the constituent components is one of the critical factors in successfully predicting the dynamic response under strong earthquake motions. To duplicate the various aspects of reinforced concrete behavior under inelastic loading reversals, a three-parameter hysteretic model will be used in the inelastic dynamic analysis.

A variety of hysteretic properties can be achieved through the combination of a tri-linear envelope and the three parameters, referred to as α, β, and γ. The main characteristics represented by these three parameters are stiffness degradation, strength deterioration and pinching or bond slip, respectively (Figure 5-5). The stiffness degradation factor α specifies the degree of reduction in the unloading stiffness and the reduction in area enclosed by the hysteresis loops for consecutive loading cycles. The pinching factor γ reduces the stiffness of the reloading paths as well as the area of the hysteresis loops and the amount of dissipated energy. The strength deterioration factor β is the ratio computed as the amount of incremental damage caused by the increase of the maximum response divided by the normalized incremental hysteresis energy.

Appropriate combinations of α, β, and γ given in Table 5-1 below are used to achieve the hysteretic behavior observed in the experimental tests of typical reinforced concrete members.

Table: 5-1: Hysteretic Parameters Used in Dynamic Analysis [10, 46]

Element	**Stiffness Degradation Coefficient, α**	**Bond-Slippage Coefficient, γ**	**Strength Deterioration Coefficient, β**	**Post-Yielding Stiffness Ratio**
Beam	2.00	1.00	0.00	0.015
Column	2.00	1.00	0.00	0.015
Wall Bending	3.00	1.00	0.00	0.010
Wall Shear	0.02	1.00	0.00	0.010
Slab Bending	1.00	1.00	0.10	0.010
Slab Shear	0.02	1.00	0.00	0.010

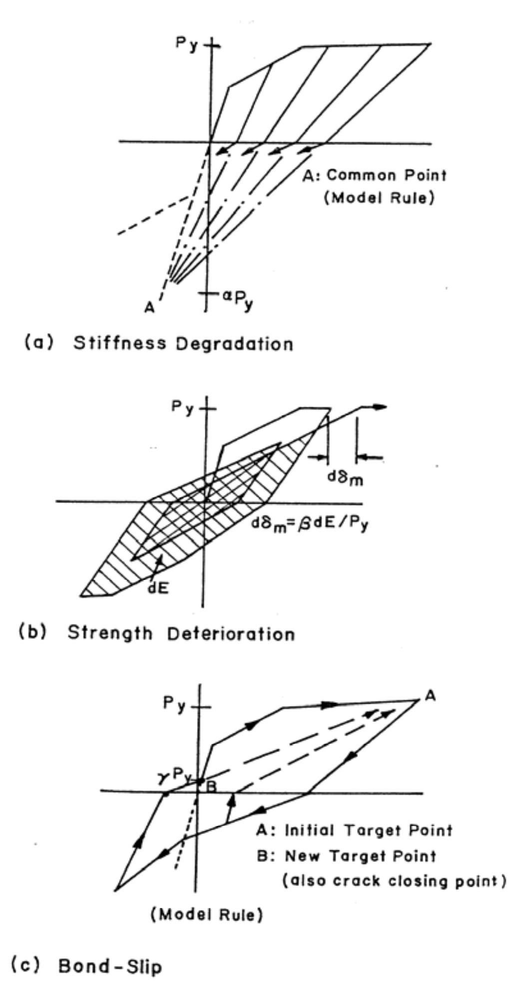

Figure 5-5: Three-Parameter Hysteretic Model [1]

5.1.10 Inelastic Dynamic Analysis

IDARC2 [1] step-by-step dynamic response analysis involves the solution of the following equation of motion;

$$M\ddot{y} + C\dot{y} + Ky = F \qquad \text{[Eq.5-22]}$$

where:

F = Vector of effective loads resulting from earthquake ground motion,
M = Lumped mass matrix,
C = Damping matrix,
K = Stiffness matrix,
y = Relative displacement of the structure with respect to the ground, $\dot{y}$ is the relative speed and $\ddot{y}$ is the relative acceleration.

Expressing Eq. 5-22 in an incremental format yields:

$$M\Delta\ddot{y}_i + C\Delta\dot{y}_i + K_i y_i = \Delta F_i \qquad \text{[Eq.5-23]}$$

The Newark Beta method is used to determine the solution of Eq. 5-23. Using a constant average acceleration, the following equations are used to obtain incremental velocity and incremental displacement:

$$\Delta\dot{y}_i = \ddot{y}_i \Delta t + \frac{1}{2}\Delta\ddot{y}_i \Delta t^2 \qquad \text{[Eq.5-24]}$$

and,

$$\Delta y_i = \dot{y}_i \Delta t + \frac{1}{2}\ddot{y}_i \Delta t^2 + \frac{1}{4}\Delta\ddot{y}_i \Delta t^2 \qquad \text{[Eq.5-25]}$$

The solution of Eq. 5-25 for $\Delta\ddot{y}_i$ and its substitution into Eq. 5-24 results in:

$$\Delta\ddot{y}_i = \frac{4}{\Delta t^2}\Delta y_i - \frac{4}{\Delta t}\dot{y}_i - 2\ddot{y}_i \qquad \text{[Eq.5-26]}$$

$$\Delta\dot{y}_i = \frac{2}{\Delta t}\Delta\dot{y}_i - 2\dot{y}_i \qquad \text{[Eq.5-27]}$$

The substitution of Eqs. 5-26 and 5-27 into the incremental equation of motion, Eq. 5-23 results in an equation to calculate the incremental displacement Δy_i namely:

$$K_i^e \Delta y_i = \Delta F_i^e \qquad \text{[Eq.5-28]}$$

where K_i^e and ΔF_i^e are defined as the effective stiffness matrix and incremental force vector, respectively. This method is unconditionally stable, and it yields accurate results when a small time interval (Δt) of 0.005 sec. is used in the analysis.

The methodology involved in this research being numerical in nature will involve studying effects of various parameters of interest. Those parameters are; floor rigidity (rigid, elastic or inelastic), three parameters (α, β, γ) used in slab hysteretic model for diaphragms with openings, lateral member supports size and location (columns, frames, braces and shear walls), opening size and location, number of stories, floor slab systems (one-way vs. two-way), floor-plan aspect ratio and regularity of building plan.

5.2 Preliminary Investigation

In the present study, a 3-story, 39ft high reinforces concrete building is devised with a diaphragm aspect ratio of 4:1. The structure's footprint is 12-20ft bays in length (240 ft total) and 3-20ft bays in depth (60ft total), with w-8in. thick shear walls at each end and 14in.x14in. –13ft high columns. The beams are 14in.x14in. and the girders are 14in. wide x 24in. deep. Floor diaphragm is a one-way 5in. slab spanning across 13 frames with intermediate supporting beams, i.e., 10ft span. All elements were designed and detailed to meet ACI 318-05 [3] and IBC 2006 [25] prescribed forces. The lateral force resisting system in the N-S direction (short direction) consists of "Building Frame System" in which the end shear walls (8 total) will resist the entire seismic load. While in the E-W direction (long direction), intermediate moment resisting frames (IMRF) are selected. The equivalent lateral forces generated were based on a site class C, seismic design category (SDC) C and seismic use group I. Two scenarios will be investigated, a solid diaphragm and an open diaphragm, i.e., with floor opening.

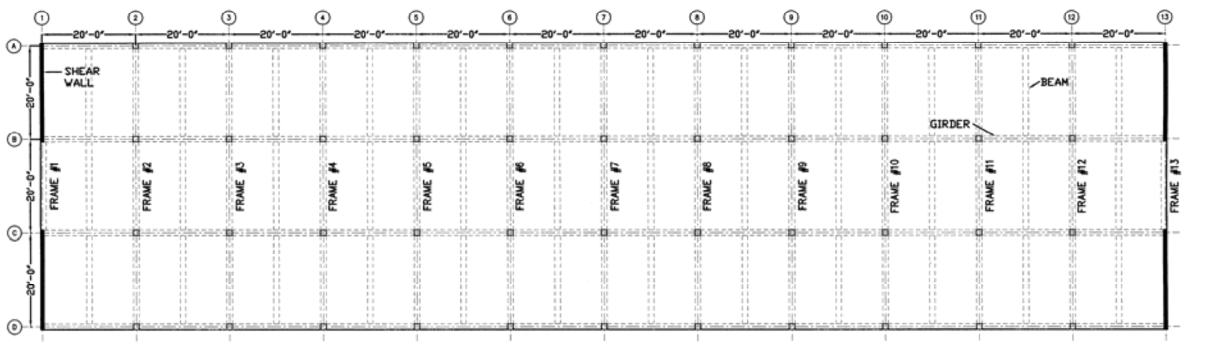

Figure 5-6: Typical Solid Diaphragm Floor Plan

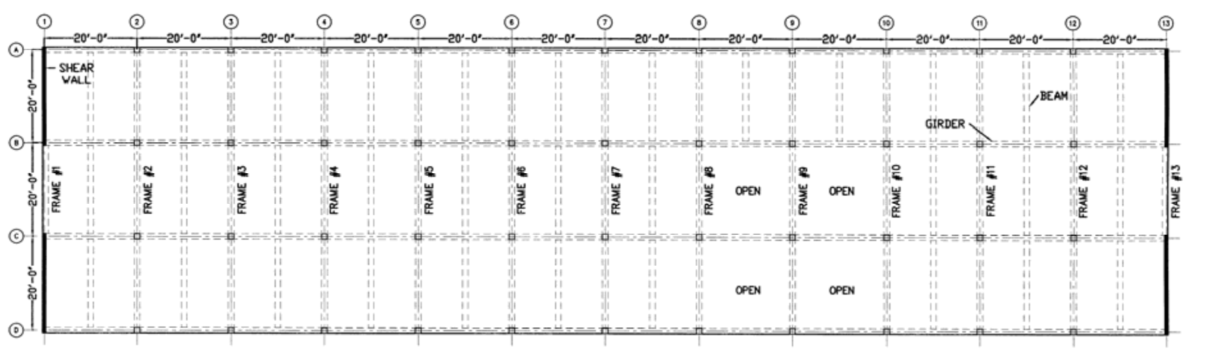

Figure 5-7: Typical Open Diaphragm Floor Plan

All elements were designed using 4000 psi at 28 days strength concrete and 60 ksi reinforcing steel with an applied uniform live load of 50 psf and super imposed dead load of 20 psf.

Table: 5-2: Reinforced Concrete Elements Details per ACI 318-05 [3]

Element Type	Element Size	Steel Reinforcing
Slab	5 in.	#3 @ 12 in. One-Way
Columns	14 in. x 14 in.	8-#6 Verticals w/#3 @ 6 in. Ties
Walls	8 in.	#6 @ 12 in. Each Way Vertical & Horizontal
Girders	14 in. x 24 in	5-#6 Top & Bottom w/#3 @ 10 in. Stirrups
Beams	14 in. x 14 in.	6-#5 Top & Bottom w/#3 @ 6 in. Stirrups

The building is assumed to be in the Saint Louis, Missouri, and hence is designed and detailed accordingly using the following seismic parameters:

Table: 5-3: Seismic Parameters Per IBC 2006 [25]

Parameter	Value
Short Period Acceleration, S_s	0.57
Long Period Acceleration, S_l	0.19
Short Period Site Coefficient, Fa	1.17
Long Period Site Coefficient, Fv	1.59
Short Period Spectral Response Acceleration Parameter, S_{DS}	0.45
Long Period Spectral Response Acceleration Parameter, S_{Dl}	0.20
Base Shear Seismic Coefficient, Cs	8.9 %
Response Modification Factor, $R_{N\text{-}S}$	5.00
Response Modification Factor, $R_{E\text{-}W}$	5.00
Over-strength Factor, $\Omega_{o,\ N\text{-}S}$	2.50
Over-strength Factor, $\Omega_{o,\ E\text{-}W}$	2.50
Deflection Amplification Factor, $C_{d,\ N\text{-}S}$	4.50
Deflection Amplification Factor, $C_{d,\ E\text{-}W}$	4.50
Fundamental Period of Structure, $T_{a,\ N\text{-}S}$	0.31 sec.
Fundamental Period of Structure, $T_{a,\ E\text{-}W}$	0.43 sec.
Building Seismic Weight, W	5150 k
Long Period, T_L	12 sec.

Since there is no available record of any severe earthquakes for the Saint Louis area, an earthquake is chosen with a period close to that of the building in question. Loma Prieta (1989) was selected since its dominant period of 0.34 seconds is close to $T_{a,\ N\text{-}S}$ of 0.31 seconds. This selection was made to maximize any resonance that may take place during an earthquake. Since Loma Prieta's peak ground acceleration (PGA) was recorded at 0.41g and the PGA for the site in question is 0.27g, the seismic input for the dynamic analysis was scaled down by a factor of 0.27/0.41 or 66% (Fig. 5-8). Fast Fourier Transform (FFT) of the earthquake record used shows the dominant frequency occurs at 2.95 Hz (Fig. 5-9) which is equivalent to a period of 0.34 sec.

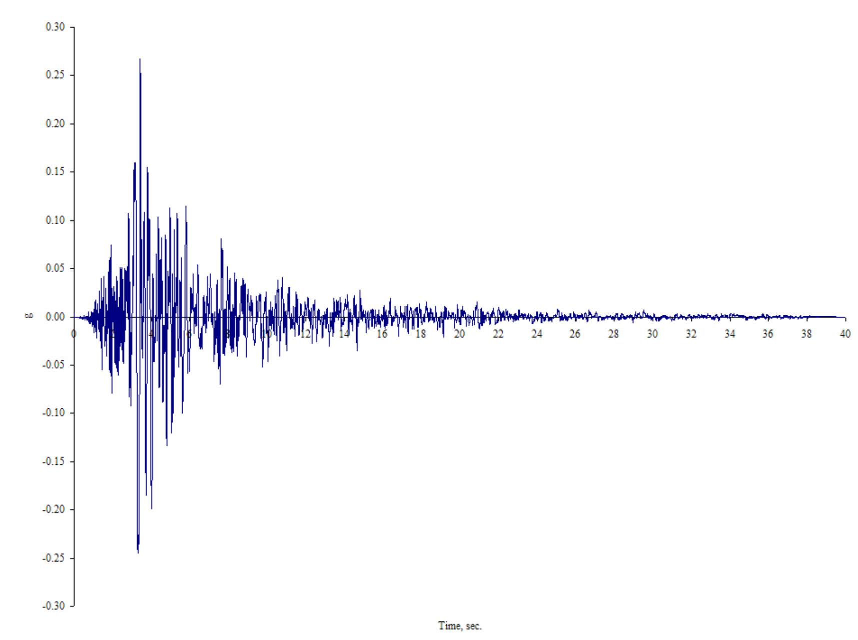

Figure 5-8: Scaled Loma Prieta Acceleration Time History

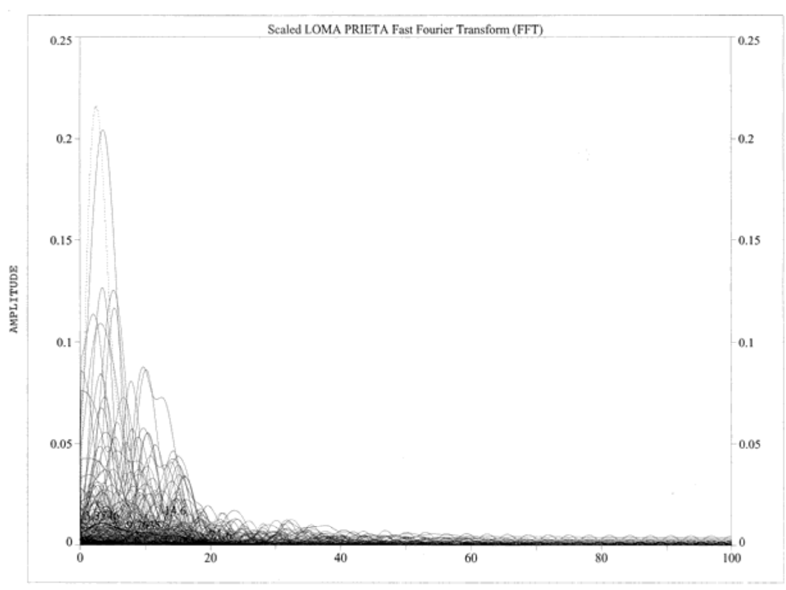

Figure 5-9: Scaled Loma Prieta Fast Fourier Transform (FFT)

Figure 5-10 shows the spectral acceleration that was developed from IBC [25] for the site. The enlarged portion (Fig.5-11) shows the "flat" region were both T_{N-S} and T_{E-W} lay. Hence the seismic coefficient, C_s will not be affected and will remain at 8.9%. The investigation will proceed by establishing the initial member forces due to gravity loads followed by Pushover analysis and finishing with dynamic analysis. Both case studies (solid and open) will give insight into how different diaphragm rigidity assumptions (inelastic, elastic and rigid) will yield different seismic responses, frame displacements and member forces.

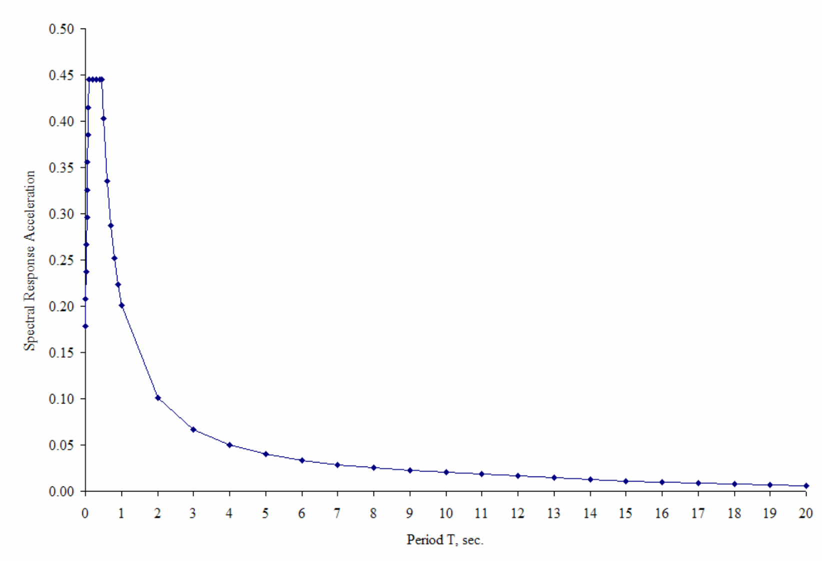

Figure 5-10: IBC 2006 [25] Site Specific Spectral Acceleration Response Spectra

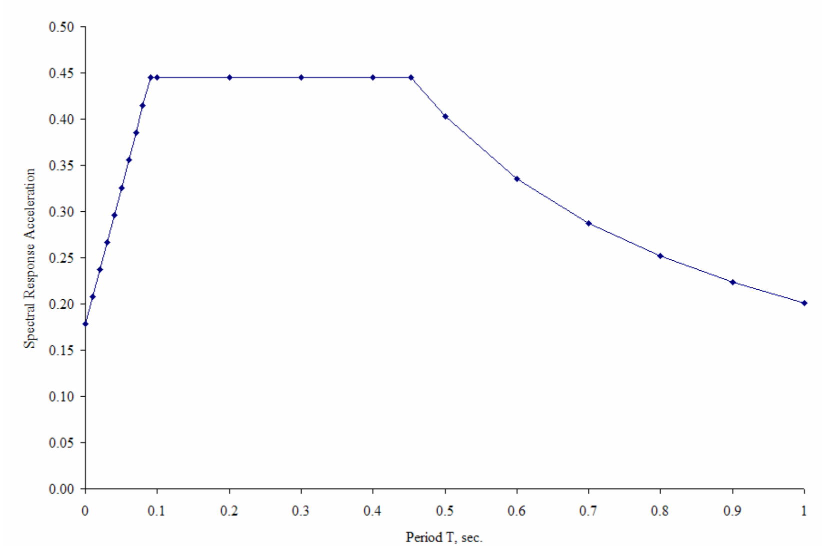

Figure 5-11: Flat Region Site Specific Spectral Acceleration Response Spectra

5.2.1 First Case Study: Solid Diaphragm

In this investigation, the solid floor plan shown in Figure 5-6 is subjected to the scaled Loma Prieta earthquake mentioned earlier. It is noteworthy to mention that rigid and elastic diaphragms are assumed to remain as such during an earthquake, i.e. diaphragms are not allowed to yield.

The pushover analysis divides the ultimate base shear coefficient into load steps, and then applies those steps incrementally. The structure ultimate base shear coefficient is assumed to take place when the structure at any given location displaces more than 2% of the overall building height or 9.36 in.

For the solid diaphragm case, the pushover analysis using inelastic diaphragms shows that structure failure occurs when the interior middle frame (Frame #7) displaced 1.9% of the total building height at a base shear coefficient value of 0.34 or 34% (compare to IBC estimate of $\Omega_o C_s$ = 2.5x0.089 = 0.22 or 22%). Figure 5-12 shows top story frames displacement as a function of base shear coefficient.

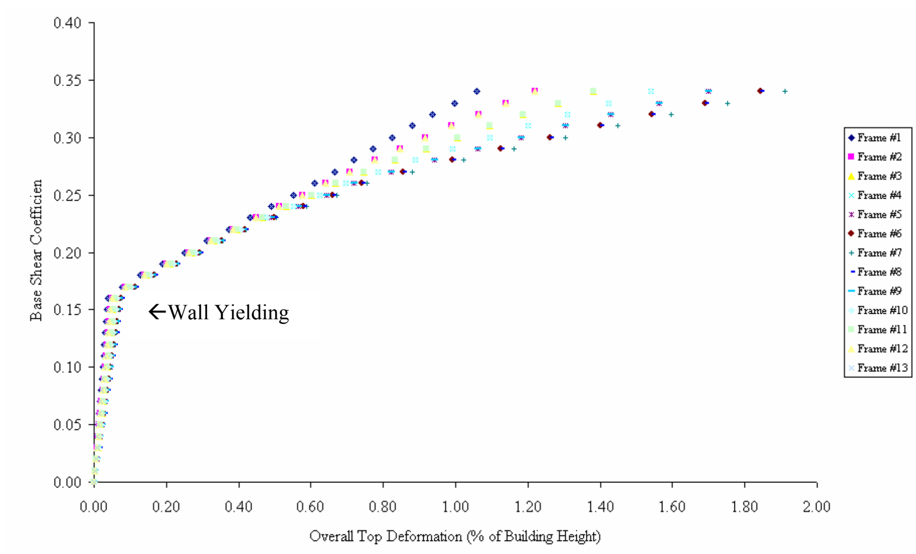

Figure 5-12: Solid Diaphragm Case Base Shear vs. Top Story Frames Displacement Using Inelastic Diaphragms

From Figure 5-12, it is evident that the end shear walls yielded first (Frame 1 & 13) at base shear coefficient value of 0.16 or 16%. The yielding then shifts towards the interior where the middle slab panel has yielded on the top floor (third level).

Before proceeding to the dynamic analysis part, the structure's period in the loading direction (North-South or short direction) is determined. The rigid diaphragm structure period is 0.26 sec. as compared to 0.301 sec. for both elastic and inelastic diaphragm structure. This is because the period is computed using the Rayliegh method (see Eq. 5-20) where the structure stiffness matrix, [K] for buildings with elastic and inelastic diaphragms models are equal because they are based on the initial stage of loading, i.e. before the diaphragm has yielded.

With the dynamic analysis consummated and the inelastic diaphragm yielding, Figure 5-13 shows that at the top floor the inelastic diaphragm frames displacements vary from 0.42 in. at the ends (shear walls) to .38 in. at the center (Frame #7). While the elastic diaphragm frames displacements varied from 0.96 in. to 1.25 in. Notice that the rigid diaphragm frame displacements remained approximately the same at 1.00 in. as expected since in-plane diaphragm deformations are not allowed to occur.

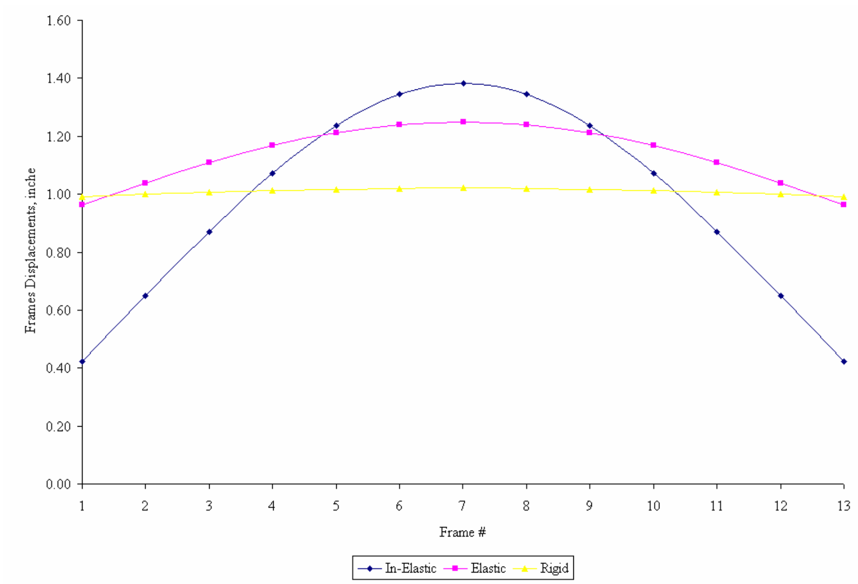

Figure 5-13: Solid Diaphragm Case Top Story Frames Displacements

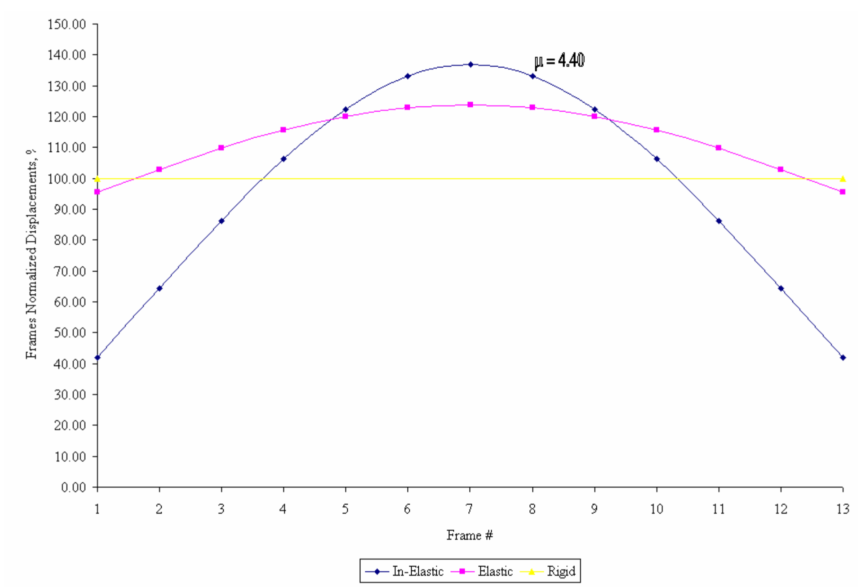

Figure 5-14: Solid Diaphragm Case Top Story Normalized Frames Displacements

From Figure 5-13, for inelastic diaphragm model the maximum frame displacement is 1.38 in. and the shear wall displacement is 0.40 in., hence the diaphragm displacement is 0.98 in. From the pushover analysis, the interior slab yielding occurred at a base shear coefficient value of 0.22, at that load step the displacement difference between Frames 1 and 7 is 1.96 in. – 1.74 in = 0.22 in. Thus, the ductility demand imposed on the inelastic diaphragm is 0.98/0.22 = 4.40, which is significantly larger than the ductility provided in such floor systems, 3.0, [46]. Figure 5-15 shows the frames shear distribution for the different diaphragms types. It is clear that interior frames do share the seismic load, which is contradictory to the prevalent assumption that end shear walls take the entire lateral load. Even more, Figure 5-16 shows the base shear distribution amongst the frames. Table 5-4 shows the frames base shear as a percentage of the total lateral load.

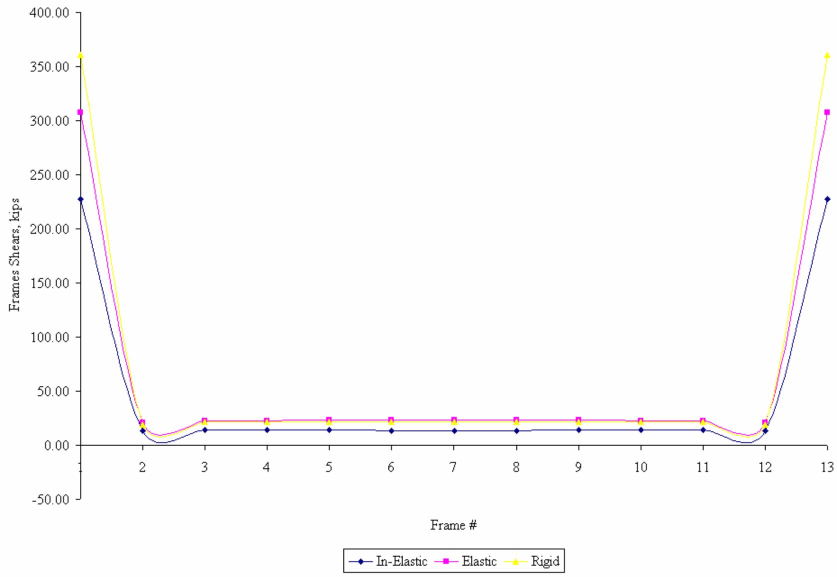

Figure 5-15: Solid Diaphragm Case Top Story Frames Shears

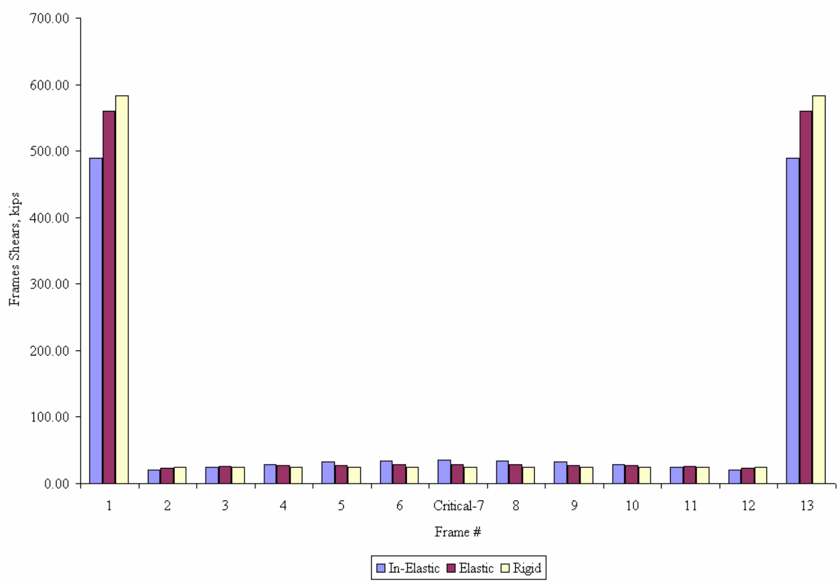

Figure 5-16: Solid Diaphragm Case Frames Base Shear

Table 5-4: Solid Diaphragm Case Frames Base Shear as a Percentage of the Total Lateral Load

Solid Diaphragm Maximum Base Shear Distribution, kips					
Slab Model	End Walls		Interior Frames		Base Shear
	Shear	% Total	Shear	% Total	
Inelastic	979.80	75.53	317.49	24.47	1297.29
Elastic	1120.80	79.33	291.96	20.67	1412.76
Rigid	1165.20	81.33	267.55	18.67	1432.75

It is apparent that all the interior frames are to resist anywhere from 18% to 25% of the total lateral seismic load. This demand is not accounted for in current design practices. The base shear being highest for the rigid floor assumption, 1433 k is due to the period being the smallest. While the base shear for the elastic diaphragm case is 1412 k due to a higher period. However, for the inelastic diaphragm case, since the diaphragm has undergone cracking and yielding, the structure has become more flexible and dissipated more energy resulting in a lower base shear, 1297 k. In spite of lowest value of total base shear (Table 5-4) interior frames are subjected to the highest value of frame shears when inelastic slab model is used (317.49 k which is 19% and 8.7% more than the case with rigid and elastic slab models, respectively). Appendix A shows all the figures and results relating to the first and second stories, along with hysteretic results for the top story end shear wall and interior frame.

5.2.2 Second Case Study: Open Diaphragm

Pushover analysis for this case shows that yielding of frames is no longer following a symmetric pattern using elastic, inelastic or rigid diaphragm models as compared to the solid case. This is due to unsymmetrical stiffness and mass distribution of the floor system with the presence of the opening (see Fig. 5-7). Note that the overall structure strength is less due to the loss of diaphragm floor area, which resulted in a reduced in-plane bending moment capacity of the floor diaphragm (see Fig. 5-17).

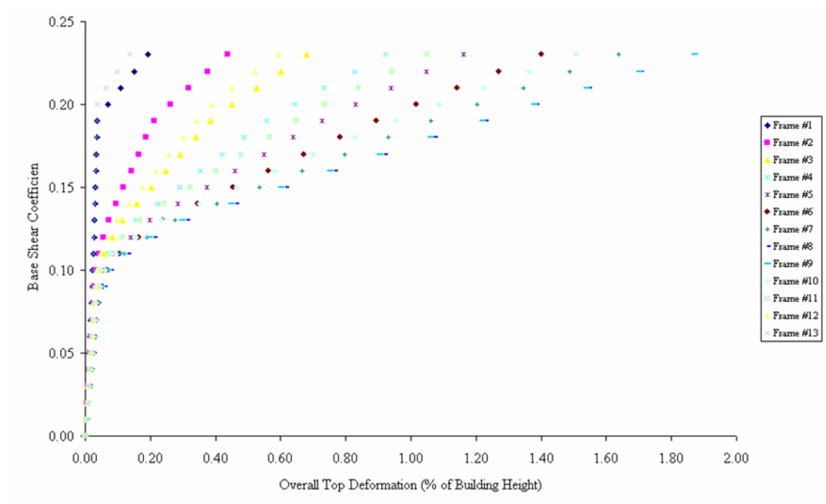

Figure 5-17: Open Diaphragm Case Base Shear vs. Top Story Frames Displacements

From this preliminary pushover analysis, the yielding started at the slab panel between frames 8 and 9 on the first floor, then the second and then the third floor. Later, the shear walls yielded at the lower level. It is interesting to compare the yielding pattern to that of the solid diaphragm case. In the open case, the diaphragm yielded first because its strength was less than the solid case due to the floor area lost by the opening, subsequently, the inelastic deformation in the diaphragm redistributed the lateral forces to the frames from the walls. For this case, the slab yielding occurred at base shear coefficient value of 0.08 or 8% and the pushover analysis was stopped at a base shear coefficient value of 0.23 or 23%, which is approximately 33% less than the solid diaphragm case for an opening size that is only about 10% of the floor area. Current building codes [25] allow a reduction in the diaphragm area of up to 50% before regarding the condition as a plan irregularity.

Moving to the dynamic analysis, the interior frames were subjected to almost 30.55% of the total lateral load using the inelastic diaphragm model (compared to 24.47% in the solid case). Note that the period is higher, 0.309 sec. as compared to 0.301 sec. due to the decreased diaphragm stiffness in the case with opening Also, the total base shear in the open case is 29% less than the solid case where the inelastic diaphragm model is used while no significant change in total base shear was observed when using rigid or elastic diaphragm models. Table 5-5 shows the complete base shear distribution results.

Table 5-5: Open Diaphragm Case Frames Base Shear as a Percentage of the Total Lateral Load

Open Diaphragm Maximum Base Shear Distribution, kips					
Slab Model	End Walls		Interior Frames		Base Shear
	Shear	% Total	Shear	% Total	
Inelastic	698.30	69.45	307.21	30.55	1005.51
Elastic	1066.90	77.28	313.63	22.72	1380.53
Rigid	1243.80	83.61	243.87	16.39	1487.67

As for frames displacement, the maximum frames displacements is higher, 1.57 in. at Frame #8 as compared to 1.38 in. for the solid diaphragm case. As for the elastic and rigid diaphragm assumption, the frame displacements were almost equal to the solid case. The slight discrepancy (less than 1%) is due to numerical computations.

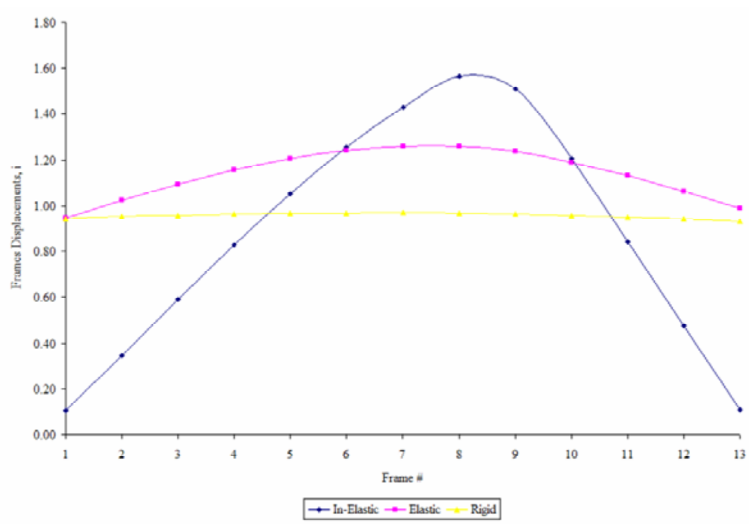

Figure 5-18: Open Diaphragm Case Top Story Frames Displacements

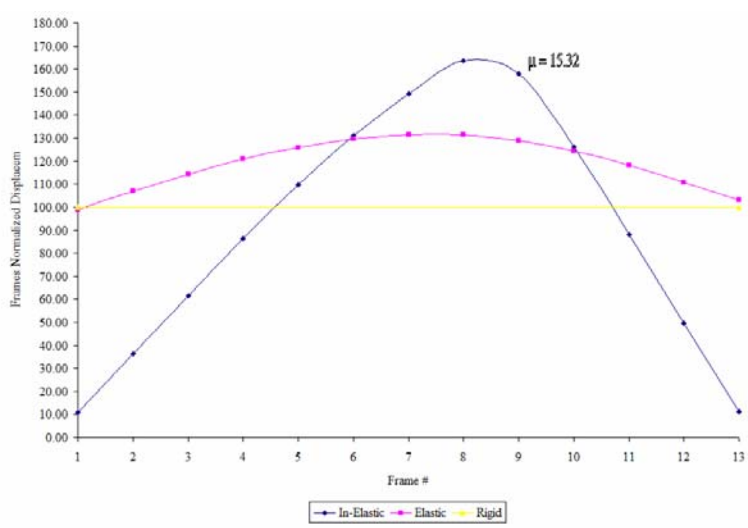

Figure 5-19: Open Diaphragm Case Top Story Normalized Frames Displacements

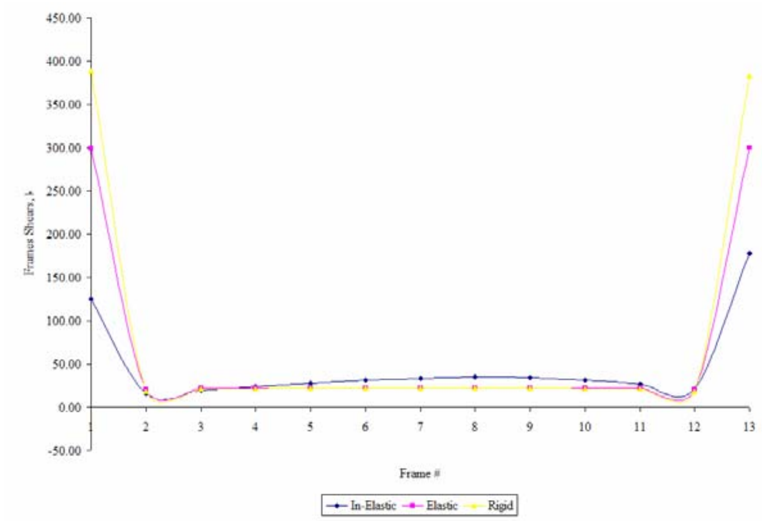

Figure 5-20: Open Diaphragm Case Top Story Frames Shears

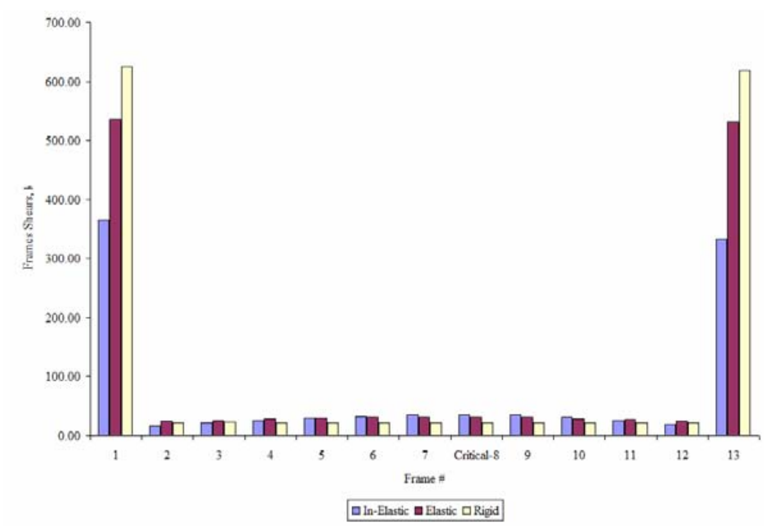

Figure 5-21: Open Diaphragm Case Frames Base Shear

From the normalized frame displacements (Fig. 5-19), the ductility demand on the inelastic diaphragm is 15.32, which is significantly larger that 4.40 obtained in the solid case.

Appendix A shows all the figures and results relating to the first and second stories, along with hysteretic results for the top story end shear wall and interior frame.

6. Concluding Remarks and Anticipated Future Results

There is a significant void in the published literature on the subject of analysis and behavior of diaphragms with openings. Similarly, the preliminary investigation of inelastic seismic response of a typical three-story reinforced concrete building with end shear walls with or without diaphragm openings (a total of six cases of dynamic time history and six cases of push-over static analyses using IDARC2 [1]) shows that current design practices [3, 25] of ignoring diaphragm in-plane flexibility (rigid) is an incorrect representation of the diaphragm's true behavior. Hence, floor openings for elevator shafts or stairs cannot be overlooked in such buildings.

From the preliminary investigation, it is clear that interior frames resisted a significant part of lateral loads contrary to engineering practice. For the open case, the interior frames resisted 16%, 23% and 31% for the Rigid, Elastic and Inelastic models, respectively. For the solid case, the interior frames resisted 19%, 21% and 25% for the Rigid, Elastic and Inelastic models, respectively. This clearly shows that in real-life, the end shear walls are over-designed while the frames are under-designed. Also, the base shears were significantly different, 1006 k for the open case and 1297 k for the solid case – as much as 30%. Though the building period was the same under the rigid floor assumption for the open and solid case, the period was different for the flexible (elastic or inelastic) floor assumption - 0.301 sec. for the solid case and 0.309 sec. for the open case. Also, in-plane displacement ductility demand for floor diaphragms with openings (15.3) was significantly higher than for floors without openings (4.40).

Based on examining the preliminary investigation results, it is concluded that to accurately obtain the seismic response of RC buildings with diaphragm openings, it is <u>necessary</u> to use the inelastic diaphragm model. In other words, the use of rigid or elastic diaphragm assumptions does not capture the influence of floor opening on the seismic response of RC buildings.

Hence, this will require enhancing the current fiber model procedure in IDARC2 [1] to capture the flexural and shear properties of slabs with openings more accurately and to properly account for the hysteretic parameters for slabs with openings. The results will be validated with available test data for shear walls with openings [59]. Once IDARC2 [1] inelastic algorithms are updated to accurately account for flexible (elastic and inelastic) diaphragms with openings, a variety of structural configurations will be studied for diaphragms with openings at various locations. It is anticipated that clear insights will emerge on the lateral load distribution patterns to the lateral load resisting members in scenarios of practical interest. These findings will be encapsulated in a form of design recommendations for engineers. A criterion for as to when diaphragm in-plane behavior and openings can be ignored will be part of those recommendations.

A clear description of the role of the diaphragm and the effect of its stiffness deterioration on the lateral load distribution will be formulated. Such results would provide a basis for assessing the viability of the current design procedures in the context of severe seismic loading. It is anticipated that this research effort will be completed within 2 years.

7. References

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Appendix A – IDARC2 [1] Case Study Detailed Results

Solid Diaphragm Base Shear VS Overall Top Deformation (% Of Building Height)														
STEP	Base V	Frame #1	Frame #2	Frame #3	Frame #4	Frame #5	Frame #6	Frame #7	Frame #8	Frame #9	Frame #10	Frame #11	Frame #12	Frame #13
1	0.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.01	0.00220	0.00270	0.00310	0.00350	0.00380	0.00400	0.00410	0.00400	0.00380	0.00350	0.00310	0.00270	0.00220
3	0.02	0.00460	0.00570	0.00670	0.00750	0.00820	0.00850	0.00870	0.00850	0.00820	0.00750	0.00670	0.00570	0.00460
4	0.03	0.00700	0.00870	0.01020	0.01150	0.01250	0.01310	0.01330	0.01310	0.01250	0.01150	0.01020	0.00870	0.00700
5	0.04	0.00940	0.01170	0.01380	0.01550	0.01680	0.01760	0.01790	0.01760	0.01680	0.01550	0.01380	0.01170	0.00940
6	0.05	0.01190	0.01470	0.01730	0.01950	0.02120	0.02220	0.02250	0.02220	0.02120	0.01950	0.01730	0.01470	0.01190
7	0.06	0.01430	0.01770	0.02090	0.02350	0.02550	0.02670	0.02710	0.02670	0.02550	0.02350	0.02090	0.01770	0.01430
8	0.07	0.01670	0.02070	0.02440	0.02750	0.02980	0.03130	0.03180	0.03130	0.02980	0.02750	0.02440	0.02070	0.01670
9	0.08	0.01910	0.02380	0.02800	0.03160	0.03430	0.03590	0.03650	0.03590	0.03430	0.03160	0.02800	0.02380	0.01910
10	0.09	0.02160	0.02690	0.03170	0.03570	0.03880	0.04060	0.04130	0.04060	0.03880	0.03570	0.03170	0.02690	0.02160
11	0.10	0.02410	0.03000	0.03540	0.03990	0.04330	0.04540	0.04610	0.04540	0.04330	0.03990	0.03540	0.03000	0.02410
12	0.11	0.02660	0.03310	0.03910	0.04410	0.04790	0.05020	0.05100	0.05020	0.04790	0.04410	0.03910	0.03310	0.02660
13	0.12	0.02910	0.03630	0.04280	0.04830	0.05250	0.05510	0.05600	0.05510	0.05250	0.04830	0.04280	0.03630	0.02910
14	0.13	0.03160	0.03940	0.04660	0.05260	0.05710	0.05990	0.06090	0.05990	0.05710	0.05260	0.04660	0.03940	0.03160
15	0.14	0.03410	0.04260	0.05030	0.05680	0.06170	0.06480	0.06580	0.06480	0.06170	0.05680	0.05030	0.04260	0.03410
16	0.15	0.03670	0.04580	0.05410	0.06110	0.06630	0.06960	0.07070	0.06960	0.06630	0.06110	0.05410	0.04580	0.03670
17	0.16	0.03920	0.04900	0.05790	0.06530	0.07100	0.07450	0.07570	0.07450	0.07100	0.06530	0.05790	0.04900	0.03920
18	0.17	0.07720	0.08730	0.09650	0.10420	0.11000	0.11360	0.11490	0.11360	0.11000	0.10420	0.09650	0.08730	0.07720
19	0.18	0.12900	0.13930	0.14860	0.15650	0.16250	0.16620	0.16740	0.16620	0.16250	0.15650	0.14860	0.13930	0.12900
20	0.19	0.18980	0.20070	0.21060	0.21890	0.22520	0.22910	0.23050	0.22910	0.22520	0.21890	0.21060	0.20070	0.18980
21	0.20	0.25070	0.26210	0.27250	0.28130	0.28790	0.29210	0.29350	0.29210	0.28790	0.28130	0.27250	0.26210	0.25070
22	0.21	0.31150	0.32350	0.33450	0.34370	0.35070	0.35500	0.35650	0.35500	0.35070	0.34370	0.33450	0.32350	0.31150
23	0.22	0.37230	0.38490	0.39640	0.40610	0.41340	0.41800	0.41950	0.41800	0.41340	0.40610	0.39640	0.38490	0.37230
24	0.23	0.43190	0.44880	0.46450	0.47840	0.48990	0.49860	0.50350	0.49860	0.48990	0.47840	0.46450	0.44880	0.43190
25	0.24	0.49160	0.51260	0.53260	0.55060	0.56630	0.57910	0.58750	0.57910	0.56630	0.55060	0.53260	0.51260	0.49160
26	0.25	0.55120	0.57650	0.60070	0.62290	0.64270	0.65970	0.67150	0.65970	0.64270	0.62290	0.60070	0.57650	0.55120
27	0.26	0.61090	0.64040	0.66870	0.69520	0.71910	0.74020	0.75550	0.74020	0.71910	0.69520	0.66870	0.64040	0.61090
28	0.27	0.66530	0.70710	0.74780	0.78650	0.82280	0.85610	0.88150	0.85610	0.82280	0.78650	0.74780	0.70710	0.66530
29	0.28	0.71740	0.77600	0.83330	0.88870	0.94160	0.99060	1.02160	0.99060	0.94160	0.88870	0.83330	0.77600	0.71740
30	0.29	0.77050	0.84570	0.91970	0.99170	1.06120	1.12590	1.16240	1.12590	1.06120	0.99170	0.91970	0.84570	0.77050
31	0.30	0.82430	0.91620	1.00690	1.09560	1.18170	1.26210	1.30420	1.26210	1.18170	1.09560	1.00690	0.91620	0.82430
32	0.31	0.87980	0.98860	1.09610	1.20160	1.30440	1.40070	1.44830	1.40070	1.30440	1.20160	1.09610	0.98860	0.87980
33	0.32	0.93700	1.06290	1.18750	1.31010	1.43010	1.54250	1.59580	1.54250	1.43010	1.31010	1.18750	1.06290	0.93700
34	0.33	0.99620	1.14020	1.28300	1.42380	1.56190	1.69130	1.75070	1.69130	1.56190	1.42380	1.28300	1.14020	0.99620
35	0.34	1.05870	1.22110	1.38230	1.54150	1.69790	1.84470	1.91030	1.84470	1.69790	1.54150	1.38230	1.22110	1.05870

Open Diaphragm Base Shear VS Overall Top Deformation (% Of Building Height)														
STEP	Base V	Frame #1	Frame #2	Frame #3	Frame #4	Frame #5	Frame #6	Frame #7	Frame #8	Frame #9	Frame #10	Frame #11	Frame #12	Frame #13
1	0.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.01	0.00220	0.00270	0.00320	0.00370	0.00400	0.00430	0.00440	0.00430	0.00420	0.00380	0.00330	0.00280	0.00220
3	0.02	0.00460	0.00580	0.00690	0.00790	0.00860	0.00910	0.00940	0.00930	0.00890	0.00810	0.00710	0.00590	0.00460
4	0.03	0.00700	0.00890	0.01060	0.01210	0.01320	0.01400	0.01440	0.01430	0.01370	0.01240	0.01080	0.00900	0.00700
5	0.04	0.00940	0.01190	0.01430	0.01630	0.01780	0.01890	0.01940	0.01930	0.01840	0.01670	0.01460	0.01210	0.00940
6	0.05	0.01180	0.01500	0.01800	0.02050	0.02240	0.02380	0.02440	0.02430	0.02320	0.02100	0.01830	0.01520	0.01180
7	0.06	0.01420	0.01810	0.02160	0.02470	0.02710	0.02860	0.02940	0.02920	0.02790	0.02530	0.02210	0.01830	0.01420
8	0.07	0.01660	0.02110	0.02530	0.02890	0.03170	0.03350	0.03440	0.03420	0.03270	0.02970	0.02580	0.02140	0.01660
9	0.08	0.01900	0.02430	0.02910	0.03320	0.03640	0.03860	0.03960	0.03940	0.03760	0.03410	0.02970	0.02460	0.01900
10	0.09	0.02120	0.02890	0.03630	0.04290	0.04850	0.05300	0.05640	0.05850	0.05420	0.04710	0.03900	0.03030	0.02110
11	0.10	0.02330	0.03370	0.04360	0.05270	0.06080	0.06780	0.07360	0.07810	0.07110	0.06030	0.04860	0.03610	0.02320
12	0.11	0.02500	0.04270	0.05980	0.07620	0.09150	0.10560	0.11850	0.13010	0.11550	0.09410	0.07170	0.04840	0.02470
13	0.12	0.02660	0.05590	0.08470	0.11260	0.13950	0.16530	0.18970	0.21280	0.19760	0.15720	0.11420	0.07040	0.02620
14	0.13	0.02830	0.07170	0.11450	0.15640	0.19730	0.23690	0.27520	0.31220	0.29720	0.23380	0.16580	0.09710	0.02780
15	0.14	0.02980	0.09460	0.15890	0.22230	0.28450	0.34550	0.40500	0.46320	0.44850	0.34990	0.24370	0.13670	0.02910
16	0.15	0.03130	0.11770	0.20360	0.28850	0.37220	0.45450	0.53540	0.61480	0.60030	0.46650	0.32190	0.17640	0.03040
17	0.16	0.03280	0.14080	0.24830	0.35470	0.45990	0.56360	0.66580	0.76650	0.75220	0.58310	0.40010	0.21620	0.03170
18	0.17	0.03430	0.16390	0.29290	0.42090	0.54750	0.67270	0.79620	0.91820	0.90410	0.69970	0.47830	0.25590	0.03300
19	0.18	0.03580	0.18750	0.33850	0.48850	0.63700	0.78400	0.92930	1.07300	1.06180	0.82790	0.56420	0.29950	0.03420
20	0.19	0.03730	0.21100	0.38410	0.55600	0.72650	0.89530	1.06250	1.22790	1.21940	0.95620	0.65010	0.34310	0.03540
21	0.20	0.06930	0.26110	0.45220	0.64210	0.83040	1.01710	1.20210	1.38520	1.37780	1.08530	0.73660	0.38690	0.03660
22	0.21	0.10770	0.31690	0.52540	0.73270	0.93840	1.14240	1.34460	1.54490	1.53970	1.22260	0.83730	0.45090	0.06390
23	0.22	0.15080	0.37680	0.60220	0.82630	1.04870	1.26940	1.48830	1.70520	1.70230	1.36150	0.94110	0.51960	0.09750
24	0.23	0.19330	0.43720	0.68030	0.92210	1.16230	1.40060	1.63700	1.87150	1.87130	1.50670	1.05070	0.59360	0.13590

Solid Diaphragm Frames Displacements, inches									
	LEVEL 1			LEVEL 2			LEVEL 3		
Frame #	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid
1	0.09539	0.22440	0.24320	0.25590	0.58480	0.60940	0.42380	0.96320	0.9922
2	0.11830	0.21290	0.23860	0.39310	0.62520	0.61370	0.64850	1.03800	1.0010
3	0.14160	0.20200	0.23510	0.52770	0.66200	0.61770	0.86990	1.10800	1.0080
4	0.16560	0.19200	0.23290	0.65230	0.69300	0.62070	1.07200	1.16700	1.0130
5	0.18690	0.18430	0.23160	0.75340	0.71610	0.62290	1.23600	1.21200	1.0170
6	0.20140	0.17940	0.23080	0.81920	0.73050	0.62420	1.34400	1.24000	1.0200
Critical-7	0.20650	0.17780	0.23050	0.84090	0.73560	0.62450	1.38200	1.25000	1.0210
8	0.20140	0.17940	0.23080	0.81920	0.73050	0.62420	1.34400	1.24000	1.0200
9	0.18690	0.18430	0.23160	0.75340	0.71610	0.62290	1.23600	1.21200	1.0170
10	0.16560	0.19200	0.23290	0.65230	0.69300	0.62070	1.07200	1.16700	1.0130
11	0.14160	0.20200	0.23510	0.52770	0.66200	0.61770	0.86990	1.10800	1.0080
12	0.11830	0.21290	0.23860	0.39310	0.62520	0.61370	0.64850	1.03800	1.0010
13	0.09539	0.22440	0.24320	0.25590	0.58480	0.60940	0.42380	0.96320	0.9922
Average	0.15576	0.19752	0.23499	0.58801	0.67375	0.61859	0.96695	1.13126	1.00949

Solid Diaphragm Frames Shears, kips									
	LEVEL 1			LEVEL 2			LEVEL 3		
Frame #	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid
1	489.90	560.40	582.60	392.20	479.60	436.1	227.20	307.80	360.7
2	20.96	23.72	23.96	16.78	20.62	14.86	13.54	20.56	19.24
3	25.14	25.29	24.14	21.19	23.33	15.07	14.20	22.65	22.01
4	29.13	26.51	24.36	25.72	26.13	15.49	14.36	22.77	21.93
5	32.08	27.69	24.42	28.60	27.85	15.62	13.78	23.08	21.83
6	34.09	28.39	24.59	30.54	28.88	15.79	13.45	23.11	21.85
Critical-7	34.69	28.76	24.61	31.06	29.18	16.01	13.13	23.10	21.95
8	34.09	28.39	24.59	30.54	28.88	15.79	13.45	23.11	21.85
9	32.08	27.69	24.42	28.60	27.85	15.62	13.78	23.08	21.83
10	29.13	26.51	24.36	25.72	26.13	15.49	14.36	22.77	21.93
11	25.14	25.29	24.14	21.19	23.33	15.07	14.20	22.65	22.01
12	20.96	23.72	23.96	16.78	20.62	14.86	13.54	20.56	19.24
13	489.90	560.40	582.60	392.20	479.60	436.1	227.20	307.80	360.7
Σ	1297.29	1412.76	1432.75	1061.12	1242.00	1041.87	606.19	863.04	957.07

	Solid Diaph. Base Shear, kips			Normalized Solid Diaph. Frames Displacements, inches					
Frame #	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	In-Elastic	Elastic	In-Elastic	Elastic
1	489.90	560.4	582.60	40.59	95.49	41.37	94.54	41.98	95.41
2	20.96	23.72	23.96	50.34	90.60	63.55	101.07	64.24	102.82
3	25.14	25.29	24.14	60.26	85.96	85.31	107.02	86.17	109.76
4	29.13	26.51	24.36	70.47	81.70	105.45	112.03	106.19	115.60
5	32.08	27.69	24.42	79.53	78.43	121.79	115.76	122.44	120.06
6	34.09	28.39	24.59	85.70	76.34	132.43	118.09	133.14	122.83
Critical-7	34.69	28.76	24.61	87.88	75.66	135.94	118.92	136.90	123.82
8	34.09	28.39	24.59	85.70	76.34	132.43	118.09	133.14	122.83
9	32.08	27.69	24.42	79.53	78.43	121.79	115.76	122.44	120.06
10	29.13	26.51	24.36	70.47	81.70	105.45	112.03	106.19	115.60
11	25.14	25.29	24.14	60.26	85.96	85.31	107.02	86.17	109.76
12	20.96	23.72	23.96	50.34	90.60	63.55	101.07	64.24	102.82
13	489.90	560.4	582.60	40.59	95.49	41.37	94.54	41.98	95.41
Σ	1297.29	1412.76	1432.75	1	100.00	1	100.00	1	100.00
				13	100.00	13	100.00	13	100.00

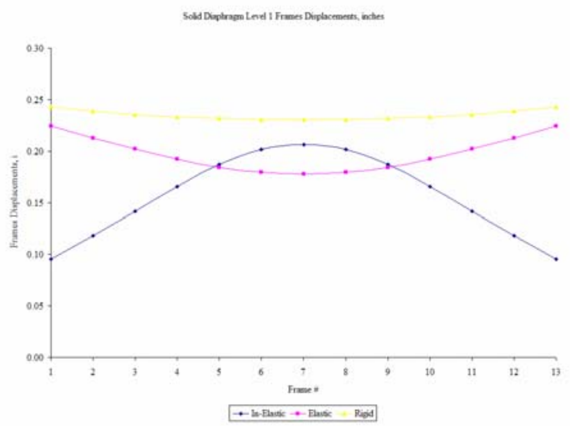
Solid Diaph. Max. Base Shear Distribution, kips									
Slab	End Walls		Interior Frames		Base	μ	4.40	Period, seconds	
Model	Shear	% Total	Shear	% Total	Shear	Damage Index		Model	Solid
In-Elastic	979.80	75.53	317.49	24.47	1297.29	In-Elastic	0.100	In-Elastic	0.301
Elastic	1120.80	79.33	291.96	20.67	1412.76	Elastic	0.207	Elastic	0.301
Rigid	1165.20	81.33	267.55	18.67	1432.75	Rigid	0.227	Rigid	0.260

Open Diaphragm Frames Displacements, inches									
	LEVEL 1			LEVEL 2			LEVEL 3		
Frame #	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid
1	0.03029	0.22760	0.22160	0.06766	0.58080	0.57480	0.10450	0.94840	0.94470
2	0.05309	0.21270	0.21790	0.20380	0.61910	0.57940	0.34720	1.02500	0.95250
3	0.07749	0.19790	0.21420	0.33990	0.65400	0.58270	0.58960	1.09500	0.95910
4	0.10270	0.18500	0.21150	0.47450	0.68330	0.58530	0.82700	1.15700	0.96410
5	0.12730	0.17540	0.20990	0.60230	0.70670	0.58690	1.05200	1.20600	0.96760
6	0.14960	0.17000	0.20870	0.71850	0.72330	0.58740	1.25400	1.24000	0.96980
7	0.16610	0.16830	0.20810	0.81650	0.73220	0.58720	1.42800	1.25800	0.97050
Critical-8	0.17480	0.17000	0.20800	0.89280	0.73320	0.58640	1.56500	1.25800	0.96940
9	0.16710	0.17580	0.20880	0.86690	0.72380	0.58420	1.51100	1.23600	0.96420
10	0.14000	0.18750	0.21070	0.69190	0.70270	0.58030	1.20700	1.19000	0.95620
11	0.10340	0.20260	0.21220	0.48640	0.67490	0.57670	0.84220	1.13100	0.95060
12	0.06592	0.21990	0.21500	0.27740	0.64170	0.57260	0.47440	1.06200	0.94320
13	0.02860	0.23730	0.21840	0.06759	0.60510	0.56750	0.10720	0.98770	0.93430
Average	0.10665	0.19462	0.21269	0.50047	0.67545	0.58088	0.86993	1.13801	0.95740

Open Diaphragm Frames Shears, kips									
	LEVEL 1			LEVEL 2			LEVEL 3		
Frame #	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	Rigid
1	365.00	535.20	625.70	284.30	460.20	478.40	124.70	299.40	389.10
2	16.97	23.93	22.29	10.57	20.49	14.81	15.29	20.24	18.58
3	21.85	26.26	22.47	13.42	23.40	14.48	19.79	22.24	21.09
4	25.92	28.29	22.11	16.85	26.90	15.12	24.52	22.14	21.49
5	29.48	29.93	22.15	20.24	28.68	15.47	27.89	21.96	21.94
6	32.32	31.18	22.04	23.21	30.26	15.73	31.07	22.04	22.06
7	34.76	31.65	21.99	25.03	31.11	15.93	33.19	22.32	22.07
Critical-8	35.73	31.59	22.04	27.51	30.97	15.83	35.03	22.38	21.94
9	35.13	30.73	22.11	26.22	29.42	15.52	34.41	22.50	21.86
10	31.34	29.01	22.25	22.32	27.45	14.94	31.64	22.43	21.31
11	25.33	26.84	22.18	17.23	23.88	14.69	26.67	22.04	20.84
12	18.38	24.22	22.24	13.11	20.99	14.56	20.97	20.39	18.22
13	333.30	531.70	618.10	273.70	466.30	479.20	178.10	300.00	383.60
Σ	1005.51	1380.53	1487.67	773.71	1220.05	1124.68	603.27	840.08	1004.10

	Open Diaph. Base Shear, kips			Normalized Open Diaph. Frames Displacements, inches					
Frame #	In-Elastic	Elastic	Rigid	In-Elastic	Elastic	In-Elastic	Elastic	In-Elastic	Elastic
1	365.00	535.20	625.70	14.24	107.01	11.65	99.99	10.91	99.06
2	16.97	23.93	22.29	24.96	100.00	35.08	106.58	36.26	107.06
3	21.85	26.26	22.47	36.43	93.05	58.51	112.59	61.58	114.37
4	25.92	28.29	22.11	48.29	86.98	81.69	117.63	86.38	120.85
5	29.48	29.93	22.15	59.85	82.47	103.69	121.66	109.88	125.97
6	32.32	31.18	22.04	70.34	79.93	123.69	124.52	130.98	129.52
7	34.76	31.65	21.99	78.09	79.13	140.56	126.05	149.15	131.40
Critical-8	35.73	31.59	22.04	82.18	79.93	153.70	126.22	163.46	131.40
9	35.13	30.73	22.11	78.56	82.65	149.24	124.60	157.82	129.10
10	31.34	29.01	22.25	65.82	88.16	119.11	120.97	126.07	124.29
11	25.33	26.84	22.18	48.61	95.25	83.74	116.19	87.97	118.13
12	18.38	24.22	22.24	30.99	103.39	47.76	110.47	49.55	110.93
13	333.30	531.70	618.10	13.45	111.57	11.64	104.17	11.20	103.16
Σ	1005.51	1380.53	1487.67	1	100.00	1	100.00	1	100.00
				13	100.00	13	100.00	13	100.00

