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STRUCTURAL WALLS IN EARTHQUAKE-RESISTANT BUILDINGS

Dynamic Analysis of Isolated Structural Walls

REPRESENTATIVE LOADING HISTORY

by

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16. Abstract (Limit: 200 words)

An analytical investigation attempts to estimate the maximum forces and deformations that can reasonably be expected in critical regions of structural walls subjected to strong ground motion. This document deals with the qualitative description of "a representative loading history" which can be used in testing isolated structural wall specimens under slowly reversing loads. One hundred and seventy rotational response histories, representing a broad range of parameter values, are examined. The representative loading history is described in terms of the magnitude of the largest rotational deformation that can reasonably be expected in the hinging region of isolated walls, the total number of cycles of such large-amplitude deformations, and the sequence in which these large-amplitude deformations occur relative to deformations of lesser amplitude. Also considered are the forces (moments and shears) that can accompany these deformations. For the isolated walls considered in this study, the maximum number of large-amplitude cycles that can reasonably be expected for a 20-second duration of strong ground motion is six. A significant result is the fact that the first large-amplitude cycle of deformation can occur early in the response, with hardly any inelastic cycle preceding it.

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SYNOPSIS

Although structural walls have a long history of satisfactory use in stiffening buildings against wind, there is insufficient information on their behavior under strong earthquakes. Observations of the performance of buildings during recent earthquakes have demonstrated the superior performance of buildings stiffened by properly proportioned and designed structural walls - from the point of view of safety and especially from the standpoint of damage control.

The primary objective of the analytical investigation, of which the work reported here is a part, is the estimation of the maximum forces and deformations that can reasonably be expected in critical regions of structural walls subjected to strong ground motion. The results of the analytical investigation, when correlated with data from the concurrent experimental program, will form the basis for the design procedure to be developed as the ultimate objective of the overall investigation.

This is the fourth part of the report on the analytical investigation. It deals mainly with the qualitative description of "a representative loading history" which can be used in testing isolated structural wall specimens under slowly reversing loads. A total of 170 rotational response histories, representing a broad range of parameter values, are examined. The representative loading history is described in terms of the magnitude of the largest rotational deformation that can rea-

sonably be expected in the hinging region of isolated walls, the total number of cycles of such large-amplitude deformations and the sequence in which these large-amplitude deformations occur relative to deformations of lesser amplitude. Also considered are the forces (moments and shears) that can accompany these deformations.

It is shown that, for the isolated walls considered in this study, the maximum number of large-amplitude cycles that can reasonably be expected for a 20-second duration of strong ground motion is six. A significant result is the fact that the first large-amplitude cycle of deformation can occur early in the response, with hardly any inelastic cycle preceding it.

Dynamic Analysis Of Isolated Structural Walls

REPRESENTATIVE LOADING HISTORY

by

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BACKGROUND

Although structural walls (shear walls)* have a long history of satisfactory use in stiffening multistory buildings against wind, not enough information is available on the behavior of such elements under strong earthquake conditions.

Observations of the performance of buildings subjected to earthquakes during the past decade have focused attention on the need to minimize damage in addition to ensuring the general safety of buildings during strong earthquakes. The need to control damage to both structural and nonstructural components during earthquakes becomes particularly important in hospitals and other facilities which must continue operation following a major disaster. Damage control, in addition to life safety, is also economically desirable in tall buildings designed for residen-

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*In conformity with the nomenclature adopted by the Applied Technology Council(1) and in the forthcoming revised edition of Appendix A to ACI 318-77, Building Code Requirements for Reinforced Concrete(2), the term "structural wall" is used in place of "shear wall".

tial and commercial occupancy, since the nonstructural components in such buildings usually account for 60 to 80 percent of the total cost.

There is little doubt that structural walls offer an efficient way to stiffen a building against lateral loads. When proportioned so that they possess adequate lateral stiffness to reduce interstory distortions due to earthquake-induced motions, walls effectively reduce the likelihood of damage to the nonstructural elements in a building. When used with rigid frames, walls form a structural system that combines the gravity-load-carrying efficiency of the rigid frame with the lateral-load-resisting efficiency of the structural wall.

Observations of the comparative performance of rigid frame buildings and buildings stiffened by structural walls during recent earthquakes,(3,4,5) have clearly demonstrated the superior performance of buildings stiffened by properly proportioned and designed structural walls, from the point of view of safety and especially from the standpoint of damage control.

