JBA 109-070
June 30, 1989

STATISTICAL EVALUATION OF NONLINEAR RESPONSE OF SEISMIC ISOLATION SYSTEMS (Volume I)

by

Charles A. Kircher
Bahman Lashkari

June 30, 1989

This study is based on work supported in part by the National Science Foundation under Grant No. CES-8901279.

Any opinions, findings and conclusions or recommendations expressed in this study are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Jack R. Benjamin & Associates, Inc.
Consulting Engineers
Mountain Bay Plaza, Suite 501
444 Castro Street, Mountain View, California 94041

ACKNOWLEDGEMENT

This study was supported in part by the National Science Foundation (NSF) under Grant No. CES-8901279 with Dr. Andrew J. Eggenberger serving as the cognizant NSF program official. The support provided by the NSF is gratefully acknowledged.

The earthquake records used in this study were obtained with assistance provided by Dr. Omar Khemici. The authors would like to thank Dr. Khemici for his contribution to this study.

EXECUTIVE SUMMARY

This study rigorously calculated the seismic response of 31 different isolated buildings using nonlinear time history analysis. The buildings were modeled as rigid structures supported by bilinear, hysteretic isolators whose properties were varied from model to model to produce effective periods of 1.0 to 4.0 seconds and effective damping values of 5% to 40% of critical.

Each isolated building was analyzed using a set of earthquake time histories that represent the Seismic Zone 4 ground motion criteria of current building codes for a structure located at either a rock, stiff soil or medium soil site. Multiple time histories were used for each site condition to evaluate the variation in calculated response as a function of the inherent variability of ground motion. In total, 866 individual time history analyses were performed.

The primary purpose of the study was to create a collection of nonlinear response data that could be used to evaluate key design requirements for isolated buildings, such as the design displacement of the isolation system. Accordingly, the study has compared calculated responses with the design requirements proposed by the Structural Engineers Association of California (SEAOC) for design of isolated buildings. The results of these comparisons provide a basis for judging the validity and applicability of the SEAOC design requirements, and for modifying the requirements, as appropriate.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1. INTRODUCTION

1.1 Statement of Problem

Seismic isolation, commonly referred to as base isolation, is a design concept based on the premise that a structure can be substantially isolated from potentially damaging earthquake ground motion. The advantages of seismic isolation and recent advances in isolation systems have already led to the design and construction of a number of isolated structures in the United States. Other countries, such as Japan, are also active in this area and are developing and implementing base isolation technology on a much larger scale.

Currently, there are no seismic isolation design codes adopted for use in the regulation of isolated structures in the United States. Consequently, structural engineers, peer reviewers and building officials are without an established basis for preparing designs and judging design acceptability. This situation creates an uncertainty in the design process that can inhibit building owners and their agents (e.g., architects/engineers) from pursuing seismic isolation. In short, the development and adoption of a seismic design code for isolated structures is one of the key elements required for broad acceptance and application of this unique and promising earthquake hazard mitigation technology.

Two parameters, whose values are critical in the design of all isolated structures, are: (1) the peak response of the isolation system and (2) the number of full-amplitude cycles the isolation system must endure without failure. Peak response governs the size and configuration of the isolators, and the number of full-amplitude cycles affects test verification of isolator durability. The importance of the values of these parameters used for design cannot be overemphasized. Underdesign of the isolation system can result in isolated structures that may not perform adequately during a major earthquake. Conversely, overdesign can

result in an isolation system that may be prohibitively expensive, or simply not feasible.

Peak response of the isolation system is dependent on the level of ground shaking (i.e., on site seismicity and soil characteristics), and on the force-deflection properties of the isolation system. In general, the force-deflection properties of the isolation system are nonlinear and require special modeling and time history analysis techniques, if seismic response is to be rigorously determined. Such techniques require the use of computer programs and complex analytical procedures that are neither widely used by practicing engineers nor readily verifiable by third-party reviewers.

Complex analytical procedures have not been considered appropriate as the sole basis for seismic design of conventional fixed-base buildings. Rather, existing design codes rely on simple methods and prescriptive formulas that can be consistently implemented by design engineers, peer reviewers and building officials alike. The apparent conflict between the need to use complex analytical methods to calculate isolated structure response and the need to prescribe design requirements by simple methods and formulas has created a dilemma for seismic isolation code committees. It is the intent of this research to provide a basis for the determination of an appropriate balance between these two design approaches.

This study has rigorously calculated the dynamic response of a number of different isolated buildings (i.e., 31 different bilinear isolation systems) using a comprehensive collection of earthquake time histories (i.e., 29 different earthquake recordings, two components each). The primary purpose for performing these calculations was to create a collection of nonlinear response data that could be used to evaluate key design requirements for isolated buildings, such as the design displacement of the isolation system. Accordingly, this study has also compared calculated peak response with that prescribed by the

design requirements proposed by the Structural Engineers Association of California (SEAOC) for design of isolated buildings. The results of these comparisons provide a basis for judging the validity and applicability of the SEAOC design requirements.

While this study is directed at the evaluation of the nonlinear response of isolated buildings, the results of the earthquake time history analyses represent the response of any dynamic system that has the same basic properties as those modeled. Thus, the peak seismic displacements calculated in this study for an isolated building are equally valid as the results for a conventional fixed-base building with comparable mass and stiffness characteristics (e.g., a conventional building of comparable period and damping).

1.2 Report Organization

Chapter 2 provides background information on the pertinent seismic criteria and prescriptive formulas of the SEAOC design requirements for isolated buildings. Chapter 3 describes the technical approach used to perform the nonlinear analyses and statistical evaluations of response. Chapter 4 lists and describes the key attributes of the earthquake records and related scaling factors. Chapter 5 describes the model of the building and the properties of the different isolation systems. Chapter 6 describes and evaluates results. Chapter 7 concludes with a summary of findings and recommendations for additional research. Chapter 8 is a list of references.

Appendices A through F contain tabular summarizes of results. Due to their length, Appendices A through F are bound as a second volume of this report.

2. BACKGROUND

2.1 SEAOC Seismic Design Requirements

The seismic isolation concept and the criteria that would be appropriate for design and construction of isolated structures has been considered by various Structural Engineers Association of California (SEAOC) groups since the early 1980's. This effort is consistent with one of SEAOC's primary responsibilities: the development of seismic provisions that establish minimum design and construction standards. Since 1959 the Seismology Committee of the SEAOC has been developing provisions for the earthquake resistant design of structures. These provisions are published as a SEAOC document, Recommended Lateral Force Requirements (commonly known as the Blue Book), and serve as the role model for the seismic requirements of several building codes. The recently revised 1988, fifth edition, of the Blue Book [Ref. 1], has already been incorporated into the 1988 Edition of the Uniform Building Code [Ref. 2.], the most widely used code for buildings located in zones of high seismicity.

In 1986, the Northern Section of the SEAOC published, Tentative Seismic Isolation Design Requirements, [Ref. 3], (referred to as the Yellow Book) the first and only published design provisions for isolated structures. These provisions were based on the same seismic criteria as the 1988 Blue Book, and use similar design concepts such as the prescription of design force and displacement by simple formulas. Recent projects, such as the Los Angeles County Fire Command and Control Facility [Ref. 4], have used these provisions to establish project-specific seismic design requirements.

In parallel with the North, the Southern Section of SEAOC has studied base isolation theory and design methods for isolated structures. In the late 1980's, members of the Southern Section published several

papers that provided guidelines for the design of buildings with base isolators [Ref. 5]. In these papers, the authors have emphasized the need to thoroughly understand and evaluate site seismicity, isolator characteristics and potential inelastic response of the isolated structure.

Recognizing the need for a consensus opinion, representatives of the Northern, Southern and Central Sections of SEAOC have recently combined existing material into a draft document titled, "Tentative General Requirements for the design and Construction of Seismic-Isolated Structures," [Ref. 6]. When complete and approved, this document will serve as an appendix to Chapter 1 of the 1988 Blue Book, and will provide criteria that can be incorporated into building codes, such as the Uniform Building Code.

Current thinking within SEAOC is to require rigorous dynamic analysis for all, or virtually all, isolated buildings, but to also prescribe, by formula, a minimum design displacement of the isolation system. This approach ensures that complex or nonlinear structures will be evaluated using the appropriate dynamic analysis method but also provides a simple formula for validating the final design. The concept of using a simple prescriptive formula to define a lower-bound limit for isolation system displacement is analogous to the UBC's (and the SEAOC Blue Book's) use of a prescriptive formula to define a minimum base shear for design of conventional fixed-base buildings. It is a process which ensures a measure of uniformity in buildings of common construction and guards against gross underdesign of key elements.

The following sections provide additional background on ATC-3 ground motion spectra (the spectra used as the basis for the seismic criteria of the Yellow Book, the Blue Book and the UBC), isolation system design formulas, torsional design considerations and prototype testing requirements.

2.2 ATC-3 Design Spectra

The prescriptive formula for design displacement originally published in the Yellow Book [Ref. 3] and now being proposed by SEAOC for inclusion as a Blue Book appendix is based on the same seismic design spectra as that used by the 1988 Blue Book for design of conventional, fixed-base buildings. These spectra have been taken from the Applied Technology Council report, "Tentative Provisions for the Development of Seismic Regulations for Buildings," (ATC-3), [Ref. 7]. The ATC-3 study established, by consensus opinion, the shape of smooth ground response spectra recommended for seismic design of buildings. As shown by the curves in Figure 2-1, these spectra are a function of seismic zone, soil type and building period. As documented in the ATC-3 report's commentary, the shape of these spectra is based on previous studies of earthquake response spectra, in particular the work by Seed, Ugas and Lysmer [Ref. 8].

The intent of the ATC-3 effort was to create smooth design spectra of regular shape which would envelop most ground response spectra up to and including a 500-year return period event. The smooth design spectra prescribed by the ATC-3 study were not intended to, nor could they without undue conservatism, envelop all of the individual ground response spectra upon which they are based. Rather, the possibility of exceeding the design-basis event is accounted for in the ATC-3 study, as it is in the UBC and Blue Book, by conservatisms in allowable forces and stresses and by requiring key structural elements to be ductile.

In the case of an isolated building, the key structural element is the isolation system and the critical design parameter is peak lateral displacement. Like a conventional, fixed-base building which relies implicitly on the reserve capacity of members to sustain forces which exceed the design-basis event, the isolated building must rely on the reserve capacity of the isolation system to survive response which exceeds the design displacement. Accordingly, the isolation system must

be designed with sufficient margin to account for the full range of possible responses which can occur due to the design-basis event.

2.3 Design Formulas

The design displacement formula prescribed by the Yellow Book is given below:

$$D = 10ZNST/B \qquad (2\text{-}1)$$

where,

D = Design Displacement of the isolation system at the center of the building in the direction under consideration,

Z = Seismic Zone coefficient (e.g., 0.3 for Zone 3, and 0.4 for Zone 4),

S = Soil Type coefficient (i.e., 1.0 for Soil Type S_1, 1.5 for Soil Type S_2, 2.0 for Soil Type S_3, and 2.7 for Soil Type S_4),

T = Isolated-building period,

N = Near-Field coefficient (e.g., 1.0 for sites located 15 km, or greater, from an active fault, 1.2 for sites located 10 km from an active fault, and 1.5 for sites located 5 km, or less, from an active fault),

B = Damping coefficient defined by Figure 2-2.

This formula is based directly on the shape of the ATC-3 spectra for periods greater than 1 second, with two additional factors: (1) the near-field coefficient, N, to account for the possibility of increased displacement at sites near faults and (2) the damping coefficient, B, to account for damping in the isolation system other than 5% of critical. The relationship between this formula and the ATC-3 spectra may be seen by first setting both the damping and near-field terms to 1.0 (i.e., 5%-damped response for sites not near an active fault). Equation (2-1) becomes:

$$D = 10ZST \qquad (2\text{-}2)$$

Design displacement, D, may then be converted to spectral acceleration, SA, by multiplying by $(2\pi/T)^2/g$, where g is the gravity constant (386.4 in./sec.^{2}):

$$SA = 10ZST(2\pi/T)^2/386.4$$

$$= ZS/T \qquad (2\text{-}3)$$

At periods greater than 1 second, the above expression of spectral acceleration is seen to be consistent with the 5%-damped design spectra recommended by the ATC-3 study for use in building codes (Figure 2-1).

Design spectra, such as those defined by Equation 2-3 above, are based on the response of a linearly elastic dynamic system. In contrast, isolation systems are typically inelastic, by varying degrees, with stiffnesses that range from approximately linear (e.g., pure rubber systems after initial yield) to highly nonlinear (e.g., sliding systems without a restoring force). Inelastic behavior of the isolation system is desireable since it results in dissipation of energy and damping of dynamic response. On the other hand, it poses a problem in the use of linear design spectra. To use the design displacement formula (Equation 2-1), an effective period of the isolated building is defined as follows:

$$T = 2\pi \sqrt{\frac{W}{k_{min} g}} \qquad (2\text{-}4)$$

where, W = building weight,

g = gravity constant, and

k_{min} = effective stiffness of the isolation system, determined by cyclic-load test as the slope of a line between the origin and the minimum test value of force at the design displacement.

By basing the effective period, T, on the minimum effective stiffness of the isolation system, determined by test, the above formula approximates the longest period of the isolated building at peak response. In this manner the design displacement, which is proportional to the period, is intended to prescribe the maximum excursion of the isolated structure due to the design-basis event.

In Equation 2-1, the damping coefficient, B, is used to adjust peak displacement response of the isolation system for values of effective damping greater (or less) than 5% of critical. The relationship between the damping coefficient, B, and the value of effective damping, β, is shown in Figure 2-2, and is based on Table 1-K of the Yellow Book. As in the determination of the effective period, determination of effective damping is complicated by the nonlinear nature of isolation systems. Relying again on test results, the effective damping, β, is prescribed on the basis of the hysteretic behavior of the isolation system, as follows:

$$\beta = A/2\pi k_{eff} D^2 \qquad (2\text{-}5)$$

where, A = area of the hysteresis loop determined from test results at an amplitude equal to the design displacement, and

k_{eff} = effective stiffness of isolation system.

By basing the damping coefficient, B, on the force-deflection behavior of the isolation system, the above formula estimates the reduction in displacement response for systems which have damping values greater than 5% of critical.

The peak force in the isolation system, F_{max}, corresponding to the peak displacement, D, is given by the following expression:

$$F_{max} = k_{max} D \qquad (2\text{-}6)$$

where, k_{max} = effective stiffness of the isolation system, determined by cyclic-load test as the slope of a line between the origin and the maximum test value of force at the design displacement.

For systems with nominal variation in test results, k_{max} may be assumed to be equal to k_{min} and expressed simply as k_{eff}. The peak force and displacement results contained in this study are based on this assumption.

2.4 Torsion

Torsion of isolation systems, particularly nonlinear isolation systems which yield or soften, can be a significant contribution to the total response of the isolation system. Design codes for conventional buildings, as well as isolated buildings, require, as a minimum, consideration of an accidental 5% mass eccentricity when calculating response of force-resisting elements. The Yellow Book requires design of the isolation system for additional displacement due to building rotation caused by accidental plus actual mass eccentricity.

2.5 Prototype Testing

The prototype testing requirements of the Yellow Book include cyclic testing at the design displacement to measure degradation, if any, in the stiffness characteristics of the isolators. Systems with significant stiffness degradation or loss of stability are not considered acceptable. In these tests, the number of cycles specified is intended to envelop the number of full-amplitude cycles which could reasonably be expected to occur during the design-basis event. Ten cycles at the design displacement are required by the Yellow Book.

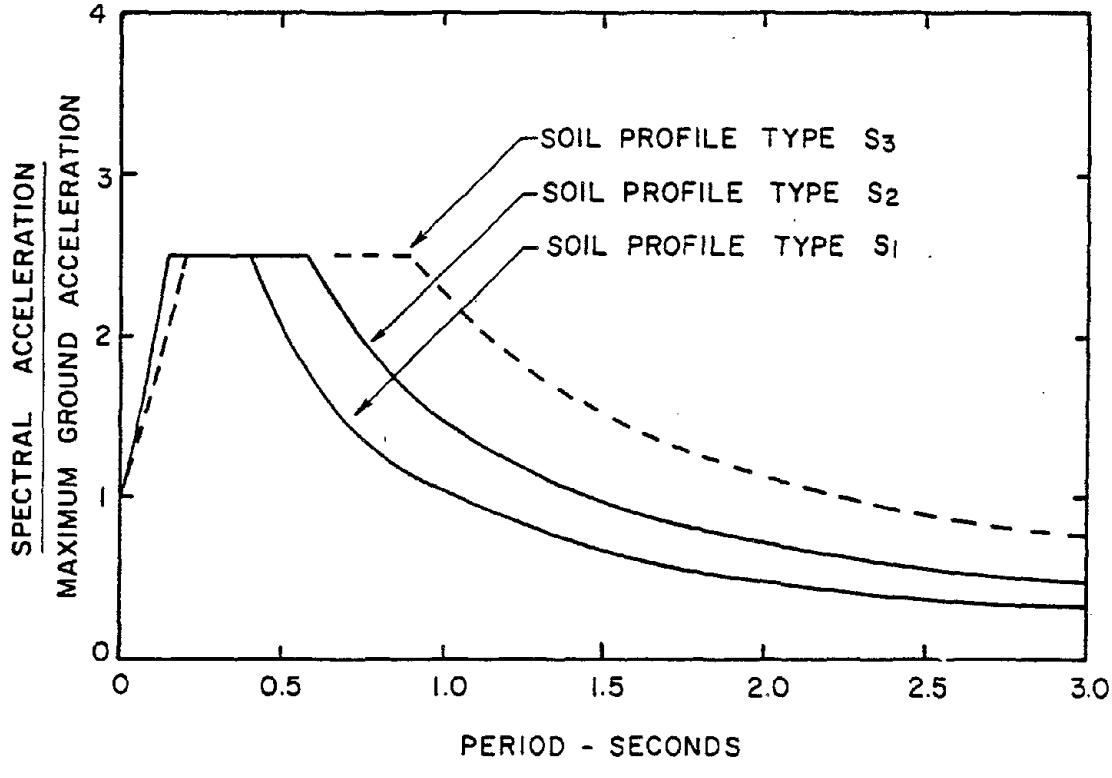

FIGURE 2-1 NORMALIZED RESPONSE SPECTRA RECOMMENDED FOR USE IN BUILDING CODES, FROM ATC-3 [REF.7]

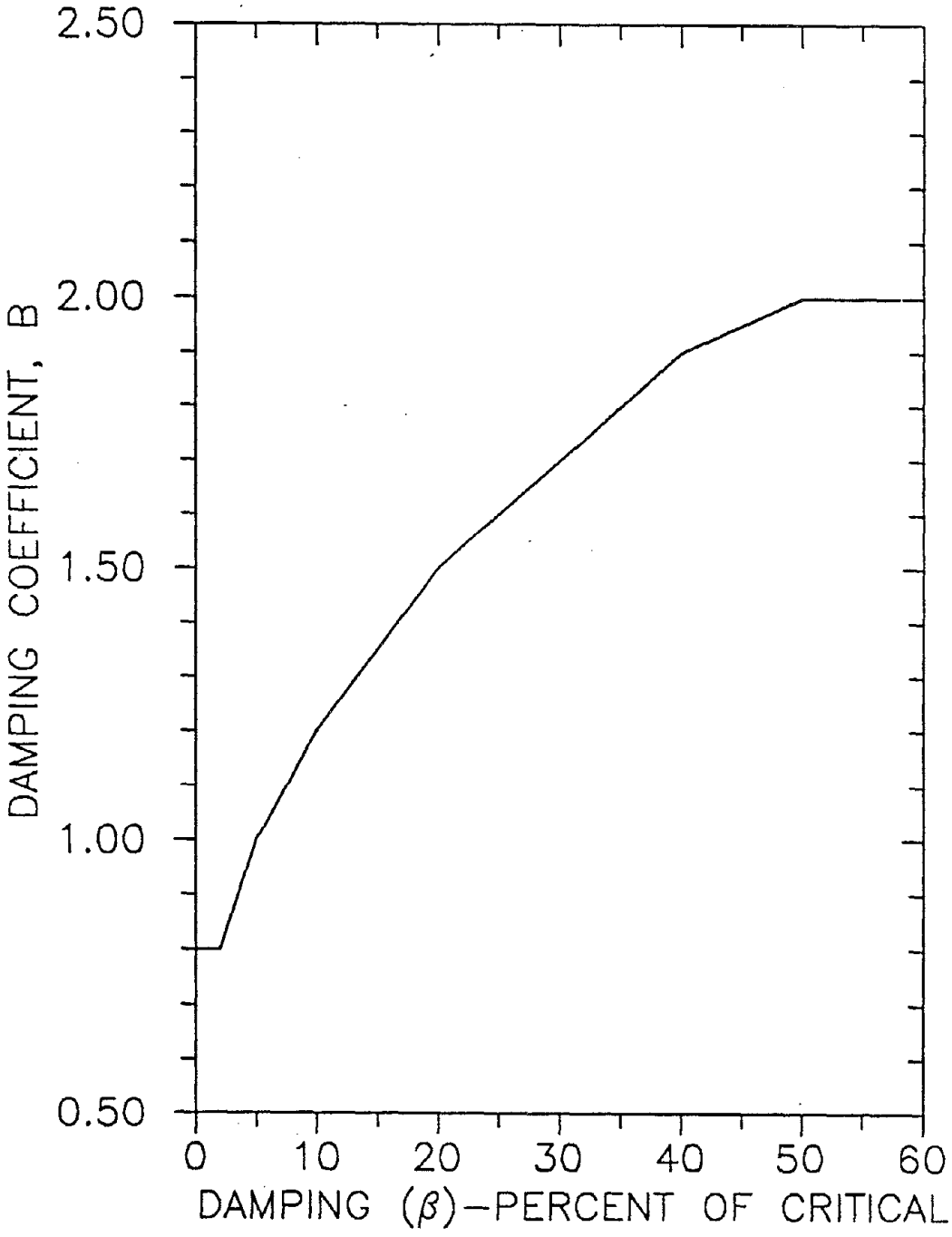

FIGURE 2-2 PLOT OF THE DAMPING COEFFICIENT, B, AS A FUNCTION OF EFFECTIVE DAMPING, β

3. TECHNICAL APPROACH

3.1 Overview

The technical approach of this study is divided into a number of sequential tasks that include: selecting appropriate earthquake time histories, developing isolated building models, performing nonlinear analyses, statistically evaluating response results and finally comparing and evaluating the Yellow Book design requirements with the results of the nonlinear analyses.

This study has emphasized breadth of coverage. Accordingly, the nonlinear analyses included a number of different building models with bilinear isolation systems that have a broad range of yield levels (i.e., 0.03g to 0.15g), effective periods (i.e., 1.0 to 4.0 seconds) and effective damping values (i.e., 5% to 40% of critical). Likewise, for each of three different site conditions (i.e., rock, stiff soil or medium soil sites) a set of nine or ten earthquakes was used to evaluate the variation in nonlinear response due to variation in ground motion. Further, each set of nonlinear analyses was performed twice using earthquake records scaled first by peak ground acceleration (PGA) and then scaled by peak ground velocity (PGV). In all, a total of 866 individual nonlinear analyses were performed encompassing 31 different isolated building models and 29 different pairs of earthquake time histories.

The intent of this study was to use sets of recorded earthquake time histories that are consistent in amplitude and frequency content with the design spectra required by seismic codes. Accordingly, time history records were selected from the earthquakes used by Seed et al. to develop site-dependent spectra [Ref. 8]. The Seed study is the primary basis for the design spectra of ATC-3 [Ref. 7], the 1988 Blue Book [Ref. 1] and the 1988 UBC [Ref. 2]. As described in Chapter 2, the Seed Study

is also the primary basis for the prescriptive design displacement formula of the Yellow Book [Ref. 3].

3.2 Nonlinear Analyses

The nonlinear analyses of isolated building models were performed using DRAIN-2D [Ref. 9], compiled for execution on micro-computers. The degrees of freedom of each model permitted translational and rotational response of the isolated building in the plane of the isolation system. It was assumed that the structure above the isolation system is rigid and that nonlinear response is limited to elements of the isolation system. A 5% mass eccentricity was added to each model to evaluate torsional response.

A number of response parameters were calculated including: peak force at the center of mass, peak displacement at the center of the building and peak displacement at the corner of the building. In addition to peak response, cumulative inelastic displacement of isolation system elements was also calculated as was the ratio of cumulative inelastic displacement to maximum peak-to-peak displacement. This ratio provides a measure of the effective number of cycles of full-amplitude response.

3.3 Statistical Evaluation of Response

Each isolated building model was analyzed using a set of nine or ten pairs of horizontal earthquake components. To quantify the variation in response results, as well as to manage the volume of data produced, statistical properties (e.g., mean values, and standard deviations) of response parameters were calculated for each earthquake set. The mean and mean plus one standard deviation (mean + 1σ) values, reported in results tables, provide a measure of the level and inherent variation of response parameters as a function of the variation in the ground motion.

3.4 Comparison of Results With Code Requirements

The study provides a large quantity of results upon which many comparisons and evaluations may be based. Comparisons of response for different ground motions (i.e., different site conditions and different scaling factors) are of particular interest, as are evaluations of design requirements for torsional response and prototype testing. However, the evaluation of primary interest is the comparison of peak isolation system displacement, calculated using nonlinear time history analysis, with the design displacement prescribed by the static analysis method of the Yellow Book.

4. EARTHQUAKE TIME HISTORIES

4.1 Records from Rock, Stiff Soil and Medium Soil Sites

The intent of this study was to evaluate nonlinear response using sets of earthquake time histories that are consistent in amplitude and frequency content with the design spectra currently required by seismic codes. Accordingly, earthquake time histories were selected from the records used by Seed et al. [Ref. 8] to develop site-dependent design spectra. As discussed in Chapter 2, the results of the Seed study have been used as the primary basis for the shape of the ATC-3 design spectra (Figure 2-1), the seismic criteria of the Blue Book [Ref. 1] and the UBC [Ref. 2] for design of conventional buildings and the seismic criteria of the Yellow Book [Ref. 3] for design of isolated buildings.

The Seed study developed site-dependent spectra by calculating mean and mean-plus-one-standard-deviation spectra of normalized acceleration time history records. The earthquake records were grouped by one of four different site conditions, listed below with the corresponding ATC-3 soil type:

(1) Rock sites - Soil Type S_1.

(2) Stiff soils with depths less than about 150 ft. - Soil Type S_1 (referred to in this study as "stiff soil" sites).

(3) Deep cohesionless soils with depths greater than about 250 ft. - Soil Type S_2 (referred to in this study as "medium soil" sites).

(4) Soil deposits consisting of soft to medium stiff clays with associated strata of sands or gravels - Soil Type S_3 (referred to in this study as "soft soil" sites).

Horizontal earthquake records with peak ground acceleration (PGA) values of 0.05g, or greater, were selected by the Seed study from available data up to and including the San Fernando Earthquake of 1971. The Seed study treated the two horizontal components as independent records and

collected about 30 records each for rock, stiff soil and medium soil sites and 15 records for soft soil sites.

In this study, only earthquake records with both horizontal components exceeding 0.10g PGA were considered appropriate for the nonlinear analyses. After elimination of the less significant recordings the following number of records remained in each group:

(1) Rock sites - 10 pairs (20 records).
(2) Stiff soil sites - 10 pairs (20 records).
(3) Medium soil sites - 9 pairs (18 records).

Since there were no records greater than 0.10 g PGA for soft soil sites this site condition was not evaluated in this study. Pertinent information on each pair of horizontal earthquake time histories is provided in Table 4.1 for records at rock sites, in Table 4.2 for records at stiff soil sites and in Table 4.3 for records at medium soil sites. Values of the PGA and the peak ground velocity (PGV) given in these tables were taken directly from the California Institute of Technology (CIT) data [Ref. 10]. In certain cases it was noted that the PGA values reported in the Seed study differed from the CIT data. No explanation for the discrepancies could be found, except that some values reported by the Seed study may have been for "uncorrected" records.

Each set of earthquake records has a large proportion of the records from one event, the San Fernando earthquake of 1971. The Seed study investigated the potential biasing of results that can occur if the spectra are dominated by the San Fernando earthquake, and concluded that the results were not unduly influenced by that one event. On the basis of the findings of the Seed study, it was concluded that the earthquake records used in this study are representative of the ATC-3 design spectra for Soil Type S_1 (rock and stiff soil sites) and for Soil Type S_2 (medium soil sites), respectively.

4.2 Seismic Zone 4 Scaling Factors

Seismic design codes prescribe ground motion criteria by seismic zone, as well as by site condition. For this study, Seismic Zone 4 was selected as the seismic zone of interest since it is both the zone of highest seismicity and the zone where most isolated structures have been, and will be constructed. The effective PGA for Seismic Zone 4 is 0.4g, the value of acceleration specified by the ATC-3 study for scaling of normalized design spectra. As summarized in Tables 4-1 through 4-3, the unscaled records have a variety of PGA values, most of which are considerably less than 0.4g. Thus, scaling of the records was required in order that their response spectra be consistent with Seismic Zone 4 design spectra.

Two methods were used in this study to scale time histories: scaling by PGA and scaling by peak ground velocity (PGV). The first method, which parallels the approach taken by the Seed, scaled each pair of earthquake components by a common factor such that the average PGA of the two components is equal to 0.4g. This method is consistent with the approach used by the Seed study except that the Seed study scaled (i.e., normalized) each component individually, rather than in pairs. Regardless, as shown in Figures 4-1 through 4-3 the average 5%-damped response spectra of the PGA-scaled time histories used in this study closely match the average response spectra of the Seed study for each site condition.

The advantage of using PGA to scale the records is that it is the same method used implicitly in the Seed study to develop site-dependent design spectra. The short coming of scaling the time histories by PGA is that the response of an isolated structure is primarily influenced by the amplitude and frequency content of the velocity domain of the design spectrum. As a second method of scaling, each pair of earthquake components was scaled by a common factor such that the average PGV of the two components was equal to either 12 in./sec. for rock sites, 18

in./sec. for stiff sites or 22.5 in./sec for medium soil sites. These PGV values were determined to correspond, approximately, to a PGA value of 0.4g for each of the respective soil conditions. Scaling the records by PGV, rather than by PGA, was considered a more appropriate method of representing the amplitude and frequency content of ground motion at periods greater than 1 second. The basis for selecting the specific PGV values corresponding to a 0.4g PGA, is discussed below.

Two approaches were used as the basis for determining PGV scaling values. In the first approach, PGV was calculated as the long-period amplitude of the design spectrum divided by a factor relating peak spectral response to PGV. This approach may be expressed as follows:

$$PGV = \frac{0.4g\ (ATC\text{-}3)}{1.65\ (2\pi/T)} \qquad (4\text{-}1)$$

where: ATC-3 = the value of the normalized design spectrum (Figure 2-1) for a given site condition and period, T,

T = arbitrary value of period, greater than 1 second.

In the above formula, the 1.65 factor represents the median ratio between peak spectral velocity and PGV for 5%-damped response in the velocity domain and is taken directly from Table 1 of Earthquake Spectra and Design [Ref. 11].

The second approach, which based PGV on the ratio of the PGV to the PGA of each individual record, may be expressed as follows:

$$PGV = 0.4g\ \bar{R}_{V/A} \qquad (4\text{-}2)$$

where: $\bar{R}_{V/A}$ = the average value of the ratio of PGV/PGA for all records of a common site condition.

A comparison of the PGV values based on these two approaches and the values used in this study is provided in Table 4-4. The PGV values used in this study for stiff soil sites, 18 in./sec., and medium soil sites, 22.5 in./sec., essential bound the values of either approach. The PGV used in this study for sites, 12 in./sec., falls somewhere between the values of the two approaches. As shown in Figures 4-1, 4-2 and 4-3 for each site condition, respectively, the average spectra of PGV-scaled and PGA-scaled time histories closely match the average spectrum developed by the Seed study.

As shown by comparisons of acceleration spectra, Figures 4-1, 4-2 and 4-3, and by comparisons of displacement spectra, Figure 4-4, 4-5 and 4-6, the average spectra of the time histories match the design criteria reasonably well for stiff soil and medium soil sites. For rock sites, however, the average acceleration spectrum of the time histories used in this study, as well as the average spectrum of the Seed study, is only about one-half to one-third of the ATC-3 design criteria at long periods. The reason for the large discrepancy between the design criteria of the ATC-3 study and the average spectrum for rock sites is not known. Apparently, the ATC-3 study felt that the time histories used by the Seed Study to develop rock spectra do not contain a level of ground motion appropriate for design of long-period structures. Regardless of the motive, the ATC-3 study defined rock and stiff soil as a single site condition (Soil Type S_1) and based the design criteria for this site condition on the average spectrum of stiff soil time histories.

TABLE 4-1. HORIZONTAL EARTHQUAKE COMPONENTS RECORDED AT ROCK SITES

No.[1]	Earthquake (Station No.)	Date	Magnitude	Approx. Dist. (km)	Local MMI	Direction	PGA (g)	PGV (in./sec.)	PGD (in.)
1T	Helena (323)	10/31/35	6.0	8	--	S00W	0.146	2.89	0.56
1L						S90W	0.145	-5.24	-1.47
2T	Kern County	07/21/52	7.6	56	VII	S69E	0.179	-6.97	-3.60
2L	(095)					N21E	0.156	-6.18	-2.64
3T	Lytle Creek	09/12/70	5.4	15	VI	S25W	0.198	-3.79	0.41
3L	(290)					S65E	0.142	-3.49	-0.87
4T	Parkfield (097)	06/27/66	5.6	7	VII	S25W	-0.347	8.87	-2.16
4L						N65W	-0.269	-5.71	1.83
5T	San Fernando	02/09/71	6.6	30	VII	S08E	0.217	3.89	2.76
5L	(284)					S82W	0.202	2.46	-1.81
6T	San Fernando	02/09/71	6.6	26	VII	S69E	0.171	-2.26	0.49
6L	(126)					S21W	-0.146	-3.38	0.69
7T	San Fernando	02/09/71	6.6	3	IX	S16E	-1.170	-44.57	14.83
7L	(279)					S74W	1.075	-22.72	-4.26
8T	San Fernando	02/09/71	6.6	40	VII	N87W	-0.169	-2.62	-2.33
8L	(104)					N03E	-0.140	2.08	-1.24
9T	San Fernando	02/09/71	6.6	21	VIII	N21E	-0.353	5.81	0.70
9L	(128)					N69W	0.283	-5.02	3.49
10T	San Fernando	02/09/71	6.6	24	VII	N00E	-0.167	4.88	-1.91
10L	(220)					S90W	0.150	5.91	-2.14

1. T(L) designates the component applied to the transverse (longitudinal) direction of the isolated building, as defined in Figure 5-1.

TABLE 4-2 HORIZONTAL EARTHQUAKE COMPONENTS RECORDED AT STIFF SOIL SITES

No.[1]	Earthquake (Station No.)	Date	Magnitude	Approx. Dist. (km)	Local MMI	Direction	PGA (g)	PGV (in./sec.)	PGD (in.)
1T	Lower CA (117)	12/30/34	6.5	58	--	S90W	-0.183	4.55	-1.44
1L						S00W	-0.160	-8.21	-1.65
2T	Imperial Valley	05/18/40	6.6	8	VIII	S00E	0.348	13.17	4.28
2L	El Centro (117)					S90W	0.214	-14.53	-7.79
3T	Parkfield (014)	06/27/66	5.6	5	VIII	N85E	-0.434	-10.02	-2.80
3L						N05W	-0.355	-9.12	-2.09
4T	San Fernando	02/09/71	6.6	21	VIII	N21E	-0.315	-6.76	1.67
4L	(110)					N69W	-0.270	-10.94	3.73
5T	San Fernando	02/09/71	6.6	35	VII	N90E	-0.211	-8.32	-5.79
5L	(135)					S00W	0.170	-6.50	3.17
6T	San Fernando	02/09/71	6.6	39	VII	N00E	-0.136	8.79	4.50
6L	(208)					S90W	0.144	7.30	-4.57
7T	San Fernando	02/09/71	6.6	39	VII	North	0.157	-6.90	3.17
7L	(211)					West	-0.132	8.45	-4.57
8T	San Fernando	02/09/71	6.6	28	VII	N11E	0.225	-11.12	-5.30
8L	(466)					N79W	-0.149	-9.23	-4.06
9T	San Fernando	02/09/71	6.6	28	VII	S12W	-0.248	12.43	7.21
9L	(253)					N78W	0.201	-7.01	3.73
10T	San Fernando	02/09/71	6.6	39	VII	N90E	-0.165	-6.54	-4.08
10L	(199)					S00W	-0.161	7.24	3.56

1. T(L) designates the component applied to the transverse (longitudinal) direction of the isolated building, as defined in Figure 5-1.

TABLE 4-3 HORIZONTAL EARTHQUAKE COMPONENTS RECORDED AT MEDIUM SOIL SITE

No.[1]	Earthquake (Station No.)	Date	Magnitude	Approx. Dist. (km)	Local MMI	Direction	PGA (g)	PGV (in./sec.)	PGD (in.)
1T	Western Wash.	04/13/49	7.1	20	VIII	N86E	-0.280	-6.72	4.08
1L	(325)					N04W	0.165	8.43	-3.38
2T	Eureka (022)	12/21/54	6.5	25	VIII	N79E	-0.258	11.56	5.53
2L						N11W	0.168	-12.44	4.88
3T	Eureka (023)	12/21/54	6.5	30	VII	N46W	0.201	-10.24	-3.79
3L						N44E	0.159	14.03	-5.58
4T	Ferndale (023)	12/10/67	5.6	25	VII	S44W	-0.237	4.70	0.65
4L						N46W	0.105	4.65	-0.67
5T	San Fernando	02/09/71	6.6	16	VII	N00W	-0.255	-11.81	-5.87
5L	(241)					S90W	-0.134	9.42	5.45
6T	San Fernando	02/09/71	6.6	19	VII	S00W	0.116	12.46	-6.93
6L	(458)					S90W	0.105	-11.33	6.02
7T	San Fernando	02/09/71	6.6	30	VII	N00E	-0.201	-3.87	-1.07
7L	(264)					N90E	-0.185	-6.47	-2.72
8T	San Fernando	02/09/71	6.6	30	VII	S82E	0.212	5.48	-1.95
8L	(267)					S08W	0.142	3.62	-1.14
9T	Puget Sound	04/29/65	6.5	58	VII	S86W	-0.198	5.14	-1.51
9L	(325)					S04E	0.137	3.21	-1.07

1. T(L) designates the component applied to the transverse (longitudinal) direction of the isolated building, as defined in Figure 5-1.

TABLE 4-4 COMPARISON OF PEAK GROUND VELOCITY VALUES CORRESPONDING TO 0.4G PEAK GROUND ACCELERATION

Site Condition (Soil Type)	$PGV^1 = \frac{0.4g\ (ATC\text{-}3)}{1.65\ (2\pi/T)}$ (in./sec.)	$PGV^2 = 0.4g\ \bar{R}_{V/A}$ (in./sec.)	PGV Values Used in this Study to Scale Time Histories (in./sec.)
Rock (S_1)	14.9	10.0	12.0
Stiff (S_1)	14.9	17.6	18.0
Medium (S_2)	22.4	19.6	22.5

1. ATC-3 is the value of the normalized response spectrum shown in Figure 2-1 at a period, T, of 1.0 second, or greater.

2. $\bar{R}_{V/A}$ is the average value of the ratios of peak ground velocity and peak ground acceleration of each time history corresponding to a particular site condition.