Open Diaph. Max. Base Shear Distribution, kips									
Slab	End Walls		Interior Frames		Base Shear	μ	15.32	Period, seconds	
Model	Shear	% Total	Shear	% Total		Damage Index		Model	Open
In-Elastic	698.30	69.45	307.21	30.55	1005.51	In-Elastic	0.051	In-Elastic	0.309
Elastic	1066.90	77.28	313.63	22.72	1380.53	Elastic	0.207	Elastic	0.309
Rigid	1243.80	83.61	243.87	16.39	1487.67	Rigid	0.212	Rigid	0.260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Frames Displacements, i
Frame #
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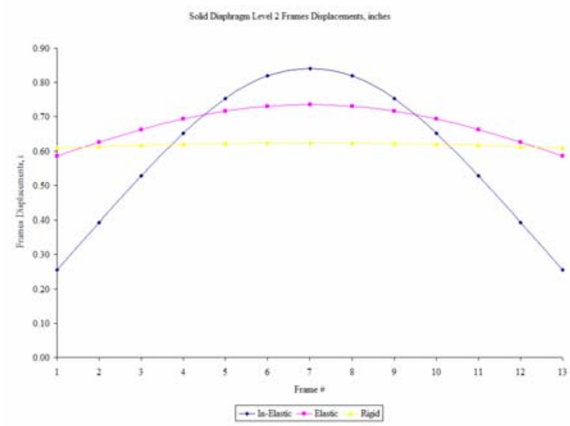
Elastic
Rigid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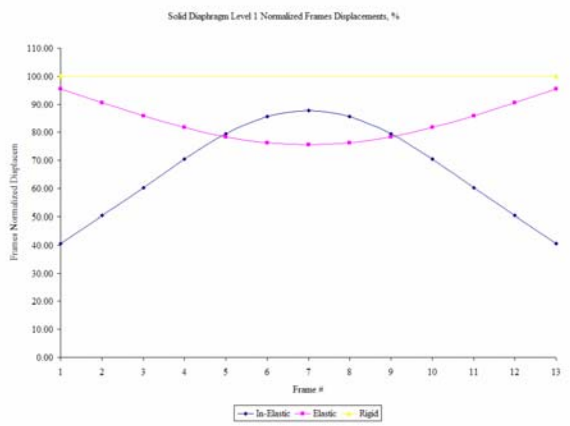
Elastic
Rigid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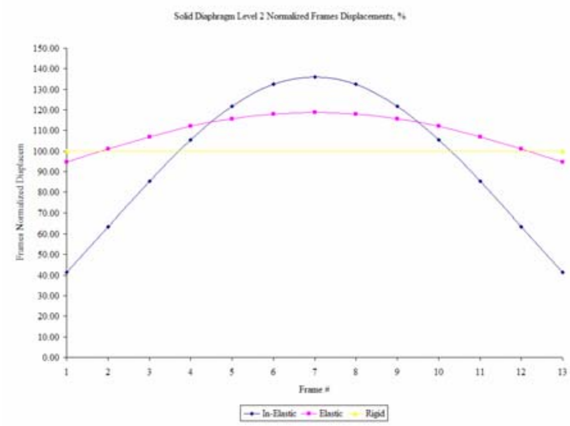
Frames Normalized Displacem
Frame #
In-Elastic
Elastic
Rigid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Frame #
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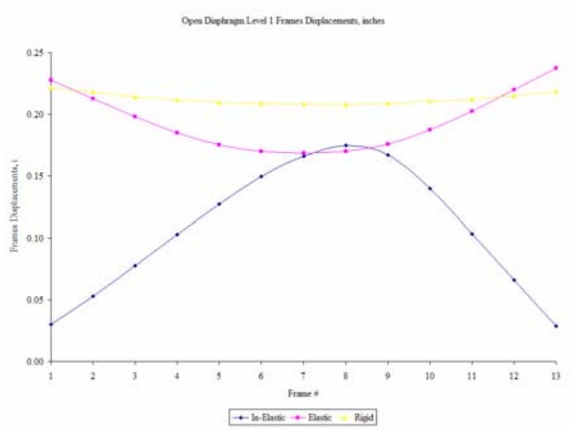
Elastic
Rigid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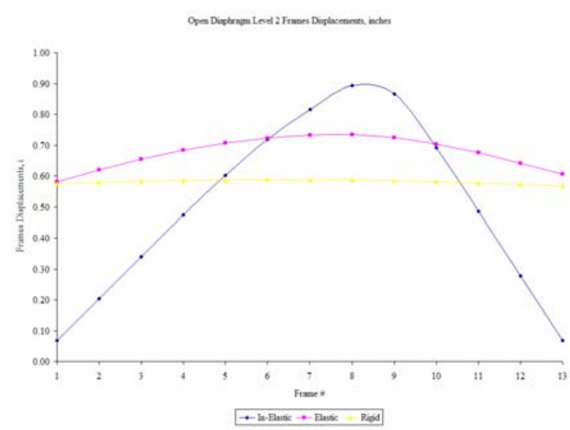
Rigid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Frames Displacements, i
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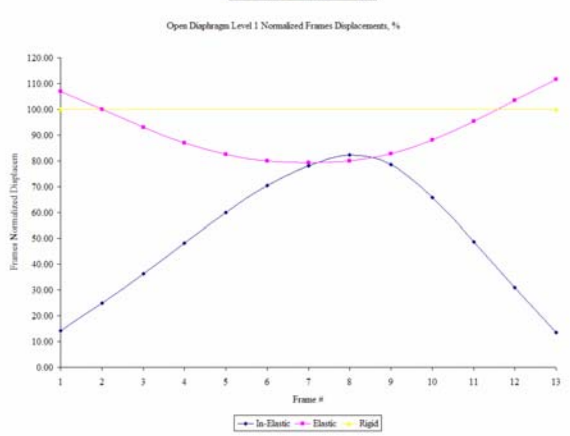
Elastic
Rigid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Frames Normalized Displacem
Frame #
In-Elastic
Elastic
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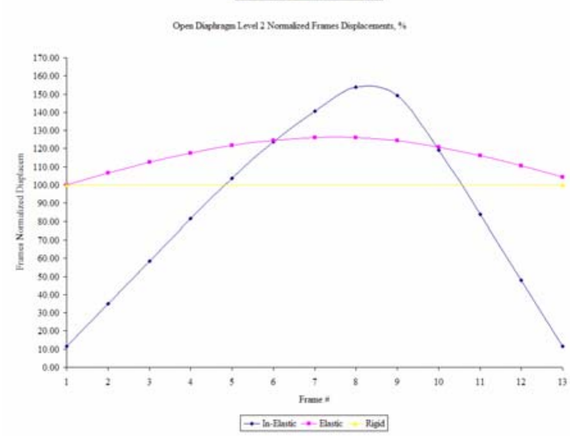
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Frames Normalized Displacem
Frame #
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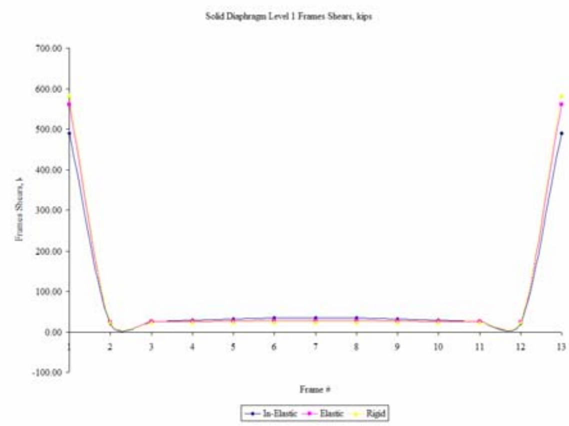
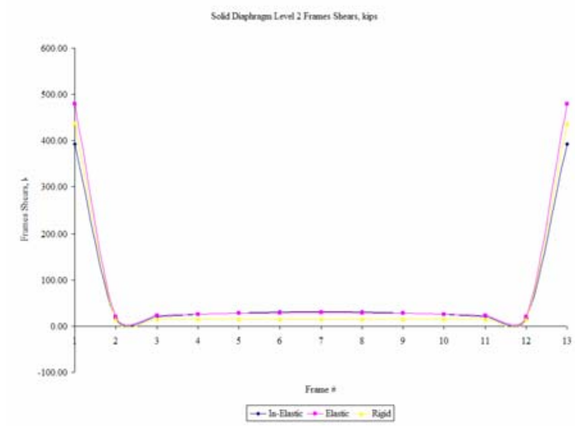
Elastic
Rigid


Solid Diaphragm Level 1 Frames Shears, kips
Frames Shears, k
Frame #
In-Elastic
Elastic
Rigid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Frames Shears, k
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Elastic
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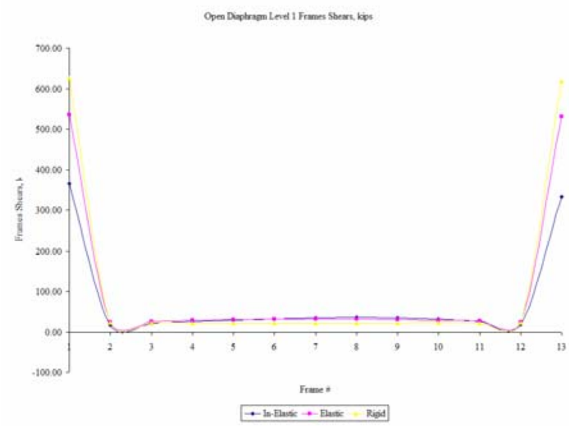
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Frames Shears, k
Frame #
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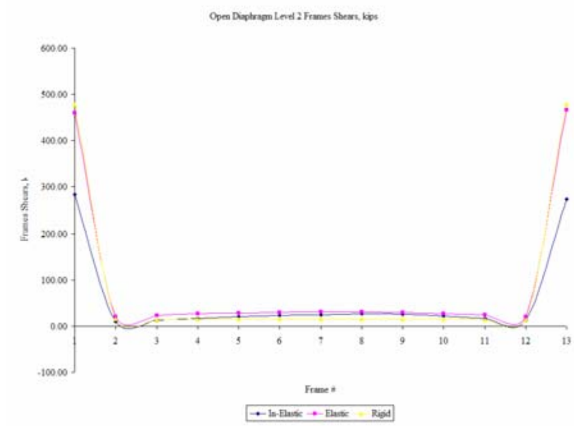
Elastic
Rigid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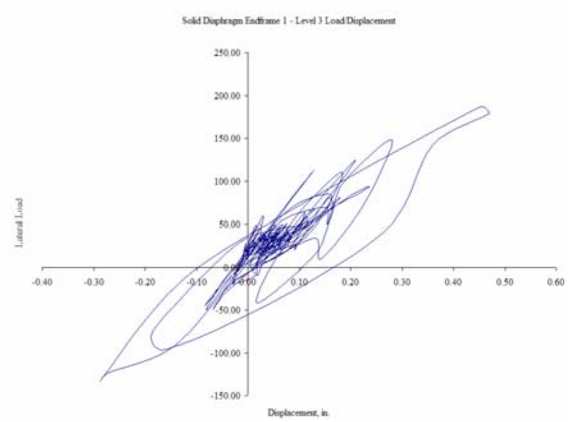
Frames Shears, k
Frame #
In-Elastic
Elastic
Rigid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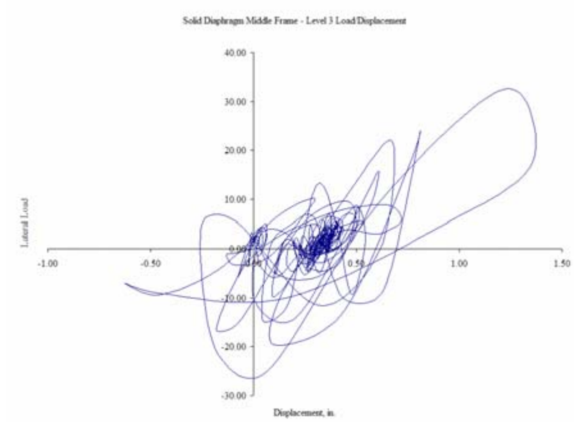
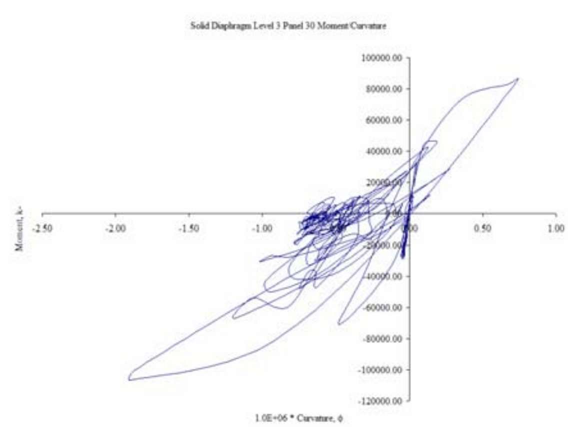
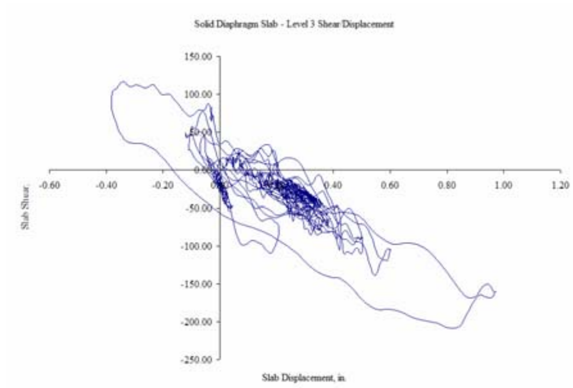
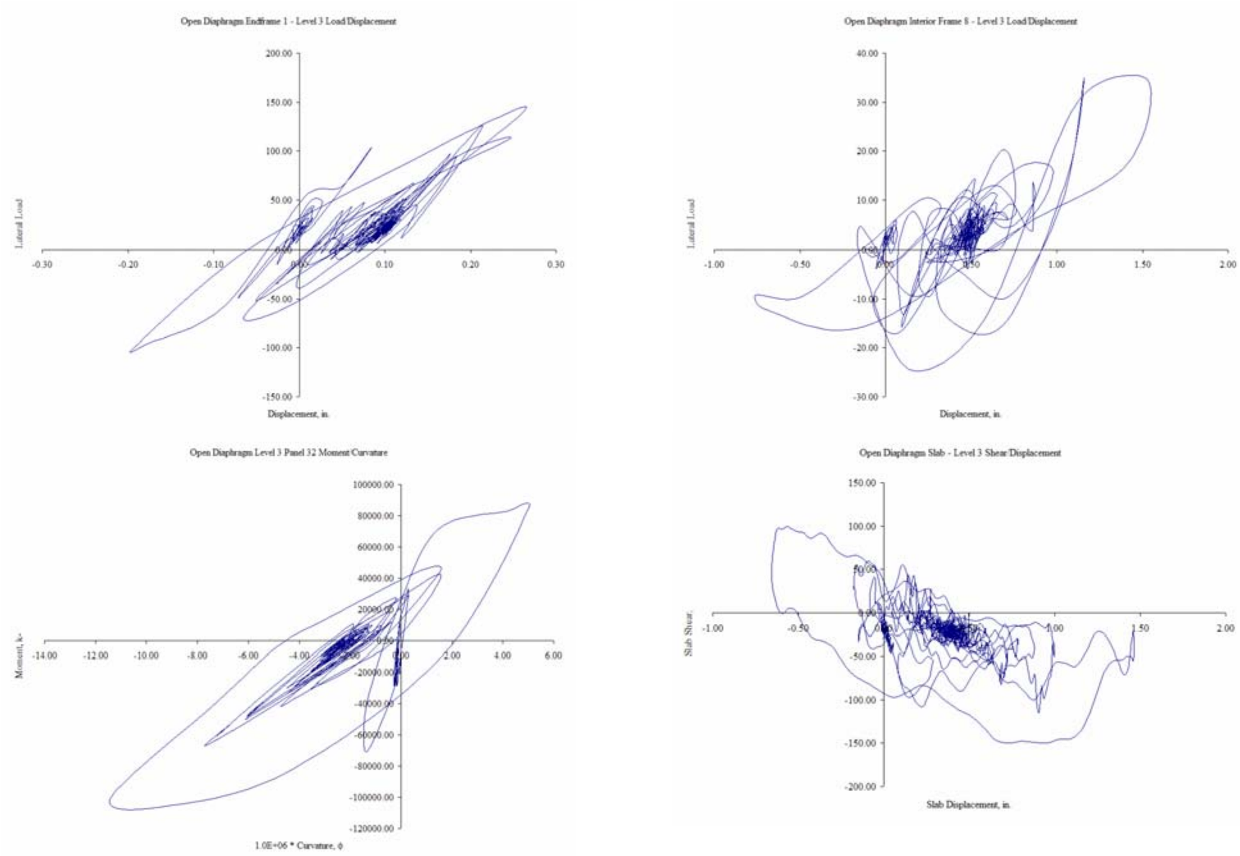
Lateral Load
Displacement, in.


Solid Diaphragm Middle Frame - Level 3 Load/Displacement
Lateral Load
Displacement, in.


Solid Diaphragm Level 3 Panel 30 Moment/Curvature
Moment, k-
1.0E+06 * Curvature, ϕ


Solid Diaphragm Slab - Level 3 Shear/Displacement
Slab Shear,
Slab Displacement, in.


Open Diaphragm Endframe 1 - Level 3 Load/Displacement
Lateral Load
Displacement, in.
Open Diaphragm Interior Frame 8 - Level 3 Load/Displacement
Lateral Load
Displacement, in.
Open Diaphragm Level 3 Panel 32 Moment/Curvature
Moment, k-
1.0E+06 * Curvature, ϕ
Open Diaphragm Slab - Level 3 Shear/Displacement
Slab Shear,
Slab Displacement, in.

Appendix B – Complete Evaluation of Available Publications to Date

3. Literature Review

In this chapter, available literature to date will be reviewed and addressed by area.

3.1 Plywood Diaphragms

Different agencies and research groups have investigated analysis techniques and behavior of diaphragms. American Plywood Association (APA) research report 138 [54] has devised an approximate method for obtaining shear stresses at any point within plywood diaphragms and around openings.

The analysis assumes that a plywood diaphragm with openings behaves similar to a Vierendeel Truss. Chord elements between shear webs of the Vierendeel Truss are assumed to have points of contraflexure at their mid-lengths. Diaphragm segments outside the openings are analyzed first, and then segments around the openings second assuming no openings are present. The procedure is carried-out again with the openings considered. Finally the net change in chord forces due to openings is achieved by combining both results. This methodology though intuitive and does satisfy equilibrium conditions, is not altogether reliable. Faherty [22] clearly stated that this method is a simple analytical approach with no experimental verification. Kamiya [35] investigated the APA method [54] by horizontally test-loading three plywood-sheathed floor diaphragms designed to the same load. The tests conducted yielded diaphragm shear and deflection equations instead of the lengthy APA method for those three diaphragms; there was no indication on how their effort can be extended to include other configurations.

Philips [49] studied how lateral load is shared by walls transverse to the loading direction in wood-framed buildings. The study shows that such interaction between transverse walls and plywood sheathed diaphragms can go up as high as 25 percent; the percentage decreased with increasing applied load and no opening effects were investigated. Gebremedhin [23] examined how plywood sheathed diaphragms distributed lateral loads to frames. Opening effects were looked at in a manner only to state that for walls with openings, the stiffness decrease is not linear to the opening size. For a 25 percent loss in frame area, the wall stiffness decreased by 17 percent and for a 50 percent loss in frame area the stiffness of the same wall decreased by 64 percent.

Carney [14] provided a bibliography on wood and plywood diaphragms research going back as far as the 1920’s. Virtually none addressed diaphragm openings. Peralta [48] experimentally investigated in-plane behavior of existing wood floor and roof diaphragms in un-reinforced masonry buildings consistent with elements and connection details typical for pre-1950 construction. The outcome was curves defining the relationship between the applied lateral force and the diaphragm mid-span displacement. Opening effects on diaphragm stiffness were not addressed either.

Itani [26] introduced a finite element model to analyze the non-linear load-deflection behavior of sheathed wood diaphragms. The model is general and is in good agreement with experimental measurements. Nonetheless it is does not deal with openings and how to extend the developed model to account for them. Pudd [50] developed a new state-of-the-art analytical model for sheathing-to-framing connections in wood shear walls and diaphragms. Although the new model is unlike previous analytical models, being suitable for both monotonic and cyclic analysis, it did not account for effects of openings on neither shear walls nor diaphragms.

Degenkolb [19] investigated pitched and curved timber diaphragms emphasizing that boundary stresses exist at any break in the sheathing plane and should be provided in the design of an efficient diaphragm - no opening effects were considered. Bower [11] published plywood deflection formulas under lateral loading, stating that they can be modified to apply to any diaphragm shape or loading pattern without giving examples.

Westphal [56] used three-dimensional finite element models to obtain in-plane deformations of wood roof diaphragms and story drift due to seismic load for buildings with plan aspect ratio ranging from 1.2 to 1.6. The results obtained show that the predicted diaphragm deflections by the International Building Code (IBC) [25] are conservative. However, effects of openings on this conclusion were not investigated.

3.2 Light gage Diaphragms

In the area of light gage steel deck (or metal decks), Nilson [44, 45] set the benchmark for all future experimental work in metal diaphragms. Although the full-scale tests were extensive, with emphasis on shear strengths and diaphragm deflections, openings effects were never addressed. Bryan [12] further developed Nislon [44,45] work to a more general theory for determining stiffness and strength of light gage metal deck. Nonetheless the theory developed did not account for diaphragm openings. Easley [20] focused on the buckling aspect of corrugated metal shear diaphragms. It was concluded that for most applications, buckling occurs when the number of fasteners is sufficient so that localized failure at the fasteners does not occur. However, opening effects on diaphragm buckling were not looked into.

Davies [17, 18] developed a method to replace a metal deck diaphragm by a series of frame elements connected by springs. This method can also be extended to account for openings. A major disadvantage of this method is that results obtained are purely linear.
Atrek [9] established a non-linear analysis method for light gage steel decks. Results resembled closely available experimental data, nonetheless openings were not addressed and no insight was given on how to extend this method to cover diaphragms other than the tested ones.

Luttrell [39, 40] suggested a method to obtain shear stress distribution around an opening in metal deck diaphragms. The method developed would ratio the shear distribution around the opening by the percentage of diaphragm length lost parallel to the loading direction. A linear increase in shear concentration may be acceptable for metal decks but no evidence confirms that this method can be applied to concrete diaphragms.

3.3 National Building Codes Criteria

International Building Code (IBC) [25] section 1616.5.1 mandates that a diaphragm with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50 percent of the gross enclosed diaphragm area, or change in effective diaphragm stiffness of more than 50 percent from one story to the next, shall be considered as irregular in plan. For structures with this diaphragm discontinuity, the code prescribes an increase of 25 percent in the design forces determined for connections of diaphragms to vertical elements and to collectors, and for connections of collectors to the vertical elements. The code does not ascribe any criteria pertaining to the diaphragm design itself.

In the area of steel design, American Institute of Steel Construction (AISC) [6] steel design guide No.2 shows some insight into designing steel beams with web openings. Unfortunately, it cannot be extrapolated to diaphragms, since its theory is calibrated using experimental results for steel beams only.

However, in the area of concrete design, American Concrete Institute (ACI) building code, ACI 318-05 [3] addresses the effect of an opening on slabs in local terms. It restricts opening size in column strips and limits the allowable maximum openings size in middle strips. The interrupted reinforcement by an opening must be placed at one-half on each side of the opening. ACI 318-05 [3] does not address the overall effect of an opening on the floor. This reinforcement replacement criterion has no restriction on the opening size as long as it is within the prescribed column and middle strips requirement.

3.4 Structural Concrete Design

In the field of concrete beams with web openings, Nasser [43], Mansur [41] and Abdalla [2], shed light on how an opening in rectangular RC or pre-stressed beams affects stress distributions and capacity of a concrete beam. Unfortunately, all the examined beams were governed by flexure and not by shear as in the case of diaphragms, not to mention that the theory provided was calibrated against available experimental results with no proof that it can be extended to include other configurations. Other studies were conducted in the area of concrete panels, in particular in the area of buckling. Swartz [53], Aghayere [5], and Park [47] addressed buckling of concrete plates under combined in-plane and transverse loads. Since concrete diaphragms can be considered as concrete plates with beams as web stiffeners, this buckling approach does not address openings.

3.5 Seismic Behavior of Reinforced Concrete Buildings

Other available literature is in the area of seismic behavior of RC buildings. ACI committee 442 [4] provided a summary of available methods to date for designing buildings to resist lateral loads. Although the report provided a compact reference, it did not touch upon openings and their effects on diaphragm design. Aktan [7] simulated real-life seismic response of RC structures by experimentally testing scaled down prototypes of two existing buildings. Despite the fact that those analytical models proposed to achieve real-life similitude of those two existing buildings were accurate, opening effects were not incorporated.

Button [13] investigated the influence of floor diaphragm flexibility on three different types of buildings; large plan aspect ratio, three-winged (Y-shaped) and separate towered. Regardless of the insight given into how lateral force distribution differs from rigid to flexible diaphragms, openings were not considered. Jain [27, 28, 29, 30, 31, 32] analyzed different types of structures ranging from V-shaped, Y-shaped to long and narrow buildings. Though the study proved to be conducive to understanding the dynamics of such structures, it did not address the effects of openings.

Kunnath [38] developed a modeling scheme for the inelastic response of floor diaphragms. The proposed model ability to account for in-plane diaphragm deformations, confirmed the possibility of building collapse, as a result of diaphragm yielding for the class of buildings studied. Nonetheless, opening effects were not incorporated in the model. Nakashima [42] concluded after analyzing a seven story RC building using linear and non-linear analysis that inclusion of diaphragm flexibility changed little the actual period of the structure and the maximum total base shear. Effects of diaphragm openings were not integrated as part of the analysis.

Panahshahi [46] combined an experimental and analytical approach to study the effect of flexible floor diaphragms on the inelastic seismic response of RC buildings. Using shake-table testing of a single-story 1:6 scale model structure, an analytical modeling scheme was developed. The test revealed that for rectangular buildings, interior frames ductility demands may be exceeded. The tests however did not address diaphragm openings at all.

3.6 Diaphragm Performance Based Design

In the domain of diaphragm performance-based design, Anderson [8] developed analytical models using commercial computer programs [15, 16] to evaluate the seismic performance of low-rise buildings with concrete walls and flexible diaphragms. Again, openings were not part of the models devised. Barron [10] evaluated the impact of diaphragm flexibility on the structural response of four buildings having 2:1 and 3:1 plan aspect ratio and were three and five stories in height respectively. The buildings in question did not have any diaphragm openings. Hence the models were applicable only for solid diaphragms (no floor openings), which are uncommon in real-life. Hueste [24] analyzed a prototype five-story RC frame office building designed for mid-1980s code requirements in the Central United Stated. Recommending an addition of shear walls and RC columns jackets led to decrease in the probability of exceeding the life safety (LS) limit state. Unfortunately, retrofitting recommendations were specific to this structure only and no diaphragm opening effects were looked into.

Kunnath [37] developed an analytical modeling scheme to assess the damage ability of RC buildings experiencing inelastic behavior under earthquake loads. The results of the response analysis, expressed as damage indices, were geared towards framed buildings only without any regards to diaphragm openings. Jeong [33] proposed a three-dimensional seismic assessment methodology for plan-irregular buildings. The analysis showed that plan-irregular structures suffer high levels of earthquake damage due to torsional effects. The analysis also proved that normal damage monitoring approaches may be inaccurate and even unconservative. However, the assessment did not account for diaphragm openings.

Ju [34] investigated the difference between the rigid floor and flexible floor analysis of buildings, using Finite Element Method to analyze buildings with and without shear walls. An error formula was generated to estimate the error in column forces for buildings with plan symmetric arrangement of shear walls under the rigid floor assumption. Although 520 models were generated, none dealt with diaphragm openings. Kim [36] proposed a linear static methodology applicable only to buildings with flexible diaphragms. The procedure is based on the assumption that the diaphragm stiffness is small relative to the stiffness of the walls, and that flexible diaphragms within the structure tend to respond independently on one another. Although the proposed approach gave insight into the limitations of current building codes, it did not tackle any diaphragm opening effects.

Other related research addresses the consequence of assuming a rigid floor on lateral force distribution. Roper [51] briefly examined the appropriateness of assuming that floor diaphragms are perfectly rigid in their plane. Two models were used, the first was for a cruciform-shape building and the second was for a rectangular building. Both models showed discrepancy between rigid and flexible floor diaphragm lateral force distribution. In particular, when shear walls exhibit an abrupt change in stiffness. Still, effects of opening on lateral force distribution were not explored. Tokoro [55] replicated an existing instrumented three story building using ETABS [16] and compared the model's diaphragm drift to the code allowable drift and judged the structure as within the code's given drift limit; without considering any diaphragm opening effects.

Saffarini [52] analytically investigated thirty-seven buildings establishing diaphragm lateral deflection and interstory shears as comparison criteria between assuming rigid or flexible diaphragms. The analysis reflected considerable difference in diaphragm deflections and shears. The investigation briefly addressed opening effects as part of other parameters under investigation. It was concluded that an opening definitely decreased the floor stiffness, and hence increased the inadequacy of the rigid floor assumption. Easterling [21] presented the results of an experimental research program in which thirty-two full-size composite (steel-deck-reinforced concrete floor slabs) diaphragms were loaded to failure. The research major contribution was the development of a better design approach for composite floor systems. Also stressing the importance of deformed bar reinforcing to improve ductility and restrain the cracking associated with concrete failure around headed studs. The recommendations were only pertinent to the cantilevered diaphragms tested and no opening effects were examined.

In the present study, the applicability of rigid, elastic and inelastic floor diaphragm models for RC buildings with floor openings is investigated. In turn the influence of in-plane floor deformations on the lateral force distribution and the overall seismic response and possible modes of failure of the structure are studied. Although there has been a lot of work done in the area of diaphragms, ranging from analysis assumptions to design recommendations, none provide in-depth understanding of diaphragm to frame or diaphragm to shear wall interaction especially in the presence of openings in RC buildings. Nor was any research done in order to provide simplified accurate techniques for analysis and design of such buildings as desired by the structural engineering community.

Appendix C – Supporting Letters from Dr. Kunnath and Dr. Panahshahi

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DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
530-754-6428
530-752-7872(FAX)

July 25, 2007

Dr. Kevin Z. Truman, Chair and The Albert P. and
Blanche Y. Greensfelder Professor of Civil Engineering
Department of Civil Engineering, Urbauer Hall Room #211
Washington University in St. Louis, St. Louis, MO 63130

Dear Dr. Kevin Truman,

This letter is written in support of Mr. Mohamed T. Al Harash's doctoral proposal titled "Inelastic Seismic Response of RC Buildings with Floor Diaphragm Openings."

Mr. Al Harash plans to use IDARC2 for his analytical study – a software tool which I authored at the University at Buffalo. The program was developed as part of a larger project co-supervised by Drs. Reinhorn and Panahshahi to conduct inelastic static and seismic simulations of rectangular plan structures with inelastic diaphragms.

Mr. Al Harash proposes to enhance IDARC2 by:

- incorporating floor diaphragms with openings
- develop a preprocessor for IDARC2 to enable a more user friendly visual based input

I would like to suggest that Mr. Al Harash also include the following tasks to ensure a reliable and robust evaluation of such buildings:

- a routine to estimate the flexural and shear properties of slabs with openings – this will require enhancement of the current fiber model program in IDARC2
- separate identification studies to estimate hysteretic parameters for slabs with openings – this may include finite element simulations to calibrate macro-model based analyses

It is my opinion that a detailed study of RC buildings with floor openings which include the analytical developments/enhancements listed above will contribute to the state-of-the-art and practice in structural engineering. It will also provide an enhanced computational tool for both the research and practicing community to use.

Please do not hesitate to contact me at (530) 754-6428 or skkunnath@ucdavis.edu if you have any questions regarding this matter.

Sincerely,

Sashi K. Kunnath, Ph.D., P.E.
Professor

SOUTHERN ILLINOIS UNIVERSITY
EDWARDSVILLE

July 23, 2007

Dr. Kevin Z. Truman, Chair and The Albert P. and
Blanche Y. Greensfelder Professor of Civil Engineering
Department of Civil Engineering, Urbauer Hall Room #211
Washington University in St. Louis, St. Louis, Mo 63130

Dear Dr. Kevin Truman,

I am writing in support of Mr. Mohamed T. Al Harash's doctoral proposal (July 2007) entitled "Inelastic Seismic Response of R/C Buildings with Floor Diaphragm Openings."

After a thorough literature review of the subject, Mr. Al Harash has identified the existing gap in the state-of-the- practice of design of reinforced concrete building with floor diaphragms with openings where floor deformations significantly influence the seismic response of the buildings. Design guidelines are needed to address this category of RC buildings.

Mr. Al Harash has successfully conducted a preliminary investigation of the inelastic seismic response of a typical low-rise reinforced concrete building with floor diaphragm opening using IDARC2, an inelastic computer program (developed at SUNY/Buffalo by N. Panahshahi, S. Kunnath, and A. Reinforn, 1988) which is capable of conducting pushover and inelastic dynamic (time-history) analysis of reinforced concrete building with rigid, elastic, or inelastic floor diaphragms subjected to ground motions. His results clearly indicate that to properly obtain the dynamic response of the building with diaphragm openings, the use of inelastic diaphragm model is necessary. His proposal highlights the main characteristic of the analytical procedures used in IDARC2. Mr. Al Harash made an hour-long presentation of the results of his preliminary study as a guest lecturer in my Earthquake Engineering class (CE 549) on May 2, 2007, and he addressed the audience's questions and comments effectively.

Mr. Al Harash proposal also includes an enhancement of IDARC2 to incorporate modeling of diaphragms with openings and at the same time to reformat IDARC2 pre-processing from a tedious text-input to a more user friendly visual based input. Completion of this task will demonstrate a strong knowledge of the inelastic algorithms used in IDARC2 program for conducting seismic response of RC buildings with flexible diaphragms.

In summary, I believe successful completion of the proposed research will contribute to the state-of-the-practice for structural engineers by providing valuable design guidelines for seismic design RC buildings with flexible diaphragms with openings, and it will also provide a timely enhanced computational tool for the research community to use.

Please do not hesitate to contact me at (618) 650-2819 or npanahs@siue.edu if you have any questions regarding this matter.

Sincerely,

Nader Panahshahi

Nader Panahshahi, Ph.D.
Professor

Appendix A.1

Conference Papers Abstracts

14WCEE Abstract

ACI Fall 2008 Convention Abstract

2010 Structures Congress Abstract

INELASTIC SEISMIC RESPONSE OF REINFORCED CONCRETE BUILDINGS WITH FLOOR DIAPHRAGM OPENINGS

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ABSTRACT

Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls. Furthermore, they play a key role in distributing earthquake-induced loads to the lateral load resisting systems by diaphragm action. In reinforced concrete buildings, the in-plane flexibility of the floor diaphragms is often ignored for simplicity in practical design (i.e., the floor systems are frequently treated as perfectly rigid diaphragms). Past research, which is acknowledged in recent building standards, has shown that this assumption can result in considerable error when predicting seismic response of reinforced concrete buildings when diaphragm plan aspect ratio is greater than 3:1 (Kunnath, 1991 & ASCE-7, 2005). However, the influence of floor diaphragm openings (typically for the purpose of stairways, shafts, and other architectural applications) has never been considered. In order to investigate the influence of diaphragm openings on the seismic response of reinforced concrete buildings; two 3-story reinforced concrete buildings are designed as a Building Frame System according to the International Building Code (IBC, 2006). Each building is assumed to be in the Saint Louis, Missouri area and it's analyzed with and without floor openings -4 cases. The inelastic behavior of the buildings is investigated under both static lateral loads (push-over) and dynamic ground motions (time-history), where a suite of three well-known earthquakes is scaled to model moderate ground motions in the Saint Louis, Missouri region. The diaphragm parametric study conducted involves two opening size/locations and two lateral load resisting frames stiffness/locations, where three types of floor diaphragm models (rigid, elastic, and inelastic) are assumed. The result summary is presented in this paper and discussed. It was concluded that in order to capture the seismic response of reinforced concrete buildings with floor diaphragm openings accurately; it is necessary to use an inelastic diaphragm model.

KEYWORDS: Inelastic, seismic, response, concrete, diaphragm, openings

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SEISMIC RESPONSE OF REINFORCED CONCRETE BUILDINGS WITH FLOOR DIAPHRAGM OPENINGS

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ABSTRACT

Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns and walls. Furthermore, they play a key role in distributing earthquake-induced loads to the lateral load resisting systems by the diaphragm action. Past research, which is acknowledged in recent ASCE7-05 building standard, has shown that the commonly practiced rigid diaphragm assumption (i.e., ignoring in-plane diaphragm deformations) can result in considerable error when predicting seismic response of reinforced concrete buildings when diaphragm plan aspect ratio is greater than 3:1. However, the influence of floor diaphragm openings (typically for the purpose of stairways, shafts, and other architectural applications) is not considered. In order to investigate the influence of diaphragm openings on the seismic response of reinforced concrete buildings, a comprehensive analytical study is currently in progress. In this presentation, two three-story RC buildings are designed as if in St. Louis, Missouri, as a Dual Braced System according to the IBC (2006), one with floor openings and the other without. The inelastic behavior of the buildings is investigated under static push-over analysis and dynamic ground motions, where a suite of three well-known earthquakes is scaled to model moderate ground motions in the St. Louis region. Three types of floor diaphragm models (rigid, elastic, and inelastic) are included in this study, and the results are presented and compared. It is concluded that in order to capture the accurate response of the reinforced concrete buildings with floor openings, the use of an inelastic diaphragm model is necessary.

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Inelastic Seismic Response of Rectangular RC Buildings with Plan Aspect Ratio of 3:1 with Floor Diaphragm Openings

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ABSTRACT

Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls, and distribute earthquake-induced loads to the lateral load resisting systems by diaphragm action. In reinforced concrete buildings, the inplane flexibility of the floor diaphragms is often ignored for simplicity in practical design (i.e., floor systems are frequently treated as perfectly rigid diaphragms). Past research has shown that this assumption can result in considerable error when predicting seismic response of low-rise rectangular RC buildings with end shear walls with large diaphragm plan aspect ratio (>3.0). This error is further amplified when the influence of floor diaphragm openings (i.e., stairways, shafts, etc.) is not considered (Al Harash 2008). The ASCE/SEI 7-05, "Minimum Design Loads for Buildings and Other Structures" allows the use of a rigid floor assumption in buildings with plan aspect ratio of 3:1 or less, where no plan irregularities exist. In order to investigate the influence of diaphragm openings on the inelastic seismic response of reinforced concrete buildings, four 3-story reinforced concrete building with end shear walls are designed, as if in St. Louis, Missouri, as a Building Frame System according to International Building Code (IBC 2006). The buildings are 9 bays by 3 bays in plan - 3:1 aspect ratio - and carry openings symmetrically placed at bays 1 and 9, 2 and 8, 3 and 7, 4 and 6, respectively. The inelastic behavior of the building is investigated under both static lateral loads (pushover analysis) and dynamic (time-history) ground motions, where a well-known earthquake, having a dominant period close to the fundamental period of the building, is scaled down to model moderate ground motions in the St. Louis region. A parametric study involving diaphragm's opening location (4 locations) is conducted with three types of floor diaphragm models (rigid, elastic, and inelastic). The analysis summary of all twelve cases is presented and compared. It is observed that the base shear redistribution due to inelastic slab deformations increases the load subjected to the interior frames significantly (up to 49%), when diaphragm openings are located within the middle half of the building. It is concluded that, the true response of such RC buildings can only be captured if an inelastic diaphragm model is utilized; hence, assuming a rigid floor diaphragm assumption per ASCE/SEI 7-05 is inappropriate.

KEYWORDS: Inelastic, seismic, response, concrete, diaphragm, openings

Appendix A.2

ACI Structural Journal Paper Abstract

Inelastic Seismic Response of Reinforced Concrete (RC) Buildings with Floor Diaphragm Openings

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Abstract: In RC buildings, in-plane flexibility of floor diaphragms is often ignored for, along with the effects of any openings present. Hence several 3-story reinforced concrete buildings are designed as a Building Frame System according to the ASCE 7-05 and International Building Code (2006). Each building is assumed to be in the Saint Louis, Missouri area, and it's analyzed using the enhanced fiber model (strain compatibility) computation routine in IDARC2 software where a suite of three well-known earthquakes is scaled to model the Midwest region. The comprehensive analytical study conducted involves placing different opening in various floor plan locations with respect to the location of the shear walls, where three types of floor diaphragm models (rigid, elastic, and inelastic) are assumed. Building floor plan aspect ratios of 3:1 and 4:1 were investigated and the results are then presented and discussed. It is concluded that in order to capture the seismic response of reinforced concrete buildings with floor diaphragm openings accurately; it is necessary to use the inelastic diaphragm model.

CE Database subject headings: Seismic; Inelastic; Pushover; Compatibility; Fiber; Diaphragm, Opening.

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Appendix A.3

Sample IDARC2 Input and Output Files

Sample IDARC2 Input File

InElastic-Loma Prieta, Open Bays 6 and 7, 3-13'-Story, 240'x60' 4:1 Aspect Ratio, Dynamic, 12x3-20' Bays, 13 Frames, 2-2 End Shearwalls

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V E R S I O N   2

INELASTIC DAMAGE ANALYSIS OF REINFORCED CONCRETE STRUCTURES
WITH FLEXIBLE FLOOR DIAPHRAGMS

STATE UNIVERSITY OF NEW YORK AT BUFFALO
DEPARTMENT OF CIVIL ENGINEERING

SEPTEMBER 1988

1

INPUT DATA:

TITLE: InElastic-Loma Prieta, Open Bays 6 and 7, 3-13'-Story, 240'x60' 4:1 Aspect Ratio

********** BUILDING CONFIGURATION AND MATERIAL INFORMATION **********

NUMBER OF STORIES   3
NUMBER OF FRAMES   13

NO. OF TYPES OF CONCRETE   1
NO. OF TYPES OF STEEL   1

********** ELEMENT INFORMATION **********

NO. OF TYPES OF COLUMNS   18
NO. OF TYPES OF BEAMS   1
NO. OF TYPES OF SHEAR WALLS   6
NO. OF TYPES OF EDGE COLUMNS   0
NO. OF TYPES OF TRANSVERSE BEAMS   3
NO. OF TYPES OF SLABS   2

NUMBER OF COLUMNS 132
NUMBER OF BEAMS 105
NUMBER OF SHEAR WALLS 12
NUMBER OF EDGE COLUMNS 0
NUMBER OF TRANSVERSE BEAMS 144
NUMBER OF SLAB ELEMENTS 36

ESTIMATED BASE SHEAR COEFFICIENT : .4
(% OF TOTAL WEIGHT)

SYSTEM OF UNITS: INCH, KIPS

1

********** STORY HEIGHT AND FLOOR WEIGHTS **********

STORY	HEIGHT FROM BASE	FLOOR WEIGHT							
3	468.000	96.170	141.470	141.470	141.470	141.470	115.000	84.400	115.000
		141.470	141.470	141.470	141.470	96.170			
2	312.000	123.680	146.780	146.780	146.780	146.780	120.320	95.520	120.320
		146.780	146.780	146.780	146.780	123.680			
1	156.000	123.680	146.780	146.780	146.780	146.780	120.320	95.520	120.320
		146.780	146.780	146.780	146.780	123.680			

********** X CO-ORDINATE DISTANCE OF COLUMN FROM REFERENCE POINT **********

FRAME	COLUMN COORDINATE (IN ORDER)			
1	120.00	600.00		
2	.00	240.00	480.00	720.00
3	.00	240.00	480.00	720.00
4	.00	240.00	480.00	720.00
5	.00	240.00	480.00	720.00

6	.00	240.00	480.00	720.00
7	.00	240.00	480.00	720.00
8	.00	240.00	480.00	720.00
9	.00	240.00	480.00	720.00
10	.00	240.00	480.00	720.00
11	.00	240.00	480.00	720.00
12	.00	240.00	480.00	720.00
13	120.00	600.00		

********** CONCRETE PROPERTIES **********

TYPE	STRENGTH	MODULUS	STRAIN AT TENSION CRACK	STRAIN AT MAX STRENGTH (%)	BOND STRENGTH
1	4.000	3605.000	-.000111	.300	1.000

********** REINFORCEMENT PROPERTIES **********

TYPE	YIELD STRENGTH	ULTIMATE STRENGTH	YOUNGS MODULUS	MODULUS AT HARDENING	STRAIN AT HARDENING
1	60.000	75.000	29000.000	870.000	3.000

********** COLUMN TYPES **********

COLUMN TYPE	CONCRETE TYPE	STEEL TYPE	DEPTH	WIDTH	COVER	LENGTH	RIGID ZONE (BOT)	RIGID ZONE (TOP)
1	1	1	14.000	14.000	2.250	156.000	.000	7.000
2	1	1	14.000	14.000	2.250	156.000	.000	7.000
3	1	1	14.000	14.000	2.250	156.000	7.000	7.000

4	1	1	14.000	14.000	2.250	156.000	7.000	7.000
5	1	1	14.000	14.000	2.250	156.000	7.000	7.000
6	1	1	14.000	14.000	2.250	156.000	7.000	7.000
7	1	1	14.000	14.000	2.250	156.000	.000	7.000
8	1	1	14.000	14.000	2.250	156.000	.000	7.000
9	1	1	14.000	14.000	2.250	156.000	7.000	7.000
10	1	1	14.000	14.000	2.250	156.000	7.000	7.000
11	1	1	14.000	14.000	2.250	156.000	7.000	7.000
12	1	1	14.000	14.000	2.250	156.000	7.000	7.000
13	1	1	14.000	14.000	2.250	156.000	.000	7.000
14	1	1	14.000	14.000	2.250	156.000	.000	7.000
15	1	1	14.000	14.000	2.250	156.000	7.000	7.000
16	1	1	14.000	14.000	2.250	156.000	7.000	7.000
17	1	1	14.000	14.000	2.250	156.000	7.000	7.000
18	1	1	14.000	14.000	2.250	156.000	7.000	7.000

***** AXIAL LOAD AND REINFORCEMENT OF COLUMNS *****

TYPE	AXIAL LOAD	MOMENT (BOT)	MOMENT (TOP)	STEEL AREA	PERIMETER OF BARS	WEB REINF RATIO	CONFINEMENT RATIO
1	68.800	168.000	-439.200	3.520	18.8500	.2620	.6400
2	149.000	18.000	-37.200	3.520	18.8500	.2620	.6400
3	45.500	439.200	-471.600	3.520	18.8500	.2620	.6400
4	98.000	37.200	-20.400	3.520	18.8500	.2620	.6400
5	21.800	471.600	-631.200	3.520	18.8500	.2620	.6400
6	49.000	20.400	-86.400	3.520	18.8500	.2620	.6400
7	56.100	136.800	-358.800	3.520	18.8500	.2620	.6400
8	121.500	14.400	-30.000	3.520	18.8500	.2620	.6400
9	37.100	358.800	-307.200	3.520	18.8500	.2620	.6400
10	80.500	30.000	-36.000	3.520	18.8500	.2620	.6400
11	17.800	420.000	-513.600	3.520	18.8500	.2620	.6400
12	39.800	16.800	-70.800	3.520	18.8500	.2620	.6400
13	43.700	109.200	-289.200	3.520	18.8500	.2620	.6400
14	94.600	12.000	-25.200	3.520	18.8500	.2620	.6400
15	28.500	289.200	-297.600	3.520	18.8500	.2620	.6400
16	61.300	22.800	-27.600	3.520	18.8500	.2620	.6400
17	13.100	297.600	-380.400	3.520	18.8500	.2620	.6400
18	29.200	14.400	-51.600	3.520	18.8500	.2620	.6400

********** BEAM TYPES **********

BEAM TYPE	CONCRETE TYPE	STEEL TYPE	DEPTH	WIDTH	SLAB WIDTH	SLAB THICKNESS	COVER	MEMBER LENGTH	RIGID ZONE (LEFT)	RIGID ZONE (RIGHT)
1	1	1	24.000	14.000	60.000	5.000	2.000	240.000	7.000	7.000

***** INITIAL MOMENTS AND REINFORCEMENT OF BEAMS *****

BEAM TYPE	MOMENT (LEFT)	MOMENT (RIGHT)	STEEL AREA (BOTTOM)	STEEL AREA (TOP)	PERIMETER OF BARS (BOT)	PERIMETER OF BARS (TOP)	WEB REINF RATIO	CONFINEMENT RATIO
1	-580.000	-580.000	1.000	1.000	5.8400	5.8400	.262	.6400

********** SHEAR WALL TYPES **********

WALL TYPE	CONCRETE TYPE	STEEL TYPE	DIST BET. EDGE COLS	WALL THICKNESS	DEPTH OF EDGE COL	WIDTH OF EDGE COL	DEPTH OF WALL
1	1	1	240.000	8.000	.000	.000	156.000
2	1	1	240.000	8.000	.000	.000	156.000
3	1	1	240.000	8.000	.000	.000	156.000
4	1	1	240.000	8.000	.000	.000	156.000
5	1	1	240.000	8.000	.000	.000	156.000
6	1	1	240.000	8.000	.000	.000	156.000

***** AXIAL LOAD AND REINFORCEMENT OF SHEAR WALLS *****

WALL TYPE	AXIAL LOAD	VERTICAL REINF RATIO	HORIZONTAL REINF RATIO	GROSS STEEL AREA IN EDGE COL
1	174.000	.4580	.4580	.0000
2	111.000	.4580	.4580	.0000
3	48.000	.4580	.4580	.0000

4	135.000	.4580	.4580	.0000
5	85.500	.4580	.4580	.0000
6	36.000	.4580	.4580	.0000

********** TRANSVERSE BEAMS **********

TYPE	STIFFNESS	STIFFNESS (TORSIONAL)	ARM LENGTH
1	90.360	77279.780	-120.000
2	90.360	77279.780	120.000
3	90.360	77279.780	.000

********** SLAB PROPERTIES **********

TYPE	CONC TYPE	LENGTH
1	1	240.0000

DATA FOR 7 SECTIONS:

SECTION	STEEL TYPE	THICKNESS	DEPTH	MAIN REINF	LATERAL REINF	FIBERS
1	1	24.0000	14.0000	.006000	.001830	10
2	1	5.0000	221.0000	.001830	.001830	20
3	1	24.0000	14.0000	.006000	.001830	10
4	1	5.0000	222.0000	.001830	.001830	20
5	1	24.0000	14.0000	.006000	.001830	10
6	1	5.0000	221.0000	.001830	.001830	20
7	1	24.0000	14.0000	.006000	.001830	10

TYPE CONC LENGTH

	TYPE	
2	1	240.0000

DATA FOR 7 SECTIONS:

SECTION	STEEL TYPE	THICKNESS	DEPTH	MAIN REINF	LATERAL REINF	FIBERS
1	1	24.0000	14.0000	.004000	.004000	10
2	1	.0100	221.0000	.000010	.000010	20
3	1	24.0000	14.0000	.004000	.004000	10
4	1	5.0000	221.0000	.001830	.001830	20
5	1	24.0000	14.0000	.004000	.004000	10
6	1	.0100	221.0000	.000010	.000010	20
7	1	24.0000	14.0000	.004000	.004000	10

ACTIVE OPTION FOR SLAB TYPE: FLEXIBLE

1

*************** NODAL CONNECTIVITY INFORMATION ***************

********** COLUMN ELEMENTS **********

COL. NO.	TYPE	I-COORD	J-COORD	L-COORD (BOT)	L-COORD (TOP)
1	1	2	1	0	1
2	1	3	1	0	1
3	1	4	1	0	1
4	1	5	1	0	1
5	7	6	1	0	1
6	13	7	1	0	1
7	7	8	1	0	1
8	1	9	1	0	1

9	1	10	1	0	1
10	1	11	1	0	1
11	1	12	1	0	1
12	2	2	2	0	1
13	2	3	2	0	1
14	2	4	2	0	1
15	2	5	2	0	1
16	8	6	2	0	1
17	14	7	2	0	1
18	8	8	2	0	1
19	2	9	2	0	1
20	2	10	2	0	1
21	2	11	2	0	1
22	2	12	2	0	1
23	2	2	3	0	1
24	2	3	3	0	1
25	2	4	3	0	1
26	2	5	3	0	1
27	8	6	3	0	1
28	14	7	3	0	1
29	8	8	3	0	1
30	2	9	3	0	1
31	2	10	3	0	1
32	2	11	3	0	1
33	2	12	3	0	1
34	1	2	4	0	1
35	1	3	4	0	1
36	1	4	4	0	1
37	1	5	4	0	1
38	7	6	4	0	1
39	13	7	4	0	1
40	7	8	4	0	1
41	1	9	4	0	1
42	1	10	4	0	1
43	1	11	4	0	1
44	1	12	4	0	1
45	3	2	1	1	2
46	3	3	1	1	2
47	3	4	1	1	2
48	3	5	1	1	2
49	9	6	1	1	2
50	15	7	1	1	2
51	9	8	1	1	2
52	3	9	1	1	2
53	3	10	1	1	2
54	3	11	1	1	2
55	3	12	1	1	2
56	4	2	2	1	2
57	4	3	2	1	2
58	4	4	2	1	2
59	4	5	2	1	2

60	10	6	2	1	2
61	16	7	2	1	2
62	10	8	2	1	2
63	4	9	2	1	2
64	4	10	2	1	2
65	4	11	2	1	2
66	4	12	2	1	2
67	4	2	3	1	2
68	4	3	3	1	2
69	4	4	3	1	2
70	4	5	3	1	2
71	10	6	3	1	2
72	16	7	3	1	2
73	10	8	3	1	2
74	4	9	3	1	2
75	4	10	3	1	2
76	4	11	3	1	2
77	4	12	3	1	2
78	3	2	4	1	2
79	3	3	4	1	2
80	3	4	4	1	2
81	3	5	4	1	2
82	9	6	4	1	2
83	15	7	4	1	2
84	9	8	4	1	2
85	3	9	4	1	2
86	3	10	4	1	2
87	3	11	4	1	2
88	3	12	4	1	2
89	5	2	1	2	3
90	5	3	1	2	3
91	5	4	1	2	3
92	5	5	1	2	3
93	11	6	1	2	3
94	17	7	1	2	3
95	11	8	1	2	3
96	5	9	1	2	3
97	5	10	1	2	3
98	5	11	1	2	3
99	5	12	1	2	3
100	6	2	2	2	3
101	6	3	2	2	3
102	6	4	2	2	3
103	6	5	2	2	3
104	12	6	2	2	3
105	18	7	2	2	3
106	12	8	2	2	3
107	6	9	2	2	3
108	6	10	2	2	3
109	6	11	2	2	3
110	6	12	2	2	3

111	6	2	3	2	3
112	6	3	3	2	3
113	6	4	3	2	3
114	6	5	3	2	3
115	12	6	3	2	3
116	18	7	3	2	3
117	12	8	3	2	3
118	6	9	3	2	3
119	6	10	3	2	3
120	6	11	3	2	3
121	6	12	3	2	3
122	5	2	4	2	3
123	5	3	4	2	3
124	5	4	4	2	3
125	5	5	4	2	3
126	11	6	4	2	3
127	17	7	4	2	3
128	11	8	4	2	3
129	5	9	4	2	3
130	5	10	4	2	3
131	5	11	4	2	3
132	5	12	4	2	3

********** BEAM ELEMENTS **********

BEAM NO.	TYPE	L-COORD	I-COORD	J-COORD (LEFT)	J-COORD (RIGHT)
1	1	1	2	1	2
2	1	1	3	1	2
3	1	1	4	1	2
4	1	1	5	1	2
5	1	1	6	1	2
6	1	1	7	1	2
7	1	1	8	1	2
8	1	1	9	1	2
9	1	1	10	1	2
10	1	1	11	1	2
11	1	1	12	1	2
12	1	1	2	2	3
13	1	1	3	2	3
14	1	1	4	2	3
15	1	1	5	2	3
16	1	1	6	2	3

17	1	1	7	2	3
18	1	1	8	2	3
19	1	1	9	2	3
20	1	1	10	2	3
21	1	1	11	2	3
22	1	1	12	2	3
23	1	1	2	3	4
24	1	1	3	3	4
25	1	1	4	3	4
26	1	1	5	3	4
27	1	1	6	3	4
28	1	1	7	3	4
29	1	1	8	3	4
30	1	1	9	3	4
31	1	1	10	3	4
32	1	1	11	3	4
33	1	1	12	3	4
34	1	1	1	1	2
35	1	1	13	1	2
36	1	2	2	1	2
37	1	2	3	1	2
38	1	2	4	1	2
39	1	2	5	1	2
40	1	2	6	1	2
41	1	2	7	1	2
42	1	2	8	1	2
43	1	2	9	1	2
44	1	2	10	1	2
45	1	2	11	1	2
46	1	2	12	1	2
47	1	2	2	2	3
48	1	2	3	2	3
49	1	2	4	2	3
50	1	2	5	2	3
51	1	2	6	2	3
52	1	2	7	2	3
53	1	2	8	2	3
54	1	2	9	2	3
55	1	2	10	2	3
56	1	2	11	2	3
57	1	2	12	2	3
58	1	2	2	3	4
59	1	2	3	3	4
60	1	2	4	3	4
61	1	2	5	3	4
62	1	2	6	3	4
63	1	2	7	3	4
64	1	2	8	3	4
65	1	2	9	3	4
66	1	2	10	3	4
67	1	2	11	3	4

68	1	2	12	3	4
69	1	2	1	1	2
70	1	2	13	1	2
71	1	3	2	1	2
72	1	3	3	1	2
73	1	3	4	1	2
74	1	3	5	1	2
75	1	3	6	1	2
76	1	3	7	1	2
77	1	3	8	1	2
78	1	3	9	1	2
79	1	3	10	1	2
80	1	3	11	1	2
81	1	3	12	1	2
82	1	3	2	2	3
83	1	3	3	2	3
84	1	3	4	2	3
85	1	3	5	2	3
86	1	3	6	2	3
87	1	3	7	2	3
88	1	3	8	2	3
89	1	3	9	2	3
90	1	3	10	2	3
91	1	3	11	2	3
92	1	3	12	2	3
93	1	3	2	3	4
94	1	3	3	3	4
95	1	3	4	3	4
96	1	3	5	3	4
97	1	3	6	3	4
98	1	3	7	3	4
99	1	3	8	3	4
100	1	3	9	3	4
101	1	3	10	3	4
102	1	3	11	3	4
103	1	3	12	3	4
104	1	3	1	1	2
105	1	3	13	1	2

********** SHEAR WALL ELEMENTS **********

WALL NO.	TYPE	I-COORD	J-COORD	L-COORD (BOTTOM)	L-COORD (TOP)

1	1	1	1	0	1
2	1	1	2	0	1
3	1	13	1	0	1
4	1	13	2	0	1
5	2	1	1	1	2
6	2	1	2	1	2
7	2	13	1	1	2
8	2	13	2	1	2
9	3	1	1	2	3
10	3	1	2	2	3
11	3	13	1	2	3
12	3	13	2	2	3

********** TRANSVERSE BEAM ELEMENTS **********

NO.	TYPE	L-COORD	I-COORD	J-COORD	I-COORD	J-COORD
			----(WALL//COL)----		------(COLUMN)-----	
1	2	1	1	1	2	1
2	3	1	2	1	3	1
3	3	1	3	1	4	1
4	3	1	4	1	5	1
5	3	1	5	1	6	1
6	3	1	6	1	7	1
7	3	1	7	1	8	1
8	3	1	8	1	9	1
9	3	1	9	1	10	1
10	3	1	10	1	11	1
11	3	1	11	1	12	1
12	2	1	13	1	12	1
13	1	1	1	1	2	2
14	3	1	2	2	3	2
15	3	1	3	2	4	2
16	3	1	4	2	5	2
17	3	1	5	2	6	2
18	3	1	6	2	7	2
19	3	1	7	2	8	2
20	3	1	8	2	9	2
21	3	1	9	2	10	2
22	3	1	10	2	11	2
23	3	1	11	2	12	2
24	1	1	13	1	12	2
25	2	1	1	2	2	3
26	3	1	2	3	3	3
27	3	1	3	3	4	3

28	3	1	4	3	5	3
29	3	1	5	3	6	3
30	3	1	6	3	7	3
31	3	1	7	3	8	3
32	3	1	8	3	9	3
33	3	1	9	3	10	3
34	3	1	10	3	11	3
35	3	1	11	3	12	3
36	2	1	13	2	12	3
37	1	1	1	2	2	4
38	3	1	2	4	3	4
39	3	1	3	4	4	4
40	3	1	4	4	5	4
41	3	1	5	4	6	4
42	3	1	6	4	7	4
43	3	1	7	4	8	4
44	3	1	8	4	9	4
45	3	1	9	4	10	4
46	3	1	10	4	11	4
47	3	1	11	4	12	4
48	1	1	13	2	12	4
49	2	2	1	1	2	1
50	3	2	2	1	3	1
51	3	2	3	1	4	1
52	3	2	4	1	5	1
53	3	2	5	1	6	1
54	3	2	6	1	7	1
55	3	2	7	1	8	1
56	3	2	8	1	9	1
57	3	2	9	1	10	1
58	3	2	10	1	11	1
59	3	2	11	1	12	1
60	2	2	13	1	12	1
61	1	2	1	1	2	2
62	3	2	2	2	3	2
63	3	2	3	2	4	2
64	3	2	4	2	5	2
65	3	2	5	2	6	2
66	3	2	6	2	7	2
67	3	2	7	2	8	2
68	3	2	8	2	9	2
69	3	2	9	2	10	2
70	3	2	10	2	11	2
71	3	2	11	2	12	2
72	1	2	13	1	12	2
73	2	2	1	2	2	3
74	3	2	2	3	3	3
75	3	2	3	3	4	3
76	3	2	4	3	5	3
77	3	2	5	3	6	3
78	3	2	6	3	7	3

79	3	2	7	3	8	3
80	3	2	8	3	9	3
81	3	2	9	3	10	3
82	3	2	10	3	11	3
83	3	2	11	3	12	3
84	2	2	13	2	12	3
85	1	2	1	2	2	4
86	3	2	2	4	3	4
87	3	2	3	4	4	4
88	3	2	4	4	5	4
89	3	2	5	4	6	4
90	3	2	6	4	7	4
91	3	2	7	4	8	4
92	3	2	8	4	9	4
93	3	2	9	4	10	4
94	3	2	10	4	11	4
95	3	2	11	4	12	4
96	1	2	13	2	12	4
97	2	3	1	1	2	1
98	3	3	2	1	3	1
99	3	3	3	1	4	1
100	3	3	4	1	5	1
101	3	3	5	1	6	1
102	3	3	6	1	7	1
103	3	3	7	1	8	1
104	3	3	8	1	9	1
105	3	3	9	1	10	1
106	3	3	10	1	11	1
107	3	3	11	1	12	1
108	2	3	13	1	12	1
109	1	3	1	1	2	2
110	3	3	2	2	3	2
111	3	3	3	2	4	2
112	3	3	4	2	5	2
113	3	3	5	2	6	2
114	3	3	6	2	7	2
115	3	3	7	2	8	2
116	3	3	8	2	9	2
117	3	3	9	2	10	2
118	3	3	10	2	11	2
119	3	3	11	2	12	2
120	1	3	13	1	12	2
121	2	3	1	2	2	3
122	3	3	2	3	3	3
123	3	3	3	3	4	3
124	3	3	4	3	5	3
125	3	3	5	3	6	3
126	3	3	6	3	7	3
127	3	3	7	3	8	3
128	3	3	8	3	9	3
129	3	3	9	3	10	3

130	3	3	10	3	11	3
131	3	3	11	3	12	3
132	2	3	13	2	12	3
133	1	3	1	2	2	4
134	3	3	2	4	3	4
135	3	3	3	4	4	4
136	3	3	4	4	5	4
137	3	3	5	4	6	4
138	3	3	6	4	7	4
139	3	3	7	4	8	4
140	3	3	8	4	9	4
141	3	3	9	4	10	4
142	3	3	10	4	11	4
143	3	3	11	4	12	4
144	1	3	13	2	12	4

********** SLAB ELEMENTS **********

SLAB NO.	SLAB TYPE	L-COORD	I-COORD FRAME I	I-COORD FRAME J
1	1	1	1	2
2	1	1	2	3
3	1	1	3	4
4	1	1	4	5
5	1	1	5	6
6	2	1	6	7
7	2	1	7	8
8	1	1	8	9
9	1	1	9	10
10	1	1	10	11
11	1	1	11	12
12	1	1	12	13
13	1	2	1	2
14	1	2	2	3
15	1	2	3	4
16	1	2	4	5
17	1	2	5	6
18	2	2	6	7
19	2	2	7	8
20	1	2	8	9
21	1	2	9	10
22	1	2	10	11
23	1	2	11	12
24	1	2	12	13

25	1	3	1	2
26	1	3	2	3
27	1	3	3	4
28	1	3	4	5
29	1	3	5	6
30	2	3	6	7
31	2	3	7	8
32	1	3	8	9
33	1	3	9	10
34	1	3	10	11
35	1	3	11	12
36	1	3	12	13

1

*************** CONFIGURATION OF PLAN ***************

```
PLAN OF FRAME 13:     ==========O=======================================O=========

PLAN OF FRAME 12:     O===================O===================O==================O

PLAN OF FRAME 11:     O===================O===================O==================O

PLAN OF FRAME 10:     O===================O===================O==================O

PLAN OF FRAME  9:     O===================O===================O==================O
```

```
 PLAN OF FRAME  8:     O===================O===================O==================O


 PLAN OF FRAME  7:     O===================O===================O==================O


 PLAN OF FRAME  6:     O===================O===================O==================O


 PLAN OF FRAME  5:     O===================O===================O==================O


 PLAN OF FRAME  4:     O===================O===================O==================O


 PLAN OF FRAME  3:     O===================O===================O==================O


 PLAN OF FRAME  2:     O===================O===================O==================O


 PLAN OF FRAME  1:     ==========O=======================================O=========
1                    ********** FRAME ELEVATION AND ELEMENT TYPES **********
```

ELEVATION OF FRAME NO. 1

```
       +-----------+
       W     01    W
       W           W
     03W         03W
       W           W
       W           W
       +-----------+
       W     01    W
       W           W
     02W         02W
       W           W
       W           W
       +-----------+
       W     01    W
       W           W
     01W         01W
       W           W
       W           W
```

NOTATION:

```
-  =  BEAM                 NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN               COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL           SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN          EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 2

```
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 05        ! 06        ! 06        ! 05
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
```

```
       !           !           !           !
       ! 03        ! 04        ! 04        ! 03
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 01        ! 02        ! 02        ! 01
       !           !           !           !
       !           !           !           !
```

NOTATION:

```
-  =  BEAM                 NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN               COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL           SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN          EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 3

```
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 05        ! 06        ! 06        ! 05
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 03        ! 04        ! 04        ! 03
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 01        ! 02        ! 02        ! 01
       !           !           !           !
       !           !           !           !
```

NOTATION:

```
 -  =  BEAM                    NUMBERS INDICATE ELEMENT TYPES
 !  =  COLUMN                  COLUMN TYPE NUMBERS ON RIGHT
 W  =  SHEAR WALL              SHEAR WALL NUMBERS ON LEFT, AND
 I  =  EDGE COLUMN             EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 4

```
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 05        ! 06        ! 06        ! 05
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 03        ! 04        ! 04        ! 03
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 01        ! 02        ! 02        ! 01
!           !           !           !
!           !           !           !
```

NOTATION:

```
 -  =  BEAM                    NUMBERS INDICATE ELEMENT TYPES
 !  =  COLUMN                  COLUMN TYPE NUMBERS ON RIGHT
 W  =  SHEAR WALL              SHEAR WALL NUMBERS ON LEFT, AND
 I  =  EDGE COLUMN             EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 5

```
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 05        ! 06        ! 06        ! 05
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 03        ! 04        ! 04        ! 03
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 01        ! 02        ! 02        ! 01
!           !           !           !
!           !           !           !
```

NOTATION:

```
-  =  BEAM                 NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN               COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL           SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN          EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 6

```
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 11        ! 12        ! 12        ! 11
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 09        ! 10        ! 10        ! 09
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
```

```
       !     01    !     01    !     01    !
       !           !           !           !
       ! 07        ! 08        ! 08        ! 07
       !           !           !           !
       !           !           !           !
```

```
NOTATION:

-  =  BEAM                    NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN                  COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL              SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN             EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 7

```
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 17        ! 18        ! 18        ! 17
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 15        ! 16        ! 16        ! 15
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 13        ! 14        ! 14        ! 13
       !           !           !           !
       !           !           !           !
```

```
NOTATION:

-  =  BEAM                    NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN                  COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL              SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN             EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 8

```
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 11        ! 12        ! 12        ! 11
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 09        ! 10        ! 10        ! 09
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 07        ! 08        ! 08        ! 07
!           !           !           !
!           !           !           !
```

NOTATION:

```
-  =  BEAM                    NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN                  COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL              SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN             EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 9

```
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 05        ! 06        ! 06        ! 05
```

```
        !           !           !           !
        !           !           !           !
        +-----------+-----------+-----------+
        !     01    !     01    !     01    !
        !           !           !           !
        ! 03        ! 04        ! 04        ! 03
        !           !           !           !
        !           !           !           !
        +-----------+-----------+-----------+
        !     01    !     01    !     01    !
        !           !           !           !
        ! 01        ! 02        ! 02        ! 01
        !           !           !           !
        !           !           !           !
```