The need to minimize damage during strong earthquakes, in addition to the primary requirement of life safety (i.e., no collapse), clearly imposes more stringent requirements on the design of structures. This need to minimize damage provided the impetus for a closer examination of the structural wall as an earthquake-resisting element. Among the more immediate questions to be answered before a rational design procedure can be developed are:

1. What magnitudes of deformation and associated forces can reasonably be expected at critical regions of structural walls corresponding to specific combinations of structural and ground motion parameters? How many cycles of large deformation can be expected in critical regions of walls under earthquakes of average duration?

2. What stiffness and strength should structural walls in typical building configurations have relative to the expected ground motion in order to limit the deformations to acceptable levels?

3. What design and detailing requirements must be met to provide walls with the strength and deformation capacities indicated by analysis?

The combined analytical and experimental investigation, of which this study is a part, was undertaken to provide answers to the above questions. The ultimate objective of the overall investigation is the development of practical and reliable design procedures for earthquake-resistant structural walls and wall systems.

The analytical program undertaken to accomplish part of the desired objective consists of the following steps:

(a) Characterization of input motions in terms of the significant parameters to enable the calculation of critical or 'near-maximum' response using a minimum number of input motions(6).

(b) Determination of the relative influence of the various structural and ground motion parameters on dynamic structural response through parametric studies(7). The purpose of this study is to identify the most significant variables.

(c) Calculation of estimates of strength and deformation demands in critical regions of structural walls as affected by the significant parameters determined in Step (b). A number of input accelerograms chosen on the basis of information developed in Steps (a) and (b) are used(8).

(d) Development of procedure for determining design force levels(8) by correlating the stiffness, strength and deformation demands obtained in Step (c) with the corresponding capacities determined from the concurrent experimental program(9).

The first phase of this investigation is concerned mainly with isolated structural walls. A detailed consideration of the dynamic response of frame-wall and coupled wall structures is planned for the subsequent phases of the investigation.

This is the fourth part of the report on the analytical investigation. It describes a procedure for defining a "representative loading history" which can be used in testing laboratory specimens under slowly reversing loads to simulate earthquake loading. The representative loading history, for a particular set of structural and ground motion parameters, is described in terms of the magnitude of the largest rotational deformation that can reasonably be expected in the hinging region, the total number of cycles of such large-amplitude deformations and the sequence in which these large-amplitude deformations occur relative to deformations of lesser amplitude. Also considered are the forces (moments and shears) that can accompany these deformations. To determine the number and sequence of large-amplitude cycles, a total of 170 rotational response histories of the critical region at the base of isolated structural walls, were examined. These represent a broad range of parameter values.

The first part of the report on the analytical investigation(6) dealt mainly with the characterization of input motions in terms of duration, intensity and frequency content, with particular regard to the effects of these on dynamic inelastic response. The second part of the report(7) discussed the results of parametric studies designed to isolate the most significant structural and ground motion parameters. A procedure for determining design force levels for isolated structural walls is developed in the third part of the report on the analytical investigation(8).

INTRODUCTION

A major objective of the analytical investigation is the determination of the force and deformation demands in structures corresponding to particular combinations of the significant structural and ground motion parameters. Since design attention will have to be focused on the critically stressed regions in structures, these demands will have to be defined mainly in relation to the hinging regions in elements. A complete characterization of these demands would include not only the maximum amplitude but also the number of large-amplitude cycles that can reasonably be expected, the sequence of such large-amplitude cycles relative to cycles of lesser amplitude, and associated forces. The development of a "representative loading history" for critical regions in structures which can be used in testing large-size specimens under slowly applied reversing loads is one of the more important results that can be obtained from dynamic inelastic analyses.

In developing a procedure for determining design force levels discussed in Ref. 8, the correlation between calculated demands and measured capacities is based on critical (maximum) values. It was implicitly assumed, in undertaking the correlation, that the loading program used in the laboratory to obtain capacity values was either representative of or more conservative than the loading associated with dynamic response to strong ground motion. The loading program used in testing the first series of isolated wall specimens was characterized by loading cycles of progressively increasing amplitude, with the moment, shear and rotation all in phase. This type of loading has been commonly used(9-29) to simulate earthquake loading conditions.