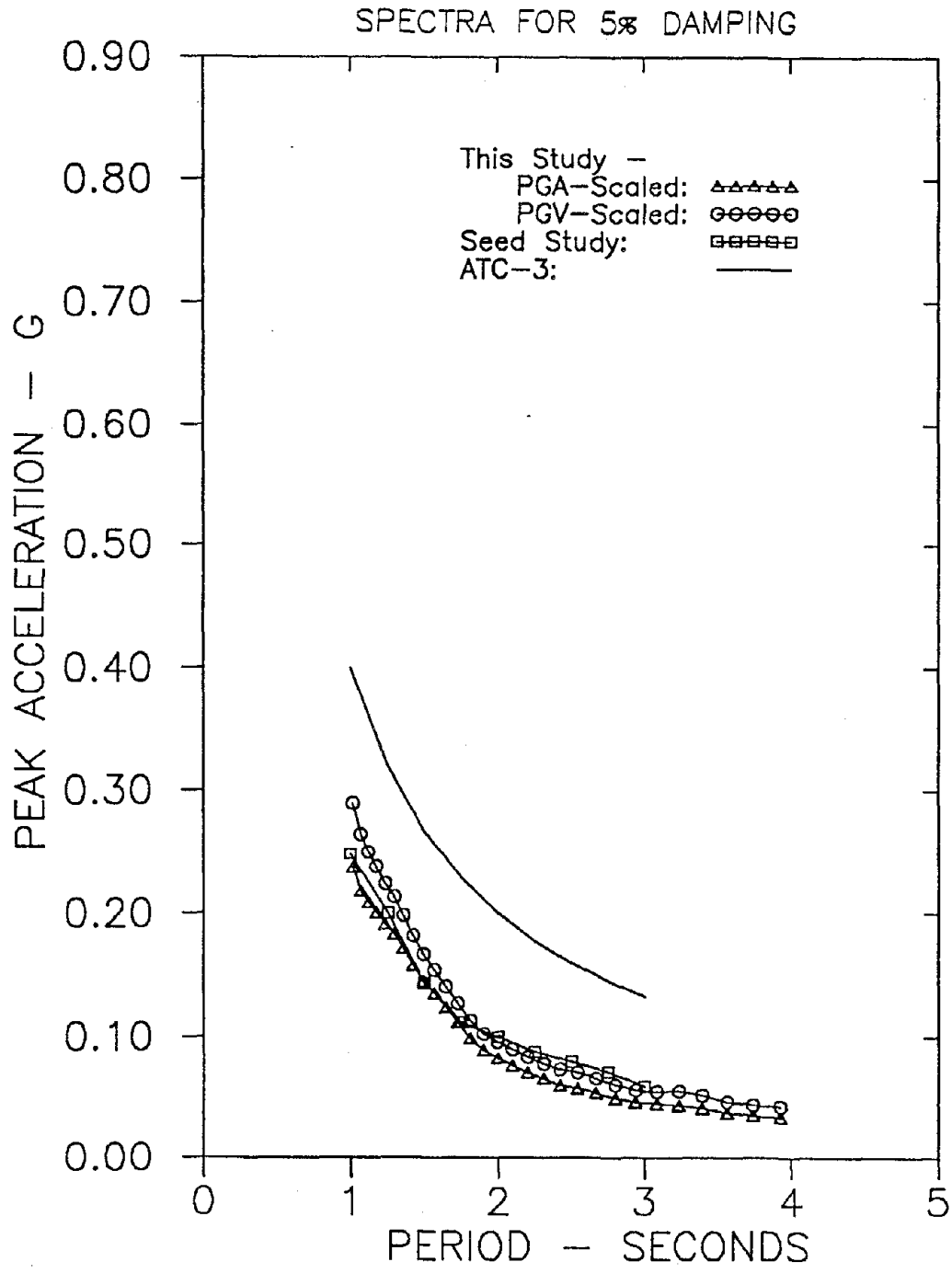

FIGURE 4-1 COMPARISON OF THE AVERAGE ACCELERATION SPECTRA OF THE TIME HISTORIES USED IN THIS STUDY, THE AVERAGE RESPONSE SPECTRUM OF SEED ET AL. [REF. 8] AND THE DESIGN SPECTRUM OF ATC-3 [REF. 7] - ROCK SITES.

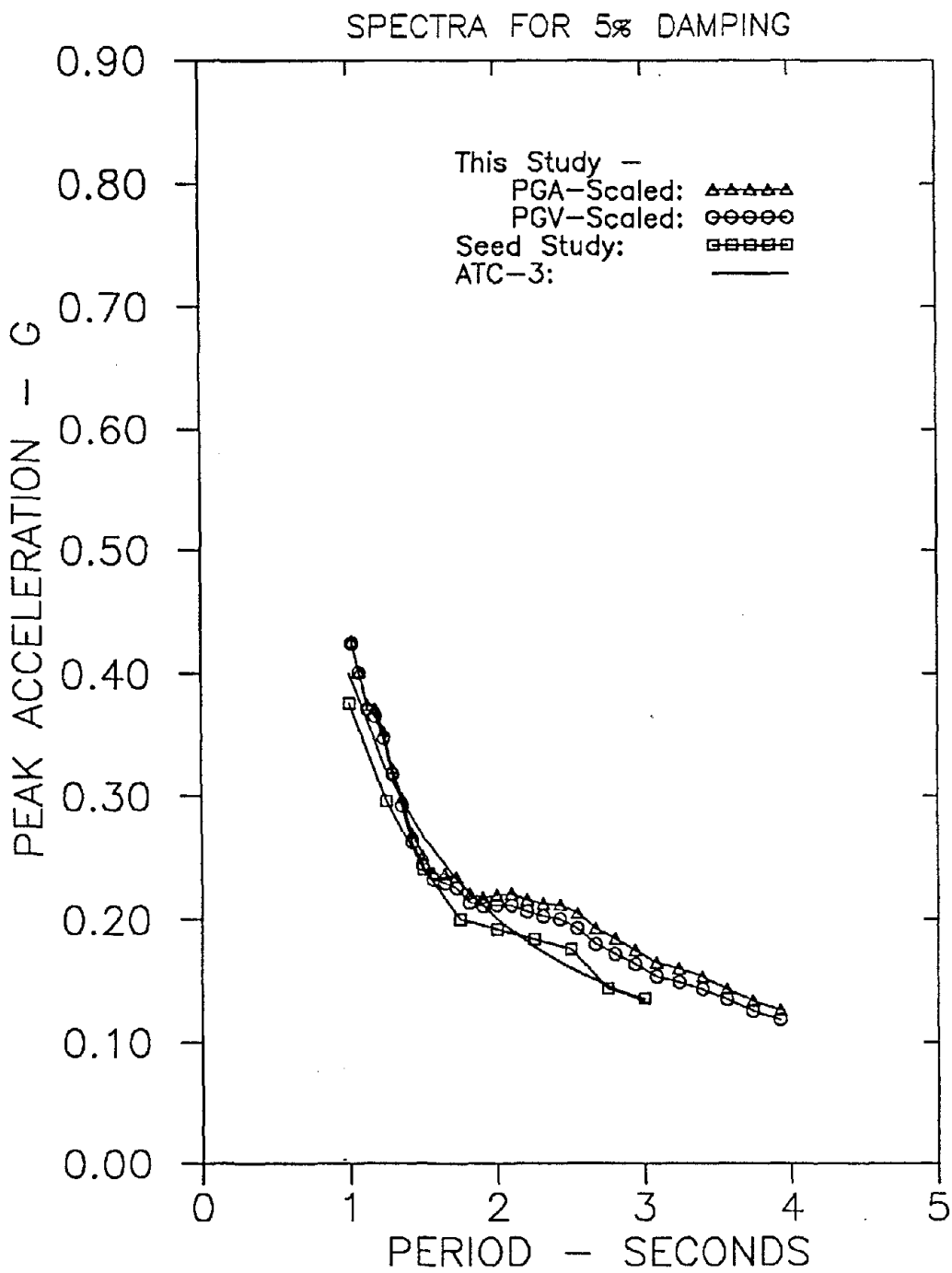

FIGURE 4-2 COMPARISON OF THE AVERAGE ACCELERATION SPECTRA OF THE TIME HISTORIES USED IN THIS STUDY, THE AVERAGE RESPONSE SPECTRUM OF SEED ET AL. [REF. 8] AND THE DESIGN SPECTRUM OF ATC-3 [REF. 7] - STIFF SOIL SITES.

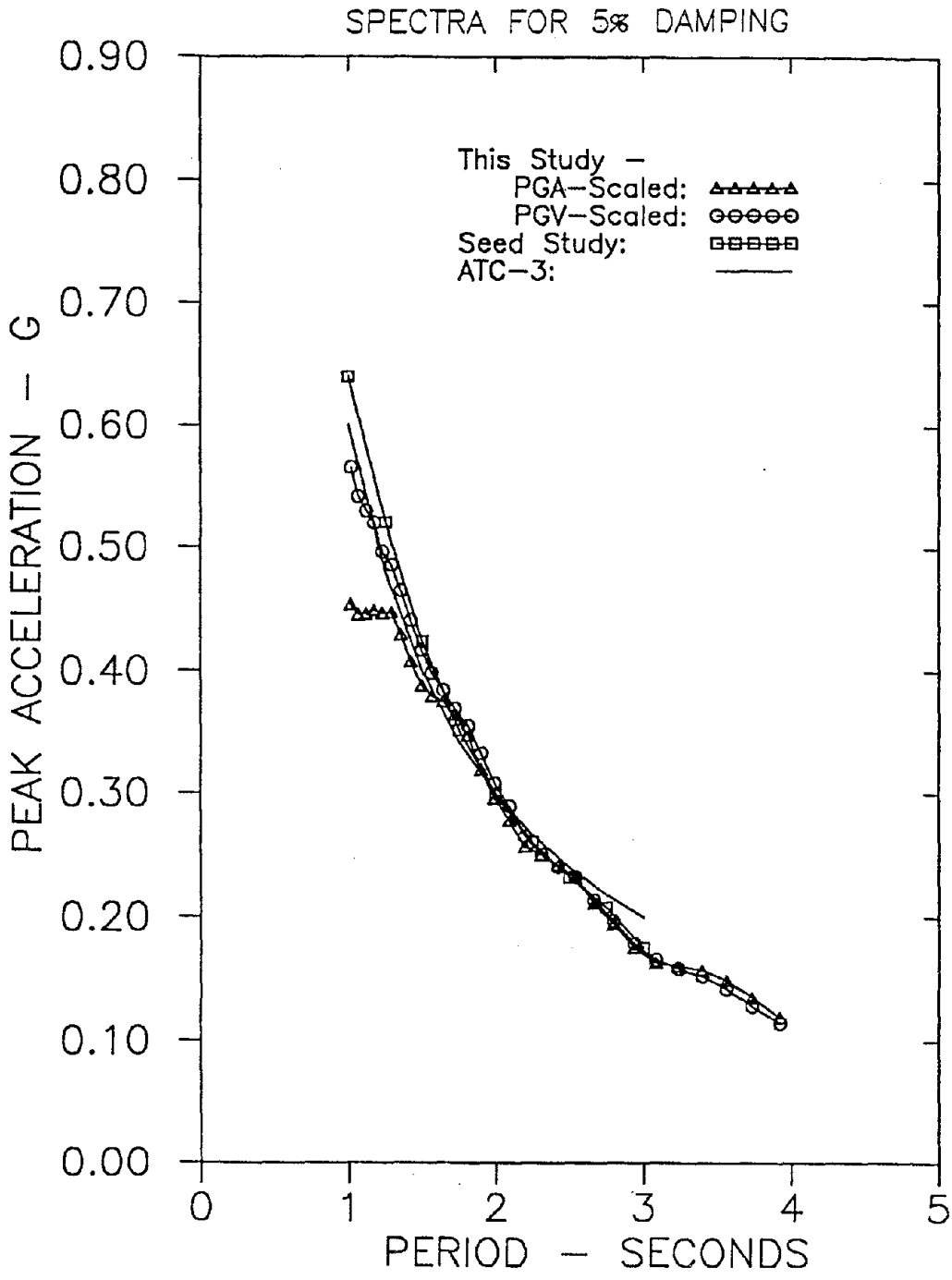

FIGURE 4-3 COMPARISON OF THE AVERAGE ACCELERATION SPECTRA OF THE TIME HISTORIES USED IN THIS STUDY, THE AVERAGE RESPONSE SPECTRUM OF SEED ET AL. [REF. 8] AND THE DESIGN SPECTRUM OF ATC-3 [REF. 7] - MEDIUM SOIL SITES.

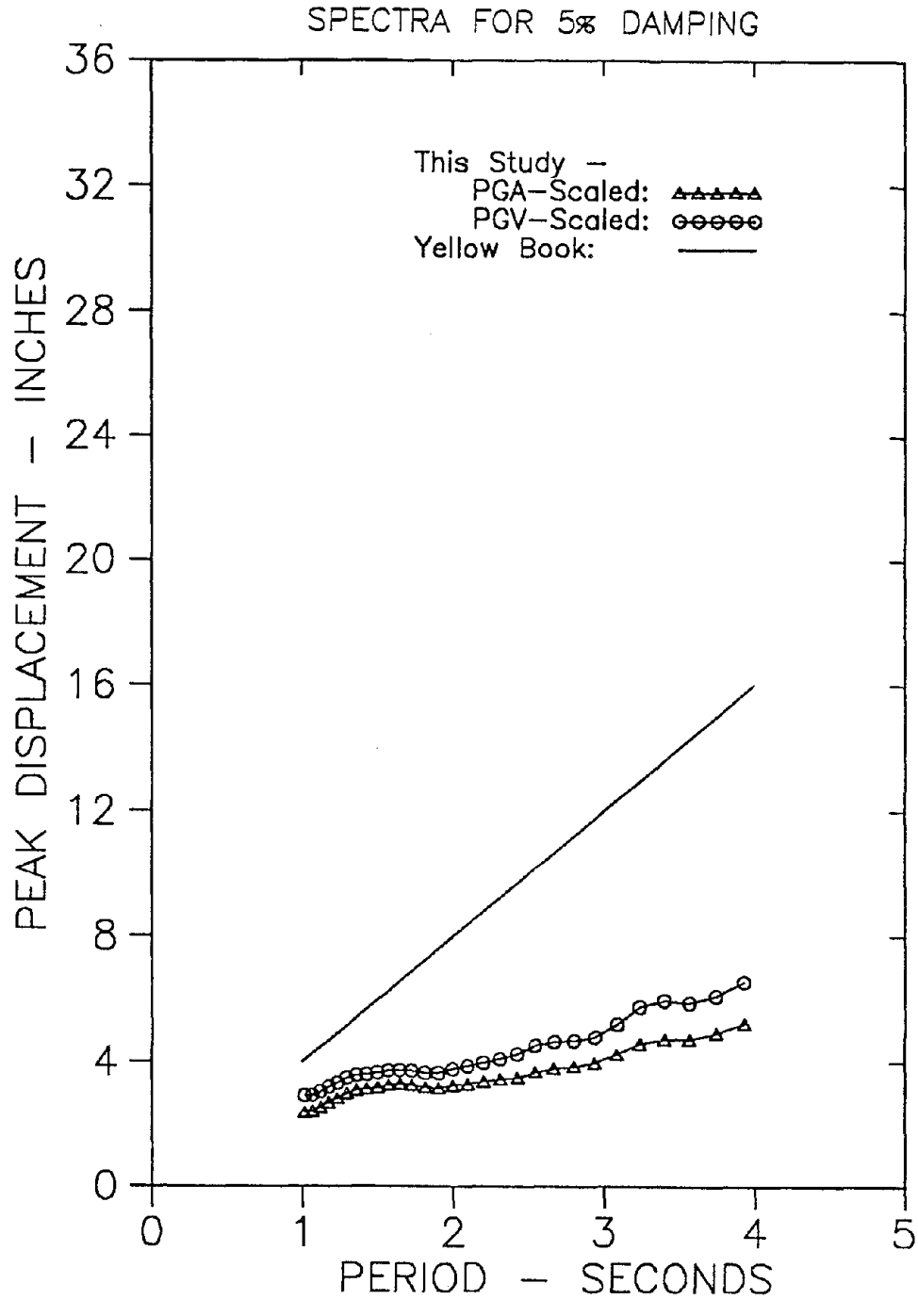

FIGURE 4-4 COMPARISON OF THE AVERAGE DISPLACEMENT SPECTRA OF THE TIME HISTORIES USED IN THIS STUDY AND THE DESIGN CRITERIA OF THE YELLOW BOOK [REF. 3] - ROCK SITES.

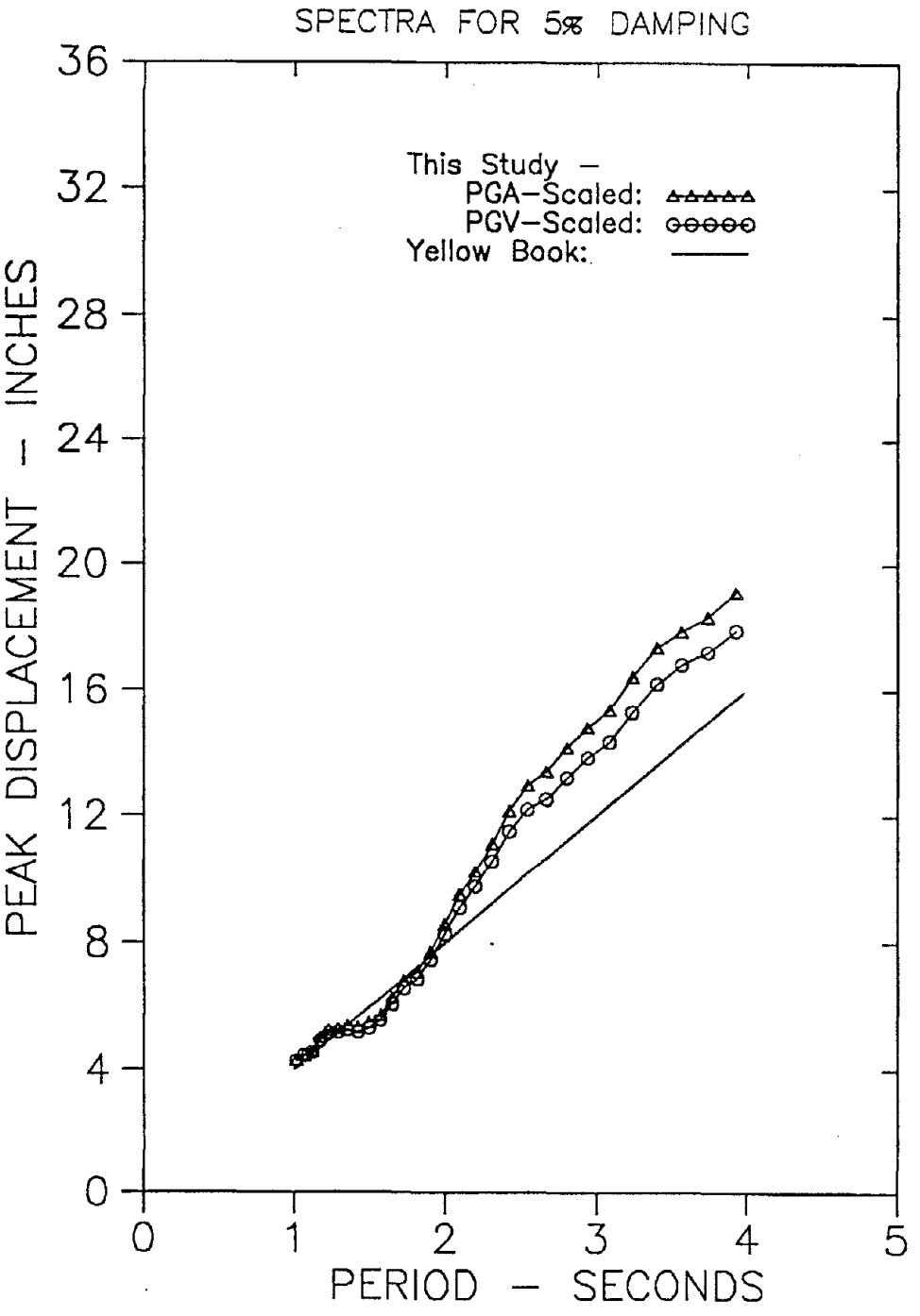

FIGURE 4-5 COMPARISON OF THE AVERAGE DISPLACEMENT SPECTRA OF THE TIME HISTORIES USED IN THIS STUDY AND THE DESIGN CRITERIA OF THE YELLOW BOOK [REF. 3] - STIFF SOIL SITES.

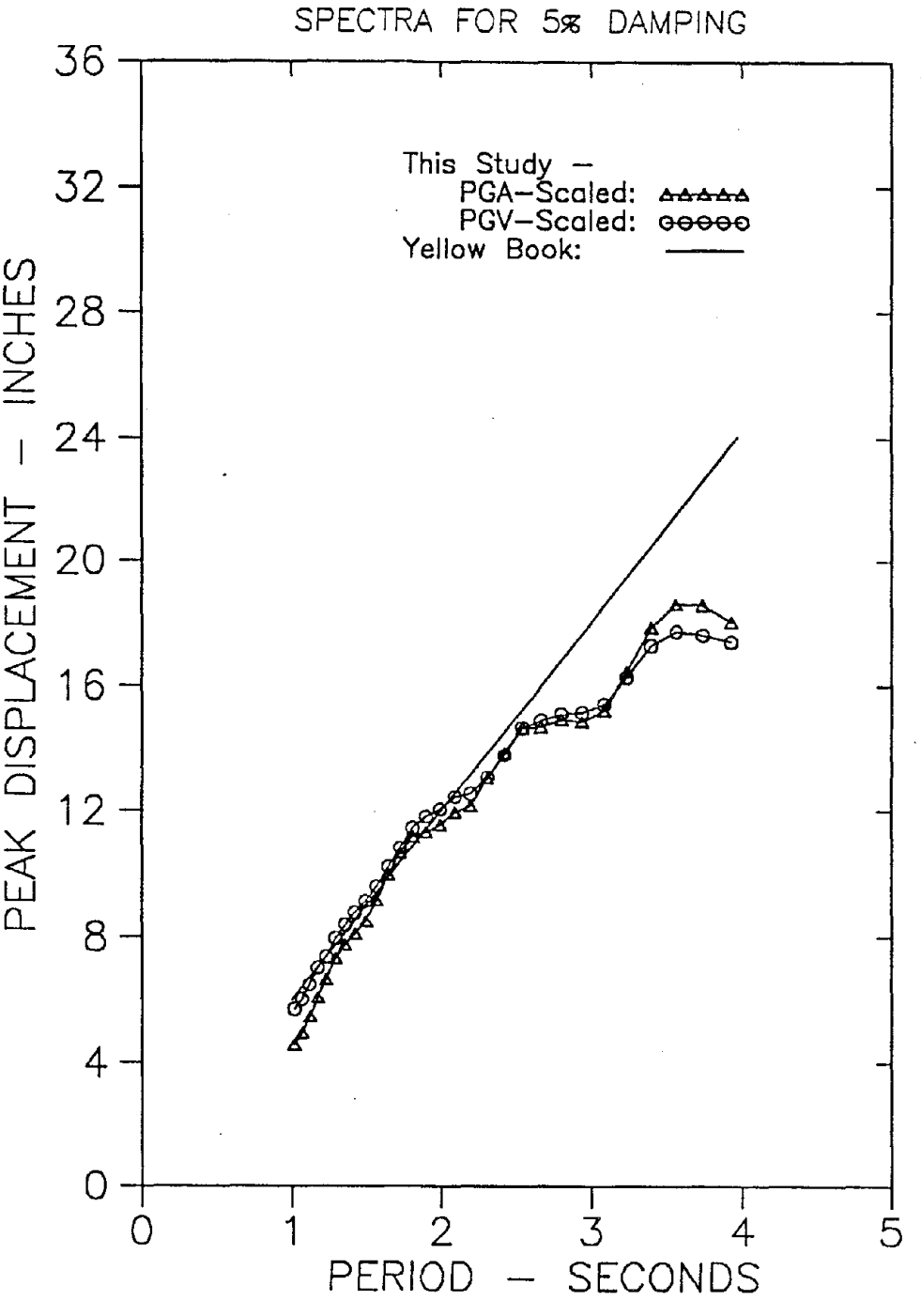

FIGURE 4-6 COMPARISON OF THE AVERAGE DISPLACEMENT SPECTRA OF THE TIME HISTORIES USED IN THIS STUDY AND THE DESIGN CRITERIA OF THE YELLOW BOOK [REF. 3] - MEDIUM SOIL SITES.

5. STRUCTURE/ISOLATION SYSTEM MODELS

5.1 Structure Configuration

The models of the structure/isolation system used in this study were all identical with the exception of the isolation system. The structure was modeled as a rigid body supported by a horizontally-flexible, vertically-rigid isolation system. In plan, the structure was configured to be rectangular, four bays by eight bays, with each bay measuring 20 feet by 20 feet. A total of 45 individual isolators were modeled at the intersections of the bays.

The structure/isolation system models used in this study are reasonable representations of isolated buildings that have a relatively stiff superstructure (e.g., the superstructure has a lateral stiffness at least ten times the effective stiffness of the isolation system). The type of lateral force resisting system or the specific height of the building which would qualify as "relatively stiff" will vary for each different isolation system. In general the models used in this study are valid representations of shear wall or braced frame buildings of modest height, and are less valid for moment frame buildings or taller buildings.

The primary response parameter of interest in this study is the peak lateral displacement of the isolated structure in the horizontal plane. Accordingly, the degrees of freedom for the models were chosen to permit translational and torsional response of the isolated building. To investigate the potential for torsion a 5 percent "accidental" mass eccentricity was added to each model. This is the minimum amount of mass eccentricity permitted by seismic codes. Figure 5-1 is a plan view of the isolated building showing dimensions, orientation and the location of the center of mass.

5.2 Isolation System Properties

The force-deflection properties of each isolator were modeled by bilinear, hysteretic elements with a different yield point and a different degree of yielding for each model. Yield levels were varied from as low as 0.03g to as high as 0.15g, and the degree of yielding was varied from only a slight change in initial stiffness to an almost full plastic state. The intent in varying these parameters over a broad range of yielded conditions was to create isolated building models that represent the dynamic characteristics of most, if not all, feasible isolation schemes.

Most commercially available isolation systems, including all elastomeric bearings and certain sliding systems that have a significant restoring force, can be reasonably well modeled as bilinear, hysteretic elements. In contrast, the peak response of pure sliding systems, or sliding systems without a significant restoring force, may not be accurately predicted by models using such simple elements. Consequently, the results of this study may not be applicable to such systems. Likewise, the results may not be applicable to isolation systems with stiffness properties that are significantly affected by changes in vertical load, the rate of loading or the direction of loading (i.e., stiffnesses coupled between different directions of response). Since the isolation system models are all assumed to yield, to some degree, the results of this study are representative of systems which soften and may not be applicable to systems which harden.

The properties of the isolation system, based on a bilinear, hysteretic modeling of elements, may be idealized as shown in Figure 5-2. For a given displacement amplitude, d, isolation system may be characterized by an effective period, T, and an effective damping, β, using equations (2-4) and (2-5), respectively. The effective period, T, may be expressed as:

$$T = 2\pi \sqrt{W/k_{eff}g}$$

$$= 0.320 \sqrt{d/a} \qquad (5\text{-}1)$$

where: T = effective period in seconds,

a = peak acceleration in units of g, and

d = peak displacement in inches.

The effective damping, β, may be expressed as:

$$\beta = \text{Area}/2\pi k_{eff} d^2$$

$$\beta = 0.637(a_y d - d_y a)/ad \qquad (5\text{-}2)$$

provided: $a \geq a_y \geq ad_y/d$

where: β = effective damping as a percent of critical,

a_y = acceleration yield level in units of g, and

d_y = displacement yield level in inches.

For the models used in this study the yield displacement, d_y, was assumed to be 0.5 inch, in all cases. Accordingly, Equation (5-2) may be expressed as:

$$\beta = 6.22(a_y T^2 - 0.051)/d \qquad (5\text{-}3)$$

provided: $a \geq a_y \geq 0.051/T^2$

As shown by the above expressions, the values of effective period, T, and effective damping, β, are a function of the amplitude of response (i.e.,

a function of the level of earthquake load). In general, the value of effective period will increase and the value of effective damping will decrease with an increase in the amplitude of response.

The isolation systems used in this study were selected to have an effective period of either 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 or 4.0 seconds for a displacement amplitude equal to the design displacement, D, as prescribed by Equation (2-1). The isolation systems were also defined on the basis of having one of the following yield accelerations: 0.03g, 0.05g, 0.07g, 0.10g or 0.15g. The value of effective damping is dependent on the above parameters. The only other restriction placed on effective damping was that the value of effective damping not be less than 5% of critical, nor greater than 40% of critical.

On the basis of the above, fourteen different models of isolation systems were developed for evaluation using earthquake records from rock or stiff soil sites and seventeen different models were developed for evaluation using earthquake records from medium soil sites. The same models could be used for both rock and stiff soil sites since the design displacement, prescribed by Equation (2-1), is the same for these two site conditions (i.e., same Soil Type coefficient, S_1 = 1.0). The properties of the models used for rock and stiff soil evaluations are summarized in Table 5-1 and illustrated in Figure 5-3, and the properties of the models used for medium soil evaluations are summarized in Table 5-2 and illustrated in Figure 5-4.

TABLE 5-1 PROPERTIES OF THE FOURTEEN ISOLATION SYSTEMS ANALYZED USING TIME HISTORIES RECORDED AT ROCK OR STIFF SOIL SITES

No.	Yield Force/W	Equivalent Linear Properties [Ref. 3]		Design Parameters [Ref. 3]	
		Effective Period, T (Seconds)	Effective Damping, β (% of Critical)	D (in.)	F_{max}/W
1	0.10	1.0	9%	3.5	0.36
2	0.15	1.0	25%	2.5	0.26
3	0.05	1.5	7%	5.6	0.25
4	0.07	1.5	15%	4.5	0.20
5	0.10	1.5	31%	3.5	0.16
6	0.03	2.0	6%	7.9	0.20
7	0.05	2.0	16%	5.8	0.15
8	0.07	2.0	31%	4.7	0.12
9	0.03	2.5	10%	8.3	0.14
10	0.05	2.5	27%	6.1	0.10
11	0.03	3.0	16%	8.9	0.10
12	0.05	3.0	39%	6.4	0.073
13	0.03	3.5	22%	9.1	0.076
14	0.03	4.0	28%	9.7	0.062

TABLE 5-2 PROPERTIES OF THE SEVENTEEN ISOLATION SYSTEMS ANALYZED USING TIME HISTORIES RECORDED AT MEDIUM SOIL SITES

No.	Yield Force/W	Equivalent Linear Properties [Ref. 3]		Design Parameters [Ref. 3]	
		Effective Period, T (Seconds)	Effective Damping, β (% of Critical)	D (in.)	F_{max}/W
1	0.15	1.0	13%	4.6	0.47
2	0.07	1.5	8%	7.9	0.36
3	0.10	1.5	17%	6.4	0.29
4	0.15	1.5	36%	4.9	0.22
5	0.05	2.0	9%	10.4	0.27
6	0.07	2.0	17%	8.6	0.22
7	0.10	2.0	31%	7.0	0.18
8	0.03	2.5	6%	14.5	0.24
9	0.05	2.5	15%	11.2	0.18
10	0.07	2.5	26%	9.3	0.15
11	0.03	3.0	9%	15.7	0.18
12	0.05	3.0	20%	11.8	0.13
13	0.07	3.0	37%	9.8	0.11
14	0.03	3.5	12%	16.8	0.14
15	0.05	3.5	28%	12.7	0.11
16	0.03	4.0	15%	17.8	0.11
17	0.05	4.0	35%	13.3	0.085

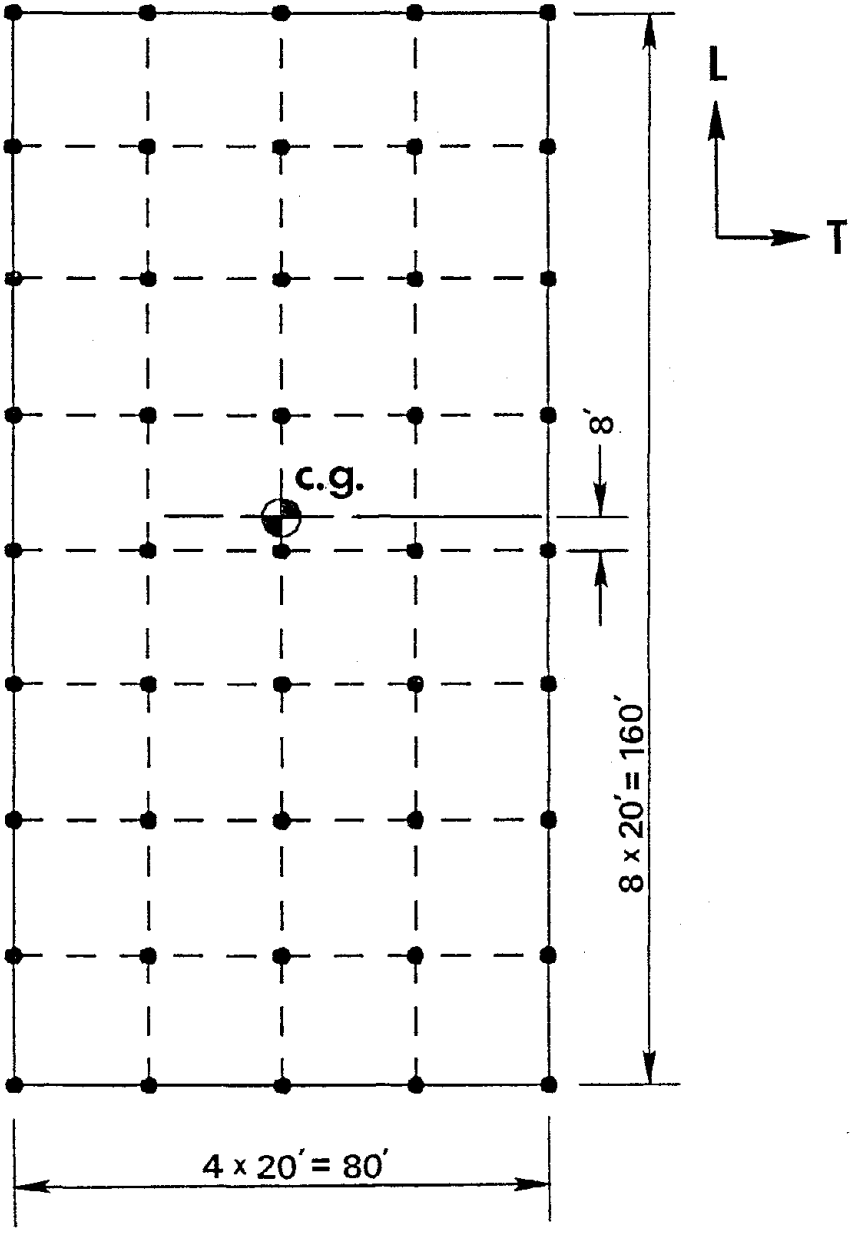

FIGURE 5-1 PLAN VIEW OF ISOLATED BUILDING

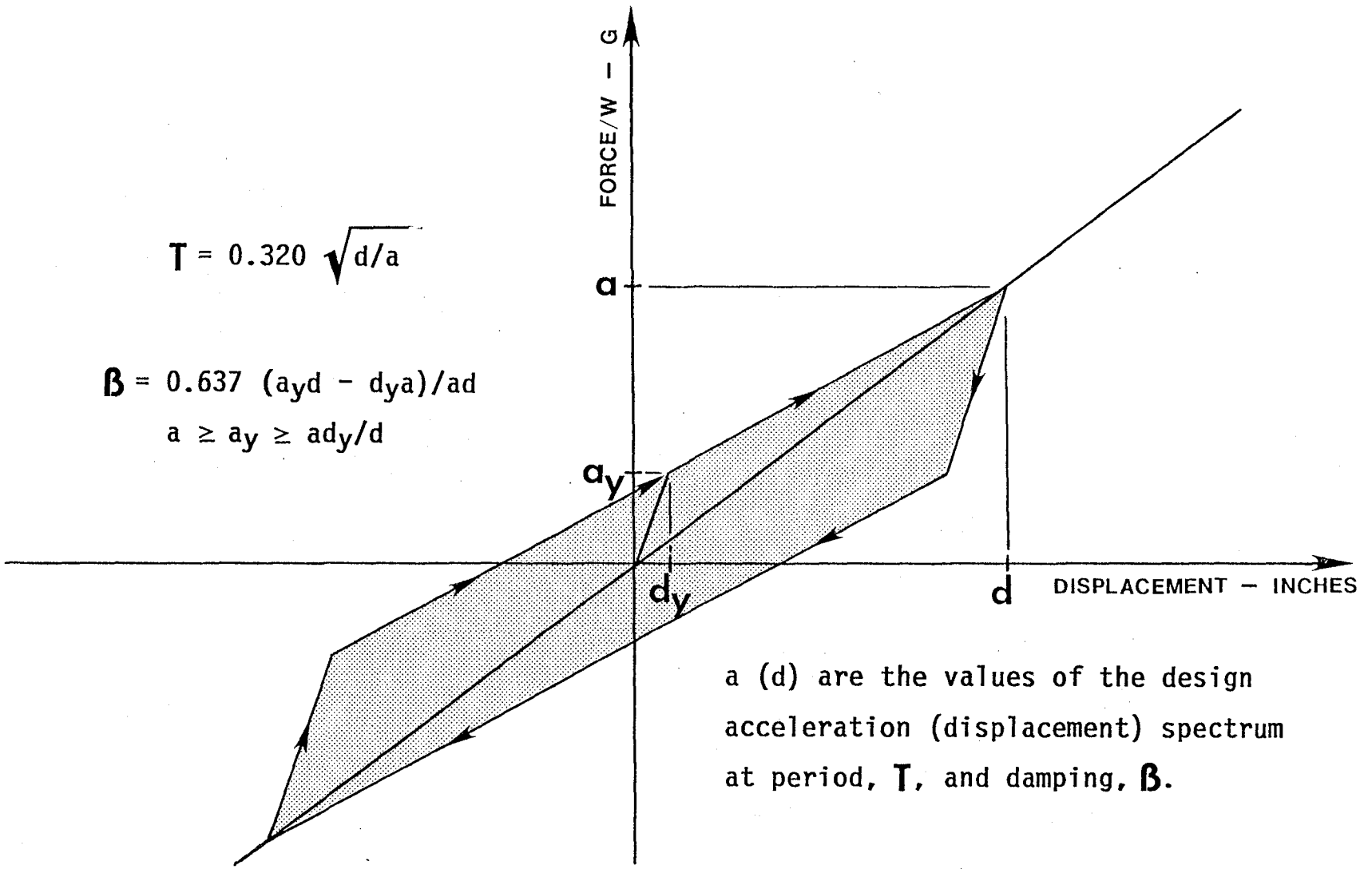

FIGURE 5-2 IDEALIZED PROPERTIES OF THE ISOLATION SYSTEM

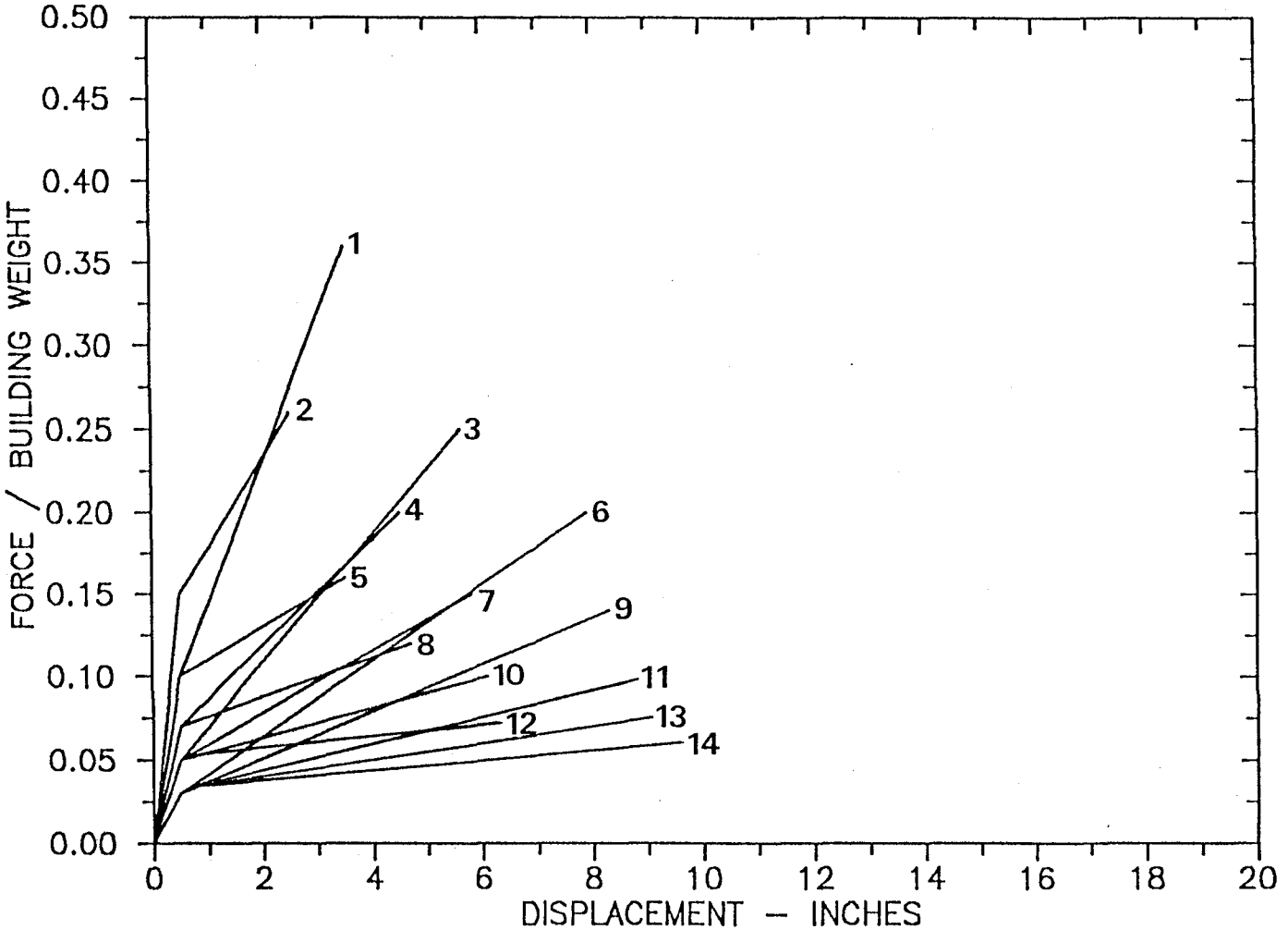

FIGURE 5-3 FORCE-DEFLECTION CHARACTERISTICS OF THE FOURTEEN ISOLATION SYSTEMS ANALYZED USING EARTHQUAKE TIME HISTORIES RECORDED AT ROCK OR STIFF SOIL SITE

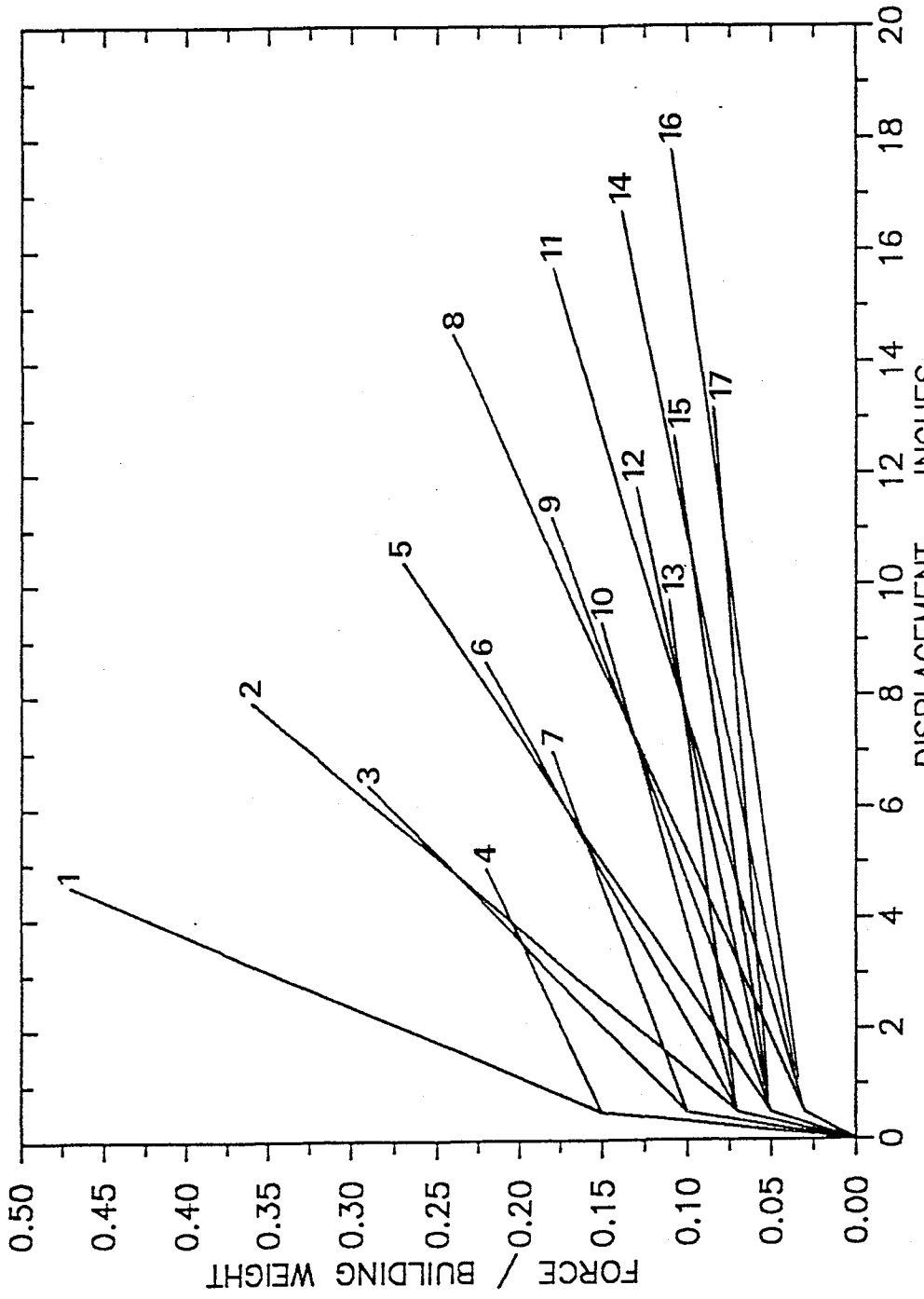

FIGURE 5-4 FORCE-DEFLECTION CHARACTERISTICS OF THE SEVENTEEN ISOLATION SYSTEMS ANALYZED USING EARTHQUAKE TIME HISTORIES RECORDED AT MEDIUM SOIL SITES

6. RESULTS

6.1 Tabulation of Peak and Cyclic Response

The results of the nonlinear analyses are contained in the tables of Appendices A through F, which are organized by the type of earthquake records used in the analyses as follows:

Appendix A. - records from rock sites, PGA-scaled,
Appendix B. - records from rock sites, PGV-scaled,
Appendix C. - records from stiff soil sites, PGA-scaled,
Appendix D. - records from stiff soil sites, PGV-scaled,
Appendix E. - records from medium soil sites, PGA-scaled,
Appendix F. - records from medium soil sites, PGV-scaled.