NOTATION:

```
-  =  BEAM                 NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN               COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL           SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN          EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 10

```
        +-----------+-----------+-----------+
        !     01    !     01    !     01    !
        !           !           !           !
        ! 05        ! 06        ! 06        ! 05
        !           !           !           !
        !           !           !           !
        +-----------+-----------+-----------+
        !     01    !     01    !     01    !
        !           !           !           !
        ! 03        ! 04        ! 04        ! 03
        !           !           !           !
        !           !           !           !
        +-----------+-----------+-----------+
        !     01    !     01    !     01    !
        !           !           !           !
        ! 01        ! 02        ! 02        ! 01
        !           !           !           !
        !           !           !           !
```

NOTATION:

```
 -  =  BEAM                  NUMBERS INDICATE ELEMENT TYPES
 !  =  COLUMN                COLUMN TYPE NUMBERS ON RIGHT
 W  =  SHEAR WALL            SHEAR WALL NUMBERS ON LEFT, AND
 I  =  EDGE COLUMN           EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 11

```
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 05        ! 06        ! 06        ! 05
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 03        ! 04        ! 04        ! 03
       !           !           !           !
       !           !           !           !
       +-----------+-----------+-----------+
       !     01    !     01    !     01    !
       !           !           !           !
       ! 01        ! 02        ! 02        ! 01
       !           !           !           !
       !           !           !           !
```

NOTATION:

```
 -  =  BEAM                  NUMBERS INDICATE ELEMENT TYPES
 !  =  COLUMN                COLUMN TYPE NUMBERS ON RIGHT
 W  =  SHEAR WALL            SHEAR WALL NUMBERS ON LEFT, AND
 I  =  EDGE COLUMN           EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```


1

ELEVATION OF FRAME NO. 12

```
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 05        ! 06        ! 06        ! 05
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 03        ! 04        ! 04        ! 03
!           !           !           !
!           !           !           !
+-----------+-----------+-----------+
!     01    !     01    !     01    !
!           !           !           !
! 01        ! 02        ! 02        ! 01
!           !           !           !
!           !           !           !
```

NOTATION:

```
-  =  BEAM                NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN              COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL          SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN         EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

1

ELEVATION OF FRAME NO. 13

```
  +-----------+
  W     01    W
  W           W
03W         03W
  W           W
  W           W
  +-----------+
  W     01    W
  W           W
```

```
     02W         02W
       W           W
       W           W
       +-----------+
       W     01    W
       W           W
     01W         01W
       W           W
       W           W
```

NOTATION:

-	=	BEAM	NUMBERS INDICATE ELEMENT TYPES
!	=	COLUMN	COLUMN TYPE NUMBERS ON RIGHT
W	=	SHEAR WALL	SHEAR WALL NUMBERS ON LEFT, AND
I	=	EDGE COLUMN	EDGE COLUMN NUMBERS BELOW COLUMN TYPES

1

******************** LOADING DATA ********************

NO. OF UNIFORMLY LOADED BEAMS 105
NO. OF LATERAL LOADING POINTS 0
NO. OF APPLIED NODAL MOMENTS 0

UNIFORM LOAD DATA:

LOAD NO.	BEAM NO.	LOAD VALUE
1	1	.160
2	2	.160
3	3	.160
4	4	.160
5	5	.080
6	6	.080
7	7	.080
8	8	.160

9	9	.160
10	10	.160
11	11	.160
12	12	.160
13	13	.160
14	14	.160
15	15	.160
16	16	.160
17	17	.160
18	18	.160
19	19	.160
20	20	.160
21	21	.160
22	22	.160
23	23	.160
24	24	.160
25	25	.160
26	26	.160
27	27	.080
28	28	.080
29	29	.080
30	30	.160
31	31	.160
32	32	.160
33	33	.160
34	34	.080
35	35	.080
36	36	.160
37	37	.160
38	38	.160
39	39	.160
40	40	.080
41	41	.080
42	42	.080
43	43	.160
44	44	.160
45	45	.160
46	46	.160
47	47	.160
48	48	.160
49	49	.160
50	50	.160
51	51	.160
52	52	.160
53	53	.160
54	54	.160
55	55	.160
56	56	.160
57	57	.160
58	58	.160
59	59	.160

60	60	.160
61	61	.160
62	62	.080
63	63	.080
64	64	.080
65	65	.160
66	66	.160
67	67	.160
68	68	.160
69	69	.080
70	70	.080
71	71	.160
72	72	.160
73	73	.160
74	74	.160
75	75	.080
76	76	.080
77	77	.080
78	78	.160
79	79	.160
80	80	.160
81	81	.160
82	82	.160
83	83	.160
84	84	.160
85	85	.160
86	86	.160
87	87	.160
88	88	.160
89	89	.160
90	90	.160
91	91	.160
92	92	.160
93	93	.160
94	94	.160
95	95	.160
96	96	.160
97	97	.080
98	98	.080
99	99	.080
100	100	.160
101	101	.160
102	102	.160
103	103	.160
104	104	.080
105	105	.080

1

*************** O U T P U T   O F   R E S U L T S ***************

ACTIVE SYSTEM OF UNITS: INCH, KIPS

********** RESULTS OF STATIC ANALYSIS **********

STORY DISPLACEMENTS:

STORY NO.	LATERAL DISPLACEMENTS									
	FRAME: 1	2	3	4	5	6	7	8	9	10
	FRAME: 11	12	13							
1	.00058	.00028	.00004	-.00016	-.00030	-.00040	-.00043	-.00040	-.00030	-.00016
	.00004	.00028	.00058							
2	.00185	.00233	.00278	.00318	.00351	.00376	.00386	.00376	.00351	.00318
	.00278	.00233	.00185							
3	.00339	.00497	.00641	.00765	.00865	.00939	.00969	.00939	.00865	.00765
	.00641	.00497	.00339							

1

********** COLUMN OUTPUT **********

COL	--- LATERAL DISPL ---		----- SHEAR -----		----- MOMENT -----	
NO.	BOT	TOP	BOT	TOP	BOT	TOP
1	.00000	.00028	1.027	-1.027	115.179	-339.047
2	.00000	.00004	1.073	-1.073	112.452	-334.837
3	.00000	-.00016	1.087	-1.087	111.466	-333.699
4	.00000	-.00030	1.085	-1.085	111.397	-334.091
5	.00000	-.00040	.551	-.551	107.769	-305.778

6	.00000	-.00043	.541	-.541	80.609	-237.135
7	.00000	-.00040	.551	-.551	107.769	-305.778
8	.00000	-.00030	1.085	-1.085	111.397	-334.091
9	.00000	-.00016	1.087	-1.087	111.466	-333.699
10	.00000	.00004	1.073	-1.073	112.452	-334.837
11	.00000	.00028	1.027	-1.027	115.179	-339.047
12	.00000	.00028	.331	-.331	1.214	-4.666
13	.00000	.00004	.345	-.345	.186	-3.643
14	.00000	-.00016	.357	-.357	-.697	-2.699
15	.00000	-.00030	.374	-.374	-1.779	-1.190
16	.00000	-.00040	.594	-.594	-16.862	27.207
17	.00000	-.00043	.604	-.604	-19.853	32.985
18	.00000	-.00040	.594	-.594	-16.862	27.207
19	.00000	-.00030	.374	-.374	-1.779	-1.190
20	.00000	-.00016	.357	-.357	-.697	-2.699
21	.00000	.00004	.345	-.345	.186	-3.643
22	.00000	.00028	.331	-.331	1.214	-4.666
23	.00000	.00028	.896	-.896	-28.049	50.244
24	.00000	.00004	.933	-.933	-30.294	53.551
25	.00000	-.00016	.945	-.945	-31.157	54.458
26	.00000	-.00030	.935	-.935	-30.837	53.337
27	.00000	-.00040	.365	-.365	-5.016	4.978
28	.00000	-.00043	.350	-.350	-6.657	8.223
29	.00000	-.00040	.365	-.365	-5.016	4.978
30	.00000	-.00030	.935	-.935	-30.837	53.337
31	.00000	-.00016	.945	-.945	-31.157	54.458
32	.00000	.00004	.933	-.933	-30.294	53.551
33	.00000	.00028	.896	-.896	-28.049	50.244
34	.00000	.00028	-1.452	1.452	243.578	-579.984
35	.00000	.00004	-1.482	1.482	244.813	-583.209
36	.00000	-.00016	-1.470	1.470	243.924	-582.253
37	.00000	-.00030	-1.436	1.436	241.982	-579.130
38	.00000	-.00040	-.700	.700	172.536	-427.312
39	.00000	-.00043	-.674	.674	143.547	-355.237
40	.00000	-.00040	-.700	.700	172.536	-427.312
41	.00000	-.00030	-1.436	1.436	241.982	-579.130
42	.00000	-.00016	-1.470	1.470	243.924	-582.253
43	.00000	.00004	-1.482	1.482	244.813	-583.209
44	.00000	.00028	-1.452	1.452	243.578	-579.984
45	.00028	.00233	2.019	-2.019	292.873	-331.287
46	.00004	.00278	2.046	-2.046	290.955	-329.358
47	-.00016	.00318	2.023	-2.023	292.726	-330.764
48	-.00030	.00351	1.990	-1.990	295.531	-332.759
49	-.00040	.00376	.942	-.942	292.971	-239.300
50	-.00043	.00386	.921	-.921	225.120	-230.867
51	-.00040	.00376	.942	-.942	292.971	-239.300
52	-.00030	.00351	1.990	-1.990	295.531	-332.759
53	-.00016	.00318	2.023	-2.023	292.726	-330.764
54	.00004	.00278	2.046	-2.046	290.955	-329.358
55	.00028	.00233	2.019	-2.019	292.873	-331.287
56	.00028	.00233	.726	-.726	-12.283	33.206

57	.00004	.00278	.695	-.695	-9.786	31.329
58	-.00016	.00318	.663	-.663	-7.457	29.150
59	-.00030	.00351	.649	-.649	-6.559	28.068
60	-.00040	.00376	1.022	-1.022	-41.842	37.302
61	-.00043	.00386	1.026	-1.026	-49.451	45.868
62	-.00040	.00376	1.022	-1.022	-41.842	37.302
63	-.00030	.00351	.649	-.649	-6.559	28.068
64	-.00016	.00318	.663	-.663	-7.457	29.150
65	.00004	.00278	.695	-.695	-9.786	31.329
66	.00028	.00233	.726	-.726	-12.283	33.206
67	.00028	.00233	1.716	-1.716	-87.960	98.067
68	.00004	.00278	1.713	-1.713	-87.980	97.707
69	-.00016	.00318	1.680	-1.680	-85.540	95.374
70	-.00030	.00351	1.617	-1.617	-80.934	91.029
71	-.00040	.00376	.393	-.393	.082	-10.079
72	-.00043	.00386	.350	-.350	-3.949	-4.664
73	-.00040	.00376	.393	-.393	.082	-10.079
74	-.00030	.00351	1.617	-1.617	-80.934	91.029
75	-.00016	.00318	1.680	-1.680	-85.540	95.374
76	.00004	.00278	1.713	-1.713	-87.980	97.707
77	.00028	.00233	1.716	-1.716	-87.960	98.067
78	.00028	.00233	-3.021	3.021	659.413	-680.411
79	.00004	.00278	-3.136	3.136	668.129	-687.988
80	-.00016	.00318	-3.163	3.163	670.195	-689.691
81	-.00030	.00351	-3.139	3.139	668.443	-688.073
82	-.00040	.00376	-1.682	1.682	481.899	-422.960
83	-.00043	.00386	-1.646	1.646	409.564	-410.932
84	-.00040	.00376	-1.682	1.682	481.899	-422.960
85	-.00030	.00351	-3.139	3.139	668.443	-688.073
86	-.00016	.00318	-3.163	3.163	670.195	-689.691
87	.00004	.00278	-3.136	3.136	668.129	-687.988
88	.00028	.00233	-3.021	3.021	659.413	-680.411
89	.00233	.00497	2.268	-2.268	319.779	-460.998
90	.00278	.00641	2.306	-2.306	317.720	-457.670
91	.00318	.00765	2.275	-2.275	319.903	-459.909
92	.00351	.00865	2.234	-2.234	322.527	-463.102
93	.00376	.00939	1.130	-1.130	344.854	-428.350
94	.00386	.00969	1.107	-1.107	223.790	-296.974
95	.00376	.00939	1.130	-1.130	344.854	-428.350
96	.00351	.00865	2.234	-2.234	322.527	-463.102
97	.00318	.00765	2.275	-2.275	319.903	-459.909
98	.00278	.00641	2.306	-2.306	317.720	-457.670
99	.00233	.00497	2.268	-2.268	319.779	-460.998
100	.00233	.00497	.682	-.682	-30.193	-40.213
101	.00278	.00641	.632	-.632	-26.960	-44.081
102	.00318	.00765	.585	-.585	-23.718	-47.412
103	.00351	.00865	.563	-.563	-21.972	-48.762
104	.00376	.00939	.995	-.995	-53.102	.542
105	.00386	.00969	.999	-.999	-55.592	20.250
106	.00376	.00939	.995	-.995	-53.102	.542
107	.00351	.00865	.563	-.563	-21.972	-48.762

108	.00318	.00765	.585	-.585	-23.718	-47.412
109	.00278	.00641	.632	-.632	-26.960	-44.081
110	.00233	.00497	.682	-.682	-30.193	-40.213
111	.00233	.00497	1.889	-1.889	-105.811	55.592
112	.00278	.00641	1.882	-1.882	-104.835	55.623
113	.00318	.00765	1.833	-1.833	-101.409	52.129
114	.00351	.00865	1.742	-1.742	-95.396	45.189
115	.00376	.00939	.310	-.310	-2.971	-46.527
116	.00386	.00969	.248	-.248	-1.364	-32.167
117	.00376	.00939	.310	-.310	-2.971	-46.527
118	.00351	.00865	1.742	-1.742	-95.396	45.189
119	.00318	.00765	1.833	-1.833	-101.409	52.129
120	.00278	.00641	1.882	-1.882	-104.835	55.623
121	.00233	.00497	1.889	-1.889	-105.811	55.592
122	.00233	.00497	-3.530	3.530	706.405	-897.711
123	.00278	.00641	-3.695	3.695	716.854	-910.633
124	.00318	.00765	-3.734	3.734	719.499	-913.475
125	.00351	.00865	-3.699	3.699	717.611	-910.430
126	.00376	.00939	-2.006	2.006	553.809	-664.609
127	.00386	.00969	-1.953	1.953	428.277	-527.114
128	.00376	.00939	-2.006	2.006	553.809	-664.609
129	.00351	.00865	-3.699	3.699	717.611	-910.430
130	.00318	.00765	-3.734	3.734	719.499	-913.475
131	.00278	.00641	-3.695	3.695	716.854	-910.633
132	.00233	.00497	-3.530	3.530	706.405	-897.711

********** BEAM OUTPUT **********

BEAM	--- VERTICAL DISPL ---		----- SHEAR -----		----- MOMENT -----	
NO.	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
1	-.00968	-.01200	15.720	22.680	-754.381	-1540.848
2	-.01027	-.01292	15.667	22.733	-745.268	-1543.740
3	-.01028	-.01299	15.661	22.739	-744.356	-1544.274
4	-.00994	-.01292	15.689	22.711	-749.451	-1542.888
5	-.00530	-.01228	7.369	11.831	-648.763	-1153.006
6	-.00499	-.01221	7.400	11.800	-654.195	-1151.350
7	-.00530	-.01228	7.369	11.831	-648.763	-1153.006
8	-.00994	-.01292	15.689	22.711	-749.451	-1542.888
9	-.01028	-.01299	15.661	22.739	-744.356	-1544.274
10	-.01027	-.01292	15.667	22.733	-745.268	-1543.740
11	-.00968	-.01200	15.720	22.680	-754.381	-1540.848
12	-.01200	-.01435	16.074	22.326	-913.907	-1620.461
13	-.01292	-.01540	16.024	22.376	-910.502	-1628.323

14	-.01299	-.01545	16.015	22.385	-909.508	-1629.246
15	-.01292	-.01501	16.001	22.399	-905.328	-1628.292
16	-.01228	-.00923	16.445	21.955	-880.552	-1503.264
17	-.01221	-.00883	16.435	21.965	-877.038	-1501.833
18	-.01228	-.00923	16.445	21.955	-880.552	-1503.264
19	-.01292	-.01501	16.001	22.399	-905.328	-1628.292
20	-.01299	-.01545	16.015	22.385	-909.508	-1629.246
21	-.01292	-.01540	16.024	22.376	-910.502	-1628.323
22	-.01200	-.01435	16.074	22.326	-913.907	-1620.461
23	-.01435	-.01114	20.275	18.125	-1112.403	-869.366
24	-.01540	-.01196	20.307	18.093	-1109.640	-859.382
25	-.01545	-.01200	20.301	18.099	-1108.922	-860.193
26	-.01501	-.01162	20.283	18.117	-1111.090	-866.310
27	-.00923	-.00636	10.322	8.878	-877.446	-714.172
28	-.00883	-.00600	10.309	8.891	-879.894	-719.592
29	-.00923	-.00636	10.322	8.878	-877.446	-714.172
30	-.01501	-.01162	20.283	18.117	-1111.090	-866.310
31	-.01545	-.01200	20.301	18.099	-1108.922	-860.193
32	-.01540	-.01196	20.307	18.093	-1109.640	-859.382
33	-.01435	-.01114	20.275	18.125	-1112.403	-869.366
34	-.00083	-.00088	9.476	9.724	-882.019	-910.100
35	-.00083	-.00088	9.476	9.724	-882.019	-910.100
36	-.01604	-.01989	15.984	22.416	-804.473	-1531.398
37	-.01709	-.02154	15.921	22.479	-795.506	-1536.587
38	-.01711	-.02167	15.891	22.509	-791.453	-1539.397
39	-.01651	-.02153	15.905	22.495	-792.937	-1537.635
40	-.00889	-.02043	7.633	11.567	-677.420	-1121.898
41	-.00833	-.02030	7.664	11.536	-681.125	-1118.665
42	-.00889	-.02043	7.633	11.567	-677.420	-1121.898
43	-.01651	-.02153	15.905	22.495	-792.937	-1537.635
44	-.01711	-.02167	15.891	22.509	-791.453	-1539.397
45	-.01709	-.02154	15.921	22.479	-795.506	-1536.587
46	-.01604	-.01989	15.984	22.416	-804.473	-1531.398
47	-.01989	-.02377	16.374	22.026	-926.151	-1564.852
48	-.02154	-.02563	16.319	22.081	-920.224	-1571.229
49	-.02167	-.02572	16.295	22.105	-917.292	-1573.912
50	-.02153	-.02495	16.248	22.152	-910.329	-1577.526
51	-.02043	-.01547	16.393	22.007	-863.834	-1498.105
52	-.02030	-.01475	16.362	22.038	-858.635	-1500.064
53	-.02043	-.01547	16.393	22.007	-863.834	-1498.105
54	-.02153	-.02495	16.248	22.152	-910.329	-1577.526
55	-.02167	-.02572	16.295	22.105	-917.292	-1573.912
56	-.02154	-.02563	16.319	22.081	-920.224	-1571.229
57	-.01989	-.02377	16.374	22.026	-926.151	-1564.852
58	-.02377	-.01847	19.797	18.603	-1094.589	-959.729
59	-.02563	-.01994	19.769	18.631	-1088.126	-959.531
60	-.02572	-.02002	19.736	18.664	-1084.933	-963.852
61	-.02495	-.01933	19.715	18.685	-1085.900	-969.589
62	-.01547	-.01067	9.937	9.263	-856.657	-780.411
63	-.01475	-.01002	9.934	9.266	-859.216	-783.751
64	-.01547	-.01067	9.937	9.263	-856.657	-780.411

65	-.02495	-.01933	19.715	18.685	-1085.900	-969.589
66	-.02572	-.02002	19.736	18.664	-1084.933	-963.852
67	-.02563	-.01994	19.769	18.631	-1088.126	-959.531
68	-.02377	-.01847	19.797	18.603	-1094.589	-959.729
69	-.00140	-.00150	9.406	9.794	-874.022	-917.763
70	-.00140	-.00150	9.406	9.794	-874.022	-917.763
71	-.01912	-.02383	15.280	23.120	-679.350	-1565.159
72	-.02042	-.02587	15.196	23.204	-664.139	-1568.957
73	-.02045	-.02603	15.177	23.223	-661.229	-1570.493
74	-.01970	-.02586	15.212	23.188	-667.031	-1568.280
75	-.01065	-.02451	7.216	11.984	-612.933	-1151.650
76	-.00997	-.02434	7.261	11.939	-620.032	-1148.651
77	-.01065	-.02451	7.216	11.984	-612.933	-1151.650
78	-.01970	-.02586	15.212	23.188	-667.031	-1568.280
79	-.02045	-.02603	15.177	23.223	-661.229	-1570.493
80	-.02042	-.02587	15.196	23.204	-664.139	-1568.957
81	-.01912	-.02383	15.280	23.120	-679.350	-1565.159
82	-.02383	-.02859	15.821	22.579	-904.153	-1667.788
83	-.02587	-.03090	15.751	22.649	-899.809	-1679.172
84	-.02603	-.03101	15.735	22.665	-897.810	-1680.997
85	-.02586	-.03005	15.702	22.698	-889.825	-1680.338
86	-.02451	-.01871	15.973	22.427	-822.492	-1551.720
87	-.02434	-.01782	15.951	22.449	-815.825	-1550.136
88	-.02451	-.01871	15.973	22.427	-822.492	-1551.720
89	-.02586	-.03005	15.702	22.698	-889.825	-1680.338
90	-.02603	-.03101	15.735	22.665	-897.810	-1680.997
91	-.02587	-.03090	15.751	22.649	-899.809	-1679.172
92	-.02383	-.02859	15.821	22.579	-904.153	-1667.788
93	-.02859	-.02202	20.568	17.832	-1086.562	-777.362
94	-.03090	-.02383	20.612	17.788	-1081.216	-762.086
95	-.03101	-.02393	20.594	17.806	-1079.429	-764.488
96	-.03005	-.02308	20.562	17.838	-1083.361	-775.612
97	-.01871	-.01277	10.539	8.661	-881.088	-668.967
98	-.01782	-.01197	10.518	8.682	-885.760	-678.194
99	-.01871	-.01277	10.539	8.661	-881.088	-668.967
100	-.03005	-.02308	20.562	17.838	-1083.361	-775.612
101	-.03101	-.02393	20.594	17.806	-1079.429	-764.488
102	-.03090	-.02383	20.612	17.788	-1081.216	-762.086
103	-.02859	-.02202	20.568	17.832	-1086.562	-777.362
104	-.00169	-.00182	9.388	9.812	-871.517	-919.340
105	-.00169	-.00182	9.388	9.812	-871.517	-919.340

********** WALL OUTPUT **********

WALL --- LATERAL DISPL --- ----- SHEAR ----- ----- MOMENT -----

NO.	BOT	TOP	BOT	TOP	BOT	TOP
1	.00000	.00058	-1.399	1.399	1220.798	1002.603
2	.00000	.00058	-3.372	3.372	1067.497	541.470
3	.00000	.00058	-1.399	1.399	1220.798	1002.603
4	.00000	.00058	-3.372	3.372	1067.497	541.470
5	.00058	.00185	-.838	.838	652.917	522.193
6	.00058	.00185	-5.241	5.241	925.997	108.475
7	.00058	.00185	-.838	.838	652.917	522.193
8	.00058	.00185	-5.241	5.241	925.997	108.475
9	.00185	.00339	.622	-.622	207.248	304.260
10	.00185	.00339	-5.483	5.483	484.625	-370.680
11	.00185	.00339	.622	-.622	207.248	304.260
12	.00185	.00339	-5.483	5.483	484.625	-370.680

********** SLAB OUTPUT **********

SLAB	--- LATERAL	DISPL ---	----- SHEAR	-----	----- MOMENT	-----
NO.	FRONT	REAR	FRONT	REAR	FRONT	REAR
1	.00058	.00028	1.308	-1.308	.000	313.884
2	.00028	.00004	.670	-.670	313.884	474.780
3	.00004	-.00016	.221	-.221	474.780	527.926
4	-.00016	-.00030	-.062	.062	527.926	512.935
5	-.00030	-.00040	-.220	.220	512.935	460.193
6	-.00040	-.00043	-.085	.085	460.193	439.810
7	-.00043	-.00040	.085	-.085	439.810	460.193
8	-.00040	-.00030	.220	-.220	460.193	512.935
9	-.00030	-.00016	.062	-.062	512.935	527.926
10	-.00016	.00004	-.221	.221	527.926	474.780
11	.00004	.00028	-.670	.670	474.780	313.884
12	.00028	.00058	-1.308	1.308	313.884	.000
13	.00185	.00233	-1.218	1.218	.000	-292.236
14	.00233	.00278	-1.086	1.086	-292.236	-552.964
15	.00278	.00318	-.893	.893	-552.964	-767.192
16	.00318	.00351	-.648	.648	-767.192	-922.792
17	.00351	.00376	-.372	.372	-922.792	-1012.038
18	.00376	.00386	-.125	.125	-1012.038	-1042.155
19	.00386	.00376	.125	-.125	-1042.155	-1012.038
20	.00376	.00351	.372	-.372	-1012.038	-922.792
21	.00351	.00318	.648	-.648	-922.792	-767.192
22	.00318	.00278	.893	-.893	-767.192	-552.964

23	.00278	.00233	1.086	-1.086	-552.964	-292.236
24	.00233	.00185	1.218	-1.218	-292.236	.000
25	.00339	.00497	-4.861	4.861	.000	-1166.604
26	.00497	.00641	-3.553	3.553	-1166.604	-2019.364
27	.00641	.00765	-2.429	2.429	-2019.364	-2602.276
28	.00765	.00865	-1.469	1.469	-2602.276	-2954.894
29	.00865	.00939	-.629	.629	-2954.894	-3105.836
30	.00939	.00969	-.200	.200	-3105.836	-3153.907
31	.00969	.00939	.200	-.200	-3153.907	-3105.836
32	.00939	.00865	.629	-.629	-3105.836	-2954.894
33	.00865	.00765	1.469	-1.469	-2954.894	-2602.276
34	.00765	.00641	2.429	-2.429	-2602.276	-2019.364
35	.00641	.00497	3.553	-3.553	-2019.364	-1166.604
36	.00497	.00339	4.861	-4.861	-1166.604	.000

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******************** FAILURE SEQUENCE ********************

YIELDING DETECTED IN BEAM 1 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 2 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 3 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 4 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 8 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 9 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 10 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 11 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 12 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 13 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 14 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 15 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 16 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 17 AT BASE SHEAR COEFF VALUE: .010

YIELDING DETECTED IN BEAM 18 AT BASE SHEAR COEFF VALUE: .010

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YIELDING DETECTED IN BEAM    19  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    20  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    21  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    22  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    36  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    37  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    38  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    39  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    43  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    44  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    45  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    46  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    47  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    48  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    49  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    50  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    51  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    52  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    53  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    54  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    55  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    56  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    57  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    71  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    72  AT BASE SHEAR COEFF VALUE:      .010
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YIELDING DETECTED IN BEAM    73  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    74  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    78  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    79  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    80  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    81  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    82  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    83  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    84  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    85  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    86  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    87  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    88  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    89  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    90  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    91  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM    92  AT BASE SHEAR COEFF VALUE:      .010
YIELDING DETECTED IN BEAM     5  AT BASE SHEAR COEFF VALUE:      .020
YIELDING DETECTED IN BEAM     6  AT BASE SHEAR COEFF VALUE:      .020
YIELDING DETECTED IN BEAM     7  AT BASE SHEAR COEFF VALUE:      .020
YIELDING DETECTED IN BEAM    40  AT BASE SHEAR COEFF VALUE:      .030
YIELDING DETECTED IN BEAM    41  AT BASE SHEAR COEFF VALUE:      .030
YIELDING DETECTED IN BEAM    42  AT BASE SHEAR COEFF VALUE:      .030
YIELDING DETECTED IN BEAM    75  AT BASE SHEAR COEFF VALUE:      .030
YIELDING DETECTED IN BEAM    77  AT BASE SHEAR COEFF VALUE:      .030
YIELDING DETECTED IN BEAM    76  AT BASE SHEAR COEFF VALUE:      .040
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YIELDING DETECTED IN BEAM    69  AT BASE SHEAR COEFF VALUE:      .050
YIELDING DETECTED IN BEAM    70  AT BASE SHEAR COEFF VALUE:      .050
YIELDING DETECTED IN BEAM   104  AT BASE SHEAR COEFF VALUE:      .050
YIELDING DETECTED IN BEAM   105  AT BASE SHEAR COEFF VALUE:      .050
YIELDING DETECTED IN BEAM    34  AT BASE SHEAR COEFF VALUE:      .070
YIELDING DETECTED IN BEAM    35  AT BASE SHEAR COEFF VALUE:      .070
YIELDING DETECTED IN BEAM    60  AT BASE SHEAR COEFF VALUE:      .070
YIELDING DETECTED IN BEAM    61  AT BASE SHEAR COEFF VALUE:      .070
YIELDING DETECTED IN BEAM    65  AT BASE SHEAR COEFF VALUE:      .070
YIELDING DETECTED IN BEAM    66  AT BASE SHEAR COEFF VALUE:      .070
YIELDING DETECTED IN BEAM    59  AT BASE SHEAR COEFF VALUE:      .080
YIELDING DETECTED IN BEAM    67  AT BASE SHEAR COEFF VALUE:      .080
YIELDING DETECTED IN BEAM    26  AT BASE SHEAR COEFF VALUE:      .090
YIELDING DETECTED IN BEAM    30  AT BASE SHEAR COEFF VALUE:      .090
YIELDING DETECTED IN BEAM    58  AT BASE SHEAR COEFF VALUE:      .090
YIELDING DETECTED IN BEAM    68  AT BASE SHEAR COEFF VALUE:      .090
YIELDING DETECTED IN BEAM    25  AT BASE SHEAR COEFF VALUE:      .100
YIELDING DETECTED IN BEAM    31  AT BASE SHEAR COEFF VALUE:      .100
YIELDING DETECTED IN BEAM    62  AT BASE SHEAR COEFF VALUE:      .100
YIELDING DETECTED IN BEAM    63  AT BASE SHEAR COEFF VALUE:      .100
YIELDING DETECTED IN BEAM    64  AT BASE SHEAR COEFF VALUE:      .100
YIELDING DETECTED IN BEAM    27  AT BASE SHEAR COEFF VALUE:      .110
YIELDING DETECTED IN BEAM    28  AT BASE SHEAR COEFF VALUE:      .110
YIELDING DETECTED IN BEAM    29  AT BASE SHEAR COEFF VALUE:      .110
YIELDING DETECTED IN BEAM    24  AT BASE SHEAR COEFF VALUE:      .120
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YIELDING DETECTED IN BEAM    32  AT BASE SHEAR COEFF VALUE:      .120
YIELDING DETECTED IN BEAM    23  AT BASE SHEAR COEFF VALUE:      .140
YIELDING DETECTED IN BEAM    33  AT BASE SHEAR COEFF VALUE:      .140
FLEXURAL YIELDING IN WALL     1  AT BASE SHEAR COEFF VALUE:      .180
FLEXURAL YIELDING IN WALL     2  AT BASE SHEAR COEFF VALUE:      .180
FLEXURAL YIELDING IN WALL     3  AT BASE SHEAR COEFF VALUE:      .180
FLEXURAL YIELDING IN WALL     4  AT BASE SHEAR COEFF VALUE:      .180
YIELDING DETECTED IN BEAM    93  AT BASE SHEAR COEFF VALUE:      .200
YIELDING DETECTED IN BEAM   103  AT BASE SHEAR COEFF VALUE:      .200
YIELDING DETECTED IN BEAM    94  AT BASE SHEAR COEFF VALUE:      .210
YIELDING DETECTED IN BEAM    95  AT BASE SHEAR COEFF VALUE:      .210
YIELDING DETECTED IN BEAM    96  AT BASE SHEAR COEFF VALUE:      .210
YIELDING DETECTED IN BEAM   100  AT BASE SHEAR COEFF VALUE:      .210
YIELDING DETECTED IN BEAM   101  AT BASE SHEAR COEFF VALUE:      .210
YIELDING DETECTED IN BEAM   102  AT BASE SHEAR COEFF VALUE:      .210
YIELDING DETECTED IN BEAM    97  AT BASE SHEAR COEFF VALUE:      .220
YIELDING DETECTED IN BEAM    98  AT BASE SHEAR COEFF VALUE:      .220
YIELDING DETECTED IN BEAM    99  AT BASE SHEAR COEFF VALUE:      .220
FLEXURAL YIELDING IN SLAB    30  AT BASE SHEAR COEFF VALUE:      .240
FLEXURAL YIELDING IN SLAB    31  AT BASE SHEAR COEFF VALUE:      .240
FLEXURAL YIELDING IN SLAB    18  AT BASE SHEAR COEFF VALUE:      .260
FLEXURAL YIELDING IN SLAB    19  AT BASE SHEAR COEFF VALUE:      .260
FLEXURAL YIELDING IN SLAB    30  AT BASE SHEAR COEFF VALUE:      .270
FLEXURAL YIELDING IN SLAB    31  AT BASE SHEAR COEFF VALUE:      .270
FLEXURAL YIELDING IN SLAB     6  AT BASE SHEAR COEFF VALUE:      .380
FLEXURAL YIELDING IN SLAB     7  AT BASE SHEAR COEFF VALUE:      .380
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YIELDING DETECTED IN COLUMN   4  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN   5  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN   6  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN   7  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN   8  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  28  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  36  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  37  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  38  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  39  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  40  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  41  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN  42  AT BASE SHEAR COEFF VALUE:      .410
YIELDING DETECTED IN COLUMN   2  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN   3  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN   9  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  10  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  16  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  17  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  18  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  27  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  29  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  34  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  35  AT BASE SHEAR COEFF VALUE:      .420
YIELDING DETECTED IN COLUMN  43  AT BASE SHEAR COEFF VALUE:      .420
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YIELDING DETECTED IN COLUMN  44  AT BASE SHEAR COEFF VALUE:      .420

YIELDING DETECTED IN BEAM    63  AT BASE SHEAR COEFF VALUE:      .420

YIELDING DETECTED IN COLUMN   1  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  11  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  14  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  15  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  19  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  20  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  25  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  26  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  30  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  31  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  50  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  72  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN 116  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN BEAM    41  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN BEAM    62  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN BEAM    64  AT BASE SHEAR COEFF VALUE:      .430

YIELDING DETECTED IN COLUMN  12  AT BASE SHEAR COEFF VALUE:      .440

YIELDING DETECTED IN COLUMN  13  AT BASE SHEAR COEFF VALUE:      .440

YIELDING DETECTED IN COLUMN  21  AT BASE SHEAR COEFF VALUE:      .440

YIELDING DETECTED IN COLUMN  22  AT BASE SHEAR COEFF VALUE:      .440

YIELDING DETECTED IN COLUMN  23  AT BASE SHEAR COEFF VALUE:      .440

YIELDING DETECTED IN COLUMN  24  AT BASE SHEAR COEFF VALUE:      .440

YIELDING DETECTED IN COLUMN  32  AT BASE SHEAR COEFF VALUE:      .440

YIELDING DETECTED IN COLUMN  33  AT BASE SHEAR COEFF VALUE:      .440
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 YIELDING DETECTED IN COLUMN  49  AT BASE SHEAR COEFF VALUE:      .440

 YIELDING DETECTED IN COLUMN  51  AT BASE SHEAR COEFF VALUE:      .440

 YIELDING DETECTED IN BEAM    40  AT BASE SHEAR COEFF VALUE:      .440

 YIELDING DETECTED IN BEAM    42  AT BASE SHEAR COEFF VALUE:      .440
1
 ***************  O U T P U T     O F     R E S U L T S  ***************




 ACTIVE SYSTEM OF UNITS:  INCH, KIPS




 FUNDAMENTAL PERIOD OF STRUCTURE (SEC):        .286


 MAXIMUM BASE SHEAR COEFFICIENT:               .440


 MAXIMUM DEFORMATION AT TOP ... FRAME 1:       .652
   (% OF BUILDING HEIGHT)
                                FRAME 2:       .857
                                FRAME 3:      1.060
                                FRAME 4:      1.261
                                FRAME 5:      1.460
                                FRAME 6:      1.656
                                FRAME 7:      1.752
                                FRAME 8:      1.656
                                FRAME 9:      1.460
                                FRAME10:      1.261
                                FRAME11:      1.060
                                FRAME12:       .857
                                FRAME13:       .652
```

********** VARIATION OF BASE SHEAR VS. OVERALL DEFORMATION (PERCENT) **********

STEP	BASE SHEAR	OVERALL TOP DEFORMATION (% OF BLDG. HEIGHT) FRA #: 1	2	3	4	5	6	7	8	9	10	FRA #: 11	12	13
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0100	.0017	.0022	.0027	.0031	.0035	.0037	.0038	.0037	.0035	.0031	.0027	.0022	.0017
3	.0200	.0036	.0047	.0057	.0066	.0073	.0078	.0080	.0078	.0073	.0066	.0057	.0047	.0036
4	.0300	.0056	.0073	.0088	.0101	.0112	.0120	.0123	.0120	.0112	.0101	.0088	.0073	.0056
5	.0400	.0076	.0098	.0120	.0138	.0153	.0164	.0168	.0164	.0153	.0138	.0120	.0098	.0076
6	.0500	.0095	.0124	.0151	.0174	.0193	.0207	.0213	.0207	.0193	.0174	.0151	.0124	.0095
7	.0600	.0116	.0151	.0183	.0212	.0235	.0251	.0258	.0251	.0235	.0212	.0183	.0151	.0116
8	.0700	.0136	.0178	.0216	.0249	.0276	.0296	.0304	.0296	.0276	.0249	.0216	.0178	.0136
9	.0800	.0157	.0205	.0249	.0288	.0319	.0342	.0352	.0342	.0319	.0288	.0249	.0205	.0157
10	.0900	.0179	.0233	.0284	.0328	.0363	.0389	.0400	.0389	.0363	.0328	.0284	.0233	.0179
11	.1000	.0201	.0262	.0319	.0368	.0408	.0437	.0449	.0437	.0408	.0368	.0319	.0262	.0201
12	.1100	.0224	.0292	.0355	.0410	.0455	.0488	.0501	.0488	.0455	.0410	.0355	.0292	.0224
13	.1200	.0247	.0322	.0392	.0453	.0503	.0539	.0554	.0539	.0503	.0453	.0392	.0322	.0247
14	.1300	.0270	.0353	.0430	.0496	.0551	.0590	.0607	.0590	.0551	.0496	.0430	.0353	.0270
15	.1400	.0293	.0383	.0467	.0539	.0598	.0642	.0660	.0642	.0598	.0539	.0467	.0383	.0293
16	.1500	.0317	.0414	.0504	.0583	.0647	.0693	.0713	.0693	.0647	.0583	.0504	.0414	.0317
17	.1600	.0340	.0445	.0542	.0626	.0695	.0745	.0766	.0745	.0695	.0626	.0542	.0445	.0340
18	.1700	.0363	.0475	.0579	.0669	.0743	.0797	.0819	.0797	.0743	.0669	.0579	.0475	.0363
19	.1800	.0387	.0506	.0616	.0712	.0791	.0848	.0872	.0848	.0791	.0712			

		.0616	.0506	.0387							
20	.1900	.0661	.0783	.0895	.0994	.1073	.1132	.1157	.1132	.1073	.0994
		.0895	.0783	.0661							
21	.2000	.0936	.1060	.1175	.1275	.1356	.1416	.1441	.1416	.1356	.1275
		.1175	.1060	.0936							
22	.2100	.1217	.1344	.1461	.1563	.1646	.1707	.1732	.1707	.1646	.1563
		.1461	.1344	.1217							
23	.2200	.1512	.1642	.1762	.1867	.1952	.2015	.2041	.2015	.1952	.1867
		.1762	.1642	.1512							
24	.2300	.1814	.1949	.2074	.2183	.2271	.2336	.2363	.2336	.2271	.2183
		.2074	.1949	.1814							
25	.2400	.2117	.2256	.2385	.2498	.2590	.2657	.2685	.2657	.2590	.2498
		.2385	.2256	.2117							
26	.2500	.2404	.2565	.2715	.2849	.2962	.3050	.3095	.3050	.2962	.2849
		.2715	.2565	.2404							
27	.2600	.2690	.2873	.3045	.3201	.3335	.3444	.3506	.3444	.3335	.3201
		.3045	.2873	.2690							
28	.2700	.2928	.3181	.3423	.3648	.3851	.4029	.4149	.4029	.3851	.3648
		.3423	.3181	.2928							
29	.2800	.3161	.3489	.3806	.4106	.4384	.4638	.4791	.4638	.4384	.4106
		.3806	.3489	.3161							
30	.2900	.3394	.3797	.4190	.4565	.4918	.5246	.5434	.5246	.4918	.4565
		.4190	.3797	.3394							
31	.3000	.3627	.4106	.4573	.5024	.5452	.5854	.6077	.5854	.5452	.5024
		.4573	.4106	.3627							
32	.3100	.3860	.4414	.4957	.5482	.5985	.6463	.6720	.6463	.5985	.5482
		.4957	.4414	.3860							
33	.3200	.4093	.4722	.5341	.5941	.6519	.7071	.7362	.7071	.6519	.5941
		.5341	.4722	.4093							
34	.3300	.4326	.5031	.5724	.6400	.7052	.7680	.8005	.7680	.7052	.6400
		.5724	.5031	.4326							
35	.3400	.4559	.5339	.6108	.6858	.7586	.8288	.8648	.8288	.7586	.6858
		.6108	.5339	.4559							
36	.3500	.4792	.5648	.6491	.7317	.8120	.8896	.9291	.8896	.8120	.7317
		.6491	.5648	.4792							
37	.3600	.5025	.5956	.6875	.7776	.8653	.9505	.9933	.9505	.8653	.7776
		.6875	.5956	.5025							
38	.3700	.5258	.6264	.7259	.8234	.9187	1.0113	1.0576	1.0113	.9187	.8234
		.7259	.6264	.5258							
39	.3800	.5491	.6573	.7642	.8693	.9720	1.0721	1.1219	1.0721	.9720	.8693
		.7642	.6573	.5491							
40	.3900	.5664	.6859	.8041	.9204	1.0343	1.1456	1.2006	1.1456	1.0343	.9204
		.8041	.6859	.5664							
41	.4000	.5838	.7145	.8439	.9715	1.0966	1.2191	1.2793	1.2191	1.0966	.9715
		.8439	.7145	.5838							
42	.4100	.6011	.7431	.8838	1.0225	1.1589	1.2925	1.3580	1.2925	1.1589	1.0225
		.8838	.7431	.6011							
43	.4200	.6180	.7736	.9280	1.0804	1.2304	1.3776	1.4496	1.3776	1.2304	1.0804
		.9280	.7736	.6180							
44	.4300	.6347	.8081	.9802	1.1502	1.3179	1.4828	1.5633	1.4828	1.3179	1.1502
		.9802	.8081	.6347							

```
   45          .4400     .6522     .8567    1.0599    1.2610    1.4597    1.6556    1.7517    1.6556    1.4597    1.2610
                        1.0599     .8567     .6522
1

                       ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   1

          B     0.50+
          A          |
          S          |
          E          |
                     |
          S     0.45+                                *
          H          |                               *
          E          |                              *
          A          |                             *
          R          |                            *
                0.40+                            *
          C          |                          *
          O          |                         *
          E          |                        *
          F          |                       *
          F     0.35+                       *
                     |                     *
                     |                   *
                     |                  *
                     |                 *
                0.30+                 *
                     |               *
                     |              *
                     |            *
                     |           *
                0.25+          *
                     |        *
                     |       *
                     |     *
                     |    *
                0.20+  *
                     | *
                     | *
                     | *
                     | *
                0.15+*
                     |*
                     |*
                     |*
                     |*
                0.10+*
                     |*
                     |*
                     |*
```

```
                   *
               0.05+
                   *
                   *
                   *
-------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                  0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                   |
                   |                                                                           TOP DEFORM. (% OF HT.)
                   |
                   |
1

                         ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   2

         B     0.50+
         A         |
         S         |
         E         |
                   |
         S     0.45+                                          *
         H         |                                       *
         E         |                                      *
         A         |                                    *
         R         |                                   *
               0.40+                                 *
         C         |                                *
         O         |                              *
         E         |                             *
         F         |                           *
         F     0.35+                          *
                   |                        *
                   |                       *
                   |                     *
                   |                    *
               0.30+                  *
                   |                *
                   |               *
                   |             *
                   |            *
               0.25+          *
                   |         *
                   |       *
                   |      *
                   |    *
               0.20+   *
                   |  *
                   | *
                   | *
                   | *
```

```
                0.15+ *
                    | *
                    | *
                    |*
                    |*
                0.10+*
                    |*
                    |*
                    |*
                    |*
                0.05+
                    *
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1
                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   3

          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                                    *
          H         |                                                *
          E         |                                             *
          A         |                                           *
          R         |                                         *
                0.40+                                       *
          C         |                                     *
          O         |                                   *
          E         |                                 *
          F         |                               *
          F     0.35+                              *
                    |                            *
                    |                          *
                    |                        *
                    |                      *
                0.30+                    *
                    |                  *
                    |                *
                    |              *
                    |             *
                0.25+           *
```

```
                    |         *
                    |        *
                    |      *
                    |     *
                0.20+   *
                    |  *
                    |  *
                    |  *
                    |  *
                0.15+ *
                    | *
                    | *
                    | *
                    | *
                0.10+*
                    |*
                    |*
                    |*
                    |*
                0.05+*
                    *
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

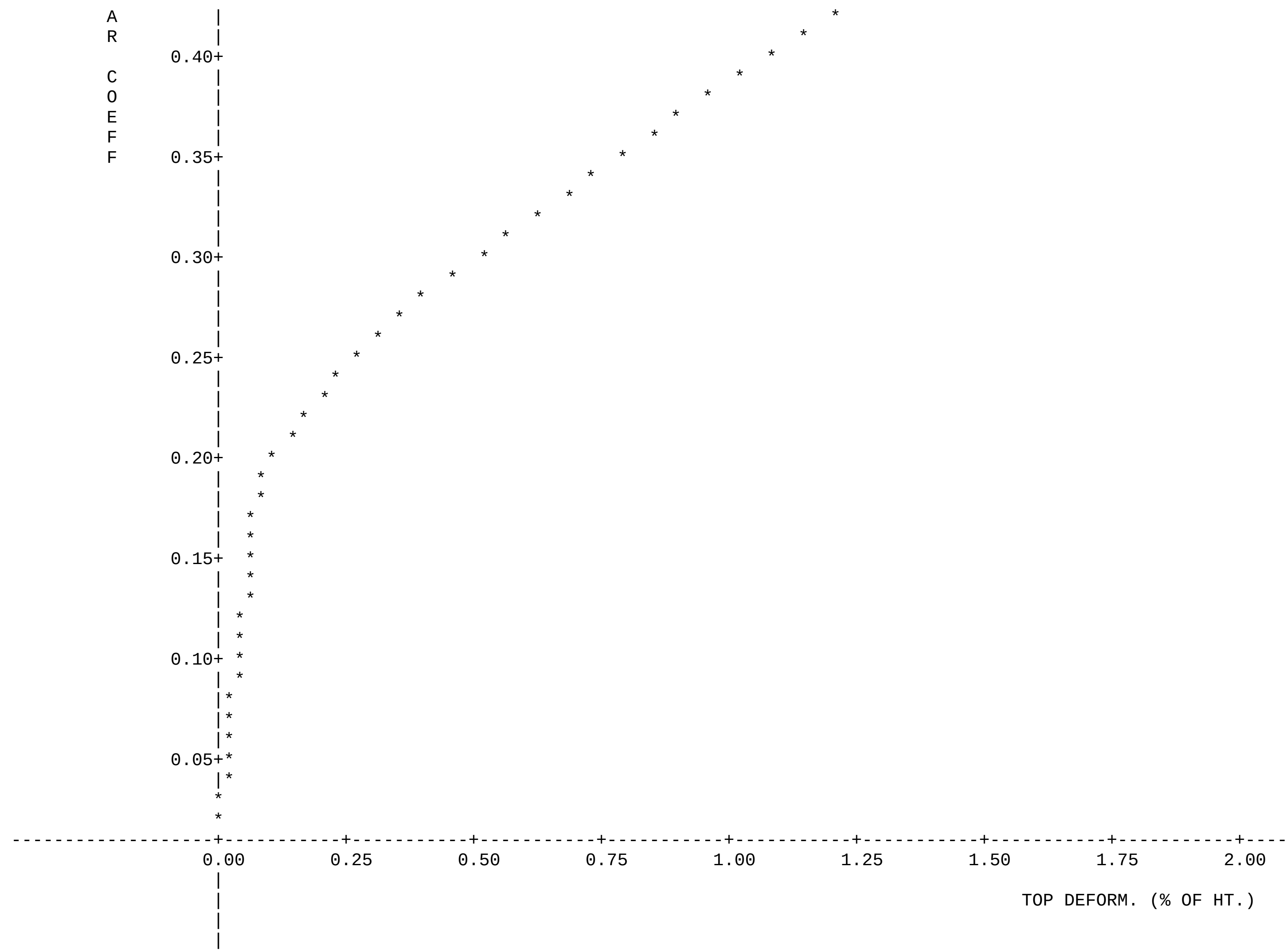
                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   4

          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                                              *
          H         |                                                         *
          E         |                                                     *
          A         |                                                  *
          R         |                                                *
                0.40+                                             *
          C         |                                          *
          O         |                                        *
          E         |                                      *
          F         |                                    *
          F     0.35+                                 *
                    |                               *
```

```
                    |                             *
                    |                          *
                    |                        *
                0.30+                      *
                    |                    *
                    |                 *
                    |               *
                    |             *
                0.25+           *
                    |          *
                    |        *
                    |       *
                    |     *
                0.20+    *
                    |   *
                    |  *
                    |  *
                    |  *
                0.15+  *
                    | *
                    | *
                    | *
                    | *
                0.10+ *
                    |*
                    |*
                    |*
                    |*
                0.05+*
                    |*
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

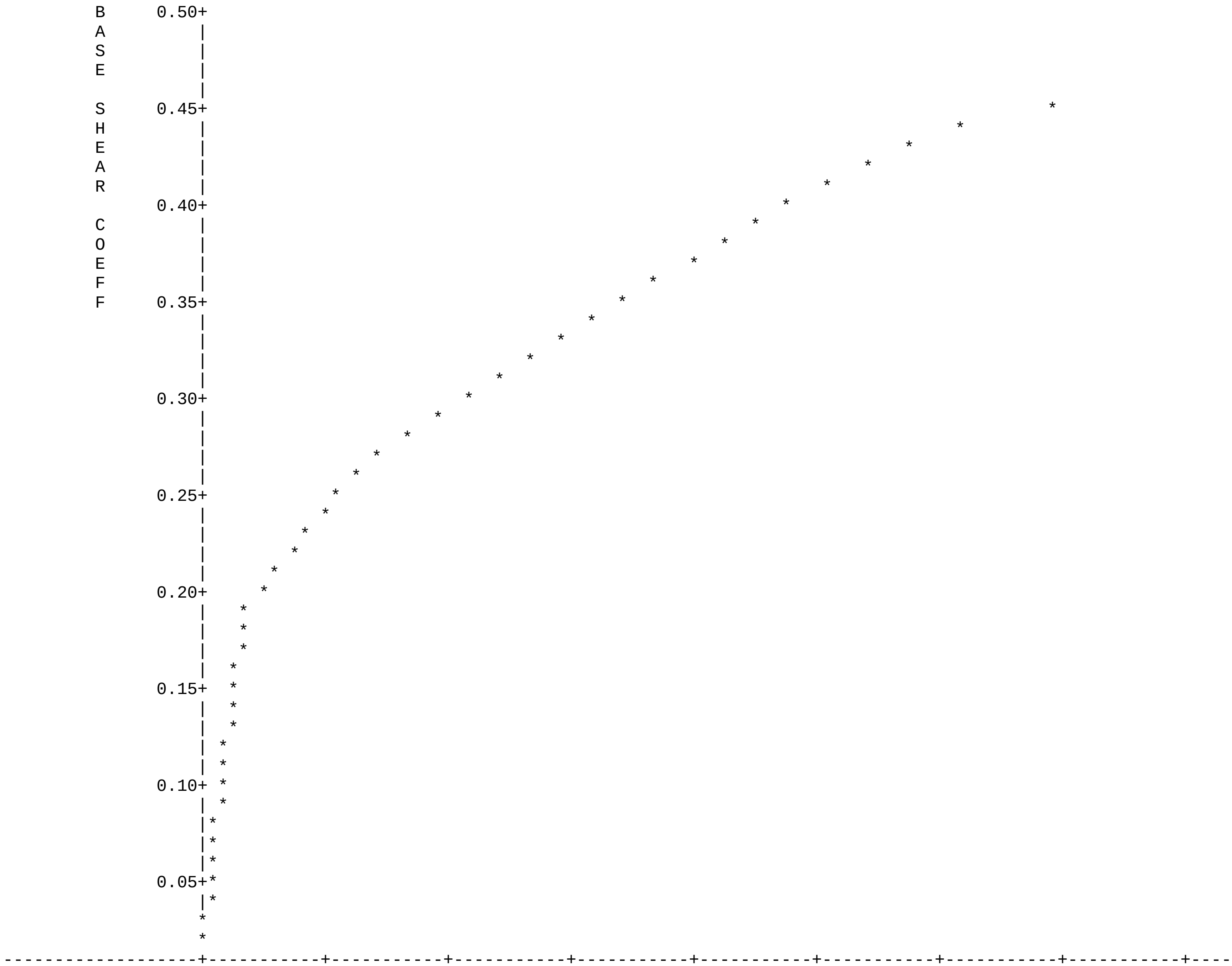
                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   5

          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                                                        *
          H         |                                                                 *
          E         |                                                             *
```



1

********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME 6


BASE SHEAR COEFF
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05

```
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   7

          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                                                                       *
          H         |                                                                             *
          E         |                                                                       *
          A         |                                                                   *
          R         |                                                               *
                0.40+                                                           *
          C         |                                                       *
          O         |                                                    *
          E         |                                                 *
          F         |                                             *
          F     0.35+                                          *
                    |                                       *
                    |                                    *
                    |                                 *
                    |                             *
                0.30+                          *
                    |                       *
                    |                    *
                    |                 *
                    |              *
                0.25+            *
                    |           *
                    |         *
                    |        *
                    |      *
                0.20+     *
                    |   *
                    |   *
                    |   *
                    |   *
                0.15+  *
                    |  *
                    |  *
                    |  *
                    | *
                0.10+ *
```

```
                    | *
                    | *
                    |*
                    |*
                0.05+*
                    |*
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   8

          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                                                                  *
          H         |                                                                         *
          E         |                                                                    *
          A         |                                                                *
          R         |                                                            *
                0.40+                                                        *
          C         |                                                     *
          O         |                                                  *
          E         |                                               *
          F         |                                           *
          F     0.35+                                        *
                    |                                     *
                    |                                  *
                    |                               *
                    |                            *
                0.30+                         *
                    |                      *
                    |                   *
                    |                *
                    |              *
                0.25+            *
                    |           *
                    |         *
                    |        *
                    |      *
                0.20+     *
                    |   *
```

```
                    |   *
                    |   *
                    |  *
                0.15+  *
                    |  *
                    |  *
                    | *
                    | *
                0.10+ *
                    | *
                    |*
                    |*
                    |*
                0.05+*
                    |*
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME   9

          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                                                        *
          H         |                                                                 *
          E         |                                                             *
          A         |                                                         *
          R         |                                                      *
                0.40+                                                   *
          C         |                                                *
          O         |                                             *
          E         |                                          *
          F         |                                        *
          F     0.35+                                     *
                    |                                  *
                    |                                *
                    |                             *
                    |                          *
                0.30+                        *
                    |                     *
                    |                  *
```

```
                    |                *
                    |              *
                0.25+            *
                    |          *
                    |         *
                    |       *
                    |      *
                0.20+    *
                    |   *
                    |   *
                    |  *
                    |  *
                0.15+  *
                    |  *
                    |  *
                    | *
                    | *
                0.10+ *
                    | *
                    |*
                    |*
                    |*
                0.05+*
                    |*
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

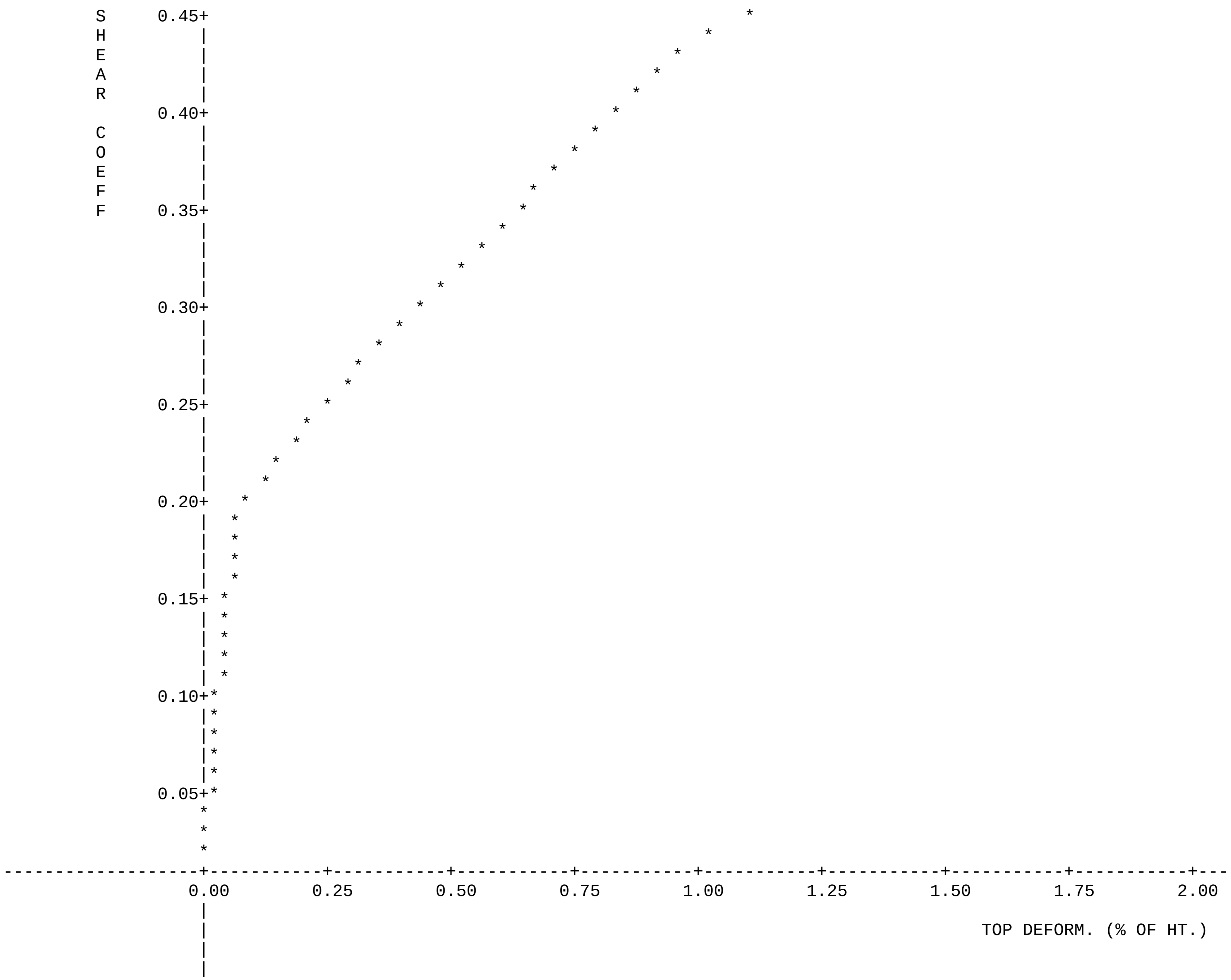
                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME  10

          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                                              *
          H         |                                                         *
          E         |                                                     *
          A         |                                                  *
          R         |                                                *
                0.40+                                             *
          C         |                                          *
          O         |                                        *
          E         |                                      *
```

```
          F         |                                    *
          F     0.35+                                 *
                    |                               *
                    |                             *
                    |                          *
                    |                        *
                0.30+                      *
                    |                    *
                    |                 *
                    |               *
                    |             *
                0.25+           *
                    |          *
                    |        *
                    |       *
                    |     *
                0.20+    *
                    |   *
                    |  *
                    |  *
                    |  *
                0.15+  *
                    | *
                    | *
                    | *
                    | *
                0.10+ *
                    |*
                    |*
                    |*
                    |*
                0.05+*
                    |*
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME  11

          B     0.50+
          A         |
          S         |
          E         |
                    |
```


SHEAR COEFF
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
TOP DEFORM. (% OF HT.)

1

```
                ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME  12

B     0.50+
A         |
S         |
E         |
          |
S     0.45+                                          *
H         |                                       *
E         |                                      *
A         |                                    *
R         |                                   *
      0.40+                                 *
C         |                                *
O         |                              *
E         |                             *
F         |                           *
F     0.35+                          *
          |                        *
          |                       *
          |                     *
          |                    *
      0.30+                  *
          |                *
          |               *
          |             *
          |            *
      0.25+          *
          |         *
          |       *
          |      *
          |    *
      0.20+   *
          |  *
          | *
          | *
          | *
      0.15+ *
          | *
          | *
          |*
          |*
      0.10+*
          |*
          |*
          |*
          |*
      0.05+
          *
```

```
                    *
                    *
 -------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                   0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                    |
                    |                                                                           TOP DEFORM. (% OF HT.)
                    |
                    |
1

                          ********** PLOT OF BASE SHEAR VS. TOP DEFORMATION ****** FRAME  13


          B     0.50+
          A         |
          S         |
          E         |
                    |
          S     0.45+                                *
          H         |                               *
          E         |                              *
          A         |                             *
          R         |                            *
                0.40+                           *
          C         |                          *
          O         |                         *
          E         |                        *
          F         |                       *
          F     0.35+                      *
                    |                     *
                    |                   *
                    |                  *
                    |                 *
                0.30+                *
                    |               *
                    |              *
                    |            *
                    |           *
                0.25+          *
                    |        *
                    |       *
                    |     *
                    |    *
                0.20+  *
                    | *
                    | *
                    | *
                    | *
                0.15+*
                    |*
                    |*
```

```
                 |*
                 |*
             0.10+*
                 |*
                 |*
                 |*
                 *
             0.05+
                 *
                 *
                 *
-------------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+----
                 0.00        0.25        0.50        0.75        1.00        1.25        1.50        1.75        2.00
                 |
                 |                                                                          TOP DEFORM. (% OF HT.)
                 |
                 |
1
******************** U L T I M A T E   F A I L U R E   M O D E ********************



FAILURE MODE OF FRAME NO.  1


       +E---------Y+
       E          E
       W          W
       E          E
       W          W
       E          E
       +E---------Y+
       E          E
       W          W
       E          E
       W          W
       E          E
       +E---------Y+
       E          E
       W          W
       E          E
       W          W
       Y          Y


NOTATION:

-  =  BEAM                 E  =  ELASTIC
```

```
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN
```

1

FAILURE MODE OF FRAME NO. 2

```
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       E           E           E           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       E           E           E           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       Y           Y           Y           Y
```

NOTATION:

```
 -  =  BEAM                  E  =  ELASTIC
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN
```

1

FAILURE MODE OF FRAME NO. 3

```
       +E---------Y+E---------Y+E---------Y+
```

```
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       E           E           E           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       E           E           E           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       Y           Y           Y           Y
```

```
NOTATION:

-  =  BEAM                  E  =  ELASTIC
!  =  COLUMN                C  =  CRACK
W  =  SHEAR WALL            Y  =  YIELD
I  =  EDGE COLUMN
```

1

FAILURE MODE OF FRAME NO. 4

```
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       E           E           E           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       E           E           E           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
```

```
        !           !           !           !
        !           !           !           !
        Y           Y           Y           Y


 NOTATION:

 -  =  BEAM                 E  =  ELASTIC
 !  =  COLUMN               C  =  CRACK
 W  =  SHEAR WALL           Y  =  YIELD
 I  =  EDGE COLUMN



1

 FAILURE MODE OF FRAME NO.  5



        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        E           E           E           E
        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        E           E           E           E
        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        Y           Y           Y           Y


 NOTATION:

 -  =  BEAM                 E  =  ELASTIC
 !  =  COLUMN               C  =  CRACK
 W  =  SHEAR WALL           Y  =  YIELD
 I  =  EDGE COLUMN
```

```
1


 FAILURE MODE OF FRAME NO.  6


        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        E           E           E           E
        +Y---------Y+E---------Y+Y---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        Y           E           E           E
        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        Y           Y           Y           Y


 NOTATION:

 -  =  BEAM                  E  =  ELASTIC
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN


1


 FAILURE MODE OF FRAME NO.  7


        +E---------Y+E---------Y+E---------Y+
        E           E           Y           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        E           E           E           E
```

```
       +Y---------Y+E---------Y+Y---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       Y           E           Y           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       Y           Y           Y           Y
```

NOTATION:

```
- = BEAM            E = ELASTIC
! = COLUMN          C = CRACK
W = SHEAR WALL      Y = YIELD
I = EDGE COLUMN
```

1

FAILURE MODE OF FRAME NO. 8

```
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       E           E           E           E
       +Y---------Y+E---------Y+Y---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       Y           E           E           E
       +E---------Y+E---------Y+E---------Y+
       E           E           E           E
       !           !           !           !
       !           !           !           !
       !           !           !           !
       Y           Y           Y           Y
```

```
 NOTATION:

 -  =  BEAM                  E  =  ELASTIC
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN



1


 FAILURE MODE OF FRAME NO.  9



        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        E           E           E           E
        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        E           E           E           E
        +E---------Y+E---------Y+E---------Y+
        E           E           E           E
        !           !           !           !
        !           !           !           !
        !           !           !           !
        Y           Y           Y           Y


 NOTATION:

 -  =  BEAM                  E  =  ELASTIC
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN



1


 FAILURE MODE OF FRAME NO. 10
```

```
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
E           E           E           E
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
E           E           E           E
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
Y           Y           Y           Y
```

```
NOTATION:

-  =  BEAM                 E  =  ELASTIC
!  =  COLUMN               C  =  CRACK
W  =  SHEAR WALL           Y  =  YIELD
I  =  EDGE COLUMN
```

1

FAILURE MODE OF FRAME NO. 11

```
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
E           E           E           E
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
```

```
E           E           E           E
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
Y           Y           Y           Y
```

NOTATION:

```
-  =  BEAM                 E  =  ELASTIC
!  =  COLUMN               C  =  CRACK
W  =  SHEAR WALL           Y  =  YIELD
I  =  EDGE COLUMN
```

1

FAILURE MODE OF FRAME NO. 12

```
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
E           E           E           E
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
E           E           E           E
+E---------Y+E---------Y+E---------Y+
E           E           E           E
!           !           !           !
!           !           !           !
!           !           !           !
Y           Y           Y           Y
```

NOTATION:

```
-  =  BEAM                 E  =  ELASTIC
!  =  COLUMN               C  =  CRACK
```

```
 W  =  SHEAR WALL           Y  =  YIELD
 I  =  EDGE COLUMN



1


 FAILURE MODE OF FRAME NO. 13



        +E---------Y+
        E           E
        W           W
        E           E
        W           W
        E           E
        +E---------Y+
        E           E
        W           W
        E           E
        W           W
        E           E
        +E---------Y+
        E           E
        W           W
        E           E
        W           W
        Y           Y