A preliminary examination of response histories indicated, however, that the sequence of load cycles used in this loading program was not typical of the deformation history of the hinging region in isolated walls subjected to strong ground motion. In undertaking the correlation, it was thus necessary to assume that any difference between this loading and earthquake loading had no significant effect on the behavior of the isolated wall specimens. This assumption relates mainly to the number of large-amplitude deformation cycles and the sequence in which these cycles are applied to a specimen. It is worth noting that the cumulative measures of deformation discussed in Ref. 8* reflect, to some degree, the number of cycles of significant amplitude. However, they do not provide a definite indication of the number of such large-amplitude deformations which can be used as a basis for laboratory tests.

In view of the importance of ensuring that the loading program used in laboratory tests represent realistic loading conditions, it was decided early in the investigation to develop a representative loading history. Such a loading history, to be used in the laboratory testing of isolated structural walls under slowly reversing loads, would have to be based on analytical dynamic response data.

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*i.e. cumulative rotational ductility and cumulative rotational energy.

The principal objective of this study is the characterization of the typical response history of the critical region at the base of isolated structural walls in quantitative terms, particularly as these affect structural behavior. The deformation of major interest is the total rotation occurring in the hinging region of walls. An adequate characterization of the deformation history will have to include the following:

(1) The maximum amplitude of deformation that can be expected for a particular combination of structure period and yield level and earthquake intensity.

(2) The number of such large-amplitude cycles that can be expected for a reasonable duration of the ground motion; and

(3) The sequence of such large-amplitude cycles relative to cycles of lesser amplitude.

Of equal importance as the deformation history are the accompanying forces, i.e., moments and shears, and their variation relative to the deformation.

DESCRIPTION OF DATA

Parameters Represented

The raw data used for this study include results of dynamic response analyses undertaken in connection with the work reported in Refs. 7 and 8.

The dynamic response data used correspond to multistory isolated structural walls ranging from 10 to 40 stories in height and subjected to 10 different input motions. Figure 1 shows the type of structure considered and the lumped 12-mass model used in the analysis of 20-story walls. Note that the masses are spaced closer together near the base of the model. This was done in order to obtain a better indication of the deformation in the critical region near the base. Corresponding models for the 10-, 30- and 40- story walls are shown in Fig. 2.

Table 1 gives the ranges of values of the different structural parameters characterizing the isolated wall models as well as the ground motion parameters used in this study. A detailed description of these parameter variations is given in Refs. 7 and 8.

The basic moment-rotation relationship assumed for the hinging regions in the walls is a bilinear idealization of the primary curve typical of reinforced concrete structures. The hysteresis loop is characterized by unloading and reloading branches whose slopes decrease for response cycles subsequent to yield. This is shown in Fig. 3a, where the unloading and reloading parameters are denoted by α and β , respectively. An example of a moment-rotation loop for an isolated wall with fundamental period, T_1 = 1.4 sec., α = 0.10, and β = 0, is shown in Fig. 3b.

Of the ten different input motions used, six were of 10-second duration. The other four had 20-second durations. These were synthesized by repeating the first 10-second strong-motion portion of four records. In all cases, the input motion was assumed applied directly to the base of the structure.

The six 10-second accelerograms used for most of the analyses are shown in Fig. 4. These include the first 10 seconds of five recorded motions, as digitized at the California Institute of Technology(30) and one artificially generated accelerogram obtained by using the program described in Ref. 31. The accelerograms shown have been normalized with respect to intensity so that the spectrum intensity* of each one is equal to 1.5 times the spectrum intensity corresponding to the first 10 seconds of the N-S component of the 1940 El Centro record (denoted here by $SI_{ref.}$). The 5%-damped velocity response spectra for these six accelerograms are shown in Fig. 5. The four 20-second composite accelerograms used are shown in Fig. 6, and the corresponding 5%-damped velocity response spectra are shown in Fig. 7. The portions of each record used for the second ten seconds of the composite accelerograms are indicated in Table 2. Also shown in Table 2 are the corresponding 5%-damped spectrum intensities.

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*Spectrum intensity - defined as the area under the relative velocity response spectrum (for a single-degree-of-freedom system) corresponding to the first 10 seconds of ground motion, between periods 0.1 and 3.0 seconds.

The dynamic inelastic analyses were carried out using the computer program DRAIN-2D(32) developed at the University of California, Berkeley, as modified at the Portland Cement Association(33).