In the appendices, four part tables are used to group response results for each isolated building model as follows:

Group 1. - peak response in the transverse direction,

Group 2. - peak response in the longitudinal direction,

Group 3. - peak response in either the transverse or longitudinal direction,

Group 4. - cyclic response in either the transverse or longitudinal direction.

Response parameters of Groups 1, 2 and 3 include peak acceleration at the center of mass, peak displacement at the center of the building and peak displacement at the corner of the building. Response parameters of Group 4 include cumulative inelastic displacement and the ratio of cumulative inelastic displacement to maximum peak-to-peak displacement.

Response parameters are quantified by the minimum value, the maximum value and by statistical values (i.,e., mean value and standard deviation) of the results for each set of earthquake time histories.

Transverse and longitudinal response results are evaluated both separately, Groups 1 and 2 above, and as a combined set of results, Groups 3 and 4 above. The values of response parameters summarized in this chapter are taken from the tables of combined transverse and longitudinal response. The values of transverse response parameters and longitudinal response parameters, evaluated separately, were not found to be significantly different from the values of combined transverse and longitudinal response.

Summarizes of the peak acceleration at the center of gravity, the peak displacement at the center of the building and the ratio of the peak displacement at the corner of the building to the peak displacement at the center of the building are provided in Tables 6-1 through 6-6 for each site condition and method of scaling, respectively. In these tables the mean and the mean-plus-one-standard-deviation (mean + 1σ) values of peak response are provided to identify the variation as well as the average level of response. Three arbitrary groupings are used in these tables to distinguish between results for lightly-damped, moderately-damped and highly-damped isolation systems, respectively. Lightly-damped systems are defined to have an effective damping value of 5% to 10% of critical, moderately-damped systems are defined to have an effective damping value of 11% to 20% of critical, and highly-damped systems are defined to have an effective damping value of 21% to 40% of critical.

A summary of the mean and maximum values of the cyclic response ratio is provided in Table 6-7 for stiff and medium soil site conditions. The cyclic response ratio (i.e., cumulative inelastic displacement of the isolation system divided by maximum peak-to-peak displacement) is a measure of the effective number of full-amplitude cycles of the isolation system during the design-basis event. The mean (maximum) value of the cyclic response ratio is the average (largest) ratio found for each set of earthquake records. Cyclic response results reported in Table 6-7 are taken from the results of analyses that used PGV-scaled records. Cyclic response results of analyses that used PGA-scaled records are similar.

6.2 Comparison of Peak Response

This section compares the peak response results from two perspectives:

(1) the method used to scale the time histories (i.e., PGA-scaled or PGV-scaled records) and

(2) the site condition (i.e., rock, stiff soil or medium soil sites).

6.2.1 PGA-Scaled and PGV-Scaled Records

Tables 6-1 and 6-2 contain response results for rock sites, calculated using PGA-scaled and PGV-scaled records, respectively. Likewise, Tables 6-3 and 6-4 contain results for stiff soil sites, calculated using PGA-scaled and PGV-scaled records, respectively, and Tables 6-5 and 6-6 contain results for medium soil sites, calculated using PGA-scaled and PGV-scaled records, respectively. Comparison of the results provided in these tables indicates the following.

(1) The mean values of peak response are similar for PGA-scaled and PGV-scaled time history analyses, and mimic the trends of the mean response spectra shown in Figures 4-1 through 4-6. That is, the mean value of peak response of PGA-scaled time history analyses will be slightly greater (or slightly less) than the mean value of peak response of PGV-scaled time history analyses, if the mean response spectra of PGA-scaled time histories is slightly greater (or slightly less) than the mean response spectra of PGV-scaled time histories.

(2) The extreme values (e.g., maximum and minimum vakues) of peak response can be significantly different for PGA-scaled and PGV-scaled time history analyses, particularly for stiff or medium soil sites. This is illustrated in Figure 6-1 which is a plot of the coefficient of variation of peak response as a function of the level of effective damping for medium soil site conditions. As shown by this figure, the coefficient of variation of response for analyses which used PGA-scaled records is at least twice that corresponding to analyses which used PGV-scaled records.

It is also of interest to note that in Figure 6-1 the trends in the coefficient of variation are consistent, whether the results are based on PGA-scaled or PGV-scaled records. The variability in peak displacement does not change appreciably with an increase in the level of effective damping. This result suggests that the variability in displacement response is essentially the same as the inherent variability of the ground motion, regardless of the properties (i.e., the value of the effective damping) of the isolated structure. In contrast, the variability in peak acceleration response is reduced significantly for systems with a high value of effective damping, as expected for systems which soften (yield) appreciably.

In the following sections of Chapter 6 only the results of PGV-scaled time history analyses will be used since these results are essentially the same, except for variability, as the results of PGA-scaled time history analyses. The variability of PGV-scaled time histories (e.g., coefficient of variation of about 0.5) is considered more representative of earthquake ground motion than the variability of PGA-scaled time histories (e.g., coefficient of variation of about 1.0).

6.2.2 Rock, Stiff Soil and Medium Soil Sites

Comparison of the peak response results of Tables 6-2, 6-4 and 6-6 for rock, stiff soil and medium soil sites, respectively, indicates that peak displacements and peak accelerations of the isolated structure are significantly influenced by local site conditions. In general, peak response differs between rock, stiff soil and medium soil sites in a manner consistent with the differences in the mean spectra of the time histories of the different sites.

The peak response of isolated buildings located at rock sites was found to be low (e.g., mean peak displacement is less than 4 inches for all values of effective period and effective damping). This result is consistent with the mean spectra of the time histories recorded at rock

sites, but is not consistent with ATC-3 criteria which require buildings at rock sites to be designed for a ground response spectrum which envelops both rock and stiff soil sites. As previously discussed in Chapter 4, the time history records for rock sites may not contain an appropriate level of long-period ground motion and analyses using these records may underestimate long-period response. Accordingly, the evaluations of design requirements in subsequent sections will be based on the results of stiff soil and medium soil site analyses only.

6.3 Evaluation of Design Requirements

This section compares and evaluates the design requirements of the Yellow Book [Ref. 3] with the peak and cyclic response results of time history analyses in the following four areas:

(1) static analysis method (as compared to the more rigorous time history analysis method),

(2) design displacement, D, at the center of the building, as prescribed by Equation (2-1),

(3) additional displacement at the corner of the building due to torsion, and

(4) prototype testing (i.e., number of cycles required for verification of isolation system durability).

6.3.1 Static Analysis Method

The Yellow Book uses the concept of an effective period, T, as defined by Equation (2-4) and an effective damping factor, β, as defined by Equation (2-5), to approximate the response of buildings with nonlinear isolation systems. To evaluate the accuracy of this method of analysis, the mean peak displacement of nonlinear time history analyses is compared with the peak displacement calculated by the static analysis method. In this evaluation the static analysis method is applied using the mean spectrum of the time histories, rather than the seismic criteria implicit in Equation (2-1). The mean spectrum was used since the design

criteria of the Yellow Book and the values of the mean spectrum of the time histories are not exactly the same at all periods.

A comparison of static and dynamic (nonlinear time history) analysis peak displacement values is made in Table 6-8 for isolated buildings analyzed using stiff soil site time histories and in Table 6-9 for isolated buildings analyzed using soft soil site time histories. As shown in these tables static displacements closely match and, in all but a few cases, bound dynamic displacements. Figure 6-2 illustrates the comparison of the results of the static and dynamic methods of analysis.

On the basis of the comparisons shown in Figure 6-2 it may be stated:

(1) The static analysis method is a reasonably accurate (and conservative) method of calculating the mean peak displacement of the isolation system.

(2) The static analysis method estimates a peak displacement value that is usually 10% to 20% greater than the mean value of peak displacement calculated using time history analysis.

(3) The above statements are valid for values of effective period from 1.0 to 4.0 seconds and values of effective damping from 5% to 40% of critical.

Static analysis peak acceleration values were also found to closely match dynamic (nonlinear time history) analysis peak acceleration values. This finding, however, is valid only for first-mode response since the isolated buildings were modeled with a rigid superstructure and, thus, do not have higher modes. Consequently, if acceleration response of the structure is influenced by higher modes (e.g., due to the nonlinear characteristics of the isolation system), then the peak accelerations could be different than those calculated. This is not a concern for the calculation of peak displacement, since displacement of the isolation system is not significantly influenced by higher modes.

6.3.2 Design Displacement Formula

The Yellow Book prescribes the design displacement, D, at the center of the building by Equation (2-1), based on the effective period, T, and effective damping, β, of the isolated building and the seismic criteria of ATC-3 (Figure 2-1). The design displacement of each isolated building model has been calculated and the displacement values are listed in Table 5-1 for the models that were used in stiff soil site analyses and in Table 5-2 for the models that were used in medium soil site analyses. To evaluate the accuracy of the design displacement formula, the values of design displacement are compared with the values of peak displacement calculated by time history analysis. To facilitate this comparison plots have been generated which overlay the maximum, minimum, mean and mean + 1σ values of peak displacement with the design displacement value for each isolated structure. Figures 6-3 through 6-5 illustrate stiff soil site comparisons for lightly-damped, moderately-damped and highly-damped systems, respectively. Likewise, Figures 6-6 through 6-8 illustrate medium soil site comparisons for lightly-damped, moderately-damped and highly-damped systems, respectively.

On the basis of the comparisons shown in Figures 6-3 through 6-8 it may be stated:

(1) The design displacement, as prescribed by Equation (2-1), corresponds to response which is generally between the mean and the mean + 1σ values of peak displacement of the isolated building calculated using time history analysis.

(2) The minimum and maximum values of the peak displacement of the isolated building, calculated using time history analysis, can vary by as much as an order of magnitude for earthquake records of a common site condition and seismic zone factor.

The second observation, given above, is perhaps the more important of the two. Nonlinear time history analysis can produce very different results for different time histories, even though the time histories have been selected and scaled to represent a specific level of ground motion

and a particular site condition. Depending on the specific time history used in the analysis, peak response may be calculated to be as much as a factor of three greater, or a factor of three less, than the mean value of peak response (e.g., the target response level). In contrast, the results of the static analysis method usually differ from the mean value of peak response by only 10% to 20%.

6.3.3 Torsion

The Yellow Book requires that consideration be given to the additional displacement that can occur in the isolation system due to torsion. To evaluate the potential effects of torsion on isolated building response each model included a 5% mass eccentricity, the minimum value of mass eccentricity allowed by the 1988 UBC [Ref. 2]. Peak displacement was calculated at the building's corner (i.e., taken as the worst-case of the four corners) and the ratio of the mean value of the peak displacement at the building's corner to the mean value of the peak displacement at the building's center was calculated for each isolated building model. These peak displacement ratios are summarized in Tables 6-4 for stiff soil site analyses and in Table 6-6 for medium soil site analyses. The peak displacement ratios for stiff and medium soil sites, distinguished by damping level, are plotted in Figure 6-9 as a function of the effective period. The results indicate the following:

(1) The additional displacement due to torsion can be a significant contributor to the total displacement of the isolation system (e.g., for isolated building models with an effective period of 2 seconds, torsion was found to increase the total displacement at medium soil sites by about 35% to 45%).

(2) In general, the effects of torsion are more pronounced for isolated structures which have longer effective periods (e.g., for isolated building models with an effective period of 1 second, torsion was found to increase peak displacement by about 20%; in contrast, for isolated building models with an effective period of 4 seconds, torsion was found to increase peak displacement by at least 50%).

(3) At an effective period of about 2 seconds, or less, the effects of torsion are more pronounced for isolated structures that have larger values of effective damping (e.g., for isolated building models with a 2-second effective period, torsion was found to increase peak displacement at medium soil sites by about 35%, 40% and 45% for lightly-damped, moderately-damped and highly-damped systems, respectively.

In this study the isolated buildings were particularly susceptible to torsional displacement for two primary reasons:

(1) The distribution of isolation system stiffness was modeled as essentially uniform across the base of the building (i.e., same type and size of isolators were used at each grid line intersection).

In contrast, an isolated building with lateral force-resisting elements concentrated along the edges of the structure would inhibit torsional response.

(2) The isolation systems are all softening (yielding) systems. Consequently, the resistance to torsional displacement degrades with increase in the amplitude of rotation.

The assumptions of (1) uniform distribution of stiffness and (2) softening of the isolation system with increased displacement are consistent with the typical application and design properties of most currently available isolation systems (e.g., vertical-load supporting elastomeric bearings located bellow columns). Buildings with isolation systems that concentrate lateral stiffness at the edges of the building or that harden (e.g., incorporate a "displacement restraint" device) would be expected to have smaller displacements due to torsion (although they could have higher forces in the superstructure).

6.3.4 Prototype Testing

The Yellow Book requires prototypes of isolators to be tested using cyclic load. These tests are required to determine the stiffness properties of the isolation system and to verify the capacity of the isolators to withstand full-amplitude cyclic load without significant degradation of stiffness or strength. For the latter, the Yellow Book requires ten full cycles of load at a displacement amplitude equal to the design displacement (including torsion). To evaluate whether, or not, ten cycles is sufficient for this test, the number of effective cycles of full-amplitude response which occurred during the time history analyses was calculated and compared to the Yellow Book requirement. The number of effective cycles was estimated by the "cyclic response ratio" defined as the cumulative inelastic displacement of the isolation system divided by maximum peak-to-peak response. Table 6-7 summarizes the mean and maximum values of the cyclic response ratio for stiff and medium soil site analyses and groups the values by damping level.

In general, the mean values of the cyclic response ratio are consistent for stiff and medium soil sites. Maximum values have a slightly different trend, with the maximum value of the cyclic response ratio being approximately one and one-half times the mean value for stiff soil analyses and the maximum value of the cyclic response ratio being approximately twice the mean value for medium soil analyses. There does not appear to be a significant trend with respect to the value of effective period of the isolated building; however, there is a significant trend with respect to the value of effective damping.

Caution must be exercised in the interpretation of the cyclic response ratio results, since these ratios are based on earthquake records that may not all be representative of the duration of the design-basis event. Accordingly, the maximum value, rather than the mean value, of the cyclic response ratio should be used to establish a conservative number of test cycles.

The effective number of cycles, based on the maximum value of the cyclic response ratio, is plotted as a function of effective damping in Figure 6-10 for both stiff and medium soil sites. As shown in Figure 6-10, the Yellow Book criteria of ten test cycles does not appear to be conservative. To envelop maximum cyclic response for medium (stiff) soil sites, the number of test cycles should be about 20 (15), rather than 10. However, some reduction in the number of test cycles could be argued for systems that have a value of effective damping greater than 10% of critical.

TABLE 6-1 SUMMARY OF MEAN AND MEAN PLUS ONE STANDARD DEVIATION PEAK RESPONSE OF ISOLATED BUILDINGS - 0.4 G PGA-SCALED EARTHQUAKE TIME HISTORIES RECORDED AT ROCK SITES

a. Lightly-Damped Isolation Systems (5%-10%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
1	1.0 sec (9%)	0.212	0.303	1.8	2.9	1.17
3	1.5 sec (7%)	0.148	0.228	3.0	5.0	1.23
6	2.0 sec (6%)	0.087	0.134	3.0	5.0	1.37
9	2.5 sec (10%)	0.061	0.087	2.8	4.7	1.48

b. Moderately-Damped Isolation Systems (11%-20%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
4	1.5 sec (15%)	0.130	0.178	2.3	3.8	1.26
7	2.0 sec (16%)	0.084	0.117	2.5	4.2	1.44
11	3.0 sec (16%)	0.049	0.065	2.7	4.7	1.55

c. Highly-Damped Isolation Systems (21%-40%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
2	1.0 sec (25%)	0.194	0.225	1.3	1.9	1.21
5	1.5 sec (31%)	0.126	0.149	1.8	3.0	1.27
8	2.0 sec (31%)	0.091	0.108	2.3	4.6	1.41
10	2.5 sec (27%)	0.067	0.081	2.4	4.9	1.53
12	3.0 sec (39%)	0.058	0.064	2.4	4.1	1.59
13	3.5 sec (22%)	0.042	0.052	2.7	4.6	1.57
14	4.0 sec (28%)	0.038	0.045	2.8	4.7	1.57

TABLE 6-2 SUMMARY OF MEAN AND MEAN PLUS ONE STANDARD DEVIATION PEAK RESPONSE OF ISOLATED BUILDINGS - 12 IN./SEC. PGV-SCALED EARTHQUAKE TIME HISTORIES RECORDED AT ROCK SITES

a. Lightly-Damped Isolation Systems (5%-10%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
1	1.0 sec (9%)	0.246	0.325	2.2	3.2	1.18
3	1.5 sec (7%)	0.155	0.212	3.1	4.5	1.24
6	2.0 sec (6%)	0.096	0.171	3.3	4.9	1.38
9	2.5 sec (10%)	0.067	0.088	3.2	4.7	1.48

b. Moderately-Damped Isolation Systems (11%-20%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
4	1.5 sec (15%)	0.140	0.181	2.6	3.8	1.28
7	2.0 sec (16%)	0.093	0.117	2.8	4.1	1.42
11	3.0 sec (16%)	0.055	0.072	3.4	5.4	1.50

c. Highly-Damped Isolation Systems (21%-40%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
2	1.0 sec (25%)	0.207	0.237	1.6	2.1	1.22
5	1.5 sec (31%)	0.132	0.150	2.1	3.1	1.29
8	2.0 sec (31%)	0.094	0.106	2.5	3.5	1.39
10	2.5 sec (27%)	0.070	0.081	2.8	4.0	1.50
12	3.0 sec (39%)	0.059	0.064	2.9	4.3	1.54
13	3.5 sec (22%)	0.046	0.058	3.5	5.7	1.50
14	4.0 sec (28%)	0.040	0.048	3.5	5.9	1.51

TABLE 6-3 SUMMARY OF MEAN AND MEAN PLUS ONE STANDARD DEVIATION PEAK RESPONSE OF ISOLATED BUILDINGS - 0.4 G PGA-SCALED EARTHQUAKE TIME HISTORIES RECORDED AT STIFF SOIL SITES

a. Lightly-Damped Isolation Systems (5%-10%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
1	1.0 sec (9%)	0.338	0.460	3.3	4.7	1.14
3	1.5 sec (7%)	0.251	0.375	5.5	8.6	1.27
6	2.0 sec (6%)	0.184	0.288	7.1	11.5	1.30
9	2.5 sec (10%)	0.153	0.247	9.6	16.5	1.30

b. Moderately-Damped Isolation Systems (11%-20%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
4	1.5 sec (15%)	0.195	0.273	4.3	6.6	1.27
7	2.0 sec (16%)	0.146	0.216	5.7	9.5	1.27
11	3.0 sec (16%)	0.131	0.216	12.5	22.5	1.40

c. Highly-Damped Isolation Systems (21%-40%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
2	1.0 sec (25%)	0.251	0.298	2.4	3.3	1.16
5	1.5 sec (31%)	0.152	0.179	3.2	4.6	1.32
8	2.0 sec (31%)	0.119	0.155	4.6	7.5	1.30
10	2.5 sec (27%)	0.107	0.153	6.9	12.0	1.30
12	3.0 sec (39%)	0.074	0.093	6.8	11.7	1.45
13	3.5 sec (22%)	0.064	0.135	11.4	20.2	1.53
14	4.0 sec (28%)	0.038	0.088	10.4	17.3	1.52

TABLE 6-4 SUMMARY OF MEAN AND MEAN PLUS ONE STANDARD DEVIATION PEAK RESPONSE OF ISOLATED BUILDINGS - 18 IN./SEC. PGV-SCALED EARTHQUAKE TIME HISTORIES RECORDED AT STIFF SOIL SITES

a. Lightly-Damped Isolation Systems (5%-10%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
1	1.0 sec (9%)	0.338	0.451	3.3	4.6	1.16
3	1.5 sec (7%)	0.236	0.318	5.2	7.2	1.27
6	2.0 sec (6%)	0.181	0.250	7.0	9.9	1.30
9	2.5 sec (10%)	0.139	0.196	8.6	12.8	1.32

b. Moderately-Damped Isolation Systems (11%-20%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
4	1.5 sec (15%)	0.183	0.232	3.9	5.4	1.28
7	2.0 sec (16%)	0.136	0.179	5.2	7.5	1.31
11	3.0 sec (16%)	0.118	0.182	10.8	18.4	1.42

c. Highly-Damped Isolation Systems (21%-40%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
2	1.0 sec (25%)	0.252	0.301	2.4	3.4	1.18
5	1.5 sec (31%)	0.148	0.172	3.0	4.2	1.32
8	2.0 sec (31%)	0.113	0.135	4.0	5.8	1.39
10	2.5 sec (27%)	0.100	0.131	6.1	9.6	1.33
12	3.0 sec (39%)	0.073	0.087	6.4	9.9	1.40
13	3.5 sec (22%)	0.083	0.124	10.4	18.1	1.50
14	4.0 sec (28%)	0.061	0.083	9.5	15.6	1.53

TABLE 6-5 SUMMARY OF MEAN AND MEAN PLUS ONE STANDARD DEVIATION PEAK RESPONSE OF ISOLATED BUILDINGS - 0.4 G PGA-SCALED EARTHQUAKE TIME HISTORIES RECORDED ON MEDIUM SOIL SITES

a. Lightly-Damped Isolation Systems (5%-10%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
2	1.5 sec (8%)	0.328	0.599	7.1	14.1	1.26
5	2.0 sec (9%)	0.233	0.427	8.9	17.8	1.42
8	2.5 sec (6%)	0.210	0.402	12.7	25.7	1.53
11	3.0 sec (9%)	0.175	0.376	15.4	36.1	1.66

b. Moderately-Damped Isolation Systems (11%-20%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
1	1.0 sec (13%)	0.334	0.474	2.9	4.7	1.15
3	1.5 sec (17%)	0.265	0.431	5.6	10.8	1.34
6	2.0 sec (17%)	0.198	0.339	7.4	15.0	1.39
9	2.5 sec (15%)	0.170	0.318	10.1	22.0	1.58
12	3.0 sec (20%)	0.126	0.224	10.8	24.0	1.54
14	3.5 sec (12%)	0.118	0.228	13.4	29.6	1.59
16	4.0 sec (15%)	0.111	0.248	17.3	45.9	1.52

c. Highly-Damped Isolation Systems (21%-40%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
4	1.5 sec (36%)	0.205	0.259	3.9	7.3	1.44
7	2.0 sec (31%)	0.172	0.255	6.5	13.4	1.40
10	2.5 sec (26%)	0.143	0.233	8.4	18.1	1.51
13	3.0 sec (37%)	0.106	0.149	8.8	18.7	1.54
15	3.5 sec (28%)	0.103	0.178	12.0	28.3	1.52
17	4.0 sec (35%)	0.077	0.109	10.4	22.4	1.61

TABLE 6-6 SUMMARY OF MEAN AND MEAN PLUS ONE STANDARD DEVIATION PEAK RESPONSE OF ISOLATED BUILDINGS - 22.5 IN./SEC. PGV-SCALED EARTHQUAKE TIME HISTORIES RECORDED ON MEDIUM SOIL SITES

a. Lightly-Damped Isolation Systems (5%-10%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
2	1.5 sec (8%)	0.332	0.443	7.2	10.1	1.32
5	2.0 sec (9%)	0.237	0.332	9.1	13.5	1.36
8	2.5 sec (6%)	0.200	0.290	12.0	18.1	1.48
11	3.0 sec (9%)	0.147	0.212	12.5	19.2	1.60

b. Moderately-Damped Isolation Systems (11%-20%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
1	1.0 sec (13%)	0.386	0.480	3.5	4.7	1.22
3	1.5 sec (17%)	0.252	0.316	5.2	7.2	1.33
6	2.0 sec (17%)	0.193	0.249	7.1	10.2	1.41
9	2.5 sec (15%)	0.159	0.211	9.2	13.3	1.48
12	3.0 sec (20%)	0.111	0.140	8.8	12.7	1.56
14	3.5 sec (12%)	0.108	0.154	12.0	18.8	1.58
16	4.0 sec (15%)	0.084	0.118	11.8	18.8	1.61

c. Highly-Damped Isolation Systems (21%-40%)

Isolated Building		Peak Acceleration at C.G. (g)		Peak Displacement at Center (in.)		Displacement Ratio: Corner/ Center
No.	Period, T, and Damping, β	Mean	Mean + 1σ	Mean	Mean + 1σ	
4	1.5 sec (36%)	0.205	0.229	4.0	5.5	1.46
7	2.0 sec (31%)	0.156	0.177	5.2	6.9	1.47
10	2.5 sec (26%)	0.130	0.156	7.0	9.8	1.50
13	3.0 sec (37%)	0.098	0.112	7.1	10.3	1.57
15	3.5 sec (28%)	0.087	0.106	8.5	12.6	1.56
17	4.0 sec (35%)	0.071	0.082	8.4	12.6	1.61

TABLE 6-7 SUMMARY OF MEAN AND MAXIMUM CYCLIC RESPONSE RATIOS[1]

a. Lightly-Damped Isolation Systems (5%-10%)

Isolated Building Period, T (sec.)	Stiff Soil Sites		Medium Soil Sites	
	Mean	Maximum	Mean	Maximum
1.0	8.0	10.5	---	---
1.5	9.4	14.1	8.5	14.4
2.0	8.5	13.3	8.6	16.5
2.5	7.1	10.9	9.4	16.8
3.0	---	---	8.4	17.4

b. Moderately-Damped Isolation Systems (11%-20%)

Isolated Building Period, T (sec.)	Stiff Soil Sites		Medium Soil Sites	
	Mean	Maximum	Mean	Maximum
1.0	---	---	6.8	12.6
1.5	6.8	12.1	6.4	10.3
2.0	6.6	10.8	6.9	13.7
2.5	---	---	7.0	12.0
3.0	5.6	10.6	6.7	12.7
3.5	---	---	8.0	17.5
4.0	---	---	7.6	15.7

c. Highly-Damped Isolation Systems (21%-40%)

Isolated Building Period, T (sec.)	Stiff Soil Sites		Medium Soil Sites	
	Mean	Maximum	Mean	Maximum
1.0	5.0	7.9	---	---
1.5	5.2	7.4	5.1	10.6
2.0	5.5	9.6	5.5	10.6
2.5	5.7	8.5	6.3	13.5
3.0	5.0	7.0	6.1	11.2
3.5	5.6	9.4	6.5	11.6
4.0	5.3	8.3	6.2	10.9

[1] The cyclic response ratio is the cumulative inelastic displacement divided by the maximum peak-to-peak displacement.

TABLE 6-8 COMPARISON OF STATIC AND DYNAMIC ANALYSIS METHODS - STIFF SOIL SITES

Isolated Building		Static Displacement[1] (in.)	Dynamic Displacement[2] (in.)	Difference in Displacement (in.)	Ratio of Static to Dynamic Displacement
No.	Period, T and Damping, β				
1	1.0 sec. (9%)	3.8	3.3	0.5	1.15
2	1.0 sec. (25%)	2.7	2.4	0.3	1.13
3	1.5 sec. (7%)	5.0	5.2	-0.2	0.96
4	1.5 sec. (15%)	4.0	3.9	0.1	1.03
5	1.5 sec. (31%)	3.1	3.0	0.1	1.03
6	2.0 sec. (6%)	8.2	7.0	1.2	1.17
7	2.0 sec. (16%)	6.0	5.2	1.2	1.15
8	2.0 sec. (31%)	4.9	4.0	0.9	1.23
9	2.5 sec. (10%)	10.0	8.6	1.4	1.16
10	2.5 sec. (27%)	7.3	6.1	1.2	1.20
11	3.0 sec. (16%)	10.5	10.8	-0.3	0.97
12	3.0 sec. (39%)	7.5	6.4	1.1	1.17
13	3.5 sec. (22%)	10.8	10.4	0.4	1.04
14	4.0 sec. (28%)	11.0	9.5	1.5	1.16

1. Peak displacement corresponding to the average spectrum of PGV-scaled time histories.
2. Average peak displacement of PGV-scaled time history analyses.

TABLE 6-9 COMPARISON OF STATIC AND DYNAMIC ANALYSIS METHODS - MEDIUM SOIL SITES

Isolated Building		Static Displacement[1] (in.)	Dynamic Displacement[2] (in.)	Difference in Displacement (in.)	Ratio of Static to Dynamic Displacement
No.	Period, T and Damping, β				
1	1.0 sec. (13%)	4.3	3.5	0.8	1.23
2	1.5 sec. (8%)	7.9	7.2	0.7	1.10
3	1.5 sec. (17%)	6.4	5.2	1.2	1.23
4	1.5 sec. (36%)	4.9	4.0	0.9	1.23
5	2.0 sec. (9%)	10.4	9.1	1.3	1.14
6	2.0 sec. (17%)	8.6	7.1	1.5	1.21
7	2.0 sec. (31%)	7.0	5.2	1.8	1.35
8	2.5 sec. (6%)	13.9	12.0	1.9	1.16
9	2.5 sec. (15%)	10.8	9.2	1.6	1.17
10	2.5 sec. (26%)	8.9	7.0	1.9	1.27
11	3.0 sec. (9%)	13.3	12.5	0.8	1.06
12	3.0 sec. (20%)	10.0	8.8	1.2	1.14
13	3.0 sec. (37%)	8.3	7.1	1.2	1.17
14	3.5 sec. (12%)	14.1	12.0	2.1	1.18
15	3.5 sec. (28%)	10.7	8.5	2.2	1.26
16	4.0 sec. (15%)	13.0	11.8	1.2	1.10
17	4.0 sec. (35%)	9.7	8.4	1.3	1.15

1. Peak displacement corresponding to the average spectrum of PGV-scaled time histories.
2. Average peak displacement of PGV-scaled time history analyses.

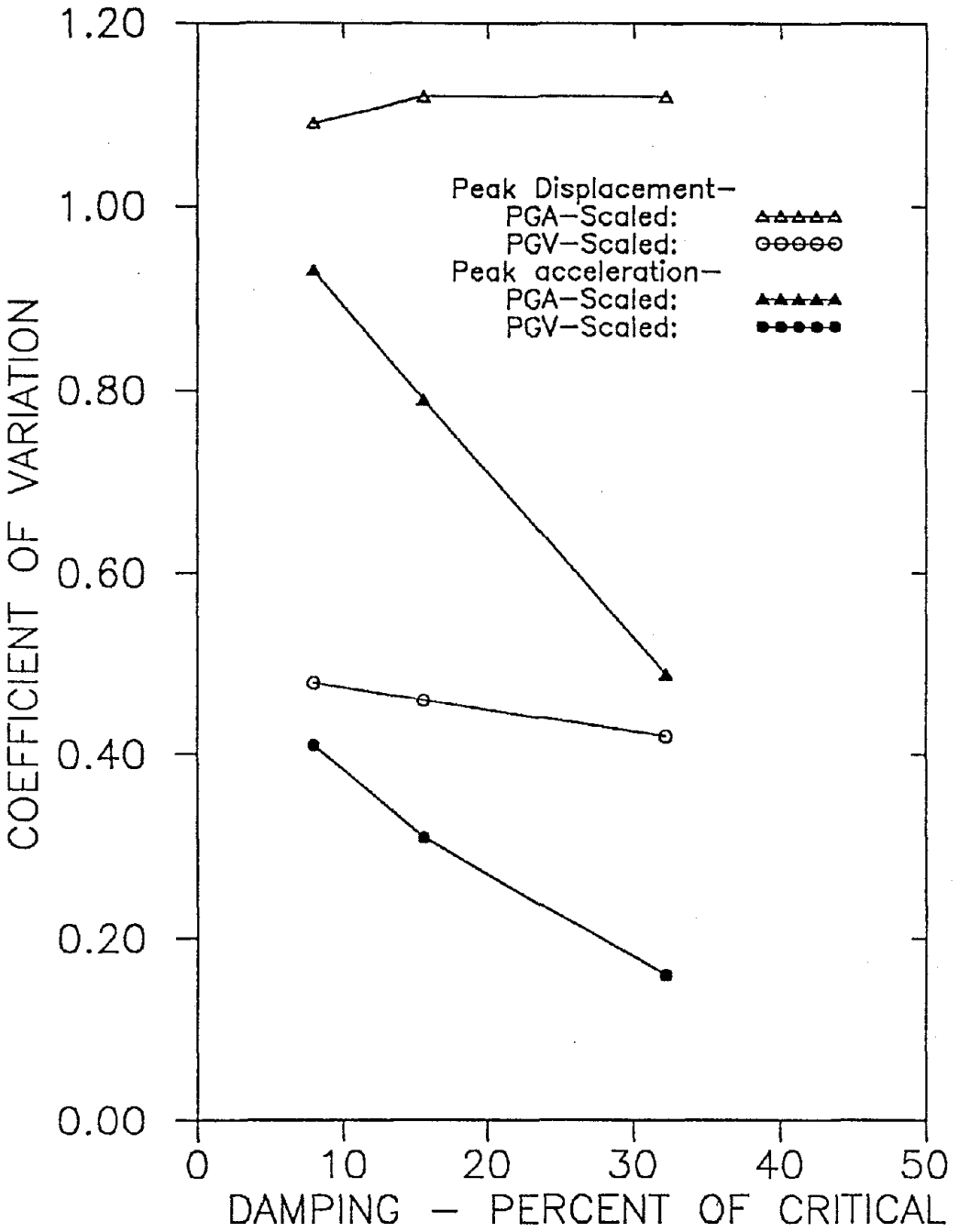

FIGURE 6-1 TRENDS IN THE COEFFICIENT OF VARIATION OF PEAK RESPONSE AS A FUNCTION OF EFFECTIVE DAMPING

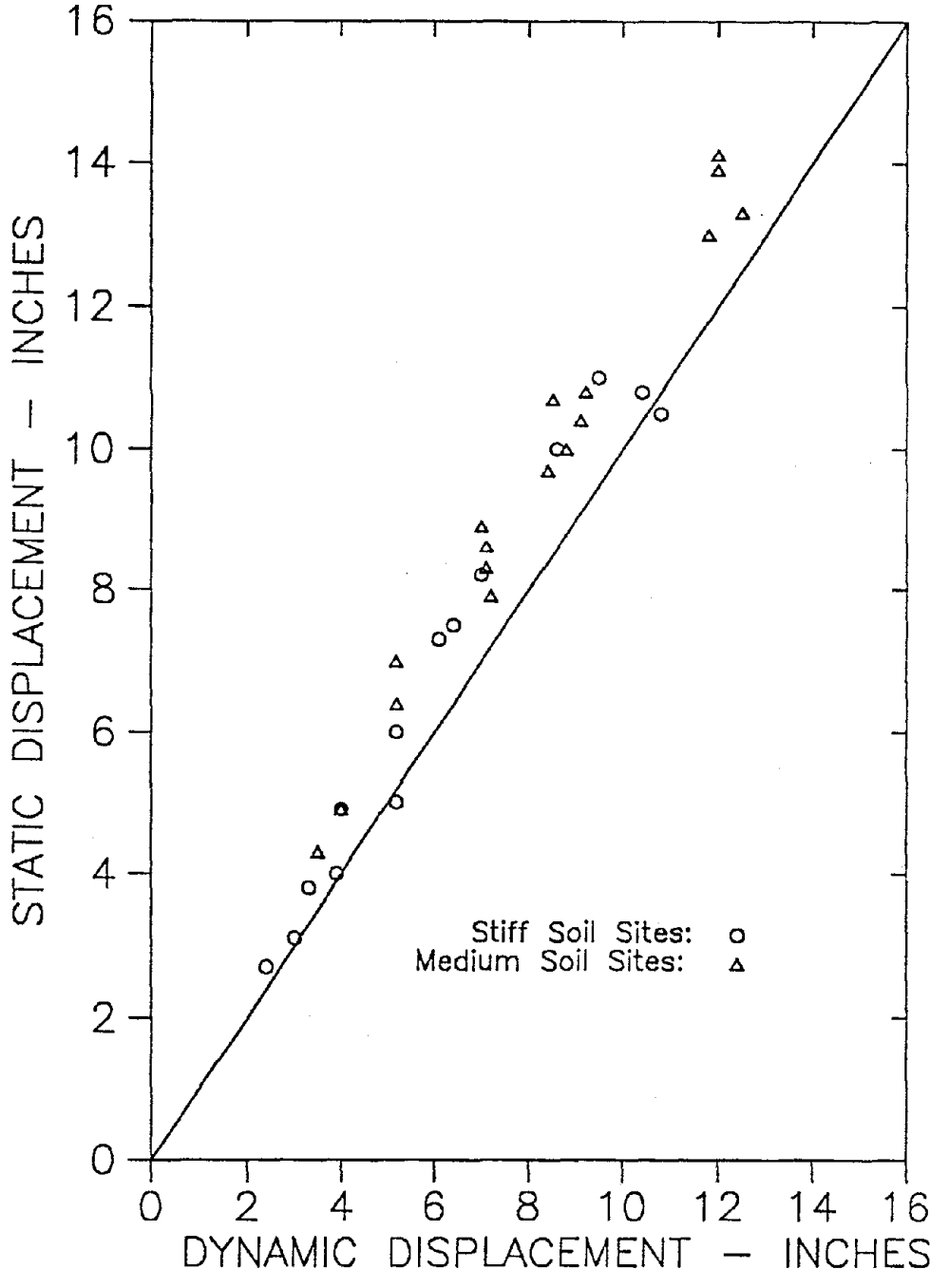

FIGURE 6-2 COMPARISON OF STATIC AND DYNAMIC (NONLINEAR TIME HISTORY) ANALYSIS PEAK DISPLACEMENT

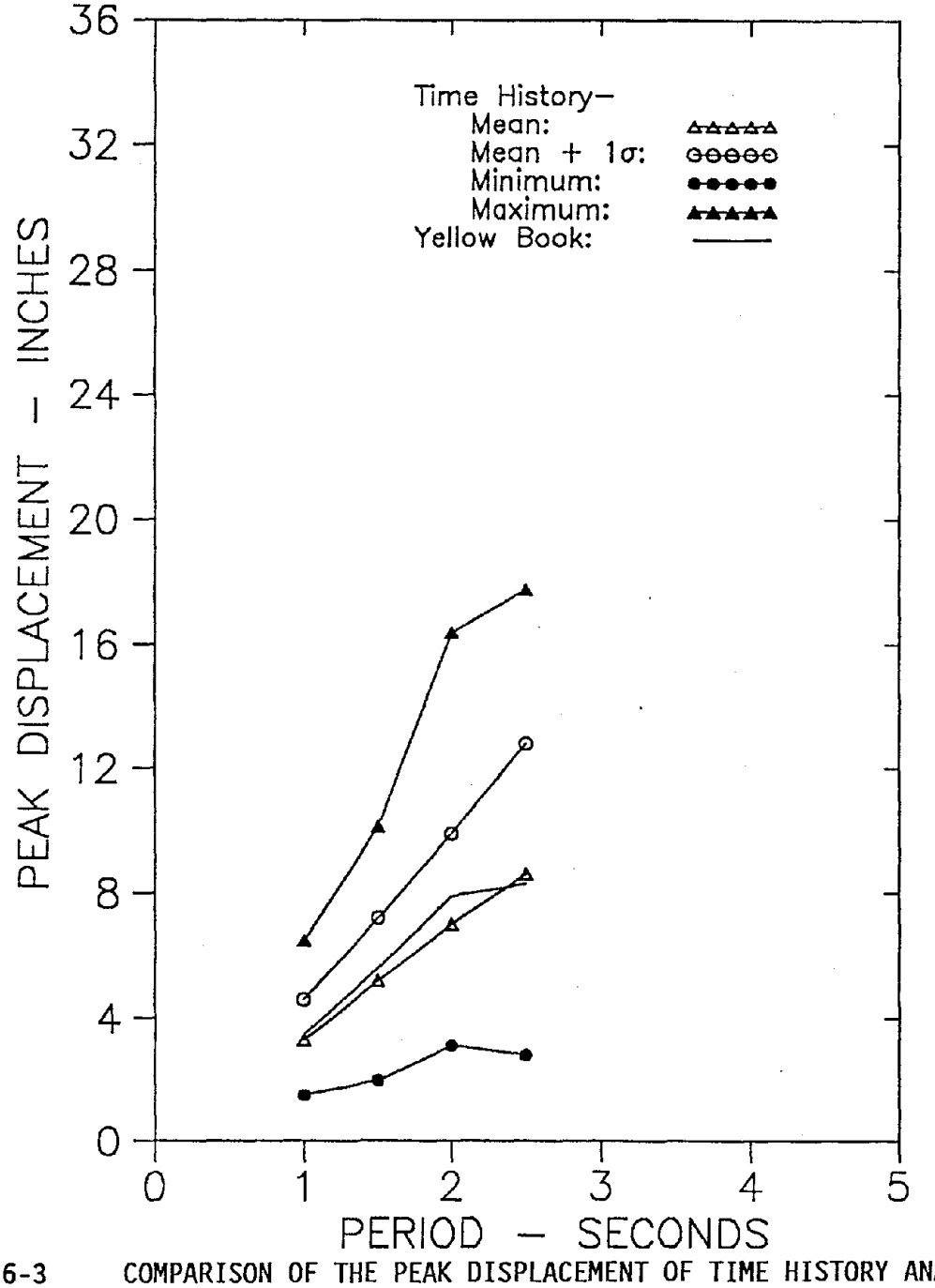

FIGURE 6-3 COMPARISON OF THE PEAK DISPLACEMENT OF TIME HISTORY ANALYSES WITH THE DESIGN DISPLACEMENT, D, PRESCRIBED BY THE YELLOW BOOK [REF. 3] - STIFF SOIL SITES AND LIGHTLY-DAMPED ISOLATION SYSTEMS (5% - 10%)