 NOTATION:

 -  =  BEAM                 E  =  ELASTIC
 !  =  COLUMN               C  =  CRACK
 W  =  SHEAR WALL           Y  =  YIELD
 I  =  EDGE COLUMN
```

```
 ********** SLAB STATE AT FAILURE OF FRAME **********
```

SLAB	FRONT	MIDDLE	REAR
1	E	E	E
2	E	E	E
3	E	E	E
4	E	E	E
5	E	E	E
6	Y	E	Y
7	Y	E	Y
8	E	E	E
9	E	E	E
10	E	E	E
11	E	E	E
12	E	E	E
13	E	E	E
14	E	E	E
15	E	E	E
16	E	E	E
17	E	E	E
18	Y	E	Y
19	Y	E	Y
20	E	E	E
21	E	E	E
22	E	E	E
23	E	E	E

24	E	E	E
25	E	E	E
26	E	E	E
27	E	E	E
28	E	E	E
29	E	E	E
30	Y	E	Y
31	Y	E	Y
32	E	E	E
33	E	E	E
34	E	E	E
35	E	E	E
36	E	E	E

1

OUTPUT NOTATION:

AXIAL STIFFNESS = (E A)/L : KIP/IN
FLEXURAL STIFFNESS = (EI) : KSI

********** COLUMN PROPERTIES **********

NO.	MEMBER LENGTH	AXIAL STIFFNESS	CRACKING MOMENT	YIELD MOMENT	INITIAL FLEXURAL STIFFNESS	POST YIELDING STIFFNESS	YIELD CURVATURE
1	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3051E+06	.7261E-03
2	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3035E+06	.6941E-03
3	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3024E+06	.6711E-03
4	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3013E+06	.6424E-03
5	.1490E+03	.4529E+04	.5761E+03	.2318E+04	.1543E+08	.2773E+06	.6150E-03

6	.1490E+03	.4529E+04	.5471E+03	.2264E+04	.1543E+08	.2484E+06	.5965E-03
7	.1490E+03	.4529E+04	.5761E+03	.2318E+04	.1543E+08	.2773E+06	.6150E-03
8	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3013E+06	.6424E-03
9	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3024E+06	.6711E-03
10	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3035E+06	.6941E-03
11	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3051E+06	.7261E-03
12	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3230E+06	.6719E-03
13	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3230E+06	.6723E-03
14	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3181E+06	.6289E-03
15	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3167E+06	.6151E-03
16	.1490E+03	.4529E+04	.7287E+03	.2591E+04	.1543E+08	.3329E+06	.5848E-03
17	.1490E+03	.4529E+04	.6659E+03	.2481E+04	.1543E+08	.3271E+06	.5822E-03
18	.1490E+03	.4529E+04	.7287E+03	.2591E+04	.1543E+08	.3329E+06	.5848E-03
19	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3167E+06	.6151E-03
20	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3181E+06	.6289E-03
21	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3230E+06	.6723E-03
22	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3230E+06	.6719E-03
23	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3241E+06	.6807E-03
24	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3242E+06	.6813E-03
25	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3190E+06	.6376E-03
26	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3176E+06	.6246E-03
27	.1490E+03	.4529E+04	.7287E+03	.2591E+04	.1543E+08	.3348E+06	.6078E-03
28	.1490E+03	.4529E+04	.6659E+03	.2481E+04	.1543E+08	.3283E+06	.6020E-03
29	.1490E+03	.4529E+04	.7287E+03	.2591E+04	.1543E+08	.3348E+06	.6078E-03
30	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3176E+06	.6246E-03
31	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3190E+06	.6376E-03
32	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3242E+06	.6813E-03
33	.1490E+03	.4529E+04	.7928E+03	.2702E+04	.1543E+08	.3241E+06	.6807E-03
34	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3055E+06	.7331E-03
35	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3040E+06	.7036E-03
36	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3026E+06	.6741E-03
37	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3014E+06	.6449E-03
38	.1490E+03	.4529E+04	.5761E+03	.2318E+04	.1543E+08	.2769E+06	.6002E-03
39	.1490E+03	.4529E+04	.5471E+03	.2264E+04	.1543E+08	.2485E+06	.5819E-03
40	.1490E+03	.4529E+04	.5761E+03	.2318E+04	.1543E+08	.2769E+06	.6002E-03
41	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3014E+06	.6449E-03
42	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3026E+06	.6741E-03
43	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3040E+06	.7036E-03
44	.1490E+03	.4529E+04	.6057E+03	.2372E+04	.1543E+08	.3055E+06	.7331E-03
45	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2563E+06	.8357E-03
46	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2557E+06	.8550E-03
47	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2559E+06	.8472E-03
48	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2561E+06	.8394E-03
49	.1420E+03	.4529E+04	.5317E+03	.2235E+04	.1533E+08	.2315E+06	.8306E-03
50	.1420E+03	.4529E+04	.5117E+03	.2198E+04	.1533E+08	.2202E+06	.8273E-03
51	.1420E+03	.4529E+04	.5317E+03	.2235E+04	.1533E+08	.2315E+06	.8306E-03
52	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2561E+06	.8394E-03
53	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2559E+06	.8472E-03
54	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2557E+06	.8550E-03
55	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2563E+06	.8357E-03
56	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3480E+06	.8030E-03

57	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3510E+06	.8372E-03
58	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3508E+06	.8474E-03
59	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3509E+06	.8410E-03
60	.1420E+03	.4529E+04	.6330E+03	.2422E+04	.1533E+08	.3301E+06	.8358E-03
61	.1420E+03	.4529E+04	.5882E+03	.2340E+04	.1533E+08	.2953E+06	.8311E-03
62	.1420E+03	.4529E+04	.6330E+03	.2422E+04	.1533E+08	.3301E+06	.8358E-03
63	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3509E+06	.8410E-03
64	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3508E+06	.8474E-03
65	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3510E+06	.8372E-03
66	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3480E+06	.8030E-03
67	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3510E+06	.8365E-03
68	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3507E+06	.8491E-03
69	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3509E+06	.8404E-03
70	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3510E+06	.8358E-03
71	.1420E+03	.4529E+04	.6330E+03	.2422E+04	.1533E+08	.3303E+06	.8307E-03
72	.1420E+03	.4529E+04	.5882E+03	.2340E+04	.1533E+08	.2955E+06	.8265E-03
73	.1420E+03	.4529E+04	.6330E+03	.2422E+04	.1533E+08	.3303E+06	.8307E-03
74	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3510E+06	.8358E-03
75	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3509E+06	.8404E-03
76	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3507E+06	.8491E-03
77	.1420E+03	.4529E+04	.6738E+03	.2495E+04	.1533E+08	.3510E+06	.8365E-03
78	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2561E+06	.8424E-03
79	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2557E+06	.8559E-03
80	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2559E+06	.8467E-03
81	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2561E+06	.8397E-03
82	.1420E+03	.4529E+04	.5317E+03	.2235E+04	.1533E+08	.2317E+06	.8261E-03
83	.1420E+03	.4529E+04	.5117E+03	.2198E+04	.1533E+08	.2203E+06	.8231E-03
84	.1420E+03	.4529E+04	.5317E+03	.2235E+04	.1533E+08	.2317E+06	.8261E-03
85	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2561E+06	.8397E-03
86	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2559E+06	.8467E-03
87	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2557E+06	.8559E-03
88	.1420E+03	.4529E+04	.5513E+03	.2272E+04	.1533E+08	.2561E+06	.8424E-03
89	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2243E+06	.8088E-03
90	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2249E+06	.7954E-03
91	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2250E+06	.7805E-03
92	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2248E+06	.7624E-03
93	.1420E+03	.4529E+04	.4867E+03	.2150E+04	.1533E+08	.2268E+06	.7614E-03
94	.1420E+03	.4529E+04	.4757E+03	.2129E+04	.1533E+08	.2292E+06	.7592E-03
95	.1420E+03	.4529E+04	.4867E+03	.2150E+04	.1533E+08	.2268E+06	.7614E-03
96	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2248E+06	.7624E-03
97	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2250E+06	.7805E-03
98	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2249E+06	.7954E-03
99	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2243E+06	.8088E-03
100	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2669E+06	.8093E-03
101	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2662E+06	.7882E-03
102	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2651E+06	.7589E-03
103	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2647E+06	.7441E-03
104	.1420E+03	.4529E+04	.5380E+03	.2247E+04	.1533E+08	.2397E+06	.7370E-03
105	.1420E+03	.4529E+04	.5133E+03	.2201E+04	.1533E+08	.2205E+06	.7501E-03
106	.1420E+03	.4529E+04	.5380E+03	.2247E+04	.1533E+08	.2397E+06	.7370E-03
107	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2647E+06	.7441E-03

108	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2651E+06	.7589E-03
109	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2662E+06	.7882E-03
110	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2669E+06	.8093E-03
111	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2666E+06	.7989E-03
112	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2658E+06	.7771E-03
113	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2650E+06	.7533E-03
114	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2646E+06	.7419E-03
115	.1420E+03	.4529E+04	.5380E+03	.2247E+04	.1533E+08	.2398E+06	.7443E-03
116	.1420E+03	.4529E+04	.5133E+03	.2201E+04	.1533E+08	.2207E+06	.7605E-03
117	.1420E+03	.4529E+04	.5380E+03	.2247E+04	.1533E+08	.2398E+06	.7443E-03
118	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2646E+06	.7419E-03
119	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2650E+06	.7533E-03
120	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2658E+06	.7771E-03
121	.1420E+03	.4529E+04	.5595E+03	.2287E+04	.1533E+08	.2666E+06	.7989E-03
122	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2243E+06	.8091E-03
123	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2249E+06	.7957E-03
124	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2250E+06	.7758E-03
125	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2246E+06	.7516E-03
126	.1420E+03	.4529E+04	.4867E+03	.2150E+04	.1533E+08	.2264E+06	.7236E-03
127	.1420E+03	.4529E+04	.4757E+03	.2129E+04	.1533E+08	.2286E+06	.7124E-03
128	.1420E+03	.4529E+04	.4867E+03	.2150E+04	.1533E+08	.2264E+06	.7236E-03
129	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2246E+06	.7516E-03
130	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2250E+06	.7758E-03
131	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2249E+06	.7957E-03
132	.1420E+03	.4529E+04	.4960E+03	.2168E+04	.1533E+08	.2243E+06	.8091E-03

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********** BEAM PROPERTIES ********** ***** POSITIVE MOMENTS,CURVATURES *****

BEAM NO.	MEMBER LENGTH	INITIAL MOMENT (LEFT)	INITIAL MOMENT (RIGHT)	CRACKING MOMENT (+)	YIELD MOMENT (+)	CRACK CLOSING MOMENT	INITIAL FLEXURAL STIFFNESS	POST YIELDING STIFFNESS (+)	YIELD CURVATURE (+)
1	.2260E+03	-.7544E+03	-.1541E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
2	.2260E+03	-.7453E+03	-.1544E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
3	.2260E+03	-.7444E+03	-.1544E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
4	.2260E+03	-.7495E+03	-.1543E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
5	.2260E+03	-.6488E+03	-.1153E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
6	.2260E+03	-.6542E+03	-.1151E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
7	.2260E+03	-.6488E+03	-.1153E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
8	.2260E+03	-.7495E+03	-.1543E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
9	.2260E+03	-.7444E+03	-.1544E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
10	.2260E+03	-.7453E+03	-.1544E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
11	.2260E+03	-.7544E+03	-.1541E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
12	.2260E+03	-.9139E+03	-.1620E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
13	.2260E+03	-.9105E+03	-.1628E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
14	.2260E+03	-.9095E+03	-.1629E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04

15	.2260E+03	-.9053E+03	-.1628E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
16	.2260E+03	-.8806E+03	-.1503E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
17	.2260E+03	-.8770E+03	-.1502E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
18	.2260E+03	-.8806E+03	-.1503E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
19	.2260E+03	-.9053E+03	-.1628E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
20	.2260E+03	-.9095E+03	-.1629E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
21	.2260E+03	-.9105E+03	-.1628E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
22	.2260E+03	-.9139E+03	-.1620E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
23	.2260E+03	-.1112E+04	-.8694E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
24	.2260E+03	-.1110E+04	-.8594E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
25	.2260E+03	-.1109E+04	-.8602E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
26	.2260E+03	-.1111E+04	-.8663E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
27	.2260E+03	-.8774E+03	-.7142E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
28	.2260E+03	-.8799E+03	-.7196E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
29	.2260E+03	-.8774E+03	-.7142E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
30	.2260E+03	-.1111E+04	-.8663E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
31	.2260E+03	-.1109E+04	-.8602E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
32	.2260E+03	-.1110E+04	-.8594E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
33	.2260E+03	-.1112E+04	-.8694E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
34	.2260E+03	-.8820E+03	-.9101E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
35	.2260E+03	-.8820E+03	-.9101E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
36	.2260E+03	-.8045E+03	-.1531E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
37	.2260E+03	-.7955E+03	-.1537E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
38	.2260E+03	-.7915E+03	-.1539E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
39	.2260E+03	-.7929E+03	-.1538E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
40	.2260E+03	-.6774E+03	-.1122E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
41	.2260E+03	-.6811E+03	-.1119E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
42	.2260E+03	-.6774E+03	-.1122E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
43	.2260E+03	-.7929E+03	-.1538E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
44	.2260E+03	-.7915E+03	-.1539E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
45	.2260E+03	-.7955E+03	-.1537E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
46	.2260E+03	-.8045E+03	-.1531E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
47	.2260E+03	-.9262E+03	-.1565E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
48	.2260E+03	-.9202E+03	-.1571E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
49	.2260E+03	-.9173E+03	-.1574E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
50	.2260E+03	-.9103E+03	-.1578E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
51	.2260E+03	-.8638E+03	-.1498E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
52	.2260E+03	-.8586E+03	-.1500E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
53	.2260E+03	-.8638E+03	-.1498E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
54	.2260E+03	-.9103E+03	-.1578E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
55	.2260E+03	-.9173E+03	-.1574E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
56	.2260E+03	-.9202E+03	-.1571E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
57	.2260E+03	-.9262E+03	-.1565E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
58	.2260E+03	-.1095E+04	-.9597E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
59	.2260E+03	-.1088E+04	-.9595E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
60	.2260E+03	-.1085E+04	-.9639E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
61	.2260E+03	-.1086E+04	-.9696E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
62	.2260E+03	-.8567E+03	-.7804E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
63	.2260E+03	-.8592E+03	-.7838E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
64	.2260E+03	-.8567E+03	-.7804E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
65	.2260E+03	-.1086E+04	-.9696E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04

66	.2260E+03	-.1085E+04	-.9639E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
67	.2260E+03	-.1088E+04	-.9595E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
68	.2260E+03	-.1095E+04	-.9597E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
69	.2260E+03	-.8740E+03	-.9178E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
70	.2260E+03	-.8740E+03	-.9178E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
71	.2260E+03	-.6794E+03	-.1565E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
72	.2260E+03	-.6641E+03	-.1569E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
73	.2260E+03	-.6612E+03	-.1570E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
74	.2260E+03	-.6670E+03	-.1568E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
75	.2260E+03	-.6129E+03	-.1152E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
76	.2260E+03	-.6200E+03	-.1149E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
77	.2260E+03	-.6129E+03	-.1152E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
78	.2260E+03	-.6670E+03	-.1568E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
79	.2260E+03	-.6612E+03	-.1570E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
80	.2260E+03	-.6641E+03	-.1569E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
81	.2260E+03	-.6794E+03	-.1565E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
82	.2260E+03	-.9042E+03	-.1668E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
83	.2260E+03	-.8998E+03	-.1679E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
84	.2260E+03	-.8978E+03	-.1681E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
85	.2260E+03	-.8898E+03	-.1680E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
86	.2260E+03	-.8225E+03	-.1552E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
87	.2260E+03	-.8158E+03	-.1550E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
88	.2260E+03	-.8225E+03	-.1552E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
89	.2260E+03	-.8898E+03	-.1680E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
90	.2260E+03	-.8978E+03	-.1681E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
91	.2260E+03	-.8998E+03	-.1679E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
92	.2260E+03	-.9042E+03	-.1668E+04	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
93	.2260E+03	-.1087E+04	-.7774E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
94	.2260E+03	-.1081E+04	-.7621E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
95	.2260E+03	-.1079E+04	-.7645E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
96	.2260E+03	-.1083E+04	-.7756E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
97	.2260E+03	-.8811E+03	-.6690E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
98	.2260E+03	-.8858E+03	-.6782E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
99	.2260E+03	-.8811E+03	-.6690E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
100	.2260E+03	-.1083E+04	-.7756E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
101	.2260E+03	-.1079E+04	-.7645E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
102	.2260E+03	-.1081E+04	-.7621E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
103	.2260E+03	-.1087E+04	-.7774E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
104	.2260E+03	-.8715E+03	-.9193E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04
105	.2260E+03	-.8715E+03	-.9193E+03	.1136E+04	.1262E+04	-.1262E+04	.9782E+08	.4891E+06	.9287E-04

***** NEGATIVE MOMENTS, CURVATURES *****

BEAM NO.	CRACKING MOMENT (-)	YIELD MOMENT (-)			POST YIELDING STIFFNESS (-)	YIELD CURVATURE (-)

1	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
2	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
3	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
4	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
5	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
6	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
7	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
8	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
9	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
10	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
11	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
12	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
13	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
14	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
15	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
16	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
17	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
18	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
19	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
20	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
21	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
22	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
23	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
24	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
25	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
26	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
27	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
28	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
29	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
30	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
31	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
32	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
33	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
34	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
35	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
36	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
37	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
38	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
39	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
40	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
41	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
42	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
43	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
44	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
45	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
46	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
47	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
48	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
49	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
50	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04

51	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
52	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
53	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
54	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
55	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
56	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
57	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
58	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
59	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
60	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
61	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
62	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
63	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
64	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
65	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
66	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
67	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
68	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
69	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
70	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
71	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
72	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
73	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
74	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
75	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
76	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
77	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
78	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
79	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
80	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
81	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
82	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
83	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
84	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
85	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
86	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
87	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
88	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
89	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
90	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
91	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
92	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
93	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
94	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
95	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
96	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
97	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
98	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
99	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
100	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04
101	-.1072E+04	-.1191E+04	.4891E+06	-.8767E-04

102	-.1072E+04	-.1191E+04		.4891E+06	-.8767E-04
103	-.1072E+04	-.1191E+04		.4891E+06	-.8767E-04
104	-.1072E+04	-.1191E+04		.4891E+06	-.8767E-04
105	-.1072E+04	-.1191E+04		.4891E+06	-.8767E-04

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********** SHEAR WALL PROPERTIES **********   ***** FLEXURAL PROPERTIES *****

WALL NO.	MEMBER LENGTH	AXIAL STIFFNESS	CRACKING MOMENT	YIELD MOMENT	INITIAL FLEXURAL STIFFNESS	POST YIELDING STIFFNESS	YIELD CURVATURE
1	.1560E+03	.4437E+05	.3628E+05	.6876E+05	.2801E+11	.7002E+09	.8640E-05
2	.1560E+03	.4437E+05	.3628E+05	.6876E+05	.2801E+11	.7002E+09	.8640E-05
3	.1560E+03	.4437E+05	.3628E+05	.6876E+05	.2801E+11	.7002E+09	.8640E-05
4	.1560E+03	.4437E+05	.3628E+05	.6876E+05	.2801E+11	.7002E+09	.8640E-05
5	.1560E+03	.4437E+05	.3362E+05	.6290E+05	.2844E+11	.7110E+09	.7886E-05
6	.1560E+03	.4437E+05	.3362E+05	.6290E+05	.2844E+11	.7110E+09	.7886E-05
7	.1560E+03	.4437E+05	.3362E+05	.6290E+05	.2844E+11	.7110E+09	.7886E-05
8	.1560E+03	.4437E+05	.3362E+05	.6290E+05	.2844E+11	.7110E+09	.7886E-05
9	.1560E+03	.4437E+05	.3091E+05	.5600E+05	.2895E+11	.7237E+09	.7123E-05
10	.1560E+03	.4437E+05	.3091E+05	.5600E+05	.2895E+11	.7237E+09	.7123E-05
11	.1560E+03	.4437E+05	.3091E+05	.5600E+05	.2895E+11	.7237E+09	.7123E-05
12	.1560E+03	.4437E+05	.3091E+05	.5600E+05	.2895E+11	.7237E+09	.7123E-05

***** SHEAR PROPERTIES *****

NOTATION:

SHEAR STIFFNESS   = (GA) : KIPS
SHEAR DEFORMATION = NONDIMENSIONAL AV. STRAIN

WALL NO.	CRACKING SHEAR	YIELD SHEAR	INITIAL SHEAR STIFFNESS	POST YIELD SHEAR STIFFNESS	YIELD SHEAR DEFORMATION
1	.6617E+03	.7352E+03	.2769E+07	.1384E+05	.9773E-03
2	.6629E+03	.7366E+03	.2769E+07	.1384E+05	.9865E-03
3	.6617E+03	.7352E+03	.2769E+07	.1384E+05	.9773E-03
4	.6629E+03	.7366E+03	.2769E+07	.1384E+05	.9865E-03

5	.7583E+03	.8426E+03	.2769E+07	.1384E+05	.1953E-02
6	.7592E+03	.8435E+03	.2769E+07	.1384E+05	.1964E-02
7	.7583E+03	.8426E+03	.2769E+07	.1384E+05	.1953E-02
8	.7592E+03	.8435E+03	.2769E+07	.1384E+05	.1964E-02
9	.7777E+03	.8641E+03	.2769E+07	.1384E+05	.2263E-02
10	.7768E+03	.8631E+03	.2769E+07	.1384E+05	.2251E-02
11	.7777E+03	.8641E+03	.2769E+07	.1384E+05	.2263E-02
12	.7768E+03	.8631E+03	.2769E+07	.1384E+05	.2251E-02

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********** TRANSVERSE BEAM PROPERTIES **********

NO.	STIFFNESS (VERTICAL)	STIFFNESS (TORSIONAL)	ARM LENGTH
1	.90360E+02	.77280E+05	.12000E+03
2	.90360E+02	.77280E+05	.00000E+00
3	.90360E+02	.77280E+05	.00000E+00
4	.90360E+02	.77280E+05	.00000E+00
5	.90360E+02	.77280E+05	.00000E+00
6	.90360E+02	.77280E+05	.00000E+00
7	.90360E+02	.77280E+05	.00000E+00
8	.90360E+02	.77280E+05	.00000E+00
9	.90360E+02	.77280E+05	.00000E+00
10	.90360E+02	.77280E+05	.00000E+00
11	.90360E+02	.77280E+05	.00000E+00
12	.90360E+02	.77280E+05	.12000E+03
13	.90360E+02	.77280E+05	-.12000E+03
14	.90360E+02	.77280E+05	.00000E+00
15	.90360E+02	.77280E+05	.00000E+00
16	.90360E+02	.77280E+05	.00000E+00
17	.90360E+02	.77280E+05	.00000E+00
18	.90360E+02	.77280E+05	.00000E+00
19	.90360E+02	.77280E+05	.00000E+00
20	.90360E+02	.77280E+05	.00000E+00
21	.90360E+02	.77280E+05	.00000E+00
22	.90360E+02	.77280E+05	.00000E+00
23	.90360E+02	.77280E+05	.00000E+00
24	.90360E+02	.77280E+05	-.12000E+03
25	.90360E+02	.77280E+05	.12000E+03
26	.90360E+02	.77280E+05	.00000E+00
27	.90360E+02	.77280E+05	.00000E+00
28	.90360E+02	.77280E+05	.00000E+00
29	.90360E+02	.77280E+05	.00000E+00
30	.90360E+02	.77280E+05	.00000E+00
31	.90360E+02	.77280E+05	.00000E+00
32	.90360E+02	.77280E+05	.00000E+00
33	.90360E+02	.77280E+05	.00000E+00
34	.90360E+02	.77280E+05	.00000E+00

35	.90360E+02	.77280E+05	.00000E+00
36	.90360E+02	.77280E+05	.12000E+03
37	.90360E+02	.77280E+05	-.12000E+03
38	.90360E+02	.77280E+05	.00000E+00
39	.90360E+02	.77280E+05	.00000E+00
40	.90360E+02	.77280E+05	.00000E+00
41	.90360E+02	.77280E+05	.00000E+00
42	.90360E+02	.77280E+05	.00000E+00
43	.90360E+02	.77280E+05	.00000E+00
44	.90360E+02	.77280E+05	.00000E+00
45	.90360E+02	.77280E+05	.00000E+00
46	.90360E+02	.77280E+05	.00000E+00
47	.90360E+02	.77280E+05	.00000E+00
48	.90360E+02	.77280E+05	-.12000E+03
49	.90360E+02	.77280E+05	.12000E+03
50	.90360E+02	.77280E+05	.00000E+00
51	.90360E+02	.77280E+05	.00000E+00
52	.90360E+02	.77280E+05	.00000E+00
53	.90360E+02	.77280E+05	.00000E+00
54	.90360E+02	.77280E+05	.00000E+00
55	.90360E+02	.77280E+05	.00000E+00
56	.90360E+02	.77280E+05	.00000E+00
57	.90360E+02	.77280E+05	.00000E+00
58	.90360E+02	.77280E+05	.00000E+00
59	.90360E+02	.77280E+05	.00000E+00
60	.90360E+02	.77280E+05	.12000E+03
61	.90360E+02	.77280E+05	-.12000E+03
62	.90360E+02	.77280E+05	.00000E+00
63	.90360E+02	.77280E+05	.00000E+00
64	.90360E+02	.77280E+05	.00000E+00
65	.90360E+02	.77280E+05	.00000E+00
66	.90360E+02	.77280E+05	.00000E+00
67	.90360E+02	.77280E+05	.00000E+00
68	.90360E+02	.77280E+05	.00000E+00
69	.90360E+02	.77280E+05	.00000E+00
70	.90360E+02	.77280E+05	.00000E+00
71	.90360E+02	.77280E+05	.00000E+00
72	.90360E+02	.77280E+05	-.12000E+03
73	.90360E+02	.77280E+05	.12000E+03
74	.90360E+02	.77280E+05	.00000E+00
75	.90360E+02	.77280E+05	.00000E+00
76	.90360E+02	.77280E+05	.00000E+00
77	.90360E+02	.77280E+05	.00000E+00
78	.90360E+02	.77280E+05	.00000E+00
79	.90360E+02	.77280E+05	.00000E+00
80	.90360E+02	.77280E+05	.00000E+00
81	.90360E+02	.77280E+05	.00000E+00
82	.90360E+02	.77280E+05	.00000E+00
83	.90360E+02	.77280E+05	.00000E+00
84	.90360E+02	.77280E+05	.12000E+03
85	.90360E+02	.77280E+05	-.12000E+03

86	.90360E+02	.77280E+05	.00000E+00
87	.90360E+02	.77280E+05	.00000E+00
88	.90360E+02	.77280E+05	.00000E+00
89	.90360E+02	.77280E+05	.00000E+00
90	.90360E+02	.77280E+05	.00000E+00
91	.90360E+02	.77280E+05	.00000E+00
92	.90360E+02	.77280E+05	.00000E+00
93	.90360E+02	.77280E+05	.00000E+00
94	.90360E+02	.77280E+05	.00000E+00
95	.90360E+02	.77280E+05	.00000E+00
96	.90360E+02	.77280E+05	-.12000E+03
97	.90360E+02	.77280E+05	.12000E+03
98	.90360E+02	.77280E+05	.00000E+00
99	.90360E+02	.77280E+05	.00000E+00
100	.90360E+02	.77280E+05	.00000E+00
101	.90360E+02	.77280E+05	.00000E+00
102	.90360E+02	.77280E+05	.00000E+00
103	.90360E+02	.77280E+05	.00000E+00
104	.90360E+02	.77280E+05	.00000E+00
105	.90360E+02	.77280E+05	.00000E+00
106	.90360E+02	.77280E+05	.00000E+00
107	.90360E+02	.77280E+05	.00000E+00
108	.90360E+02	.77280E+05	.12000E+03
109	.90360E+02	.77280E+05	-.12000E+03
110	.90360E+02	.77280E+05	.00000E+00
111	.90360E+02	.77280E+05	.00000E+00
112	.90360E+02	.77280E+05	.00000E+00
113	.90360E+02	.77280E+05	.00000E+00
114	.90360E+02	.77280E+05	.00000E+00
115	.90360E+02	.77280E+05	.00000E+00
116	.90360E+02	.77280E+05	.00000E+00
117	.90360E+02	.77280E+05	.00000E+00
118	.90360E+02	.77280E+05	.00000E+00
119	.90360E+02	.77280E+05	.00000E+00
120	.90360E+02	.77280E+05	-.12000E+03
121	.90360E+02	.77280E+05	.12000E+03
122	.90360E+02	.77280E+05	.00000E+00
123	.90360E+02	.77280E+05	.00000E+00
124	.90360E+02	.77280E+05	.00000E+00
125	.90360E+02	.77280E+05	.00000E+00
126	.90360E+02	.77280E+05	.00000E+00
127	.90360E+02	.77280E+05	.00000E+00
128	.90360E+02	.77280E+05	.00000E+00
129	.90360E+02	.77280E+05	.00000E+00
130	.90360E+02	.77280E+05	.00000E+00
131	.90360E+02	.77280E+05	.00000E+00
132	.90360E+02	.77280E+05	.12000E+03
133	.90360E+02	.77280E+05	-.12000E+03
134	.90360E+02	.77280E+05	.00000E+00
135	.90360E+02	.77280E+05	.00000E+00
136	.90360E+02	.77280E+05	.00000E+00

137	.90360E+02	.77280E+05	.00000E+00
138	.90360E+02	.77280E+05	.00000E+00
139	.90360E+02	.77280E+05	.00000E+00
140	.90360E+02	.77280E+05	.00000E+00
141	.90360E+02	.77280E+05	.00000E+00
142	.90360E+02	.77280E+05	.00000E+00
143	.90360E+02	.77280E+05	.00000E+00
144	.90360E+02	.77280E+05	-.12000E+03

********** SLAB ELEMENT PROPERTIES **********

SHEAR PROPERTIES

NO.	CRACKING SHEAR	YIELD SHEAR	SHEAR STIFFNESS
1	.107291E+04	.134114E+04	.672549E+07
2	.911514E+03	.113939E+04	.672549E+07
3	.817465E+03	.102183E+04	.672549E+07
4	.722550E+03	.903187E+03	.672549E+07
5	.627754E+03	.784692E+03	.672549E+07
6	.184148E+03	.251752E+03	.353783E+07
7	.184148E+03	.251752E+03	.353783E+07
8	.627754E+03	.784692E+03	.672549E+07
9	.722550E+03	.903187E+03	.672549E+07
10	.817465E+03	.102183E+04	.672549E+07
11	.911514E+03	.113939E+04	.672549E+07
12	.107291E+04	.134114E+04	.672549E+07
13	.107291E+04	.134114E+04	.672549E+07
14	.818407E+03	.102301E+04	.672549E+07
15	.659314E+03	.824142E+03	.672549E+07
16	.533870E+03	.667337E+03	.672549E+07
17	.400115E+03	.500144E+03	.672549E+07
18	.219981E+03	.274976E+03	.353783E+07
19	.219981E+03	.274976E+03	.353783E+07
20	.400115E+03	.500144E+03	.672549E+07
21	.533870E+03	.667337E+03	.672549E+07
22	.659314E+03	.824142E+03	.672549E+07
23	.818407E+03	.102301E+04	.672549E+07
24	.107291E+04	.134114E+04	.672549E+07
25	.107291E+04	.134114E+04	.672549E+07
26	.830648E+03	.103831E+04	.672549E+07
27	.688112E+03	.860139E+03	.672549E+07
28	.569209E+03	.711511E+03	.672549E+07
29	.428882E+03	.536102E+03	.672549E+07

30	.173058E+03	.248653E+03	.353783E+07
31	.173058E+03	.248653E+03	.353783E+07
32	.428882E+03	.536102E+03	.672549E+07
33	.569209E+03	.711511E+03	.672549E+07
34	.688112E+03	.860139E+03	.672549E+07
35	.830648E+03	.103831E+04	.672549E+07
36	.107291E+04	.134114E+04	.672549E+07

FLEXURAL PROPERTIES

NO.	CRACKING MOMENT	YIELD MOMENT	INITIAL STIFFNESS	YIELD CURVATURE	POST-YIELD STIFFNESS
1	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
2	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
3	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
4	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
5	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
6	.45056E+05	.13653E+06	.30838E+12	.21922E-05	.77096E+10
7	.45056E+05	.13653E+06	.30838E+12	.21922E-05	.77096E+10
8	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
9	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
10	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
11	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
12	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
13	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
14	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
15	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
16	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
17	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
18	.45056E+05	.13653E+06	.30838E+12	.21922E-05	.77096E+10
19	.45056E+05	.13653E+06	.30838E+12	.21922E-05	.77096E+10
20	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
21	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
22	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
23	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
24	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
25	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
26	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
27	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
28	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
29	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
30	.45056E+05	.13653E+06	.30838E+12	.21922E-05	.77096E+10
31	.45056E+05	.13653E+06	.30838E+12	.21922E-05	.77096E+10
32	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
33	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
34	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11

35	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11
36	.77735E+05	.23556E+06	.70668E+12	.22233E-05	.17667E+11

1

*************************************** D Y N A M I C   A N A L Y S I S ***************************************

INPUT DATA:

********** DETAILS OF INPUT BASE MOTION **********

MAX SCALED VALUE OF HORIZONTAL COMPONENT (g):   .270

MAX SCALED VALUE OF VERTICAL COMPONENT (g):   .000

TIME INTERVAL OF ANALYSIS (SEC):   .005000

TOTAL DURATION OF RESPONSE ANALYSIS (SEC):   5.000

DAMPING COEFFICIENT (% OF CRITICAL):   5.000

VERTICAL COMPONENT OF BASE MOTION: 0

(=0, NOT INCLUDED; =1, INCLUDED)

WAVE NAME: SCALED LOMA PRIETA EQ WAVE 0.27G

NO. OF POINTS IN INPUT BASE MOTION: 7990

TIME INTERVAL OF INPUT WAVE (SEC):   .005000

********** PROPERTIES FOR HYSTERETIC RULE **********

NO. OF TYPES OF HYSTERETIC RULES: 6

RULE NO.	DEGRADING COEFFICIENT	SLIPPAGE COEFFICIENT	DETERIORATING COEFFICIENT	POST-YIELD STIFFNESS RATIO
1	2.000	.800	.010	.01500
2	4.000	.800	.010	.01500
3	3.500	1.000	.150	.01500
4	.100	1.000	.150	.01500
5	2.500	.800	.150	.01500
6	.100	.800	.150	.01500

********** HYSTERETIC RULE FOR COLUMNS **********

COLUMN NO.	HYSTERESIS RULE NO.
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1
17	1
18	1
19	1
20	1

21	1
22	1
23	1
24	1
25	1
26	1
27	1
28	1
29	1
30	1
31	1
32	1
33	1
34	1
35	1
36	1
37	1
38	1
39	1
40	1
41	1
42	1
43	1
44	1
45	1
46	1
47	1
48	1
49	1
50	1
51	1
52	1
53	1
54	1
55	1
56	1
57	1
58	1
59	1
60	1
61	1
62	1
63	1
64	1
65	1
66	1
67	1
68	1
69	1
70	1
71	1

72	1
73	1
74	1
75	1
76	1
77	1
78	1
79	1
80	1
81	1
82	1
83	1
84	1
85	1
86	1
87	1
88	1
89	1
90	1
91	1
92	1
93	1
94	1
95	1
96	1
97	1
98	1
99	1
100	1
101	1
102	1
103	1
104	1
105	1
106	1
107	1
108	1
109	1
110	1
111	1
112	1
113	1
114	1
115	1
116	1
117	1
118	1
119	1
120	1
121	1
122	1

123	1
124	1
125	1
126	1
127	1
128	1
129	1
130	1
131	1
132	1

********** HYSTERETIC RULE FOR BEAMS **********

BEAM NO.	HYSTERESIS RULE NO.
1	2
2	2
3	2
4	2
5	2
6	2
7	2
8	2
9	2
10	2
11	2
12	2
13	2
14	2
15	2
16	2
17	2
18	2
19	2
20	2
21	2
22	2
23	2
24	2
25	2
26	2
27	2
28	2

29	2
30	2
31	2
32	2
33	2
34	2
35	2
36	2
37	2
38	2
39	2
40	2
41	2
42	2
43	2
44	2
45	2
46	2
47	2
48	2
49	2
50	2
51	2
52	2
53	2
54	2
55	2
56	2
57	2
58	2
59	2
60	2
61	2
62	2
63	2
64	2
65	2
66	2
67	2
68	2
69	2
70	2
71	2
72	2
73	2
74	2
75	2
76	2
77	2
78	2
79	2

80	2
81	2
82	2
83	2
84	2
85	2
86	2
87	2
88	2
89	2
90	2
91	2
92	2
93	2
94	2
95	2
96	2
97	2
98	2
99	2
100	2
101	2
102	2
103	2
104	2
105	2

********** HYSTERETIC RULE FOR SHEAR WALLS **********

WALL NO.	HYSTERESIS RULE (FLEXURE)	HYSTERESIS RULE (SHEAR)
1	3	4
2	3	4
3	3	4
4	3	4
5	3	4
6	3	4
7	3	4
8	3	4
9	3	4
10	3	4
11	3	4
12	3	4

********** HYSTERETIC RULE FOR SLABS **********

SLAB NO.	HYSTERESIS RULE (FLEXURE)	HYSTERESIS RULE (SHEAR)
1	5	6
2	5	6
3	5	6
4	5	6
5	5	6
6	5	6
7	5	6
8	5	6
9	5	6
10	5	6
11	5	6
12	5	6
13	5	6
14	5	6
15	5	6
16	5	6
17	5	6
18	5	6
19	5	6
20	5	6
21	5	6
22	5	6
23	5	6
24	5	6
25	5	6
26	5	6
27	5	6
28	5	6
29	5	6
30	5	6
31	5	6
32	5	6
33	5	6
34	5	6
35	5	6
36	5	6

********** COMMENCING DYNAMIC ANALYSIS **********

YIELDING DETECTED IN SLAB NO. 18

YIELDING DETECTED IN SLAB NO. 19

YIELDING DETECTED IN SLAB NO. 30

YIELDING DETECTED IN SLAB NO. 31

PRINTING FORCES AT TIME....... 3.400000

***** COLUMNS *****

COL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.64544E+03	-.70840E+03	.90861E+01
2	.71456E+03	-.79060E+03	.10102E+02
3	.78743E+03	-.85948E+03	.11053E+02
4	.85094E+03	-.90239E+03	.11767E+02
5	.88314E+03	-.89846E+03	.11957E+02
6	.88279E+03	-.88524E+03	.11866E+02
7	.88314E+03	-.89846E+03	.11957E+02
8	.85094E+03	-.90239E+03	.11767E+02
9	.78743E+03	-.85948E+03	.11053E+02
10	.71456E+03	-.79060E+03	.10102E+02
11	.64544E+03	-.70840E+03	.90861E+01
12	.67468E+03	-.52029E+03	.80199E+01
13	.84044E+03	-.69296E+03	.10291E+02
14	.92233E+03	-.80170E+03	.11571E+02
15	.98796E+03	-.85809E+03	.12390E+02

16	.99353E+03	-.84686E+03	.12352E+02
17	.96860E+03	-.82854E+03	.12061E+02
18	.99353E+03	-.84686E+03	.12352E+02
19	.98796E+03	-.85809E+03	.12390E+02
20	.92233E+03	-.80170E+03	.11571E+02
21	.84044E+03	-.69296E+03	.10291E+02
22	.67468E+03	-.52029E+03	.80199E+01
23	.67851E+03	-.52747E+03	.80938E+01
24	.83878E+03	-.68331E+03	.10215E+02
25	.92137E+03	-.79658E+03	.11530E+02
26	.98586E+03	-.85564E+03	.12359E+02
27	.99621E+03	-.88649E+03	.12636E+02
28	.96670E+03	-.88354E+03	.12418E+02
29	.99621E+03	-.88649E+03	.12636E+02
30	.98586E+03	-.85564E+03	.12359E+02
31	.92137E+03	-.79658E+03	.11530E+02
32	.83878E+03	-.68331E+03	.10215E+02
33	.67851E+03	-.52747E+03	.80938E+01
34	.65482E+03	-.77381E+03	.95881E+01
35	.71895E+03	-.82504E+03	.10362E+02
36	.77953E+03	-.86802E+03	.11057E+02
37	.84134E+03	-.92074E+03	.11826E+02
38	.85091E+03	-.82982E+03	.11280E+02
39	.84646E+03	-.83701E+03	.11298E+02
40	.85091E+03	-.82982E+03	.11280E+02
41	.84134E+03	-.92074E+03	.11826E+02
42	.77953E+03	-.86802E+03	.11057E+02
43	.71895E+03	-.82504E+03	.10362E+02
44	.65482E+03	-.77381E+03	.95881E+01
45	.62381E+03	-.66304E+03	.90623E+01
46	.65294E+03	-.68917E+03	.94515E+01
47	.68073E+03	-.71854E+03	.98540E+01
48	.68828E+03	-.73732E+03	.10039E+02
49	.66623E+03	-.69422E+03	.95806E+01
50	.63219E+03	-.68669E+03	.92879E+01
51	.66623E+03	-.69422E+03	.95806E+01
52	.68828E+03	-.73732E+03	.10039E+02
53	.68073E+03	-.71854E+03	.98540E+01
54	.65294E+03	-.68917E+03	.94515E+01
55	.62381E+03	-.66304E+03	.90623E+01
56	.46039E+03	-.45778E+03	.64660E+01
57	.53964E+03	-.59575E+03	.79957E+01
58	.59242E+03	-.67908E+03	.89542E+01
59	.62077E+03	-.71091E+03	.93780E+01
60	.58867E+03	-.67487E+03	.88982E+01
61	.58907E+03	-.66520E+03	.88329E+01
62	.58867E+03	-.67487E+03	.88982E+01
63	.62077E+03	-.71091E+03	.93780E+01
64	.59242E+03	-.67908E+03	.89542E+01
65	.53964E+03	-.59575E+03	.79957E+01
66	.46039E+03	-.45778E+03	.64660E+01

67	.46693E+03	-.45996E+03	.65274E+01
68	.52547E+03	-.58257E+03	.78031E+01
69	.57337E+03	-.67592E+03	.87978E+01
70	.61391E+03	-.71028E+03	.93253E+01
71	.65269E+03	-.73027E+03	.97392E+01
72	.63775E+03	-.68412E+03	.93089E+01
73	.65269E+03	-.73027E+03	.97392E+01
74	.61391E+03	-.71028E+03	.93253E+01
75	.57337E+03	-.67592E+03	.87978E+01
76	.52547E+03	-.58257E+03	.78031E+01
77	.46693E+03	-.45996E+03	.65274E+01
78	.66699E+03	-.67541E+03	.94535E+01
79	.67815E+03	-.70831E+03	.97638E+01
80	.68183E+03	-.72974E+03	.99407E+01
81	.67907E+03	-.73997E+03	.99932E+01
82	.60398E+03	-.69978E+03	.91814E+01
83	.57757E+03	-.68102E+03	.88634E+01
84	.60398E+03	-.69978E+03	.91814E+01
85	.67907E+03	-.73997E+03	.99932E+01
86	.68183E+03	-.72974E+03	.99407E+01
87	.67815E+03	-.70831E+03	.97638E+01
88	.66699E+03	-.67541E+03	.94535E+01
89	.57072E+03	-.62288E+03	.84057E+01
90	.56294E+03	-.62398E+03	.83586E+01
91	.56379E+03	-.62249E+03	.83541E+01
92	.57085E+03	-.63086E+03	.84628E+01
93	.56198E+03	-.61137E+03	.82630E+01
94	.52616E+03	-.57137E+03	.77291E+01
95	.56198E+03	-.61137E+03	.82630E+01
96	.57085E+03	-.63086E+03	.84628E+01
97	.56379E+03	-.62249E+03	.83541E+01
98	.56294E+03	-.62398E+03	.83586E+01
99	.57072E+03	-.62288E+03	.84057E+01
100	.32840E+03	-.45075E+03	.54870E+01
101	.31699E+03	-.45640E+03	.54464E+01
102	.30153E+03	-.45367E+03	.53183E+01
103	.31704E+03	-.46965E+03	.55400E+01
104	.27513E+03	-.42966E+03	.49633E+01
105	.32371E+03	-.44331E+03	.54016E+01
106	.27513E+03	-.42966E+03	.49633E+01
107	.31704E+03	-.46965E+03	.55400E+01
108	.30153E+03	-.45367E+03	.53183E+01
109	.31699E+03	-.45640E+03	.54464E+01
110	.32840E+03	-.45075E+03	.54870E+01
111	.35842E+03	-.50936E+03	.61111E+01
112	.30901E+03	-.45197E+03	.53590E+01
113	.28137E+03	-.43709E+03	.50596E+01
114	.30930E+03	-.46254E+03	.54355E+01
115	.43403E+03	-.54244E+03	.68765E+01
116	.44468E+03	-.52922E+03	.68584E+01
117	.43403E+03	-.54244E+03	.68765E+01

118	.30930E+03	-.46254E+03	.54355E+01
119	.28137E+03	-.43709E+03	.50596E+01
120	.30901E+03	-.45197E+03	.53590E+01
121	.35842E+03	-.50936E+03	.61111E+01
122	.62536E+03	-.69410E+03	.92920E+01
123	.62885E+03	-.68734E+03	.92690E+01
124	.62135E+03	-.68671E+03	.92117E+01
125	.62508E+03	-.69101E+03	.92682E+01
126	.59610E+03	-.65667E+03	.88224E+01
127	.56133E+03	-.63733E+03	.84413E+01
128	.59610E+03	-.65667E+03	.88224E+01
129	.62508E+03	-.69101E+03	.92682E+01
130	.62135E+03	-.68671E+03	.92117E+01
131	.62885E+03	-.68734E+03	.92690E+01
132	.62536E+03	-.69410E+03	.92920E+01

***** BEAMS *****

BEAM NO.	MOMENT (LEFT)	MOMENT (RIGHT)	SHEAR
1	.79005E+02	-.12267E+04	.57774E+01
2	.17223E+03	-.12502E+04	.62937E+01
3	.25489E+03	-.12819E+04	.67998E+01
4	.35074E+03	-.13013E+04	.73101E+01
5	.46835E+03	-.13150E+04	.78910E+01
6	.48868E+03	-.13190E+04	.79986E+01
7	.46835E+03	-.13150E+04	.78910E+01
8	.35074E+03	-.13013E+04	.73101E+01
9	.25489E+03	-.12819E+04	.67998E+01
10	.17223E+03	-.12502E+04	.62937E+01
11	.79005E+02	-.12267E+04	.57774E+01
12	-.65104E+02	-.12270E+04	.51409E+01
13	.16578E+03	-.12893E+04	.64382E+01
14	.31024E+03	-.13239E+04	.72307E+01
15	.35319E+03	-.13463E+04	.75200E+01
16	.40342E+03	-.13547E+04	.77794E+01
17	.36663E+03	-.13519E+04	.76039E+01
18	.40342E+03	-.13547E+04	.77794E+01
19	.35319E+03	-.13463E+04	.75200E+01
20	.31024E+03	-.13239E+04	.72307E+01
21	.16578E+03	-.12893E+04	.64382E+01
22	-.65104E+02	-.12270E+04	.51409E+01
23	-.39194E+02	-.12084E+04	.51735E+01
24	.10807E+03	-.12422E+04	.59745E+01
25	.22199E+03	-.12757E+04	.66269E+01

26	.31219E+03	-.12943E+04	.71086E+01
27	.43702E+03	-.13064E+04	.77140E+01
28	.41752E+03	-.12992E+04	.75962E+01
29	.43702E+03	-.13064E+04	.77140E+01
30	.31219E+03	-.12943E+04	.71086E+01
31	.22199E+03	-.12757E+04	.66269E+01
32	.10807E+03	-.12422E+04	.59745E+01
33	-.39194E+02	-.12084E+04	.51735E+01
34	.16514E+03	-.12396E+04	.62155E+01
35	.16514E+03	-.12396E+04	.62155E+01
36	-.83100E+02	-.12039E+04	.49594E+01
37	-.12520E+03	-.12009E+04	.47596E+01
38	-.65613E+02	-.12074E+04	.50522E+01
39	-.32851E+02	-.12113E+04	.52143E+01
40	.83209E+02	-.12185E+04	.57596E+01
41	.12809E+03	-.12131E+04	.59345E+01
42	.83209E+02	-.12185E+04	.57596E+01
43	-.32851E+02	-.12113E+04	.52143E+01
44	-.65613E+02	-.12074E+04	.50522E+01
45	-.12520E+03	-.12009E+04	.47596E+01
46	-.83100E+02	-.12039E+04	.49594E+01
47	-.19418E+03	-.12095E+04	.44926E+01
48	-.32623E+02	-.12352E+04	.53211E+01
49	.13535E+02	-.12503E+04	.55922E+01
50	.42489E+02	-.12490E+04	.57146E+01
51	.46844E+02	-.12582E+04	.57745E+01
52	.14578E+02	-.12544E+04	.56150E+01
53	.46844E+02	-.12582E+04	.57745E+01
54	.42489E+02	-.12490E+04	.57146E+01
55	.13535E+02	-.12503E+04	.55922E+01
56	-.32623E+02	-.12352E+04	.53211E+01
57	-.19418E+03	-.12095E+04	.44926E+01
58	-.99132E+02	-.12152E+04	.49382E+01
59	-.11647E+03	-.12044E+04	.48136E+01
60	-.57234E+02	-.12224E+04	.51557E+01
61	-.41528E+02	-.12314E+04	.52649E+01
62	.11827E+03	-.11769E+04	.57307E+01
63	.11517E+03	-.11773E+04	.57189E+01
64	.11827E+03	-.11769E+04	.57307E+01
65	-.41528E+02	-.12314E+04	.52649E+01
66	-.57234E+02	-.12224E+04	.51557E+01
67	-.11647E+03	-.12044E+04	.48136E+01
68	-.99132E+02	-.12152E+04	.49382E+01
69	.23363E+03	-.12608E+04	.66125E+01
70	.23363E+03	-.12608E+04	.66125E+01
71	-.40393E+03	-.11461E+04	.32838E+01
72	-.47344E+03	-.11267E+04	.28903E+01
73	-.45142E+03	-.11248E+04	.29796E+01
74	-.46397E+03	-.11269E+04	.29332E+01
75	-.39578E+03	-.11186E+04	.31984E+01
76	-.33877E+03	-.11291E+04	.34971E+01

77	-.39578E+03	-.11186E+04	.31984E+01
78	-.46397E+03	-.11269E+04	.29332E+01
79	-.45142E+03	-.11248E+04	.29796E+01
80	-.47344E+03	-.11267E+04	.28903E+01
81	-.40393E+03	-.11461E+04	.32838E+01
82	-.53207E+03	-.11190E+04	.25970E+01
83	-.52871E+03	-.11491E+04	.27450E+01
84	-.54392E+03	-.11505E+04	.26842E+01
85	-.52006E+03	-.11510E+04	.27917E+01
86	-.46966E+03	-.11570E+04	.30413E+01
87	-.44420E+03	-.11588E+04	.31620E+01
88	-.46966E+03	-.11570E+04	.30413E+01
89	-.52006E+03	-.11510E+04	.27917E+01
90	-.54392E+03	-.11505E+04	.26842E+01
91	-.52871E+03	-.11491E+04	.27450E+01
92	-.53207E+03	-.11190E+04	.25970E+01
93	-.45933E+03	-.10318E+04	.25332E+01
94	-.61964E+03	-.90015E+03	.12412E+01
95	-.63188E+03	-.91407E+03	.12486E+01
96	-.62619E+03	-.94000E+03	.13886E+01
97	-.44269E+03	-.83176E+03	.17215E+01
98	-.45982E+03	-.84501E+03	.17044E+01
99	-.44269E+03	-.83176E+03	.17215E+01
100	-.62619E+03	-.94000E+03	.13886E+01
101	-.63188E+03	-.91407E+03	.12486E+01
102	-.61964E+03	-.90015E+03	.12412E+01
103	-.45933E+03	-.10318E+04	.25332E+01
104	.23249E+03	-.12661E+04	.66307E+01
105	.23249E+03	-.12661E+04	.66307E+01

***** WALLS *****

WALL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.72815E+05	.36488E+05	.26647E+03
2	.72806E+05	.36468E+05	.26625E+03
3	.72815E+05	.36488E+05	.26647E+03
4	.72806E+05	.36468E+05	.26625E+03
5	.37958E+05	.92054E+04	.20104E+03
6	.37941E+05	.91662E+04	.20152E+03
7	.37958E+05	.92054E+04	.20104E+03
8	.37941E+05	.91662E+04	.20152E+03
9	.12622E+05	-.34816E+04	.10323E+03
10	.12642E+05	-.35849E+04	.10402E+03
11	.12622E+05	-.34816E+04	.10323E+03

12	.12642E+05	-.35849E+04	.10402E+03

***** SLABS *****

SLAB NO.	MOMENT (FRONT)	MOMENT (REAR)	SHEAR
1	-.11863E-09	-.31721E+05	.13217E+03
2	-.31721E+05	-.60028E+05	.11794E+03
3	-.60028E+05	-.80962E+05	.92672E+02
4	-.80962E+05	-.95753E+05	.57482E+02
5	-.95753E+05	-.99132E+05	.25735E+02
6	-.92494E+05	-.96946E+05	.52764E+01
7	-.96946E+05	-.92494E+05	-.52764E+01
8	-.99132E+05	-.95753E+05	-.25735E+02
9	-.95753E+05	-.80962E+05	-.57482E+02
10	-.80962E+05	-.60028E+05	-.92672E+02
11	-.60028E+05	-.31721E+05	-.11794E+03
12	-.31721E+05	-.31750E-09	-.13217E+03
13	.34259E-10	-.44021E+05	.18342E+03
14	-.44021E+05	-.80966E+05	.15933E+03
15	-.80966E+05	-.10994E+06	.12613E+03
16	-.10994E+06	-.12572E+06	.85968E+02
17	-.12572E+06	-.13253E+06	.40919E+02
18	-.13386E+06	-.13655E+06	.11101E+02
19	-.13655E+06	-.13386E+06	-.11101E+02
20	-.13253E+06	-.12572E+06	-.40919E+02
21	-.12572E+06	-.10994E+06	-.85968E+02
22	-.10994E+06	-.80966E+05	-.12613E+03
23	-.80966E+05	-.44021E+05	-.15933E+03
24	-.44021E+05	.42378E-09	-.18342E+03
25	.10850E-09	-.44717E+05	.18632E+03
26	-.44717E+05	-.77516E+05	.14558E+03
27	-.77516E+05	-.10096E+06	.10907E+03
28	-.10096E+06	-.12049E+06	.86176E+02
29	-.12049E+06	-.12579E+06	.29538E+02
30	-.13227E+06	-.13702E+06	.12239E+02
31	-.13702E+06	-.13227E+06	-.12239E+02
32	-.12579E+06	-.12049E+06	-.29538E+02
33	-.12049E+06	-.10096E+06	-.86176E+02
34	-.10096E+06	-.77516E+05	-.10907E+03
35	-.77516E+05	-.44717E+05	-.14558E+03
36	-.44717E+05	-.80048E-11	-.18632E+03

YIELDING DETECTED IN SLAB NO. 18

YIELDING DETECTED IN SLAB NO. 19

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***** COLUMNS *****

COL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.64610E+03	-.70829E+03	.90898E+01
2	.71632E+03	-.79100E+03	.10116E+02
3	.79059E+03	-.86046E+03	.11081E+02
4	.85561E+03	-.90401E+03	.11809E+02
5	.88893E+03	-.90062E+03	.12010E+02
6	.88864E+03	-.88701E+03	.11917E+02
7	.88893E+03	-.90062E+03	.12010E+02
8	.85561E+03	-.90401E+03	.11809E+02
9	.79059E+03	-.86046E+03	.11081E+02
10	.71632E+03	-.79100E+03	.10116E+02
11	.64610E+03	-.70829E+03	.90898E+01
12	.67432E+03	-.51455E+03	.79790E+01
13	.83988E+03	-.68465E+03	.10232E+02
14	.92465E+03	-.79967E+03	.11573E+02
15	.99159E+03	-.85600E+03	.12400E+02
16	.99821E+03	-.84495E+03	.12370E+02
17	.97524E+03	-.83112E+03	.12123E+02
18	.99821E+03	-.84495E+03	.12370E+02
19	.99159E+03	-.85600E+03	.12400E+02
20	.92465E+03	-.79967E+03	.11573E+02
21	.83988E+03	-.68465E+03	.10232E+02
22	.67432E+03	-.51455E+03	.79790E+01
23	.67833E+03	-.52207E+03	.80564E+01
24	.83793E+03	-.67405E+03	.10148E+02
25	.92256E+03	-.78959E+03	.11491E+02
26	.98940E+03	-.85349E+03	.12368E+02
27	.10030E+04	-.89009E+03	.12706E+02
28	.97362E+03	-.88719E+03	.12489E+02
29	.10030E+04	-.89009E+03	.12706E+02
30	.98940E+03	-.85349E+03	.12368E+02

31	.92256E+03	-.78959E+03	.11491E+02
32	.83793E+03	-.67405E+03	.10148E+02
33	.67833E+03	-.52207E+03	.80564E+01
34	.65505E+03	-.77267E+03	.95820E+01
35	.71992E+03	-.82357E+03	.10359E+02
36	.78168E+03	-.86660E+03	.11062E+02
37	.84484E+03	-.91960E+03	.11842E+02
38	.85495E+03	-.82593E+03	.11281E+02
39	.85061E+03	-.83271E+03	.11297E+02
40	.85495E+03	-.82593E+03	.11281E+02
41	.84484E+03	-.91960E+03	.11842E+02
42	.78168E+03	-.86660E+03	.11062E+02
43	.71992E+03	-.82357E+03	.10359E+02
44	.65505E+03	-.77267E+03	.95820E+01
45	.63063E+03	-.66992E+03	.91588E+01
46	.66201E+03	-.69853E+03	.95813E+01
47	.69162E+03	-.73006E+03	.10012E+02
48	.70113E+03	-.75120E+03	.10228E+02
49	.68072E+03	-.70942E+03	.97897E+01
50	.64725E+03	-.70259E+03	.95059E+01
51	.68072E+03	-.70942E+03	.97897E+01
52	.70113E+03	-.75120E+03	.10228E+02
53	.69162E+03	-.73006E+03	.10012E+02
54	.66201E+03	-.69853E+03	.95813E+01
55	.63063E+03	-.66992E+03	.91588E+01
56	.48599E+03	-.48068E+03	.68075E+01
57	.57231E+03	-.62769E+03	.84507E+01
58	.62148E+03	-.69204E+03	.92501E+01
59	.65440E+03	-.72654E+03	.97249E+01
60	.62592E+03	-.69295E+03	.92878E+01
61	.60441E+03	-.68008E+03	.90457E+01
62	.62592E+03	-.69295E+03	.92878E+01
63	.65440E+03	-.72654E+03	.97249E+01
64	.62148E+03	-.69204E+03	.92501E+01
65	.57231E+03	-.62769E+03	.84507E+01
66	.48599E+03	-.48068E+03	.68075E+01
67	.49303E+03	-.48333E+03	.68757E+01
68	.55707E+03	-.61408E+03	.82476E+01
69	.60364E+03	-.69003E+03	.91104E+01
70	.64873E+03	-.72731E+03	.96904E+01
71	.66854E+03	-.74585E+03	.99605E+01
72	.65452E+03	-.70059E+03	.95430E+01
73	.66854E+03	-.74585E+03	.99605E+01
74	.64873E+03	-.72731E+03	.96904E+01
75	.60364E+03	-.69003E+03	.91104E+01
76	.55707E+03	-.61408E+03	.82476E+01
77	.49303E+03	-.48333E+03	.68757E+01
78	.67192E+03	-.67965E+03	.95181E+01
79	.68444E+03	-.71409E+03	.98488E+01
80	.68906E+03	-.73628E+03	.10038E+02
81	.68764E+03	-.74782E+03	.10109E+02

82	.61407E+03	-.70874E+03	.93156E+01
83	.58840E+03	-.69064E+03	.90073E+01
84	.61407E+03	-.70874E+03	.93156E+01
85	.68764E+03	-.74782E+03	.10109E+02
86	.68906E+03	-.73628E+03	.10038E+02
87	.68444E+03	-.71409E+03	.98488E+01
88	.67192E+03	-.67965E+03	.95181E+01
89	.57489E+03	-.62749E+03	.84675E+01
90	.56797E+03	-.62954E+03	.84332E+01
91	.57047E+03	-.62995E+03	.84536E+01
92	.57813E+03	-.63923E+03	.85730E+01
93	.56878E+03	-.62015E+03	.83727E+01
94	.53295E+03	-.58029E+03	.78397E+01
95	.56878E+03	-.62015E+03	.83727E+01
96	.57813E+03	-.63923E+03	.85730E+01
97	.57047E+03	-.62995E+03	.84536E+01
98	.56797E+03	-.62954E+03	.84332E+01
99	.57489E+03	-.62749E+03	.84675E+01
100	.33610E+03	-.46294E+03	.56271E+01
101	.32711E+03	-.47353E+03	.56383E+01
102	.31943E+03	-.47817E+03	.56169E+01
103	.33510E+03	-.49542E+03	.58487E+01
104	.29369E+03	-.45563E+03	.52769E+01
105	.34492E+03	-.47074E+03	.57440E+01
106	.29369E+03	-.45563E+03	.52769E+01
107	.33510E+03	-.49542E+03	.58487E+01
108	.31943E+03	-.47817E+03	.56169E+01
109	.32711E+03	-.47353E+03	.56383E+01
110	.33610E+03	-.46294E+03	.56271E+01
111	.36836E+03	-.52537E+03	.62939E+01
112	.32002E+03	-.47046E+03	.55668E+01
113	.30420E+03	-.46515E+03	.54180E+01
114	.33421E+03	-.49354E+03	.58292E+01
115	.45468E+03	-.55468E+03	.71082E+01
116	.46587E+03	-.54160E+03	.70949E+01
117	.45468E+03	-.55468E+03	.71082E+01
118	.33421E+03	-.49354E+03	.58292E+01
119	.30420E+03	-.46515E+03	.54180E+01
120	.32002E+03	-.47046E+03	.55668E+01
121	.36836E+03	-.52537E+03	.62939E+01
122	.62758E+03	-.69849E+03	.93385E+01
123	.63111E+03	-.69230E+03	.93198E+01
124	.62403E+03	-.69332E+03	.92772E+01
125	.62730E+03	-.69814E+03	.93341E+01
126	.59743E+03	-.66377E+03	.88816E+01
127	.56246E+03	-.64453E+03	.84999E+01
128	.59743E+03	-.66377E+03	.88816E+01
129	.62730E+03	-.69814E+03	.93341E+01
130	.62403E+03	-.69332E+03	.92772E+01
131	.63111E+03	-.69230E+03	.93198E+01
132	.62758E+03	-.69849E+03	.93385E+01

***** BEAMS *****

BEAM NO.	MOMENT (LEFT)	MOMENT (RIGHT)	SHEAR
1	.87134E+02	-.12293E+04	.58248E+01
2	.18254E+03	-.12539E+04	.63559E+01
3	.26749E+03	-.12866E+04	.68765E+01
4	.36581E+03	-.13073E+04	.74031E+01
5	.48598E+03	-.13219E+04	.79995E+01
6	.50577E+03	-.13246E+04	.80989E+01
7	.48598E+03	-.13219E+04	.79995E+01
8	.36581E+03	-.13073E+04	.74031E+01
9	.26749E+03	-.12866E+04	.68765E+01
10	.18254E+03	-.12539E+04	.63559E+01
11	.87134E+02	-.12293E+04	.58248E+01
12	-.45828E+02	-.12315E+04	.52462E+01
13	.18734E+03	-.12953E+04	.65605E+01
14	.33348E+03	-.13308E+04	.73640E+01
15	.37900E+03	-.13545E+04	.76702E+01
16	.42971E+03	-.13617E+04	.79266E+01
17	.38442E+03	-.13571E+04	.77061E+01
18	.42971E+03	-.13617E+04	.79266E+01
19	.37900E+03	-.13545E+04	.76702E+01
20	.33348E+03	-.13308E+04	.73640E+01
21	.18734E+03	-.12953E+04	.65605E+01
22	-.45828E+02	-.12315E+04	.52462E+01
23	-.20985E+02	-.12128E+04	.52734E+01
24	.12443E+03	-.12469E+04	.60679E+01
25	.23930E+03	-.12813E+04	.67283E+01
26	.33343E+03	-.13014E+04	.72336E+01
27	.45250E+03	-.13125E+04	.78096E+01
28	.43316E+03	-.13055E+04	.76932E+01
29	.45250E+03	-.13125E+04	.78096E+01
30	.33343E+03	-.13014E+04	.72336E+01
31	.23930E+03	-.12813E+04	.67283E+01
32	.12443E+03	-.12469E+04	.60679E+01
33	-.20985E+02	-.12128E+04	.52734E+01
34	.17297E+03	-.12418E+04	.62599E+01
35	.17297E+03	-.12418E+04	.62599E+01
36	-.69477E+02	-.12080E+04	.50376E+01
37	-.10991E+03	-.12055E+04	.48478E+01
38	-.46508E+02	-.12130E+04	.51613E+01
39	-.98113E+01	-.12179E+04	.53455E+01
40	.10574E+03	-.12253E+04	.58896E+01

41	.15162E+03	-.12200E+04	.60692E+01
42	.10574E+03	-.12253E+04	.58896E+01
43	-.98113E+01	-.12179E+04	.53455E+01
44	-.46508E+02	-.12130E+04	.51613E+01
45	-.10991E+03	-.12055E+04	.48478E+01
46	-.69477E+02	-.12080E+04	.50376E+01
47	-.16547E+03	-.12162E+04	.46492E+01
48	.31198E+01	-.12444E+04	.55202E+01
49	.41398E+02	-.12574E+04	.57471E+01
50	.71818E+02	-.12566E+04	.58780E+01
51	.78836E+02	-.12662E+04	.59516E+01
52	.45926E+02	-.12623E+04	.57887E+01
53	.78836E+02	-.12662E+04	.59516E+01
54	.71818E+02	-.12566E+04	.58780E+01
55	.41398E+02	-.12574E+04	.57471E+01
56	.31198E+01	-.12444E+04	.55202E+01
57	-.16547E+03	-.12162E+04	.46492E+01
58	-.70499E+02	-.12220E+04	.50953E+01
59	-.82646E+02	-.12125E+04	.49995E+01
60	-.24465E+02	-.12311E+04	.53391E+01
61	-.48618E+01	-.12414E+04	.54714E+01
62	.14739E+03	-.11865E+04	.59022E+01
63	.14547E+03	-.11874E+04	.58975E+01
64	.14739E+03	-.11865E+04	.59022E+01
65	-.48618E+01	-.12414E+04	.54714E+01
66	-.24465E+02	-.12311E+04	.53391E+01
67	-.82646E+02	-.12125E+04	.49995E+01
68	-.70499E+02	-.12220E+04	.50953E+01
69	.24617E+03	-.12645E+04	.66843E+01
70	.24617E+03	-.12645E+04	.66843E+01
71	-.39657E+03	-.11482E+04	.33259E+01
72	-.46775E+03	-.11283E+04	.29228E+01
73	-.44375E+03	-.11271E+04	.30236E+01
74	-.45531E+03	-.11295E+04	.29830E+01
75	-.38637E+03	-.11217E+04	.32535E+01
76	-.32953E+03	-.11322E+04	.35516E+01
77	-.38637E+03	-.11217E+04	.32535E+01
78	-.45531E+03	-.11295E+04	.29830E+01
79	-.44375E+03	-.11271E+04	.30236E+01
80	-.46775E+03	-.11283E+04	.29228E+01
81	-.39657E+03	-.11482E+04	.33259E+01
82	-.52057E+03	-.11214E+04	.26584E+01
83	-.51220E+03	-.11528E+04	.28344E+01
84	-.52108E+03	-.11557E+04	.28080E+01
85	-.49575E+03	-.11564E+04	.29233E+01
86	-.44603E+03	-.11615E+04	.31660E+01
87	-.41915E+03	-.11636E+04	.32939E+01
88	-.44603E+03	-.11615E+04	.31660E+01
89	-.49575E+03	-.11564E+04	.29233E+01
90	-.52108E+03	-.11557E+04	.28080E+01
91	-.51220E+03	-.11528E+04	.28344E+01

92	-.52057E+03	-.11214E+04	.26584E+01
93	-.44334E+03	-.10391E+04	.26360E+01
94	-.60449E+03	-.90444E+03	.13272E+01
95	-.60871E+03	-.92028E+03	.13786E+01
96	-.60117E+03	-.94693E+03	.15299E+01
97	-.43342E+03	-.83858E+03	.17927E+01
98	-.45184E+03	-.85198E+03	.17706E+01
99	-.43342E+03	-.83858E+03	.17927E+01
100	-.60117E+03	-.94693E+03	.15299E+01
101	-.60871E+03	-.92028E+03	.13786E+01
102	-.60449E+03	-.90444E+03	.13272E+01
103	-.44334E+03	-.10391E+04	.26360E+01
104	.24494E+03	-.12698E+04	.67023E+01
105	.24494E+03	-.12698E+04	.67023E+01

***** WALLS *****

WALL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.72859E+05	.37944E+05	.26213E+03
2	.72850E+05	.37928E+05	.26188E+03
3	.72859E+05	.37944E+05	.26213E+03
4	.72850E+05	.37928E+05	.26188E+03
5	.39468E+05	.95377E+04	.20859E+03
6	.39447E+05	.95059E+04	.20900E+03
7	.39468E+05	.95377E+04	.20859E+03
8	.39447E+05	.95059E+04	.20900E+03
9	.13050E+05	-.35809E+04	.10661E+03
10	.13065E+05	-.36747E+04	.10731E+03
11	.13050E+05	-.35809E+04	.10661E+03
12	.13065E+05	-.36747E+04	.10731E+03

***** SLABS *****

SLAB NO.	MOMENT (FRONT)	MOMENT (REAR)	SHEAR
1	-.11136E-09	-.28292E+05	.11788E+03
2	-.28292E+05	-.57504E+05	.12172E+03
3	-.57504E+05	-.80758E+05	.10234E+03

4	-.80758E+05	-.96987E+05	.63473E+02
5	-.96987E+05	-.10071E+06	.27180E+02
6	-.94076E+05	-.97966E+05	.29374E+01
7	-.97966E+05	-.94076E+05	-.29374E+01
8	-.10071E+06	-.96987E+05	-.27180E+02
9	-.96987E+05	-.80758E+05	-.63473E+02
10	-.80758E+05	-.57504E+05	-.10234E+03
11	-.57504E+05	-.28292E+05	-.12172E+03
12	-.28292E+05	-.30295E-09	-.11788E+03
13	.92467E-10	-.44766E+05	.18653E+03
14	-.44766E+05	-.81203E+05	.15721E+03
15	-.81203E+05	-.11037E+06	.12691E+03
16	-.11037E+06	-.12783E+06	.93007E+02
17	-.12783E+06	-.13556E+06	.44734E+02
18	-.13657E+06	-.13712E+06	.83571E+00
19	-.13712E+06	-.13657E+06	-.83571E+00
20	-.13556E+06	-.12783E+06	-.44734E+02
21	-.12783E+06	-.11037E+06	-.93007E+02
22	-.11037E+06	-.81203E+05	-.12691E+03
23	-.81203E+05	-.44766E+05	-.15721E+03
24	-.44766E+05	.36557E-09	-.18653E+03
25	.13761E-09	-.43091E+05	.17955E+03
26	-.43091E+05	-.75341E+05	.14330E+03
27	-.75341E+05	-.10368E+06	.12948E+03
28	-.10368E+06	-.12318E+06	.86051E+02
29	-.12318E+06	-.12928E+06	.32865E+02
30	-.13576E+06	-.13772E+06	.59604E+00
31	-.13772E+06	-.13576E+06	-.59604E+00
32	-.12928E+06	-.12318E+06	-.32865E+02
33	-.12318E+06	-.10368E+06	-.86051E+02
34	-.10368E+06	-.75341E+05	-.12948E+03
35	-.75341E+05	-.43091E+05	-.14330E+03
36	-.43091E+05	-.22557E-10	-.17955E+03

YIELDING DETECTED IN SLAB NO. 30

YIELDING DETECTED IN SLAB NO. 31

PRINTING FORCES AT TIME....... 3.410000

***** COLUMNS *****

COL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.64451E+03	-.70434E+03	.90527E+01
2	.71489E+03	-.78863E+03	.10091E+02
3	.78942E+03	-.85764E+03	.11054E+02
4	.85553E+03	-.90159E+03	.11793E+02
5	.89006E+03	-.89889E+03	.12006E+02
6	.89029E+03	-.88525E+03	.11916E+02
7	.89006E+03	-.89889E+03	.12006E+02
8	.85553E+03	-.90159E+03	.11793E+02
9	.78942E+03	-.85764E+03	.11054E+02
10	.71489E+03	-.78863E+03	.10091E+02
11	.64451E+03	-.70434E+03	.90527E+01
12	.66659E+03	-.50341E+03	.78524E+01
13	.82928E+03	-.66754E+03	.10046E+02
14	.91999E+03	-.78411E+03	.11437E+02
15	.98795E+03	-.84031E+03	.12270E+02
16	.99598E+03	-.83055E+03	.12259E+02
17	.97736E+03	-.82996E+03	.12130E+02
18	.99598E+03	-.83055E+03	.12259E+02
19	.98795E+03	-.84031E+03	.12270E+02
20	.91999E+03	-.78411E+03	.11437E+02
21	.82928E+03	-.66754E+03	.10046E+02
22	.66659E+03	-.50341E+03	.78524E+01
23	.67065E+03	-.51103E+03	.79307E+01
24	.82636E+03	-.65508E+03	.99425E+01
25	.91740E+03	-.77225E+03	.11340E+02
26	.98553E+03	-.83700E+03	.12232E+02
27	.10046E+04	-.88906E+03	.12709E+02
28	.97591E+03	-.88663E+03	.12500E+02
29	.10046E+04	-.88906E+03	.12709E+02
30	.98553E+03	-.83700E+03	.12232E+02
31	.91740E+03	-.77225E+03	.11340E+02
32	.82636E+03	-.65508E+03	.99425E+01
33	.67065E+03	-.51103E+03	.79307E+01
34	.65351E+03	-.76890E+03	.95463E+01
35	.71782E+03	-.81781E+03	.10306E+02
36	.77967E+03	-.85966E+03	.11002E+02
37	.84382E+03	-.91282E+03	.11790E+02
38	.85470E+03	-.81849E+03	.11229E+02
39	.85085E+03	-.82502E+03	.11247E+02
40	.85470E+03	-.81849E+03	.11229E+02
41	.84382E+03	-.91282E+03	.11790E+02
42	.77967E+03	-.85966E+03	.11002E+02
43	.71782E+03	-.81781E+03	.10306E+02
44	.65351E+03	-.76890E+03	.95463E+01
45	.63685E+03	-.67591E+03	.92448E+01

46	.67098E+03	-.70758E+03	.97082E+01
47	.70298E+03	-.74163E+03	.10173E+02
48	.71419E+03	-.76476E+03	.10415E+02
49	.69523E+03	-.72408E+03	.99951E+01
50	.66330E+03	-.71896E+03	.97342E+01
51	.69523E+03	-.72408E+03	.99951E+01
52	.71419E+03	-.76476E+03	.10415E+02
53	.70298E+03	-.74163E+03	.10173E+02
54	.67098E+03	-.70758E+03	.97082E+01
55	.63685E+03	-.67591E+03	.92448E+01
56	.50880E+03	-.49998E+03	.71040E+01
57	.60593E+03	-.65584E+03	.88857E+01
58	.65618E+03	-.70637E+03	.95954E+01
59	.67671E+03	-.74316E+03	.99991E+01
60	.63875E+03	-.71144E+03	.95084E+01
61	.62099E+03	-.69576E+03	.92729E+01
62	.63875E+03	-.71144E+03	.95084E+01
63	.67671E+03	-.74316E+03	.99991E+01
64	.65618E+03	-.70637E+03	.95954E+01
65	.60593E+03	-.65584E+03	.88857E+01
66	.50880E+03	-.49998E+03	.71040E+01
67	.51632E+03	-.50342E+03	.71813E+01
68	.59068E+03	-.64482E+03	.87007E+01