Basic Data

Of the information necessary to describe a loading history for a particular set of structural and ground motion parameters, the maximum amplitude of deformation and the accompanying shears and moments are discussed in detail in Ref. 8. Some 300 analyses were used as bases for these. The major question considered here concerns the number of large-amplitude cycles of deformation in the hinging region as well as the sequence of such large-amplitude cycles relative to cycles of lesser amplitude.

The data considered consist of response history plots of the total rotation in the hinging region at the base of each wall. The rotational deformation in the hinging region is taken as equal to the nodal rotation at a height above the base representing the hinging length, as shown in Fig. 8.

Rotation histories for nodes at the first and second floor levels of a particular 20-story wall subjected to the first 10 seconds of the E-W component of the 1940 El Centro record are shown in Fig. 9. Note the similarity in shape between the response history curves for nodes located at the first and second floor levels. This is generally true for nodes near the base of the wall and is due mainly to the predominance of the fundamental mode of response. Also shown in this figure is the horizontal displacement history for the floor at midheight.

Examples of the rotational response histories considered in this investigation are shown in Appendix A. These plots were examined to determine the number and sequence of such large-amplitude cycles. For this particular purpose, the rotation history of any node near the base of the wall will provide essentially the same information with respect to number of cycles and sequence. The plots shown in Appendix A all correspond to the node nearest to the base in the models of Fig. 2.

ANALYSIS OF DATA

Maximum Amplitude of Rotational Deformation and Accompanying Shears

In Ref. 8, the critical value of rotational ductility demand is obtained as a function of the fundamental period and the flexural yield level, for selected values of ground motion intensity and wall height. Plots such as Fig. 10 give the rotational ductility, μ_r, that has to be developed at the base of an isolated wall of a particular height, fundamental period, T_1, and flexural yield level, M_y, when subjected to an input motion of specific intensity.

The tendency of the ductility demand to decrease with an increase in the assumed hinging length, as indicated in Fig. 11, should be noted. This figure shows the calculated ductility ratios based on nodal rotations at the first and second floor levels for 20-story walls, both divided by the corresponding value at the second floor level (Fig. 1). The data points are shown connected by straight lines, on the assumption of a linear variation of the ratio between the two assumed hinging lengths from 20.75 ft to 12.0 ft. Results of experiments on isolated walls(9,36) suggest a hinging length, i.e., the length over which most of the inelastic deformation in a member occurs, equal to the width of the wall.

Another important set of results of the study reported in Ref. 8 are plots, such as shown in Fig. 12, giving the critical shear at the base of isolated walls as a function of T_1 and M_y, for particular values of the input motion intensity.

Since the rotational ductility of a reinforced concrete wall or other element can be significantly affected by shear, this factor has to be considered in developing a loading program. It will be noted in Fig. 12 that the critical shear at the base increases with increasing yield level, M_y, but does not vary significantly with changing values of the fundamental period, T_1.

Plots of critical rotational ductility demand and shears for other wall heights are also shown in Figs. 10b,c,d and 12b,c,d. All these plots correspond to a ground motion intensity of 1.5 SI_{ref}. Response data for input motion intensities of 0.75 SI_{ref} and 1.0 SI_{ref} have also been generated(8).

The maximum amplitude of deformation and the accompanying shears to be used in any loading program will depend on the range of values of the structure period, yield level, height and earthquake intensity represented by the loading program. It is evident from the charts shown in Figs. 10 and 12 that the greater the ductility demand used in a loading program, the broader the range of parameter combinations that can be considered as 'represented' by the test. In Fig. 10, for example, a maximum loading amplitude corresponding to a rotational ductility ratio of 5, would represent the demand on all 20-story isolated walls having combinations of the fundamental period, T_1, and yield level, M_y, for which the associated curves lie below the horizontal line $\mu_r = 5$.

It will be noted from Figs. 10 and 12 that while an increase in yield level generally results in a decrease in ductility demand, it is also accompanied by an increase in the maximum shear force. Experiments(9,36) have indicated that the presence of high shears can limit the rotational capacity (or ductility) of the hinging region in walls subjected to reversed loading.

Shear Stress Levels. In determining the magnitude of the rotational deformation requirements associated with response to strong ground motions, it is important to ascertain the magnitude of the accompanying shear forces. These can have a significant effect on both the flexural strength and deformation capacity of reinforced concrete elements. Results of experiments on beams(16,17) and walls(9,10,34,36) have clearly demonstrated the major influence that shear can have on the behavior of reinforced concrete structures. This is particularly true of structures subjected to reversed loading with deformations well into the inelastic range.