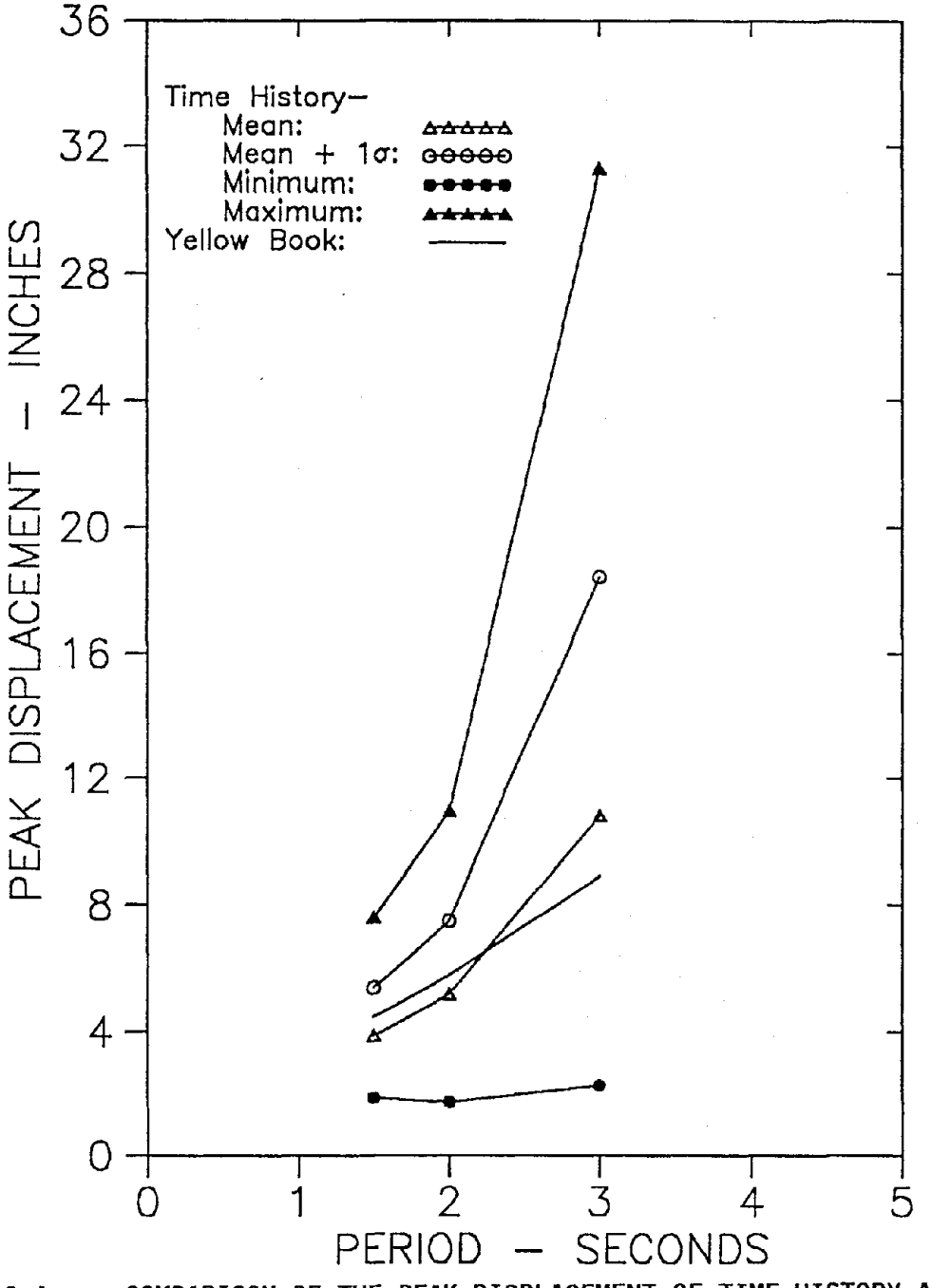

FIGURE 6-4 COMPARISON OF THE PEAK DISPLACEMENT OF TIME HISTORY ANALYSES WITH THE DESIGN DISPLACEMENT, D, PRESCRIBED BY THE YELLOW BOOK [REF. 3] - STIFF SOIL SITES AND MODERATELY-DAMPED ISOLATION SYSTEMS (11% - 20%)

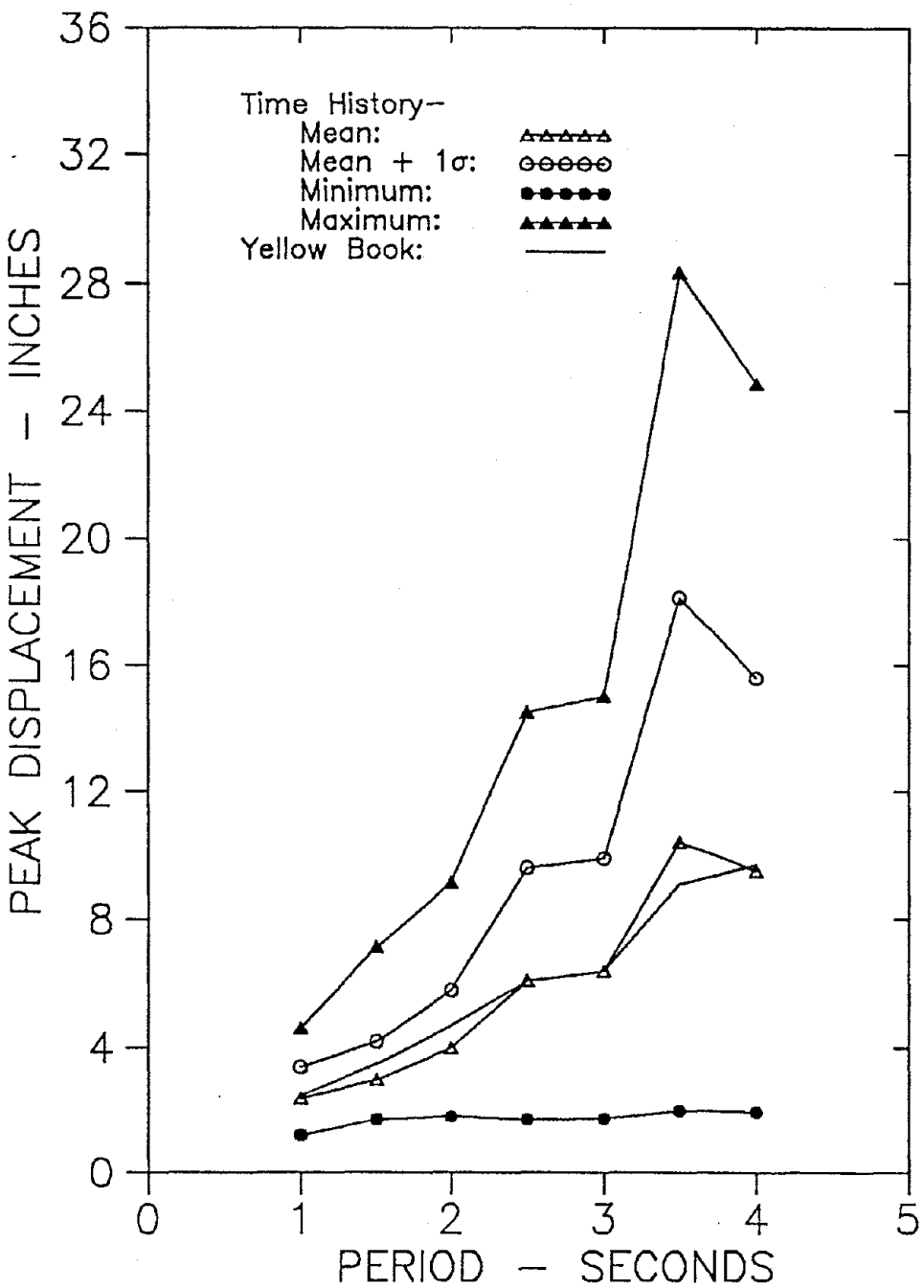

FIGURE 6-5 COMPARISON OF THE PEAK DISPLACEMENT OF TIME HISTORY ANALYSES WITH THE DESIGN DISPLACEMENT, D, PRESCRIBED BY THE YELLOW BOOK [REF. 3] - STIFF SOIL SITES AND HIGHLY-DAMPED ISOLATION SYSTEMS (21% - 40%)

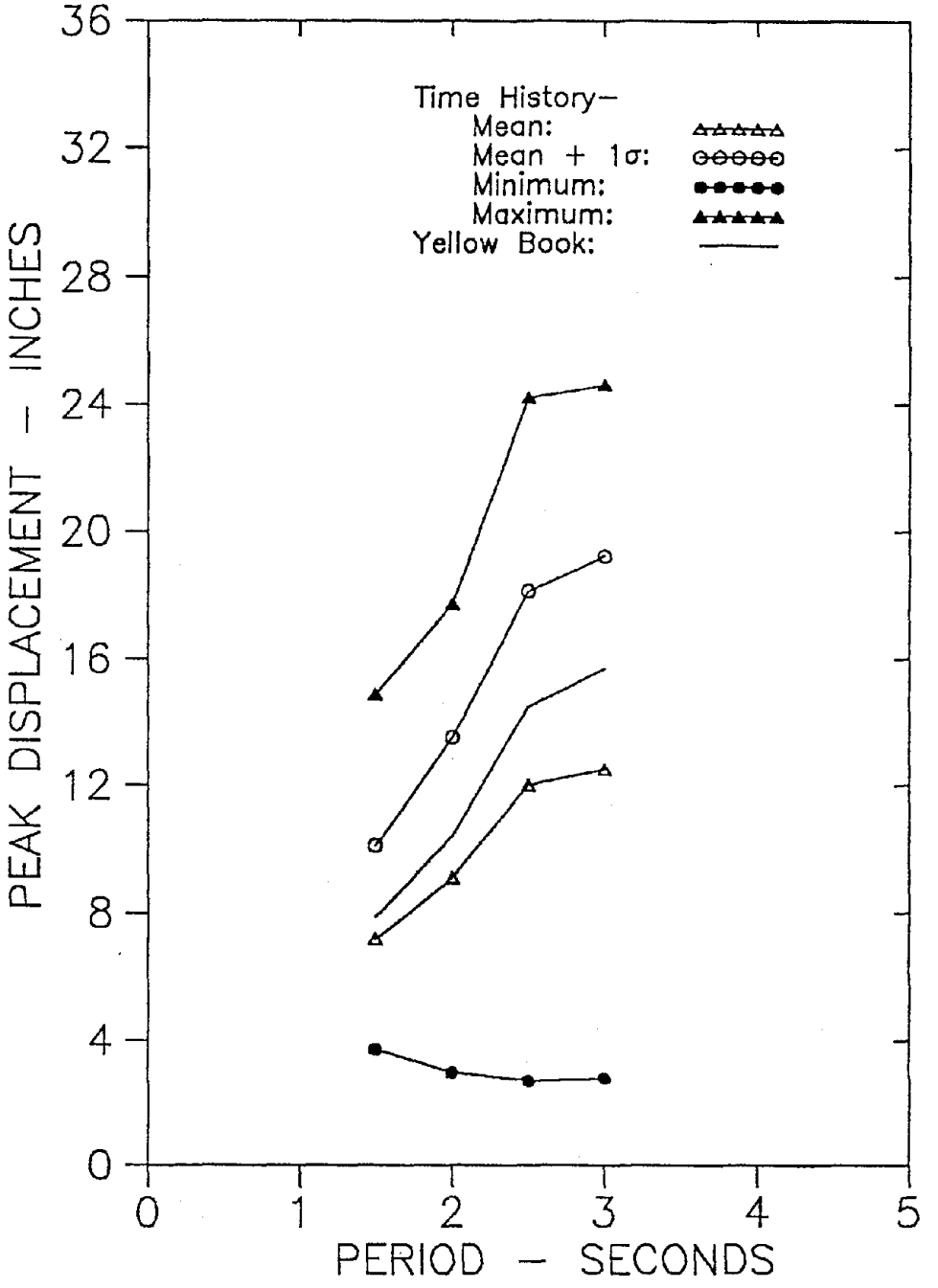

FIGURE 6-6 COMPARISON OF THE PEAK DISPLACEMENT OF TIME HISTORY ANALYSES WITH THE DESIGN DISPLACEMENT, D, PRESCRIBED BY THE YELLOW BOOK [REF. 3] - MEDIUM SOIL SITES AND LIGHTLY-DAMPED ISOLATION SYSTEMS (5% - 10%)

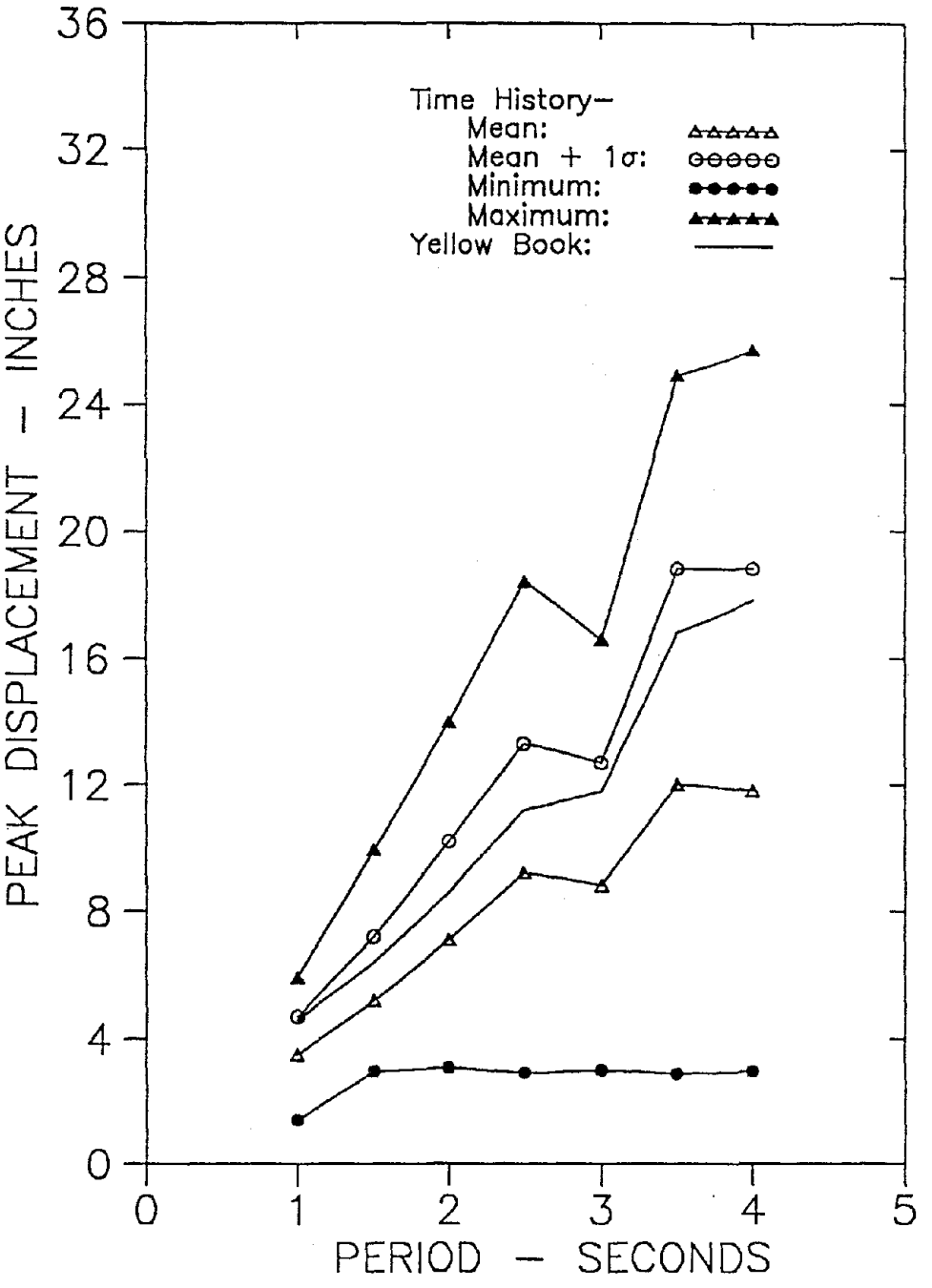

FIGURE 6-7 COMPARISON OF THE PEAK DISPLACEMENT OF TIME HISTORY ANALYSES WITH THE DESIGN DISPLACEMENT, D, PRESCRIBED BY THE YELLOW BOOK [REF. 3] - MEDIUM SOIL SITES AND MODERATELY-DAMPED ISOLATION SYSTEMS (11% - 20%)

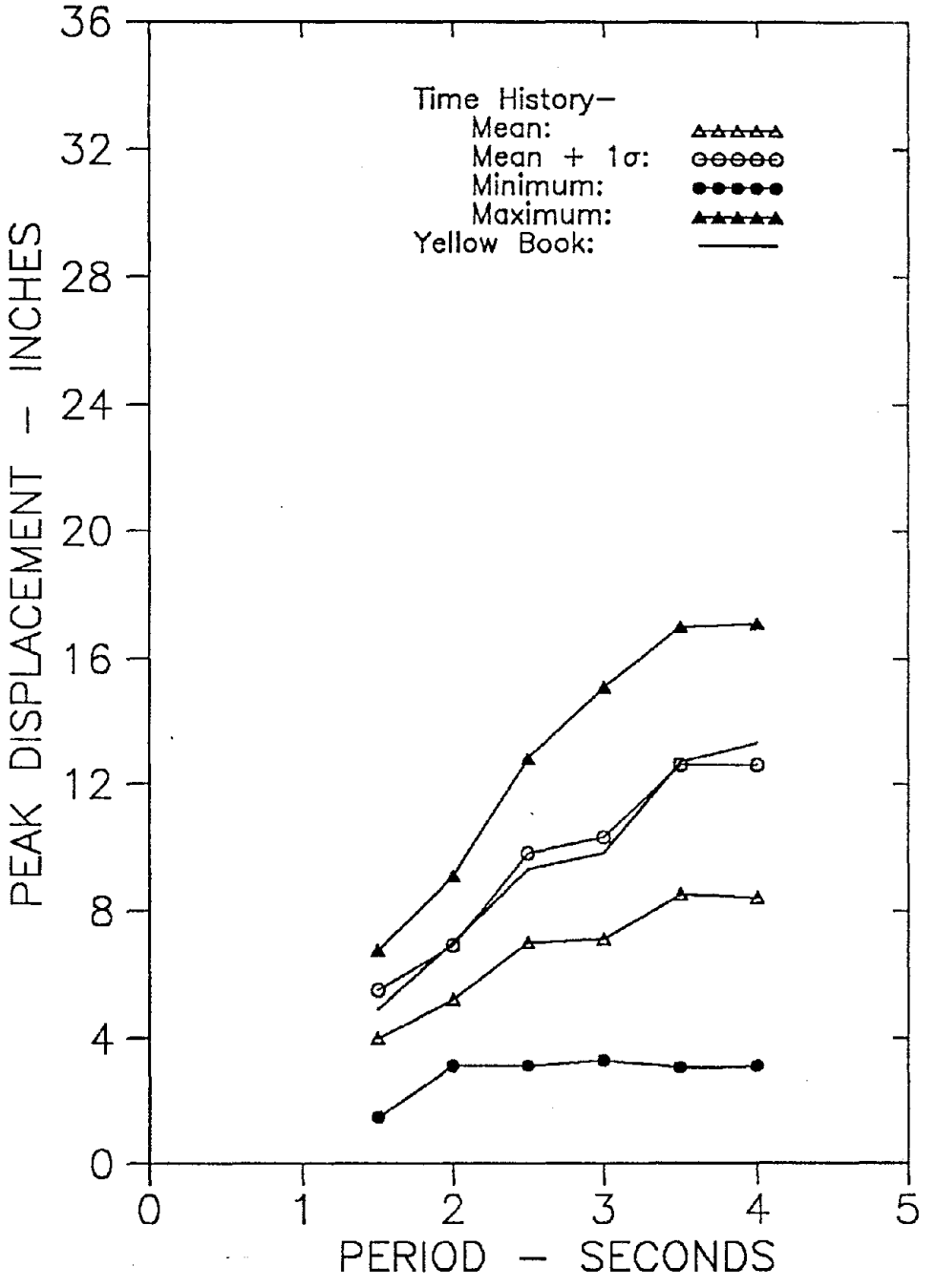

FIGURE 6-8 COMPARISON OF THE PEAK DISPLACEMENT OF TIME HISTORY ANALYSES WITH THE DESIGN DISPLACEMENT, D, PRESCRIBED BY THE YELLOW BOOK [REF. 3] - MEDIUM SOIL SITES AND HIGHLY-DAMPED ISOLATION SYSTEMS (21% - 40%)

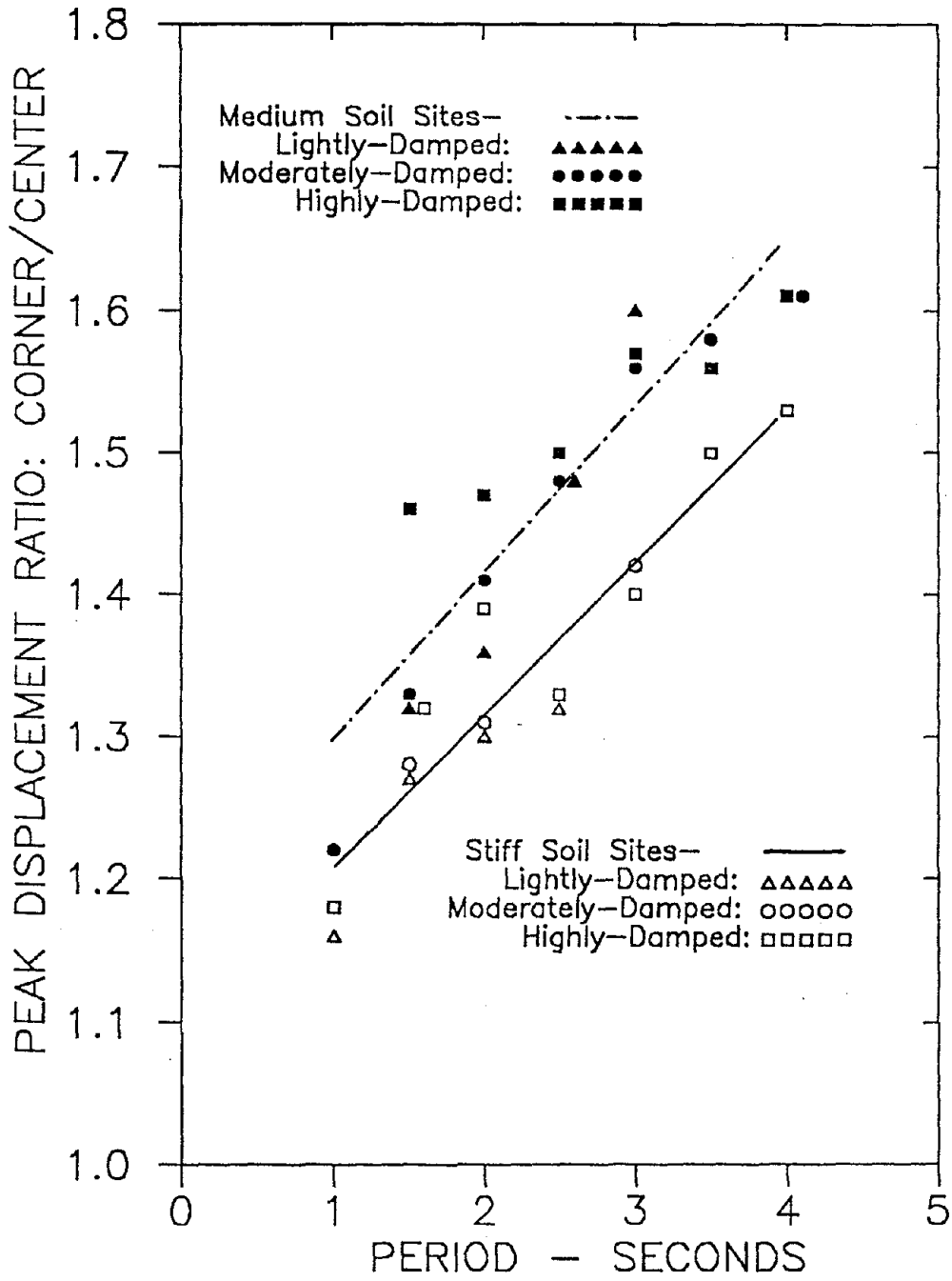

FIGURE 6-9 TRENDS IN THE PEAK DISPLACEMENT RATIO: CORNER/CENTER AS A FUNCTION OF EFFECTIVE PERIOD

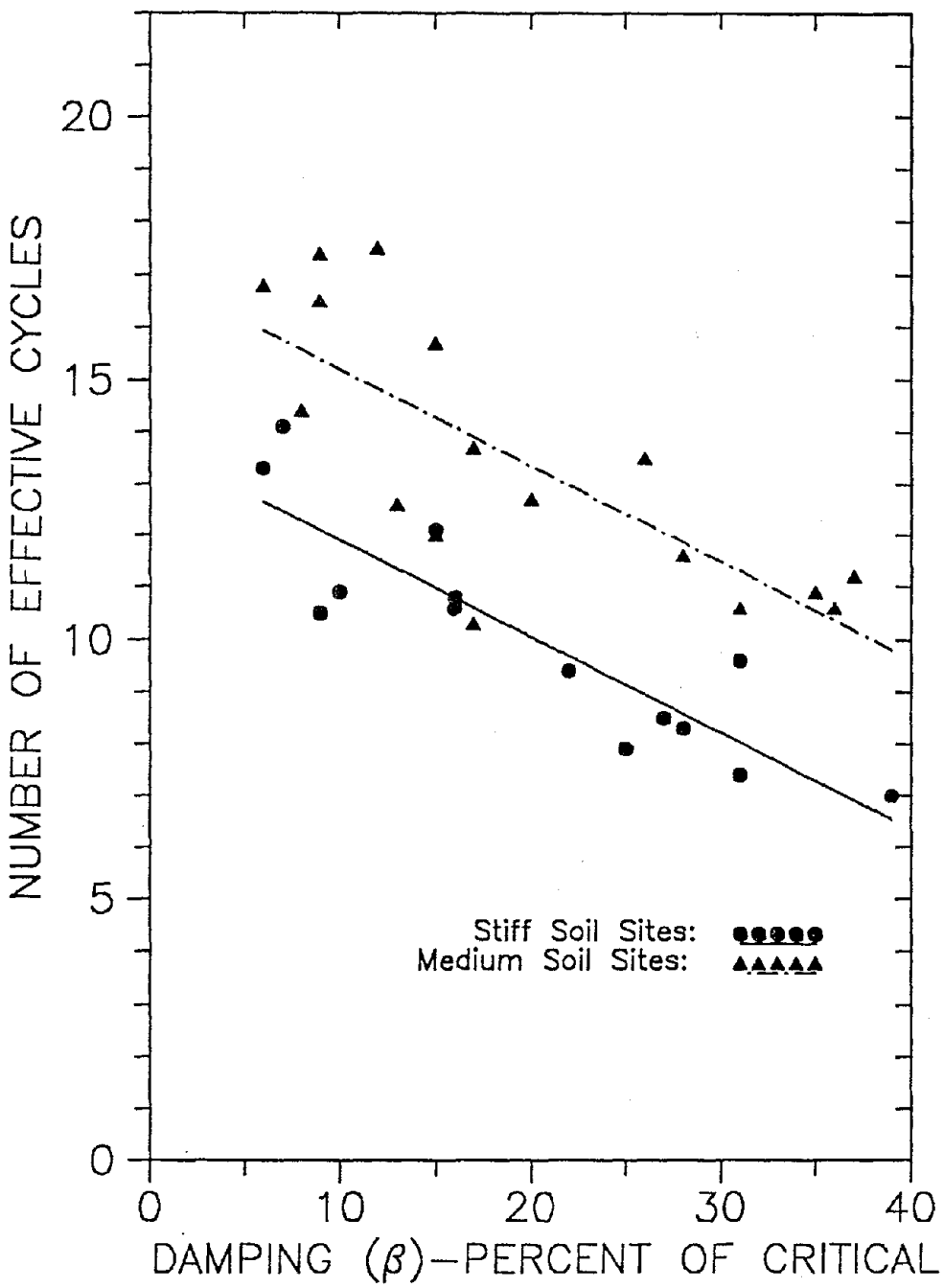

FIGURE 6-10 TRENDS IN THE NUMBER OF EFFECTIVE CYCLES OF FULL-AMPLITUDE RESPONSE AS A FUNCTION OF EFFECTIVE PERIOD

7. CONCLUSION

7.1 Summary

This study rigorously calculated the seismic response of 31 different isolated buildings using nonlinear time history analysis. The buildings were modeled as rigid structures supported by bilinear, hysteretic isolators whose properties were varied from model to model to produce effective periods of 1.0 to 4.0 seconds and effective damping values of 5% to 40% of critical.

Each isolated building was analyzed using a set of earthquake time histories that represent the Seismic Zone 4 ground motion criteria of current building codes for a structure located at either a rock, stiff soil or medium soil site. Multiple time histories were used for each site condition to evaluate the variation in calculated response as a function of the inherent variability of ground motion. In total, 866 individual time history analyses were performed.

The primary purpose of the study was to create a collection of nonlinear response data that could be used to evaluate key design requirements for isolated buildings, such as the design displacement of the isolation system. Accordingly, the study has compared calculated responses with the design requirements proposed by the Structural Engineers Association of California (SEAOC) for design of isolated buildings. The results of these comparisons provide a basis for judging the validity and applicability of the SEAOC design requirements, and for modifying the requirements, as appropriate.

The key findings of this study are summarized below:

(1) **Time History Analysis** - A set of earthquake time histories that represents both the level and inherent variability of the design-basis event can produce peak displacement results that vary greatly from one analysis to another.

For example, the maximum (or minimum) value of peak displacement of a set of nine or ten time history analyses was found to be as much as 3 times greater (or 3 times less) than the mean peak displacement of the time history analyses.

(2) **Static Analysis** - Static analysis (i.e., peak response based on the value of the design spectrum at the effective period and effective damping of the isolated building) is a reasonably accurate and conservative method for calculating the mean peak displacement of the isolation system.

For example, the peak displacement calculated using the static analysis method was found usually to be 10% to 20% greater than the mean peak displacement of the time history analyses.

(3) **Design Displacement Formula** - The SEAOC formula for design displacement (i.e., repeated as Equation (2-1) of Chapter 2) prescribes a peak displacement for design of the isolation system that is generally conservative with respect to the mean peak displacement calculated using time history analysis.

For example, the value of the design displacement prescribed by Equation (2-1) for isolated buildings at medium soil sites was found consistently to be between the mean and mean + 1σ values of peak displacement of the time history analyses.

(4) **Torsion** - The additional displacement due to torsion can be a significant contributor to the total displacement of the isolation system.

For example, a 5% mass eccentricity was found by time history analysis to generate, on the average, 35% to 45% additional displacement in the isolation systems of buildings with a 2-second effective period.

(5) **Number of Test Cycles** - The 10 cycles of full-amplitude response proposed by SEAOC for testing the durability of isolator prototypes does not appear to be sufficient to envelop maximum cyclic response of the isolation system.

For example, 20 (15) cycles would need to be specified for prototype testing to envelop the maximum response of isolated buildings at medium (stiff) soil sites.

7.2 Recommendations for Additional Research

This study has calculated the peak and cyclic response of isolated buildings that were modeled by a rigid superstructure with bilinear, hysteretic isolators. While these modeling assumptions are reasonable for the determination of the peak displacement of most currently-available isolation systems, they are neither comprehensive of all isolation systems nor are they appropriate, in general, for evaluating peak force in the superstructure. Accordingly, the following topics are recommended for additional research related to the development and evaluation of design requirements for isolated buildings.

(1) **Complex Isolation Systems** - The response of buildings with isolation systems that can not be accurately modeled using bilinear, hysteretic elements should be investigated. Such systems include, hardening systems (e.g., systems with a displacement limiting device), pure sliding systems and other systems whose properties are sensitive to either the rate of load, cross-axis load or variation in vertical load. A necessary prerequisite for these studies would be additional research, as required, to develop the appropriate models of such isolation systems.

(2) **Isolated Structures with a Flexible Superstructure** - The response of isolated buildings with a flexible superstructure should be investigated. Of particular interest would be the identification of trends in the amplification (or deamplification) of the peak response of the superstructure as a function of superstructure and isolation system nonlinearity.

(3) **Torsion** - The peak torsional response of the isolation system should be investigated for buildings with varying degrees of mass eccentricity. Of particular interest would be the identification of trends in torsional response as a function of isolation system stiffness and configuration.

8. REFERENCES

1. Seismology Committee of the Structural Engineers Association of California, Recommended Lateral Force Requirements and Tentative Commentary, (Blue Book), San Francisco, California, 1988.

2. International Congress of Building Officials, Uniform Building Code, Whittier, California, 1988 Edition.

3. Structural Engineers Association of Northern California, Tentative Seismic Isolation Design Requirements, (Yellow Book), San Francisco, California, September 1986.

4. Anderson, T. L., "Seismic Isolation for the Los Angeles County Fire Command and Control Facility," Proceedings of the 1989 ASCE Structures Congress, San Francisco, California, May 1988.

5. Kariotis, J. C., Ewing, R. D., and Dewdney, H. S., "Draft Guidelines for the Design of Buildings with Base Isolators," Proceedings of a Seminar and Workshop on Base Isolation and Passive Energy Dissipation, ATC-17, Applied Technology Council, Redwood City, California, 1986.

6. Ad Hoc Subcommittee of the Seismology Committee of the Structural Engineers Association of California, Tentative General Requirements for the Design and Construction of Seismic-Isolated Structures, Draft Appendix to Chapter 1 of the SEAOC BLue Book, March 1989, draft.

7. Applied Technology Council, Tentative Provisions for the Development of Seismic Regulations for Buildings, ATC 3-06, NBS 510, NSF 78-8, Washington, D.C., June 1978.

8. Seed, H. B., Ugas, C. and Lysmer, J., "Site-Dependent Spectra for Earthquake-Resistant Design," EERC 74-12, University of California at Berkeley, November 1974.

9. Powell, G. H., Drain-2D User Guide, EERC Report 73-22, Earthquake Engineering Research Center, University of California at Berkeley, October 1973.

10. Analyses of Strong Motion Earthquake Accelerograms, Earthquake Engineering Research Laboratory, California Institute of Technology, Report No. EERL 75-80, Vol. III, Part T, 1975.

11. Newmark, N. M., and Hall, W. J., Earthquake Spectra and Design, Earthquake Engineering Research Institute, 1982.

JBA 109-070

STATISTICAL EVALUATION OF NONLINEAR RESPONSE OF SEISMIC ISOLATION SYSTEMS (VOLUME II)

BY

CHARLES A. KIRCHER
BAHMAN LASHKARI

JUNE 30, 1989

Jack R. Benjamin & Associates, Inc.
Consulting Engineers
Mountain Bay Plaza, Suite 501
444 Castro Street, Mountain View, California 94041

JBA 109-070
June 30, 1989

STATISTICAL EVALUATION OF NONLINEAR RESPONSE OF SEISMIC ISOLATION SYSTEMS (Volume II)

by

Charles A. Kircher
Bahman Lashkari

June 30, 1989

This study is based on work supported in part by the National Science Foundation under Grant No. CES-8901279.

Any opinions, findings and conclusions or recommendations expressed in this study are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Jack R. Benjamin & Associates, Inc.
Consulting Engineers
Mountain Bay Plaza, Suite 501
444 Castro Street, Mountain View, California 94041

ACKNOWLEDGEMENT

This study was supported in part by the National Science Foundation (NSF) under Grant No. CES-8901279 with Dr. Andrew J. Eggenberger serving as the cognizant NSF program official. The support provided by the NSF is gratefully acknowledged.

The earthquake records used in this study were obtained with assistance provided by Dr. Omar Khemici. The authors would like to thank Dr. Khemici for his contribution to this study.

EXECUTIVE SUMMARY

This study rigorously calculated the seismic response of 31 different isolated buildings using nonlinear time history analysis. The buildings were modeled as rigid structures supported by bilinear, hysteretic isolators whose properties were varied from model to model to produce effective periods of 1.0 to 4.0 seconds and effective damping values of 5% to 40% of critical.