69	.63783E+03	-.70516E+03	.94577E+01
70	.67597E+03	-.74520E+03	.10008E+02
71	.68418E+03	-.76084E+03	.10176E+02
72	.67209E+03	-.71771E+03	.97873E+01
73	.68418E+03	-.76084E+03	.10176E+02
74	.67597E+03	-.74520E+03	.10008E+02
75	.63783E+03	-.70516E+03	.94577E+01
76	.59068E+03	-.64482E+03	.87007E+01
77	.51632E+03	-.50342E+03	.71813E+01
78	.67727E+03	-.68357E+03	.95834E+01
79	.69253E+03	-.72017E+03	.99486E+01
80	.69906E+03	-.74365E+03	.10160E+02
81	.69866E+03	-.75614E+03	.10245E+02
82	.62591E+03	-.71775E+03	.94624E+01
83	.60170E+03	-.70123E+03	.91756E+01
84	.62591E+03	-.71775E+03	.94624E+01
85	.69866E+03	-.75614E+03	.10245E+02
86	.69906E+03	-.74365E+03	.10160E+02
87	.69253E+03	-.72017E+03	.99486E+01
88	.67727E+03	-.68357E+03	.95834E+01
89	.57836E+03	-.63133E+03	.85189E+01
90	.57310E+03	-.63509E+03	.85083E+01
91	.57650E+03	-.63673E+03	.85438E+01
92	.58479E+03	-.64692E+03	.86740E+01
93	.57536E+03	-.62859E+03	.84786E+01
94	.53878E+03	-.58820E+03	.79365E+01
95	.57536E+03	-.62859E+03	.84786E+01
96	.58479E+03	-.64692E+03	.86740E+01

97	.57650E+03	-.63673E+03	.85438E+01
98	.57310E+03	-.63509E+03	.85083E+01
99	.57836E+03	-.63133E+03	.85189E+01
100	.34123E+03	-.47197E+03	.57268E+01
101	.33344E+03	-.48854E+03	.57886E+01
102	.33441E+03	-.50013E+03	.58770E+01
103	.35101E+03	-.51927E+03	.61287E+01
104	.31171E+03	-.48141E+03	.55854E+01
105	.36367E+03	-.49591E+03	.60534E+01
106	.31171E+03	-.48141E+03	.55854E+01
107	.35101E+03	-.51927E+03	.61287E+01
108	.33441E+03	-.50013E+03	.58770E+01
109	.33344E+03	-.48854E+03	.57886E+01
110	.34123E+03	-.47197E+03	.57268E+01
111	.37610E+03	-.53832E+03	.64396E+01
112	.33062E+03	-.48863E+03	.57693E+01
113	.32454E+03	-.49053E+03	.57399E+01
114	.35681E+03	-.52210E+03	.61895E+01
115	.47514E+03	-.56666E+03	.73366E+01
116	.48498E+03	-.55289E+03	.73089E+01
117	.47514E+03	-.56666E+03	.73366E+01
118	.35681E+03	-.52210E+03	.61895E+01
119	.32454E+03	-.49053E+03	.57399E+01
120	.33062E+03	-.48863E+03	.57693E+01
121	.37610E+03	-.53832E+03	.64396E+01
122	.62923E+03	-.70206E+03	.93753E+01
123	.63327E+03	-.69720E+03	.93695E+01
124	.62583E+03	-.69911E+03	.93306E+01
125	.62873E+03	-.70450E+03	.93889E+01
126	.59840E+03	-.67051E+03	.89360E+01
127	.56249E+03	-.65076E+03	.85440E+01
128	.59840E+03	-.67051E+03	.89360E+01
129	.62873E+03	-.70450E+03	.93889E+01
130	.62583E+03	-.69911E+03	.93306E+01
131	.63327E+03	-.69720E+03	.93695E+01
132	.62923E+03	-.70206E+03	.93753E+01

***** BEAMS *****

BEAM NO.	MOMENT (LEFT)	MOMENT (RIGHT)	SHEAR
1	.90808E+02	-.12306E+04	.58471E+01
2	.18949E+03	-.12564E+04	.63976E+01
3	.27653E+03	-.12899E+04	.69311E+01
4	.37694E+03	-.13116E+04	.74715E+01

5	.49966E+03	-.13271E+04	.80831E+01
6	.51989E+03	-.13291E+04	.81815E+01
7	.49966E+03	-.13271E+04	.80831E+01
8	.37694E+03	-.13116E+04	.74715E+01
9	.27653E+03	-.12899E+04	.69311E+01
10	.18949E+03	-.12564E+04	.63976E+01
11	.90808E+02	-.12306E+04	.58471E+01
12	-.34440E+02	-.12341E+04	.53084E+01
13	.20190E+03	-.12995E+04	.66433E+01
14	.35003E+03	-.13358E+04	.74596E+01
15	.39795E+03	-.13605E+04	.77808E+01
16	.44967E+03	-.13671E+04	.80388E+01
17	.39902E+03	-.13616E+04	.77903E+01
18	.44967E+03	-.13671E+04	.80388E+01
19	.39795E+03	-.13605E+04	.77808E+01
20	.35003E+03	-.13358E+04	.74596E+01
21	.20190E+03	-.12995E+04	.66433E+01
22	-.34440E+02	-.12341E+04	.53084E+01
23	-.10146E+02	-.12150E+04	.53313E+01
24	.13503E+03	-.12494E+04	.61259E+01
25	.25140E+03	-.12845E+04	.67962E+01
26	.34816E+03	-.13057E+04	.73179E+01
27	.46402E+03	-.13166E+04	.78788E+01
28	.44582E+03	-.13102E+04	.77698E+01
29	.46402E+03	-.13166E+04	.78788E+01
30	.34816E+03	-.13057E+04	.73179E+01
31	.25140E+03	-.12845E+04	.67962E+01
32	.13503E+03	-.12494E+04	.61259E+01
33	-.10146E+02	-.12150E+04	.53313E+01
34	.17654E+03	-.12428E+04	.62801E+01
35	.17654E+03	-.12428E+04	.62801E+01
36	-.58257E+02	-.12114E+04	.51024E+01
37	-.94768E+02	-.12104E+04	.49365E+01
38	-.28141E+02	-.12183E+04	.52663E+01
39	.48762E+01	-.12243E+04	.54386E+01
40	.12759E+03	-.12320E+04	.60159E+01
41	.17450E+03	-.12267E+04	.61999E+01
42	.12759E+03	-.12320E+04	.60159E+01
43	.48762E+01	-.12243E+04	.54386E+01
44	-.28141E+02	-.12183E+04	.52663E+01
45	-.94768E+02	-.12104E+04	.49365E+01
46	-.58257E+02	-.12114E+04	.51024E+01
47	-.14224E+03	-.12216E+04	.47758E+01
48	.32977E+02	-.12520E+04	.56857E+01
49	.68518E+02	-.12643E+04	.58976E+01
50	.10057E+03	-.12641E+04	.60382E+01
51	.11081E+03	-.12742E+04	.61283E+01
52	.76219E+02	-.12700E+04	.59566E+01
53	.11081E+03	-.12742E+04	.61283E+01
54	.10057E+03	-.12641E+04	.60382E+01
55	.68518E+02	-.12643E+04	.58976E+01

56	.32977E+02	-.12520E+04	.56857E+01
57	-.14224E+03	-.12216E+04	.47758E+01
58	-.46277E+02	-.12279E+04	.52284E+01
59	-.48515E+02	-.12208E+04	.51870E+01
60	.27737E+01	-.12397E+04	.54975E+01
61	.11191E+02	-.12512E+04	.55859E+01
62	.17568E+03	-.11957E+04	.60681E+01
63	.17478E+03	-.11970E+04	.60696E+01
64	.17568E+03	-.11957E+04	.60681E+01
65	.11191E+02	-.12512E+04	.55859E+01
66	.27737E+01	-.12397E+04	.54975E+01
67	-.48515E+02	-.12208E+04	.51870E+01
68	-.46277E+02	-.12279E+04	.52284E+01
69	.25349E+03	-.12666E+04	.67263E+01
70	.25349E+03	-.12666E+04	.67263E+01
71	-.39079E+03	-.11500E+04	.33592E+01
72	-.46212E+03	-.11299E+04	.29549E+01
73	-.43680E+03	-.11291E+04	.30633E+01
74	-.44733E+03	-.11318E+04	.30287E+01
75	-.37741E+03	-.11245E+04	.33057E+01
76	-.32133E+03	-.11349E+04	.35997E+01
77	-.37741E+03	-.11245E+04	.33057E+01
78	-.44733E+03	-.11318E+04	.30287E+01
79	-.43680E+03	-.11291E+04	.30633E+01
80	-.46212E+03	-.11299E+04	.29549E+01
81	-.39079E+03	-.11500E+04	.33592E+01
82	-.51257E+03	-.11230E+04	.27009E+01
83	-.49821E+03	-.11559E+04	.29102E+01
84	-.50060E+03	-.11603E+04	.29192E+01
85	-.47317E+03	-.11615E+04	.30457E+01
86	-.42257E+03	-.11661E+04	.32901E+01
87	-.39581E+03	-.11681E+04	.34171E+01
88	-.42257E+03	-.11661E+04	.32901E+01
89	-.47317E+03	-.11615E+04	.30457E+01
90	-.50060E+03	-.11603E+04	.29192E+01
91	-.49821E+03	-.11559E+04	.29102E+01
92	-.51257E+03	-.11230E+04	.27009E+01
93	-.43033E+03	-.10446E+04	.27178E+01
94	-.58920E+03	-.90883E+03	.14143E+01
95	-.58775E+03	-.92556E+03	.14947E+01
96	-.57816E+03	-.95313E+03	.16592E+01
97	-.42468E+03	-.84494E+03	.18596E+01
98	-.44460E+03	-.85809E+03	.18296E+01
99	-.42468E+03	-.84494E+03	.18596E+01
100	-.57816E+03	-.95313E+03	.16592E+01
101	-.58775E+03	-.92556E+03	.14947E+01
102	-.58920E+03	-.90883E+03	.14143E+01
103	-.43033E+03	-.10446E+04	.27178E+01
104	.25240E+03	-.12720E+04	.67452E+01
105	.25240E+03	-.12720E+04	.67452E+01

***** WALLS *****

WALL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.72654E+05	.38962E+05	.25429E+03
2	.72645E+05	.38947E+05	.25403E+03
3	.72654E+05	.38962E+05	.25429E+03
4	.72645E+05	.38947E+05	.25403E+03
5	.40507E+05	.99176E+04	.21282E+03
6	.40485E+05	.98907E+04	.21318E+03
7	.40507E+05	.99176E+04	.21282E+03
8	.40485E+05	.98907E+04	.21318E+03
9	.13481E+05	-.36363E+04	.10973E+03
10	.13493E+05	-.37236E+04	.11037E+03
11	.13481E+05	-.36363E+04	.10973E+03
12	.13493E+05	-.37236E+04	.11037E+03

***** SLABS *****

SLAB NO.	MOMENT (FRONT)	MOMENT (REAR)	SHEAR
1	-.11136E-09	-.24795E+05	.10331E+03
2	-.24795E+05	-.52469E+05	.11531E+03
3	-.52469E+05	-.76468E+05	.10545E+03
4	-.76468E+05	-.96557E+05	.79554E+02
5	-.96557E+05	-.10184E+06	.33650E+02
6	-.95198E+05	-.99908E+05	.63543E+01
7	-.99908E+05	-.95198E+05	-.63543E+01
8	-.10184E+06	-.96557E+05	-.33650E+02
9	-.96557E+05	-.76468E+05	-.79554E+02
10	-.76468E+05	-.52469E+05	-.10545E+03
11	-.52469E+05	-.24795E+05	-.11531E+03
12	-.24795E+05	-.30249E-09	-.10331E+03
13	.63363E-10	-.44721E+05	.18634E+03
14	-.44721E+05	-.81349E+05	.15801E+03
15	-.81349E+05	-.11099E+06	.12891E+03
16	-.11099E+06	-.12827E+06	.92241E+02
17	-.12827E+06	-.13554E+06	.42831E+02
18	-.13656E+06	-.13862E+06	.71585E+01

19	-.13862E+06	-.13656E+06	-.71585E+01
20	-.13554E+06	-.12827E+06	-.42831E+02
21	-.12827E+06	-.11099E+06	-.92241E+02
22	-.11099E+06	-.81349E+05	-.12891E+03
23	-.81349E+05	-.44721E+05	-.15801E+03
24	-.44721E+05	.38012E-09	-.18634E+03
25	.10850E-09	-.41839E+05	.17433E+03
26	-.41839E+05	-.78001E+05	.16007E+03
27	-.78001E+05	-.10629E+06	.12881E+03
28	-.10629E+06	-.12374E+06	.77506E+02
29	-.12374E+06	-.13157E+06	.40067E+02
30	-.13669E+06	-.13901E+06	-.35945E+01
31	-.13901E+06	-.13669E+06	.35945E+01
32	-.13157E+06	-.12374E+06	-.40067E+02
33	-.12374E+06	-.10629E+06	-.77506E+02
34	-.10629E+06	-.78001E+05	-.12881E+03
35	-.78001E+05	-.41839E+05	-.16007E+03
36	-.41839E+05	-.80048E-11	-.17433E+03

********** MAXIMUM RESPONSE ******* .... FRAME NO. 1

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.1178E+00	.1178E+00	.1624E+01	.1449E+03	.5578E+03
	(3.4050)	(3.4050)	(3.3450)	(3.6450)	(3.3900)
2	.1735E+00	.2908E+00	.3729E+01	.1366E+03	.4260E+03
	(3.4100)	(3.4100)	(3.3500)	(4.0500)	(3.4100)
3	.1812E+00	.4715E+00	.6004E+01	.2139E+03	.2321E+03
	(3.4150)	(3.4100)	(3.3250)	(4.2050)	(3.4200)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 2

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.2060E+00	.2060E+00	.2676E+01	.1196E+03	.3479E+02
	(3.4050)	(3.4050)	(3.3400)	(3.3450)	(3.4000)
2	.2466E+00	.4448E+00	.5488E+01	.1493E+03	.3425E+02
	(3.4250)	(3.4150)	(3.3400)	(3.3800)	(3.4250)
3	.1902E+00	.6337E+00	.7771E+01	.2082E+03	.3058E+02
	(3.4200)	(3.4200)	(3.3350)	(3.4200)	(3.4200)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 3

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.2920E+00	.2920E+00	.3890E+01	.1263E+03	.4097E+02
	(3.4050)	(3.4050)	(3.4500)	(3.3450)	(3.4000)
2	.3296E+00	.5981E+00	.7229E+01	.1335E+03	.4018E+02
	(3.4450)	(3.4200)	(3.3400)	(3.3850)	(3.4550)
3	.2063E+00	.7994E+00	.9655E+01	.2038E+03	.3084E+02
	(3.4300)	(3.4250)	(3.3400)	(3.3950)	(3.8800)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 4

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.3725E+00	.3725E+00	.4950E+01	.1435E+03	.4521E+02
	(3.4050)	(3.4050)	(3.4500)	(3.7800)	(3.4000)
2	.4275E+00	.7433E+00	.8764E+01	.1662E+03	.4329E+02
	(3.4550)	(3.4250)	(3.3400)	(3.3950)	(3.4600)
3	.2379E+00	.9603E+00	.1132E+02	.2245E+03	.3639E+02
	(3.8800)	(3.4300)	(3.3400)	(3.3900)	(3.8850)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 5

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.4454E+00	.4454E+00	.6215E+01	.1646E+03	.4842E+02
	(3.4100)	(3.4100)	(3.7450)	(3.6900)	(3.4050)
2	.5108E+00	.8715E+00	.1022E+02	.1746E+03	.4568E+02
	(3.4550)	(3.4250)	(3.3350)	(3.4300)	(3.4550)
3	.2898E+00	.1106E+01	.1309E+02	.2399E+03	.3823E+02
	(3.8800)	(3.4350)	(3.5150)	(3.5900)	(3.8850)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 6

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.5029E+00	.5029E+00	.7238E+01	.1774E+03	.4837E+02
	(3.4100)	(3.4100)	(3.7450)	(3.4200)	(3.4050)
2	.5744E+00	.9727E+00	.1172E+02	.2032E+03	.4551E+02
	(3.4500)	(3.4300)	(3.4950)	(3.4400)	(3.4550)
3	.3398E+00	.1228E+01	.1496E+02	.4068E+03	.3992E+02
	(3.8800)	(3.4350)	(3.5100)	(3.4650)	(3.8850)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 7

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.5279E+00	.5279E+00	.7648E+01	.2526E+03	.4783E+02
	(3.4100)	(3.4100)	(3.7500)	(3.4250)	(3.4050)
2	.6079E+00	.1023E+01	.1274E+02	.2748E+03	.4500E+02
	(3.4500)	(3.4300)	(3.4950)	(3.4450)	(3.4550)
3	.3661E+00	.1290E+01	.1592E+02	.4912E+03	.4066E+02
	(3.8850)	(3.4400)	(3.5200)	(3.4550)	(3.8850)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 8

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.5029E+00	.5029E+00	.7238E+01	.1774E+03	.4837E+02
	(3.4100)	(3.4100)	(3.7450)	(3.4200)	(3.4050)
2	.5744E+00	.9727E+00	.1172E+02	.2032E+03	.4551E+02
	(3.4500)	(3.4300)	(3.4950)	(3.4400)	(3.4550)
3	.3398E+00	.1228E+01	.1496E+02	.4068E+03	.3992E+02
	(3.8800)	(3.4350)	(3.5100)	(3.4650)	(3.8850)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 9

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.4454E+00	.4454E+00	.6215E+01	.1646E+03	.4842E+02
	(3.4100)	(3.4100)	(3.7450)	(3.6900)	(3.4050)
2	.5108E+00	.8715E+00	.1022E+02	.1746E+03	.4568E+02

	(3.4550)	(3.4250)	(3.3350)	(3.4300)	(3.4550)
3	.2898E+00	.1106E+01	.1309E+02	.2399E+03	.3823E+02
	(3.8800)	(3.4350)	(3.5150)	(3.5900)	(3.8850)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 10

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.3725E+00	.3725E+00	.4950E+01	.1435E+03	.4521E+02
	(3.4050)	(3.4050)	(3.4500)	(3.7800)	(3.4000)
2	.4275E+00	.7433E+00	.8764E+01	.1662E+03	.4329E+02
	(3.4550)	(3.4250)	(3.3400)	(3.3950)	(3.4600)
3	.2379E+00	.9603E+00	.1132E+02	.2245E+03	.3639E+02
	(3.8800)	(3.4300)	(3.3400)	(3.3900)	(3.8850)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 11

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.2920E+00	.2920E+00	.3890E+01	.1263E+03	.4097E+02
	(3.4050)	(3.4050)	(3.4500)	(3.3450)	(3.4000)
2	.3296E+00	.5981E+00	.7229E+01	.1335E+03	.4018E+02
	(3.4450)	(3.4200)	(3.3400)	(3.3850)	(3.4550)
3	.2063E+00	.7994E+00	.9655E+01	.2038E+03	.3084E+02
	(3.4300)	(3.4250)	(3.3400)	(3.3950)	(3.8800)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 12

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.2060E+00	.2060E+00	.2676E+01	.1196E+03	.3479E+02
	(3.4050)	(3.4050)	(3.3400)	(3.3450)	(3.4000)
2	.2466E+00	.4448E+00	.5488E+01	.1493E+03	.3425E+02
	(3.4250)	(3.4150)	(3.3400)	(3.3800)	(3.4250)
3	.1902E+00	.6337E+00	.7771E+01	.2082E+03	.3058E+02
	(3.4200)	(3.4200)	(3.3350)	(3.4200)	(3.4200)

********** MAXIMUM RESPONSE ******* .... FRAME NO. 13

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	.1178E+00	.1178E+00	.1624E+01	.1449E+03	.5578E+03
	(3.4050)	(3.4050)	(3.3450)	(3.6450)	(3.3900)
2	.1735E+00	.2908E+00	.3729E+01	.1366E+03	.4260E+03
	(3.4100)	(3.4100)	(3.3500)	(4.0500)	(3.4100)
3	.1812E+00	.4715E+00	.6004E+01	.2139E+03	.2321E+03
	(3.4150)	(3.4100)	(3.3250)	(4.2050)	(3.4200)

********** MAX STORY SHEARS **********

STORY	BASE SHEAR	TIME OF OCCURENCE
1	.15914E+04	.33900E+01
2	.12745E+04	.34150E+01
3	.80453E+03	.34200E+01

***** DISPL AT FRAMES AT MAX TOP DISPL *****

STORY FRAME NUMBERS

STORY	1	2	3	4	5	6	7	8	9	10	11	12	13
1	.9815E-01	.1662E+00	.2330E+00	.2958E+00	.3520E+00	.3966E+00	.4165E+00	.3966E+00	.3520E+00	.2958E+00	.2330E+00	.1662E+00	.9815E-01
2	.2401E+00	.4023E+00	.5624E+00	.7150E+00	.8481E+00	.9534E+00	.1007E+01	.9534E+00	.8481E+00	.7150E+00	.5624E+00	.4023E+00	.2401E+00
3	.3889E+00	.5789E+00	.7648E+00	.9421E+00	.1099E+01	.1227E+01	.1290E+01	.1227E+01	.1099E+01	.9421E+00	.7648E+00	.5789E+00	.3889E+00

***** SHEAR DISTRIBUTION ACROSS FRAMES *****

STORY FRAME NUMBERS

STORY	1	2	3	4	5	6	7	8	9	10	11	12	13
1	.5578E+03	.3410E+02	.4056E+02	.4467E+02	.4766E+02	.4752E+02	.4679E+02	.4752E+02	.4766E+02	.4467E+02	.4056E+02	.3410E+02	.5578E+03
2	.4241E+03	.3369E+02	.3829E+02	.4031E+02	.4141E+02	.3998E+02	.3892E+02	.3998E+02	.4141E+02	.4031E+02	.3829E+02	.3369E+02	.4241E+03
3	.2321E+03	.3058E+02	.3028E+02	.3063E+02	.3167E+02	.3151E+02	.3092E+02	.3151E+02	.3167E+02	.3063E+02	.3028E+02	.3058E+02	.2321E+03

********* SHEAR DISTRIBUTION AT MAX BASE SHEAR *********

TIME OF OCCURENCE = 3.3900

LEVEL	STORY SHEAR
1	.159137E+04
2	.115953E+04
3	.659759E+03

***** COLUMNS *****

COL NO.	** MAXIMUM MOMENTS ** BOT	TOP	MAX SHEAR
1	.6461E+03 (3.40)	-.7084E+03 (3.40)	.9090E+01 (3.40)
2	.7163E+03 (3.40)	-.7910E+03 (3.40)	.1012E+02 (3.40)
3	.7906E+03 (3.40)	-.8605E+03 (3.40)	.1108E+02 (3.40)
4	.8556E+03 (3.40)	-.9040E+03 (3.40)	.1181E+02 (3.40)
5	.8901E+03 (3.41)	-.9006E+03 (3.40)	.1201E+02 (3.40)
6	.8903E+03 (3.41)	-.8870E+03 (3.40)	.1192E+02 (3.40)
7	.8901E+03 (3.41)	-.9006E+03 (3.40)	.1201E+02 (3.40)
8	.8556E+03 (3.40)	-.9040E+03 (3.40)	.1181E+02 (3.40)
9	.7906E+03 (3.40)	-.8605E+03 (3.40)	.1108E+02 (3.40)
10	.7163E+03 (3.40)	-.7910E+03 (3.40)	.1012E+02 (3.40)
11	.6461E+03 (3.40)	-.7084E+03 (3.40)	.9090E+01 (3.40)
12	.6747E+03 (3.40)	-.5203E+03 (3.40)	.8020E+01 (3.40)
13	.8404E+03 (3.40)	-.6940E+03 (3.39)	.1029E+02 (3.40)
14	.9246E+03 (3.40)	-.8017E+03 (3.40)	.1157E+02 (3.40)
15	.9916E+03 (3.40)	-.8581E+03 (3.40)	.1240E+02 (3.40)
16	-.1063E+04 (3.68)	.9727E+03 (3.68)	-.1367E+02 (3.68)
17	-.1060E+04 (3.68)	.9769E+03 (3.68)	-.1367E+02 (3.68)
18	-.1063E+04 (3.68)	.9727E+03 (3.68)	-.1367E+02 (3.68)
19	.9916E+03 (3.40)	-.8581E+03 (3.40)	.1240E+02 (3.40)
20	.9246E+03 (3.40)	-.8017E+03 (3.40)	.1157E+02 (3.40)
21	.8404E+03 (3.40)	-.6940E+03 (3.39)	.1029E+02 (3.40)
22	.6747E+03 (3.40)	-.5203E+03 (3.40)	.8020E+01 (3.40)
23	.6785E+03 (3.40)	-.5275E+03 (3.40)	.8094E+01 (3.40)
24	.8388E+03 (3.40)	-.6855E+03 (3.39)	.1022E+02 (3.40)
25	.9226E+03 (3.40)	-.7967E+03 (3.39)	.1153E+02 (3.40)
26	.9894E+03 (3.40)	-.8556E+03 (3.40)	.1237E+02 (3.40)
27	-.1011E+04 (3.68)	-.8901E+03 (3.40)	.1271E+02 (3.41)
28	-.1061E+04 (3.68)	.9193E+03 (3.68)	-.1329E+02 (3.68)
29	-.1011E+04 (3.68)	-.8901E+03 (3.40)	.1271E+02 (3.41)
30	.9894E+03 (3.40)	-.8556E+03 (3.40)	.1237E+02 (3.40)
31	.9226E+03 (3.40)	-.7967E+03 (3.39)	.1153E+02 (3.40)
32	.8388E+03 (3.40)	-.6855E+03 (3.39)	.1022E+02 (3.40)
33	.6785E+03 (3.40)	-.5275E+03 (3.40)	.8094E+01 (3.40)
34	.6551E+03 (3.40)	-.7738E+03 (3.40)	.9588E+01 (3.40)
35	.7199E+03 (3.40)	-.8250E+03 (3.40)	.1036E+02 (3.40)
36	.7817E+03 (3.40)	-.8680E+03 (3.40)	.1106E+02 (3.40)
37	.8448E+03 (3.40)	-.9207E+03 (3.40)	.1184E+02 (3.40)
38	.8549E+03 (3.40)	-.8400E+03 (3.39)	.1131E+02 (3.39)
39	-.8794E+03 (3.68)	-.8382E+03 (3.39)	.1130E+02 (3.40)
40	.8549E+03 (3.40)	-.8400E+03 (3.39)	.1131E+02 (3.39)
41	.8448E+03 (3.40)	-.9207E+03 (3.40)	.1184E+02 (3.40)
42	.7817E+03 (3.40)	-.8680E+03 (3.40)	.1106E+02 (3.40)
43	.7199E+03 (3.40)	-.8250E+03 (3.40)	.1036E+02 (3.40)
44	.6551E+03 (3.40)	-.7738E+03 (3.40)	.9588E+01 (3.40)
45	.6473E+03 (3.42)	-.6846E+03 (3.42)	.9380E+01 (3.42)

46	.7180E+03	(3.46)	-.7405E+03	(3.45)	.1027E+02	(3.46)
47	.7863E+03	(3.46)	-.8009E+03	(3.45)	.1118E+02	(3.46)
48	.8268E+03	(3.46)	-.8458E+03	(3.45)	.1177E+02	(3.46)
49	.8305E+03	(3.46)	-.8280E+03	(3.45)	.1167E+02	(3.45)
50	.8120E+03	(3.46)	-.8354E+03	(3.45)	.1160E+02	(3.45)
51	.8305E+03	(3.46)	-.8280E+03	(3.45)	.1167E+02	(3.45)
52	.8268E+03	(3.46)	-.8458E+03	(3.45)	.1177E+02	(3.46)
53	.7863E+03	(3.46)	-.8009E+03	(3.45)	.1118E+02	(3.46)
54	.7180E+03	(3.46)	-.7405E+03	(3.45)	.1027E+02	(3.46)
55	.6473E+03	(3.42)	-.6846E+03	(3.42)	.9380E+01	(3.42)
56	.5436E+03	(3.42)	-.5254E+03	(3.42)	.7528E+01	(3.42)
57	.6872E+03	(3.45)	-.6982E+03	(3.45)	.9756E+01	(3.45)
58	.7353E+03	(3.45)	-.7642E+03	(3.45)	.1056E+02	(3.45)
59	.7801E+03	(3.45)	-.8200E+03	(3.45)	.1127E+02	(3.45)
60	-.9011E+03	(3.59)	.8371E+03	(3.60)	-.1224E+02	(3.59)
61	-.8935E+03	(3.58)	.8211E+03	(3.60)	-.1207E+02	(3.60)
62	-.9011E+03	(3.59)	.8371E+03	(3.60)	-.1224E+02	(3.59)
63	.7801E+03	(3.45)	-.8200E+03	(3.45)	.1127E+02	(3.45)
64	.7353E+03	(3.45)	-.7642E+03	(3.45)	.1056E+02	(3.45)
65	.6872E+03	(3.45)	-.6982E+03	(3.45)	.9756E+01	(3.45)
66	.5436E+03	(3.42)	-.5254E+03	(3.42)	.7528E+01	(3.42)
67	.5527E+03	(3.42)	-.5305E+03	(3.42)	.7628E+01	(3.42)
68	.6848E+03	(3.45)	-.6925E+03	(3.45)	.9699E+01	(3.45)
69	.7331E+03	(3.46)	-.7627E+03	(3.45)	.1053E+02	(3.45)
70	.7761E+03	(3.45)	-.8214E+03	(3.45)	.1125E+02	(3.45)
71	.8144E+03	(3.45)	-.8701E+03	(3.45)	.1186E+02	(3.45)
72	-.8246E+03	(3.58)	-.8433E+03	(3.45)	.1168E+02	(3.45)
73	.8144E+03	(3.45)	-.8701E+03	(3.45)	.1186E+02	(3.45)
74	.7761E+03	(3.45)	-.8214E+03	(3.45)	.1125E+02	(3.45)
75	.7331E+03	(3.46)	-.7627E+03	(3.45)	.1053E+02	(3.45)
76	.6848E+03	(3.45)	-.6925E+03	(3.45)	.9699E+01	(3.45)
77	.5527E+03	(3.42)	-.5305E+03	(3.42)	.7628E+01	(3.42)
78	.6896E+03	(3.43)	-.6905E+03	(3.43)	.9719E+01	(3.43)
79	.7424E+03	(3.46)	-.7463E+03	(3.45)	.1048E+02	(3.46)
80	.7847E+03	(3.46)	-.7872E+03	(3.45)	.1107E+02	(3.46)
81	.8118E+03	(3.46)	-.8115E+03	(3.45)	.1141E+02	(3.46)
82	.7654E+03	(3.46)	-.7859E+03	(3.45)	.1090E+02	(3.45)
83	.7527E+03	(3.46)	-.7783E+03	(3.44)	.1071E+02	(3.45)
84	.7654E+03	(3.46)	-.7859E+03	(3.45)	.1090E+02	(3.45)
85	.8118E+03	(3.46)	-.8115E+03	(3.45)	.1141E+02	(3.46)
86	.7847E+03	(3.46)	-.7872E+03	(3.45)	.1107E+02	(3.46)
87	.7424E+03	(3.46)	-.7463E+03	(3.45)	.1048E+02	(3.46)
88	.6896E+03	(3.43)	-.6905E+03	(3.43)	.9719E+01	(3.43)
89	.5839E+03	(3.42)	-.6375E+03	(3.42)	.8601E+01	(3.42)
90	.6284E+03	(3.88)	-.6719E+03	(3.88)	.9154E+01	(3.88)
91	.6664E+03	(3.88)	-.7236E+03	(3.88)	.9785E+01	(3.88)
92	.7211E+03	(3.89)	-.7775E+03	(3.88)	.1055E+02	(3.88)
93	.7301E+03	(3.88)	-.7991E+03	(3.88)	.1076E+02	(3.88)
94	.7119E+03	(3.88)	-.7726E+03	(3.88)	.1045E+02	(3.88)
95	.7301E+03	(3.88)	-.7991E+03	(3.88)	.1076E+02	(3.88)
96	.7211E+03	(3.89)	-.7775E+03	(3.88)	.1055E+02	(3.88)

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 97  .6664E+03 ( 3.88)-.7236E+03 ( 3.88)      .9785E+01 ( 3.88)
 98  .6284E+03 ( 3.88)-.6719E+03 ( 3.88)      .9154E+01 ( 3.88)
 99  .5839E+03 ( 3.42)-.6375E+03 ( 3.42)      .8601E+01 ( 3.42)
100 -.5411E+03 ( 3.61)-.4852E+03 ( 3.42)     -.7224E+01 ( 3.61)
101 -.5841E+03 ( 3.61) .5648E+03 ( 3.61)     -.8090E+01 ( 3.61)
102 -.6089E+03 ( 3.61)-.6646E+03 ( 3.88)     -.8391E+01 ( 3.61)
103 -.6065E+03 ( 3.60)-.6546E+03 ( 3.88)      .8635E+01 ( 3.88)
104 -.6203E+03 ( 3.60)-.7408E+03 ( 3.88)      .9263E+01 ( 3.88)
105  .7679E+03 ( 3.88)-.7361E+03 ( 3.88)      .1059E+02 ( 3.88)
106 -.6203E+03 ( 3.60)-.7408E+03 ( 3.88)      .9263E+01 ( 3.88)
107 -.6065E+03 ( 3.60)-.6546E+03 ( 3.88)      .8635E+01 ( 3.88)
108 -.6089E+03 ( 3.61)-.6646E+03 ( 3.88)     -.8391E+01 ( 3.61)
109 -.5841E+03 ( 3.61) .5648E+03 ( 3.61)     -.8090E+01 ( 3.61)
110 -.5411E+03 ( 3.61)-.4852E+03 ( 3.42)     -.7224E+01 ( 3.61)
111 -.4887E+03 ( 3.61)-.5576E+03 ( 3.42)      .6665E+01 ( 3.42)
112 -.5732E+03 ( 3.61)-.5385E+03 ( 3.43)     -.7777E+01 ( 3.61)
113 -.6020E+03 ( 3.61)-.7278E+03 ( 3.88)      .8452E+01 ( 3.88)
114 -.6041E+03 ( 3.60)-.6570E+03 ( 3.88)      .8656E+01 ( 3.88)
115  .6433E+03 ( 3.88)-.7143E+03 ( 3.88)      .9561E+01 ( 3.88)
116  .6398E+03 ( 3.88)-.6993E+03 ( 3.88)      .9430E+01 ( 3.88)
117  .6433E+03 ( 3.88)-.7143E+03 ( 3.88)      .9561E+01 ( 3.88)
118 -.6041E+03 ( 3.60)-.6570E+03 ( 3.88)      .8656E+01 ( 3.88)
119 -.6020E+03 ( 3.61)-.7278E+03 ( 3.88)      .8452E+01 ( 3.88)
120 -.5732E+03 ( 3.61)-.5385E+03 ( 3.43)     -.7777E+01 ( 3.61)
121 -.4887E+03 ( 3.61)-.5576E+03 ( 3.42)      .6665E+01 ( 3.42)
122  .6319E+03 ( 3.42)-.7073E+03 ( 3.42)      .9431E+01 ( 3.42)
123  .6510E+03 ( 3.88)-.7100E+03 ( 3.43)      .9524E+01 ( 3.88)
124  .6649E+03 ( 3.89)-.7471E+03 ( 3.88)      .9943E+01 ( 3.88)
125  .6808E+03 ( 3.89)-.7959E+03 ( 3.88)      .1039E+02 ( 3.88)
126  .6761E+03 ( 3.88)-.7926E+03 ( 3.88)      .1034E+02 ( 3.88)
127  .6556E+03 ( 3.89)-.7904E+03 ( 3.88)      .1018E+02 ( 3.88)
128  .6761E+03 ( 3.88)-.7926E+03 ( 3.88)      .1034E+02 ( 3.88)
129  .6808E+03 ( 3.89)-.7959E+03 ( 3.88)      .1039E+02 ( 3.88)
130  .6649E+03 ( 3.89)-.7471E+03 ( 3.88)      .9943E+01 ( 3.88)
131  .6510E+03 ( 3.88)-.7100E+03 ( 3.43)      .9524E+01 ( 3.88)
132  .6319E+03 ( 3.42)-.7073E+03 ( 3.42)      .9431E+01 ( 3.42)


                        ***** BEAMS *****


BEAM        ** MAXIMUM MOMENTS **                   MAX SHEAR
 NO.       LEFT             RIGHT


  1 -.1169E+04 ( 3.64)-.1231E+04 ( 3.41)      .5847E+01 ( 3.41)
  2 -.1217E+04 ( 3.65)-.1257E+04 ( 3.41)      .6398E+01 ( 3.41)
  3 -.1251E+04 ( 3.66)-.1290E+04 ( 3.41)      .6931E+01 ( 3.41)
  4 -.1269E+04 ( 3.66)-.1312E+04 ( 3.41)      .7472E+01 ( 3.41)
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5	-.1268E+04 (3.67)	-.1328E+04 (3.41)	.8106E+01 (3.41)
6	-.1272E+04 (3.67)	-.1331E+04 (3.41)	.8218E+01 (3.41)
7	-.1268E+04 (3.67)	-.1328E+04 (3.41)	.8106E+01 (3.41)
8	-.1269E+04 (3.66)	-.1312E+04 (3.41)	.7472E+01 (3.41)
9	-.1251E+04 (3.66)	-.1290E+04 (3.41)	.6931E+01 (3.41)
10	-.1217E+04 (3.65)	-.1257E+04 (3.41)	.6398E+01 (3.41)
11	-.1169E+04 (3.64)	-.1231E+04 (3.41)	.5847E+01 (3.41)
12	-.1119E+04 (3.22)	-.1235E+04 (3.41)	.5326E+01 (3.41)
13	-.1153E+04 (3.22)	-.1302E+04 (3.41)	.6688E+01 (3.41)
14	-.1184E+04 (3.23)	-.1338E+04 (3.41)	.7508E+01 (3.41)
15	-.1215E+04 (3.23)	-.1361E+04 (3.41)	.7785E+01 (3.41)
16	-.1215E+04 (3.23)	-.1368E+04 (3.41)	.8057E+01 (3.41)
17	-.1219E+04 (3.67)	-.1364E+04 (3.41)	.7826E+01 (3.41)
18	-.1215E+04 (3.23)	-.1368E+04 (3.41)	.8057E+01 (3.41)
19	-.1215E+04 (3.23)	-.1361E+04 (3.41)	.7785E+01 (3.41)
20	-.1184E+04 (3.23)	-.1338E+04 (3.41)	.7508E+01 (3.41)
21	-.1153E+04 (3.22)	-.1302E+04 (3.41)	.6688E+01 (3.41)
22	-.1119E+04 (3.22)	-.1235E+04 (3.41)	.5326E+01 (3.41)
23	-.1180E+04 (3.64)	-.1215E+04 (3.41)	-.5505E+01 (3.64)
24	-.1202E+04 (3.23)	-.1250E+04 (3.41)	.6148E+01 (3.41)
25	-.1239E+04 (3.23)	-.1285E+04 (3.41)	.6818E+01 (3.41)
26	-.1258E+04 (3.23)	-.1306E+04 (3.41)	.7318E+01 (3.41)
27	-.1237E+04 (3.23)	-.1318E+04 (3.41)	.7900E+01 (3.41)
28	-.1242E+04 (3.23)	-.1312E+04 (3.41)	.7806E+01 (3.41)
29	-.1237E+04 (3.23)	-.1318E+04 (3.41)	.7900E+01 (3.41)
30	-.1258E+04 (3.23)	-.1306E+04 (3.41)	.7318E+01 (3.41)
31	-.1239E+04 (3.23)	-.1285E+04 (3.41)	.6818E+01 (3.41)
32	-.1202E+04 (3.23)	-.1250E+04 (3.41)	.6148E+01 (3.41)
33	-.1180E+04 (3.64)	-.1215E+04 (3.41)	-.5505E+01 (3.64)
34	-.1184E+04 (3.64)	-.1243E+04 (3.41)	.6280E+01 (3.41)
35	-.1184E+04 (3.64)	-.1243E+04 (3.41)	.6280E+01 (3.41)
36	-.1200E+04 (3.62)	-.1216E+04 (3.42)	.5181E+01 (3.42)
37	-.1212E+04 (3.61)	-.1223E+04 (3.43)	.5178E+01 (3.43)
38	-.1234E+04 (3.60)	-.1241E+04 (3.45)	.5700E+01 (3.45)
39	-.1268E+04 (3.60)	-.1260E+04 (3.46)	.6131E+01 (3.46)
40	-.1235E+04 (3.60)	-.1282E+04 (3.46)	.6991E+01 (3.46)
41	-.1230E+04 (3.60)	-.1281E+04 (3.45)	.7281E+01 (3.45)
42	-.1235E+04 (3.60)	-.1282E+04 (3.46)	.6991E+01 (3.46)
43	-.1268E+04 (3.60)	-.1260E+04 (3.46)	.6131E+01 (3.46)
44	-.1234E+04 (3.60)	-.1241E+04 (3.45)	.5700E+01 (3.45)
45	-.1212E+04 (3.61)	-.1223E+04 (3.43)	.5178E+01 (3.43)
46	-.1200E+04 (3.62)	-.1216E+04 (3.42)	.5181E+01 (3.42)
47	-.1113E+04 (3.62)	-.1228E+04 (3.42)	.4932E+01 (3.42)
48	-.1129E+04 (3.61)	-.1267E+04 (3.43)	.6015E+01 (3.43)
49	-.1134E+04 (3.61)	-.1290E+04 (3.45)	.6429E+01 (3.45)
50	-.1156E+04 (3.60)	-.1305E+04 (3.45)	.6880E+01 (3.45)
51	-.1169E+04 (3.60)	-.1324E+04 (3.46)	.7272E+01 (3.46)
52	-.1178E+04 (3.60)	-.1323E+04 (3.45)	.7194E+01 (3.45)
53	-.1169E+04 (3.60)	-.1324E+04 (3.46)	.7272E+01 (3.46)
54	-.1156E+04 (3.60)	-.1305E+04 (3.45)	.6880E+01 (3.45)
55	-.1134E+04 (3.61)	-.1290E+04 (3.45)	.6429E+01 (3.45)

56	-.1129E+04	(3.61)	-.1267E+04	(3.43)	.6015E+01	(3.43)
57	-.1113E+04	(3.62)	-.1228E+04	(3.42)	.4932E+01	(3.42)
58	-.1180E+04	(3.62)	-.1236E+04	(3.42)	.5410E+01	(3.42)
59	-.1179E+04	(3.61)	-.1242E+04	(3.43)	.5604E+01	(3.43)
60	-.1187E+04	(3.60)	-.1272E+04	(3.45)	.6061E+01	(3.45)
61	-.1201E+04	(3.60)	-.1303E+04	(3.46)	.6450E+01	(3.46)
62	-.1174E+04	(3.60)	-.1262E+04	(3.46)	.7161E+01	(3.46)
63	-.1173E+04	(3.60)	-.1268E+04	(3.45)	.7208E+01	(3.45)
64	-.1174E+04	(3.60)	-.1262E+04	(3.46)	.7161E+01	(3.46)
65	-.1201E+04	(3.60)	-.1303E+04	(3.46)	.6450E+01	(3.46)
66	-.1187E+04	(3.60)	-.1272E+04	(3.45)	.6061E+01	(3.45)
67	-.1179E+04	(3.61)	-.1242E+04	(3.43)	.5604E+01	(3.43)
68	-.1180E+04	(3.62)	-.1236E+04	(3.42)	.5410E+01	(3.42)
69	-.1203E+04	(3.63)	-.1267E+04	(3.41)	.6730E+01	(3.41)
70	-.1203E+04	(3.63)	-.1267E+04	(3.41)	.6730E+01	(3.41)
71	-.1109E+04	(3.62)	-.1152E+04	(3.42)	.3396E+01	(3.42)
72	-.1102E+04	(3.61)	-.1135E+04	(3.43)	.3232E+01	(3.88)
73	-.1115E+04	(3.99)	-.1146E+04	(3.88)	.3577E+01	(3.88)
74	-.1121E+04	(3.99)	-.1155E+04	(3.88)	.3957E+01	(3.88)
75	-.1120E+04	(3.60)	-.1157E+04	(3.88)	.4386E+01	(3.88)
76	-.1110E+04	(3.60)	-.1168E+04	(3.88)	.4689E+01	(3.88)
77	-.1120E+04	(3.60)	-.1157E+04	(3.88)	.4386E+01	(3.88)
78	-.1121E+04	(3.99)	-.1155E+04	(3.88)	.3957E+01	(3.88)
79	-.1115E+04	(3.99)	-.1146E+04	(3.88)	.3577E+01	(3.88)
80	-.1102E+04	(3.61)	-.1135E+04	(3.43)	.3232E+01	(3.88)
81	-.1109E+04	(3.62)	-.1152E+04	(3.42)	.3396E+01	(3.42)
82	-.9611E+03	(3.20)	-.1125E+04	(3.42)	.2753E+01	(3.42)
83	-.1074E+04	(3.61)	-.1163E+04	(3.43)	.3092E+01	(3.43)
84	-.1077E+04	(3.61)	-.1175E+04	(3.48)	.3661E+01	(3.88)
85	-.1075E+04	(3.59)	-.1181E+04	(3.48)	.3545E+01	(3.48)
86	-.9659E+03	(3.60)	-.1191E+04	(3.47)	.4363E+01	(3.88)
87	-.9618E+03	(3.99)	-.1191E+04	(3.88)	.4383E+01	(3.88)
88	-.9659E+03	(3.60)	-.1191E+04	(3.47)	.4363E+01	(3.88)
89	-.1075E+04	(3.59)	-.1181E+04	(3.48)	.3545E+01	(3.48)
90	-.1077E+04	(3.61)	-.1175E+04	(3.48)	.3661E+01	(3.88)
91	-.1074E+04	(3.61)	-.1163E+04	(3.43)	.3092E+01	(3.43)
92	-.9611E+03	(3.20)	-.1125E+04	(3.42)	.2753E+01	(3.42)
93	-.1133E+04	(3.62)	-.1050E+04	(3.42)	-.4164E+01	(3.62)
94	-.1117E+04	(3.61)	-.9213E+03	(3.43)	-.4202E+01	(3.61)
95	-.1116E+04	(3.60)	-.9955E+03	(3.88)	-.4343E+01	(3.61)
96	-.1119E+04	(3.60)	-.1041E+04	(3.88)	-.4532E+01	(3.60)
97	-.1092E+04	(3.99)	-.9752E+03	(3.88)	-.5120E+01	(3.60)
98	-.1091E+04	(3.99)	-.1025E+04	(3.88)	-.5093E+01	(3.60)
99	-.1092E+04	(3.99)	-.9752E+03	(3.88)	-.5120E+01	(3.60)
100	-.1119E+04	(3.60)	-.1041E+04	(3.88)	-.4532E+01	(3.60)
101	-.1116E+04	(3.60)	-.9955E+03	(3.88)	-.4343E+01	(3.61)
102	-.1117E+04	(3.61)	-.9213E+03	(3.43)	-.4202E+01	(3.61)
103	-.1133E+04	(3.62)	-.1050E+04	(3.42)	-.4164E+01	(3.62)
104	-.1209E+04	(3.63)	-.1272E+04	(3.41)	.6752E+01	(3.41)
105	-.1209E+04	(3.63)	-.1272E+04	(3.41)	.6752E+01	(3.41)

***** WALLS *****

WALL NO.	** MAXIMUM MOMENTS ** BOT	TOP	MAX SHEAR
1	.7286E+05 (3.40)	.3935E+05 (3.41)	.2790E+03 (3.39)
2	.7285E+05 (3.40)	.3933E+05 (3.41)	.2788E+03 (3.39)
3	.7286E+05 (3.40)	.3935E+05 (3.41)	.2790E+03 (3.39)
4	.7285E+05 (3.40)	.3933E+05 (3.41)	.2788E+03 (3.39)
5	.4088E+05 (3.41)	.1097E+05 (3.42)	.2128E+03 (3.41)
6	.4085E+05 (3.41)	.1094E+05 (3.42)	.2132E+03 (3.41)
7	.4088E+05 (3.41)	.1097E+05 (3.42)	.2128E+03 (3.41)
8	.4085E+05 (3.41)	.1094E+05 (3.42)	.2132E+03 (3.41)
9	.1447E+05 (3.42)	-.3636E+04 (3.41)	.1157E+03 (3.42)
10	.1448E+05 (3.42)	-.3724E+04 (3.41)	.1164E+03 (3.42)
11	.1447E+05 (3.42)	-.3636E+04 (3.41)	.1157E+03 (3.42)
12	.1448E+05 (3.42)	-.3724E+04 (3.41)	.1164E+03 (3.42)

***** SLABS *****

SLAB NO.	** MAXIMUM MOMENTS ** FRAME I	FRAME J	MAX SHEAR
1	.2087E-09 (3.73)	-.3382E+05 (3.39)	.1409E+03 (3.39)
2	-.3382E+05 (3.39)	-.6086E+05 (3.39)	.1217E+03 (3.40)
3	-.6086E+05 (3.39)	-.8096E+05 (3.40)	.1054E+03 (3.41)
4	-.8096E+05 (3.40)	-.9699E+05 (3.40)	.9712E+02 (3.42)
5	-.9699E+05 (3.40)	-.1019E+06 (3.41)	.7290E+02 (3.42)
6	-.9528E+05 (3.41)	-.1032E+06 (3.42)	.2914E+02 (3.42)
7	-.1032E+06 (3.42)	-.9528E+05 (3.41)	-.2914E+02 (3.42)
8	-.1019E+06 (3.41)	-.9699E+05 (3.40)	-.7290E+02 (3.42)
9	-.9699E+05 (3.40)	-.8096E+05 (3.40)	-.9712E+02 (3.42)
10	-.8096E+05 (3.40)	-.6086E+05 (3.39)	-.1054E+03 (3.41)
11	-.6086E+05 (3.39)	-.3382E+05 (3.39)	-.1217E+03 (3.40)
12	-.3382E+05 (3.39)	-.7338E-09 (3.72)	-.1409E+03 (3.39)
13	.8613E-09 (4.72)	-.4529E+05 (3.38)	.1887E+03 (3.38)
14	-.4529E+05 (3.38)	-.8160E+05 (3.41)	.1627E+03 (3.42)
15	-.8160E+05 (3.41)	-.1114E+06 (3.41)	.1473E+03 (3.43)
16	-.1114E+06 (3.41)	-.1283E+06 (3.41)	.1211E+03 (3.43)
17	-.1283E+06 (3.41)	-.1361E+06 (3.43)	.7954E+02 (3.44)
18	-.1368E+06 (3.43)	-.1448E+06 (3.44)	.2913E+02 (3.44)

19	-.1448E+06 (3.44)	-.1368E+06 (3.43)	-.2913E+02 (3.44)
20	-.1361E+06 (3.43)	-.1283E+06 (3.41)	-.7954E+02 (3.44)
21	-.1283E+06 (3.41)	-.1114E+06 (3.41)	-.1211E+03 (3.43)
22	-.1114E+06 (3.41)	-.8160E+05 (3.41)	-.1473E+03 (3.43)
23	-.8160E+05 (3.41)	-.4529E+05 (3.38)	-.1627E+03 (3.42)
24	-.4529E+05 (3.38)	.6421E-09 (3.33)	-.1887E+03 (3.38)
25	-.4331E-09 (3.52)	-.5036E+05 (3.42)	.2098E+03 (3.42)
26	-.5036E+05 (3.42)	-.8555E+05 (3.42)	.1747E+03 (3.43)
27	-.8555E+05 (3.42)	-.1111E+06 (3.43)	.1544E+03 (3.45)
28	-.1111E+06 (3.43)	-.1279E+06 (3.43)	.1438E+03 (3.46)
29	-.1279E+06 (3.43)	-.1357E+06 (3.44)	.1054E+03 (3.46)
30	-.1405E+06 (3.44)	-.1512E+06 (3.45)	.4217E+02 (3.45)
31	-.1512E+06 (3.45)	-.1405E+06 (3.44)	-.4217E+02 (3.45)
32	-.1357E+06 (3.44)	-.1279E+06 (3.43)	-.1054E+03 (3.46)
33	-.1279E+06 (3.43)	-.1111E+06 (3.43)	-.1438E+03 (3.46)
34	-.1111E+06 (3.43)	-.8555E+05 (3.42)	-.1544E+03 (3.45)
35	-.8555E+05 (3.42)	-.5036E+05 (3.42)	-.1747E+03 (3.43)
36	-.5036E+05 (3.42)	-.4125E-09 (4.06)	-.2098E+03 (3.42)

********** MAXIMUM MOMENTS AND SHEARS **********

(AT MAXIMUM DISPLACEMENT OF MID FRAME)

MAX DISPLACEMENT =   1.2904   AT TIME : 3.4400   AT ACCLN :   .188 G

***** COLUMNS *****

COL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.50651E+03	-.58483E+03	.73244E+01
2	.51300E+03	-.61043E+03	.75398E+01
3	.52790E+03	-.62169E+03	.77154E+01
4	.54132E+03	-.61373E+03	.77520E+01
5	.54387E+03	-.57120E+03	.74837E+01
6	.52713E+03	-.53951E+03	.71586E+01
7	.54387E+03	-.57120E+03	.74837E+01

8	.54132E+03	-.61373E+03	.77520E+01
9	.52790E+03	-.62169E+03	.77154E+01
10	.51300E+03	-.61043E+03	.75398E+01
11	.50651E+03	-.58483E+03	.73244E+01
12	.51317E+03	-.35767E+03	.58446E+01
13	.59620E+03	-.43704E+03	.69345E+01
14	.62578E+03	-.49445E+03	.75183E+01
15	.64096E+03	-.50153E+03	.76678E+01
16	.61125E+03	-.45371E+03	.71474E+01
17	.58521E+03	-.44016E+03	.68817E+01
18	.61125E+03	-.45371E+03	.71474E+01
19	.64096E+03	-.50153E+03	.76678E+01
20	.62578E+03	-.49445E+03	.75183E+01
21	.59620E+03	-.43704E+03	.69345E+01
22	.51317E+03	-.35767E+03	.58446E+01
23	.51794E+03	-.36661E+03	.59366E+01
24	.58888E+03	-.41634E+03	.67465E+01
25	.62026E+03	-.47675E+03	.73624E+01
26	.63297E+03	-.48708E+03	.75172E+01
27	.62351E+03	-.50643E+03	.75835E+01
28	.58066E+03	-.49016E+03	.71867E+01
29	.62351E+03	-.50643E+03	.75835E+01
30	.63297E+03	-.48708E+03	.75172E+01
31	.62026E+03	-.47675E+03	.73624E+01
32	.58888E+03	-.41634E+03	.67465E+01
33	.51794E+03	-.36661E+03	.59366E+01
34	.52664E+03	-.67002E+03	.80312E+01
35	.53235E+03	-.67044E+03	.80724E+01
36	.53660E+03	-.66020E+03	.80322E+01
37	.54579E+03	-.65807E+03	.80796E+01
38	.51781E+03	-.52586E+03	.70045E+01
39	.50284E+03	-.51634E+03	.68402E+01
40	.51781E+03	-.52586E+03	.70045E+01
41	.54579E+03	-.65807E+03	.80796E+01
42	.53660E+03	-.66020E+03	.80322E+01
43	.53235E+03	-.67044E+03	.80724E+01
44	.52664E+03	-.67002E+03	.80312E+01
45	.63381E+03	-.66796E+03	.91674E+01
46	.70496E+03	-.73485E+03	.10140E+02
47	.76263E+03	-.78947E+03	.10930E+02
48	.79972E+03	-.83267E+03	.11496E+02
49	.80461E+03	-.81384E+03	.11398E+02
50	.78744E+03	-.82264E+03	.11339E+02
51	.80461E+03	-.81384E+03	.11398E+02
52	.79972E+03	-.83267E+03	.11496E+02
53	.76263E+03	-.78947E+03	.10930E+02
54	.70496E+03	-.73485E+03	.10140E+02
55	.63381E+03	-.66796E+03	.91674E+01
56	.52092E+03	-.50189E+03	.72029E+01
57	.68306E+03	-.69598E+03	.97115E+01
58	.72199E+03	-.75500E+03	.10401E+02

59	.76191E+03	-.80960E+03	.11067E+02
60	.74839E+03	-.79841E+03	.10893E+02
61	.74479E+03	-.79698E+03	.10858E+02
62	.74839E+03	-.79841E+03	.10893E+02
63	.76191E+03	-.80960E+03	.11067E+02
64	.72199E+03	-.75500E+03	.10401E+02
65	.68306E+03	-.69598E+03	.97115E+01
66	.52092E+03	-.50189E+03	.72029E+01
67	.53001E+03	-.50639E+03	.72986E+01
68	.67939E+03	-.68997E+03	.96433E+01
69	.71837E+03	-.75293E+03	.10361E+02
70	.75914E+03	-.81084E+03	.11056E+02
71	.79444E+03	-.85529E+03	.11618E+02
72	.79761E+03	-.82898E+03	.11455E+02
73	.79444E+03	-.85529E+03	.11618E+02
74	.75914E+03	-.81084E+03	.11056E+02
75	.71837E+03	-.75293E+03	.10361E+02
76	.67939E+03	-.68997E+03	.96433E+01
77	.53001E+03	-.50639E+03	.72986E+01
78	.68359E+03	-.68223E+03	.96185E+01
79	.72868E+03	-.74013E+03	.10344E+02
80	.75920E+03	-.77591E+03	.10811E+02
81	.78153E+03	-.80253E+03	.11155E+02
82	.73385E+03	-.78078E+03	.10666E+02
83	.72298E+03	-.77535E+03	.10552E+02
84	.73385E+03	-.78078E+03	.10666E+02
85	.78153E+03	-.80253E+03	.11155E+02
86	.75920E+03	-.77591E+03	.10811E+02
87	.72868E+03	-.74013E+03	.10344E+02
88	.68359E+03	-.68223E+03	.96185E+01
89	.54913E+03	-.59908E+03	.80860E+01
90	.57820E+03	-.64177E+03	.85913E+01
91	.59609E+03	-.66177E+03	.88582E+01
92	.61016E+03	-.68213E+03	.91007E+01
93	.60785E+03	-.67265E+03	.90176E+01
94	.57293E+03	-.63506E+03	.85070E+01
95	.60785E+03	-.67265E+03	.90176E+01
96	.61016E+03	-.68213E+03	.91007E+01
97	.59609E+03	-.66177E+03	.88582E+01
98	.57820E+03	-.64177E+03	.85913E+01
99	.54913E+03	-.59908E+03	.80860E+01
100	.30684E+03	-.43962E+03	.52568E+01
101	.34415E+03	-.51297E+03	.60360E+01
102	.39131E+03	-.56453E+03	.67313E+01
103	.43029E+03	-.58869E+03	.71759E+01
104	.41408E+03	-.57110E+03	.69379E+01
105	.46469E+03	-.56515E+03	.72524E+01
106	.41408E+03	-.57110E+03	.69379E+01
107	.43029E+03	-.58869E+03	.71759E+01
108	.39131E+03	-.56453E+03	.67313E+01
109	.34415E+03	-.51297E+03	.60360E+01

110	.30684E+03	-.43962E+03	.52568E+01
111	.34418E+03	-.51015E+03	.60164E+01
112	.34804E+03	-.52514E+03	.61491E+01
113	.38512E+03	-.56579E+03	.66965E+01
114	.44033E+03	-.59270E+03	.72749E+01
115	.55544E+03	-.62647E+03	.83233E+01
116	.54513E+03	-.61164E+03	.81463E+01
117	.55544E+03	-.62647E+03	.83233E+01
118	.44033E+03	-.59270E+03	.72749E+01
119	.38512E+03	-.56579E+03	.66965E+01
120	.34804E+03	-.52514E+03	.61491E+01
121	.34418E+03	-.51015E+03	.60164E+01
122	.59580E+03	-.66476E+03	.88772E+01
123	.62998E+03	-.70156E+03	.93770E+01
124	.62412E+03	-.71841E+03	.94544E+01
125	.62318E+03	-.73217E+03	.95447E+01
126	.58728E+03	-.70377E+03	.90919E+01
127	.54597E+03	-.68572E+03	.86739E+01
128	.58728E+03	-.70377E+03	.90919E+01
129	.62318E+03	-.73217E+03	.95447E+01
130	.62412E+03	-.71841E+03	.94544E+01
131	.62998E+03	-.70156E+03	.93770E+01
132	.59580E+03	-.66476E+03	.88772E+01

***** BEAMS *****

BEAM NO.	MOMENT (LEFT)	MOMENT (RIGHT)	SHEAR
1	-.41049E+02	-.11478E+04	.48973E+01
2	.38301E+02	-.11839E+04	.54080E+01
3	.90675E+02	-.11986E+04	.57049E+01
4	.16535E+03	-.11943E+04	.60164E+01
5	.27033E+03	-.12091E+04	.65459E+01
6	.28617E+03	-.12096E+04	.66185E+01
7	.27033E+03	-.12091E+04	.65459E+01
8	.16535E+03	-.11943E+04	.60164E+01
9	.90675E+02	-.11986E+04	.57049E+01
10	.38301E+02	-.11839E+04	.54080E+01
11	-.41049E+02	-.11478E+04	.48973E+01
12	-.96222E+02	-.11859E+04	.48215E+01
13	.12125E+03	-.12538E+04	.60843E+01
14	.22969E+03	-.12719E+04	.66443E+01
15	.25501E+03	-.12888E+04	.68311E+01
16	.29391E+03	-.12934E+04	.70233E+01
17	.24325E+03	-.12878E+04	.67747E+01

18	.29391E+03	-.12934E+04	.70233E+01
19	.25501E+03	-.12888E+04	.68311E+01
20	.22969E+03	-.12719E+04	.66443E+01
21	.12125E+03	-.12538E+04	.60843E+01
22	-.96222E+02	-.11859E+04	.48215E+01
23	-.10219E+03	-.11120E+04	.44681E+01
24	.29789E+02	-.11337E+04	.51482E+01
25	.97830E+02	-.11405E+04	.54795E+01
26	.14704E+03	-.11236E+04	.56222E+01
27	.25967E+03	-.11263E+04	.61327E+01
28	.24090E+03	-.11126E+04	.59888E+01
29	.25967E+03	-.11263E+04	.61327E+01
30	.14704E+03	-.11236E+04	.56222E+01
31	.97830E+02	-.11405E+04	.54795E+01
32	.29789E+02	-.11337E+04	.51482E+01
33	-.10219E+03	-.11120E+04	.44681E+01
34	-.74646E+02	-.10405E+04	.42739E+01
35	-.74646E+02	-.10405E+04	.42739E+01
36	-.10530E+03	-.11694E+04	.47085E+01
37	-.57547E+02	-.12219E+04	.51518E+01
38	.40507E+02	-.12392E+04	.56623E+01
39	.10074E+03	-.12525E+04	.59876E+01
40	.25686E+03	-.12689E+04	.67510E+01
41	.31799E+03	-.12670E+04	.70132E+01
42	.25686E+03	-.12689E+04	.67510E+01
43	.10074E+03	-.12525E+04	.59876E+01
44	.40507E+02	-.12392E+04	.56623E+01
45	-.57547E+02	-.12219E+04	.51518E+01
46	-.10530E+03	-.11694E+04	.47085E+01
47	-.14018E+03	-.12119E+04	.47423E+01
48	.81824E+02	-.12608E+04	.59410E+01
49	.15978E+03	-.12888E+04	.64098E+01
50	.22391E+03	-.12976E+04	.67325E+01
51	.26804E+03	-.13135E+04	.69978E+01
52	.24335E+03	-.13106E+04	.68761E+01
53	.26804E+03	-.13135E+04	.69978E+01
54	.22391E+03	-.12976E+04	.67325E+01
55	.15978E+03	-.12888E+04	.64098E+01
56	.81824E+02	-.12608E+04	.59410E+01
57	-.14018E+03	-.12119E+04	.47423E+01
58	-.73233E+02	-.11878E+04	.49315E+01
59	.21793E+02	-.12411E+04	.55878E+01
60	.92095E+02	-.12696E+04	.60252E+01
61	.12538E+03	-.12920E+04	.62715E+01
62	.32020E+03	-.12462E+04	.69309E+01
63	.32096E+03	-.12500E+04	.69510E+01
64	.32020E+03	-.12462E+04	.69309E+01
65	.12538E+03	-.12920E+04	.62715E+01
66	.92095E+02	-.12696E+04	.60252E+01
67	.21793E+02	-.12411E+04	.55878E+01
68	-.73233E+02	-.11878E+04	.49315E+01

69	-.62477E+02	-.10402E+04	.43264E+01
70	-.62477E+02	-.10402E+04	.43264E+01
71	-.43705E+03	-.11025E+04	.29443E+01
72	-.45410E+03	-.11309E+04	.29945E+01
73	-.41049E+03	-.11374E+04	.32163E+01
74	-.41125E+03	-.11416E+04	.32318E+01
75	-.33198E+03	-.11369E+04	.35618E+01
76	-.27296E+03	-.11471E+04	.38678E+01
77	-.33198E+03	-.11369E+04	.35618E+01
78	-.41125E+03	-.11416E+04	.32318E+01
79	-.41049E+03	-.11374E+04	.32163E+01
80	-.45410E+03	-.11309E+04	.29945E+01
81	-.43705E+03	-.11025E+04	.29443E+01
82	-.50957E+03	-.11227E+04	.27129E+01
83	-.47491E+03	-.11563E+04	.30149E+01
84	-.43620E+03	-.11741E+04	.32651E+01
85	-.40326E+03	-.11765E+04	.34215E+01
86	-.33176E+03	-.11844E+04	.37727E+01
87	-.32349E+03	-.11828E+04	.38021E+01
88	-.33176E+03	-.11844E+04	.37727E+01
89	-.40326E+03	-.11765E+04	.34215E+01
90	-.43620E+03	-.11741E+04	.32651E+01
91	-.47491E+03	-.11563E+04	.30149E+01
92	-.50957E+03	-.11227E+04	.27129E+01
93	-.47071E+03	-.99188E+03	.23061E+01
94	-.55253E+03	-.91289E+03	.15945E+01
95	-.51938E+03	-.94360E+03	.18771E+01
96	-.51074E+03	-.97951E+03	.20742E+01
97	-.38039E+03	-.87548E+03	.21907E+01
98	-.39894E+03	-.89170E+03	.21803E+01
99	-.38039E+03	-.87548E+03	.21907E+01
100	-.51074E+03	-.97951E+03	.20742E+01
101	-.51938E+03	-.94360E+03	.18771E+01
102	-.55253E+03	-.91289E+03	.15945E+01
103	-.47071E+03	-.99188E+03	.23061E+01
104	-.65894E+02	-.10398E+04	.43094E+01
105	-.65894E+02	-.10398E+04	.43094E+01

***** WALLS *****

WALL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.48237E+05	.26871E+05	.17528E+03
2	.48210E+05	.26797E+05	.17528E+03
3	.48237E+05	.26871E+05	.17528E+03

4	.48210E+05	.26797E+05	.17528E+03
5	.27717E+05	.80841E+04	.14258E+03
6	.27724E+05	.79924E+04	.14356E+03
7	.27717E+05	.80841E+04	.14258E+03
8	.27724E+05	.79924E+04	.14356E+03
9	.10792E+05	-.27593E+04	.86869E+02
10	.10841E+05	-.29550E+04	.88434E+02
11	.10792E+05	-.27593E+04	.86869E+02
12	.10841E+05	-.29550E+04	.88434E+02

***** SLABS *****

SLAB NO.	MOMENT (FRONT)	MOMENT (REAR)	SHEAR
1	-.11312E-10	-.18618E+05	.77576E+02
2	-.18618E+05	-.39145E+05	.85528E+02
3	-.39145E+05	-.53492E+05	.65228E+02
4	-.53492E+05	-.62897E+05	.35040E+02
5	-.62897E+05	-.63541E+05	.14336E+02
6	-.56903E+05	-.61244E+05	.48184E+01
7	-.61244E+05	-.56903E+05	-.48184E+01
8	-.63541E+05	-.62897E+05	-.14336E+02
9	-.62897E+05	-.53492E+05	-.35040E+02
10	-.53492E+05	-.39145E+05	-.65228E+02
11	-.39145E+05	-.18618E+05	-.85528E+02
12	-.18618E+05	-.31159E-09	-.77576E+02
13	.26618E-09	-.32030E+05	.13346E+03
14	-.32030E+05	-.66120E+05	.14743E+03
15	-.66120E+05	-.98262E+05	.13932E+03
16	-.98262E+05	-.12067E+06	.11362E+03
17	-.12067E+06	-.13516E+06	.79542E+02
18	-.13589E+06	-.14483E+06	.27989E+02
19	-.14483E+06	-.13589E+06	-.27989E+02
20	-.13516E+06	-.12067E+06	-.79542E+02
21	-.12067E+06	-.98262E+05	-.11362E+03
22	-.98262E+05	-.66120E+05	-.13932E+03
23	-.66120E+05	-.32030E+05	-.14743E+03
24	-.32030E+05	.31191E-09	-.13346E+03
25	.10850E-09	-.40759E+05	.16983E+03
26	-.40759E+05	-.73908E+05	.14752E+03
27	-.73908E+05	-.10461E+06	.13883E+03
28	-.10461E+06	-.12705E+06	.10832E+03
29	-.12705E+06	-.13516E+06	.39654E+02
30	-.13994E+06	-.14644E+06	.40127E+01
31	-.14644E+06	-.13994E+06	-.40127E+01

32	-.13516E+06	-.12705E+06	-.39654E+02
33	-.12705E+06	-.10461E+06	-.10832E+03
34	-.10461E+06	-.73908E+05	-.13883E+03
35	-.73908E+05	-.40759E+05	-.14752E+03
36	-.40759E+05	-.44385E-10	-.16983E+03

********** MAXIMUM MOMENTS AND SHEARS **********

(AT MAXIMUM RECORDED VALUE OF WALL MOMENT)

MAX MOMENT = .7286E+05 ON WALL : 1 AT TIME : 3.40500

***** COLUMNS *****

COL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.64610E+03	-.70829E+03	.90898E+01
2	.71632E+03	-.79100E+03	.10116E+02
3	.79059E+03	-.86046E+03	.11081E+02
4	.85561E+03	-.90401E+03	.11809E+02
5	.88893E+03	-.90062E+03	.12010E+02
6	.88864E+03	-.88701E+03	.11917E+02
7	.88893E+03	-.90062E+03	.12010E+02
8	.85561E+03	-.90401E+03	.11809E+02
9	.79059E+03	-.86046E+03	.11081E+02
10	.71632E+03	-.79100E+03	.10116E+02
11	.64610E+03	-.70829E+03	.90898E+01
12	.67432E+03	-.51455E+03	.79790E+01
13	.83988E+03	-.68465E+03	.10232E+02
14	.92465E+03	-.79967E+03	.11573E+02
15	.99159E+03	-.85600E+03	.12400E+02
16	.99821E+03	-.84495E+03	.12370E+02
17	.97524E+03	-.83112E+03	.12123E+02
18	.99821E+03	-.84495E+03	.12370E+02
19	.99159E+03	-.85600E+03	.12400E+02
20	.92465E+03	-.79967E+03	.11573E+02

21	.83988E+03	-.68465E+03	.10232E+02
22	.67432E+03	-.51455E+03	.79790E+01
23	.67833E+03	-.52207E+03	.80564E+01
24	.83793E+03	-.67405E+03	.10148E+02
25	.92256E+03	-.78959E+03	.11491E+02
26	.98940E+03	-.85349E+03	.12368E+02
27	.10030E+04	-.89009E+03	.12706E+02
28	.97362E+03	-.88719E+03	.12489E+02
29	.10030E+04	-.89009E+03	.12706E+02
30	.98940E+03	-.85349E+03	.12368E+02
31	.92256E+03	-.78959E+03	.11491E+02
32	.83793E+03	-.67405E+03	.10148E+02
33	.67833E+03	-.52207E+03	.80564E+01
34	.65505E+03	-.77267E+03	.95820E+01
35	.71992E+03	-.82357E+03	.10359E+02
36	.78168E+03	-.86660E+03	.11062E+02
37	.84484E+03	-.91960E+03	.11842E+02
38	.85495E+03	-.82593E+03	.11281E+02
39	.85061E+03	-.83271E+03	.11297E+02
40	.85495E+03	-.82593E+03	.11281E+02
41	.84484E+03	-.91960E+03	.11842E+02
42	.78168E+03	-.86660E+03	.11062E+02
43	.71992E+03	-.82357E+03	.10359E+02
44	.65505E+03	-.77267E+03	.95820E+01
45	.63063E+03	-.66992E+03	.91588E+01
46	.66201E+03	-.69853E+03	.95813E+01
47	.69162E+03	-.73006E+03	.10012E+02
48	.70113E+03	-.75120E+03	.10228E+02
49	.68072E+03	-.70942E+03	.97897E+01
50	.64725E+03	-.70259E+03	.95059E+01
51	.68072E+03	-.70942E+03	.97897E+01
52	.70113E+03	-.75120E+03	.10228E+02
53	.69162E+03	-.73006E+03	.10012E+02
54	.66201E+03	-.69853E+03	.95813E+01
55	.63063E+03	-.66992E+03	.91588E+01
56	.48599E+03	-.48068E+03	.68075E+01
57	.57231E+03	-.62769E+03	.84507E+01
58	.62148E+03	-.69204E+03	.92501E+01
59	.65440E+03	-.72654E+03	.97249E+01
60	.62592E+03	-.69295E+03	.92878E+01
61	.60441E+03	-.68008E+03	.90457E+01
62	.62592E+03	-.69295E+03	.92878E+01
63	.65440E+03	-.72654E+03	.97249E+01
64	.62148E+03	-.69204E+03	.92501E+01
65	.57231E+03	-.62769E+03	.84507E+01
66	.48599E+03	-.48068E+03	.68075E+01
67	.49303E+03	-.48333E+03	.68757E+01
68	.55707E+03	-.61408E+03	.82476E+01
69	.60364E+03	-.69003E+03	.91104E+01
70	.64873E+03	-.72731E+03	.96904E+01
71	.66854E+03	-.74585E+03	.99605E+01

72	.65452E+03	-.70059E+03	.95430E+01
73	.66854E+03	-.74585E+03	.99605E+01
74	.64873E+03	-.72731E+03	.96904E+01
75	.60364E+03	-.69003E+03	.91104E+01
76	.55707E+03	-.61408E+03	.82476E+01
77	.49303E+03	-.48333E+03	.68757E+01
78	.67192E+03	-.67965E+03	.95181E+01
79	.68444E+03	-.71409E+03	.98488E+01
80	.68906E+03	-.73628E+03	.10038E+02
81	.68764E+03	-.74782E+03	.10109E+02
82	.61407E+03	-.70874E+03	.93156E+01
83	.58840E+03	-.69064E+03	.90073E+01
84	.61407E+03	-.70874E+03	.93156E+01
85	.68764E+03	-.74782E+03	.10109E+02
86	.68906E+03	-.73628E+03	.10038E+02
87	.68444E+03	-.71409E+03	.98488E+01
88	.67192E+03	-.67965E+03	.95181E+01
89	.57489E+03	-.62749E+03	.84675E+01
90	.56797E+03	-.62954E+03	.84332E+01
91	.57047E+03	-.62995E+03	.84536E+01
92	.57813E+03	-.63923E+03	.85730E+01
93	.56878E+03	-.62015E+03	.83727E+01
94	.53295E+03	-.58029E+03	.78397E+01
95	.56878E+03	-.62015E+03	.83727E+01
96	.57813E+03	-.63923E+03	.85730E+01
97	.57047E+03	-.62995E+03	.84536E+01
98	.56797E+03	-.62954E+03	.84332E+01
99	.57489E+03	-.62749E+03	.84675E+01
100	.33610E+03	-.46294E+03	.56271E+01
101	.32711E+03	-.47353E+03	.56383E+01
102	.31943E+03	-.47817E+03	.56169E+01
103	.33510E+03	-.49542E+03	.58487E+01
104	.29369E+03	-.45563E+03	.52769E+01
105	.34492E+03	-.47074E+03	.57440E+01
106	.29369E+03	-.45563E+03	.52769E+01
107	.33510E+03	-.49542E+03	.58487E+01
108	.31943E+03	-.47817E+03	.56169E+01
109	.32711E+03	-.47353E+03	.56383E+01
110	.33610E+03	-.46294E+03	.56271E+01
111	.36836E+03	-.52537E+03	.62939E+01
112	.32002E+03	-.47046E+03	.55668E+01
113	.30420E+03	-.46515E+03	.54180E+01
114	.33421E+03	-.49354E+03	.58292E+01
115	.45468E+03	-.55468E+03	.71082E+01
116	.46587E+03	-.54160E+03	.70949E+01
117	.45468E+03	-.55468E+03	.71082E+01
118	.33421E+03	-.49354E+03	.58292E+01
119	.30420E+03	-.46515E+03	.54180E+01
120	.32002E+03	-.47046E+03	.55668E+01
121	.36836E+03	-.52537E+03	.62939E+01
122	.62758E+03	-.69849E+03	.93385E+01

123	.63111E+03	-.69230E+03	.93198E+01
124	.62403E+03	-.69332E+03	.92772E+01
125	.62730E+03	-.69814E+03	.93341E+01
126	.59743E+03	-.66377E+03	.88816E+01
127	.56246E+03	-.64453E+03	.84999E+01
128	.59743E+03	-.66377E+03	.88816E+01
129	.62730E+03	-.69814E+03	.93341E+01
130	.62403E+03	-.69332E+03	.92772E+01
131	.63111E+03	-.69230E+03	.93198E+01
132	.62758E+03	-.69849E+03	.93385E+01

***** BEAMS *****

BEAM NO.	MOMENT (LEFT)	MOMENT (RIGHT)	SHEAR
1	.87134E+02	-.12293E+04	.58248E+01
2	.18254E+03	-.12539E+04	.63559E+01
3	.26749E+03	-.12866E+04	.68765E+01
4	.36581E+03	-.13073E+04	.74031E+01
5	.48598E+03	-.13219E+04	.79995E+01
6	.50577E+03	-.13246E+04	.80989E+01
7	.48598E+03	-.13219E+04	.79995E+01
8	.36581E+03	-.13073E+04	.74031E+01
9	.26749E+03	-.12866E+04	.68765E+01
10	.18254E+03	-.12539E+04	.63559E+01
11	.87134E+02	-.12293E+04	.58248E+01
12	-.45828E+02	-.12315E+04	.52462E+01
13	.18734E+03	-.12953E+04	.65605E+01
14	.33348E+03	-.13308E+04	.73640E+01
15	.37900E+03	-.13545E+04	.76702E+01
16	.42971E+03	-.13617E+04	.79266E+01
17	.38442E+03	-.13571E+04	.77061E+01
18	.42971E+03	-.13617E+04	.79266E+01
19	.37900E+03	-.13545E+04	.76702E+01
20	.33348E+03	-.13308E+04	.73640E+01
21	.18734E+03	-.12953E+04	.65605E+01
22	-.45828E+02	-.12315E+04	.52462E+01
23	-.20985E+02	-.12128E+04	.52734E+01
24	.12443E+03	-.12469E+04	.60679E+01
25	.23930E+03	-.12813E+04	.67283E+01
26	.33343E+03	-.13014E+04	.72336E+01
27	.45250E+03	-.13125E+04	.78096E+01
28	.43316E+03	-.13055E+04	.76932E+01
29	.45250E+03	-.13125E+04	.78096E+01
30	.33343E+03	-.13014E+04	.72336E+01

31	.23930E+03	-.12813E+04	.67283E+01
32	.12443E+03	-.12469E+04	.60679E+01
33	-.20985E+02	-.12128E+04	.52734E+01
34	.17297E+03	-.12418E+04	.62599E+01
35	.17297E+03	-.12418E+04	.62599E+01
36	-.69477E+02	-.12080E+04	.50376E+01
37	-.10991E+03	-.12055E+04	.48478E+01
38	-.46508E+02	-.12130E+04	.51613E+01
39	-.98113E+01	-.12179E+04	.53455E+01
40	.10574E+03	-.12253E+04	.58896E+01
41	.15162E+03	-.12200E+04	.60692E+01
42	.10574E+03	-.12253E+04	.58896E+01
43	-.98113E+01	-.12179E+04	.53455E+01
44	-.46508E+02	-.12130E+04	.51613E+01
45	-.10991E+03	-.12055E+04	.48478E+01
46	-.69477E+02	-.12080E+04	.50376E+01
47	-.16547E+03	-.12162E+04	.46492E+01
48	.31198E+01	-.12444E+04	.55202E+01
49	.41398E+02	-.12574E+04	.57471E+01
50	.71818E+02	-.12566E+04	.58780E+01
51	.78836E+02	-.12662E+04	.59516E+01
52	.45926E+02	-.12623E+04	.57887E+01
53	.78836E+02	-.12662E+04	.59516E+01
54	.71818E+02	-.12566E+04	.58780E+01
55	.41398E+02	-.12574E+04	.57471E+01
56	.31198E+01	-.12444E+04	.55202E+01
57	-.16547E+03	-.12162E+04	.46492E+01
58	-.70499E+02	-.12220E+04	.50953E+01
59	-.82646E+02	-.12125E+04	.49995E+01
60	-.24465E+02	-.12311E+04	.53391E+01
61	-.48618E+01	-.12414E+04	.54714E+01
62	.14739E+03	-.11865E+04	.59022E+01
63	.14547E+03	-.11874E+04	.58975E+01
64	.14739E+03	-.11865E+04	.59022E+01
65	-.48618E+01	-.12414E+04	.54714E+01
66	-.24465E+02	-.12311E+04	.53391E+01
67	-.82646E+02	-.12125E+04	.49995E+01
68	-.70499E+02	-.12220E+04	.50953E+01
69	.24617E+03	-.12645E+04	.66843E+01
70	.24617E+03	-.12645E+04	.66843E+01
71	-.39657E+03	-.11482E+04	.33259E+01
72	-.46775E+03	-.11283E+04	.29228E+01
73	-.44375E+03	-.11271E+04	.30236E+01
74	-.45531E+03	-.11295E+04	.29830E+01
75	-.38637E+03	-.11217E+04	.32535E+01
76	-.32953E+03	-.11322E+04	.35516E+01
77	-.38637E+03	-.11217E+04	.32535E+01
78	-.45531E+03	-.11295E+04	.29830E+01
79	-.44375E+03	-.11271E+04	.30236E+01
80	-.46775E+03	-.11283E+04	.29228E+01
81	-.39657E+03	-.11482E+04	.33259E+01

82	-.52057E+03	-.11214E+04	.26584E+01
83	-.51220E+03	-.11528E+04	.28344E+01
84	-.52108E+03	-.11557E+04	.28080E+01
85	-.49575E+03	-.11564E+04	.29233E+01
86	-.44603E+03	-.11615E+04	.31660E+01
87	-.41915E+03	-.11636E+04	.32939E+01
88	-.44603E+03	-.11615E+04	.31660E+01
89	-.49575E+03	-.11564E+04	.29233E+01
90	-.52108E+03	-.11557E+04	.28080E+01
91	-.51220E+03	-.11528E+04	.28344E+01
92	-.52057E+03	-.11214E+04	.26584E+01
93	-.44334E+03	-.10391E+04	.26360E+01
94	-.60449E+03	-.90444E+03	.13272E+01
95	-.60871E+03	-.92028E+03	.13786E+01
96	-.60117E+03	-.94693E+03	.15299E+01
97	-.43342E+03	-.83858E+03	.17927E+01
98	-.45184E+03	-.85198E+03	.17706E+01
99	-.43342E+03	-.83858E+03	.17927E+01
100	-.60117E+03	-.94693E+03	.15299E+01
101	-.60871E+03	-.92028E+03	.13786E+01
102	-.60449E+03	-.90444E+03	.13272E+01
103	-.44334E+03	-.10391E+04	.26360E+01
104	.24494E+03	-.12698E+04	.67023E+01
105	.24494E+03	-.12698E+04	.67023E+01

***** WALLS *****

WALL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.72859E+05	.37944E+05	.26213E+03
2	.72850E+05	.37928E+05	.26188E+03
3	.72859E+05	.37944E+05	.26213E+03
4	.72850E+05	.37928E+05	.26188E+03
5	.39468E+05	.95377E+04	.20859E+03
6	.39447E+05	.95059E+04	.20900E+03
7	.39468E+05	.95377E+04	.20859E+03
8	.39447E+05	.95059E+04	.20900E+03
9	.13050E+05	-.35809E+04	.10661E+03
10	.13065E+05	-.36747E+04	.10731E+03
11	.13050E+05	-.35809E+04	.10661E+03
12	.13065E+05	-.36747E+04	.10731E+03

***** SLABS *****

SLAB NO.	MOMENT (FRONT)	MOMENT (REAR)	SHEAR
1	-.11136E-09	-.28292E+05	.11788E+03
2	-.28292E+05	-.57504E+05	.12172E+03
3	-.57504E+05	-.80758E+05	.10234E+03
4	-.80758E+05	-.96987E+05	.63473E+02
5	-.96987E+05	-.10071E+06	.27180E+02
6	-.94076E+05	-.97966E+05	.29374E+01
7	-.97966E+05	-.94076E+05	-.29374E+01
8	-.10071E+06	-.96987E+05	-.27180E+02
9	-.96987E+05	-.80758E+05	-.63473E+02
10	-.80758E+05	-.57504E+05	-.10234E+03
11	-.57504E+05	-.28292E+05	-.12172E+03
12	-.28292E+05	-.30295E-09	-.11788E+03
13	.92467E-10	-.44766E+05	.18653E+03
14	-.44766E+05	-.81203E+05	.15721E+03
15	-.81203E+05	-.11037E+06	.12691E+03
16	-.11037E+06	-.12783E+06	.93007E+02
17	-.12783E+06	-.13556E+06	.44734E+02
18	-.13657E+06	-.13712E+06	.83571E+00
19	-.13712E+06	-.13657E+06	-.83571E+00
20	-.13556E+06	-.12783E+06	-.44734E+02
21	-.12783E+06	-.11037E+06	-.93007E+02
22	-.11037E+06	-.81203E+05	-.12691E+03
23	-.81203E+05	-.44766E+05	-.15721E+03
24	-.44766E+05	.36557E-09	-.18653E+03
25	.13761E-09	-.43091E+05	.17955E+03
26	-.43091E+05	-.75341E+05	.14330E+03
27	-.75341E+05	-.10368E+06	.12948E+03
28	-.10368E+06	-.12318E+06	.86051E+02
29	-.12318E+06	-.12928E+06	.32865E+02
30	-.13576E+06	-.13772E+06	.59604E+00
31	-.13772E+06	-.13576E+06	-.59604E+00
32	-.12928E+06	-.12318E+06	-.32865E+02
33	-.12318E+06	-.10368E+06	-.86051E+02
34	-.10368E+06	-.75341E+05	-.12948E+03
35	-.75341E+05	-.43091E+05	-.14330E+03
36	-.43091E+05	-.22557E-10	-.17955E+03

********** MAXIMUM MOMENTS AND SHEARS **********

(AT MAXIMUM RECORDED VALUE OF SLAB MOMENT)

MAX MOMENT = -.1512E+06 ON SLAB : 30 AT TIME : 3.45500

***** COLUMNS *****

COL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.38194E+03	-.47931E+03	.57802E+01
2	.32953E+03	-.45611E+03	.52728E+01
3	.29264E+03	-.41908E+03	.47767E+01
4	.25938E+03	-.35951E+03	.41536E+01
5	.23610E+03	-.29072E+03	.35357E+01
6	.20868E+03	-.24829E+03	.30670E+01
7	.23610E+03	-.29072E+03	.35357E+01
8	.25938E+03	-.35951E+03	.41536E+01
9	.29264E+03	-.41908E+03	.47767E+01
10	.32953E+03	-.45611E+03	.52728E+01
11	.38194E+03	-.47931E+03	.57802E+01
12	.37636E+03	-.23170E+03	.40809E+01
13	.38264E+03	-.23220E+03	.41264E+01
14	.35397E+03	-.23032E+03	.39214E+01
15	.32709E+03	-.19698E+03	.35172E+01
16	.27060E+03	-.12269E+03	.26395E+01
17	.23688E+03	-.10122E+03	.22691E+01
18	.27060E+03	-.12269E+03	.26395E+01
19	.32709E+03	-.19698E+03	.35172E+01
20	.35397E+03	-.23032E+03	.39214E+01
21	.38264E+03	-.23220E+03	.41264E+01
22	.37636E+03	-.23170E+03	.40809E+01
23	.38153E+03	-.24140E+03	.41807E+01
24	.37894E+03	-.21846E+03	.40094E+01
25	.35033E+03	-.21607E+03	.38013E+01
26	.31514E+03	-.17456E+03	.32866E+01
27	.28032E+03	-.16867E+03	.30134E+01
28	.22918E+03	-.14485E+03	.25103E+01
29	.28032E+03	-.16867E+03	.30134E+01
30	.31514E+03	-.17456E+03	.32866E+01
31	.35033E+03	-.21607E+03	.38013E+01
32	.37894E+03	-.21846E+03	.40094E+01
33	.38153E+03	-.24140E+03	.41807E+01

34	.40479E+03	-.56952E+03	.65390E+01
35	.35208E+03	-.52206E+03	.58667E+01
36	.30869E+03	-.47287E+03	.52454E+01
37	.28205E+03	-.44061E+03	.48501E+01
38	.22690E+03	-.28362E+03	.34263E+01
39	.20174E+03	-.26573E+03	.31374E+01
40	.22690E+03	-.28362E+03	.34263E+01
41	.28205E+03	-.44061E+03	.48501E+01
42	.30869E+03	-.47287E+03	.52454E+01
43	.35208E+03	-.52206E+03	.58667E+01
44	.40479E+03	-.56952E+03	.65390E+01
45	.62109E+03	-.64872E+03	.89423E+01
46	.71608E+03	-.74047E+03	.10257E+02
47	.78253E+03	-.80090E+03	.11151E+02
48	.82205E+03	-.84585E+03	.11746E+02
49	.82948E+03	-.82799E+03	.11672E+02
50	.81177E+03	-.83511E+03	.11598E+02
51	.82948E+03	-.82799E+03	.11672E+02
52	.82205E+03	-.84585E+03	.11746E+02
53	.78253E+03	-.80090E+03	.11151E+02
54	.71608E+03	-.74047E+03	.10257E+02
55	.62109E+03	-.64872E+03	.89423E+01
56	.49058E+03	-.47011E+03	.67654E+01
57	.68715E+03	-.69816E+03	.97557E+01
58	.73534E+03	-.76421E+03	.10560E+02
59	.78014E+03	-.81982E+03	.11267E+02
60	.76756E+03	-.80600E+03	.11081E+02
61	.76283E+03	-.80236E+03	.11022E+02
62	.76756E+03	-.80600E+03	.11081E+02
63	.78014E+03	-.81982E+03	.11267E+02
64	.73534E+03	-.76421E+03	.10560E+02
65	.68715E+03	-.69816E+03	.97557E+01
66	.49058E+03	-.47011E+03	.67654E+01
67	.50029E+03	-.47472E+03	.68663E+01
68	.68482E+03	-.69250E+03	.96994E+01
69	.73272E+03	-.76270E+03	.10531E+02
70	.77610E+03	-.82133E+03	.11250E+02
71	.81436E+03	-.87014E+03	.11863E+02
72	.81654E+03	-.84261E+03	.11684E+02
73	.81436E+03	-.87014E+03	.11863E+02
74	.77610E+03	-.82133E+03	.11250E+02
75	.73272E+03	-.76270E+03	.10531E+02
76	.68482E+03	-.69250E+03	.96994E+01
77	.50029E+03	-.47472E+03	.68663E+01
78	.67575E+03	-.66936E+03	.94726E+01
79	.74069E+03	-.74634E+03	.10472E+02
80	.78187E+03	-.78718E+03	.11050E+02
81	.80907E+03	-.81149E+03	.11412E+02
82	.76330E+03	-.78415E+03	.10898E+02
83	.75028E+03	-.76895E+03	.10699E+02
84	.76330E+03	-.78415E+03	.10898E+02

85	.80907E+03	-.81149E+03	.11412E+02
86	.78187E+03	-.78718E+03	.11050E+02
87	.74069E+03	-.74634E+03	.10472E+02
88	.67575E+03	-.66936E+03	.94726E+01
89	.46369E+03	-.50783E+03	.68417E+01
90	.53158E+03	-.59447E+03	.79299E+01
91	.59097E+03	-.65909E+03	.88032E+01
92	.61899E+03	-.69313E+03	.92403E+01
93	.62943E+03	-.69676E+03	.93394E+01
94	.60610E+03	-.67086E+03	.89927E+01
95	.62943E+03	-.69676E+03	.93394E+01
96	.61899E+03	-.69313E+03	.92403E+01
97	.59097E+03	-.65909E+03	.88032E+01
98	.53158E+03	-.59447E+03	.79299E+01
99	.46369E+03	-.50783E+03	.68417E+01
100	.21556E+03	-.34577E+03	.39530E+01
101	.28874E+03	-.45720E+03	.52531E+01
102	.38404E+03	-.55880E+03	.66397E+01
103	.45214E+03	-.60128E+03	.74185E+01
104	.46787E+03	-.60044E+03	.75233E+01
105	.52524E+03	-.60702E+03	.79737E+01
106	.46787E+03	-.60044E+03	.75233E+01
107	.45214E+03	-.60128E+03	.74185E+01
108	.38404E+03	-.55880E+03	.66397E+01
109	.28874E+03	-.45720E+03	.52531E+01
110	.21556E+03	-.34577E+03	.39530E+01
111	.25212E+03	-.41527E+03	.46999E+01
112	.29144E+03	-.46863E+03	.53526E+01
113	.37943E+03	-.56207E+03	.66302E+01
114	.46792E+03	-.60843E+03	.75799E+01
115	.58187E+03	-.65437E+03	.87059E+01
116	.58392E+03	-.65196E+03	.87034E+01
117	.58187E+03	-.65437E+03	.87059E+01
118	.46792E+03	-.60843E+03	.75799E+01
119	.37943E+03	-.56207E+03	.66302E+01
120	.29144E+03	-.46863E+03	.53526E+01
121	.25212E+03	-.41527E+03	.46999E+01
122	.51831E+03	-.57885E+03	.77265E+01
123	.58580E+03	-.65546E+03	.87413E+01
124	.61142E+03	-.71296E+03	.93266E+01
125	.62318E+03	-.74073E+03	.96050E+01
126	.59904E+03	-.72572E+03	.93293E+01
127	.57174E+03	-.72084E+03	.91027E+01
128	.59904E+03	-.72572E+03	.93293E+01
129	.62318E+03	-.74073E+03	.96050E+01
130	.61142E+03	-.71296E+03	.93266E+01
131	.58580E+03	-.65546E+03	.87413E+01
132	.51831E+03	-.57885E+03	.77265E+01

***** BEAMS *****

BEAM NO.	MOMENT (LEFT)	MOMENT (RIGHT)	SHEAR
1	-.17204E+03	-.10501E+04	.38851E+01
2	-.10046E+03	-.10901E+04	.43792E+01
3	-.61625E+02	-.10910E+04	.45547E+01
4	-.13584E+02	-.10699E+04	.46740E+01
5	.19099E+01	-.10746E+04	.47631E+01
6	.63026E+01	-.10703E+04	.47637E+01
7	.19099E+01	-.10746E+04	.47631E+01
8	-.13584E+02	-.10699E+04	.46740E+01
9	-.61625E+02	-.10910E+04	.45547E+01
10	-.10046E+03	-.10901E+04	.43792E+01
11	-.17204E+03	-.10501E+04	.38851E+01
12	-.16552E+03	-.11317E+04	.42751E+01
13	.70983E+01	-.11787E+04	.52467E+01
14	.79196E+02	-.11827E+04	.55836E+01
15	.85241E+02	-.12019E+04	.56952E+01
16	.10800E+03	-.12026E+04	.57990E+01
17	.52617E+02	-.11954E+04	.55220E+01
18	.10800E+03	-.12026E+04	.57990E+01
19	.85241E+02	-.12019E+04	.56952E+01
20	.79196E+02	-.11827E+04	.55836E+01
21	.70983E+01	-.11787E+04	.52467E+01
22	-.16552E+03	-.11317E+04	.42751E+01
23	-.21445E+03	-.99191E+03	.34401E+01
24	-.80370E+02	-.99123E+03	.40304E+01
25	-.44378E+02	-.96945E+03	.40932E+01
26	-.11692E+02	-.92555E+03	.40436E+01
27	.25032E+02	-.90614E+03	.41202E+01
28	-.14260E+00	-.88079E+03	.38967E+01
29	.25032E+02	-.90614E+03	.41202E+01
30	-.11692E+02	-.92555E+03	.40436E+01
31	-.44378E+02	-.96945E+03	.40932E+01
32	-.80370E+02	-.99123E+03	.40304E+01
33	-.21445E+03	-.99191E+03	.34401E+01
34	-.23959E+03	-.88289E+03	.28464E+01
35	-.23959E+03	-.88289E+03	.28464E+01
36	-.22250E+03	-.10737E+04	.37664E+01
37	-.99215E+02	-.11914E+04	.48328E+01
38	.47345E+02	-.12410E+04	.57005E+01
39	.12357E+03	-.12595E+04	.61196E+01
40	.29512E+03	-.12809E+04	.69735E+01
41	.36428E+03	-.12813E+04	.72811E+01
42	.29512E+03	-.12809E+04	.69735E+01
43	.12357E+03	-.12595E+04	.61196E+01

44	.47345E+02	-.12410E+04	.57005E+01
45	-.99215E+02	-.11914E+04	.48328E+01
46	-.22250E+03	-.10737E+04	.37664E+01
47	-.18002E+03	-.11822E+04	.44342E+01
48	.57115E+02	-.12464E+04	.57676E+01
49	.16233E+03	-.12895E+04	.64239E+01
50	.25027E+03	-.13045E+04	.68796E+01
51	.31671E+03	-.13238E+04	.72587E+01
52	.30261E+03	-.13232E+04	.71941E+01
53	.31671E+03	-.13238E+04	.72587E+01
54	.25027E+03	-.13045E+04	.68796E+01
55	.16233E+03	-.12895E+04	.64239E+01
56	.57115E+02	-.12464E+04	.57676E+01
57	-.18002E+03	-.11822E+04	.44342E+01
58	-.17982E+03	-.10876E+04	.40166E+01
59	-.17363E+02	-.12038E+04	.52497E+01
60	.97846E+02	-.12719E+04	.60609E+01
61	.15256E+03	-.13023E+04	.64374E+01
62	.35454E+03	-.12616E+04	.71509E+01
63	.36111E+03	-.12680E+04	.72084E+01
64	.35454E+03	-.12616E+04	.71509E+01
65	.15256E+03	-.13023E+04	.64374E+01
66	.97846E+02	-.12719E+04	.60609E+01
67	-.17363E+02	-.12038E+04	.52497E+01
68	-.17982E+03	-.10876E+04	.40166E+01
69	-.25310E+03	-.84017E+03	.25976E+01
70	-.25310E+03	-.84017E+03	.25976E+01
71	-.54590E+03	-.10032E+04	.20235E+01
72	-.50228E+03	-.10919E+04	.26090E+01
73	-.41325E+03	-.11363E+04	.31992E+01
74	-.39966E+03	-.11449E+04	.32973E+01
75	-.30637E+03	-.11436E+04	.37047E+01
76	-.23749E+03	-.11559E+04	.40639E+01
77	-.30637E+03	-.11436E+04	.37047E+01
78	-.39966E+03	-.11449E+04	.32973E+01
79	-.41325E+03	-.11363E+04	.31992E+01
80	-.50228E+03	-.10919E+04	.26090E+01
81	-.54590E+03	-.10032E+04	.20235E+01
82	-.51849E+03	-.11164E+04	.26456E+01
83	-.49353E+03	-.11421E+04	.28696E+01
84	-.44082E+03	-.11689E+04	.32217E+01
85	-.39298E+03	-.11783E+04	.34749E+01
86	-.30752E+03	-.11888E+04	.38994E+01
87	-.28949E+03	-.11892E+04	.39809E+01
88	-.30752E+03	-.11888E+04	.38994E+01
89	-.39298E+03	-.11783E+04	.34749E+01
90	-.44082E+03	-.11689E+04	.32217E+01
91	-.49353E+03	-.11421E+04	.28696E+01
92	-.51849E+03	-.11164E+04	.26456E+01
93	-.57403E+03	-.88861E+03	.13919E+01
94	-.59671E+03	-.86579E+03	.11906E+01

95	-.51858E+03	-.93753E+03	.18538E+01
96	-.49608E+03	-.98801E+03	.21767E+01
97	-.35617E+03	-.89791E+03	.23971E+01
98	-.36533E+03	-.92649E+03	.24830E+01
99	-.35617E+03	-.89791E+03	.23971E+01
100	-.49608E+03	-.98801E+03	.21767E+01
101	-.51858E+03	-.93753E+03	.18538E+01
102	-.59671E+03	-.86579E+03	.11906E+01
103	-.57403E+03	-.88861E+03	.13919E+01
104	-.26814E+03	-.82571E+03	.24671E+01
105	-.26814E+03	-.82571E+03	.24671E+01

***** WALLS *****

WALL NO.	MOMENT (BOT)	MOMENT (TOP)	SHEAR
1	.27392E+05	.14195E+05	.12291E+03
2	.27356E+05	.14116E+05	.12289E+03
3	.27392E+05	.14195E+05	.12291E+03
4	.27356E+05	.14116E+05	.12289E+03
5	.14541E+05	.14627E+04	.10056E+03
6	.14550E+05	.13780E+04	.10150E+03
7	.14541E+05	.14627E+04	.10056E+03
8	.14550E+05	.13780E+04	.10150E+03
9	.35063E+04	-.20419E+04	.35565E+02
10	.35523E+04	-.22244E+04	.37030E+02
11	.35063E+04	-.20419E+04	.35565E+02
12	.35523E+04	-.22244E+04	.37030E+02

***** SLABS *****

SLAB NO.	MOMENT (FRONT)	MOMENT (REAR)	SHEAR
1	.54171E-10	-.78395E+04	.32665E+02
2	-.78395E+04	-.15642E+05	.32512E+02
3	-.15642E+05	-.21573E+05	.30160E+02
4	-.21573E+05	-.29053E+05	.27017E+02
5	-.29053E+05	-.30913E+05	.19404E+02
6	-.24275E+05	-.27996E+05	.22316E+01

7	-.27996E+05	-.24275E+05	-.22316E+01
8	-.30913E+05	-.29053E+05	-.19404E+02
9	-.29053E+05	-.21573E+05	-.27017E+02
10	-.21573E+05	-.15642E+05	-.30160E+02
11	-.15642E+05	-.78395E+04	-.32512E+02
12	-.78395E+04	-.47166E-09	-.32665E+02
13	.31347E-09	-.33436E+05	.13932E+03
14	-.33436E+05	-.65723E+05	.13992E+03
15	-.65723E+05	-.97608E+05	.13825E+03
16	-.97608E+05	-.11693E+06	.10075E+03
17	-.11693E+06	-.12436E+06	.50118E+02
18	-.12509E+06	-.12942E+06	.87916E+01
19	-.12942E+06	-.12509E+06	-.87916E+01
20	-.12436E+06	-.11693E+06	-.50118E+02
21	-.11693E+06	-.97608E+05	-.10075E+03
22	-.97608E+05	-.65723E+05	-.13825E+03
23	-.65723E+05	-.33436E+05	-.13992E+03
24	-.33436E+05	.29736E-09	-.13932E+03
25	-.72943E-10	-.24654E+05	.10272E+03
26	-.24654E+05	-.54586E+05	.13411E+03
27	-.54586E+05	-.89024E+05	.15441E+03
28	-.89024E+05	-.11602E+06	.12727E+03
29	-.11602E+06	-.13074E+06	.67187E+02
30	-.13551E+06	-.15117E+06	.42174E+02
31	-.15117E+06	-.13551E+06	-.42174E+02
32	-.13074E+06	-.11602E+06	-.67187E+02
33	-.11602E+06	-.89024E+05	-.12727E+03
34	-.89024E+05	-.54586E+05	-.15441E+03
35	-.54586E+05	-.24654E+05	-.13411E+03
36	-.24654E+05	-.11714E-09	-.10272E+03

1

******************* D A M A G E D   S T A T E   O F   F R A M E S *******************

FINAL STATE OF FRAME NO. 1