An indication of the level of the maximum nominal shear stress that can be expected for earthquakes with intensities equal to 1.5 (SI_{ref}), is given in Tables 3a and 3b. Table 3a, for example, shows the maximum nominal shear stress corresponding to rectangular wall sections of various heights. The walls considered were chosen such that their initial fundamental period would each be equal to 0.6 N, where N is the number of stories in the building. The section dimensions shown in the table were calculated on the basis of the gross areas of the sections. The wall stiffnesses corresponding to each value of the fundamental period were determined using the curves of Fig. 13. Flexural yield level (M_y) values were chosen for each section corresponding to a rotational ductility demand at the base equal to 4.0. For this purpose, curves such as shown in Fig. 14 (based on Fig. 10), determined on the basis of dynamic inelastic analyses[8], were used. The critical shear values corresponding to each structure were obtained from Fig. 15 (based on Fig. 12), also developed in Ref. 8. Similar data for flanged sections are shown in Table 3b.

Tables 3a and 3b show the maximum nominal dynamic shear stress in terms of $\sqrt{f'_c}$ for f'_c = 4000 psi and f'_c = 6000 psi.

The results shown in these tables indicate that for the range of fundamental period and ductility demand considered, maximum nominal dynamic shear stress values in the range of 4.0 $\sqrt{f'_c}$ to 7.0 $\sqrt{f'_c}$ can be expected.

It is important to note, however, that there is a significant difference between the dynamic shear force and the shear normally associated with quasi-static laboratory tests to simulate earthquake loading. The major difference lies in the variation of the shear force with time, particularly in relation to the accompanying moment and rotation. This is discussed in detail under "Comments on Character of Shear Loading."

Number of Cycles of Large Amplitude Corresponding to 20 Seconds of Strong Ground Motion

As discussed in Ref. 6, a duration of 20 seconds of the strong-motion portion of an accelerogram should provide reasonably conservative estimates of cumulative deformation requirements. This observation applies similarly to the number of large-amplitude cycles of response. Since the number of applications of reversed cycles of loading can significantly affect the behavior of reinforced concrete elements, a reliable assessment of this aspect of the deformation demand is important.

To estimate the number of large-amplitude cycles of response to strong ground motion, response history plots of the nodal rotations of the first two nodes closest to the base, as shown in Fig. 2 were prepared and examined. An example of these response plots is shown in Fig. 9. Since the response of the wall is dominated by the first or fundamental mode, in which all parts of the wall remain on the same side of the original vertical position at any instant, the calculated rotations of nodes near the base represent essentially the total rotations occurring in the segments of wall between the base and the particular nodes (Fig. 8). Because the response histories for the two nodes closest to the base are generally similar and yield essentially the same information with respect to number of cycles of response, as shown in Fig. 9, only the response of the node closest to the base was considered in detail. Plots of rotation history for the node closest to the base for some 170 cases considered in Refs. 7 and 8 were examined. The cases considered represent a broad range of values of the significant structural and ground motion parameters, as indicated in Table 1. Figure 15 shows examples of rotational response history plots. The nodal rotations in these plots have been normalized by dividing these by the corresponding yield rotations. A number of normalized rotation history plots representing samples from the 170 cases considered have been assembled in Appendix A.

Most of the analyses, and hence response plots, were done using a 10-second duration of the input motion. However, to allow for motions of longer duration, particularly as these affect cumulative response quantities such as the number of large-amplitude cycles, a few analyses were performed using 20-second composite accelerograms. As mentioned earlier, these accelerograms were synthesized from the same records that provided the 10-second motions of Fig. 4. This was done by appending to the latter another 10 seconds of the strong-motion portion of the corresponding accelerogram. The four composite accelerograms used in this study are shown in Fig. 6. The corresponding 5%-damped velocity response spectra are shown in Fig. 7. The portion of each record used for the second ten seconds of the composite accelerograms is indicated in Table 2. Also shown in Table 2 are the corresponding calculated 5%-damped spectrum intensities.

Comparison of the cumulative measures of deformation for the 20-second analyses and the 10-second analyses indicated that a good estimate of the 20-second cumulative rotational ductility could be obtained from 10-second analyses by multiplying the results of the latter by a factor of 2.0.(9)

Figure 16 shows that when the response is inelastic, the amplitude of deformation rarely remains the same for both half-cycles of a response cycle. In recognition of this fact and to have a basis for classifying response cycles according to their relative severity, the following definitions were introduced:

Relative Amplitude of Peaks

a. A "large-amplitude" peak is an inelastic half-cycle of deformation having a magnitude between 0.75 and 1.0 of the corresponding calculated maximum amplitude;

b. A "moderate-amplitude" peak is a deformation between 0.50 and 0.75 of the corresponding maximum.