Each isolated building was analyzed using a set of earthquake time histories that represent the Seismic Zone 4 ground motion criteria of current building codes for a structure located at either a rock, stiff soil or medium soil site. Multiple time histories were used for each site condition to evaluate the variation in calculated response as a function of the inherent variability of ground motion. In total, 866 individual time history analyses were performed.

The primary purpose of the study was to create a collection of nonlinear response data that could be used to evaluate key design requirements for isolated buildings, such as the design displacement of the isolation system. Accordingly, the study has compared calculated responses with the design requirements proposed by the Structural Engineers Association of California (SEAOC) for design of isolated buildings. The results of these comparisons provide a basis for judging the validity and applicability of the SEAOC design requirements, and for modifying the requirements, as appropriate.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

A. TABLES SUMMARIZING THE NONLINEAR RESPONSE OF VARIOUS ISOLATED BUILDINGS SUBJECTED TO 0.4G PGA-SCALED HORIZONTAL EARTHQUAKE TIME HISTORIES RECORDED AT ROCK SITES

A.1 Description of Appendix A

Each of the fourteen tables of Appendix A summarize the response results of 10 nonlinear analyses of an isolated building model. Each isolated building model is characterized by an equivalent linear period, with values ranging from 1.0 to 4.0 seconds, and by an equivalent viscous damping factor, with values ranging from 5% to 40% of critical.

The isolated building models were analyzed using pairs of horizontal time history components recorded at rock sites during past earthquakes. Each pair of earthquake components was scaled to have an average peak ground acceleration (PGA) of 0.4g. Additional description of the earthquake components used in the analyses may be found in Chapter 4 of this report.

The isolated building models were identical with exception of the isolation system. In plan, the isolated building is rectangular with eight 20-foot bays in the longitudinal direction and four 20-foot bays in the transverse direction. The superstructure was modeled as essentially rigid with respect to the isolation system. The force-deflection properties of the isolator units (45 total per model) were modeled by a bi-linear element with a different yield point and a different degree of yielding for each model. Additional description of the isolated building models analyzed in this study may be found in Chapter 5 of this report.

The nonlinear analyses were performed using DRAIN-2D [Ref. 9] compiled for execution on micro-computers. For the analyses of this study the degrees of freedom of the models consisted of translational and torsional response of the isolated building in the plane of the isolation system.

A.2 Description of Response Parameters

Each of the fourteen tables presents a summary of calculated responses, grouped as follows:

1. Peak Response in the Transverse Direction

2. Peak Response in the Longitudinal Direction

3. Peak Response in the Transverse and Longitudinal Directions

4. Cyclic Response in the Transverse and Longitudinal Directions

For the first three response groups, listed above, the parameters reported in the tables are identically:

1. Peak Force at the Center of Gravity of the Building

2. Peak Displacement at the Center of the Building

3. Peak Displacement at the Corner of the Building

Peak displacement of the corner of the building was based on the corner of the model which gave the largest response. Comparison of peak displacements, corner vs. center, provides a measure of the isolated building's torsional response.

For the fourth response group the parameters reported in the tables are:

1. One-Half of the Cumulative Inelastic Displacement

2. One-Half of the Maximum Peak-to-Peak Displacement

3. Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements

Elements of the models representing response at the center of the building were used to evaluate each of the above parameters. One-half of the maximum peak-to-peak displacement is the average of the positive and negative peaks. Comparison of this parameter with the peak displacement at the building's center is helpful in checking for biased response of highly nonlinear systems. The ratio of cumulative inelastic displacement to maximum peak-to-peak displacement provides a measure of the effective number of high amplitude cycles.

A.3 Description of Statistical Parameters

For each response parameter of interest the following statistical information is provided:

1. Maximum of Set (Earthquake Record No.)

2. Minimum of Set (Earthquake Record No.)

3. Mean of Set

4. Standard Deviation of Set

5. Median of Lognormal

6. Beta of Lognormal

For response parameters of either the transverse direction or longitudinal direction, the number of values in the set is ten, the number of earthquake pairs. For response parameters of combined transverse and longitudinal directions, the number of values in the set is twenty, one value from each direction for each earthquake pair. Earthquake record numbers refer to the earthquake component identifiers of Table 4.1. The median and β parameters are calculated based on an assumption that the response parameter of interest is lognormally distributed.

Table A.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.371 (2T)	3.67 (2T)	4.35 (2T)
Minimum of Set (Eq. Rec. No.)	0.131 (8T)	0.87 (8T)	1.02 (9T)
Mean of Set	0.199	1.66	2.03
Standard Deviation of Set	0.077	0.91	0.99
Median of Lognormal	0.185	1.45	1.82
β of Lognormal	0.38	0.51	0.46

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.388 (2L)	3.86 (2L)	4.22 (2L)
Minimum of Set (Eq. Rec. No.)	0.114 (9L)	0.66 (9L)	0.70 (9L)
Mean of Set	0.225	1.97	2.20
Standard Deviation of Set	0.101	1.18	1.33
Median of Lognormal	0.206	1.69	1.89
β of Lognormal	0.43	0.55	0.56

Table A.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.388 (2L)	3.86 (2L)	4.35 (2T)
Minimum of Set (Eq. Rec. No.)	0.114 (9L)	0.66 (9L)	0.70 (9L)
Mean of Set	0.212	1.81	2.11
Standard Deviation of Set	0.091	1.06	1.17
Median of Lognormal	0.195	1.56	1.85
β of Lognormal	0.41	0.54	0.52

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	47.9 (2L)	3.53 (2L)	13.6 (2L)
Minimum of Set (Eq. Rec. No.)	0.74 (9L)	0.64 (9L)	1.16 (9L)
Mean of Set	8.46	1.66	3.8
Standard Deviation of Set	11.71	1.00	2.9
Median of Lognormal	4.96	1.43	3.0
β of Lognormal	1.03	0.55	0.68

Table A.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.271 (2T)	2.78 (2T)	2.89 (2T)
Minimum of Set (Eq. Rec. No.)	0.160 (8T)	0.70 (8T)	0.85 (9T)
Mean of Set	0.192	1.29	1.67
Standard Deviation of Set	0.030	0.57	0.65
Median of Lognormal	0.190	1.18	1.56
β of Lognormal	0.16	0.42	0.38

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.247 (1L)	2.32 (1L)	2.61 (1L)
Minimum of Set (Eq. Rec. No.)	0.156 (8L)	0.62 (8L)	0.74 (8L)
Mean of Set	0.196	1.36	1.54
Standard Deviation of Set	0.032	0.61	0.72
Median of Lognormal	0.193	1.24	1.40
β of Lognormal	0.16	0.43	0.44

Table A.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.271 (2T)	2.78 (2T)	2.89 (2T)
Minimum of Set (Eq. Rec. No.)	0.156 (8L)	0.62 (8L)	0.74 (8L)
Mean of Set	0.194	1.33	1.61
Standard Deviation of Set	0.031	0.59	0.69
Median of Lognormal	0.191	1.21	1.48
β of Lognormal	0.161	0.43	0.41

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	18.9 (2L)	2.77 (2T)	9.2 (2L)
Minimum of Set (Eq. Rec. No.)	0.20 (9L)	0.58 (9L)	0.3 (9L)
Mean of Set	3.32	1.17	2.1
Standard Deviation of Set	4.72	0.58	2.0
Median of Lognormal	1.91	1.04	1.6
β of Lognormal	1.05	0.47	0.80

Table A.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.330 (2T)	7.50 (2T)	9.04 (2T)
Minimum of Set (Eq. Rec. No.)	0.070 (8T)	1.01 (8T)	1.20 (8T)
Mean of Set	0.155	3.14	3.86
Standard Deviation of Set	0.092	2.30	2.59
Median of Lognormal	0.134	2.53	3.21
β of Lognormal	0.55	0.66	0.61

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.260 (1L)	5.75 (1L)	7.22 (1L)
Minimum of Set (Eq. Rec. No.)	0.065 (8L)	0.87 (8L)	1.00 (8L)
Mean of Set	0.140	2.76	3.41
Standard Deviation of Set	0.066	1.66	2.11
Median of Lognormal	0.127	2.37	2.90
β of Lognormal	0.448	0.55	0.57

Table A.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.330 (2T)	7.50 (2T)	9.04 (2T)
Minimum of Set (Eq. Rec. No.)	0.065 (8L)	0.87 (8L)	1.00 (8L)
Mean of Set	0.148	2.95	3.64
Standard Deviation of Set	0.080	2.01	2.37
Median of Lognormal	0.130	2.44	3.05
β of Lognormal	0.51	0.62	0.60

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	75.5 (2T)	7.20 (2T)	10.5 (2T)
Minimum of Set (Eq. Rec. No.)	0.68 (8L)	0.73 (8L)	0.9 (8L)
Mean of Set	17.1	2.80	4.7
Standard Deviation of Set	19.7	1.99	2.9
Median of Lognormal	11.2	2.28	4.0
β of Lognormal	0.92	0.64	0.57

Table A.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.244 (7T)	5.73 (7T)	6.47 (7T)
Minimum of Set (Eq. Rec. No.)	0.080 (8T)	0.81 (8T)	1.12 (8T)
Mean of Set	0.133	2.39	3.04
Standard Deviation of Set	0.051	1.54	1.76
Median of Lognormal	0.124	2.01	2.64
β of Lognormal	0.37	0.59	0.54

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.213 (1L)	4.80 (1L)	5.96 (1L)
Minimum of Set (Eq. Rec. No.)	0.079 (4L)	0.76 (4L)	0.84 (4L)
Mean of Set	0.128	2.24	2.76
Standard Deviation of Set	0.044	1.32	1.68
Median of Lognormal	0.121	1.92	2.36
β of Lognormal	0.34	0.55	0.56

Table A.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.244 (7T)	5.73 (7T)	6.47 (7T)
Minimum of Set (Eq. Rec. No.)	0.079 (4L)	0.76 (4L)	0.84 (4L)
Mean of Set	0.130	2.31	2.90
Standard Deviation of Set	0.048	1.44	1.72
Median of Lognormal	0.122	1.96	2.49
β of Lognormal	0.36	0.57	0.55

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	37.2 (2T)	4.98 (7T)	10.3 (2L)
Minimum of Set (Eq. Rec. No.)	0.56 (8L)	0.68 (4L)	0.7 (8L)
Mean of Set	8.81	2.00	3.4
Standard Deviation of Set	10.34	1.29	2.4
Median of Lognormal	5.71	1.68	2.8
β of Lognormal	0.93	0.59	0.64

Table A.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.183 (2T)	4.79 (2T)	6.26 (2T)
Minimum of Set (Eq. Rec. No.)	0.105 (8T)	0.74 (8T)	1.07 (9T)
Mean of Set	0.127	1.87	2.46
Standard Deviation of Set	0.026	1.32	1.57
Median of Lognormal	0.124	1.52	2.08
β of Lognormal	0.20	0.64	0.58

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.157 (10L)	3.43 (10L)	4.21 (10L)
Minimum of Set (Eq. Rec. No.)	0.103 (9L)	0.64 (9L)	0.77 (9L)
Mean of Set	0.125	1.77	2.18
Standard Deviation of Set	0.019	0.98	1.19
Median of Lognormal	0.123	1.55	1.91
β of Lognormal	0.15	0.52	0.51

Table A.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.183 (2T)	4.79 (2T)	6.26 (2T)
Minimum of Set (Eq. Rec. No.)	0.103 (9L)	0.64 (9L)	0.77 (9L)
Mean of Set	0.126	1.82	2.32
Standard Deviation of Set	0.023	1.16	1.40
Median of Lognormal	0.124	1.53	1.99
β of Lognormal	0.18	0.59	0.56

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	23.4 (2L)	4.11 (2T)	9.9 (2L)
Minimum of Set (Eq. Rec. No.)	0.43 (9L)	0.63 (9L)	0.7 (9L)
Mean of Set	4.70	1.55	2.4
Standard Deviation of Set	6.19	1.00	2.0
Median of Lognormal	2.85	1.30	1.8
β of Lognormal	1.00	0.59	0.74

Table A.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.184 (7T)	7.10 (7T)	9.12 (7T)
Minimum of Set (Eq. Rec. No.)	0.040 (9T)	0.91 (9T)	1.31 (8T)
Mean of Set	0.083	2.77	3.91
Standard Deviation of Set	0.047	2.00	2.64
Median of Lognormal	0.072	2.25	3.24
β of Lognormal	0.52	0.65	0.61

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.166 (2L)	6.34 (2L)	8.58 (2L)
Minimum of Set (Eq. Rec. No.)	0.038 (9L)	0.86 (9L)	1.10 (9L)
Mean of Set	0.091	3.12	4.17
Standard Deviation of Set	0.047	2.00	2.73
Median of Lognormal	0.081	2.62	3.49
β of Lognormal	0.48	0.59	0.60

Table A.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.184 (7T)	7.10 (7T)	9.12 (7T)
Minimum of Set (Eq. Rec. No.)	0.038 (9L)	0.86 (9L)	1.10 (9L)
Mean of Set	0.087	2.95	4.04
Standard Deviation of Set	0.047	2.01	2.69
Median of Lognormal	0.077	2.43	3.36
β of Lognormal	0.50	0.62	0.61

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	58.9 (2T)	6.14 (7T)	10.6 (2T)
Minimum of Set (Eq. Rec. No.)	0.70 (3T)	0.74 (9L)	0.8 (3T)
Mean of Set	14.8	2.73	4.4
Standard Deviation of Set	15.9	1.88	2.5
Median of Lognormal	10.1	2.25	3.8
β of Lognormal	0.88	0.62	0.52

Table A.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.147 (7T)	5.75 (7T)	7.75 (7T)
Minimum of Set (Eq. Rec. No.)	0.057 (8T)	0.87 (8T)	1.21 (9T)
Mean of Set	0.084	2.33	3.65
Standard Deviation of Set	0.027	1.47	2.19
Median of Lognormal	0.080	1.97	3.13
β of Lognormal	0.32	0.58	0.56

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.146 (2L)	5.71 (2L)	7.84 (2L)
Minimum of Set (Eq. Rec. No.)	0.057 (8L)	0.90 (8L)	1.12 (8L)
Mean of Set	0.090	2.68	3.56
Standard Deviation of Set	0.033	1.79	2.52
Median of Lognormal	0.085	2.23	2.90
β of Lognormal	0.36	0.61	0.64

Table A.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.147 (7T)	5.75 (7T)	7.84 (2L)
Minimum of Set (Eq. Rec. No.)	0.057 (8T)	0.87 (8T)	1.12 (8L)
Mean of Set	0.087	2.50	3.60
Standard Deviation of Set	0.030	1.65	2.36
Median of Lognormal	0.082	2.09	3.01
β of Lognormal	0.34	0.60	0.60

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	36.2 (2T)	5.30 (7T)	8.9 (2T)
Minimum of Set (Eq. Rec. No.)	0.51 (8L)	0.75 (8L)	0.7 (8L)
Mean of Set	9.16	2.20	3.4
Standard Deviation of Set	10.00	1.41	2.3
Median of Lognormal	6.18	1.85	2.8
β of Lognormal	0.89	0.59	0.61

Table A.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.121 (7T)	4.75 (7T)	6.05 (7T)
Minimum of Set (Eq. Rec. No.)	0.074 (8T)	0.81 (8T)	1.39 (8T)
Mean of Set	0.091	2.21	3.27
Standard Deviation of Set	0.016	1.31	1.71
Median of Lognormal	0.089	1.90	2.90
β of Lognormal	0.17	0.55	0.49

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.120 (2L)	4.65 (2L)	6.62 (2L)
Minimum of Set (Eq. Rec. No.)	0.073 (4L)	0.76 (4L)	0.83 (9L)
Mean of Set	0.092	2.32	3.12
Standard Deviation of Set	0.017	1.43	2.05
Median of Lognormal	0.090	1.98	2.61
β of Lognormal	0.19	0.57	0.60

Table A.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.121 (7T)	4.75 (7T)	6.62 (2L)
Minimum of Set (Eq. Rec. No.)	0.073 (4L)	0.76 (4L)	0.83 (9L)
Mean of Set	0.091	2.27	3.19
Standard Deviation of Set	0.017	1.37	1.89
Median of Lognormal	0.090	1.94	2.75
β of Lognormal	0.18	1.56	0.55

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	25.42 (2T)	4.42 (7T)	7.1 (2L)
Minimum of Set (Eq. Rec. No.)	0.50 (8L)	0.69 (4L)	0.6 (8L)
Mean of Set	6.17	1.84	2.7
Standard Deviation of Set	7.16	1.14	1.9
Median of Lognormal	4.03	1.57	2.2
β of Lognormal	0.92	0.57	0.64

Table A.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.112 (2T)	6.58 (2T)	8.48 (2T)
Minimum of Set (Eq. Rec. No.)	0.035 (9T)	0.91 (9T)	1.26 (8T)
Mean of Set	0.059	2.67	4.17
Standard Deviation of Set	0.027	1.98	2.59
Median of Lognormal	0.054	2.14	3.54
β of Lognormal	0.027	0.66	0.57

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.108 (2L)	6.26 (2L)	9.02 (2L)
Minimum of Set (Eq. Rec. No.)	0.036 (9L)	0.93 (9L)	1.25 (9L)
Mean of Set	0.062	2.89	4.05
Standard Deviation of Set	0.025	1.81	2.64
Median of Lognormal	0.058	2.45	3.40
β of Lognormal	0.38	0.58	0.60

Table A.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.112 (2T)	6.58 (2T)	9.02 (2L)
Minimum of Set (Eq. Rec. No.)	0.035 (9T)	0.91 (9T)	1.25 (9L)
Mean of Set	0.061	2.78	4.11
Standard Deviation of Set	0.026	1.90	2.61
Median of Lognormal	0.056	2.29	3.47
β of Lognormal	0.41	0.62	0.58

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	47.99 (2T)	6.34 (2T)	7.6 (2T)
Minimum of Set (Eq. Rec. No.)	0.62 (3T)	0.78 (9L)	0.8 (3T)
Mean of Set	10.65	2.46	3.5
Standard Deviation of Set	12.34	1.74	2.0
Median of Lognormal	6.96	2.01	3.0
β of Lognormal	0.92	0.64	0.55

Table A.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.095 (7T)	5.61 (7T)	7.58 (7T)
Minimum of Set (Eq. Rec. No.)	0.054 (8T)	0.90 (8T)	1.23 (9T)
Mean of Set	0.066	2.24	3.79
Standard Deviation of Set	0.013	1.50	2.36
Median of Lognormal	0.064	1.86	3.22
β of Lognormal	0.20	0.61	0.57

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.091 (2L)	5.12 (2L)	7.26 (2L)
Minimum of Set (Eq. Rec. No.)	0.054 (9L)	0.95 (9L)	1.19 (9L)
Mean of Set	0.068	2.52	3.50
Standard Deviation of Set	0.014	1.59	2.34
Median of Lognormal	0.067	2.13	2.90
β of Lognormal	0.21	0.58	0.61

Table A.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.095 (7T)	5.61 (7T)	7.58 (7T)
Minimum of Set (Eq. Rec. No.)	0.054 (9L)	0.90 (8T)	1.19 (9L)
Mean of Set	0.067	2.38	3.64
Standard Deviation of Set	0.014	1.55	2.36
Median of Lognormal	0.065	1.99	3.06
β of Lognormal	0.014	0.60	0.59

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	28.65 (2T)	4.52 (7T)	7.89 (2T)
Minimum of Set (Eq. Rec. No.)	0.42 (8L)	0.80 (8T)	0.5 (8L)
Mean of Set	7.23	2.00	3.0
Standard Deviation of Set	7.98	1.27	2.1
Median of Lognormal	4.85	1.69	2.5
β of Lognormal	0.89	0.58	0.62

Table A.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.087 (2T)	7.27 (2T)	10.01 (2T)
Minimum of Set (Eq. Rec. No.)	0.034 (9T)	0.95 (9T)	1.31 (8T)
Mean of Set	0.049	2.75	4.53
Standard Deviation of Set	0.019	2.21	3.04
Median of Lognormal	0.046	2.15	3.76
β of Lognormal	0.37	0.71	0.61

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.073 (2L)	5.52 (2L)	8.22 (2L)
Minimum of Set (Eq. Rec. No.)	0.034 (8L)	0.94 (8L)	1.24 (8L)
Mean of Set	0.049	2.70	3.90
Standard Deviation of Set	0.014	1.59	2.44
Median of Lognormal	0.047	2.32	3.31
β of Lognormal	0.27	0.55	0.57

Table A.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.087 (2T)	7.27 (2T)	10.01 (2T)
Minimum of Set (Eq. Rec. No.)	0.034 (8L)	0.94 (8L)	1.24 (8L)
Mean of Set	0.049	2.72	4.22
Standard Deviation of Set	0.016	1.93	2.77
Median of Lognormal	0.046	2.22	3.52
β of Lognormal	0.33	0.64	0.60

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	41.88 (2T)	6.39 (2T)	7.2 (2L)
Minimum of Set (Eq. Rec. No.)	0.58 (3T)	0.73 (3T)	0.8 (3T)
Mean of Set	8.94	2.28	3.1
Standard Deviation of Set	10.55	1.60	1.9
Median of Lognormal	5.78	1.87	2.7
β of Lognormal	0.93	0.63	0.56

Table A.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.072 (7T)	6.17 (7T)	8.83 (7T)
Minimum of Set (Eq. Rec. No.)	0.052 (8T)	0.92 (8T)	1.28 (9T)
Mean of Set	0.057	2.38	4.19
Standard Deviation of Set	0.007	1.72	2.89
Median of Lognormal	0.057	1.92	2.89
β of Lognormal	0.12	0.65	0.62

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.069 (10L)	5.34 (10L)	8.11 (10L)
Minimum of Set (Eq. Rec. No.)	0.052 (9L)	0.95 (9L)	1.24 (9L)
Mean of Set	0.058	2.50	3.58
Standard Deviation of Set	0.006	1.56	2.38
Median of Lognormal	0.057	2.12	2.98
β of Lognormal	0.11	0.57	0.61

Table A.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.072 (7T)	6.17 (7T)	8.83 (7T)
Minimum of Set (Eq. Rec. No.)	0.052 (8T)	0.92 (8T)	1.24 (9L)
Mean of Set	0.058	2.44	3.89
Standard Deviation of Set	0.006	1.65	2.67
Median of Lognormal	0.057	2.02	3.20
β of Lognormal	0.11	0.61	0.62

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	25.81 (2T)	3.91 (1L)	6.8 (2T)
Minimum of Set (Eq. Rec. No.)	0.42 (8L)	0.76 (8T)	0.5 (8L)
Mean of Set	6.40	1.82	2.9
Standard Deviation of Set	7.09	1.10	1.9
Median of Lognormal	4.29	1.56	2.4
β of Lognormal	0.90	0.56	0.60

Table A.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.069 (2T)	7.77 (2T)	11.31 (2T)
Minimum of Set (Eq. Rec. No.)	0.033 (9T)	0.98 (9T)	1.41 (8T)
Mean of Set	0.043	2.88	4.76
Standard Deviation of Set	0.013	2.36	3.38
Median of Lognormal	0.041	2.23	3.87
β of Lognormal	0.29	0.72	0.64

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.051 (10L)	4.46 (10L)	6.86 (10L)
Minimum of Set (Eq. Rec. No.)	0.032 (8L)	0.91 (8L)	1.20 (8L)
Mean of Set	0.041	2.52	3.71
Standard Deviation of Set	0.007	1.34	2.11
Median of Lognormal	0.040	2.23	3.22
β of Lognormal	0.17	0.50	0.53

Table A.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.069 (2T)	7.77 (2T)	11.31 (2T)
Minimum of Set (Eq. Rec. No.)	0.032 (8L)	0.91 (8L)	1.20 (8L)
Mean of Set	0.042	2.70	4.23
Standard Deviation of Set	0.010	1.93	2.87
Median of Lognormal	0.041	2.20	3.50
β of Lognormal	0.24	0.64	0.62

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	38.20 (2T)	5.73 (2T)	7.2 (2L)
Minimum of Set (Eq. Rec. No.)	0.53 (3T)	0.72 (3T)	0.7 (3T)
Mean of Set	8.06	2.17	2.9
Standard Deviation of Set	9.60	1.44	1.9
Median of Lognormal	5.19	1.81	2.5
β of Lognormal	0.94	0.60	0.59

Table A.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.056 (2T)	8.10 (2T)	12.27 (2T)
Minimum of Set (Eq. Rec. No.)	0.032 (9T)	1.00 (9T)	1.41 (9T)
Mean of Set	0.039	2.99	4.91
Standard Deviation of Set	0.009	2.46	3.66
Median of Lognormal	0.038	2.31	3.94
β of Lognormal	0.22	0.72	0.66

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.044 (10L)	4.47 (10L)	6.97 (10L)
Minimum of Set (Eq. Rec. No.)	0.031 (8L)	0.87 (8L)	1.15 (8L)
Mean of Set	0.037	2.51	3.75
Standard Deviation of Set	0.004	1.28	2.07
Median of Lognormal	0.037	2.23	3.29
β of Lognormal	0.12	0.48	0.52

Table A.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.056 (2T)	8.10 (2T)	12.27 (2T)
Minimum of Set (Eq. Rec. No.)	0.031 (8L)	0.87 (8L)	1.15 (8L)
Mean of Set	0.038	2.75	4.33
Standard Deviation of Set	0.007	1.98	3.03
Median of Lognormal	0.037	2.23	3.55
β of Lognormal	0.18	0.65	0.63

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	35.3 (2T)	5.77 (2T)	7.4 (2L)
Minimum of Set (Eq. Rec. No.)	0.48 (3T)	0.73 (3T)	0.7 (3T)
Mean of Set	7.52	2.11	2.8
Standard Deviation of Set	8.91	1.36	1.9
Median of Lognormal	4.85	1.78	2.3
β of Lognormal	0.94	0.59	0.61

B. TABLES SUMMARIZING THE NONLINEAR RESPONSE OF VARIOUS ISOLATED BUILDINGS SUBJECTED TO 12 IN./SEC PGV-SCALED HORIZONTAL EARTHQUAKE TIME HISTORIES RECORDED AT ROCK SITES

B.1 Description of Appendix B

Each of the fourteen tables of Appendix B summarize the response results of 10 nonlinear analyses of an isolated building model. Each isolated building model is characterized by an equivalent linear period, with values ranging from 1.0 to 4.0 seconds, and by an equivalent viscous damping factor, with values ranging from 5% to 40% of critical.

The isolated building models were analyzed using pairs of horizontal time history components recorded at rock sites during past earthquakes. Each pair of earthquake components was scaled to have an average peak ground velocity (PGV) of 12 in./sec. Additional description of the earthquake components used in the analyses may be found in Chapter 4 of this report.

The isolated building models were identical with exception of the isolation system. In plan, the isolated building is rectangular with eight 20-foot bays in the longitudinal direction and four 20-foot bays in the transverse direction. The superstructure was modeled as essentially rigid with respect to the isolation system. The force-deflection properties of the isolator units (45 total per model) were modeled by a bi-linear element with a different yield point and a different degree of yielding for each model. Additional description of the isolated building models analyzed in this study may be found in Chapter 5 of this report.

The nonlinear analyses were performed using DRAIN-2D [Ref. 9] compiled for execution on micro-computers. For the analyses of this study the degrees of freedom of the models consisted of translational and torsional response of the isolated building in the plane of the isolation system.

B.2 Description of Response Parameters

Each of the fourteen tables presents a summary of calculated responses, grouped as follows:

1. Peak Response in the Transverse Direction

2. Peak Response in the Longitudinal Direction

3. Peak Response in the Transverse and Longitudinal Directions

4. Cyclic Response in the Transverse and Longitudinal Directions

For the first three response groups, listed above, the parameters reported in the tables are identically:

1. Peak Force at the Center of Gravity of the Building

2. Peak Displacement at the Center of the Building

3. Peak Displacement at the Corner of the Building

Peak displacement of the corner of the building was based on the corner of the model which gave the largest response. Comparison of peak displacements, corner vs. center, provides a measure of the isolated building's torsional response.

For the fourth response group the parameters reported in the tables are:

1. One-Half of the Cumulative Inelastic Displacement

2. One-Half of the Maximum Peak-to-Peak Displacement

3. Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements

Elements of the models representing response at the center of the building were used to evaluate each of the above parameters. One-half of the maximum peak-to-peak displacement is the average of the positive and negative peaks. Comparison of this parameter with the peak displacement at the building's center is helpful in checking for biased response of highly nonlinear systems. The ratio of cumulative inelastic displacement to maximum peak-to-peak displacement provides a measure of the effective number of high amplitude cycles.

B.3 Description of Statistical Parameters

For each response parameter of interest the following statistical information is provided:

1. Maximum of Set (Earthquake Record No.)

2. Minimum of Set (Earthquake Record No.)

3. Mean of Set

4. Standard Deviation of Set

5. Median of Lognormal

6. Beta of Lognormal

For response parameters of either the transverse direction or longitudinal direction, the number of values in the set is ten, the number of earthquake pairs. For response parameters of combined transverse and longitudinal directions, the number of values in the set is twenty, one value from each direction for each earthquake pair. Earthquake record numbers refer to the earthquake component identifiers of Table 4.1. The median and β parameters are calculated based on an assumption that the response parameter of interest is lognormally distributed.

Table B.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.417 (5T)	4.20 (5T)	4.96 (5T)
Minimum of Set (Eq. Rec. No.)	0.167 (8T)	1.29 (8T)	1.75 (10T)
Mean of Set	0.245	2.20	2.67
Standard Deviation of Set	0.078	0.91	0.92
Median of Lognormal	0.234	2.03	2.55
β of Lognormal	0.31	0.40	0.33

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.373 (1L)	3.69 (1L)	4.33 (1L)
Minimum of Set (Eq. Rec. No.)	0.139 (4L)	0.96 (4L)	1.12 (4L)
Mean of Set	0.248	2.23	2.53
Standard Deviation of Set	0.088	1.03	1.18
Median of Lognormal	0.233	2.02	2.30
β of Lognormal	0.35	0.44	0.44

Table B.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.417 (5T)	4.20 (5T)	4.96 (5T)
Minimum of Set (Eq. Rec. No.)	0.139 (4L)	0.96 (4L)	1.12 (4L)
Mean of Set	0.246	2.21	2.61
Standard Deviation of Set	0.083	0.97	1.06
Median of Lognormal	0.234	2.02	2.42
β of Lognormal	0.33	0.42	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	46.5 (5T)	4.20 (5T)	13.4 (2L)
Minimum of Set (Eq. Rec. No.)	1.65 (1T)	0.91 (9L)	1.3 (1T)
Mean of Set	11.03	2.05	4.8
Standard Deviation of Set	10.52	0.91	2.8
Median of Lognormal	7.98	1.87	4.1
β of Lognormal	0.80	0.43	0.55

Table B.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.268 (6T)	2.72 (6T)	3.36 (6T)
Minimum of Set (Eq. Rec. No.)	0.174 (9T)	0.95 (9T)	1.30 (8T)
Mean of Set	0.202	1.48	1.94
Standard Deviation of Set	0.026	0.49	0.59
Median of Lognormal	0.200	1.41	1.86
β of Lognormal	0.13	0.32	0.30

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.262 (6L)	2.60 (6L)	2.97 (3L)
Minimum of Set (Eq. Rec. No.)	0.168 (4L)	0.8 (4L)	0.93 (4L)
Mean of Set	0.211	1.66	1.90
Standard Deviation of Set	0.033	0.63	0.74
Median of Lognormal	0.209	1.55	1.77
β of Lognormal	0.16	0.37	0.37

Table B.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.268 (6T)	2.72 (6T)	3.36 (6T)
Minimum of Set (Eq. Rec. No.)	0.168 (4L)	0.84 (4L)	0.93 (4L)
Mean of Set	0.207	1.57	1.92
Standard Deviation of Set	0.030	0.57	0.67
Median of Lognormal	0.205	1.48	1.82
β of Lognormal	0.145	0.35	0.34

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	10.71 (2L)	2.32 (3L)	6.9 (2L)
Minimum of Set (Eq. Rec. No.)	0.96 (1T)	0.84 (4L)	1.0 (1T)
Mean of Set	3.68	1.33	2.6
Standard Deviation of Set	2.50	0.46	1.4
Median of Lognormal	3.05	1.26	2.3
β of Lognormal	0.62	0.33	0.49

Table B.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.283 (7T)	6.32 (7T)	7.24 (7T)
Minimum of Set (Eq. Rec. No.)	0.096 (3T)	1.66 (3T)	2.10 (9T)
Mean of Set	0.159	3.22	4.01
Standard Deviation of Set	0.056	1.41	1.54
Median of Lognormal	0.150	2.95	3.74
β of Lognormal	0.35	0.42	0.37

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.271 (1L)	6.03 (1L)	7.58 (1L)
Minimum of Set (Eq. Rec. No.)	0.074 (8L)	1.10 (8L)	1.31 (8L)
Mean of Set	0.151	3.03	3.74
Standard Deviation of Set	0.057	1.42	1.80
Median of Lognormal	0.142	2.75	3.37
β of Lognormal	0.36	0.45	0.46

Table B.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.283 (7T)	6.32 (7T)	7.58 (1L)
Minimum of Set (Eq. Rec. No.)	0.074 (8L)	1.10 (8L)	1.31 (8L)
Mean of Set	0.155	3.13	3.87
Standard Deviation of Set	0.057	1.42	1.69
Median of Lognormal	0.146	2.85	3.55
β of Lognormal	0.35	0.43	0.42

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	38.8 (5T)	6.15 (7T)	11.2 (5L)
Minimum of Set (Eq. Rec. No.)	1.9 (3T)	1.07 (8L)	1.7 (3T)
Mean of Set	17.5	2.98	5.4
Standard Deviation of Set	11.8	1.41	2.7
Median of Lognormal	14.5	2.69	4.8
β of Lognormal	0.61	0.45	0.48

Table B.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.238 (7T)	5.55 (7T)	6.25 (7T)
Minimum of Set (Eq. Rec. No.)	0.222 (1T)	1.58 (1T)	2.05 (4T)
Mean of Set	0.145	2.75	3.61
Standard Deviation of Set	0.038	1.15	1.24
Median of Lognormal	0.140	2.53	3.42
β of Lognormal	0.26	0.40	0.33

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.222 (1L)	5.08 (1L)	6.34 (1L)
Minimum of Set (Eq. Rec. No.)	0.086 (4L)	0.97 (4L)	1.11 (4L)
Mean of Set	0.135	2.45	3.03
Standard Deviation of Set	0.042	1.27	1.61
Median of Lognormal	0.129	2.17	2.68
β of Lognormal	0.31	0.49	0.50

Table B.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.238 (7T)	5.55 (7T)	6.34 (1L)
Minimum of Set (Eq. Rec. No.)	0.086 (4L)	0.97 (4L)	1.11 (4L)
Mean of Set	0.140	2.60	3.32
Standard Deviation of Set	0.041	1.22	1.46
Median of Lognormal	0.134	2.35	3.04
β of Lognormal	0.29	0.45	0.42

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	26.84 (5T)	4.81 (7T)	10.1 (2L)
Minimum of Set (Eq. Rec. No.)	1.99 (3T)	0.91 (4L)	1.4 (3T)
Mean of Set	9.68	2.25	4.2
Standard Deviation of Set	6.74	1.05	2.3
Median of Lognormal	7.94	2.04	3.7
β of Lognormal	0.63	0.45	0.51

Table B.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.166 (7T)	3.92 (7T)	4.94 (6T)
Minimum of Set (Eq. Rec. No.)	0.113 (8T)	1.19 (8T)	1.42 (10T)
Mean of Set	0.133	2.21	2.93
Standard Deviation of Set	0.017	0.88	1.10
Median of Lognormal	0.132	2.05	2.75
β of Lognormal	0.13	0.38	0.36

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.157 (1L)	3.42 (1L)	4.52 (6L)
Minimum of Set (Eq. Rec. No.)	0.110 (4L)	1.02 (4L)	1.23 (4L)
Mean of Set	0.131	2.08	2.57
Standard Deviation of Set	0.018	0.93	1.11
Median of Lognormal	0.129	1.90	2.36
β of Lognormal	0.14	0.43	0.41

Table B.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.166 (7T)	3.92 (7T)	4.94 (6T)
Minimum of Set (Eq. Rec. No.)	0.110 (4L)	1.02 (4L)	1.23 (4L)
Mean of Set	0.132	2.14	2.75
Standard Deviation of Set	0.018	0.91	1.12
Median of Lognormal	0.131	1.97	2.55
β of Lognormal	0.13	0.41	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	14.83 (2L)	3.45 (7T)	8.45 (2L)
Minimum of Set (Eq. Rec. No.)	0.94 (1T)	0.88 (9L)	0.94 (1T)
Mean of Set	5.44	1.80	2.93
Standard Deviation of Set	3.84	0.78	1.71
Median of Lognormal	4.45	1.65	2.53
β of Lognormal	0.64	0.41	0.54

Table B.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.179 (7T)	6.91 (7T)	8.88 (7T)
Minimum of Set (Eq. Rec. No.)	0.054 (3T)	1.54 (3T)	2.20 (3T)
Mean of Set	0.093	3.22	4.60
Standard Deviation of Set	0.035	1.51	1.98
Median of Lognormal	0.087	2.92	4.22
β of Lognormal	0.36	0.45	0.41

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.166 (1L)	6.31 (1L)	8.55 (1L)
Minimum of Set (Eq. Rec. No.)	0.057 (8L)	1.66 (8L)	2.19 (8L)
Mean of Set	0.099	3.45	4.62
Standard Deviation of Set	0.035	1.50	2.04
Median of Lognormal	0.093	3.17	4.23
β of Lognormal	0.34	0.41	0.42

Table B.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.179 (7T)	6.91 (7T)	8.88 (7T)
Minimum of Set (Eq. Rec. No.)	0.054 (3T)	1.54 (3T)	2.19 (8L)
Mean of Set	0.096	3.34	4.61
Standard Deviation of Set	0.035	1.51	2.01
Median of Lognormal	0.090	3.04	4.23
β of Lognormal	0.35	0.43	0.42

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	55.9 (5T)	5.98 (7T)	13.7 (5T)
Minimum of Set (Eq. Rec. No.)	1.6 (3T)	1.09 (3T)	1.5 (3T)
Mean of Set	18.8	3.07	5.8
Standard Deviation of Set	13.5	1.43	3.1
Median of Lognormal	15.3	2.78	5.1
β of Lognormal	0.65	0.44	0.50

Table B.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.144 (7T)	5.59 (7T)	7.53 (7T)
Minimum of Set (Eq. Rec. No.)	0.067 (1T)	1.42 (1T)	1.9 (9T)
Mean of Set	0.091	2.71	4.08
Standard Deviation of Set	0.022	1.19	1.59
Median of Lognormal	0.088	2.48	3.80
β of Lognormal	0.24	0.42	0.38

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.147 (1L)	5.74 (1L)	7.73 (1L)
Minimum of Set (Eq. Rec. No.)	0.062 (9L)	1.13 (9L)	1.41 (9L)
Mean of Set	0.095	2.95	3.94
Standard Deviation of Set	0.026	1.41	1.97
Median of Lognormal	0.092	2.66	3.52
β of Lognormal	0.27	0.45	0.47

Table B.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.147 (1L)	5.74 (1L)	7.73 (1L)
Minimum of Set (Eq. Rec. No.)	0.062 (9L)	1.13 (9L)	1.41 (9L)
Mean of Set	0.093	2.83	4.01
Standard Deviation of Set	0.024	1.31	1.79
Median of Lognormal	0.090	2.57	3.66
β of Lognormal	0.26	0.44	0.43

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	30.13 (5T)	5.15 (7T)	8.8 (5T)
Minimum of Set (Eq. Rec. No.)	1.60 (3T)	1.10 (9L)	1.2 (1T)
Mean of Set	10.57	2.48	4.0
Standard Deviation of Set	7.52	1.16	2.1
Median of Lognormal	8.61	2.25	3.5
β of Lognormal	0.64	0.45	0.50

Table B.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.119 (7T)	4.60 (7T)	5.86 (7T)
Minimum of Set (Eq. Rec. No.)	0.081 (1T)	1.41 (1T)	2.32 (9T)
Mean of Set	0.095	2.60	3.79
Standard Deviation of Set	0.012	0.96	0.99
Median of Lognormal	0.095	2.44	3.67
β of Lognormal	0.12	0.36	0.26

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.113 (1L)	4.11 (1L)	5.37 (1L)
Minimum of Set (Eq. Rec. No.)	0.077 (4L)	1.05 (4L)	1.24 (4L)
Mean of Set	0.093	2.43	3.21
Standard Deviation of Set	0.013	1.05	1.43
Median of Lognormal	0.092	2.23	2.93
β of Lognormal	0.14	0.41	0.43

Table B.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.119 (7T)	4.60 (7T)	5.86 (7T)
Minimum of Set (Eq. Rec. No.)	0.077 (4L)	1.05 (4L)	1.24 (4L)
Mean of Set	0.094	2.51	3.50
Standard Deviation of Set	0.012	1.01	1.26
Median of Lognormal	0.093	2.33	3.29
β of Lognormal	0.13	0.39	0.35

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	20.55 (5T)	4.29 (7T)	7.5 (5T)
Minimum of Set (Eq. Rec. No.)	1.72 (1T)	0.94 (4L)	1.2 (3T)
Mean of Set	7.05	2.12	3.2
Standard Deviation of Set	4.94	0.91	1.8
Median of Lognormal	5.78	1.95	2.8
β of Lognormal	0.63	0.41	0.51