```
+Y---------Y+
E           E
W           W
E           E
W           W
E           E
+Y---------Y+
E           E
W           W
E           E
W           W
C           C
```

```
       +C---------Y+
       C          C
       W          W
       E          E
       W          W
       Y          Y
```

NOTATION:

```
- = BEAM              E = ELASTIC
! = COLUMN            C = CRACK
W = SHEAR WALL        Y = YIELD
I = EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 2

```
       +C---------C+E---------C+C---------E+
       C          E           E           C
       !          !           !           !
       !          !           !           !
       !          !           !           !
       C          E           E           C
       +Y---------Y+C---------Y+C---------Y+
       C          E           E           C
       !          !           !           !
       !          !           !           !
       !          !           !           !
       C          E           E           C
       +C---------Y+C---------Y+C---------Y+
       C          E           E           C
       !          !           !           !
       !          !           !           !
       !          !           !           !
       C          E           E           C
```

NOTATION:

```
- = BEAM              E = ELASTIC
! = COLUMN            C = CRACK
W = SHEAR WALL        Y = YIELD
I = EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 3

```
+C---------C+C---------C+C---------E+
C           C           E           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
+Y---------Y+C---------Y+C---------Y+
C           C           C           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
+Y---------Y+C---------Y+Y---------Y+
C           E           E           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
```

NOTATION:

```
-  =  BEAM                  E  =  ELASTIC
!  =  COLUMN                C  =  CRACK
W  =  SHEAR WALL            Y  =  YIELD
I  =  EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 4

```
+C---------C+C---------C+C---------E+
C           C           C           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
```

```
+Y---------Y+C---------Y+C---------Y+
C           C           C           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
+Y---------Y+C---------Y+Y---------Y+
C           C           C           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
```

NOTATION:

```
-  =  BEAM                 E  =  ELASTIC
!  =  COLUMN               C  =  CRACK
W  =  SHEAR WALL           Y  =  YIELD
I  =  EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 5

```
+C---------C+C---------C+C---------E+
C           C           C           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
+Y---------Y+C---------Y+Y---------Y+
C           C           C           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
+Y---------Y+Y---------Y+Y---------Y+
C           C           C           C
!           !           !           !
!           !           !           !
!           !           !           !
C           C           C           C
```

```
 NOTATION:

 -  =  BEAM                  E  =  ELASTIC
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN



1


 FINAL STATE OF FRAME NO.  6


        +C---------C+E---------Y+C---------E+
        C           C           C           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           C           C           C
        +Y---------Y+C---------Y+C---------Y+
        C           C           C           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           C           C           C
        +Y---------Y+Y---------Y+Y---------Y+
        C           C           C           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           C           C           C
```



```
 NOTATION:

 -  =  BEAM                  E  =  ELASTIC
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN
```



```
1


 FINAL STATE OF FRAME NO.  7
```

```
+C---------C+E---------Y+C---------E+
C          C          C          C
!          !          !          !
!          !          !          !
!          !          !          !
C          C          C          C
+Y---------Y+C---------Y+C---------Y+
C          C          C          C
!          !          !          !
!          !          !          !
!          !          !          !
C          C          C          C
+Y---------Y+Y---------Y+Y---------Y+
C          C          C          C
!          !          !          !
!          !          !          !
!          !          !          !
C          C          C          C
```

NOTATION:

```
-  =  BEAM                 E  =  ELASTIC
!  =  COLUMN               C  =  CRACK
W  =  SHEAR WALL           Y  =  YIELD
I  =  EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 8

```
+C---------C+E---------Y+C---------E+
C          C          C          C
!          !          !          !
!          !          !          !
!          !          !          !
C          C          C          C
+Y---------Y+C---------Y+C---------Y+
C          C          C          C
!          !          !          !
!          !          !          !
!          !          !          !
C          C          C          C
+Y---------Y+Y---------Y+Y---------Y+
C          C          C          C
!          !          !          !
```

```
        !           !           !           !
        !           !           !           !
        C           C           C           C


 NOTATION:

 -  =  BEAM                 E  =  ELASTIC
 !  =  COLUMN               C  =  CRACK
 W  =  SHEAR WALL           Y  =  YIELD
 I  =  EDGE COLUMN



1

 FINAL STATE OF FRAME NO.  9


        +C---------C+C---------C+C---------E+
        C           C           C           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           C           C           C
        +Y---------Y+C---------Y+Y---------Y+
        C           C           C           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           C           C           C
        +Y---------Y+Y---------Y+Y---------Y+
        C           C           C           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           C           C           C


 NOTATION:

 -  =  BEAM                 E  =  ELASTIC
 !  =  COLUMN               C  =  CRACK
 W  =  SHEAR WALL           Y  =  YIELD
 I  =  EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 10

```
+C---------C+C---------C+C---------E+
C          C           C           C
!          !           !           !
!          !           !           !
!          !           !           !
C          C           C           C
+Y---------Y+C---------Y+C---------Y+
C          C           C           C
!          !           !           !
!          !           !           !
!          !           !           !
C          C           C           C
+Y---------Y+C---------Y+Y---------Y+
C          C           C           C
!          !           !           !
!          !           !           !
!          !           !           !
C          C           C           C
```

NOTATION:

```
-  =  BEAM                E  =  ELASTIC
!  =  COLUMN              C  =  CRACK
W  =  SHEAR WALL          Y  =  YIELD
I  =  EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 11

```
+C---------C+C---------C+C---------E+
C          C           E           C
!          !           !           !
!          !           !           !
!          !           !           !
C          C           C           C
+Y---------Y+C---------Y+C---------Y+
C          C           C           C
!          !           !           !
```

```
        !           !           !           !
        !           !           !           !
        C           C           C           C
        +Y---------Y+C---------Y+Y---------Y+
        C           E           E           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           C           C           C
```

NOTATION:

```
-  =  BEAM                   E  =  ELASTIC
!  =  COLUMN                 C  =  CRACK
W  =  SHEAR WALL             Y  =  YIELD
I  =  EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 12

```
        +C---------C+E---------C+C---------E+
        C           E           E           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           E           E           C
        +Y---------Y+C---------Y+C---------Y+
        C           E           E           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           E           E           C
        +C---------Y+C---------Y+C---------Y+
        C           E           E           C
        !           !           !           !
        !           !           !           !
        !           !           !           !
        C           E           E           C
```

NOTATION:

```
-  =  BEAM                   E  =  ELASTIC
```

```
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN
```

1

FINAL STATE OF FRAME NO. 13

```
       +Y---------Y+
       E           E
       W           W
       E           E
       W           W
       E           E
       +Y---------Y+
       E           E
       W           W
       E           E
       W           W
       C           C
       +C---------Y+
       C           C
       W           W
       E           E
       W           W
       Y           Y
```

NOTATION:

```
 -  =  BEAM                  E  =  ELASTIC
 !  =  COLUMN                C  =  CRACK
 W  =  SHEAR WALL            Y  =  YIELD
 I  =  EDGE COLUMN
```

1

********** FINAL STATE OF SLABS **********