Table B.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.104 (5T)	6.01 (5T)	7.72 (7T)
Minimum of Set (Eq. Rec. No.)	0.044 (1T)	1.50 (1T)	2.21 (9T)
Mean of Set	0.067	3.27	5.05
Standard Deviation of Set	0.021	1.57	1.89
Median of Lognormal	0.064	2.95	4.72
β of Lognormal	0.31	0.46	0.36

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.102 (1L)	5.83 (1L)	8.29 (1L)
Minimum of Set (Eq. Rec. No.)	0.042 (9L)	1.36 (9L)	1.91 (9L)
Mean of Set	0.066	3.17	4.46
Standard Deviation of Set	0.020	1.47	2.11
Median of Lognormal	0.063	2.87	4.03
β of Lognormal	0.29	0.44	0.45

Table B.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.104 (5T)	6.01 (5T)	8.29 (1L)
Minimum of Set (Eq. Rec. No.)	0.042 (9L)	1.36 (9L)	1.91 (9L)
Mean of Set	0.067	3.22	4.75
Standard Deviation of Set	0.021	1.52	2.03
Median of Lognormal	0.064	2.91	4.37
β of Lognormal	0.30	0.45	0.41

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	52.3 (5T)	5.72 (5T)	9.8 (5L)
Minimum of Set (Eq. Rec. No.)	1.4 (3T)	1.03 (3T)	1.4 (3T)
Mean of Set	13.4	2.84	4.3
Standard Deviation of Set	11.5	1.40	2.3
Median of Lognormal	10.1	2.55	3.8
β of Lognormal	0.75	0.47	0.49

Table B.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.094 (7T)	5.44 (7T)	7.36 (7T)
Minimum of Set (Eq. Rec. No.)	0.056 (1T)	1.20 (1T)	2.09 (3T)
Mean of Set	0.069	2.66	4.28
Standard Deviation of Set	0.011	1.19	1.72
Median of Lognormal	0.068	2.43	3.97
β of Lognormal	0.15	0.43	0.39

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.088 (1L)	4.80 (1L)	6.71 (1L)
Minimum of Set (Eq. Rec. No.)	0.055 (9L)	1.03 (9L)	1.43 (9L)
Mean of Set	0.071	2.85	3.97
Standard Deviation of Set	0.012	1.30	1.89
Median of Lognormal	0.070	2.59	3.58
β of Lognormal	0.16	0.44	0.45

Table B.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.094 (7T)	5.44 (7T)	7.36 (7T)
Minimum of Set (Eq. Rec. No.)	0.055 (9L)	1.03 (9L)	1.43 (9L)
Mean of Set	0.070	2.75	4.12
Standard Deviation of Set	0.011	1.25	1.82
Median of Lognormal	0.069	2.51	3.77
β of Lognormal	0.16	0.43	0.42

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	26.66 (5T)	4.69 (1L)	8.2 (5T)
Minimum of Set (Eq. Rec. No.)	0.80 (1T)	0.95 (1T)	0.8 (1T)
Mean of Set	8.51	0.069	3.6
Standard Deviation of Set	6.38	0.011	2.0
Median of Lognormal	6.81	0.068	3.1
β of Lognormal	0.67	0.15	0.52

Table B.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.110 (5T)	9.95 (5T)	11.01 (5T)
Minimum of Set (Eq. Rec. No.)	0.038 (1T)	1.41 (1T)	2.34 (3T)
Mean of Set	0.057	3.74	5.76
Standard Deviation of Set	0.021	2.54	2.73
Median of Lognormal	0.054	3.09	5.21
β of Lognormal	0.36	0.62	0.45

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.068 (6L)	5.01 (6L)	7.33 (6L)
Minimum of Set (Eq. Rec. No.)	0.037 (9L)	1.37 (9L)	2.00 (9L)
Mean of Set	0.052	3.04	4.45
Standard Deviation of Set	0.011	1.33	1.98
Median of Lognormal	0.050	2.78	4.06
β of Lognormal	0.22	0.42	0.43

Table B.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.110 (5T)	9.95 (5T)	11.01 (5T)
Minimum of Set (Eq. Rec. No.)	0.037 (9L)	1.37 (9L)	2.00 (9L)
Mean of Set	0.055	3.39	5.10
Standard Deviation of Set	0.017	2.06	2.47
Median of Lognormal	0.052	2.90	4.59
β of Lognormal	0.31	0.56	0.46

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	54.60 (5T)	9.07 (5T)	7.1 (5L)
Minimum of Set (Eq. Rec. No.)	1.33 (3T)	0.97 (3T)	1.4 (3T)
Mean of Set	11.81	2.85	3.7
Standard Deviation of Set	11.69	1.79	1.6
Median of Lognormal	8.39	2.41	3.4
β of Lognormal	0.83	0.58	0.43

Table B.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.071 (7T)	5.99 (7T)	8.58 (7T)
Minimum of Set (Eq. Rec. No.)	0.053 (1T)	1.20 (1T)	2.07 (3T)
Mean of Set	0.059	2.87	4.76
Standard Deviation of Set	0.005	1.35	2.17
Median of Lognormal	0.059	2.60	4.33
β of Lognormal	0.09	0.45	0.43

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.067 (10L)	4.91 (10L)	7.46 (10L)
Minimum of Set (Eq. Rec. No.)	0.053 (9L)	1.18 (9L)	1.65 (9L)
Mean of Set	0.059	2.91	4.18
Standard Deviation of Set	0.005	1.38	2.11
Median of Lognormal	0.059	2.63	3.73
β of Lognormal	0.09	0.45	0.48

Table B.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.071 (7T)	5.99 (7T)	8.58 (7T)
Minimum of Set (Eq. Rec. No.)	0.053 (9L)	1.18 (9L)	1.65 (9L)
Mean of Set	0.059	2.91	4.47
Standard Deviation of Set	0.005	1.38	2.16
Median of Lognormal	0.059	2.63	4.03
β of Lognormal	0.09	0.45	0.46

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	26.13 (5T)	4.08 (1L)	8.2 (5T)
Minimum of Set (Eq. Rec. No.)	0.71 (1T)	0.83 (1T)	0.9 (1T)
Mean of Set	7.68	2.10	3.4
Standard Deviation of Set	6.07	0.87	1.9
Median of Lognormal	6.02	1.94	2.9
β of Lognormal	0.70	0.40	0.52

Table B.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.087 (5T)	11.22 (5T)	11.36 (5T)
Minimum of Set (Eq. Rec. No.)	0.035 (1T)	1.38 (1T)	2.29 (3T)
Mean of Set	0.049	4.00	5.99
Standard Deviation of Set	0.015	2.89	2.89
Median of Lognormal	0.046	3.25	5.40
β of Lognormal	0.31	0.65	0.46

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.054 (6L)	4.91 (6L)	7.43 (6L)
Minimum of Set (Eq. Rec. No.)	0.035 (9L)	1.39 (9L)	2.06 (9L)
Mean of Set	0.043	2.92	4.37
Standard Deviation of Set	0.006	1.19	1.86
Median of Lognormal	0.043	2.70	4.02
β of Lognormal	0.15	0.39	0.41

Table B.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.087 (5T)	11.22 (5T)	11.36 (5T)
Minimum of Set (Eq. Rec. No.)	0.035 (1T)	1.38 (1T)	2.06 (9L)
Mean of Set	0.046	3.46	5.18
Standard Deviation of Set	0.012	2.27	2.56
Median of Lognormal	0.044	2.89	4.64
β of Lognormal	0.26	0.60	0.47

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	58.62 (5T)	10.93 (5T)	6.4 (5L)
Minimum of Set (Eq. Rec. No.)	1.18 (1T)	0.96 (3T)	1.1 (1T)
Mean of Set	11.12	2.88	3.4
Standard Deviation of Set	12.36	2.10	1.5
Median of Lognormal	7.43	2.33	3.1
β of Lognormal	0.90	0.65	0.43

Table B.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.069 (5T)	11.62 (5T)	12.56 (5T)
Minimum of Set (Eq. Rec. No.)	0.033 (1T)	1.36 (1T)	2.25 (3T)
Mean of Set	0.043	4.14	6.21
Standard Deviation of Set	0.010	3.00	3.22
Median of Lognormal	0.041	3.35	5.51
β of Lognormal	0.24	0.65	0.49

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.045 (6L)	4.75 (6L)	7.30 (6L)
Minimum of Set (Eq. Rec. No.)	0.033 (9L)	1.40 (9L)	2.08 (8L)
Mean of Set	0.038	2.85	4.33
Standard Deviation of Set	0.004	1.13	1.80
Median of Lognormal	0.038	2.66	4.00
β of Lognormal	0.10	0.38	0.4

Table B.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 12 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Rock Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.069 (5T)	11.62 (5T)	12.56 (5T)
Minimum of Set (Eq. Rec. No.)	0.033 (1T)	1.36 (1T)	2.08 (8L)
Mean of Set	0.040	3.50	5.27
Standard Deviation of Set	0.008	2.36	2.77
Median of Lognormal	0.040	2.90	4.66
β of Lognormal	0.20	0.61	0.49

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	52.72 (5T)	10.60 (5T)	6.1 (5L)
Minimum of Set (Eq. Rec. No.)	0.92 (1T)	0.96 (3T)	0.9 (1T)
Mean of Set	10.27	2.80	3.2
Standard Deviation of Set	11.12	2.01	1.5
Median of Lognormal	6.97	2.28	2.9
β of Lognormal	0.88	0.64	0.43

C. TABLES SUMMARIZING THE NONLINEAR RESPONSE OF VARIOUS ISOLATED BUILDINGS SUBJECTED TO 0.4G PGA-SCALED HORIZONTAL EARTHQUAKE TIME HISTORIES RECORDED AT STIFF SOIL SITES

C.1 Description of Appendix C

Each of the fourteen tables of Appendix C summarize the response results of 10 nonlinear analyses of an isolated building model. Each isolated building model is characterized by an equivalent linear period, with values ranging from 1.0 to 4.0 seconds, and by an equivalent viscous damping factor, with values ranging from 5% to 40% of critical.

The isolated building models were analyzed using pairs of horizontal time history components recorded at stiff soil sites during past earthquakes. Each pair of earthquake components was scaled to have an average peak ground acceleration (PGA) of 0.4g. Additional description of the earthquake components used in the analyses may be found in Chapter 4 of this report.

The isolated building models were identical with exception of the isolation system. In plan, the isolated building is rectangular with eight 20-foot bays in the longitudinal direction and four 20-foot bays in the transverse direction. The superstructure was modeled as essentially rigid with respect to the isolation system. The force-deflection properties of the isolator units (45 total per model) were modeled by a bi-linear element with a different yield point and a different degree of yielding for each model. Additional description of the isolated building models analyzed in this study may be found in Chapter 5 of this report.

The nonlinear analyses were performed using DRAIN-2D [Ref. 9] compiled for execution on micro-computers. For the analyses of this study the degrees of freedom of the models consisted of translational and torsional response of the isolated building in the plane of the isolation system.

C.2 Description of Response Parameters

Each of the fourteen tables presents a summary of calculated responses, grouped as follows:

1. Peak Response in the Transverse Direction

2. Peak Response in the Longitudinal Direction

3. Peak Response in the Transverse and Longitudinal Directions

4. Cyclic Response in the Transverse and Longitudinal Directions

For the first three response groups, listed above, the parameters reported in the tables are identically:

1. Peak Force at the Center of Gravity of the Building

2. Peak Displacement at the Center of the Building

3. Peak Displacement at the Corner of the Building

Peak displacement of the corner of the building was based on the corner of the model which gave the largest response. Comparison of peak displacements, corner vs. center, provides a measure of the isolated building's torsional response.

For the fourth response group the parameters reported in the tables are:

1. One-Half of the Cumulative Inelastic Displacement

2. One-Half of the Maximum Peak-to-Peak Displacement

3. Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements

Elements of the models representing response at the center of the building were used to evaluate each of the above parameters. One-half of the maximum peak-to-peak displacement is the average of the positive and negative peaks. Comparison of this parameter with the peak displacement at the building's center is helpful in checking for biased response of highly nonlinear systems. The ratio of cumulative inelastic displacement to maximum peak-to-peak displacement provides a measure of the effective number of high amplitude cycles.

C.3 Description of Statistical Parameters

For each response parameter of interest the following statistical information is provided:

1. Maximum of Set (Earthquake Record No.)

2. Minimum of Set (Earthquake Record No.)

3. Mean of Set

4. Standard Deviation of Set

5. Median of Lognormal

6. Beta of Lognormal

For response parameters of either the transverse direction or longitudinal direction, the number of values in the set is ten, the number of earthquake pairs. For response parameters of combined transverse and longitudinal directions, the number of values in the set is twenty, one value from each direction for each earthquake pair. Earthquake record numbers refer to the earthquake component identifiers of Table 4.2. The median and β parameters are calculated based on an assumption that the response parameter of interest is lognormally distributed.

Table C.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.618 (6T)	6.55 (6T)	6.79 (6T)
Minimum of Set (Eq. Rec. No.)	0.18 (3T)	1.44 (3T)	1.72 (3T)
Mean of Set	0.354	3.46	3.94
Standard Deviation of Set	0.137	1.60	1.63
Median of Lognormal	0.33	3.14	3.65
β of Lognormal	0.37	0.44	0.40

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.444 (10L)	4.52 (10L)	5.06 (10L)
Minimum of Set (Eq. Rec. No.)	0.161 (3L)	1.12 (3L)	1.38 (3L)
Mean of Set	0.322	3.10	3.52
Standard Deviation of Set	0.101	1.18	1.37
Median of Lognormal	0.307	2.89	3.28
β of Lognormal	0.31	0.37	0.38

Table C.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.618 (6T)	6.55 (6T)	6.79 (6T)
Minimum of Set (Eq. Rec. No.)	0.161 (3L)	1.21 (3L)	1.38 (3L)
Mean of Set	0.338	3.28	3.73
Standard Deviation of Set	0.122	1.42	1.52
Median of Lognormal	0.318	3.01	3.46
β of Lognormal	0.35	0.42	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	58.3 (6T)	5.81 (6T)	10.5 (6L)
Minimum of Set (Eq. Rec. No.)	3.80 (3T)	1.10 (3L)	3.3 (3T)
Mean of Set	24.9	2.99	7.9
Standard Deviation of Set	14.1	1.36	2.0
Median of Lognormal	21.7	2.73	7.6
β of Lognormal	0.53	0.43	0.25

Table C.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.384 (6T)	4.91 (6T)	5.09 (6T)
Minimum of Set (Eq. Rec. No.)	0.187 (3T)	1.20 (3T)	1.81 (3T)
Mean of Set	0.260	2.58	3.02
Standard Deviation of Set	0.053	1.00	0.94
Median of Lognormal	0.255	2.40	2.89
β of Lognormal	0.20	0.38	0.30

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.298 (1L)	3.28 (1L)	3.74 (1L)
Minimum of Set (Eq. Rec. No.)	0.195 (9L)	1.36 (9L)	1.49 (9L)
Mean of Set	0.241	2.22	2.56
Standard Deviation of Set	0.037	0.70	0.76
Median of Lognormal	0.238	2.11	2.45
β of Lognormal	0.24	0.31	0.29

Table C.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.384 (6T)	4.91 (6T)	5.09 (6T)
Minimum of Set (Eq. Rec. No.)	0.187 (3T)	1.20 (3T)	1.49 (9L)
Mean of Set	0.251	2.40	2.79
Standard Deviation of Set	0.047	0.88	0.88
Median of Lognormal	0.246	2.25	2.66
β of Lognormal	0.19	0.36	0.31

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	23.3 (2T)	4.56 (6T)	8.45 (2T)
Minimum of Set (Eq. Rec. No.)	1.45 (3T)	1.01 (3T)	1.44 (3T)
Mean of Set	11.0	2.12	4.9
Standard Deviation of Set	5.97	0.81	1.86
Median of Lognormal	9.72	1.98	4.6
β of Lognormal	0.51	0.37	0.37

Table C.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.601 (8T)	14.27 (8T)	16.40 (8T)
Minimum of Set (Eq. Rec. No.)	0.115 (3T)	2.14 (3T)	2.52 (3T)
Mean of Set	0.272	6.06	7.63
Standard Deviation of Set	0.143	3.56	3.98
Median of Lognormal	0.241	5.22	6.77
β of Lognormal	0.49	0.55	0.49

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.428 (6L)	9.95 (6L)	12.68 (6L)
Minimum of Set (Eq. Rec. No.)	0.078 (3L)	1.20 (3L)	1.62 (3L)
Mean of Set	0.231	5.02	6.39
Standard Deviation of Set	0.098	2.44	3.13
Median of Lognormal	0.212	4.51	5.73
β of Lognormal	0.41	0.46	0.46

Table C.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.601 (8T)	14.27 (8T)	16.40 (8T)
Minimum of Set (Eq. Rec. No.)	0.078 (3L)	1.20 (3L)	1.62 (3L)
Mean of Set	0.251	5.54	7.01
Standard Deviation of Set	0.124	3.10	3.64
Median of Lognormal	0.23	4.83	6.22
β of Lognormal	0.47	0.52	0.49

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	173.1 (8T)	13.79 (8T)	13.7 (6T)
Minimum of Set (Eq. Rec. No.)	5.85 (3L)	1.16 (3L)	5.1 (3L)
Mean of Set	54.4	5.23	9.4
Standard Deviation of Set	41.5	3.02	2.6
Median of Lognormal	43.2	4.53	9.1
β of Lognormal	0.68	0.54	0.27

Table C.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.439 (8T)	11.58 (8T)	13.15 (8T)
Minimum of Set (Eq. Rec. No.)	0.096 (3T)	1.28 (3T)	1.98 (3T)
Mean of Set	0.207	4.62	5.83
Standard Deviation of Set	0.095	2.85	2.96
Median of Lognormal	0.188	3.93	5.20
β of Lognormal	0.44	0.57	0.48

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.267 (6L)	6.42 (6L)	8.42 (6L)
Minimum of Set (Eq. Rec. No.)	0.094 (3L)	1.23 (3L)	1.69 (3L)
Mean of Set	0.184	3.91	5.03
Standard Deviation of Set	0.055	1.64	2.23
Median of Lognormal	0.176	3.61	4.59
β of Lognormal	0.29	0.40	0.42

Table C.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.439 (8T)	11.58 (8T)	13.15 (8T)
Minimum of Set (Eq. Rec. No.)	0.094 (3L)	1.23 (3L)	1.69 (3T)
Mean of Set	0.195	4.26	5.43
Standard Deviation of Set	0.078	2.35	2.65
Median of Lognormal	0.181	3.73	4.88
β of Lognormal	0.39	0.52	0.46

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	71.5 (8T)	10.29 (8T)	10.0 (1T)
Minimum of Set (Eq. Rec. No.)	4.25 (3L)	1.19 (3L)	3.6 (3L)
Mean of Set	26.8	3.86	6.6
Standard Deviation of Set	16.7	2.09	1.6
Median of Lognormal	22.8	3.39	6.4
β of Lognormal	0.57	0.51	0.24

Table C.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.207 (5T)	6.02 (5T)	7.24 (8T)
Minimum of Set (Eq. Rec. No.)	0.114 (3T)	1.23 (3T)	1.87 (3T)
Mean of Set	0.160	3.59	4.81
Standard Deviation of Set	0.033	1.70	1.85
Median of Lognormal	0.157	3.24	4.49
β of Lognormal	0.20	0.45	0.37

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.168 (1L)	3.98 (1L)	5.22 (1L)
Minimum of Set (Eq. Rec. No.)	0.112 (3L)	1.13 (3L)	1.53 (3L)
Mean of Set	0.144	2.76	3.55
Standard Deviation of Set	0.017	0.87	1.17
Median of Lognormal	0.143	2.63	3.37
β of Lognormal	0.12	0.31	0.32

Table C.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.207 (5T)	6.02 (5T)	7.24 (8T)
Minimum of Set (Eq. Rec. No.)	0.112 (3L)	1.13 (3L)	1.53 (3L)
Mean of Set	0.152	3.17	4.18
Standard Deviation of Set	0.027	1.41	1.67
Median of Lognormal	0.149	2.90	3.88
β of Lognormal	0.179	0.43	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	27.3 (8T)	5.58 (8T)	7.4 (7L)
Minimum of Set (Eq. Rec. No.)	2.56 (3T)	0.93 (3L)	2.4 (3T)
Mean of Set	14.04	2.77	4.9
Standard Deviation of Set	6.79	1.22	1.2
Median of Lognormal	12.64	2.54	4.8
β of Lognormal	0.46	0.42	0.25

Table C.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.492 (8T)	20.36 (8T)	27.89 (8T)
Minimum of Set (Eq. Rec. No.)	0.077 (4T)	2.50 (4T)	3.11 (3T)
Mean of Set	0.224	8.82	11.06
Standard Deviation of Set	0.127	5.48	6.69
Median of Lognormal	0.194	7.49	9.46
β of Lognormal	0.531	0.57	0.56

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.234 (8L)	9.23 (8L)	13.22 (8L)
Minimum of Set (Eq. Rec. No.)	0.054 (3L)	1.51 (3L)	2.04 (3L)
Mean of Set	0.144	5.36	7.40
Standard Deviation of Set	0.046	1.99	2.86
Median of Lognormal	0.137	5.03	6.90
β of Lognormal	0.32	0.36	0.37

Table C.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.492 (8T)	20.36 (8T)	27.89 (8T)
Minimum of Set (Eq. Rec. No.)	0.054 (3L)	1.51 (3L)	2.04 (3L)
Mean of Set	0.184	7.09	9.23
Standard Deviation of Set	0.104	4.47	5.46
Median of Lognormal	0.160	6.00	7.94
β of Lognormal	0.53	0.58	0.55

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	245.2 (8T)	20.29 (8T)	13.5 (1T)
Minimum of Set (Eq. Rec. No.)	3.5 (3L)	1.27 (3L)	2.7 (3L)
Mean of Set	62.7	6.80	8.5
Standard Deviation of Set	52.3	4.48	2.5
Median of Lognormal	48.2	5.68	8.1
β of Lognormal	0.73	0.60	0.29

Table C.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.310 (8T)	14.58 (8T)	17.85 (8T)
Minimum of Set (Eq. Rec. No.)	0.071 (3T)	1.62 (3T)	1.99 (3T)
Mean of Set	0.175	7.25	8.71
Standard Deviation of Set	0.084	4.55	4.66
Median of Lognormal	0.158	6.15	7.68
β of Lognormal	0.46	0.58	0.50

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.173 (8L)	7.13 (8L)	10.45 (8L)
Minimum of Set (Eq. Rec. No.)	0.062 (3L)	1.15 (3L)	1.57 (3L)
Mean of Set	0.117	4.11	5.67
Standard Deviation of Set	0.031	1.67	2.49
Median of Lognormal	0.113	3.81	5.19
β of Lognormal	0.26	0.39	0.42

Table C.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.310 (8T)	14.58 (8T)	17.85 (8T)
Minimum of Set (Eq. Rec. No.)	0.062 (3L)	1.15 (3L)	1.57 (3L)
Mean of Set	0.146	5.68	7.19
Standard Deviation of Set	0.070	3.77	4.03
Median of Lognormal	0.132	4.74	6.27
β of Lognormal	0.45	0.60	0.52

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	112.9 (8T)	14.46 (8T)	9.5 (1T)
Minimum of Set (Eq. Rec. No.)	4.0 (3L)	1.14 (3L)	3.5 (3L)
Mean of Set	34.9	5.16	6.4
Standard Deviation of Set	27.4	3.50	1.4
Median of Lognormal	27.5	4.27	6.2
β of Lognormal	0.69	0.62	0.22

Table C.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.208 (8T)	11.94 (8T)	12.82 (8T)
Minimum of Set (Eq. Rec. No.)	0.079 (3T)	1.25 (3T)	1.82 (3T)
Mean of Set	0.134	5.78	7.23
Standard Deviation of Set	0.044	3.65	3.53
Median of Lognormal	0.127	4.89	6.49
β of Lognormal	0.32	0.58	0.46

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.130 (8L)	5.49 (8L)	7.87 (8L)
Minimum of Set (Eq. Rec. No.)	0.079 (3L)	1.23 (3L)	1.68 (3L)
Mean of Set	0.104	3.34	4.61
Standard Deviation of Set	0.014	1.20	1.75
Median of Lognormal	0.103	3.15	4.31
β of Lognormal	0.14	0.35	0.37

Table C.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.208 (8T)	11.94 (8T)	12.82 (8T)
Minimum of Set (Eq. Rec. No.)	0.079 (3L)	1.23 (3L)	1.68 (3L)
Mean of Set	0.119	4.56	5.92
Standard Deviation of Set	0.036	2.97	3.08
Median of Lognormal	0.114	3.82	5.25
β of Lognormal	0.30	0.60	0.49

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	65.1 (8T)	10.76 (8T)	8.0 (1T)
Minimum of Set (Eq. Rec. No.)	3.4 (3L)	1.05 (3L)	2.9 (5L)
Mean of Set	22.0	4.05	5.2
Standard Deviation of Set	15.5	2.56	1.4
Median of Lognormal	17.9	3.42	5.1
β of Lognormal	0.64	0.58	0.27

Table C.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.381 (6T)	26.52 (6T)	31.55 (8T)
Minimum of Set (Eq. Rec. No.)	0.056 (3T)	2.39 (3T)	2.56 (3T)
Mean of Set	0.195	12.74	15.47
Standard Deviation of Set	0.111	8.24	8.84
Median of Lognormal	0.17	10.70	13.4
β of Lognormal	0.53	0.59	0.53

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.185 (8L)	11.91 (8L)	17.56 (8L)
Minimum of Set (Eq. Rec. No.)	0.044 (3L)	1.55 (3L)	2.09 (3L)
Mean of Set	0.110	6.42	9.42
Standard Deviation of Set	0.039	2.87	4.31
Median of Lognormal	0.104	5.86	8.57
β of Lognormal	0.34	0.43	0.44

Table C.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.381 (6T)	26.52 (6T)	31.55 (8T)
Minimum of Set (Eq. Rec. No.)	0.044 (3L)	1.55 (3L)	2.09 (3L)
Mean of Set	0.153	9.58	12.49
Standard Deviation of Set	0.094	6.93	7.59
Median of Lognormal	0.130	7.77	10.63
β of Lognormal	0.56	0.65	0.56

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	299. (8T)	25.3 (6T)	12.3 (1T)
Minimum of Set (Eq. Rec. No.)	2.6 (3L)	1.30 (3L)	2.0 (3L)
Mean of Set	69.2	8.93	7.0
Standard Deviation of Set	67.1	6.72	2.3
Median of Lognormal	49.7	7.13	6.6
β of Lognormal	0.81	0.67	0.32

Table C.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.244 (8T)	22.28 (8T)	22.93 (8T)
Minimum of Set (Eq. Rec. No.)	0.059 (3T)	1.47 (3T)	2.22 (3T)
Mean of Set	0.126	9.00	10.97
Standard Deviation of Set	0.056	6.32	5.94
Median of Lognormal	0.115	7.37	9.64
β of Lognormal	0.43	0.63	0.51

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.131 (8L)	9.54 (8L)	14.04 (8L)
Minimum of Set (Eq. Rec. No.)	0.056 (3L)	1.15 (3L)	1.50 (3L)
Mean of Set	0.088	4.78	7.03
Standard Deviation of Set	0.019	2.16	3.32
Median of Lognormal	0.086	4.35	6.36
β of Lognormal	0.22	0.43	0.45

Table C.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.244 (8T)	22.28 (8T)	22.93 (8T)
Minimum of Set (Eq. Rec. No.)	0.056 (3L)	1.15 (3L)	1.50 (3L)
Mean of Set	0.107	6.89	9.00
Standard Deviation of Set	0.046	5.17	5.20
Median of Lognormal	0.098	5.51	7.79
β of Lognormal	0.41	0.67	0.54

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	108.8 (8T)	20.37 (8T)	8.0 (1T)
Minimum of Set (Eq. Rec. No.)	3.40 (3L)	1.13 (3L)	3.0 (3L)
Mean of Set	33.5	6.25	5.3
Standard Deviation of Set	25.9	4.83	1.1
Median of Lognormal	26.5	4.94	5.1
β of Lognormal	0.69	0.69	0.21

Table C.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.401 (8T)	44.3 (8T)	44.5 (8T)
Minimum of Set (Eq. Rec. No.)	0.046 (3T)	2.34 (3T)	2.40 (3T)
Mean of Set	0.159	15.8	21.0
Standard Deviation of Set	0.103	12.2	12.9
Median of Lognormal	0.133	12.5	17.9
β of Lognormal	0.59	0.69	0.56

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.201 (8L)	20.6 (8L)	31.6 (8L)
Minimum of Set (Eq. Rec. No.)	0.039 (3L)	1.60 (3L)	2.15 (3L)
Mean of Set	0.104	9.16	14.0
Standard Deviation of Set	0.048	5.65	8.76
Median of Lognormal	0.094	7.80	11.90
β of Lognormal	0.44	0.59	0.57

Table C.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.401 (8T)	44.3 (8T)	44.5 (8T)
Minimum of Set (Eq. Rec. No.)	0.039 (3L)	1.60 (3L)	2.15 (3L)
Mean of Set	0.131	12.46	17.5
Standard Deviation of Set	0.085	10.07	11.6
Median of Lognormal	0.110	9.69	14.6
β of Lognormal	0.59	0.71	0.60

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	309. (8T)	40.4 (8T)	9.3 (1T)
Minimum of Set (Eq. Rec. No.)	2.4 (3L)	1.35 (3L)	1.8 (3L)
Mean of Set	73.5	11.51	5.8
Standard Deviation of Set	72.5	9.54	1.6
Median of Lognormal	52.3	8.86	5.5
β of Lognormal	0.82	0.72	0.28

Table C.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.136 (8T)	22.5 (8T)	25.3 (8T)
Minimum of Set (Eq. Rec. No.)	0.054 (3T)	1.51 (3T)	2.55 (3T)
Mean of Set	0.082	8.71	12.34
Standard Deviation of Set	0.024	6.09	6.62
Median of Lognormal	0.079	7.14	10.87
β of Lognormal	0.28	0.63	0.50

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.078 (2L)	7.60 (2L)	11.50 (2L)
Minimum of Set (Eq. Rec. No.)	0.053 (3L)	1.20 (3L)	1.59 (3L)
Mean of Set	0.067	4.82	7.27
Standard Deviation of Set	0.007	1.82	2.84
Median of Lognormal	0.066	4.51	6.77
β of Lognormal	0.11	0.37	0.38

Table C.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.136 (8T)	22.5 (8T)	25.3 (8T)
Minimum of Set (Eq. Rec. No.)	0.053 (3L)	1.20 (3L)	1.59 (3L)
Mean of Set	0.074	6.77	9.80
Standard Deviation of Set	0.019	4.90	5.70
Median of Lognormal	0.07	5.48	8.48
β of Lognormal	0.25	0.65	0.54

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	88.6 (8T)	18.95 (8T)	6.5 (8L)
Minimum of Set (Eq. Rec. No.)	3.2 (3L)	1.14 (3L)	2.8 (3L)
Mean of Set	28.4	5.87	4.8
Standard Deviation of Set	20.4	4.32	1.0
Median of Lognormal	23.0	4.72	4.7
β of Lognormal	0.65	0.66	0.20

Table C.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.228 (8T)	37.6 (8T)	40.1 (8T)
Minimum of Set (Eq. Rec. No.)	0.040 (3T)	2.33 (3T)	2.47 (3T)
Mean of Set	0.102	14.0	21.3
Standard Deviation of Set	0.058	10.9	12.1
Median of Lognormal	0.089	11.1	18.5
β of Lognormal	0.53	0.69	0.53

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.116 (6L)	16.6 (6L)	26.4 (6L)
Minimum of Set (Eq. Rec. No.)	0.036 (3L)	1.59 (3L)	2.14 (3L)
Mean of Set	0.074	8.65	13.59
Standard Deviation of Set	0.026	4.90	7.90
Median of Lognormal	0.069	7.53	11.74
β of Lognormal	0.35	0.53	0.54

Table C.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.228 (8T)	37.6 (8T)	40.1 (8T)
Minimum of Set (Eq. Rec. No.)	0.036 (3L)	1.59 (3L)	2.14 (3L)
Mean of Set	0.088	11.35	17.4
Standard Deviation of Set	0.047	8.84	10.9
Median of Lognormal	0.078	8.95	14.8
β of Lognormal	0.50	0.69	0.58

4.. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	196. (8T)	36.4 (3T)	7.9 (1T)
Minimum of Set (Eq. Rec. No.)	2.2 (3L)	1.35 (3L)	1.6 (3L)
Mean of Set	57.1	10.53	5.3
Standard Deviation of Set	47.7	8.75	1.4
Median of Lognormal	43.8	8.10	5.1
β of Lognormal	0.73	0.73	0.26

Table C.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.123 (8T)	27.1 (8T)	29.0 (8T)
Minimum of Set (Eq. Rec. No.)	0.037 (3T)	2.37 (3T)	2.64 (3T)
Mean of Set	0.072	12.6	18.7
Standard Deviation of Set	0.029	8.2	9.1
Median of Lognormal	0.067	10.6	16.8
β of Lognormal	0.38	0.59	0.46

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.084 (6L)	16.0 (6L)	25.9 (6L)
Minimum of Set (Eq. Rec. No.)	0.034 (3L)	1.57 (3L)	2.12 (3L)
Mean of Set	0.057	8.11	12.89
Standard Deviation of Set	0.015	4.36	7.12
Median of Lognormal	0.055	7.15	11.28
β of Lognormal	0.26	0.50	0.52

Table C.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.123 (8T)	27.1 (8T)	29.0 (8T)
Minimum of Set (Eq. Rec. No.)	0.034 (3L)	1.57 (3L)	2.12 (3L)
Mean of Set	0.064	10.37	15.80
Standard Deviation of Set	0.024	6.95	8.67
Median of Lognormal	0.060	8.61	13.86
β of Lognormal	0.36	0.61	0.51

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	122. (8T)	26.15 (8T)	8.7 (8L)
Minimum of Set (Eq. Rec. No.)	2.1 (3L)	1.34 (3L)	1.5 (3L)
Mean of Set	45.5	9.28	5.0
Standard Deviation of Set	31.2	6.91	1.6
Median of Lognormal	37.6	7.45	4.8
β of Lognormal	0.62	0.66	0.31

D. TABLES SUMMARIZING THE NONLINEAR RESPONSE OF VARIOUS ISOLATED BUILDINGS SUBJECTED TO 18 IN./SEC. PGV-SCALED HORIZONTAL EARTHQUAKE TIME HISTORIES RECORDED AT STIFF SOIL SITES

D.1 Description of Appendix D

Each of the fourteen tables of Appendix D summarize the response results of 10 nonlinear analyses of an isolated building model. Each isolated building model is characterized by an equivalent linear period, with values ranging from 1.0 to 4.0 seconds, and by an equivalent viscous damping factor, with values ranging from 5% to 40% of critical.

The isolated building models were analyzed using pairs of horizontal time history components recorded at stiff soil sites during past earthquakes. Each pair of earthquake components was scaled to have an average peak ground velocity (PGV) of 18 in./sec. Additional description of the earthquake components used in the analyses may be found in Chapter 4 of this report.

The isolated building models were identical with exception of the isolation system. In plan, the isolated building is rectangular with eight 20-foot bays in the longitudinal direction and four 20-foot bays in the transverse direction. The superstructure was modeled as essentially rigid with respect to the isolation system. The force-deflection properties of the isolator units (45 total per model) were modeled by a bi-linear element with a different yield point and a different degree of yielding for each model. Additional description of the isolated building models analyzed in this study may be found in Chapter 5 of this report.

The nonlinear analyses were performed using DRAIN-2D [Ref. 9] compiled for execution on micro-computers. For the analyses of this study the degrees of freedom of the models consisted of translational and torsional response of the isolated building in the plane of the isolation system.

D.2 Description of Response Parameters

Each of the fourteen tables presents a summary of calculated responses, grouped as follows:

1. Peak Response in the Transverse Direction

2. Peak Response in the Longitudinal Direction

3. Peak Response in the Transverse and Longitudinal Directions

4. Cyclic Response in the Transverse and Longitudinal Directions

For the first three response groups, listed above, the parameters reported in the tables are identically:

1. Peak Force at the Center of Gravity of the Building

2. Peak Displacement at the Center of the Building

3. Peak Displacement at the Corner of the Building

Peak displacement of the corner of the building was based on the corner of the model which gave the largest response. Comparison of peak displacements, corner vs. center, provides a measure of the isolated building's torsional response.

For the fourth response group the parameters reported in the tables are:

1. One-Half of the Cumulative Inelastic Displacement

2. One-Half of the Maximum Peak-to-Peak Displacement

3. Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements

Elements of the models representing response at the center of the building were used to evaluate each of the above parameters. One-half of the maximum peak-to-peak displacement is the average of the positive and negative peaks. Comparison of this parameter with the peak displacement at the building's center is helpful in checking for biased response of highly nonlinear systems. The ratio of cumulative inelastic displacement to maximum peak-to-peak displacement provides a measure of the effective number of high amplitude cycles.

D.3 Description of Statistical Parameters

For each response parameter of interest the following statistical information is provided:

1. Maximum of Set (Earthquake Record No.)

2. Minimum of Set (Earthquake Record No.)

3. Mean of Set

4. Standard Deviation of Set

5. Median of Lognormal

6. Beta of Lognormal

For response parameters of either the transverse direction or longitudinal direction, the number of values in the set is ten, the number of earthquake pairs. For response parameters of combined transverse and longitudinal directions, the number of values in the set is twenty, one value from each direction for each earthquake pair. Earthquake record numbers refer to the earthquake component identifiers of Table 4.2. The median and β parameters are calculated based on an assumption that the response parameter of interest is lognormally distributed.