```
 SLAB        FRAME I         MIDDLE        FRAME J
```

1	E	E	E
2	E	E	E
3	E	E	C
4	C	E	C
5	C	E	C
6	C	E	C
7	C	E	C
8	C	E	C
9	C	E	C
10	C	E	E
11	E	E	E
12	E	E	E
13	E	E	E
14	E	E	C
15	C	E	C
16	C	E	C
17	C	E	C
18	Y	E	Y
19	Y	E	Y
20	C	E	C
21	C	E	C
22	C	E	C
23	C	E	E
24	E	E	E
25	E	E	E
26	E	E	C
27	C	E	C
28	C	E	C
29	C	E	C
30	Y	E	Y
31	Y	E	Y
32	C	E	C
33	C	E	C
34	C	E	C
35	C	E	E
36	E	E	E

Appendix A.4

Doctoral Defense Presentation

Washington
WASHINGTON · UNIVERSITY · IN · ST · LOUIS
School of Engineering & Applied Science

Engineering Student Services

February 23, 2011

TO: Dr. David Peters, Chairman
Dr. Thomas Harmon
Dr. Srinivasan Sridharan
Dr. Hiro Mukai
Dr. Nader Panahshahi

FROM: Ralph S. Quatrano
Dean, School of Engineering

Ralph S. Quatrano

You have been nominated to the committee to conduct the Final Examination for Mohamed Al Harash, candidate for the Doctor of Science degree under the Department of Mechanical Engineering and Materials Science.

The examination has been scheduled for March 4, 2011 at 3:30 p.m. in Jolley Hall, Room 306.

We shall appreciate your serving on this committee

cc: Mohamed Al Harash
Dr. Philip Bayly

RSQ:bs

Washington University
Campus Box 1220
One Brookings Drive
St. Louis, Missouri 63130-4899
(314) 935-5484
FAX: (314) 935-5449

Doctor of Science Defense

INELASTIC SEISMIC RESPONSE OF REINFORCED CONCRETE BUILDINGS WITH FLOOR DIAPHRAGM OPENINGS

Presented by: Mohamed Al Harash

March 4, 2011
3:30 P.M.
Jolley Hall, Room 306

Floor and roof systems are designed to carry gravity loads and transfer these loads to supporting beams, columns or walls. Furthermore, they play a key role in distributing earthquake-induced loads to the lateral load resisting systems by diaphragm action. In reinforced concrete buildings, the in-plane flexibility of the floor diaphragms is often ignored for simplicity in practical design (i.e., the floor systems are frequently treated as perfectly rigid diaphragms.). In recent building standards (ASCE-7, 2005), it is acknowledged that this assumption can result in considerable errors when predicting the seismic response of reinforced concrete buildings with diaphragm plan aspect ratio of 3:1 or greater. However, the influence of floor diaphragm openings (typically for the purpose of stairways, shafts, or other architectural features.) has not been considered. In order to investigate the influence of diaphragm openings on the seismic response of reinforced concrete buildings; several 3-story reinforced concrete buildings are designed as a Building Frame System according to the International Building Code (2006).

Each building is assumed to be in the Saint Louis, Missouri area, and it's analyzed using IDAEC2, a non-commercial program capable of conducting nonlinear analysis of RC buildings with rigid, elastic, or inelastic floor diaphragms, under both static lateral loads (pushover) and dynamic ground motions (time-history), where a suite of three well-known earthquakes is scaled to model moderate ground motions in the Saint Louis region. The comprehensive analytical study conducted involves placing different opening size (none, 11%, 15% and 22% of total floor area) in various floor plan locations with respect to the location of the shear walls (located at end frames or at the interior frames), where three types of floor diaphragm models (rigid, elastic, and inelastic) are assumed. Building floor plan aspect ratios of 3:1 and 4:1 are investigated.

IDARC2 is enhanced by modifying the fiber model (strain compatibility) computation routine involved in obtaining the idealized moment-curvature curves of floor slabs with openings (symmetric and nonsymmetrical). Also, a new option is added so that the user can over-ride IDARC2 idealized moment-curvature curves for slabs with openings and by defining their own. The results are then presented and discussed. It is concluded that in order to capture the seismic response of reinforced concrete buildings with floor diaphragm openings accurately; it is necessary to use an inelastic diaphragm model for floor diaphragm aspect ration of 3:1greater. Thus, using a rigid diaphragm assumption, as specified by ASCE7-05 for buildings concrete floor diaphragms with aspect ratio of 3:1, and elastic diaphragm assumption, as allowed by ASCE7-05 for floor diaphragm with aspect ratio of 4:1, can result in significant underestimations of the lateral loads resisted by the interior building frames and building maximum frame displacements, particularly when the diaphragm openings are located in the middle two-thirds of the building plan. The base shear redistribution due to inelastic slab deformations increases the load subjected to the interior frames significantly. Hence, the influence of inelastic inplane diaphragm deformations due to floor openings cannot be overlooked in such buildings.
Simple design recommendation is given for determining proper diaphragm chord reinforcement to prevent in-plane floor slab yielding when openings are present.

Washington University in St.Louis
School of Engineering & Applied Science

Washington University in St. Louis

School of Engineering & Applied Science
Department of Mechanical Engineering & Material Science

Inelastic Seismic Response of Reinforced Concrete Buildings with Floor Diaphragm Openings

- Mohamed T. Al Harash, P.E., S.E.

  Chief Structural Engineer, FEG

  Doctoral Candidate, WUSTL

Acknowledgement

SOUTHERN ILLINOIS UNIVERSITY EDWARDSVILLE

Prof. Nader Panahshahi, Ph.D.

Washington University in St. Louis

Prof. Thomas Harmon, Ph.D.
Prof. Srinivasan Sridharan, Ph.D.
Prof. David Peters, Ph.D.
Prof. Hiro Mukai, Ph.D.

UC DAVIS UNIVERSITY OF CALIFORNIA

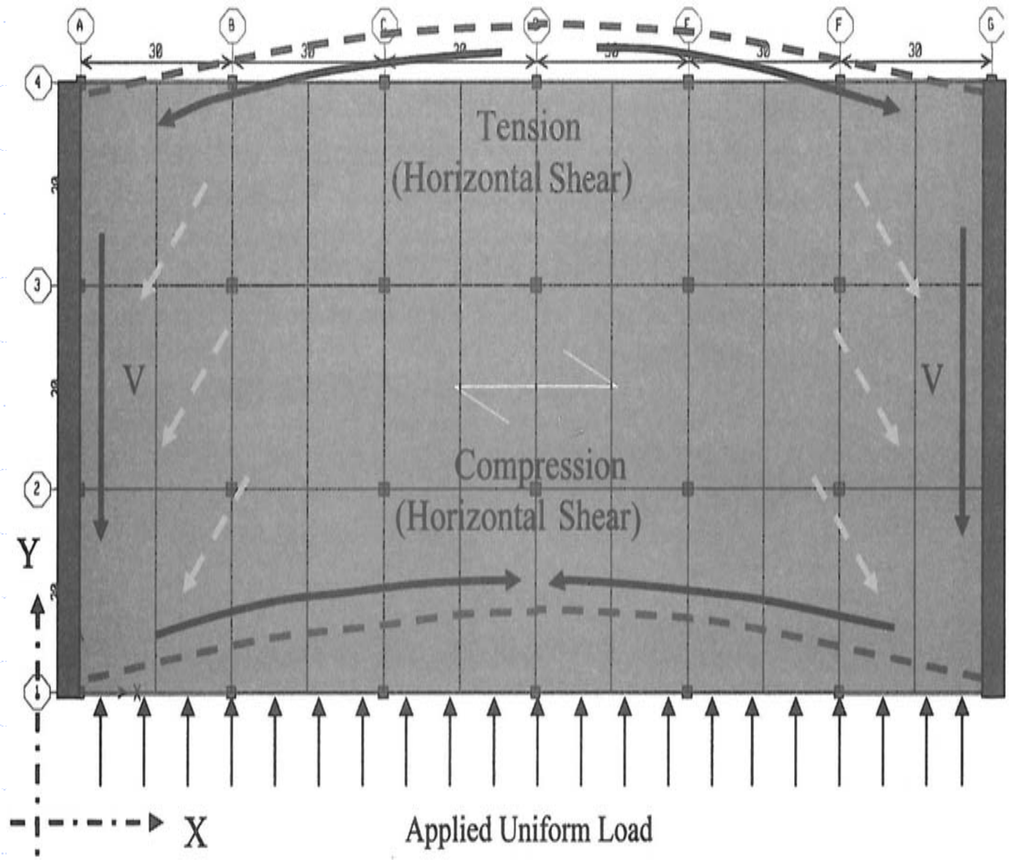
Prof. Sashi Kunnath, Ph.D.

Inelastic Seismic Response of Reinforced Concrete Buildings with Floor Diaphragm Openings

- Introduction
- Objectives
- Literature Review
- Analytical Investigation
  - Buildings Investigated
  - Geometry & Design
  - Lateral Load System(s)
- Inelastic Analysis
  - IDARC2 - Enhanced
  - Parameters Studied
- Results
  - Pushover & Dynamic
  - Sensitivity Study
    - M/ϕ Idealization
    - Hysteretic Parameters
- Design Recommendations
- Summary & Conclusions

Introduction

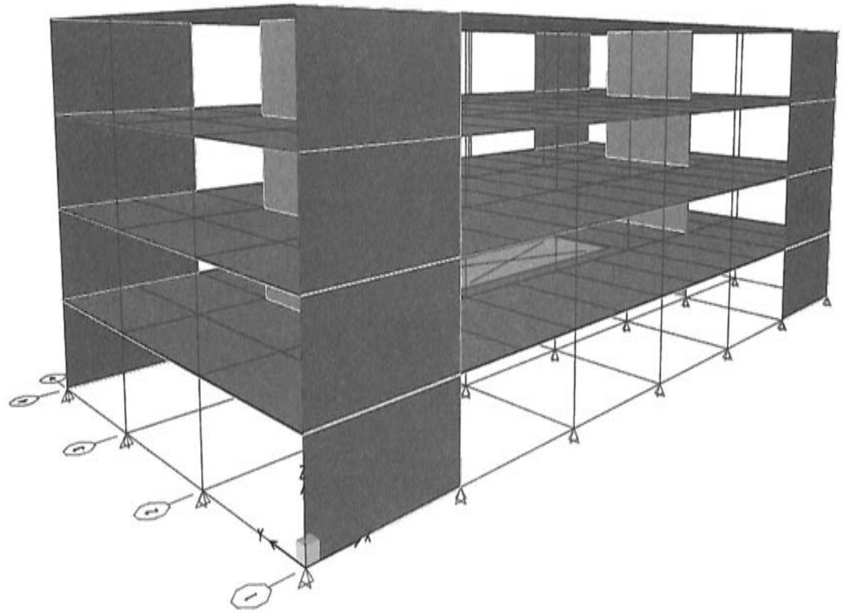
- Diaphragms
  - Gravity
  - Lateral
  - Deep Beam
  - IDARC2 (1988)
  - Types
    - Rigid
    - Elastic
    - Inelastic



Diaphragm Deflection (ICC – Design of Diaph. 2009)

Introduction (Cont.)

- Openings
  - Stairs & Elevators, etc.
- Building Codes
  - IBC 2006 & ACI 318
  - ASCE 7-05
  - Rigid - 3:1
  - Plan Irregularity
    - 50% Openings



Diaphragm Openings (ICC – Design of Diaph. 2009)

Objectives

- To Investigate Diaphragm Openings Influence on the Seismic Response of RC Buildings.
- To Enhance IDARC2 to Account for Diaphragm Openings.
- To Investigate the Influence of Hysteretic Parameters on Slabs with Openings.

Literature Review

- Building Codes: IBC, AISC, ACI, ASCE
- Flexible - Plywood/Metal Deck
- Moeini, et al. – 14WCEE, 2008 – latest !
  - 196 Rectangular RC Buildings w/ Symmetric Slab Openings and End Walls
  - If Displacement Difference Ratio b/w Rigid and Elastic Floor Analyses < 30% → Rigid

Literature Review (Cont.)

- Joint PCI-NEES Seismic Design of Buildings with Precast Concrete Diaphragms (2005) - http://www.viddler.com/explore/PCIeducation/videos/96/ 12:00
- NCEER Study of RC Buildings with Inelastic Diaphragms (1987-1990)
  - IDARC2 - Kunnath, Panahshahi, and Reinhorn (ASCE J. Struct. Eng. 1991)
  - Experimental and Analytical Study of Rectangular Buildings with End Walls
  - Plan aspect ratio > 4:1 → Inelastic Diaphragm

Analytical Investigation

Buildings Investigated

- 20 Bldgs./129 Scenarios
  - A1-A9 (sym. & non-sym. 4:1-End Shear Walls)
  - B1-B7 (sym. 4:1-Inter. Shear Walls)
  - P1 & P2 (non-sym. 4:1-ESW)
  - C1 & D1 (sym. 3:1-ESW)
- Location
  - Saint Louis, MO
  - PGA = 0.27g
- Current Practices
  - IBC 2006/ ASCE 7-05
  - ACI 318-08

Analytical Investigation (Cont.)

Geometry and Design

Seismic Parameters per IBC 2006.

Parameter	Value
Short Period Acceleration, S_s	0.57
Long Period Acceleration, S_1	0.19
Short Period Site Coefficient, Fa	1.17
Long Period Site Coefficient, Fv	1.59
Short Period Spectral Response Acceleration Parameter, S_{DS}	0.45
Long Period Spectral Response Acceleration Parameter, S_{D1}	0.20
Response Modification Factor, $R_{N\text{-}S}$ & $R_{E\text{-}W}$	5.00
Over-strength Factor, $\Omega_{o,\ N\text{-}S}$ & $\Omega_{o,\ E\text{-}W}$	2.50
Deflection Amplification Factor, $C_{d,\ N\text{-}S}$ & $C_{d,\ E\text{-}W}$	4.50
Fundamental Period of Structure, $T_{a,\ N\text{-}S}$	0.31 sec
Fundamental Period of Structure, $T_{a,\ E\text{-}W}$	0.31 sec
Base Shear Seismic Coefficient, Cs	8.9 %

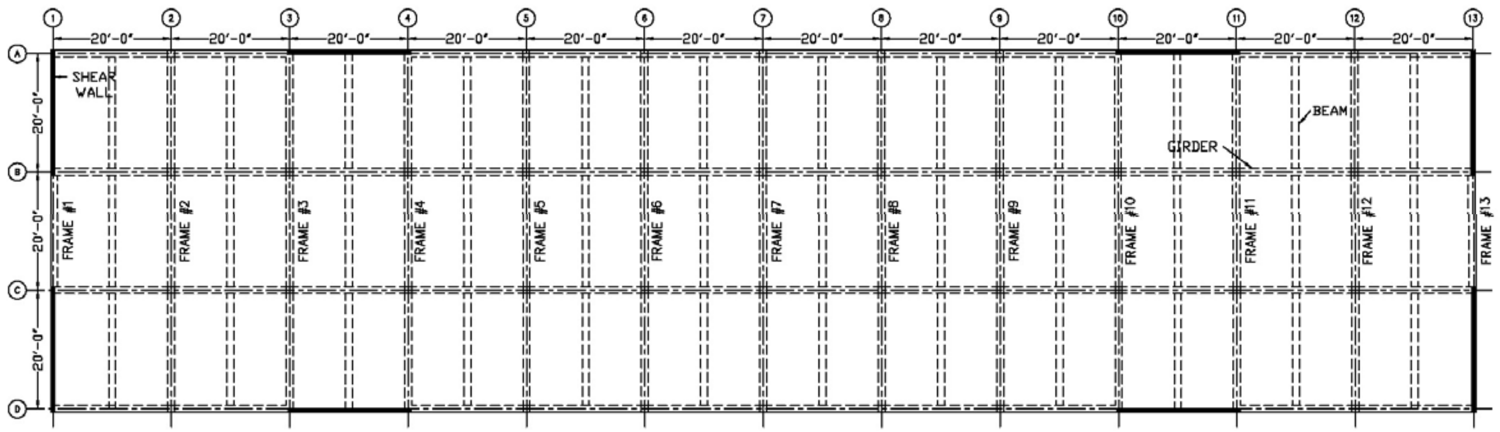
Analytical Investigation (Cont.)

Reinforcement Details

Reinforced Concrete Elements Details per ACI 318-08.

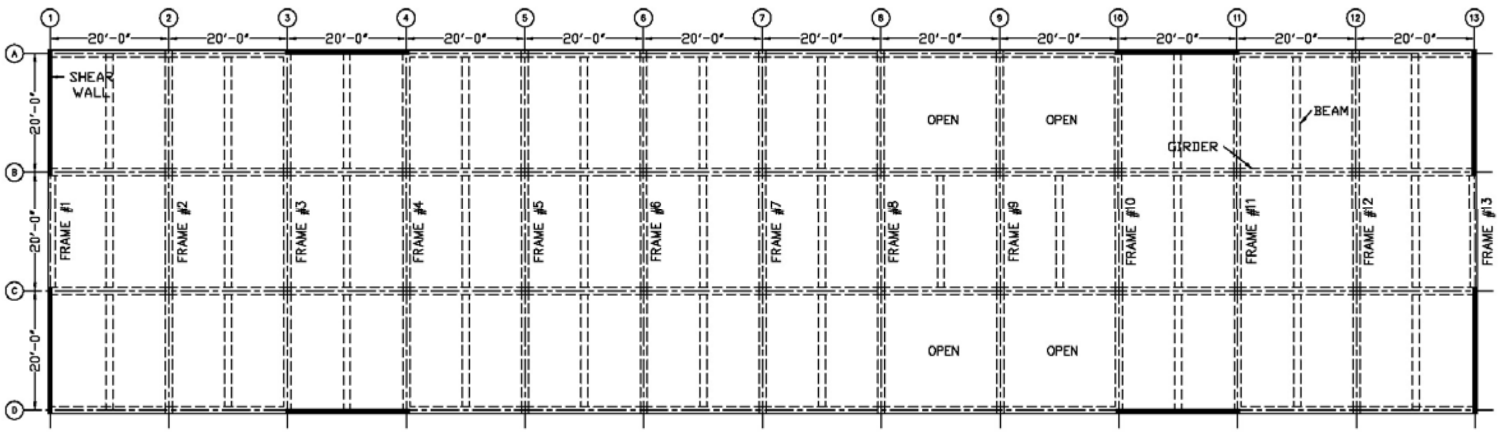
Element Type	Element Size	Steel Reinforcing
Slab	5 in.	#3 @ 12 in. one-way
Columns	14 in. x 14 in.	8-#6 verticals w/#3 @ 6 in. ties
Walls	8 in.	#6 @ 12 in. each way vertical & horizontal
Girders	14 in. x 24 in	3-#5 top & bottom w/#3 @ 10 in. stirrups – next to solid slab. 2-#5 top & bottom w/#3 @ 10 in. stirrups – next to open slab.
Beams	14 in. x 14 in.	6-#5 top & bottom w/#3 @ 6 in. stirrups

Geometry: Building A1



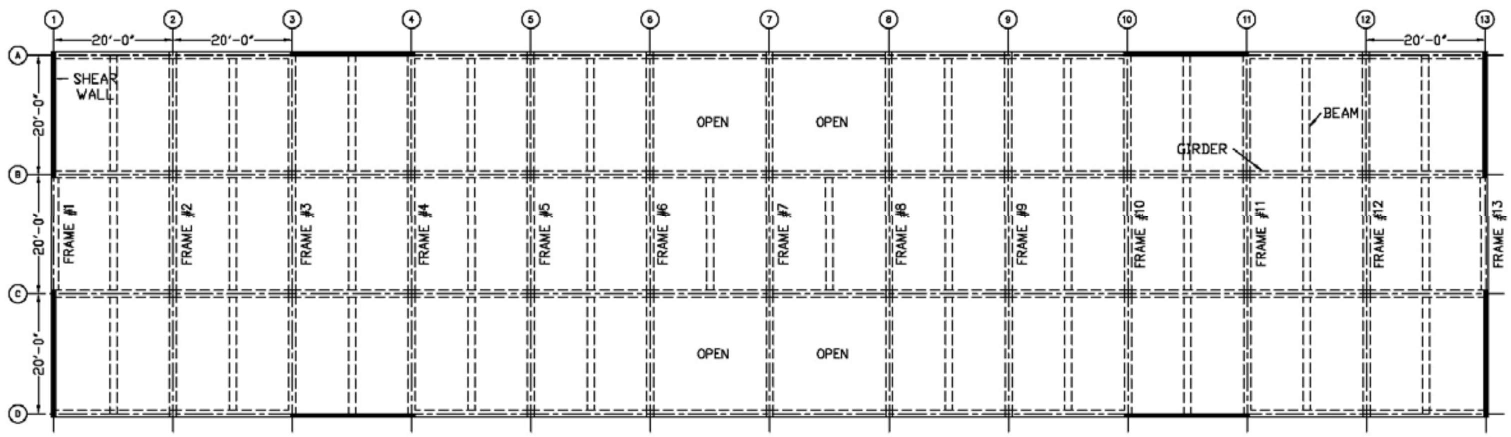
Building A1 Diaphragm Plan.

Geometry: Building A2



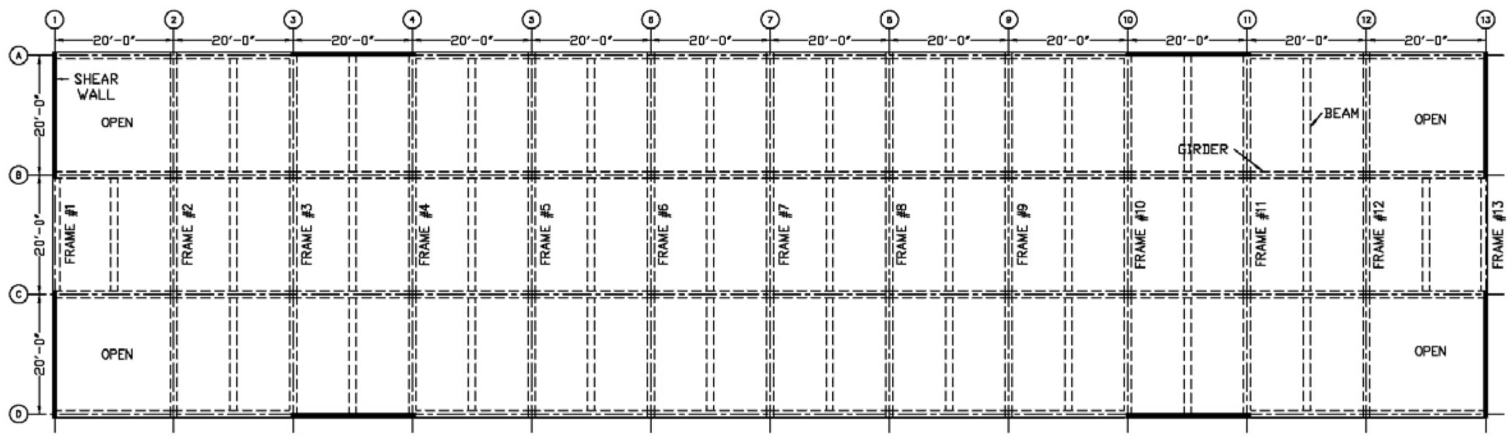
Building A2 Diaphragm Plan.

Geometry: Building A3



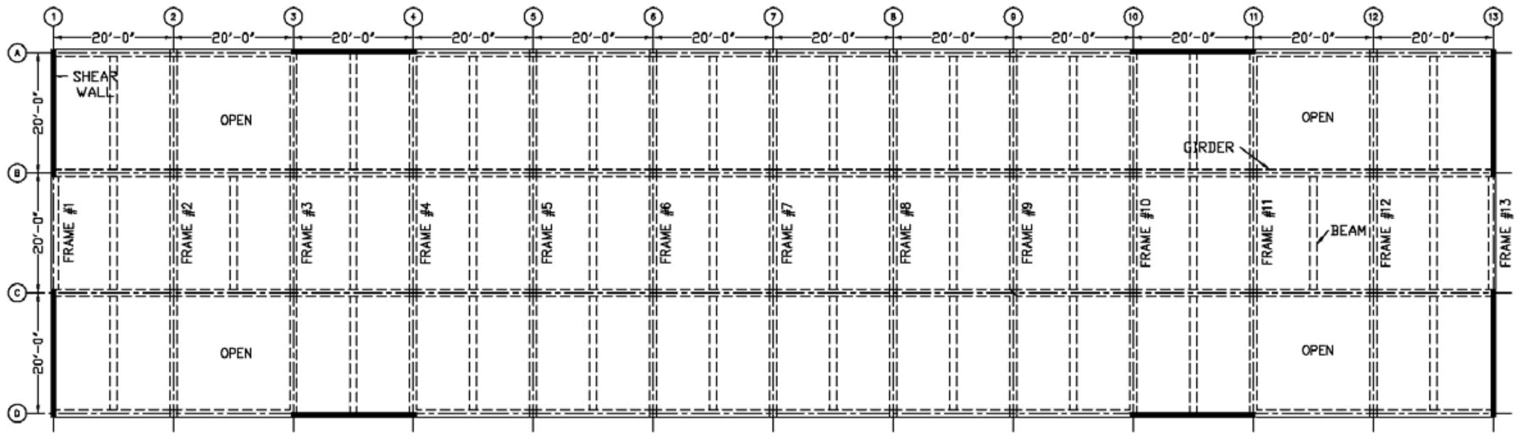
Building A3 Diaphragm Plan.

Geometry: Building A4



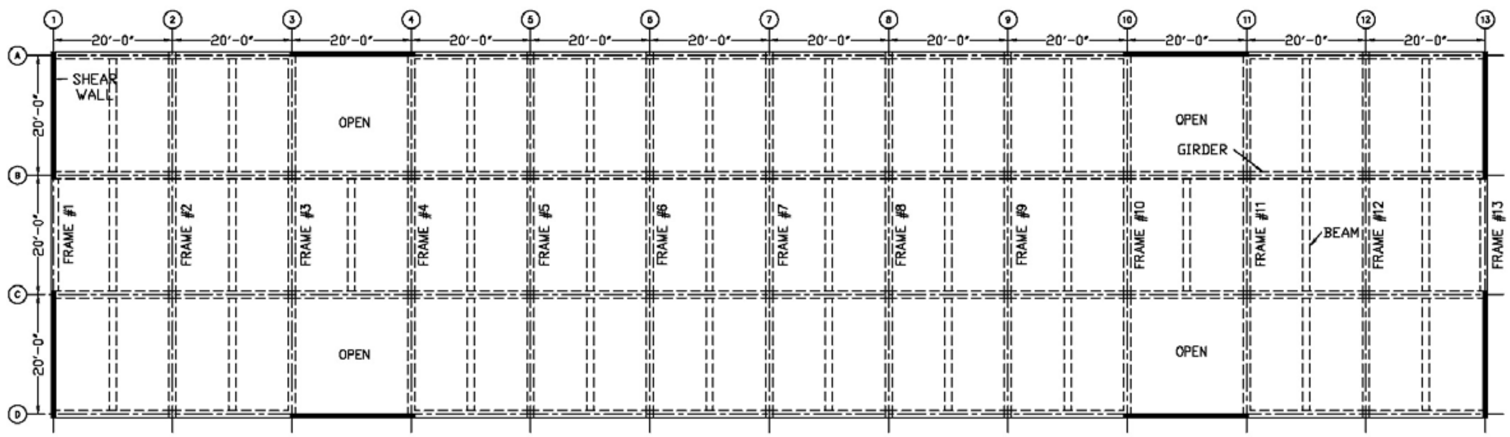
Building A4 Diaphragm Plan.

Geometry: Building A5



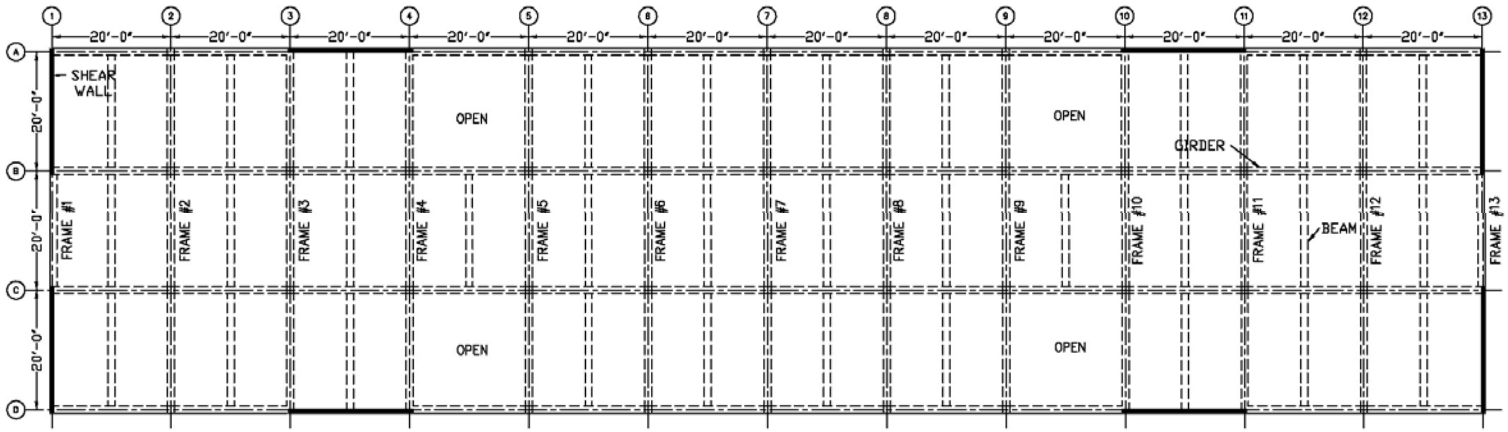
Building A5 Diaphragm Plan.

Geometry: Building A6



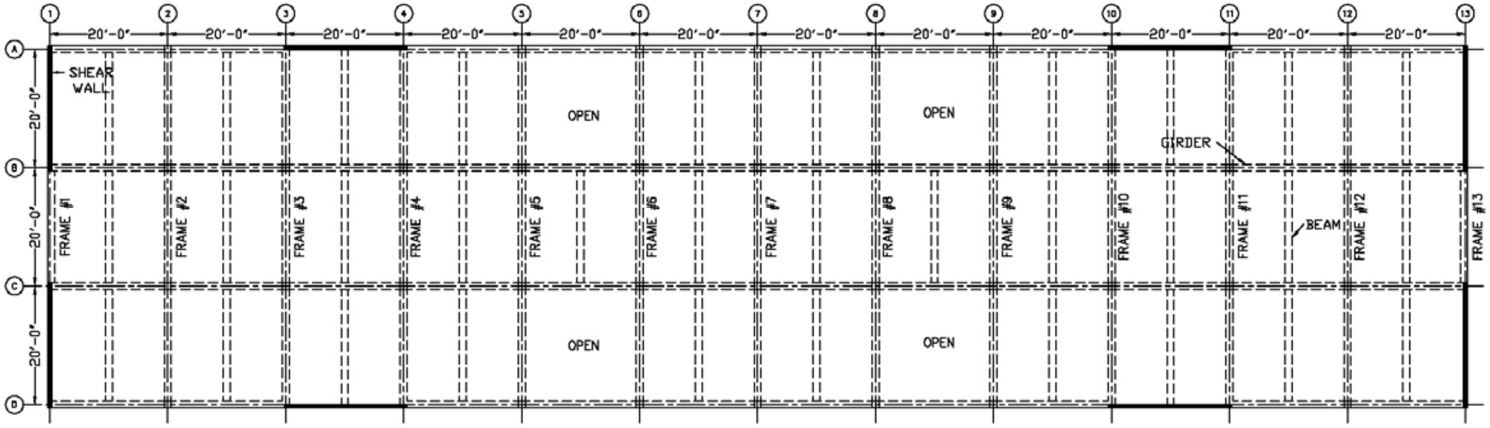
Building A6 Diaphragm Plan.

Geometry: Building A7



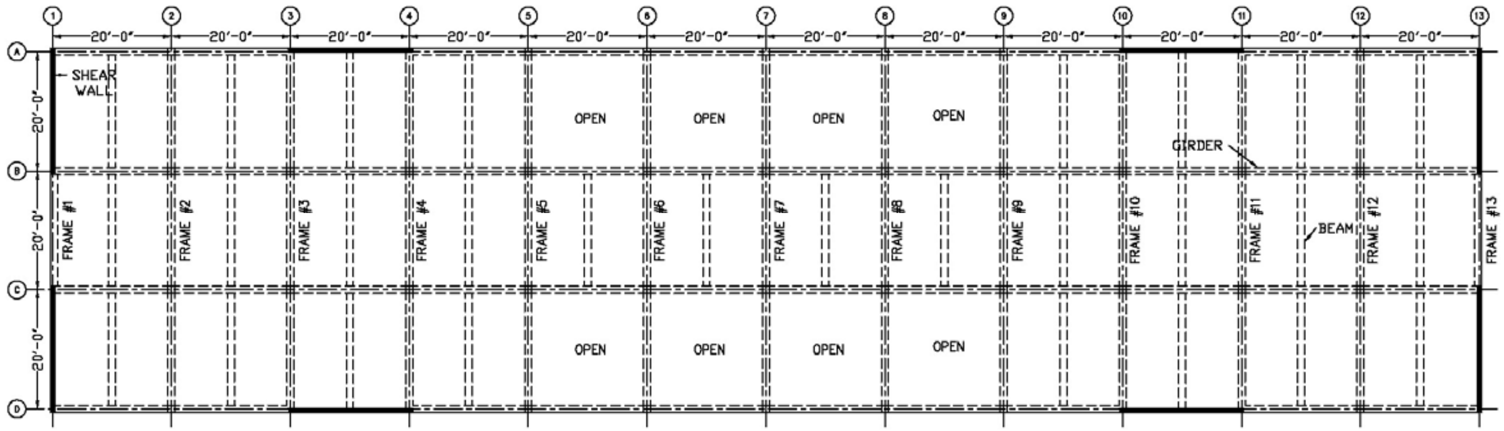
Building A7 Diaphragm Plan.

Geometry: Building A8



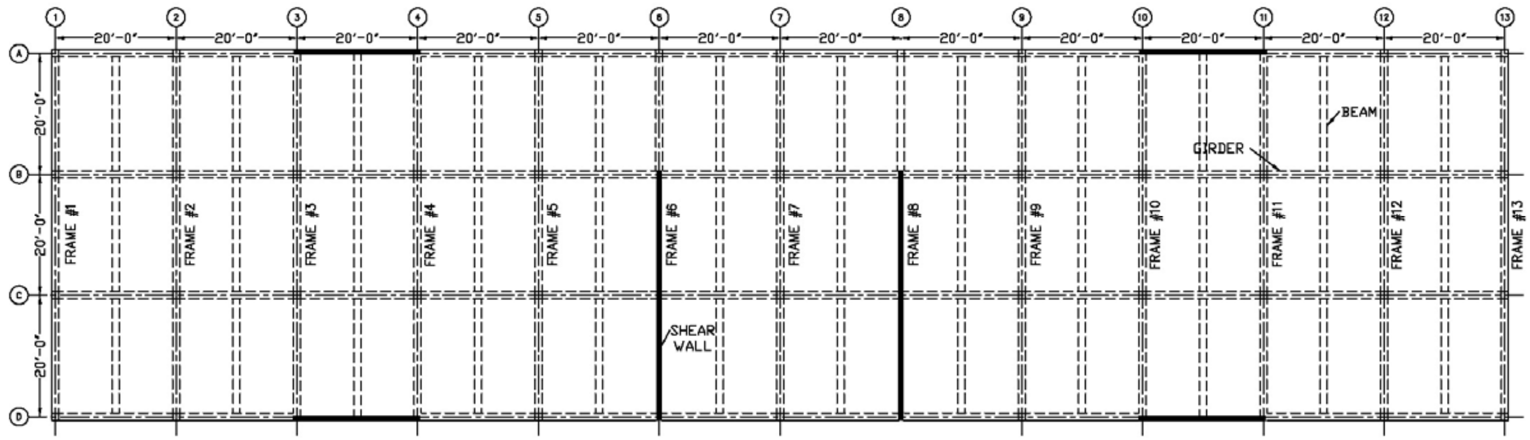
Building A8 Diaphragm Plan.

Geometry: Building A9



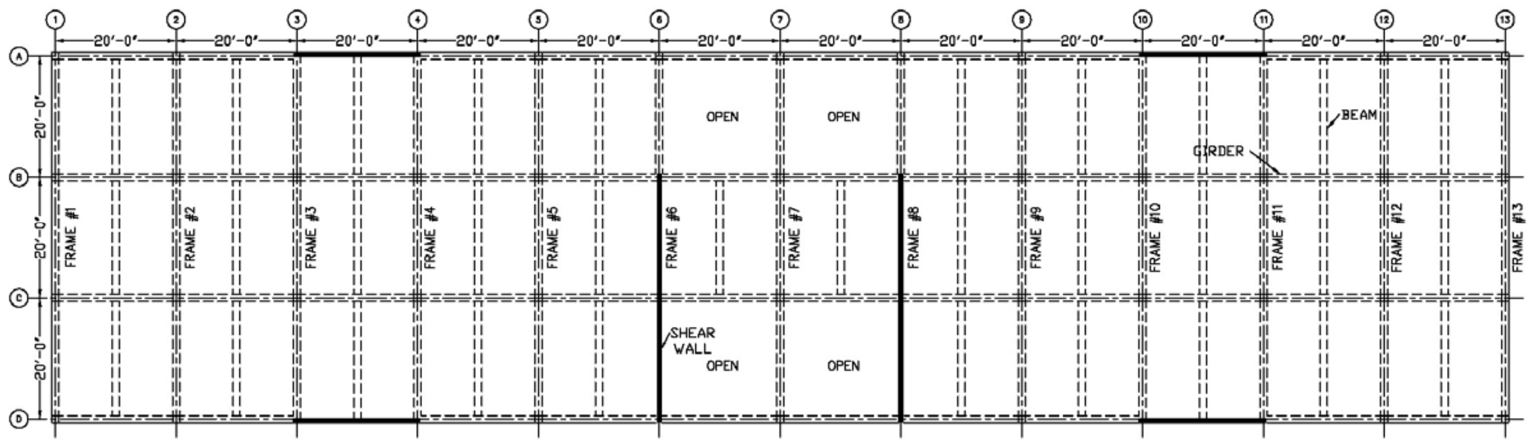
Building A9 Diaphragm Plan.

Geometry: Building B1



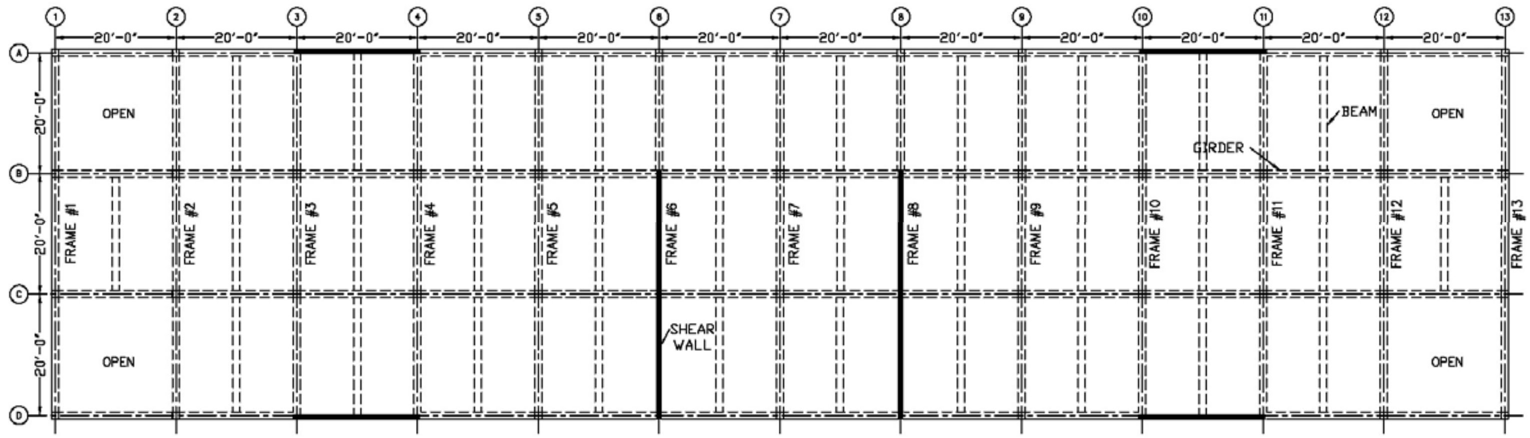
Building B1 Diaphragm Plan.

Geometry: Building B2



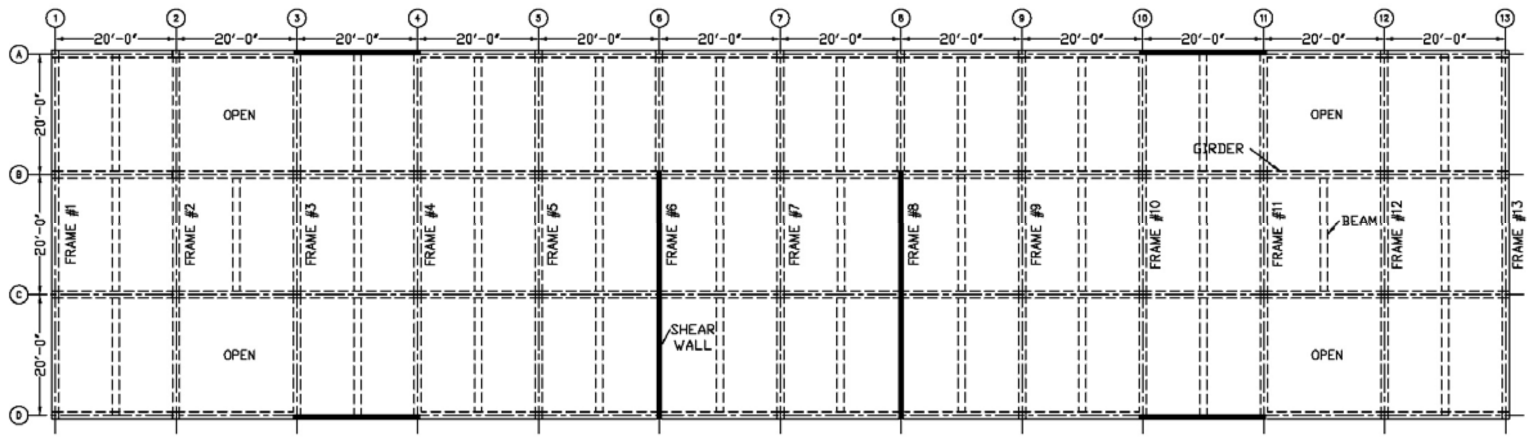
Building B2 Diaphragm Plan.

Geometry: Building B3



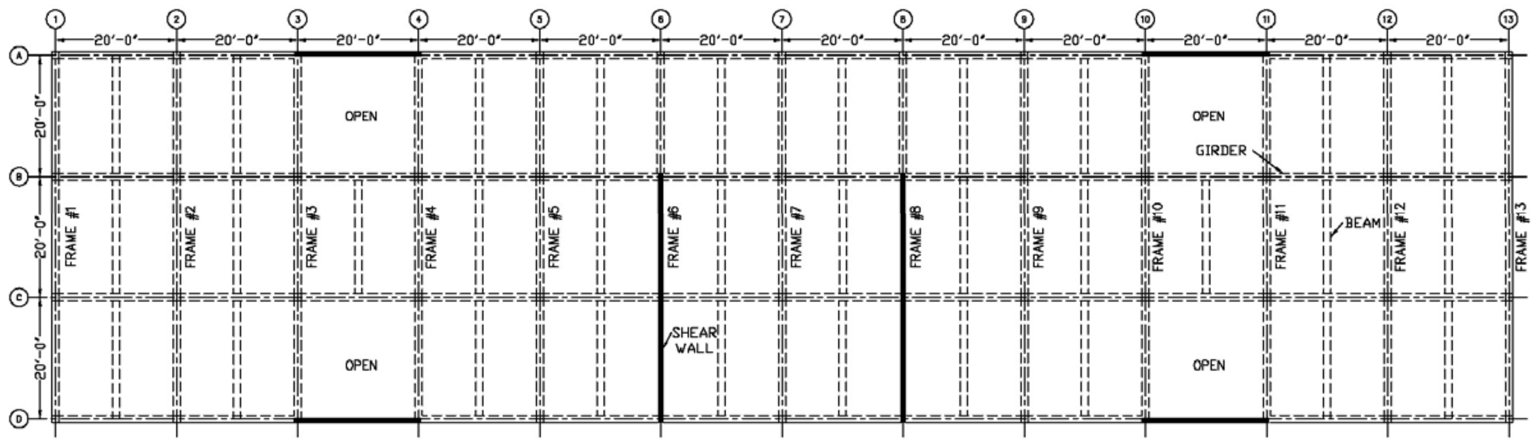
Building B3 Diaphragm Plan.

Geometry: Building B4



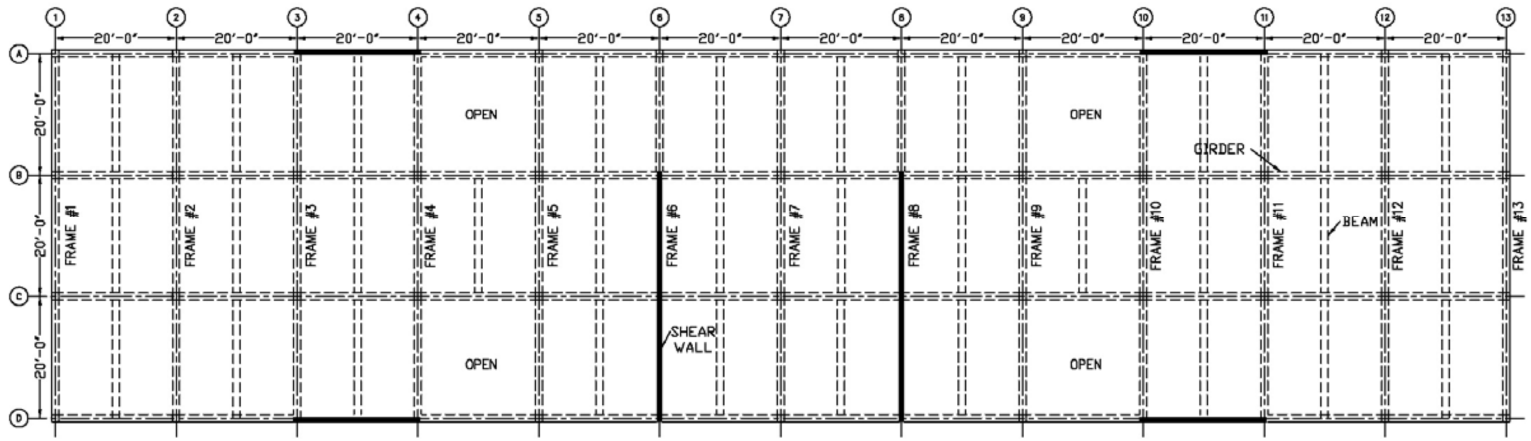
Building B4 Diaphragm Plan.

Geometry: Building B5



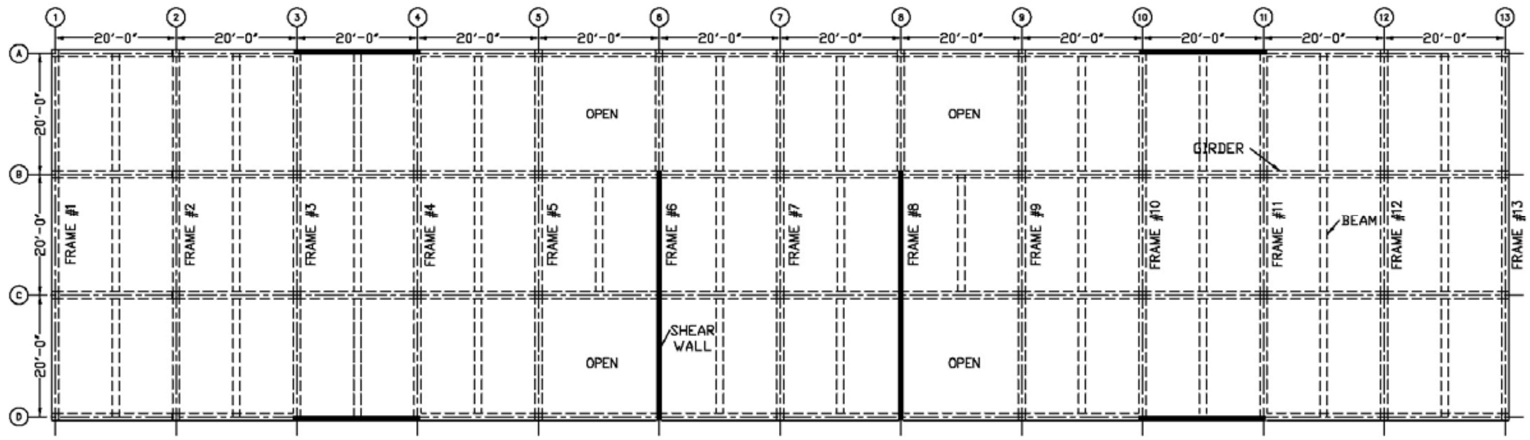
Building B5 Diaphragm Plan.

Geometry: Building B6



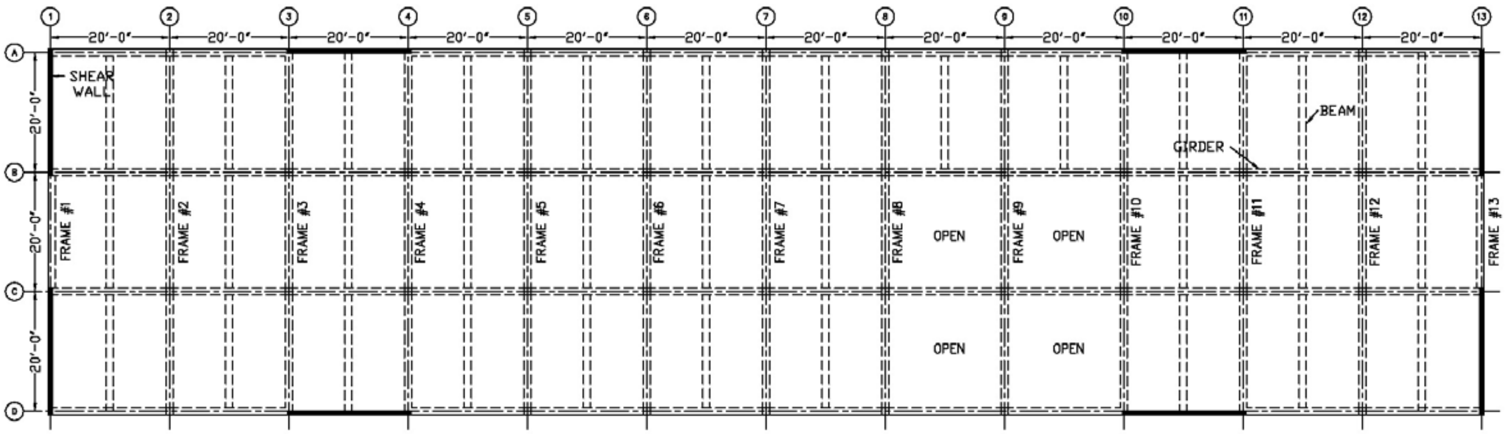
Building B6 Diaphragm Plan.

Geometry: Building B7



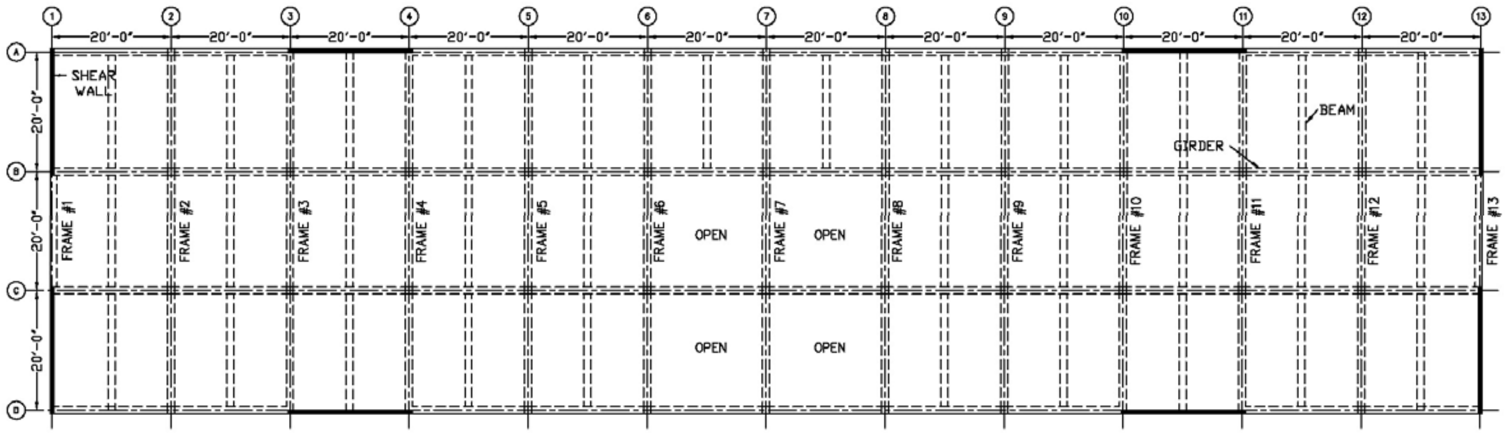
Building B7 Diaphragm Plan.

Geometry: Building P1



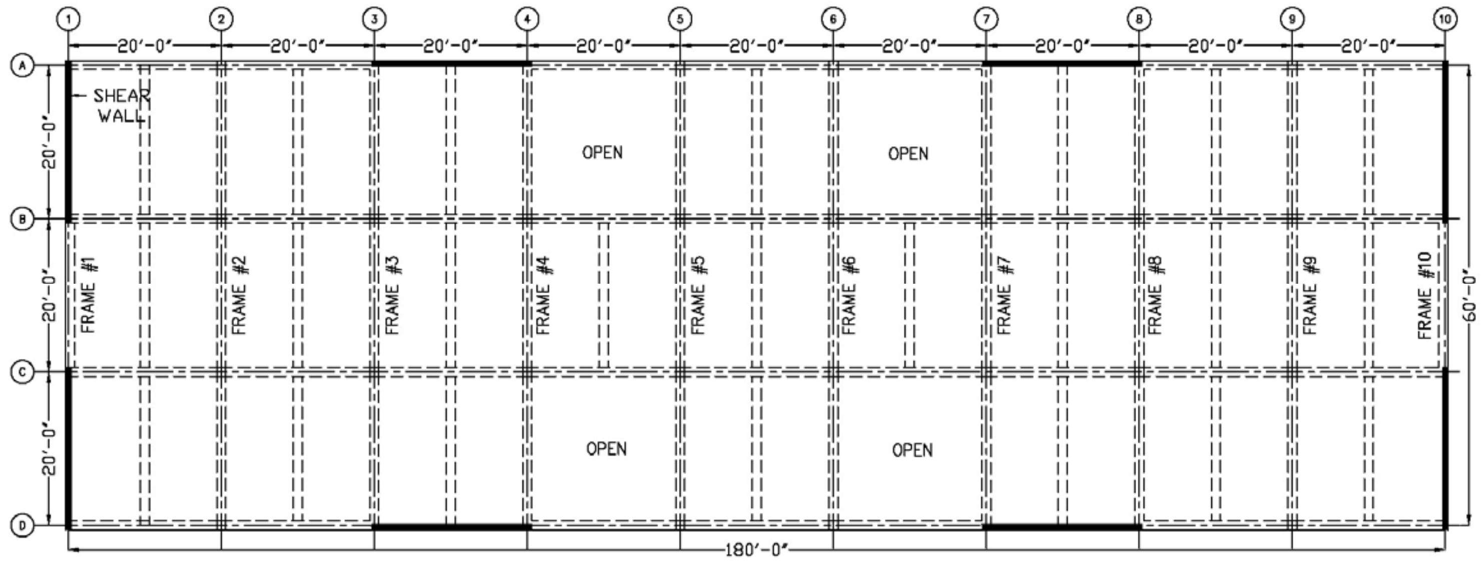
Building P1 Diaphragm Plan.

Geometry: Building P2



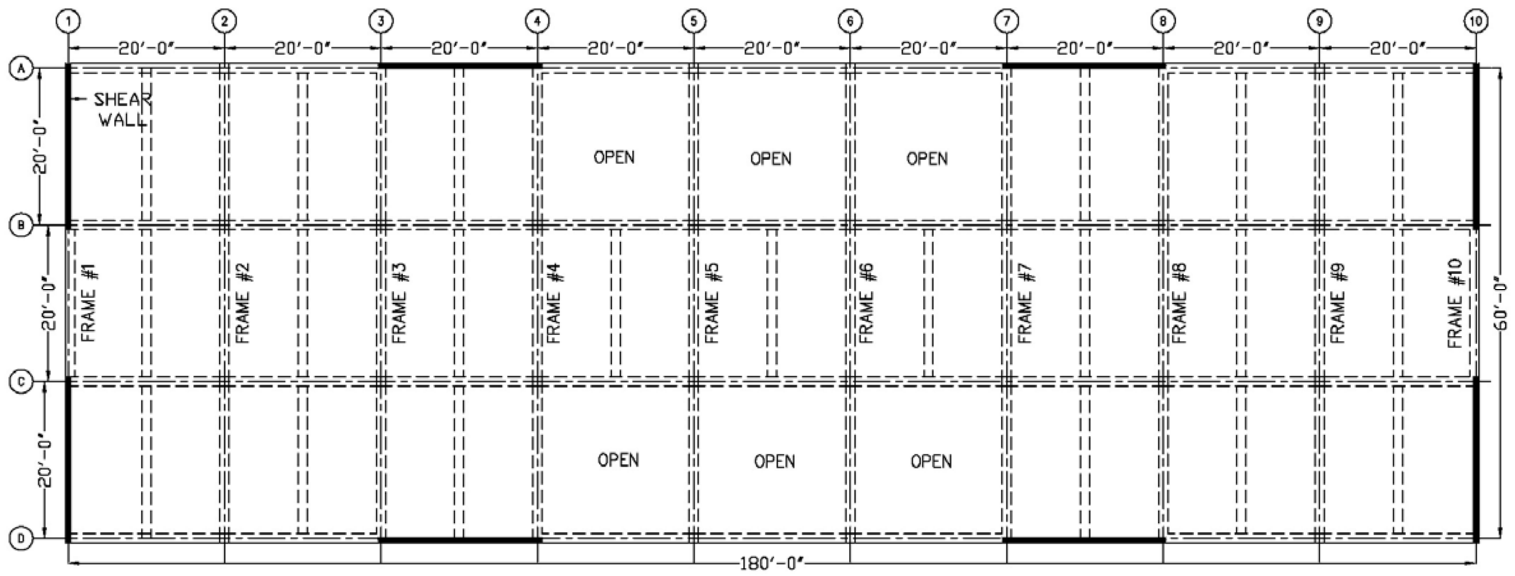
Building P2 Diaphragm Plan.

Geometry: Building C1



Building C1 Diaphragm Plan.

Geometry: Building D1



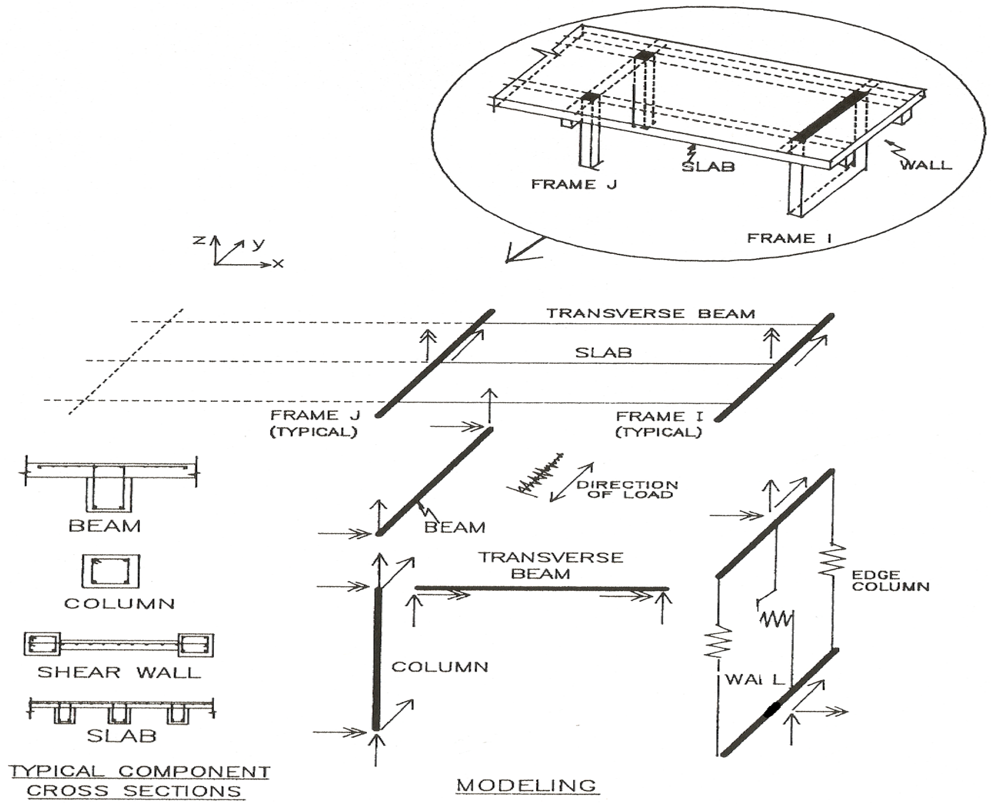
Building D1 Diaphragm Plan.

Analytical Investigation (Cont.)

Lateral Load System

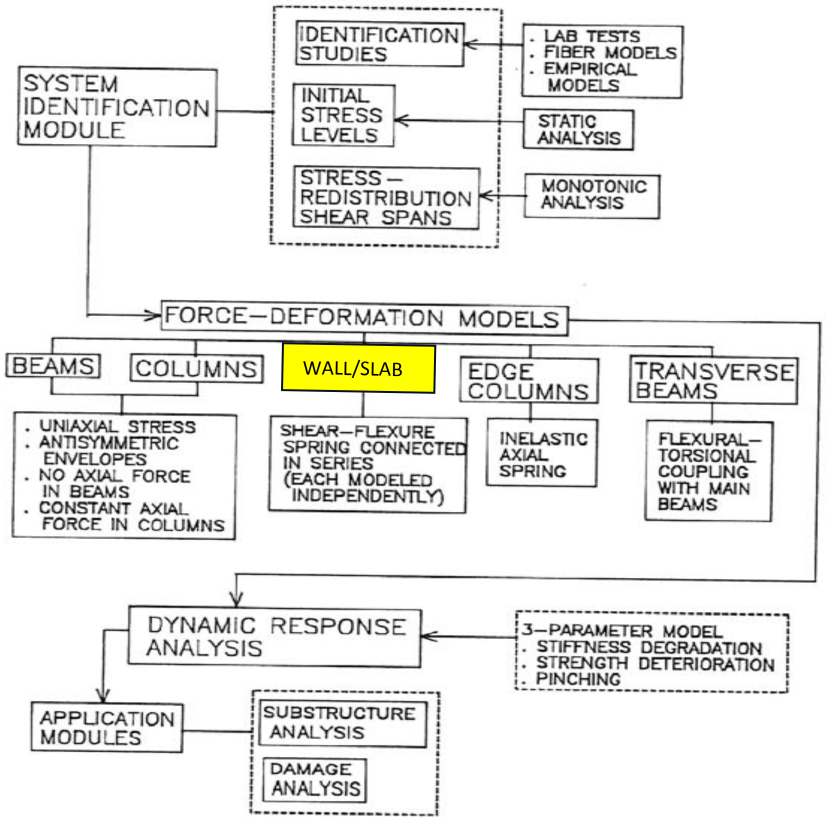
- All buildings:
  - Building Frame System – Shear Walls: Both directions
  - 4 ksi concrete & 60 ksi reinforcing steel
  - 50 psf LL & 20 psf superimposed DL + Self Weight
  - “Site class C
  - SDC: C

Inelastic Analysis



IDARC2 Structure and Component Modeling (Kunnath, et al. 1991)

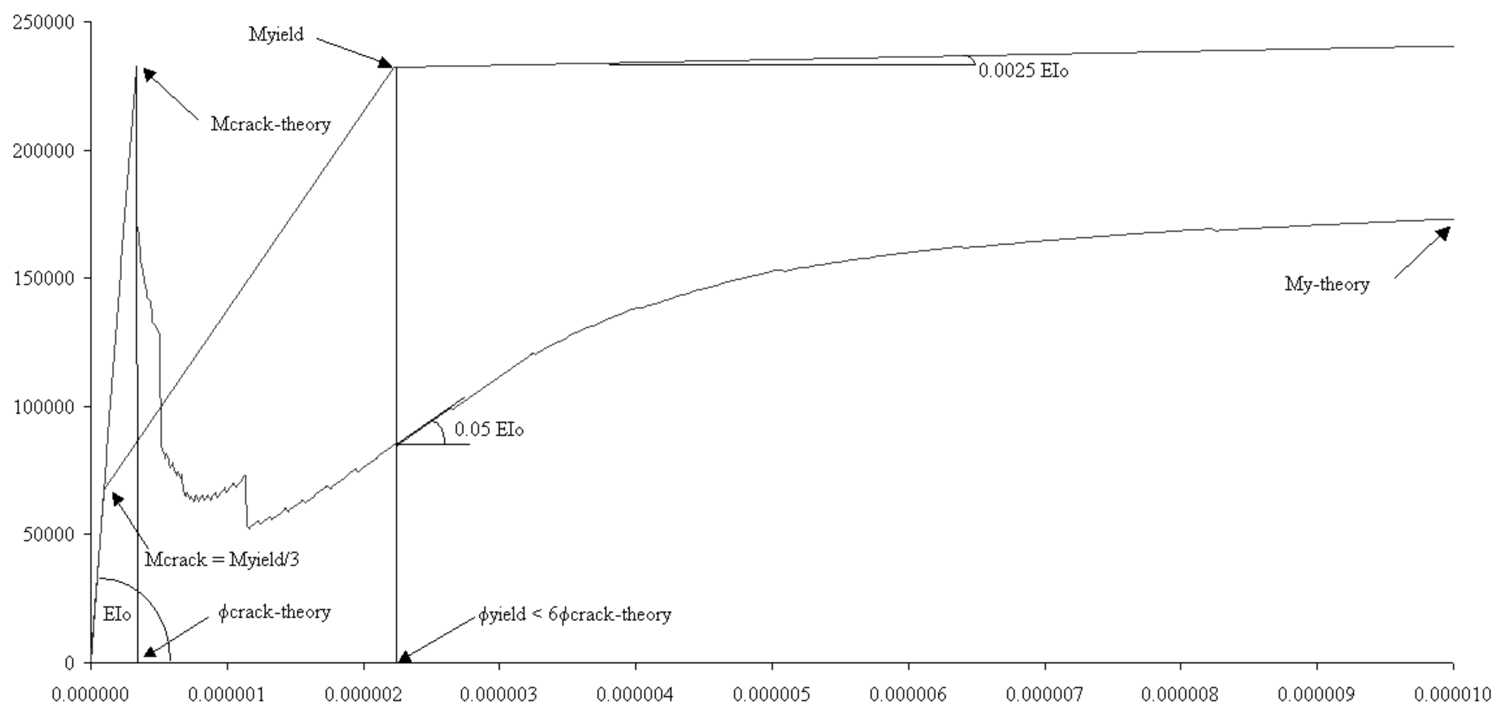
Inelastic Analysis (Cont.)



IDARC2 Program Organization (Kunnath, et al. 1990 & 1991)

Inelastic Analysis (Cont.)

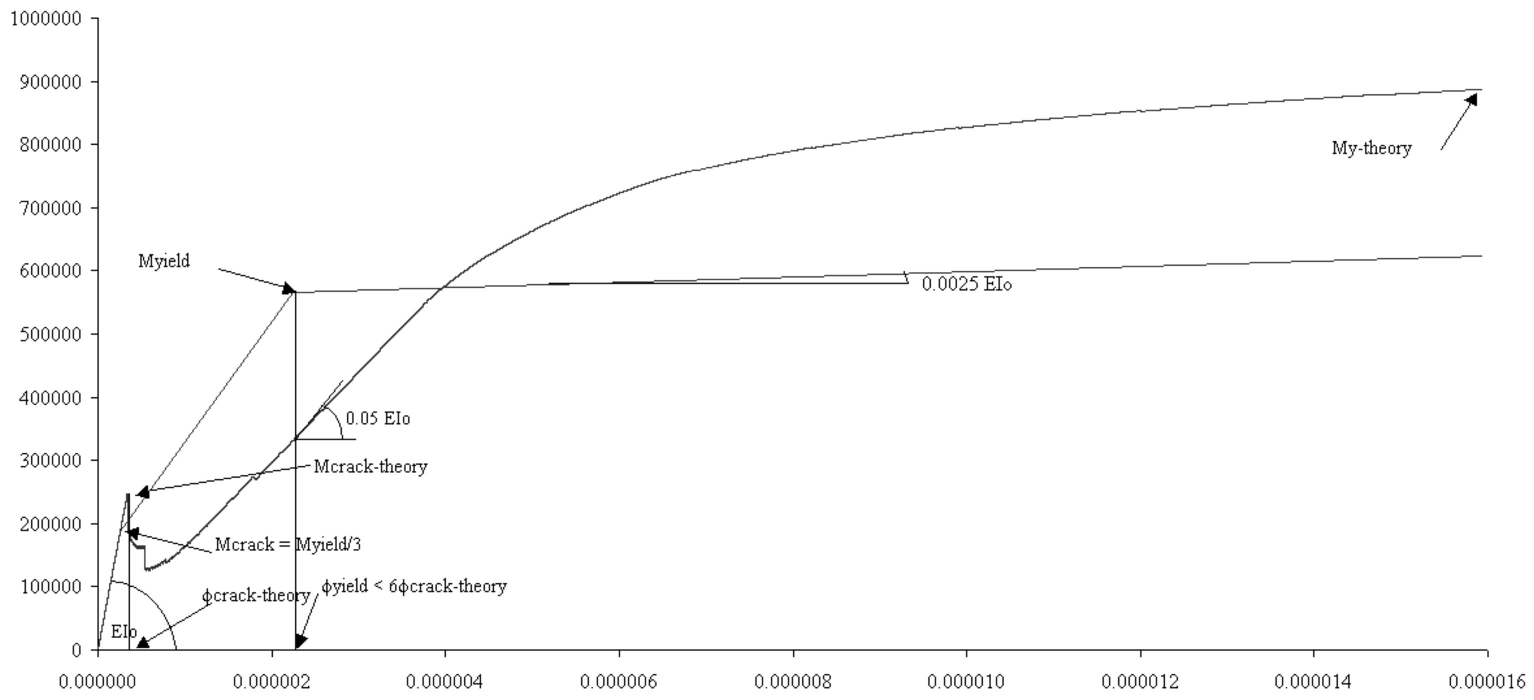
IDARC2 – Enhanced



IDARC2 Idealized Moment-Curvature Envelope Curve - Nominally Reinforced Slabs.

Inelastic Analysis (Cont.)

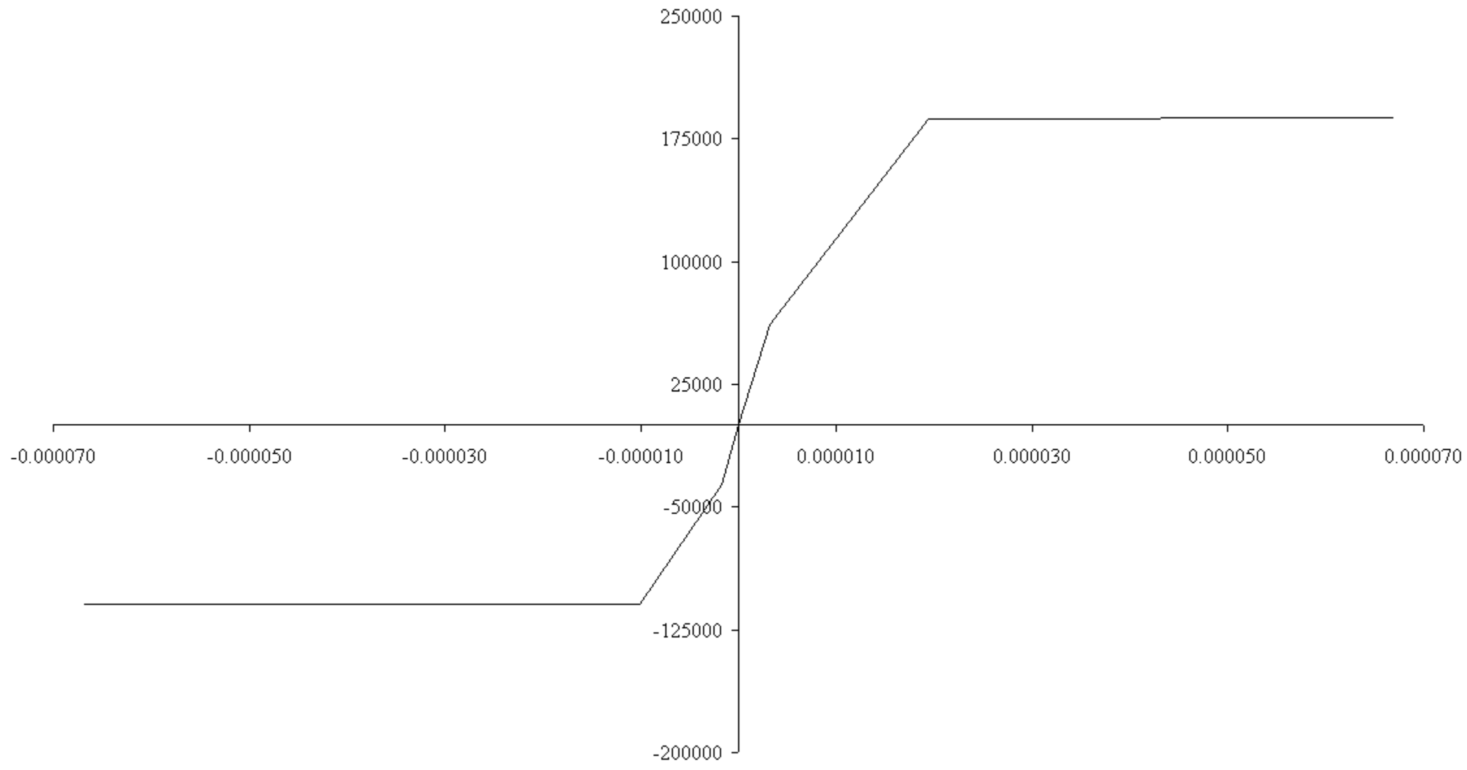
IDARC2 – Enhanced



IDARC2 Idealized Moment-Curvature Envelope Curve - Heavily Reinforced Slabs.

Inelastic Analysis (Cont.)

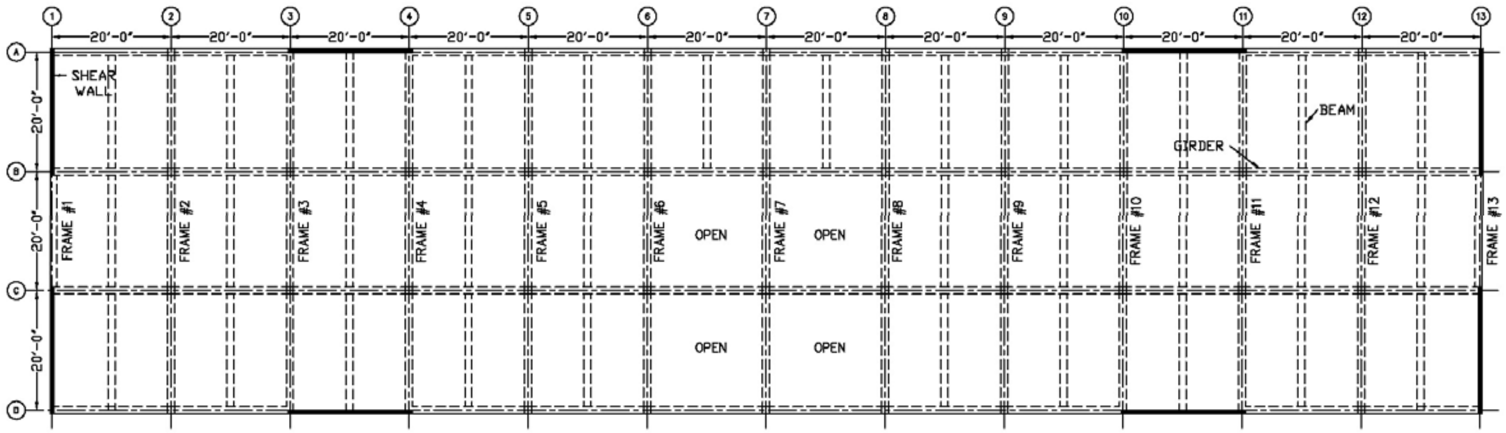
IDARC2 – Enhanced



Un-symmetric Moment-Curvature Curve.

Inelastic Analysis (Cont.)

IDARC2 – Enhanced



Building P2 - Slab Diaphragm with Un-symmetric Cross-Section

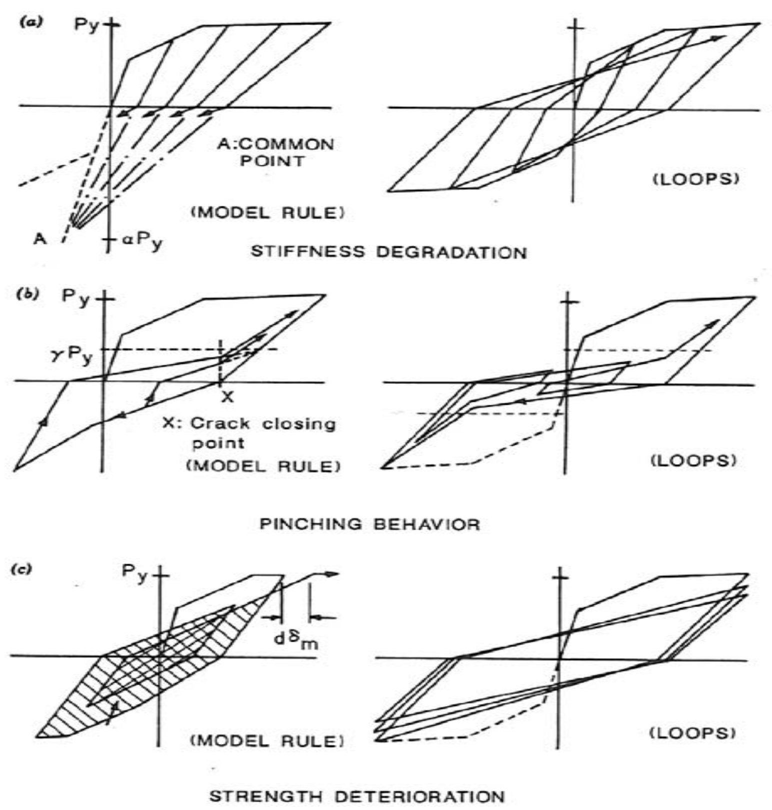
Inelastic Analysis (Cont.)

Parameters Studied

- **Stiffness degradation factor α**
  - Degree of reduction in the unloading stiffness and the reduction in area enclosed by the hysteresis loops for consecutive loading cycles.
- **Pinching factor γ**
  - Reduces the stiffness of the reloading paths as well as the area of the hysteresis loops and the amount of dissipated energy.
- **Strength deterioration factor β**
  - Ratio computed as the amount of incremental damage caused by the increase of the maximum response divided by the normalized incremental hysteresis energy.

Inelastic Analysis (Cont.)

Hysteretic Parameters



IDARC2 Three Parameter Model (Kunnath, et al. 1991)

Inelastic Analysis (Cont.)

Hysteretic Parameters

Reference Hysteretic Parameters Used in Dynamic Analysis.

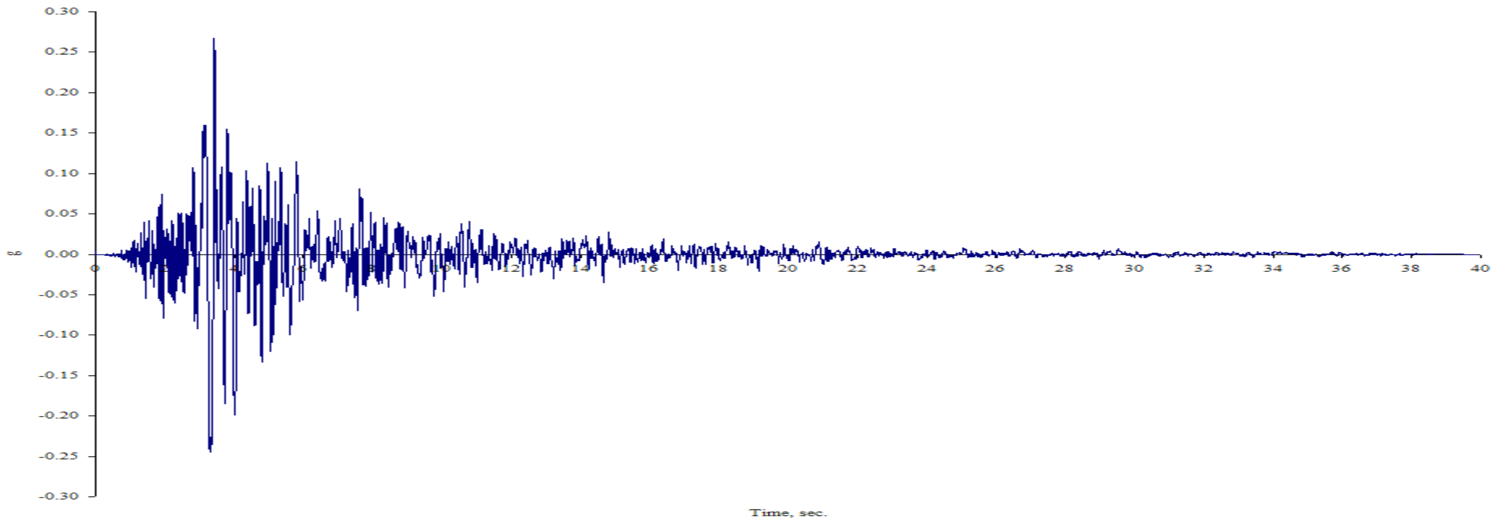
Element	Stiffness Degradation Coefficient, α	Bond-Slippage Coefficient, γ	Strength Deterioration Coefficient, β	Post-Yielding Stiffness Ratio
Beam	4.00	0.80	0.01	0.015
Column	2.00	0.80	0.01	0.015
Wall Bending	3.50	1.00	0.15	0.015
Wall Shear	0.10	1.00	0.15	0.015
Slab Bending	2.50	0.80	0.15	0.015
Slab Shear	0.10	0.80	0.15	0.015

Sensitivity studies conducted using

- 1.25α, α, 0.75α,
- 1.25γ, γ, 0.75γ,
- 1.25β, β, 0.75β.

Inelastic Analysis (Cont.)

Scaled Ground-motions



Scaled Loma Prieta Acceleration Time History.

Earthquake Characteristic Used in IDARC2 Analysis.

Earthquake	PGA, g	T_g, sec.	Scale
Loma Prieta - Corralitos - 1989	0.41	0.34 sec.	0.659
San Fernando - Pacoima -1971	1.15	0.40 sec.	0.235
Parkfield - Cholane -1966	0.48	0.40 sec.	0.563

Inelastic Analysis (Cont.)

Parameters Studied

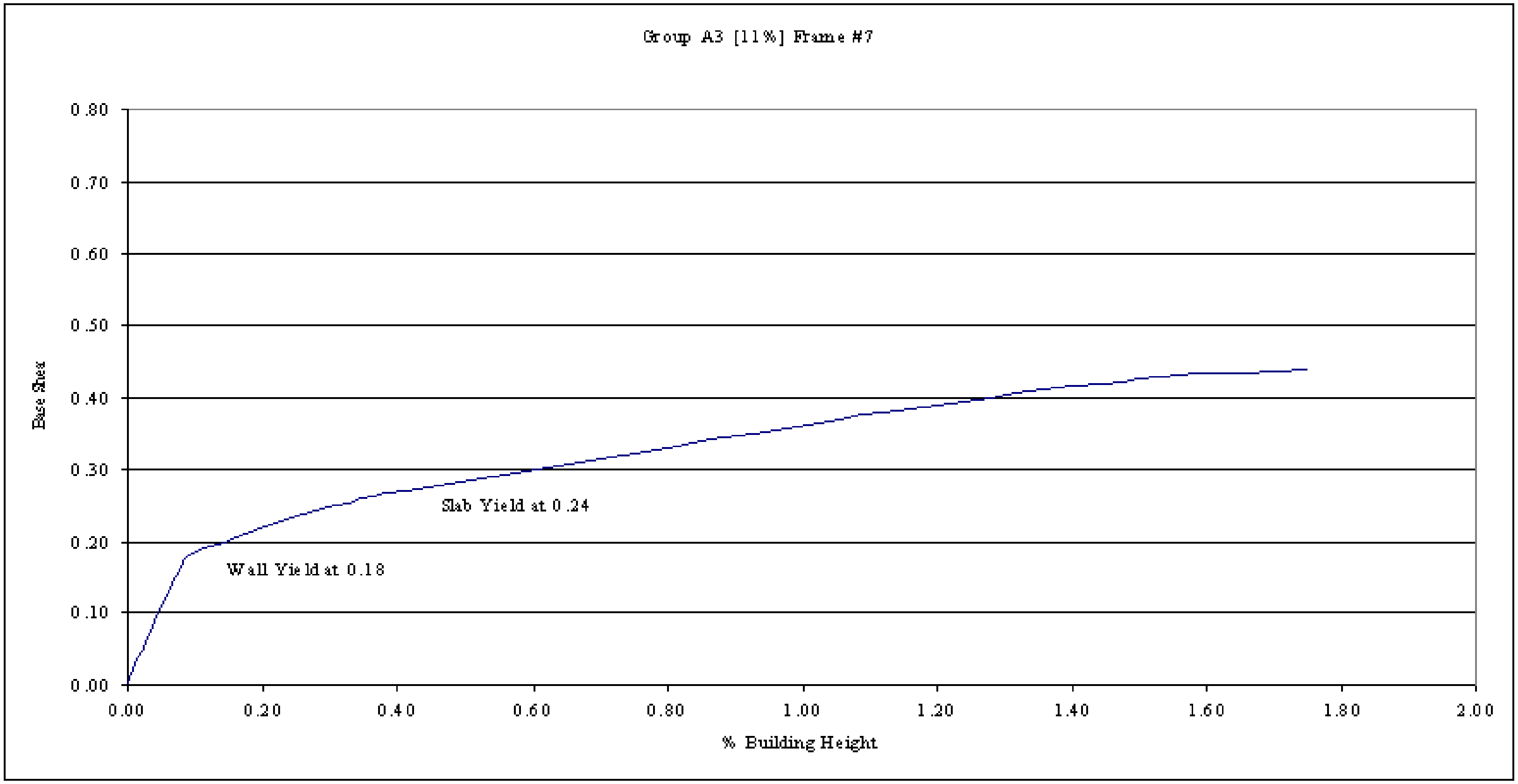
- Diaphragm Aspect Ratio (3:1 & 4:1)
- Floor Opening Location (Symmetric & Un-symm.)
- Opening Area (0%, 11%, 15%, 22%)
- Shear Wall Locations (ESW & ISW)
- Diaphragm Models (Rigid, Elastic and Inelastic)

Results: Pushover Analysis

Summary Results of Pushover Analysis: Wall/Slab Yield Sequence.

Scenario	Base Shear Coefficient	
	Wall Yielding	Slab Yielding