Table D.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.505 (2T)	5.23 (2T)	5.84 (2T)
Minimum of Set (Eq. Rec. No.)	0.207 (8T)	1.75 (8T)	2.13 (8T)
Mean of Set	0.345	3.37	3.93
Standard Deviation of Set	0.094	1.10	1.18
Median of Lognormal	0.333	3.20	3.76
β of Lognormal	0.27	0.32	0.29

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.611 (4L)	6.48 (4L)	7.43 (4L)
Minimum of Set (Eq. Rec. No.)	0.187 (9L)	1.52 (9L)	1.59 (9L)
Mean of Set	0.330	3.19	3.65
Standard Deviation of Set	0.128	1.50	1.71
Median of Lognormal	0.307	2.88	3.31
β of Lognormal	0.38	0.45	0.45

Table D.1 Summary of Nonlinear Response of a 1.0 Second, 9%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.611 (4L)	6.48 (4L)	7.43 (4L)
Minimum of Set (Eq. Rec. No.)	0.187 (9L)	1.52 (9L)	1.59 (9L)
Mean of Set	0.338	3.28	3.79
Standard Deviation of Set	0.113	1.32	1.47
Median of Lognormal	0.320	3.04	3.53
β of Lognormal	0.33	0.39	0.38

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	65.38 (4L)	6.21 (4L)	10.5 (4L)
Minimum of Set (Eq. Rec. No.)	11.36 (8L)	1.36 (8L)	6.0 (7T)
Mean of Set	24.36	2.99	8.0
Standard Deviation of Set	12.69	1.25	1.3
Median of Lognormal	21.61	2.76	7.9
β of Lognormal	0.49	0.40	0.17

Table D.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.369 (5T)	4.62 (5T)	5.38 (5T)
Minimum of Set (Eq. Rec. No.)	0.215 (8T)	1.72 (8T)	2.07 (8T)
Mean of Set	0.258	2.53	3.09
Standard Deviation of Set	0.043	0.81	0.93
Median of Lognormal	0.254	2.40	2.95
β of Lognormal	0.17	0.31	0.30

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.337 (4L)	4.01 (4L)	4.60 (4L)
Minimum of Set (Eq. Rec. No.)	0.188 (8L)	1.21 (8L)	1.46 (8L)
Mean of Set	0.247	2.34	2.64
Standard Deviation of Set	0.054	1.01	1.12
Median of Lognormal	0.242	2.14	2.43
β of Lognormal	0.22	0.42	0.41

Table D.2 Summary of Nonlinear Response of a 1.0 Second, 25%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.369 (5T)	4.62 (5T)	5.38 (5T)
Minimum of Set (Eq. Rec. No.)	0.188 (8L)	1.21 (8L)	1.46 (8L)
Mean of Set	0.252	2.43	2.86
Standard Deviation of Set	0.049	0.92	1.06
Median of Lognormal	0.248	2.27	2.68
β of Lognormal	0.19	0.37	0.36

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	28.44 (4L)	3.99 (4L)	7.9 (2T)
Minimum of Set (Eq. Rec. No.)	4.40 (8L)	1.21 (8L)	3.0 (3L)
Mean of Set	11.10	2.11	5.0
Standard Deviation of Set	6.39	0.75	1.5
Median of Lognormal	9.62	1.99	4.8
β of Lognormal	0.54	0.35	0.30

Table D.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.435 (5T)	10.14 (5T)	12.23 (5T)
Minimum of Set (Eq. Rec. No.)	0.154 (1T)	3.10 (1T)	3.94 (3T)
Mean of Set	0.252	5.55	7.05
Standard Deviation of Set	0.096	2.41	2.52
Median of Lognormal	0.236	5.09	6.64
β of Lognormal	0.37	0.42	0.35

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.284 (4L)	6.36 (4L)	7.96 (4L)
Minimum of Set (Eq. Rec. No.)	0.110 (3L)	2.00 (3L)	2.71 (3L)
Mean of Set	0.220	4.74	6.01
Standard Deviation of Set	0.061	1.52	1.88
Median of Lognormal	0.212	4.52	5.73
β of Lognormal	0.27	0.31	0.31

Table D.3 Summary of Nonlinear Response of a 1.5 Second, 7%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.435 (5T)	10.14 (5T)	12.23 (5T)
Minimum of Set (Eq. Rec. No.)	0.110 (3L)	2.00 (3L)	2.71 (3L)
Mean of Set	0.236	5.15	6.53
Standard Deviation of Set	0.082	2.05	2.28
Median of Lognormal	0.223	4.78	6.16
β of Lognormal	0.34	0.38	0.34

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	96.53 (8T)	9.47 (8T)	14.1 (1T)
Minimum of Set (Eq. Rec. No.)	17.55 (9L)	1.96 (3L)	7.0 (8L)
Mean of Set	44.83	4.79	9.4
Standard Deviation of Set	19.51	1.91	1.7
Median of Lognormal	41.11	4.45	9.2
β of Lognormal	0.42	0.38	0.18

Table D.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.307 (5T)	7.62 (5T)	8.99 (5T)
Minimum of Set (Eq. Rec. No.)	0.140 (1T)	2.59 (1T)	3.87 (7T)
Mean of Set	0.194	4.21	5.48
Standard Deviation of Set	0.055	1.66	1.68
Median of Lognormal	0.186	3.92	5.24
β of Lognormal	0.28	0.38	0.30

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.233 (4L)	5.38 (4L)	6.78 (4L)
Minimum of Set (Eq. Rec. No.)	0.116 (9L)	1.89 (9L)	2.21 (9L)
Mean of Set	0.173	3.58	4.53
Standard Deviation of Set	0.038	1.14	1.48
Median of Lognormal	0.169	3.41	4.30
β of Lognormal	0.22	0.31	0.32

Table D.4 Summary of Nonlinear Response of a 1.5 Second, 15%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.307 (5T)	7.62 (5T)	8.99 (5T)
Minimum of Set (Eq. Rec. No.)	0.116 (9L)	1.89 (9L)	2.21 (9L)
Mean of Set	0.183	3.90	5.00
Standard Deviation of Set	0.049	1.46	1.66
Median of Lognormal	0.177	3.65	4.75
β of Lognormal	0.26	0.36	0.32

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	49.53 (5T)	6.71 (5T)	12.1 (1T)
Minimum of Set (Eq. Rec. No.)	11.74 (9L)	1.65 (3L)	4.7 (8L)
Mean of Set	23.74	3.52	6.8
Standard Deviation of Set	9.02	1.23	1.5
Median of Lognormal	22.19	3.33	6.6
β of Lognormal	0.37	0.34	0.22

Table D.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.229 (5T)	7.16 (5T)	8.61 (5T)
Minimum of Set (Eq. Rec. No.)	0.133 (3T)	2.22 (3T)	3.22 (3T)
Mean of Set	0.156	3.37	4.57
Standard Deviation of Set	0.026	1.33	1.55
Median of Lognormal	0.154	3.14	4.33
β of Lognormal	0.16	0.38	0.33

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.176 (1L)	4.42 (1L)	5.79 (1L)
Minimum of Set (Eq. Rec. No.)	0.124 (8L)	1.73 (8L)	2.20 (8L)
Mean of Set	0.141	2.60	3.32
Standard Deviation of Set	0.019	0.97	1.28
Median of Lognormal	0.140	2.44	3.10
β of Lognormal	0.13	0.36	0.37

Table D.5 Summary of Nonlinear Response of a 1.5 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.229 (5T)	7.16 (5T)	8.61 (5T)
Minimum of Set (Eq. Rec. No.)	0.124 (8L)	1.73 (8L)	2.20 (3L)
Mean of Set	0.148	2.99	3.95
Standard Deviation of Set	0.024	1.23	1.55
Median of Lognormal	0.146	2.76	3.67
β of Lognormal	0.16	0.39	0.38

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	26.28 (4L)	5.73 (5T)	7.4 (1T)
Minimum of Set (Eq. Rec. No.)	6.29 (5L)	1.51 (8L)	3.0 (5L)
Mean of Set	13.44	2.61	5.2
Standard Deviation of Set	5.38	0.96	1.1
Median of Lognormal	12.47	2.45	5.1
β of Lognormal	0.39	0.36	0.21

Table D.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.400 (8T)	16.38 (8T)	22.03 (8T)
Minimum of Set (Eq. Rec. No.)	0.106 (4T)	3.75 (4T)	6.70 (1T)
Mean of Set	0.218	8.59	10.81
Standard Deviation of Set	0.078	3.35	4.00
Median of Lognormal	0.206	8.01	10.14
β of Lognormal	0.35	0.38	0.36

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.184 (8L)	7.07 (8L)	10.13 (8L)
Minimum of Set (Eq. Rec. No.)	0.091 (3L)	3.12 (3L)	4.38 (3L)
Mean of Set	0.143	5.32	7.35
Standard Deviation of Set	0.025	1.06	1.50
Median of Lognormal	0.141	5.22	7.21
β of Lognormal	0.17	0.20	0.20

Table D.6 Summary of Nonlinear Response of a 2.0 Second, 6%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.400 (8T)	16.38 (8T)	22.03 (8T)
Minimum of Set (Eq. Rec. No.)	0.091 (3L)	3.12 (3L)	4.38 (3L)
Mean of Set	0.181	6.96	9.08
Standard Deviation of Set	0.069	2.97	3.48
Median of Lognormal	0.169	6.40	8.48
β of Lognormal	0.37	0.41	0.37

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	158.1 (8T)	16.20 (8T)	13.3 (1T)
Minimum of Set (Eq. Rec. No.)	19.3 (3L)	2.75 (3L)	6.3 (6T)
Mean of Set	56.0	6.61	8.5
Standard Deviation of Set	28.3	2.95	1.7
Median of Lognormal	49.9	6.04	8.3
β of Lognormal	0.48	0.43	0.20

Table D.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.243 (8T)	10.95 (8T)	13.73 (8T)
Minimum of Set (Eq. Rec. No.)	0.094 (1T)	2.89 (1T)	4.32 (3T)
Mean of Set	0.158	6.35	8.09
Standard Deviation of Set	0.048	2.57	2.62
Median of Lognormal	0.151	5.88	7.69
β of Lognormal	0.29	0.39	0.32

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.150 (8L)	5.91 (8L)	8.65 (8L)
Minimum of Set (Eq. Rec. No.)	0.073 (3L)	1.76 (3L)	2.45 (3L)
Mean of Set	0.115	3.99	5.49
Standard Deviation of Set	0.022	1.18	1.74
Median of Lognormal	0.113	3.83	5.23
β of Lognormal	0.19	0.29	0.31

Table D.7 Summary of Nonlinear Response of a 2.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.243 (8T)	10.95 (8T)	13.73 (8T)
Minimum of Set (Eq. Rec. No.)	0.073 (3L)	1.76 (3L)	2.45 (3L)
Mean of Set	0.136	5.17	6.79
Standard Deviation of Set	0.043	2.32	2.58
Median of Lognormal	0.130	4.72	6.35
β of Lognormal	0.31	0.43	0.37

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	77.00 (8T)	10.94 (8T)	10.8 (1T)
Minimum of Set (Eq. Rec. No.)	11.78 (3L)	1.55 (3L)	5.2 (5L)
Mean of Set	29.91	4.63	6.6
Standard Deviation of Set	13.71	2.07	1.3
Median of Lognormal	27.19	4.23	6.5
β of Lognormal	0.44	0.43	0.20

Table D.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.174 (5T)	9.15 (5T)	11.22 (5T)
Minimum of Set (Eq. Rec. No.)	0.092 (3T)	2.30 (3T)	3.67 (3T)
Mean of Set	0.122	4.80	6.59
Standard Deviation of Set	0.026	2.12	2.04
Median of Lognormal	0.119	4.39	6.30
β of Lognormal	0.21	0.42	0.30

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.123 (4L)	4.87 (4L)	6.69 (4L)
Minimum of Set (Eq. Rec. No.)	0.086 (9L)	1.82 (9L)	2.23 (9L)
Mean of Set	0.104	3.29	4.53
Standard Deviation of Set	0.011	0.90	1.29
Median of Lognormal	0.103	3.17	4.36
β of Lognormal	0.10	0.27	0.28

Table D.8 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.174 (5T)	9.15 (5T)	11.22 (5T)
Minimum of Set (Eq. Rec. No.)	0.086 (9L)	1.82 (9L)	2.23 (9L)
Mean of Set	0.113	4.04	5.56
Standard Deviation of Set	0.022	1.79	1.99
Median of Lognormal	0.111	3.69	5.24
β of Lognormal	0.19	0.42	0.35

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	39.27 (8T)	7.87 (5T)	9.6 (1T)
Minimum of Set (Eq. Rec. No.)	9.75 (9L)	1.56 (9L)	3.6 (5L)
Mean of Set	19.18	3.61	5.5
Standard Deviation of Set	7.70	1.57	1.3
Median of Lognormal	17.80	3.31	5.4
β of Lognormal	0.39	0.42	0.23

Table D.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.263 (8T)	17.75 (8T)	21.05 (8T)
Minimum of Set (Eq. Rec. No.)	0.080 (4T)	4.21 (4T)	8.12 (3T)
Mean of Set	0.174	11.14	13.80
Standard Deviation of Set	0.059	4.38	3.81
Median of Lognormal	0.164	10.36	13.30
β of Lognormal	0.33	0.38	0.27

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.152 (9L)	9.49 (9L)	13.79 (9L)
Minimum of Set (Eq. Rec. No.)	0.061 (3L)	2.82 (3L)	4.24 (3L)
Mean of Set	0.104	5.97	8.70
Standard Deviation of Set	0.023	1.70	2.41
Median of Lognormal	0.102	5.74	8.38
β of Lognormal	0.22	0.28	0.27

Table D.9 Summary of Nonlinear Response of a 2.5 Second, 10%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.263 (8T)	17.75 (8T)	21.05 (8T)
Minimum of Set (Eq. Rec. No.)	0.061 (3L)	2.82 (3L)	4.24 (3L)
Mean of Set	0.139	8.55	11.25
Standard Deviation of Set	0.057	4.21	4.08
Median of Lognormal	0.128	7.67	10.57
β of Lognormal	0.39	0.47	0.35

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	187.3 (8T)	17.26 (8T)	10.9 (8T)
Minimum of Set (Eq. Rec. No.)	12.27 (3L)	2.34 (3L)	5.3 (3T)
Mean of Set	57.61	7.93	7.1
Standard Deviation of Set	37.62	4.18	1.6
Median of Lognormal	48.23	7.01	7.0
β of Lognormal	0.60	0.50	0.23

Table D.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.175 (9T)	14.53 (9T)	15.13 (9T)
Minimum of Set (Eq. Rec. No.)	0.074 (3T)	3.24 (3T)	3.53 (3T)
Mean of Set	0.115	7.78	9.86
Standard Deviation of Set	0.037	4.11	3.52
Median of Lognormal	0.109	6.88	9.29
β of Lognormal	0.31	0.50	0.35

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.097 (8L)	5.73 (8L)	8.33 (2L)
Minimum of Set (Eq. Rec. No.)	0.061 (3L)	1.73 (3L)	2.25 (3L)
Mean of Set	0.085	4.42	6.37
Standard Deviation of Set	0.010	1.16	1.79
Median of Lognormal	0.084	4.27	6.14
β of Lognormal	0.12	0.26	0.27

Table D.10 Summary of Nonlinear Response of a 2.5 Second, 27%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.175 (9T)	14.53 (9T)	15.13 (9T)
Minimum of Set (Eq. Rec. No.)	0.061 (3L)	1.73 (3L)	2.25 (3L)
Mean of Set	0.100	6.10	8.11
Standard Deviation of Set	0.031	3.46	3.29
Median of Lognormal	0.095	5.31	7.52
β of Lognormal	0.30	0.53	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	71.42 (9T)	13.02 (9T)	8.5 (1T)
Minimum of Set (Eq. Rec. No.)	10.11 (3L)	1.57 (3L)	4.4 (4T)
Mean of Set	29.50	5.37	5.7
Standard Deviation of Set	16.33	3.16	1.0
Median of Lognormal	25.81	4.63	5.6
β of Lognormal	0.52	0.55	0.18

Table D.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.291 (8T)	31.29 (8T)	36.35 (9T)
Minimum of Set (Eq. Rec. No.)	0.061 (1T)	4.20 (1T)	6.46 (3T)
Mean of Set	0.144	13.99	18.94
Standard Deviation of Set	0.076	9.04	9.93
Median of Lognormal	0.127	11.75	16.77
β of Lognormal	0.50	0.59	0.49

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.145 (8L)	13.98 (8L)	21.22 (8L)
Minimum of Set (Eq. Rec. No.)	0.045 (3L)	2.30 (3L)	3.15 (3L)
Mean of Set	0.091	7.70	11.77
Standard Deviation of Set	0.30	3.49	5.37
Median of Lognormal	0.087	7.02	10.71
β of Lognormal	0.32	0.43	0.43

Table D.11 Summary of Nonlinear Response of a 3.0 Second, 16%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.291 (8T)	31.29 (8T)	36.35 (9T)
Minimum of Set (Eq. Rec. No.)	0.045 (3L)	2.30 (3L)	3.15 (3L)
Mean of Set	0.118	10.84	15.36
Standard Deviation of Set	0.064	7.54	8.75
Median of Lognormal	0.103	8.90	13.34
β of Lognormal	0.51	0.63	0.53

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	181.2 (9T)	28.62 (8T)	10.6 (1T)
Minimum of Set (Eq. Rec. No.)	9.37 (3L)	1.90 (3L)	4.5 (10T)
Mean of Set	61.35	10.03	5.6
Standard Deviation of Set	49.95	7.37	1.4
Median of Lognormal	47.58	8.08	5.8
β of Lognormal	0.71	0.66	0.23

Table D.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.107 (9T)	15.03 (9T)	16.59 (9T)
Minimum of Set (Eq. Rec. No.)	0.061 (3T)	3.44 (3T)	3.95 (3T)
Mean of Set	0.079	8.00	10.78
Standard Deviation of Set	0.017	4.34	4.08
Median of Lognormal	0.078	7.03	10.09
β of Lognormal	0.21	0.51	0.37

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.073 (2L)	6.50 (2L)	9.70 (2L)
Minimum of Set (Eq. Rec. No.)	0.055 (3L)	1.76 (3L)	2.20 (3L)
Mean of Set	0.067	4.75	7.15
Standard Deviation of Set	0.005	1.21	1.94
Median of Lognormal	0.066	4.60	6.90
β of Lognormal	0.07	0.25	0.27

Table D.12 Summary of Nonlinear Response of a 3.0 Second, 39%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.107 (9T)	15.03 (9T)	16.59 (9T)
Minimum of Set (Eq. Rec. No.)	0.055 (3L)	1.76 (3L)	2.20 (3L)
Mean of Set	0.073	6.38	8.96
Standard Deviation of Set	0.014	3.58	3.67
Median of Lognormal	0.072	5.56	8.29
β of Lognormal	0.19	0.52	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	61.29 (9T)	14.30 (9T)	7.0 (1T)
Minimum of Set (Eq. Rec. No.)	9.34 (3L)	1.56 (3L)	3.7 (5L)
Mean of Set	25.85	5.35	5.0
Standard Deviation of Set	13.96	3.32	0.8
Median of Lognormal	22.74	4.55	5.0
β of Lognormal	0.51	0.57	0.16

Table D.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.179 (5T)	28.33 (5T)	35.90 (9T)
Minimum of Set (Eq. Rec. No.)	0.050 (1T)	4.26 (1T)	5.56 (3T)
Mean of Set	0.100	13.57	19.80
Standard Deviation of Set	0.051	9.59	9.70
Median of Lognormal	0.089	11.08	17.78
β of Lognormal	0.48	0.64	0.46

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.083 (2L)	10.42 (2L)	16.47 (8L)
Minimum of Set (Eq. Rec. No.)	0.038 (3L)	2.01 (3L)	2.75 (3L)
Mean of Set	0.066	7.29	11.43
Standard Deviation of Set	0.013	2.51	4.08
Median of Lognormal	0.065	6.89	10.76
β of Lognormal	0.20	0.33	0.35

Table D.13 Summary of Nonlinear Response of a 3.5 Second, 22%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.179 (5T)	28.33 (5T)	35.90 (9T)
Minimum of Set (Eq. Rec. No.)	0.038 (3L)	2.01 (3L)	2.75 (3L)
Mean of Set	0.083	10.43	15.61
Standard Deviation of Set	0.041	7.68	8.54
Median of Lognormal	0.075	8.40	13.70
β of Lognormal	0.47	0.66	0.51

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	145.2 (9T)	27.12 (5T)	9.4 (1T)
Minimum of Set (Eq. Rec. No.)	8.64 (3L)	1.83 (3L)	4.2 (7L)
Mean of Set	51.39	9.56	5.6
Standard Deviation of Set	38.69	7.66	1.2
Median of Lognormal	41.05	7.46	5.4
β of Lognormal	0.67	0.70	0.21

Table D.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.115 (5T)	24.84 (5T)	31.95 (5T)
Minimum of Set (Eq. Rec. No.)	0.043 (3T)	4.20 (3T)	4.93 (3T)
Mean of Set	0.070	11.92	17.88
Standard Deviation of Set	0.027	7.85	8.08
Median of Lognormal	0.065	9.95	16.29
β of Lognormal	0.38	0.60	0.43

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.064 (2L)	10.12 (2L)	16.18 (2L)
Minimum of Set (Eq. Rec. No.)	0.035 (3L)	1.96 (3L)	2.96 (3L)
Mean of Set	0.053	7.04	11.13
Standard Deviation of Set	0.008	2.15	3.48
Median of Lognormal	0.052	6.73	10.62
β of Lognormal	0.14	0.30	0.31

Table D.14 Summary of Nonlinear Response of a 4.0 Second, 28%-Damped Isolated Building Subjected to 10 Pairs of 18 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Stiff Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.115 (5T)	24.84 (5T)	31.95 (5T)
Minimum of Set (Eq. Rec. No.)	0.035 (3L)	1.96 (3L)	2.96 (3L)
Mean of Set	0.061	9.48	14.50
Standard Deviation of Set	0.022	6.25	7.08
Median of Lognormal	0.058	7.91	13.03
β of Lognormal	0.34	0.60	0.46

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	96.37 (5T)	24.23 (5T)	8.3 (1T)
Minimum of Set (Eq. Rec. No.)	8.19 (3L)	1.76 (3L)	4.0 (5T)
Mean of Set	41.31	8.43	5.3
Standard Deviation of Set	24.43	6.20	1.3
Median of Lognormal	35.56	6.79	5.1
β of Lognormal	0.55	0.66	0.24

E. TABLES SUMMARIZING THE NONLINEAR RESPONSE OF VARIOUS ISOLATED BUILDINGS SUBJECTED TO 0.4G PGA-SCALED HORIZONTAL EARTHQUAKE TIME HISTORIES RECORDED AT MEDIUM SOIL SITES

E.1 Description of Appendix E

Each of the seventeen tables of Appendix E summarize the response results of 9 nonlinear analyses of an isolated building model. Each isolated building model is characterized by an equivalent linear period, with values ranging from 1.0 to 4.0 seconds, and by an equivalent viscous damping factor, with values ranging from 5% to 40% of critical.

The isolated building models were analyzed using pairs of horizontal time history components recorded at medium soil sites during past earthquakes. Each pair of earthquake components was scaled to have an average peak ground acceleration (PGA) of 0.4g. Additional description of the earthquake components used in the analyses may be found in Chapter 4 of this report.

The isolated building models were identical with exception of the isolation system. In plan, the isolated building is rectangular with eight 20-foot bays in the longitudinal direction and four 20-foot bays in the transverse direction. The superstructure was modeled as essentially rigid with respect to the isolation system. The force-deflection properties of the isolator units (45 total per model) were modeled by a bi-linear element with a different yield point and a different degree of yielding for each model. Additional description of the isolated building models analyzed in this study may be found in Chapter 5 of this report.

The nonlinear analyses were performed using DRAIN-2D [Ref. 9] compiled for execution on micro-computers. For the analyses of this study the degrees of freedom of the models consisted of translational and torsional response of the isolated building in the plane of the isolation system.

E.2 Description of Response Parameters

Each of the seventeen tables presents a summary of calculated responses, grouped as follows:

1. Peak Response in the Transverse Direction

2. Peak Response in the Longitudinal Direction

3. Peak Response in the Transverse and Longitudinal Directions

4. Cyclic Response in the Transverse and Longitudinal Directions

For the first three response groups, listed above, the parameters reported in the tables are identically:

1. Peak Force at the Center of Gravity of the Building

2. Peak Displacement at the Center of the Building

3. Peak Displacement at the Corner of the Building

Peak displacement of the corner of the building was based on the corner of the model which gave the largest response. Comparison of peak displacements, corner vs. center, provides a measure of the isolated building's torsional response.

For the fourth response group the parameters reported in the tables are:

1. One-Half of the Cumulative Inelastic Displacement

2. One-Half of the Maximum Peak-to-Peak Displacement

3. Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements

Elements of the models representing response at the center of the building were used to evaluate each of the above parameters. One-half of the maximum peak-to-peak displacement is the average of the positive and negative peaks. Comparison of this parameter with the peak displacement at the building's center is helpful in checking for biased response of highly nonlinear systems. The ratio of cumulative inelastic displacement to maximum peak-to-peak displacement provides a measure of the effective number of high amplitude cycles.

E.3 Description of Statistical Parameters

For each response parameter of interest the following statistical information is provided:

1. **Maximum of Set (Earthquake Record No.)**

2. **Minimum of Set (Earthquake Record No.)**

3. **Mean of Set**

4. **Standard Deviation of Set**

5. **Median of Lognormal**

6. **Beta of Lognormal**

For response parameters of either the transverse direction or longitudinal direction, the number of values in the set is nine, the number of earthquake pairs. For response parameters of combined transverse and longitudinal directions, the number of values in the set is eighteen, one value from each direction for each earthquake pair. Earthquake record numbers refer to the earthquake component identifiers of Table 4.3. The median and β parameters are calculated based on an assumption that the response parameter of interest is lognormally distributed.

Table E.1 Summary of Nonlinear Response of a 1.0 Second, 13%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.639 (3T)	6.77 (3T)	7.12 (3T)
Minimum of Set (Eq. Rec. No.)	0.206 (8T)	1.22 (8T)	1.69 (8T)
Mean of Set	0.374	3.37	3.91
Standard Deviation of Set	0.161	2.07	1.99
Median of Lognormal	0.343	2.87	3.48
β of Lognormal	0.41	0.57	0.48

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.486 (3L)	4.81 (3L)	5.58 (3L)
Minimum of Set (Eq. Rec. No.)	0.204 (8L)	1.20 (8L)	1.24 (8L)
Mean of Set	0.294	2.34	2.67
Standard Deviation of Set	0.100	1.28	1.49
Median of Lognormal	0.278	2.06	2.34
β of Lognormal	0.33	0.51	0.52

Table E.1 Summary of Nonlinear Response of a 1.0 Second, 13%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.639 (3T)	6.77 (3T)	7.12 (3T)
Minimum of Set (Eq. Rec. No.)	0.204 (8L)	1.22 (8T)	1.69 (8T)
Mean of Set	0.334	2.86	3.29
Standard Deviation of Set	0.140	1.79	1.86
Median of Lognormal	0.308	2.42	2.86
β of Lognormal	0.40	0.58	0.53

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	63.7 (6T)	6.13 (6T)	10.4 (6T)
Minimum of Set (Eq. Rec. No.)	2.64 (4T)	1.08 (8L)	2.1 (4L)
Mean of Set	15.4	2.57	5.3
Standard Deviation of Set	14.8	1.60	2.2
Median of Lognormal	11.1	2.18	4.9
β of Lognormal	0.81	0.57	0.40

Table E.2 Summary of Nonlinear Response of a 1.5 Second, 8%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	1.051 (6T)	2.57 (6T)	27.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.113 (4T)	1.61 (4T)	2.13 (4T)
Mean of Set	0.350	7.70	9.35
Standard Deviation of Set	0.301	7.73	8.27
Median of Lognormal	0.266	5.43	7.00
β of Lognormal	0.74	0.84	0.76

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.797 (6L)	19.2 (6L)	25.2 (6L)
Minimum of Set (Eq. Rec. No.)	0.119 (4L)	1.76 (4L)	2.17 (4L)
Mean of Set	0.306	6.55	8.54
Standard Deviation of Set	0.235	6.04	7.93
Median of Lognormal	0.240	4.82	6.26
β of Lognormal	0.68	0.78	0.79

Table E.2 Summary of Nonlinear Response of a 1.5 Second, 8%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	1.051 (6T)	25.7 (6T)	27.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.113 (4T)	1.61 (4T)	2.13 (4T)
Mean of Set	0.328	7.13	8.95
Standard Deviation of Set	0.271	6.96	8.11
Median of Lognormal	0.250	5.10	6.63
β of Lognormal	0.72	0.82	0.78

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	345. (6T)	23.8 (6T)	14.5 (6T)
Minimum of Set (Eq. Rec. No.)	6.24 (4T)	1.58 (4T)	3.9 (4T)
Mean of Set	68.1	6.81	7.9
Standard Deviation of Set	91.4	6.60	3.3
Median of Lognormal	40.7	4.89	7.3
β of Lognormal	1.02	0.81	0.40

Table E.3 Summary of Nonlinear Response of a 1.5 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.595 (6T)	15.9 (6T)	23.2 (6T)
Minimum of Set (Eq. Rec. No.)	0.157 (7T)	2.26 (7T)	2.59 (7T)
Mean of Set	0.265	5.63	7.85
Standard Deviation of Set	0.149	4.64	6.74
Median of Lognormal	0.231	4.34	5.96
β of Lognormal	0.53	0.72	0.74

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.697 (6L)	19.0 (6L)	24.5 (6L)
Minimum of Set (Eq. Rec. No.)	0.139 (9L)	1.72 (9L)	2.51 (9L)
Mean of Set	0.265	5.62	7.20
Standard Deviation of Set	0.181	5.62	7.26
Median of Lognormal	0.218	3.97	5.07
β of Lognormal	0.62	0.83	0.84

Table E.3 Summary of Nonlinear Response of a 1.5 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.697 (6L)	19.0 (6L)	24.5 (6L)
Minimum of Set (Eq. Rec. No.)	0.139 (9L)	1.72 (9L)	2.51 (9L)
Mean of Set	0.265	5.62	7.53
Standard Deviation of Set	0.166	5.16	7.00
Median of Lognormal	0.224	4.14	5.51
β of Lognormal	0.58	0.78	0.79

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	168. (6T)	17.1 (6L)	11.4 (6T)
Minimum of Set (Eq. Rec. No.)	3.8 (4T)	1.55 (9L)	2.4 (4T)
Mean of Set	34.0	5.02	5.6
Standard Deviation of Set	43.3	4.82	2.1
Median of Lognormal	21.0	3.62	5.3
β of Lognormal	0.98	0.81	0.36

Table E.4 Summary of Nonlinear Response of a 1.5 Second, 36%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.295 (6T)	9.65 (6T)	15.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.162 (4T)	1.27 (4T)	2.30 (4T)
Mean of Set	0.206	3.99	6.14
Standard Deviation of Set	0.044	2.79	4.71
Median of Lognormal	0.201	3.27	4.87
β of Lognormal	0.21	0.63	0.68

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.343 (6L)	12.63 (6L)	16.87 (6L)
Minimum of Set (Eq. Rec. No.)	0.160 (8L)	1.15 (8L)	1.50 (8L)
Mean of Set	0.204	3.87	5.21
Standard Deviation of Set	0.062	3.89	5.26
Median of Lognormal	0.195	2.74	3.67
β of Lognormal	0.30	0.83	0.84

Table E.4 Summary of Nonlinear Response of a 1.5 Second, 36%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.343 (6L)	12.63 (6L)	16.87 (6L)
Minimum of Set (Eq. Rec. No.)	0.160 (8L)	1.15 (8L)	1.50 (8L)
Mean of Set	0.205	3.93	5.67
Standard Deviation of Set	0.054	3.38	5.01
Median of Lognormal	0.198	2.98	4.25
β of Lognormal	0.26	0.74	0.76

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	62.6 (6T)	12.0 (6L)	7.14 (6T)
Minimum of Set (Eq. Rec. No.)	1.82 (4T)	1.02 (4T)	1.70 (4L)
Mean of Set	14.6	3.40	3.82
Standard Deviation of Set	17.1	3.22	1.49
Median of Lognormal	9.52	2.47	3.56
β of Lognormal	0.93	0.80	0.38

Table E.5 Summary of Nonlinear Response of a 2.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.592 (6T)	25.4 (6T)	31.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.081 (4T)	1.94 (4T)	3.54 (4T)
Mean of Set	0.224	8.49	12.49
Standard Deviation of Set	0.164	7.53	10.09
Median of Lognormal	0.181	6.35	9.72
β of Lognormal	0.66	0.76	0.71

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.724 (6L)	31.4 (6L)	43.2 (6L)
Minimum of Set (Eq. Rec. No.)	0.084 (9L)	2.04 (9L)	2.65 (9L)
Mean of Set	0.242	9.31	12.7
Standard Deviation of Set	0.220	10.1	13.9
Median of Lognormal	0.179	6.31	8.56
β of Lognormal	0.78	0.88	0.89

Table E.5 Summary of Nonlinear Response of a 2.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.724 (6L)	31.4 (6L)	43.2 (6L)
Minimum of Set (Eq. Rec. No.)	0.081 (4T)	1.94 (4T)	2.65 (9L)
Mean of Set	0.233	8.90	12.60
Standard Deviation of Set	0.194	8.92	12.17
Median of Lognormal	0.179	6.29	9.06
β of Lognormal	0.73	0.83	0.81

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	328. (6T)	30.4 (6L)	14.1 (6T)
Minimum of Set (Eq. Rec. No.)	6.10 (6T)	1.59 (4T)	3.66 (8L)
Mean of Set	81.5	8.35	7.75
Standard Deviation of Set	102.5	8.57	3.26
Median of Lognormal	50.7	5.82	7.14
β of Lognormal	0.97	0.85	0.41

Table E.6 Summary of Nonlinear Response of a 2.0 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.514 (6T)	24.5 (6T)	26.8 (6T)
Minimum of Set (Eq. Rec. No.)	0.091 (4T)	1.62 (4T)	1.96 (4T)
Mean of Set	0.193	7.18	9.99
Standard Deviation of Set	0.128	6.93	8.76
Median of Lognormal	0.161	5.16	7.51
β of Lognormal	0.60	0.81	0.76

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.525 (6L)	25.13 (6L)	34.71 (6L)
Minimum of Set (Eq. Rec. No.)	0.090 (4L)	1.58 (4L)	2.10 (4L)
Mean of Set	0.202	7.63	10.5
Standard Deviation of Set	0.153	8.28	11.5
Median of Lognormal	0.161	5.17	7.10
β of Lognormal	0.67	0.88	0.89

Table E.6 Summary of Nonlinear Response of a 2.0 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.525 (6L)	25.1 (6L)	34.7 (6L)
Minimum of Set (Eq. Rec. No.)	0.090 (4L)	1.58 (4L)	1.96 (4T)
Mean of Set	0.198	7.40	10.25
Standard Deviation of Set	0.141	7.64	10.23
Median of Lognormal	0.161	5.15	7.26
β of Lognormal	0.64	0.85	0.83

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	239. (6T)	23.6 (6L)	11.0 (6L)
Minimum of Set (Eq. Rec. No.)	4.8 (4T)	1.41 (4T)	3.0 (2T)
Mean of Set	49.4	6.72	6.2
Standard Deviation of Set	64.3	6.95	2.2
Median of Lognormal	30.1	4.67	5.82
β of Lognormal	1.00	0.85	0.35

Table E.7 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.428 (6T)	27.9 (6T)	30.8 (6T)
Minimum of Set (Eq. Rec. No.)	0.123 (7T)	2.44 (7T)	3.11 (7T)
Mean of Set	0.177	6.88	9.56
Standard Deviation of Set	0.093	7.73	9.18
Median of Lognormal	0.156	4.57	6.89
β of Lognormal	0.49	0.90	0.81

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.322 (6L)	19.0 (6L)	26.9 (6L)
Minimum of Set (Eq. Rec. No.)	0.117 (9L)	1.92 (8L)	2.88 (9L)
Mean of Set	0.167	6.08	8.52
Standard Deviation of Set	0.072	6.02	8.58
Median of Lognormal	0.153	4.32	6.00
β of Lognormal	0.41	0.83	0.84

Table E.7 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.428 (6T)	27.9 (6T)	30.8 (6T)
Minimum of Set (Eq. Rec. No.)	0.117 (9L)	1.92 (9L)	2.88 (8L)
Mean of Set	0.172	6.48	9.04
Standard Deviation of Set	0.083	6.94	8.90
Median of Lognormal	0.155	4.42	6.44
β of Lognormal	0.46	0.87	0.82

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	163. (6T)	24.7 (6T)	7.1 (1T)
Minimum of Set (Eq. Rec. No.)	3.2 (4T)	1.50 (9L)	2.0 (4T)
Mean of Set	29.1	5.70	4.4
Standard Deviation of Set	41.3	6.40	1.5
Median of Lognormal	16.8	3.74	4.2
β of Lognormal	1.05	0.91	0.33

Table E.8 Summary of Nonlinear Response of a 2.5 Second, 6%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.533 (6T)	34.6 (6T)	64.0 (6T)
Minimum of Set (Eq. Rec. No.)	0.047 (4T)	1.67 (4T)	3.40 (4T)
Mean of Set	0.204	12.3	19.8
Standard Deviation of Set	0.150	10.2	18.6
Median of Lognormal	0.164	9.43	14.4
β of Lognormal	0.66	0.72	0.80

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.766 (6L)	50.23 (6L)	73.3 (6L)
Minimum of Set (Eq. Rec. No.)	0.054 (9L)	2.1 (9L)	3.1 (9L)
Mean of Set	0.217	13.1	19.0
Standard Deviation of Set	0.227	15.3	22.3
Median of Lognormal	0.150	8.56	12.4
β of Lognormal	0.86	0.93	0.93

Table E.8 Summary of Nonlinear Response of a 2.5 Second, 6%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.766 (6L)	50.2 (6L)	73.3 (6L)
Minimum of Set (Eq. Rec. No.)	0.047 (4T)	1.67 (4T)	3.12 (9L)
Mean of Set	0.210	12.7	19.4
Standard Deviation of Set	0.192	13.0	20.5
Median of Lognormal	0.155	8.87	13.33
β of Lognormal	0.78	0.85	0.87

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	719. (6T)	48.0 (6L)	21.1 (6T)
Minimum of Set (Eq. Rec. No.)	7.53 (4T)	1.39 (4T)	4.4 (8T)
Mean of Set	143.	11.9	8.7
Standard Deviation of Set	207.	12.5	4.0
Median of Lognormal	80.9	8.16	7.9
β of Lognormal	1.06	0.87	0.44

Table E.9 Summary of Nonlinear Response of a 2.5 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.478 (6T)	34.7 (6T)	58.2 (6T)
Minimum of Set (Eq. Rec. No.)	0.067 (4T)	1.85 (8T)	3.54 (4T)
Mean of Set	0.159	9.24	16.2
Standard Deviation of Set	0.124	9.88	17.33
Median of Lognormal	0.126	6.31	11.0
β of Lognormal	0.69	0.87	0.88

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.596 (6L)	44.2 (6L)	64.7 (6L)
Minimum of Set (Eq. Rec. No.)	0.065 (9L)	1.73 (8L)	2.44 (9L)
Mean of Set	0.181	11.0	16.0
Standard Deviation of Set	0.169	13.5	19.9
Median of Lognormal	0.133	6.94	10.0
β of Lognormal	0.79	0.96	0.97

Table E.9 Summary of Nonlinear Response of a 2.5 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.596 (6L)	44.2 (6L)	64.7 (6L)
Minimum of Set (Eq. Rec. No.)	0.065 (9L)	1.73 (9L)	2.44 (9L)
Mean of Set	0.170	10.1	16.0
Standard Deviation of Set	0.148	11.9	18.6
Median of Lognormal	0.128	6.56	10.5
β of Lognormal	0.75	0.93	0.92

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	406. (6L)	43.4 (6L)	12.1 (1L)
Minimum of Set (Eq. Rec. No.)	5.1 (4T)	1.53 (4T)	3.1 (2T)
Mean of Set	74.1	9.37	6.5
Standard Deviation of Set	110.	11.25	2.6
Median of Lognormal	41.4	5.99	6.0
β of Lognormal	1.08	0.95	0.39

Table E.10 Summary of Nonlinear Response of a 2.5 Second, 26%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.402 (6T)	36.5 (6T)	47.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.081 (4T)	1.67 (4T)	1.95 (4T)
Mean of Set	0.145	8.64	13.4
Standard Deviation of Set	0.096	10.4	14.0
Median of Lognormal	0.121	5.54	9.30
β of Lognormal	0.60	0.94	0.86

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.340 (6L)	29.7 (6L)	44.3 (6L)
Minimum of Set (Eq. Rec. No.)	0.080 (4L)	1.59 (4L)	2.11 (4L)
Mean of Set	0.141	8.13	12.0
Standard Deviation of Set	0.084	9.08	13.6
Median of Lognormal	0.121	5.43	8.00
β of Lognormal	0.55	0.90	0.91

Table E.10 Summary of Nonlinear Response of a 2.5 Second, 26%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.402 (6T)	36.5 (6T)	47.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.080 (4L)	1.59 (4L)	1.95 (4T)
Mean of Set	0.143	8.39	12.7
Standard Deviation of Set	0.090	9.75	13.8
Median of Lognormal	0.121	5.47	8.62
β of Lognormal	0.58	0.92	0.88

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	299. (6L)	36.3 (6T)	9.4 (6L)
Minimum of Set (Eq. Rec. No.)	4.8 (4T)	1.28 (4L)	2.6 (2T)
Mean of Set	51.6	7.62	5.6
Standard Deviation of Set	81.6	9.45	2.0
Median of Lognormal	27.6	4.78	5.2
β of Lognormal	1.12	0.97	0.36

Table E.11 Summary of Nonlinear Response of a 3.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.600 (6T)	59.2 (6T)	108. (6T)
Minimum of Set (Eq. Rec. No.)	0.040 (4T)	1.55 (4T)	3.42 (4T)
Mean of Set	0.160	13.9	25.8
Standard Deviation of Set	0.165	16.9	31.3
Median of Lognormal	0.112	8.82	16.4
β of Lognormal	0.85	0.95	0.95

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.810 (6L)	80.4 (6L)	121. (6L)
Minimum of Set (Eq. Rec. No.)	0.044 (9L)	1.9 (9L)	2.88 (9L)
Mean of Set	0.190	16.9	25.3
Standard Deviation of Set	0.231	23.7	35.8
Median of Lognormal	0.120	9.77	14.6
β of Lognormal	0.96	1.05	1.05

Table E.11 Summary of Nonlinear Response of a 3.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.810 (6L)	80.4 (6L)	121. (6L)
Minimum of Set (Eq. Rec. No.)	0.040 (4T)	1.55 (4T)	2.88 (9L)
Mean of Set	0.175	15.4	25.6
Standard Deviation of Set	0.201	20.7	33.7
Median of Lognormal	0.115	9.19	15.5
β of Lognormal	0.918	1.02	1.00

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	1553. (6L)	80.4 (6L)	19.3 (6L)
Minimum of Set (Eq. Rec. No.)	6.47 (4T)	1.30 (4T)	4.3 (8T)
Mean of Set	181.	14.6	7.4
Standard Deviation of Set	381.	20.5	3.8
Median of Lognormal	77.9	8.53	6.7
β of Lognormal	1.30	1.04	0.47

Table E.12 Summary of Nonlinear Response of a 3.0 Second, 20%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.435 (6T)	52.5 (6T)	67.0 (6T)
Minimum of Set (Eq. Rec. No.)	0.060 (4T)	1.80 (8T)	3.98 (4T)
Mean of Set	0.131	11.5	17.9
Standard Deviation of Set	0.113	15.2	19.8
Median of Lognormal	0.100	6.94	12.0
β of Lognormal	0.74	1.01	0.89

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.313 (6L)	36.0 (6L)	54.9 (6L)
Minimum of Set (Eq. Rec. No.)	0.060 (9L)	1.87 (9L)	2.75 (9L)
Mean of Set	0.121	10.1	15.2
Standard Deviation of Set	0.080	10.8	16.6
Median of Lognormal	0.101	6.88	10.3
β of Lognormal	0.60	0.88	0.89

Table E.12 Summary of Nonlinear Response of a 3.0 Second, 20%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.435 (6T)	52.5 (6T)	67.0 (6T)
Minimum of Set (Eq. Rec. No.)	0.060 (4T)	1.80 (4T)	2.75 (9L)
Mean of Set	0.126	10.8	16.6
Standard Deviation of Set	0.098	13.2	18.3
Median of Lognormal	0.100	6.83	11.1
β of Lognormal	0.69	0.96	0.89

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	396. (6T)	47.9 (6T)	10.7 (1L)
Minimum of Set (Eq. Rec. No.)	4.54 (4T)	1.49 (4T)	2.8 (2L)
Mean of Set	68.4	9.65	5.8
Standard Deviation of Set	107.1	12.1	2.4
Median of Lognormal	36.8	6.02	5.4
β of Lognormal	1.11	0.97	0.39

Table E.13 Summary of Nonlinear Response of a 3.0 Second, 37%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.231 (6T)	37.6 (6T)	44.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.075 (4T)	1.72 (4T)	2.02 (4T)
Mean of Set	0.108	9.21	14.1
Standard Deviation of Set	0.046	10.6	13.5
Median of Lognormal	0.099	6.04	10.2
β of Lognormal	0.41	0.92	0.81

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.193 (6L)	28.9 (6L)	46.1 (6L)
Minimum of Set (Eq. Rec. No.)	0.075 (4L)	1.58 (4L)	2.09 (4L)
Mean of Set	0.104	8.37	13.0
Standard Deviation of Set	0.040	9.13	14.6
Median of Lognormal	0.097	5.66	8.62
β of Lognormal	0.37	0.89	0.91

Table E.13 Summary of Nonlinear Response of a 3.0 Second, 37%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.231 (6T)	37.6 (6T)	44.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.075 (4T)	1.58 (4L)	2.02 (4T)
Mean of Set	0.106	8.79	13.5
Standard Deviation of Set	0.043	9.90	14.1
Median of Lognormal	0.098	5.84	9.38
β of Lognormal	0.39	0.91	0.86

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	276. (6T)	36.1 (6T)	7.6 (6T)
Minimum of Set (Eq. Rec. No.)	4.07 (4T)	1.21 (4T)	2.3 (2L)
Mean of Set	42.1	7.39	5.0
Standard Deviation of Set	66.0	9.31	1.6
Median of Lognormal	22.6	4.59	4.7
β of Lognormal	1.11	0.98	0.32

Table E.14 Summary of Nonlinear Response of a 3.5 Second, 12%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.459 (6T)	63.8 (6T)	81.5 (6T)
Minimum of Set (Eq. Rec. No.)	0.037 (4T)	1.48 (4T)	3.45 (4T)
Mean of Set	0.122	14.0	22.7
Standard Deviation of Set	0.125	18.4	24.1
Median of Lognormal	0.085	8.50	15.6
β of Lognormal	0.85	1.00	0.87

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.317 (6L)	42.7 (6L)	66.3 (6L)
Minimum of Set (Eq. Rec. No.)	0.038 (9L)	1.73 (9L)	2.62 (9L)
Mean of Set	0.114	12.8	19.7
Standard Deviation of Set	0.092	13.5	21.0
Median of Lognormal	0.088	8.77	13.5
β of Lognormal	0.71	0.87	0.87

Table E.14 Summary of Nonlinear Response of a 3.5 Second, 12%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.459 (6T)	63.8 (6T)	81.5 (6T)
Minimum of Set (Eq. Rec. No.)	0.037 (4T)	1.48 (4T)	2.62 (9L)
Mean of Set	0.118	13.4	21.2
Standard Deviation of Set	0.110	16.2	22.6
Median of Lognormal	0.086	8.55	14.5
β of Lognormal	0.79	0.95	0.87

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	563. (6T)	57.3 (6T)	9.8 (6T)
Minimum of Set (Eq. Rec. No.)	5.9 (4T)	1.25 (4T)	4.0 (8L)
Mean of Set	102.	12.3	6.8
Standard Deviation of Set	148.	15.0	2.1
Median of Lognormal	58.0	7.80	6.5
β of Lognormal	1.06	0.95	0.30

Table E.15 Summary of Nonlinear Response of a 3.5 Second, 28%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.347 (6T)	65.0 (6T)	75.8 (6T)
Minimum of Set (Eq. Rec. No.)	0.056 (4T)	1.78 (8T)	4.27 (4T)
Mean of Set	0.107	13.0	19.3
Standard Deviation of Set	0.087	19.0	22.3
Median of Lognormal	0.083	7.31	12.7
β of Lognormal	0.71	1.07	0.92

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.249 (6L)	43.8 (6L)	69.8 (6L)
Minimum of Set (Eq. Rec. No.)	0.057 (9L)	1.93 (9L)	2.91 (9L)
Mean of Set	0.098	10.9	17.8
Standard Deviation of Set	0.060	13.04	20.8
Median of Lognormal	0.084	7.04	10.8
β of Lognormal	0.56	0.94	0.95

Table E.15 Summary of Nonlinear Response of a 3.5 Second, 28%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.347 (6T)	65.0 (6T)	75.8 (6T)
Minimum of Set (Eq. Rec. No.)	0.056 (4T)	1.78 (4T)	2.91 (9L)
Mean of Set	0.103	12.0	18.2
Standard Deviation of Set	0.075	16.3	21.6
Median of Lognormal	0.083	7.07	11.7
β of Lognormal	0.65	1.03	0.94

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	593. (6T)	61.3 (6T)	9.7 (6T)
Minimum of Set (Eq. Rec. No.)	4.3 (4T)	1.47 (4T)	2.4 (2L)
Mean of Set	71.8	10.4	5.5
Standard Deviation of Set	137.8	15.3	2.2
Median of Lognormal	33.2	5.88	5.1
β of Lognormal	1.24	1.07	0.38

Table E.16 Summary of Nonlinear Response of a 4.0 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.607 (6T)	121. (6T)	145. (6T)
Minimum of Set (Eq. Rec. No.)	0.034 (4T)	1.44 (4T)	3.49 (4T)
Mean of Set	0.125	20.3	30.1
Standard Deviation of Set	0.172	35.9	42.7
Median of Lognormal	0.073	9.99	17.3
β of Lognormal	1.03	1.19	1.05

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.316 (6L)	59.8 (6L)	95.0 (6L)
Minimum of Set (Eq. Rec. No.)	0.036 (9L)	1.67 (9L)	2.46 (9L)
Mean of Set	0.097	14.4	22.6
Standard Deviation of Set	0.087	18.0	28.6
Median of Lognormal	0.072	9.00	14.0
β of Lognormal	0.77	0.97	0.98

Table E.16 Summary of Nonlinear Response of a 4.0 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.607 (6T)	121. (6T)	145.1 (6T)
Minimum of Set (Eq. Rec. No.)	0.034 (4T)	1.44 (4T)	2.46 (9L)
Mean of Set	0.111	17.3	26.3
Standard Deviation of Set	0.137	28.6	36.5
Median of Lognormal	0.070	8.99	15.4
β of Lognormal	0.96	1.15	1.04

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	1602. (6T)	119. (6T)	13.5 (6T)
Minimum of Set (Eq. Rec. No.)	5.50 (4T)	1.22 (4T)	3.7 (8L)
Mean of Set	155.	15.8	6.7
Standard Deviation of Set	366.	27.8	2.5
Median of Lognormal	60.1	7.83	6.2
β of Lognormal	1.37	1.19	0.37

Table E.17 Summary of Nonlinear Response of a 4.0 Second, 35%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.173 (6T)	46.2 (6T)	59.5 (6T)
Minimum of Set (Eq. Rec. No.)	0.053 (4T)	1.77 (4T)	4.45 (1T)
Mean of Set	0.078	10.7	17.5
Standard Deviation of Set	0.036	13.3	17.8
Median of Lognormal	0.070	6.74	12.3
β of Lognormal	0.44	0.96	0.84

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.143 (6L)	34.9 (6L)	56.3 (6L)
Minimum of Set (Eq. Rec. No.)	0.054 (9L)	2.11 (9L)	3.25 (9L)
Mean of Set	0.076	10.0	15.8
Standard Deviation of Set	0.028	10.5	17.0
Median of Lognormal	0.071	6.93	10.8
β of Lognormal	0.361	0.86	0.88

Table E.17 Summary of Nonlinear Response of a 4.0 Second, 35%-Damped Isolated Building Subjected to 9 Pairs of 0.4g Acceleration-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.173 (6T)	46.2 (6T)	59.5 (6T)
Minimum of Set (Eq. Rec. No.)	0.053 (4T)	1.77 (4T)	3.25 (9L)
Mean of Set	0.077	10.4	16.7
Standard Deviation of Set	0.032	12.0	17.4
Median of Lognormal	0.071	6.80	11.5
β of Lognormal	0.40	0.92	0.86

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	284. (6T)	43.2 (6T)	8.0 (1L)
Minimum of Set (Eq. Rec. No.)	4.09 (4T)	1.46 (4T)	2.2 (2L)
Mean of Set	48.9	8.91	5.0
Standard Deviation of Set	70.4	11.30	1.8
Median of Lognormal	27.8	5.52	4.8
β of Lognormal	1.06	0.98	0.35

F. TABLES SUMMARIZING THE NONLINEAR RESPONSE OF VARIOUS ISOLATED BUILDINGS SUBJECTED TO 22.5 IN./SEC. PGV-SCALED HORIZONTAL EARTHQUAKE TIME HISTORIES RECORDED AT MEDIUM SOIL SITES

F.1 Description of Appendix F

Each of the seventeen tables of Appendix F summarize the response results of 9 nonlinear analyses of an isolated building model. Each isolated building model is characterized by an equivalent linear period, with values ranging from 1.0 to 4.0 seconds, and by an equivalent viscous damping factor, with values ranging from 5% to 40% of critical.

The isolated building models were analyzed using pairs of horizontal time history components recorded at medium soil sites during past earthquakes. Each pair of earthquake components was scaled to have an average peak ground velocity (PGV) of 22.5 in./sec. Additional description of the earthquake components used in the analyses may be found in Chapter 4 of this report.

The isolated building models were identical with exception of the isolation system. In plan, the isolated building is rectangular with eight 20-foot bays in the longitudinal direction and four 20-foot bays in the transverse direction. The superstructure was modeled as essentially rigid with respect to the isolation system. The force-deflection properties of the isolator units (45 total per model) were modeled by a bi-linear element with a different yield point and a different degree of yielding for each model. Additional description of the isolated building models analyzed in this study may be found in Chapter 5 of this report.

The nonlinear analyses were performed using DRAIN-2D [Ref. 9] compiled for execution on micro-computers. For the analyses of this study the degrees of freedom of the models consisted of translational and torsional response of the isolated building in the plane of the isolation system.

F.2 Description of Response Parameters

Each of the seventeen tables presents a summary of calculated responses, grouped as follows:

1. Peak Response in the Transverse Direction

2. Peak Response in the Longitudinal Direction

3. Peak Response in the Transverse and Longitudinal Directions

4. Cyclic Response in the Transverse and Longitudinal Directions

For the first three response groups, listed above, the parameters reported in the tables are identically:

1. Peak Force at the Center of Gravity of the Building

2. Peak Displacement at the Center of the Building

3. Peak Displacement at the Corner of the Building

Peak displacement of the corner of the building was based on the corner of the model which gave the largest response. Comparison of peak displacements, corner vs. center, provides a measure of the isolated building's torsional response.

For the fourth response group the parameters reported in the tables are:

1. One-Half of the Cumulative Inelastic Displacement

2. One-Half of the Maximum Peak-to-Peak Displacement

3. Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements

Elements of the models representing response at the center of the building were used to evaluate each of the above parameters. One-half of the maximum peak-to-peak displacement is the average of the positive and negative peaks. Comparison of this parameter with the peak displacement at the building's center is helpful in checking for biased response of highly nonlinear systems. The ratio of cumulative inelastic displacement to maximum peak-to-peak displacement provides a measure of the effective number of high amplitude cycles.

F.3 Description of Statistical Parameters

For each response parameter of interest the following statistical information is provided:

1. Maximum of Set (Earthquake Record No.)

2. Minimum of Set (Earthquake Record No.)

3. Mean of Set

4. Standard Deviation of Set

5. Median of Lognormal

6. Beta of Lognormal

For response parameters of either the transverse direction or longitudinal direction, the number of values in the set is nine, the number of earthquake pairs. For response parameters of combined transverse and longitudinal directions, the number of values in the set is eighteen, one value from each direction for each earthquake pair. Earthquake record numbers refer to the earthquake component identifiers of Table 4.3. The median and β parameters are calculated based on an assumption that the response parameter of interest is lognormally distributed.

Table F.1 Summary of Nonlinear Response of a 1.0 Second, 13%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.573 (9T)	5.93 (9T)	7.82 (9T)
Minimum of Set (Eq. Rec. No.)	0.251 (6T)	1.73 (6T)	2.05 (6T)
Mean of Set	0.416	3.92	4.88
Standard Deviation of Set	0.095	1.21	1.59
Median of Lognormal	0.406	3.74	4.64
β of Lognormal	0.22	0.30	0.32

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.452 (8L)	4.37 (8L)	5.43 (8L)
Minimum of Set (Eq. Rec. No.)	0.223 (6L)	1.43 (6L)	1.54 (6L)
Mean of Set	0.355	3.13	3.71
Standard Deviation of Set	0.083	1.07	1.33
Median of Lognormal	0.346	2.97	3.50
β of Lognormal	0.23	0.33	0.35

Table F.1 Summary of Nonlinear Response of a 1.0 Second, 13%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.573 (9T)	5.93 (9T)	7.82 (9T)
Minimum of Set (Eq. Rec. No.)	0.223 (6L)	1.43 (6L)	1.54 (6L)
Mean of Set	0.386	3.52	4.30
Standard Deviation of Set	0.094	1.21	1.58
Median of Lognormal	0.375	3.33	4.03
β of Lognormal	0.24	0.33	0.36

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	56.3 (9T)	5.90 (9T)	12.6 (9L)
Minimum of Set (Eq. Rec. No.)	4.88 (2L)	1.37 (6L)	3.1 (3T)
Mean of Set	23.1	3.26	6.8
Standard Deviation of Set	13.9	1.11	2.7
Median of Lognormal	19.8	3.09	6.3
β of Lognormal	0.56	0.33	0.38

Table F.2 Summary of Nonlinear Response of a 1.5 Second, 8%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.630 (5T)	14.9 (5T)	17.8 (5T)
Minimum of Set (Eq. Rec. No.)	0.195 (4T)	3.72 (4T)	5.24 (2T)
Mean of Set	0.337	7.36	9.79
Standard Deviation of Set	0.142	3.66	4.02
Median of Lognormal	0.310	6.59	9.06
β of Lognormal	0.41	0.47	0.40

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.459 (3L)	10.5 (3L)	13.6 (3L)
Minimum of Set (Eq. Rec. No.)	0.244 (4L)	4.97 (4L)	6.37 (2L)
Mean of Set	0.327	7.10	9.24
Standard Deviation of Set	0.066	1.69	2.20
Median of Lognormal	0.321	6.91	8.98
β of Lognormal	0.20	0.23	0.24

Table F.2 Summary of Nonlinear Response of a 1.5 Second, 8%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.630 (5T)	14.9 (5T)	17.8 (5T)
Minimum of Set (Eq. Rec. No.)	0.195 (4T)	3.72 (4T)	5.24 (2T)
Mean of Set	0.332	7.23	9.51
Standard Deviation of Set	0.111	2.85	3.26
Median of Lognormal	0.315	6.73	9.00
β of Lognormal	0.33	0.38	0.33

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	174.1 (9T)	14.53 (5T)	14.4 (1L)
Minimum of Set (Eq. Rec. No.)	14.9 (2T)	3.30 (4T)	3.9 (2L)
Mean of Set	61.9	6.85	8.5
Standard Deviation of Set	40.4	2.88	3.0
Median of Lognormal	51.8	6.31	8.1
β of Lognormal	0.60	0.40	0.34

Table F.3 Summary of Nonlinear Response of a 1.5 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.404 (5T)	9.94 (5T)	12.7 (9T)
Minimum of Set (Eq. Rec. No.)	0.180 (2T)	2.98 (2T)	3.43 (2T)
Mean of Set	0.262	5.55	7.61
Standard Deviation of Set	0.080	2.48	3.11
Median of Lognormal	0.251	5.06	7.05
β of Lognormal	0.30	0.43	0.39

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.314 (3L)	7.15 (3L)	9.22 (3L)
Minimum of Set (Eq. Rec. No.)	0.200 (2L)	3.61 (2L)	4.42 (2L)
Mean of Set	0.241	4.88	6.24
Standard Deviation of Set	0.238	4.73	6.03
Median of Lognormal	0.17	0.25	0.26
β of Lognormal			

Table F.3 Summary of Nonlinear Response of a 1.5 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.404 (5T)	9.94 (5T)	12.7 (9T)
Minimum of Set (Eq. Rec. No.)	0.180 (2T)	2.98 (2T)	3.43 (2T)
Mean of Set	0.252	5.21	6.93
Standard Deviation of Set	0.064	1.99	2.59
Median of Lognormal	0.244	4.87	6.49
β of Lognormal	0.25	0.37	0.36

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	75.0 (9T)	8.77 (9T)	10.3 (1L)
Minimum of Set (Eq. Rec. No.)	7.70 (2L)	2.45 (2L)	3.1 (2L)
Mean of Set	31.5	4.76	6.4
Standard Deviation of Set	17.7	1.88	2.1
Median of Lognormal	27.5	4.43	6.1
β of Lognormal	0.52	0.38	0.32

Table F.4 Summary of Nonlinear Response of a 1.5 Second, 36%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.250 (9T)	6.76 (9T)	10.0 (3T)
Minimum of Set (Eq. Rec. No.)	0.176 (6T)	2.10 (6T)	2.56 (6T)
Mean of Set	0.211	4.30	6.73
Standard Deviation of Set	0.025	1.57	2.42
Median of Lognormal	0.025	1.57	2.42
β of Lognormal	0.12	0.35	0.35

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.236 (3L)	5.90 (3L)	8.40 (3L)
Minimum of Set (Eq. Rec. No.)	0.166 (6L)	1.50 (6L)	1.77 (6L)
Mean of Set	0.200	3.62	4.86
Standard Deviation of Set	0.022	1.37	1.86
Median of Lognormal	0.198	3.38	4.54
β of Lognormal	0.11	0.37	0.37

Table F.4 Summary of Nonlinear Response of a 1.5 Second, 36%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.250 (9T)	6.76 (9T)	10.1 (3T)
Minimum of Set (Eq. Rec. No.)	0.166 (6L)	1.50 (6L)	1.77 (6L)
Mean of Set	0.205	3.96	5.79
Standard Deviation of Set	0.024	1.51	2.35
Median of Lognormal	0.204	3.70	5.37
β of Lognormal	0.18	0.37	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	37.4 (9T)	5.11 (9T)	10.6 (9L)
Minimum of Set (Eq. Rec. No.)	3.83 (2L)	1.42 (6L)	2.1 (2L)
Mean of Set	15.9	3.15	5.1
Standard Deviation of Set	8.69	1.12	2.2
Median of Lognormal	13.9	2.97	4.6
β of Lognormal	0.51	0.35	0.42

Table F.5 Summary of Nonlinear Response of a 2.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.418 (5T)	17.4 (5T)	23.0 (9T)
Minimum of Set (Eq. Rec. No.)	0.104 (4T)	2.98 (4T)	5.85 (4T)
Mean of Set	0.257	10.00	5.85
Standard Deviation of Set	0.095	4.38	5.38
Median of Lognormal	0.241	9.16	12.6
β of Lognormal	0.36	0.42	0.38

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.424 (3L)	17.7 (3L)	24.2 (3L)
Minimum of Set (Eq. Rec. No.)	0.140 (9L)	4.64 (9L)	6.44 (1L)
Mean of Set	0.217	8.18	11.2
Standard Deviation of Set	0.091	4.15	5.63
Median of Lognormal	0.201	7.30	9.99
β of Lognormal	0.40	0.48	0.48

Table F.5 Summary of Nonlinear Response of a 2.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.424 (3L)	17.7 (3L)	24.2 (3L)
Minimum of Set (Eq. Rec. No.)	0.104 (4T)	2.98 (4T)	5.85 (4T)
Mean of Set	0.237	9.09	12.4
Standard Deviation of Set	0.095	4.36	5.63
Median of Lognormal	0.220	8.20	11.3
β of Lognormal	0.39	0.46	0.43

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	188.1 (5T)	17.1 (3L)	16.5 (1L)
Minimum of Set (Eq. Rec. No.)	19.1 (2L)	2.91 (4T)	4.1 (2L)
Mean of Set	73.1	8.39	8.6
Standard Deviation of Set	44.5	4.12	3.0
Median of Lognormal	62.4	7.53	8.1
β of Lognormal	0.56	0.46	0.34

Table F.6 Summary of Nonlinear Response of a 2.0 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Force at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.297 (9T)	12.8 (9T)	17.1 (3T)
Minimum of Set (Eq. Rec. No.)	0.118 (4T)	3.10 (4T)	5.74 (4T)
Mean of Set	0.198	7.42	10.7
Standard Deviation of Set	0.054	2.90	3.69
Median of Lognormal	0.171	6.91	10.1
β of Lognormal	0.27	0.38	0.34

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.319 (3L)	14.0 (3L)	19.4 (3L)
Minimum of Set (Eq. Rec. No.)	0.123 (9L)	3.37 (9L)	4.73 (9L)
Mean of Set	0.187	6.84	9.36
Standard Deviation of Set	0.057	3.10	4.28
Median of Lognormal	0.179	6.23	8.51
β of Lognormal	0.30	0.43	0.44

Table F.6 Summary of Nonlinear Response of a 2.0 Second, 17%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.319 (3L)	14.0 (3L)	19.4 (3L)
Minimum of Set (Eq. Rec. No.)	0.118 (4T)	3.10 (4T)	4.73 (9L)
Mean of Set	0.193	7.13	10.0
Standard Deviation of Set	0.056	3.02	4.05
Median of Lognormal	0.185	6.57	9.28
β of Lognormal	0.28	0.41	0.39

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	85.9 (5T)	12.11 (9T)	13.7 (1L)
Minimum of Set (Eq. Rec. No.)	12.5 (2L)	2.98 (4T)	2.9 (2T)
Mean of Set	43.7	6.52	6.9
Standard Deviation of Set	21.2	2.75	2.8
Median of Lognormal	39.4	6.01	6.4
β of Lognormal	0.46	0.41	0.40

Table F.7 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.192 (9T)	8.20 (9T)	13.5 (3T)
Minimum of Set (Eq. Rec. No.)	0.132 (4T)	3.20 (4T)	4.82 (2T)
Mean of Set	0.157	5.25	8.18
Standard Deviation of Set	0.021	1.71	2.62
Median of Lognormal	0.156	4.99	7.99
β of Lognormal	0.13	0.32	0.31

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.203 (3L)	9.09 (3L)	13.1 (3L)
Minimum of Set (Eq. Rec. No.)	0.132 (9L)	3.13 (9L)	4.38 (9L)
Mean of Set	0.155	5.05	6.98
Standard Deviation of Set	0.021	1.77	2.62
Median of Lognormal	0.153	4.76	6.53
β of Lognormal	0.14	0.34	0.36

Table F.7 Summary of Nonlinear Response of a 2.0 Second, 31%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.203 (3L)	9.09 (3L)	13.5 (3T)
Minimum of Set (Eq. Rec. No.)	0.132 (9L)	3.13 (9L)	4.38 (9L)
Mean of Set	0.156	5.15	7.58
Standard Deviation of Set	0.021	1.75	2.69
Median of Lognormal	0.154	4.87	7.14
β of Lognormal	0.13	0.33	0.34

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	55.6 (9T)	9.07 (3L)	10.6 (9L)
Minimum of Set (Eq. Rec. No.)	6.37 (2L)	2.58 (2T)	2.5 (2L)
Mean of Set	25.1	4.63	5.5
Standard Deviation of Set	12.6	1.94	2.1
Median of Lognormal	22.4	4.28	5.2
β of Lognormal	0.47	0.40	0.37

Table F.8 Summary of Nonlinear Response of a 2.5 Second, 6%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.379 (5T)	24.2 (5T)	29.2 (5T)
Minimum of Set (Eq. Rec. No.)	0.063 (4T)	2.72 (4T)	5.75 (4T)
Mean of Set	0.207	12.5	18.9
Standard Deviation of Set	0.093	6.28	6.82
Median of Lognormal	0.188	11.1	17.1
β of Lognormal	0.43	0.48	0.35

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.351 (3L)	22.2 (3L)	31.8 (3L)
Minimum of Set (Eq. Rec. No.)	0.085 (4L)	4.19 (4L)	6.09 (4L)
Mean of Set	0.193	11.5	16.7
Standard Deviation of Set	0.087	5.90	8.45
Median of Lognormal	0.176	10.2	14.9
β of Lognormal	0.43	0.48	0.48

Table F.8 Summary of Nonlinear Response of a 2.5 Second, 6%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.379 (5T)	24.2 (5T)	31.8 (3L)
Minimum of Set (Eq. Rec. No.)	0.063 (4T)	2.72 (4T)	5.75 (4T)
Mean of Set	0.200	12.0	17.8
Standard Deviation of Set	0.090	6.11	7.76
Median of Lognormal	0.182	10.7	16.3
β of Lognormal	0.43	0.48	0.42

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	259.1 (5T)	23.2 (5T)	16.8 (9L)
Minimum of Set (Eq. Rec. No.)	24.4 (4T)	2.70 (4T)	5.0 (2T)
Mean of Set	106.2	11.14	9.4
Standard Deviation of Set	63.2	5.77	2.5
Median of Lognormal	91.3	9.89	9.1
β of Lognormal	0.55	0.49	0.27

Table F.9 Summary of Nonlinear Response of a 2.5 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.231 (6T)	15.0 (6T)	23.1 (3T)
Minimum of Set (Eq. Rec. No.)	0.081 (4T)	2.94 (4T)	6.14 (4T)
Mean of Set	0.167	9.84	14.7
Standard Deviation of Set	0.050	3.97	4.98
Median of Lognormal	0.160	9.13	13.9
β of Lognormal	0.29	0.39	0.33

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.273 (3L)	18.4 (3L)	26.7 (3L)
Minimum of Set (Eq. Rec. No.)	0.092 (9L)	3.90 (9L)	5.79 (9L)
Mean of Set	0.150	8.54	12.4
Standard Deviation of Set	0.052	4.19	6.05
Median of Lognormal	0.142	7.66	11.1
β of Lognormal	0.34	0.46	0.46

Table F.9 Summary of Nonlinear Response of a 2.5 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.273 (3L)	18.4 (3L)	26.7 (3L)
Minimum of Set (Eq. Rec. No.)	0.081 (4T)	2.94 (4T)	5.79 (9L)
Mean of Set	0.159	9.19	13.6
Standard Deviation of Set	0.052	4.13	5.66
Median of Lognormal	0.151	8.38	12.5
β of Lognormal	0.32	0.43	0.40

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	123.7 (5T)	16.26 (3L)	12.0 (9L)
Minimum of Set (Eq. Rec. No.)	16.1 (2L)	2.61 (4T)	3.1 (2T)
Mean of Set	58.9	8.37	7.0
Standard Deviation of Set	31.5	3.81	2.1
Median of Lognormal	52.0	7.62	6.7
β of Lognormal	0.50	0.43	0.29

Table F.10 Summary of Nonlinear Response of a 2.5 Second, 26%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.179 (5T)	12.3 (5T)	18.5 (3T)
Minimum of Set (Eq. Rec. No.)	0.095 (4T)	3.26 (4T)	6.35 (4T)
Mean of Set	0.134	7.38	11.2
Standard Deviation of Set	0.025	2.75	3.84
Median of Lognormal	0.131	6.91	10.6
β of Lognormal	0.19	0.36	0.33

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.184 (3L)	12.8 (3L)	18.8 (3L)
Minimum of Set (Eq. Rec. No.)	0.094 (9L)	3.14 (9L)	4.63 (9L)
Mean of Set	0.127	6.64	9.72
Standard Deviation of Set	0.025	2.73	3.98
Median of Lognormal	0.124	6.14	8.99
β of0.20 0.40 Lognormal	0.39		

Table F.10 Summary of Nonlinear Response of a 2.5 Second, 26%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.184 (3L)	12.8 (3L)	18.8 (3L)
Minimum of Set (Eq. Rec. No.)	0.094 (2L)	3.14 (9L)	4.63 (9L)
Mean of Set	0.130	7.01	10.5
Standard Deviation of Set	0.026	2.77	3.99
Median of Lognormal	0.128	6.52	9.79
β of Lognormal	0.19	0.38	0.37

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	76.2 (5T)	12.50 (3L)	13.5 (9L)
Minimum of Set (Eq. Rec. No.)	11.4 (2L)	2.64 (4T)	2.6 (2T)
Mean of Set	37.2	6.20	6.3
Standard Deviation of Set	17.8	2.67	2.8
Median of Lognormal	33.6	5.69	5.8
β of Lognormal	0.45	0.41	0.42

Table F.11 Summary of Nonlinear Response of a 3.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.265 (1T)	24.6 (1T)	35.5 (5T)
Minimum of Set (Eq. Rec. No.)	0.052 (4T)	2.79 (4T)	5.61 (4T)
Mean of Set	0.152	13.1	26.3
Standard Deviation of Set	0.065	6.72	10.4
Median of Lognormal	0.140	11.6	19.1
β of Lognormal	0.41	0.48	0.46

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.245 (6L)	22.6 (6L)	33.7 (6L)
Minimum of Set (Eq. Rec. No.)	0.064 (9L)	4.01 (9L)	5.96 (9L)
Mean of Set	0.142	12.0	17.9
Standard Deviation of Set	0.065	6.64	9.96
Median of Lognormal	0.129	10.5	15.6
β of Lognormal	0.44	0.52	0.52

Table F.11 Summary of Nonlinear Response of a 3.0 Second, 9%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.265 (1T)	24.6 (1T)	35.3 (5T)
Minimum of Set (Eq. Rec. No.)	0.052 (4T)	2.79 (4T)	5.61 (4T)
Mean of Set	0.147	12.5	20.0
Standard Deviation of Set	0.065	6.70	10.3
Median of Lognormal	0.134	11.0	17.3
β of Lognormal	0.42	0.50	0.50

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	273.0 (6L)	22.64 (1T)	17.4 (9L)
Minimum of Set (Eq. Rec. No.)	21.2 (4T)	2.64 (4T)	4.6 (2L)
Mean of Set	99.8	11.68	8.4
Standard Deviation of Set	72.2	6.51	3.0
Median of Lognormal	80.8	10.20	7.9
β of Lognormal	0.65	0.52	0.35

Table F.12 Summary of Nonlinear Response of a 3.0 Second, 20%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.169 (5T)	16.6 (5T)	24.5 (5T)
Minimum of Set (Eq. Rec. No.)	0.069 (4T)	3.03 (4T)	6.35 (4T)
Mean of Set	0.117	9.50	15.2
Standard Deviation of Set	0.031	4.13	5.82
Median of Lognormal	0.113	8.71	14.2
β of Lognormal	0.26	0.42	0.37

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.165 (3L)	16.0 (3L)	24.4 (3L)
Minimum of Set (Eq. Rec. No.)	0.070 (9L)	3.26 (9L)	5.03 (9L)
Mean of Set	0.106	8.07	12.3
Standard Deviation of Set	0.027	3.60	5.51
Median of Lognormal	0.103	7.37	11.2
β of Lognormal	0.25	0.43	0.43

Table F.12 Summary of Nonlinear Response of a 3.0 Second, 20%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.169 (5T)	16.6 (5T)	24.5 (5T)
Minimum of Set (Eq. Rec. No.)	0.069 (4T)	3.03 (4T)	5.03 (9L)
Mean of Set	0.111	8.78	13.7
Standard Deviation of Set	0.029	3.94	5.86
Median of Lognormal	0.108	8.01	12.6
β of Lognormal	0.26	0.43	0.41

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	104.7 (5T)	15.02 (5T)	12.7 (9L)
Minimum of Set (Eq. Rec. No.)	15.7 (4T)	2.36 (4T)	2.7 (2L)
Mean of Set	51.0	7.89	6.7
Standard Deviation of Set	27.5	3.88	2.3
Median of Lognormal	44.8	7.07	6.3
β of Lognormal	0.51	0.47	0.33

Table F.13 Summary of Nonlinear Response of a 3.0 Second, 37%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.126 (5T)	13.3 (5T)	23.2 (3T)
Minimum of Set (Eq. Rec. No.)	0.082 (4T)	3.30 (4T)	6.88 (4T)
Mean of Set	0.100	7.42	11.8
Standard Deviation of Set	0.015	3.38	4.82
Median of Lognormal	0.099	6.75	11.0
β of Lognormal	0.15	0.43	0.39

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.133 (3L)	15.1 (3L)	23.6 (3L)
Minimum of Set (Eq. Rec. No.)	0.085 (9L)	3.86 (9L)	6.25 (9L)
Mean of Set	0.097	6.69	10.3
Standard Deviation of Set	0.014	3.16	4.98
Median of Lognormal	0.096	6.04	9.28
β of Lognormal	0.14	0.45	0.46

Table F.13 Summary of Nonlinear Response of a 3.0 Second, 37%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.133 (3L)	15.1 (3L)	23.6 (3L)
Minimum of Set (Eq. Rec. No.)	0.082 (9L)	3.30 (4T)	6.25 (9L)
Mean of Set	0.098	7.05	11.1
Standard Deviation of Set	0.014	3.29	4.96
Median of Lognormal	0.097	6.39	10.1
β of Lognormal	0.14	0.44	0.43

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	62.7 (5T)	10.66 (3L)	11.2 (9L)
Minimum of Set (Eq. Rec. No.)	10.3 (2L)	2.37 (4T)	2.3 (2L)
Mean of Set	32.9	5.65	6.1
Standard Deviation of Set	15.2	2.24	2.5
Median of Lognormal	29.8	5.26	5.6
β of Lognormal	0.44	0.38	0.39

Table F.14 Summary of Nonlinear Response of a 3.5 Second, 12%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

1. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.194 (6T)	24.7 (6T)	37.4 (5T)
Minimum of Set (Eq. Rec. No.)	0.046 (4T)	2.91 (4T)	5.44 (4T)
Mean of Set	0.112	12.6	20.5
Standard Deviation of Set	0.044	6.52	10.0
Median of Lognormal	0.105	11.2	18.4
β of Lognormal	0.38	0.49	0.46

2. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.196 (5L)	24.9 (5L)	38.4 (5L)
Minimum of Set (Eq. Rec. No.)	0.051 (9L)	3.60 (9L)	5.48 (9L)
Mean of Set	0.104	11.4	17.5
Standard Deviation of Set	0.048	7.04	10.9
Median of Lognormal	0.095	9.67	14.9
β of Lognormal	0.44	0.57	0.57

Table F.14 Summary of Nonlinear Response of a 3.5 Second, 12%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

3. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.196 (5L)	24.9 (5L)	38.4 (5L)
Minimum of Set (Eq. Rec. No.)	0.046 (4T)	2.91 (4T)	5.44 (4T)
Mean of Set	0.108	12.0	19.0
Standard Deviation of Set	0.046	6.81	10.6
Median of Lognormal	0.099	10.4	16.6
β of Lognormal	0.41	0.53	0.52

4. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	229.3 (5L)	24.70 (5L)	17.5 (9L)
Minimum of Set (Eq. Rec. No.)	19.5 (4T)	2.57 (4T)	4.1 (2L)
Mean of Set	86.1	10.95	8.0
Standard Deviation of Set	60.3	6.58	3.0
Median of Lognormal	70.5	9.39	7.5
β of Lognormal	0.63	0.56	0.36

Table F.15 Summary of Nonlinear Response of a 3.5 Second, 28%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

A. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.125 (5T)	16.8 (5T)	25.4 (3T)
Minimum of Set (Eq. Rec. No.)	0.062 (4T)	3.09 (4T)	6.49 (4T)
Mean of Set	0.091	9.31	14.6
Standard Deviation of Set	0.020	4.33	6.33
Median of Lognormal	0.088	8.44	13.4
β of Lognormal	0.22	0.44	0.42

B. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.126 (3L)	17.0 (3L)	26.4 (3L)
Minimum of Set (Eq. Rec. No.)	0.065 (9L)	3.84 (9L)	6.16 (9L)
Mean of Set	0.083	7.71	12.0
Standard Deviation of Set	0.017	3.71	5.81
Median of Lognormal	0.081	6.95	10.8
β of Lognormal	0.20	0.46	0.46

Table F.15 Summary of Nonlinear Response of a 3.5 Second, 28%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

C. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.126 (3L)	17.0 (3L)	26.4 (3L)
Minimum of Set (Eq. Rec. No.)	0.062 (4T)	3.09 (4T)	6.16 (9L)
Mean of Set	0.087	8.51	13.3
Standard Deviation of Set	0.019	4.11	6.21
Median of Lognormal	0.085	7.67	12.1
β of Lognormal	0.22	0.46	0.44

D. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	92.5 (5T)	14.91 (5T)	11.6 (9L)
Minimum of Set (Eq. Rec. No.)	14.4 (2L)	2.20 (4T)	2.3 (2L)
Mean of Set	45.4	7.26	6.5
Standard Deviation of Set	23.6	3.45	2.3
Median of Lognormal	40.3	6.56	6.10
β of Lognormal	0.49	0.45	0.35

Table F.16 Summary of Nonlinear Response of a 4.0 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

A. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.151 (6T)	25.7 (6T)	39.7 (5T)
Minimum of Set (Eq. Rec. No.)	0.042 (4T)	2.98 (4T)	5.31 (4T)
Mean of Set	0.087	12.3	20.2
Standard Deviation of Set	0.033	6.90	10.7
Median of Lognormal	0.081	10.7	17.9
β of Lognormal	0.37	0.52	0.49

B. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.139 (5L)	23.1 (5L)	36.4 (5L)
Minimum of Set (Eq. Rec. No.)	0.046 (9L)	3.78 (9L)	5.97 (4L)
Mean of Set	0.082	11.3	17.8
Standard Deviation of Set	0.034	7.03	11.1
Median of Lognormal	0.076	9.63	15.2
β of Lognormal	0.40	0.57	0.57

Table F.16 Summary of Nonlinear Response of a 4.0 Second, 15%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

C. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.151 (6T)	25.7 (6T)	39.7 (5T)
Minimum of Set (Eq. Rec. No.)	0.042 (4T)	2.98 (4T)	5.31 (4T)
Mean of Set	0.084	11.8	19.0
Standard Deviation of Set	0.034	6.98	10.9
Median of Lognormal	0.078	10.2	16.5
β of Lognormal	0.38	0.55	0.53

D. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	243.9 (6T)	24.36 (6T)	15.7 (9L)
Minimum of Set (Eq. Rec. No.)	18.5 (4T)	2.62 (4T)	3.8 (2L)
Mean of Set	76.1	10.39	7.6
Standard Deviation of Set	55.7	6.37	3.0
Median of Lognormal	61.4	8.86	7.1
β of Lognormal	0.66	0.57	0.38

Table F.17 Summary of Nonlinear Response of a 4.0 Second, 35%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

A. Peak Response in the Transverse Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.095 (6T)	17.1 (6T)	26.2 (3T)
Minimum of Set (Eq. Rec. No.)	0.057 (4T)	3.14 (4T)	6.55 (4T)
Mean of Set	0.073	8.94	14.6
Standard Deviation of Set	0.012	4.45	6.59
Median of Lognormal	0.072	8.00	13.4
β of Lognormal	0.16	0.47	0.43

B. Peak Response in the Longitudinal Direction

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.095 (3L)	17.1 (3L)	27.1 (3L)
Minimum of Set (Eq. Rec. No.)	0.061 (9L)	4.39 (9L)	7.13 (9L)
Mean of Set	0.070	7.86	12.4
Standard Deviation of Set	0.010	3.79	6.11
Median of Lognormal	0.069	7.08	11.1
β of Lognormal	0.15	0.46	0.47

Table F.17 Summary of Nonlinear Response of a 4.0 Second, 35%-Damped Isolated Building Subjected to 9 Pairs of 22.5 in./sec. Velocity-Scaled Horizontal Earthquake Time Histories Recorded at Medium Soil Sites.

C. Peak Response in the Transverse and Longitudinal Directions

Statistical Parameter	Peak Acceleration at the Center of Gravity (g)	Peak Displacement (in.)	
		Center	Corner
Maximum of Set (Eq. Rec. No.)	0.095 (6T)	17.1 (6T)	27.1 (3L)
Minimum of Set (Eq. Rec. No.)	0.057 (4T)	3.14 (4T)	6.55 (4T)
Mean of Set	0.071	8.40	13.5
Standard Deviation of Set	0.011	4.17	6.45
Median of Lognormal	0.070	7.52	12.2
β of Lognormal	0.16	0.47	0.45

D. Cyclic Response in the Transverse and Longitudinal Directions

Statistical Parameter	One-Half of the Cumulative Inelastic Displacement (in.)	One-Half of the Maximum Peak-to-Peak Displacement (in.)	Ratio of Cumulative Inelastic and Maximum Peak-to-Peak Displacements
Maximum of Set (Eq. Rec. No.)	81.4 (5T)	13.78 (5T)	10.9 (1L)
Minimum of Set (Eq. Rec. No.)	14.1 (2L)	2.13 (4T)	2.2 (2L)
Mean of Set	41.5	7.08	6.2
Standard Deviation of Set	20.6	3.29	2.4
Median of Lognormal	37.2	6.42	5.8
β of Lognormal	0.47	0.44	0.37