1A1-4:1-ESW-Solid-IE	0.180	0.420
1A2-4:1-ESW-(8&9-T&B)-IE	0.170	0.250
1A3-4:1-ESW-(6&7-T&B)-IE	0.180	0.240
1A4-4:1-ESW-(1&12-T&B)-IE	0.170	0.380
1A5-4:1-ESW-(2&11-T&B)-IE	0.180	0.390
1A6-4:1-ESW-(3&10-T&B)-IE	0.180	0.320
1A7-4:1-ESW-(4&9-T&B)-IE	0.180	0.260
1A8-4:1-ESW-(5&8-T&B)-IE	0.180	0.240
1A9-4:1-ESW-(5 6 7 8-T&B)-IE	0.190	0.280
1B1-4:1-ISW-Solid-IE	0.170	0.490
1B2-4:1-ISW-(6&7-T&B)-IE	0.200	0.300
1B3-4:1-ISW-(1&12-T&B)-IE	0.190	0.540
1B4-4:1-ISW-(2&11-T&B)-IE	0.220	-
1B5-4:1-ISW-(3&10-T&B)-IE	0.230	0.630
1B6-4:1-ISW-(4&9-T&B)-IE	0.230	0.520
1B7-4:1-ISW-(5&8-T&B)-IE	0.220	0.310
1P1-4:1-ESW-(8&9-M&B)-IE	0.170	0.170
1P2-4:1-ESW-(6&7-M&B)-IE	0.170	0.170
1C1-3:1-ESW-(4&6-T&B)-IE	0.230	0.530
1D1-3:1-ESW-(4 5 6-T&B)-IE	0.240	0.590

Results: Pushover Analysis (Cont.)



Pushover Results for Building 1A3 (Lateral load-vs-Drift at Frame 7).

Results: Pushover Analysis (Cont.)

- Plan Aspect Ratio 4:1
  - Solid: Slab/End Wall = 2.5
  - Solid: Slab/Int. Wall = 2.8
  - ***Symmetric Openings in Middle 2/3: Slab/End Wall = 1.3***
  - Symmetric Openings in Middle 1/2: Slab/Int. Wall = 1.5
  - Symmetric Openings at End 1/3: Slab/End Wall = 2.0
  - Symmetric Openings at End 1/3: Slab/Int. Wall = 2.8
  - UnSymmetric Openings in Mid-region:
    - ***Slab & End Wall - Yield Simultaneously***

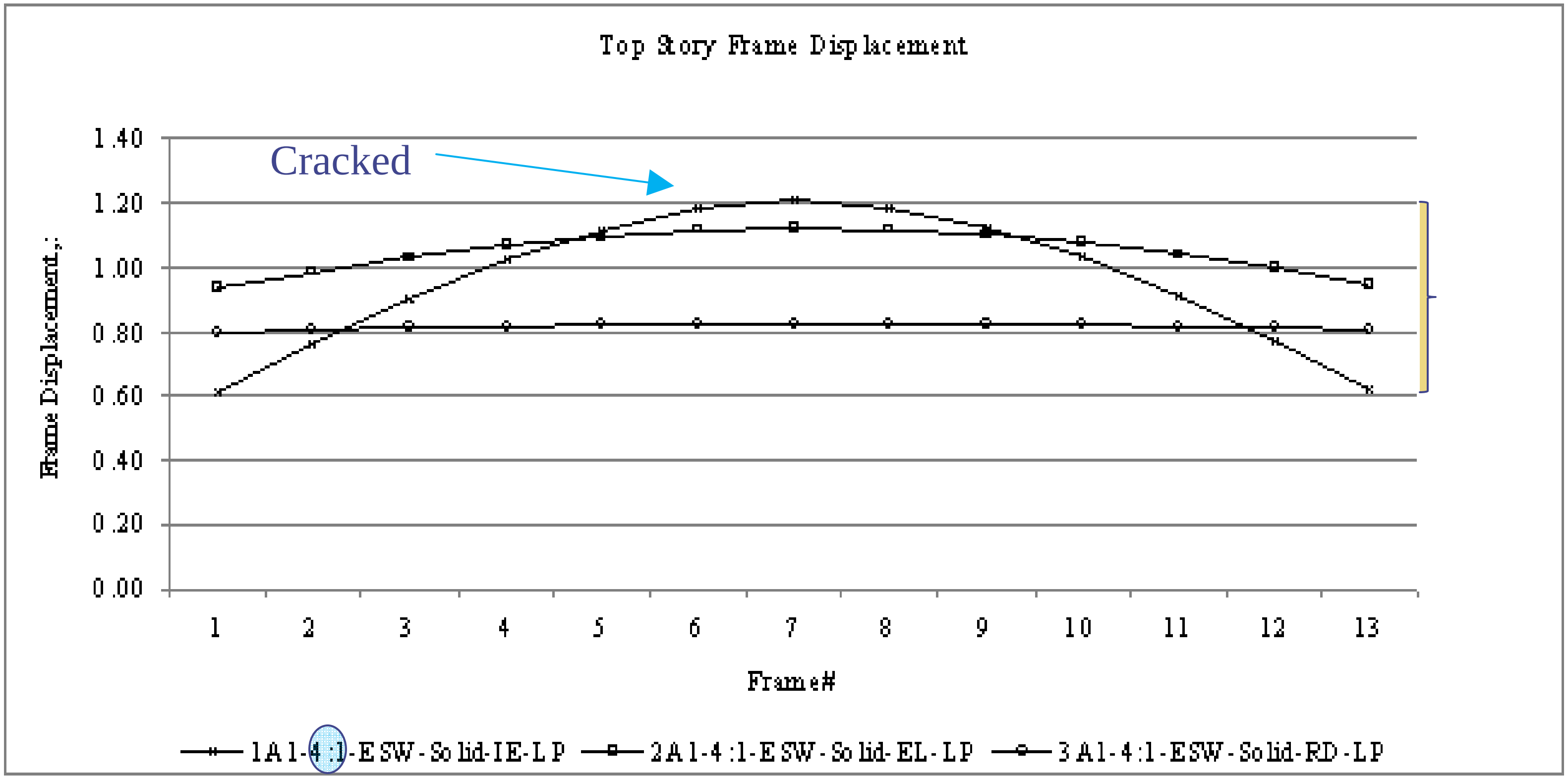
- Plan Aspect Ratio 3:1
  - Openings in Middle 2/3: Slab/End Wall = 2.3

Results: Dynamic Analysis

Max. Building Displacement with Inelastic Diaphragm Model

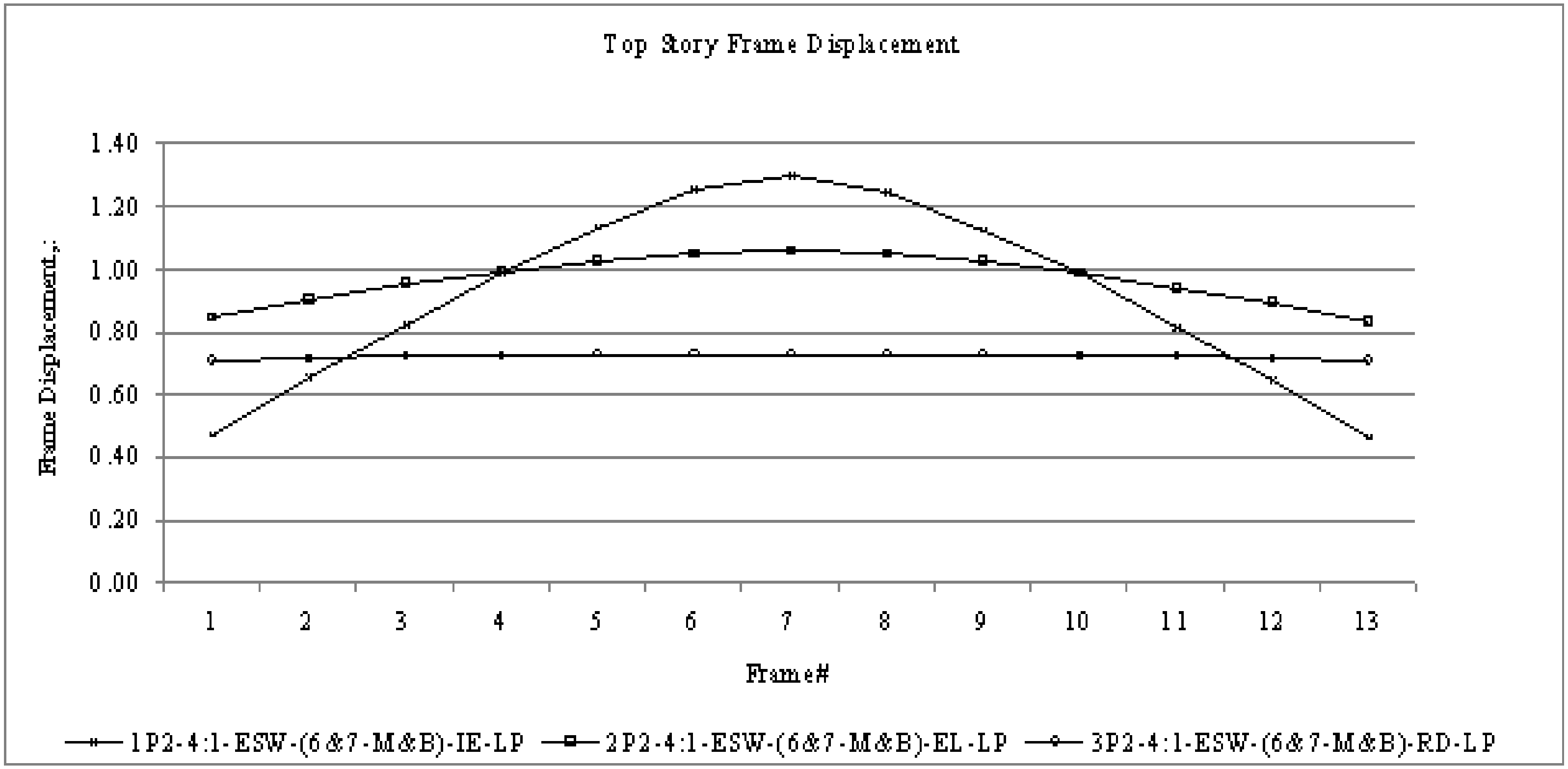
Scenario	Bldg. Max. Top Displ., in.	Diaph. Max. Inplane Defl., in.
1A1-4:1-ESW-Solid-IE-LP	1.2040	0.5920
1A2-4:1-ESW-(8&9-T&B)-IE-LP	1.3230	1.0612
1A3-4:1-ESW-(6&7-T&B)-IE-LP	1.2740	0.8264
1A4-4:1-ESW-(1&12-T&B)-IE-LP	1.0530	0.3583
1A5-4:1-ESW-(2&11-T&B)-IE-LP	1.0870	0.5491
1A6-4:1-ESW-(3&10-T&B)-IE-LP	1.0760	0.5128
1A7-4:1-ESW-(4&9-T&B)-IE-LP	1.2370	0.8853
1A8-4:1-ESW-(5&8-T&B)-IE-LP	1.2260	0.8150
1A9-4:1-ESW-(5 6 7 8-T&B)-IE-LP	1.1970	0.7775
1B1-4:1-ISW-Solid-IE-LP	0.5964	0.2302
1B2-4:1-ISW-(6&7-T&B)-EL-LP	0.6730	0.4054
1B3-4:1-ISW-(1&12-T&B)-IE-LP	0.5040	0.1960
1B4-4:1-ISW-(2&11-T&B)-IE-LP	0.4053	0.1358
1B5-4:1-ISW-(3&10-T&B)-IE-LP	0.4746	0.2300
1B6-4:1-ISW-(4&9-T&B)-IE-LP	0.5348	0.3404
1B7-4:1-ISW-(5&8-T&B)-IE-LP	0.5003	0.2960
1P1-4:1-ESW-(8&9-M&B)-IE-LP	1.2410	0.8939
1P2-4:1-ESW-(6&7-M&B)-IE-LP	1.2920	0.8253
1C1-3:1-ESW-(4&6-T&B)-IE-LP	0.6649	0.2627
1D1-3:1-ESW-(4 5 6-T&B)-IE-LP	0.5912	0.1910

Results: Dynamic Analysis (Cont.)



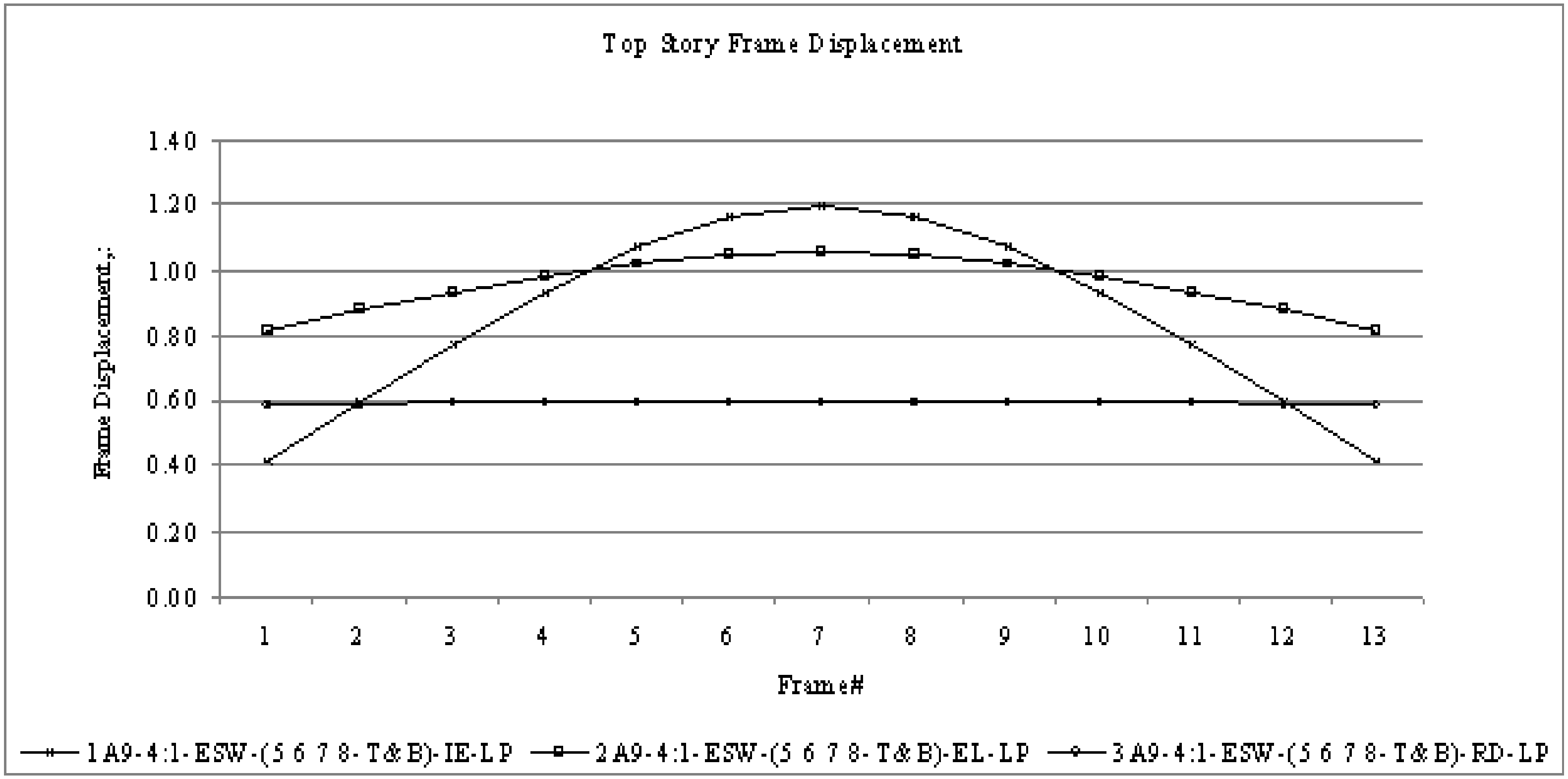
Building A1 [0%] Top Story max. Frame Deflection vs. Frame Numbers.

Results: Dynamic Analysis (Cont.)



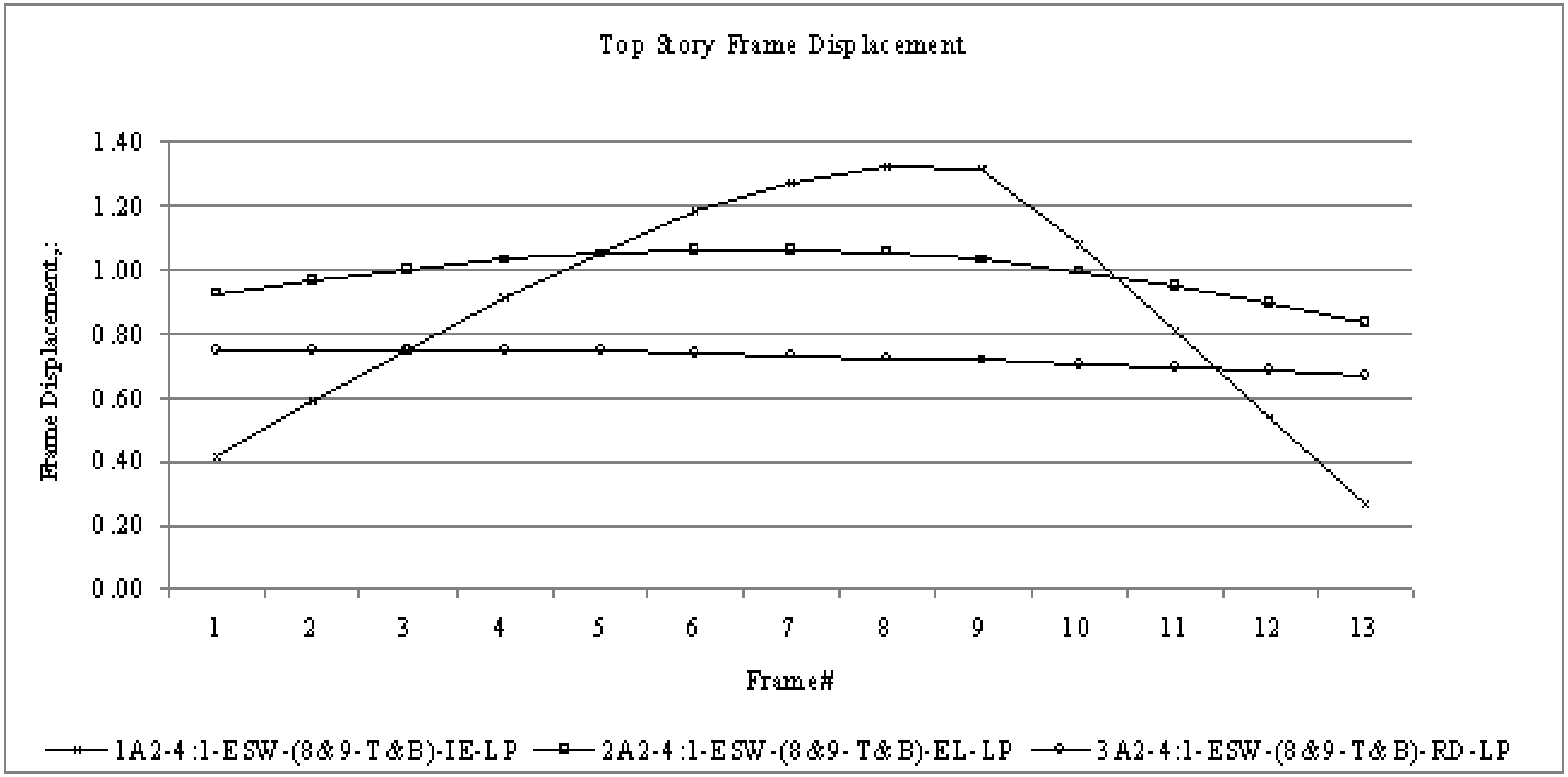
Building P2 [11%] Top Story max. Frame Deflection vs. Frame Numbers.

Results: Dynamic Analysis (Cont.)



Building A9 [22%] Top Story max. Frame Deflection vs. Frame Numbers.

Results: Dynamic Analysis (Cont.)



Building A2 [11%] Top Story max. Frame Deflection vs. Frame Numbers.

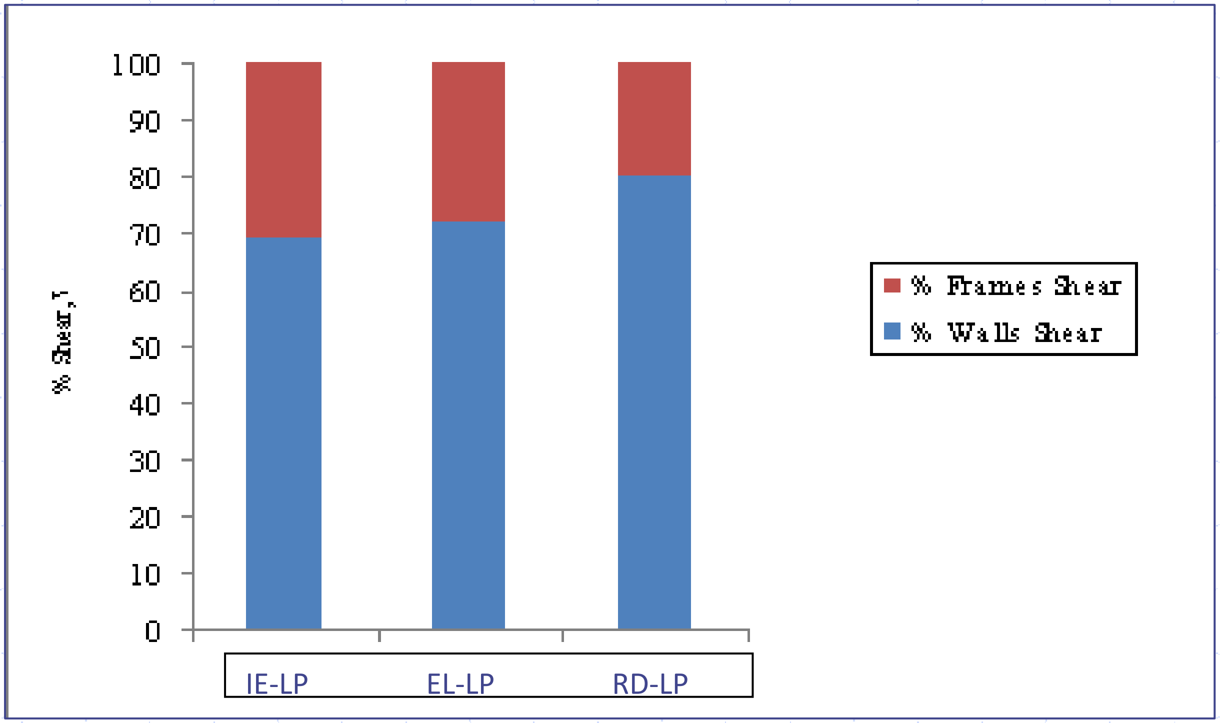
Results: Dynamic Analysis (Cont.)

Error Index for All Inelastic Building Cases

Scenario	Bldg. Max. ASCE7-05 Top Displ., in.	Bldg. Max. Dynamic Top Displ., in.	Error Index, %
1A1-4:1-ESW-Solid-IE	0.80	1.204	49.77
1A2-4:1-ESW-(8&9-T&B)-IE	0.86	1.323	53.25
1A3-4:1-ESW-(6&7-T&B)-IE	0.88	1.274	44.28
1A4-4:1-ESW-(1&12-T&B)-IE	0.82	1.053	27.68
1A5-4:1-ESW-(2&11-T&B)-IE	0.83	1.087	31.47
1A6-4:1-ESW-(3&10-T&B)-IE	0.84	1.076	28.52
1A7-4:1-ESW-(4&9-T&B)-IE	0.86	1.237	44.17
1A8-4:1-ESW-(5&8-T&B)-IE	0.88	1.226	39.33
1A9-4:1-ESW-(5 6 7 8-T&B)-IE	0.92	1.197	29.64
1B1-4:1-ISW-Solid-IE	0.40	0.596	48.61
1B2-4:1-ISW-(6&7-T&B)-IE	0.47	0.673	43.62
1B3-4:1-ISW-(1&12-T&B)-IE	0.34	0.504	47.23
1B4-4:1-ISW-(2&11-T&B)-IE	0.28	0.405	46.83
1B5-4:1-ISW-(3&10-T&B)-IE	0.32	0.475	48.95
1B6-4:1-ISW-(4&9-T&B)-IE	0.37	0.535	44.87
1B7-4:1-ISW-(5&8-T&B)-IE	0.43	0.500	16.05
1P1-4:1-ESW-(8&9-M&B)-IE	0.82	1.241	52.10
1P2-4:1-ESW-(6&7-M&B)-IE	0.83	1.292	55.83
1C1-3:1-ESW-(4&6-T&B)-IE	0.49	0.665	36.44
1D1-3:1-ESW-(4 5 6-T&B)-IE	0.48	0.591	22.29

$$Error \cdot Index = \frac{\left(\Delta_{Top \cdot Level \cdot Interior \cdot Frame \cdot Maximum \cdot Inelastic \cdot Displacement} - \Delta_{ASCE\ 7-05}\right)}{\Delta_{ASCE\ 7-05}}$$

Results: Dynamic Analysis (Cont.)



Building A9 [22%] Shear Distribution – Loma Prieta.

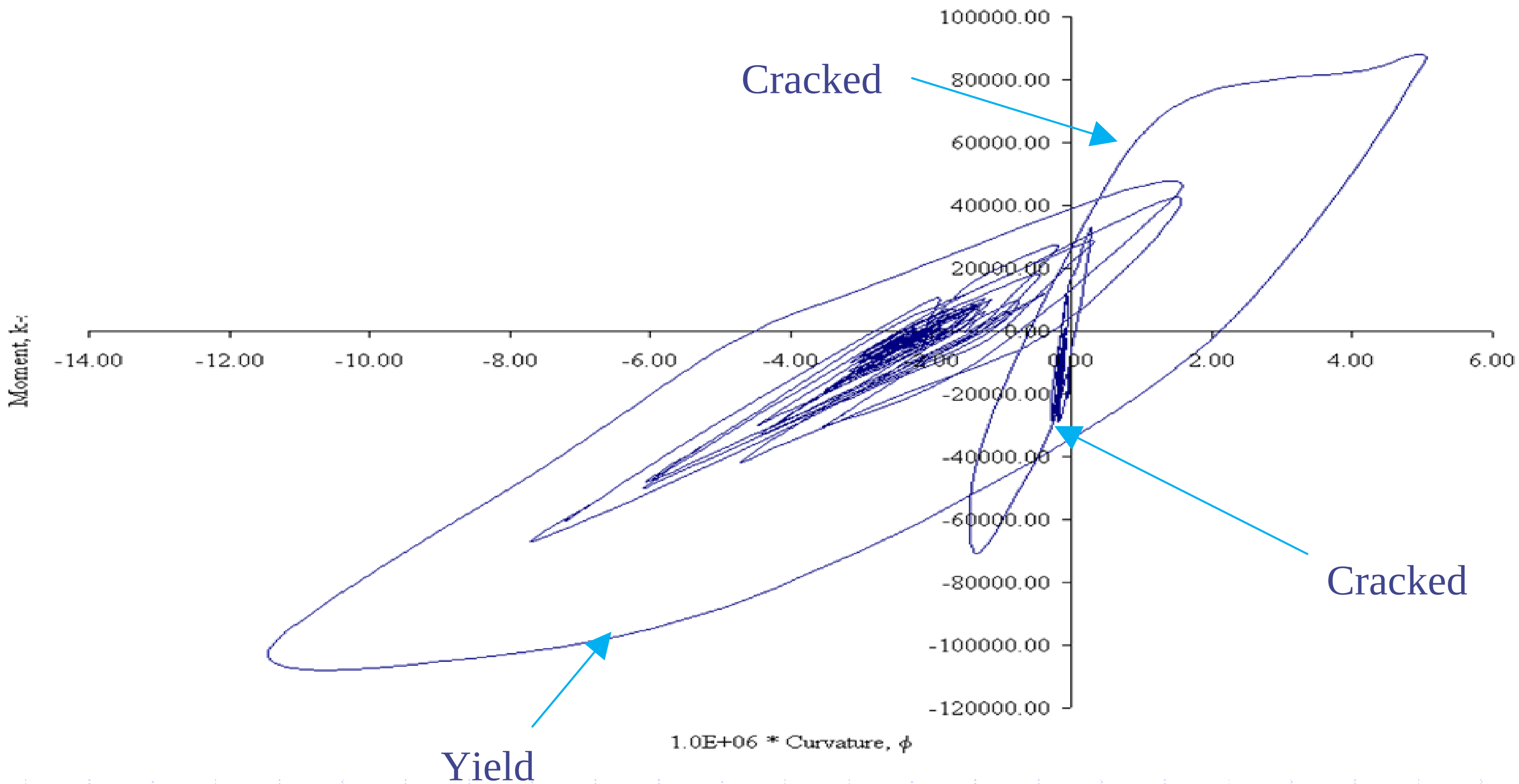
Results: Dynamic Analysis (Cont.)

- Diaphragm Aspect Ratio
  - 4:1 Yielding of Slabs with Openings
  - 3:1 No Slab Yielding with Openings – Inplane Cracking Observed
- Floor Opening Size & Location
  - Slab Opening Location more Significant than Opening Size
  - Slab Yielding Occurs when Opening Located in Middle 2/3

Results: Dynamic Analysis (Cont.)

- Ground Motion
  - Scaled Loma Prieta - Most Severe Case
- Shear Wall Location
  - End Walls – More Critical
- Diaphragm Slab Models
  - Best Overall Building Response Obtained by Inelastic Slab Model
- Slab Elements Subjected to 1-2 Cycle of Inelastic Loading

Results: Dynamic Analysis (Cont.)



Slab M/ϕ Hysteretic Plot -1P1-4:1-ESW-(8&9-M&B)-IE-LP-USER

Results: Sensitivity Study (Cont.)

Sensitivity Study Analysis Results Summary.

Sensitivity Analysis						
Scenario	Base Shear, k	%V to Walls	%V to Frames	V to Frames, k	Bldg. Max. Top Displ., in.	Diaph. Max. Inplane Defl., in.
1A3-4:1-ESW-(6&7-T&B)-IE-LP	1545.51	69.14	30.86	476.90	1.274	0.826
1.25α	1554.10	69.60	30.40	472.50	1.265	0.825
0.75α	1580.50	69.75	30.25	478.10	1.277	0.867
1.25γ	1542.90	69.22	30.78	474.90	1.302	0.896
0.75γ	1553.50	69.44	30.56	474.70	1.298	0.897
1.25β	1580.60	69.88	30.12	476.00	1.277	0.874
0.75β	1546.50	69.14	30.86	477.30	1.251	0.767
0.25My	1487.10	68.48	31.52	468.70	1.567	1.351
0.50My	1644.40	70.80	29.20	480.20	1.187	0.629

Results: Sensitivity Study (Cont.)

M/ϕ Idealization and Hysteretic Parameters

- Slab is Subjected to 1-2 Cycle of Inelastic Loading

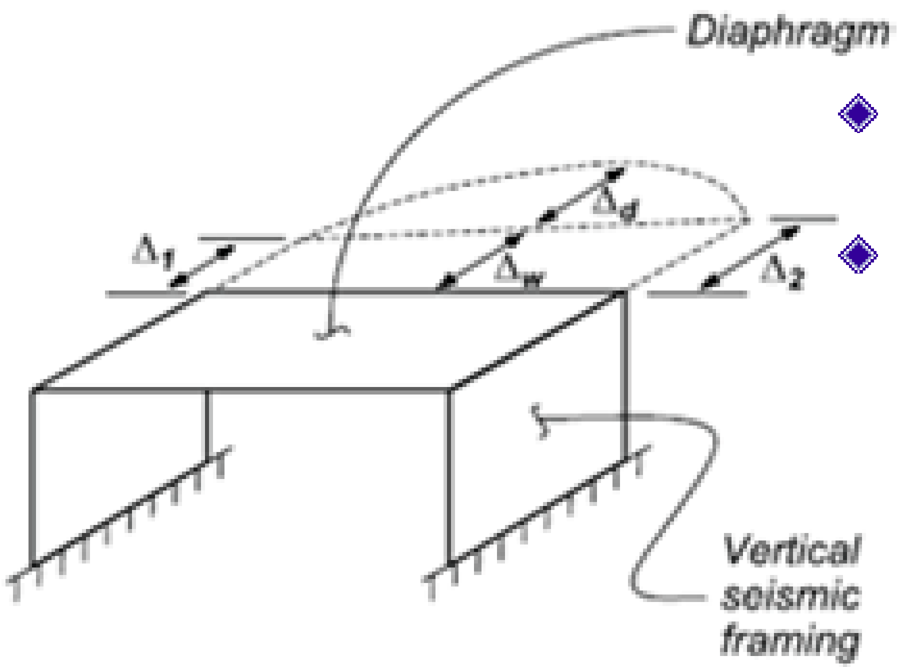
- α, β, γ effects:
  - Frame Displacement: ±4%
  - Frame Shear: ±3%

- (1/4, 1/3, 1/2) My effects:
  - Frame Displacement: ±6%
  - Frame Shear: ±5%

Design Recommendations

- Objectives
  - To provide simplified design guidelines to reduce the likelihood of diaphragm inplane yielding, by adequately reinforcing the diaphragm chord members to resist the design seismic loads using the results obtained in this study.

Design Recommendations (Cont.)



- $\Delta_{diaph.}/\Delta_{wall} > 2$ → Flexible $_{\text{ASCE7-05}}$
- $\Delta_{diaph.}/\Delta_{wall} < 1/2$ → Rigid $_{\text{FEMA 356}}$

Diaphragm Classification/Wall Displacement Terminology.

Design Recommendations (Cont.)

ASCE 7-05 / FEMA 356 (2000) Diaphragm Type Classification.

Scenario	Diaph. Type
1A1-4:1-ESW-Solid-IE	STIFF
1A2-4:1-ESW-(8&9-T&B)-IE	STIFF
1A3-4:1-ESW-(6&7-T&B)-IE	STIFF
1A4-4:1-ESW-(1&12-T&B)-IE	STIFF
1A5-4:1-ESW-(2&11-T&B)-IE	STIFF
1A6-4:1-ESW-(3&10-T&B)-IE	STIFF
1A7-4:1-ESW-(4&9-T&B)-IE	STIFF
1A8-4:1-ESW-(5&8-T&B)-IE	STIFF
1A9-4:1-ESW-(5 6 7 8-T&B)-IE	STIFF
1B1-4:1-ISW-Solid-IE	STIFF
1B2-4:1-ISW-(6&7-T&B)-IE	FLEXIBLE
1B3-4:1-ISW-(1&12-T&B)-IE	STIFF
1B4-4:1-ISW-(2&11-T&B)-IE	STIFF
1B5-4:1-ISW-(3&10-T&B)-IE	STIFF
1B6-4:1-ISW-(4&9-T&B)-IE	STIFF
1B7-4:1-ISW-(5&8-T&B)-IE	FLEXIBLE
1P1-4:1-ESW-(8&9-M&B)-IE	STIFF
1P2-4:1-ESW-(6&7-M&B)-IE	STIFF
1C1-3:1-ESW-(4&6-T&B)-IE	STIFF
1D1-3:1-ESW-(4 5 6-T&B)-IE	STIFF

Per FEMA 356

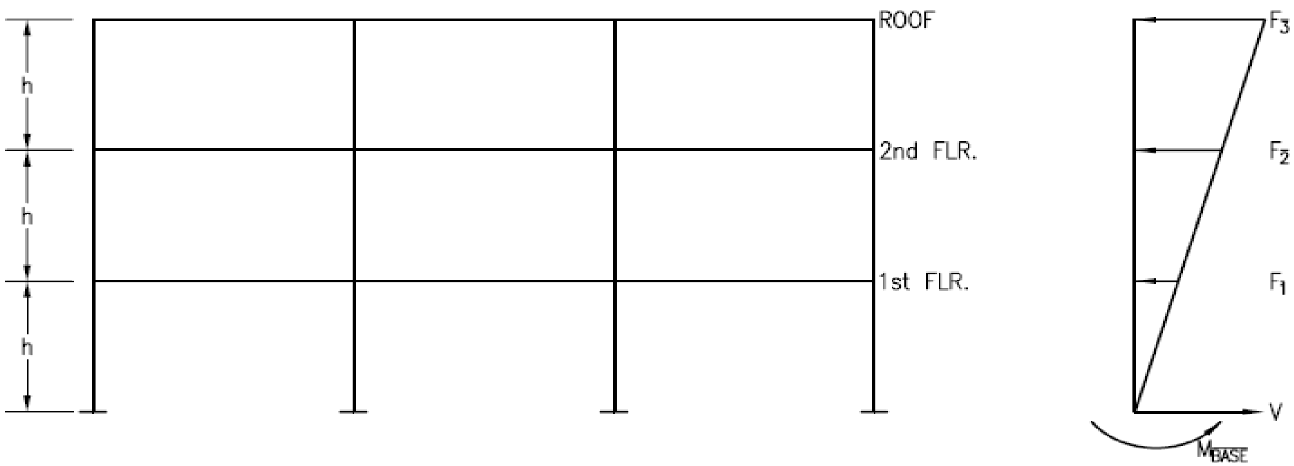
Design Recommendations (Cont.)

$$C_{vx} = \frac{W_x h_x^k}{\sum W_i h_i^k} \text{ , where k = 1.0}$$

$C_1 = 1/6$ or $F_1 = \frac{V}{6}$ [Eq. 6-3]

$C_2 = 1/3$ or $F_2 = \frac{V}{3}$ [Eq. 6-4]

$C_3 = 1/2$ or $F_3 = \frac{V}{2}$ [Eq. 6-5]

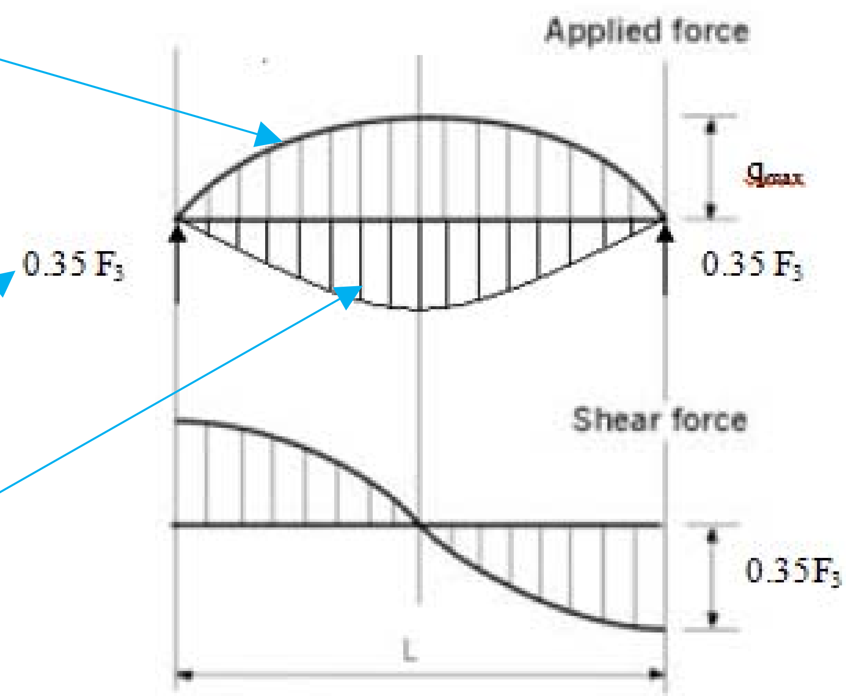


$$= \frac{3Vh}{2} + \frac{2Vh}{3} + \frac{Vh}{6} = 2.33\,Vh \quad \text{[Eq. 6-6]}$$

Seismic Loading Distribution per IBC 2006.

Design Recommendations (Cont.)

$$w_3 = \frac{1.5F_3}{L}\left[1-\left(\frac{2x}{L}\right)^2\right]$$



Wall Shear
and Frame Shears
Based on Current
Study

$$M_{Slab(max)} = \frac{3}{4}(0.35F_3)\left(\frac{L}{2}\right) = 0.13125F_3L = 0.065625VL = \frac{VL}{15.24} \qquad \text{[Eq. 6-8]}$$

Top Floor Diaphragm Loading per FEMA 356.

Design Recommendations (Cont.)

- A margin of safety of 2.17 is introduced in Eq. 6-8, to reduce the likelihood of yielding in slabs prior to yielding of shearwalls, as observed in the obtained pushover and dynamic results.

$$M_{Slab\,(max)} = 2.17 \times \frac{VL}{15.24} = 0.143VL \qquad \text{[Eq. 6-9]}$$

Design Recommendations (Cont.)

- If slab inplane cracking moment, per ACI 318-08, is greater than $M_{slab(max)}$ given in Eq. 6-9, the following chord reinforcement area, A_s, should be used.

$$A_s = \frac{M_{Slab(max)}}{f_y \cdot D} \qquad \text{[Eq. 6-12]}$$

where D is the diaphragm overall depth and f_y is the reinforcement yielding strength.

Summary

- Literature void exists on the seismic response of RC buildings with diaphragm openings.
- RC floor diaphragms are typically designed for gravity but not lateral; with the effects of slab opening being typically ignored.
- 3-Story rectangular RC buildings with/ without diaphragm openings with shear walls were designed per current building codes in St. Louis, MO.

Summary (Cont.)

- Inelastic Seismic Response of these buildings was studies using an enhanced computational tool.
- Findings were presented and discussed.

Conclusions

- For floor diaphragm aspect ratio of 3:1 or greater, it is necessary to use an inelastic diaphragm model to capture the seismic response of reinforced concrete buildings with floor diaphragm openings accurately.
- The base shear redistribution due to inelastic slab deformations increases the load subjected to the interior frames significantly (up to 30%).
- The influence of inelastic inplane diaphragm deformations due to floor openings cannot be overlooked in such buildings, particularly when the diaphragm openings are located in the middle two-thirds of the building.

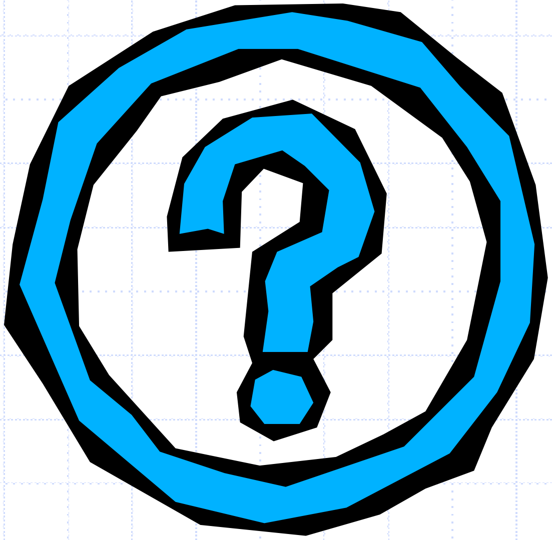
Conclusions

- Inplane yielding of the floor diaphragm is controlled by shear and not flexure, and it occurs when diaphragm openings are placed within the middle 2/3 of the building.

- Hysteretic parameters obtained from experimental research on solid diaphragms are found to be adequate for diaphragms with openings.

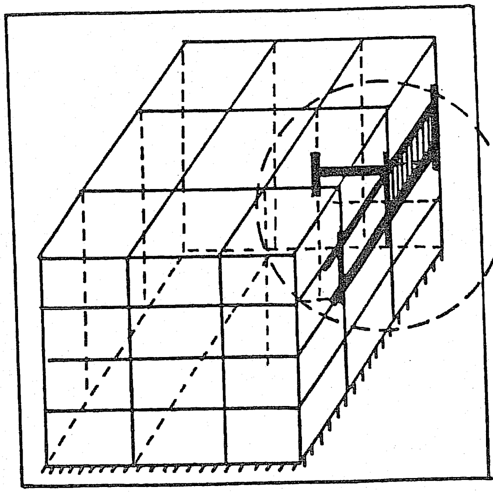
- Simplified design guidelines were provided to ensure the likelihood of wall yielding prior to slab yielding.

Questions



Appendix A.5

IDARC [69] & IDARC2 [68] Component Modeling



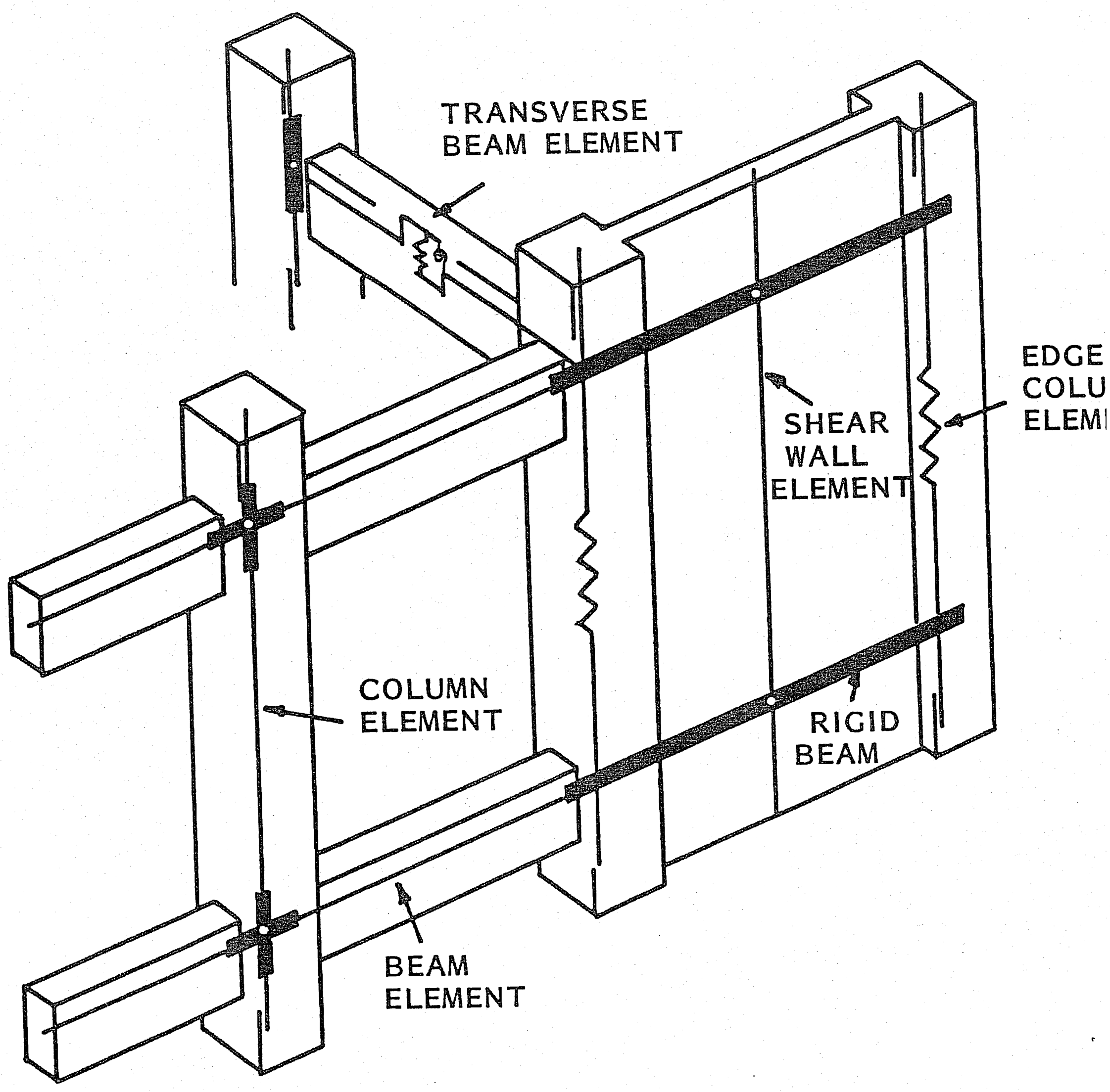
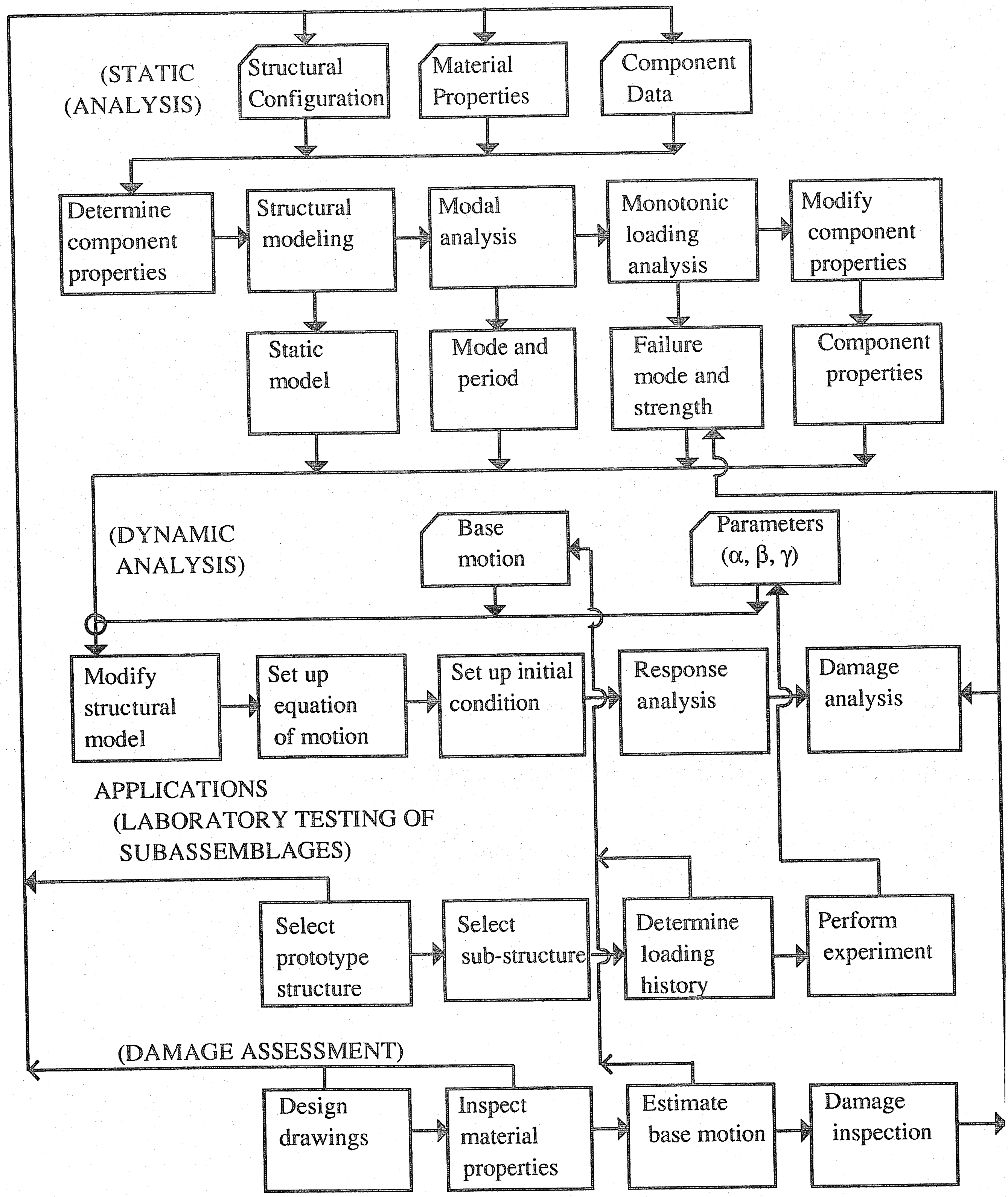


FIGURE 2-1 Component Modeling

TABLE 3-I PROGRAM ORGANIZATION

1. SYSTEM IDENTIFICATION	INPUT DATA	Structural configuration Material properties Element Information Base Excitation Related Parameters
	ESTABLISH COMPONENT PROPERTIES	Yield curvature, moment Ultimate strength, etc.
	STRUCTURAL MODELING AND ANALYSIS	Fundamental period Ultimate failure mode Store results for ensuing dynamic analysis
2. DYNAMIC RESPONSE ANALYSIS (OPTIONAL)	EQUATIONS OF MOTION	
	RESPONSE ANALYSIS INCLUDING HYSTERETIC BEHAVIOR OF COMPONENTS	Newmark-Beta Algorithm Three-parameter model
3. APPLICATIONS (OPTIONAL)	SUBSTRUCTURE ANALYSIS	Response of selected structures
	DAMAGE ANALYSIS	Damage index for independent components as well as total building

TABLE 3-II PROGRAM FLOW AND RELATED APPLICATIONS



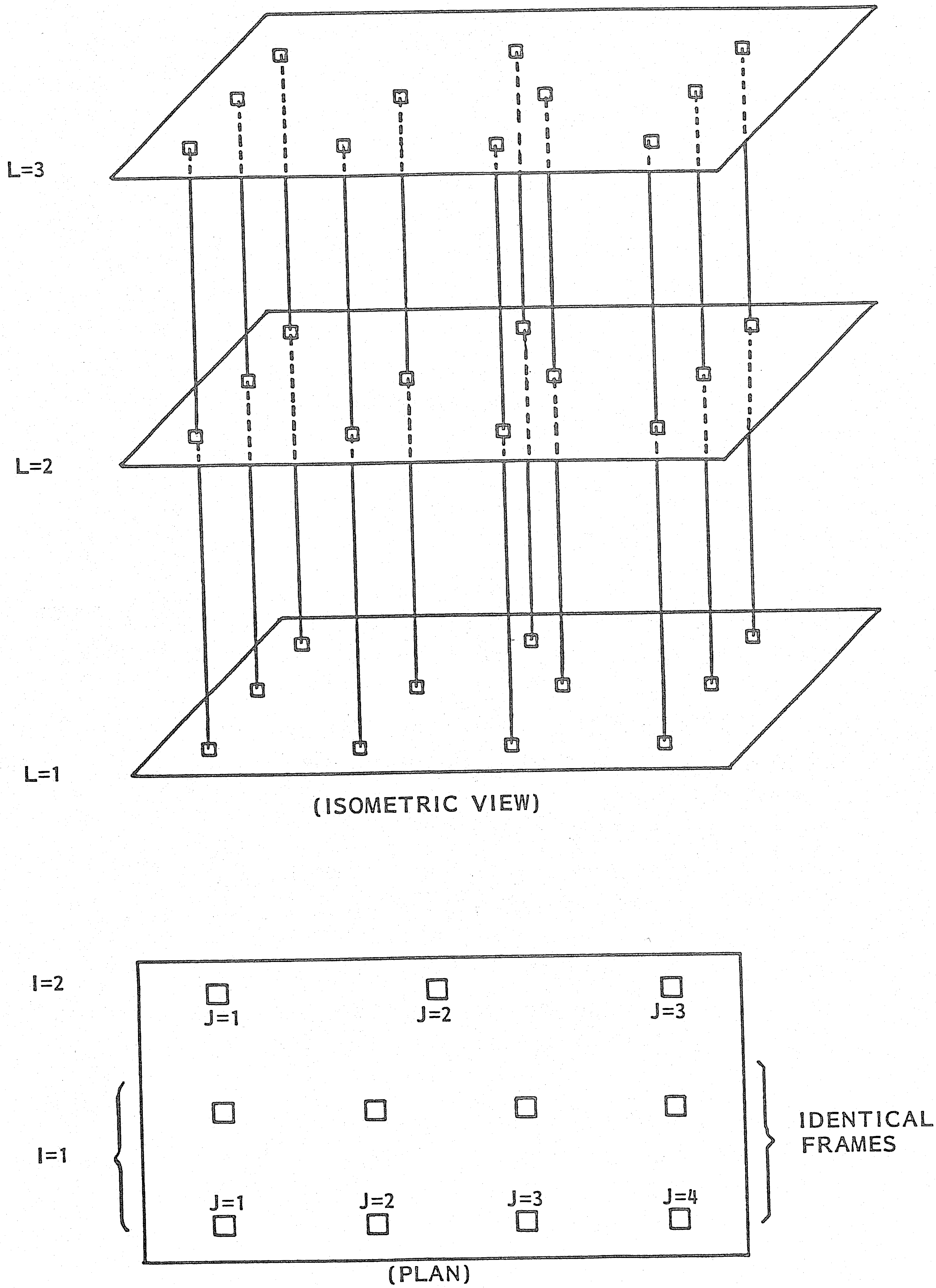


FIGURE 3-1 Idealized Structural Model

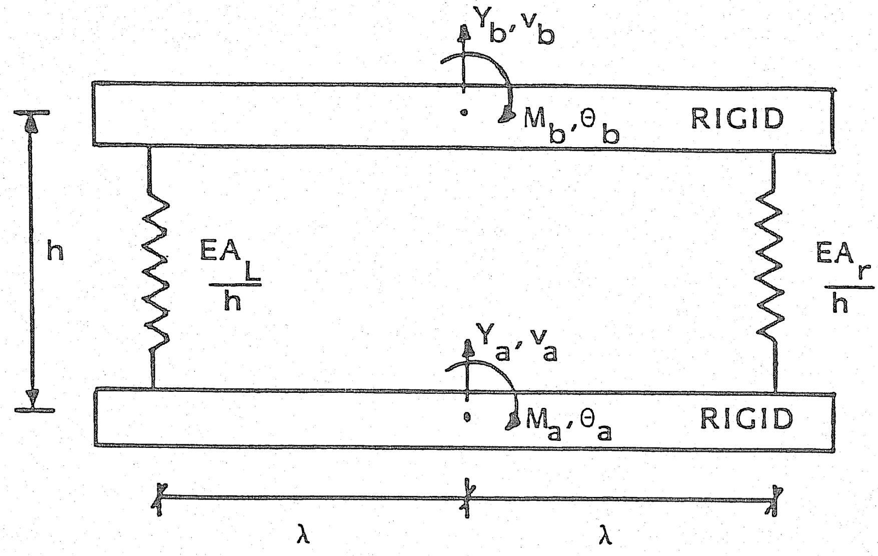


FIGURE 3-9 Edge Column Elements

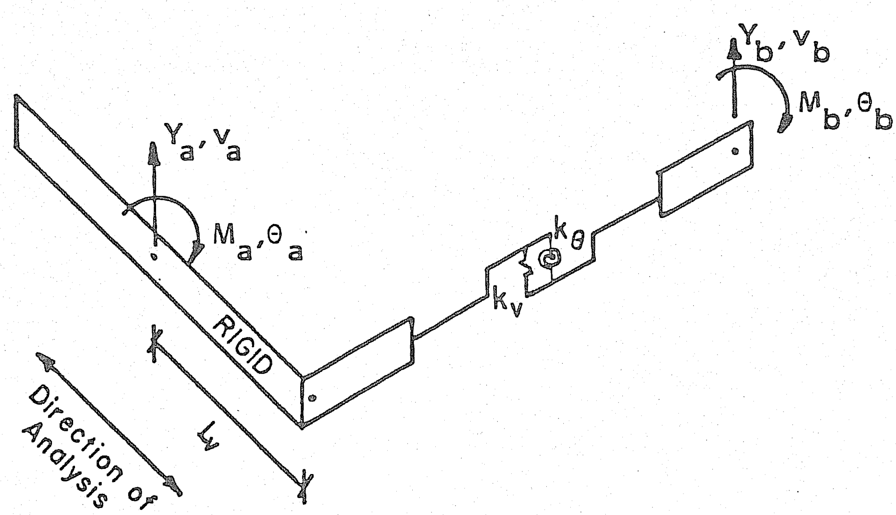


FIGURE 3-10 Transverse Beam Element

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Vita

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	Master of Engineering - Structural 08/00	McGill University Montreal, Quebec, Canada
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	12/03 – 08/06	**H.O.K. Inc.**	**St. Louis, MO**
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Publications:

- Anamika Rathore, Nader Panahshahi, and Mohamed T. Al Harash, “Seismic Response of Reinforced Concrete Buildings with Floor Diaphragm Openings.” The ACI Fall 2008 Convention, St. Louis, MO, November 2-6, 2008.

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Short Title: Response of Diaphragms with Openings AL HARASH, D.Sc. 2011

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March 2, 2011

Dr. Thomas Harmon, Professor and Director of Undergraduate Studies
The Clifford W. Murphy Professor of Civil Engineering
Department of Mechanical Engineering and Materials Science
Washington University in St. Louis, St. Louis, MO 63130

Dear Professor Thomas Harmon:

This letter is written in support of Mr. Mohamed T. Al Harash's doctoral dissertation titled "Inelastic Seismic Response of Reinforced Concrete Buildings with Floor Diaphragm Openings."

Mr. Al Harash has used IDARC2 for his doctoral dissertation analytical study – a software tool which I authored at the University at Buffalo. The program was developed as part of a larger project co-supervised by Drs. Reinhorn and Panahshahi to conduct inelastic static and seismic simulations of rectangular plan structures with inelastic diaphragms.

Mr. Al Harash has significantly enhanced IDARC2 by ensuring a more reliable evaluation of such buildings through the successful implementation of the following:

- A routine to estimate the inelastic flexural properties of slab elements with openings – by improving the current fiber model routine in IDARC2
- Allowing for the user-controlled input of idealized moment-curvature slab properties with or without openings.

Mr. Al Harash has successfully conducted various parametric and sensitivity studies as part of his Doctoral research under the close supervision of Dr. Panahshahi and obtained valuable results regarding the seismic behavior of RC buildings with floor diaphragm openings. These new findings, as presented in his dissertation, have great potential for improving the current state-of-the-art practice in structural engineering in seismic zones.

In summary, the newly enhanced IDARC2 by Mr. Al Harash provides a valuable computational tool for both the research and practicing communities to use in the future.

Please do not hesitate to contact me at (530) 754-9471 or skkunnath@ucdavis.edu if you have any questions regarding this matter.

Sincerely,

Sashi K. Kunnath
Professor and Department Chair

CC: Dr. Nader Panahshahi