Large-Amplitude Cycles:

a. "Fully reversed" cycles are complete cycles (+ and -) with at least one large-amplitude peak and the other peak, on reversal, of at least moderate amplitude. This is illustrated in Fig. 16a;

b. "Partially reversed" cycles are cycles with one large-amplitude peak and the other 0.50 or less of the calculated maximum amplitude. This is illustrated in Fig. 16b.

"Moderate" amplitude cycles are those with one peak value between 0.50 and 0.75 of the maximum (i.e., moderate amplitude) and the other 0.50 or less.

In the plots of nodal rotation history, shown in Fig. 15 and Appendix A, the rotations have been normalized by dividing these by the corresponding nodal rotation when yielding first occurred at the base. Thus, the two horizontal dotted lines on each side of the zero axis (i.e., through ordinates +1.0 and -1.0) represent the initial yield rotation for all cases. Rotations exceeding the initial yield values on each side of the zero axis were considered inelastic.

The procedure used in determining the number of fully reversed and partially reversed large-amplitude cycles can best be explained with reference to a particular nodal rotation history, such as shown in Fig. 17. In this figure, the maximum calculated amplitude of deformation is denoted by θ_{max}. A deformation cycle in which one peak was inelastic (either of large or moderate amplitude) and the other less than the yield amplitude was counted as 1/2 of an inelastic cycle. A few cases where the maximum amplitude was only slightly greater than the yield amplitude or cases of cycles in which both peaks were elastic (i.e., less than the yield amplitude) but which would otherwise qualify as either large or moderate amplitude peaks relative to the maximum, were also counted as 1/2 of an inelastic cycle.

Results of the examination of response histories to determine the number of large-amplitude cycles, etc. are listed in Table A-1 of Appendix A. Included in the tabulation are the maximum amplitude of deformation, the total number of large and moderate amplitude peaks, the number of fully reversed and partially reversed cycles and the total number of inelastic cycles. The "Total No. of Inelastic Cycles" listed in the last column of Table A-1 include both "large-amplitude" and "moderate-amplitude" cycles.

Figure 18a shows a histogram indicating the distribution of cases, in terms of the percentage of the total number considered, having a specific number of fully reversed cycles. Another way of presenting the data of Fig. 18a is the percentage exceedance plot shown in Fig. 18b, which is the complement of the associated cumulative frequency plot. This plot gives the percentage of the total number of cases having fully reversed cycles exceeding a specific number (as indicated in the abscissa).

It is significant to note in Fig. 18 that for the broad range of parameter values represented, the number of fully reversed cycles corresponding to 20 seconds of strong ground motion rarely exceeds six. Figure 18b indicates that for more than 95% of the cases considered, the number of fully reversed large-amplitude cycles of response is less than 4.

Histograms and percentage exceedance plots for the number of "large-amplitude" peaks (i.e., half cycles) and the total number of inelastic cycles (not necessarily all "large-amplitude" as defined above) are given in Figs. 19 and 20, respectively. These figures indicate that for the range of parameter values considered, both the number of large-amplitude peaks and the total number of inelastic cycles of response under a 20-second strong motion excitation rarely exceed ten. Figure 20b also indicates that for more than 95% of the cases considered, the number of inelastic cycles of response, corresponding to 20 seconds of strong ground motion, is less than eight.

The values plotted in Fig. 18 through 20 correspond to a 20-second duration of strong ground motion. As mentioned, most of the analyses used only 10 seconds of input motion. The results of these 10-second analyses (i. e., those relating to cumulative measures of deformation) were then multiplied by 2.0 to obtain values for the 20-second input motions. The factor of 2.0 was based on a comparison(8) of the cumulative rotational ductility for a limited number of cases analyzed using the 20-second composite accelerograms shown in Fig. 6, with the corresponding 10-second values. Table 4, from Ref. 8, shows the average ratios of the cumulative cyclic rotational ductility and the cumulative rotational energy (these terms are defined in Fig. 21) associated with the 20-second composite accelerograms to the corresponding 10-second results. Ratios for nodal rotations at the first and second floor levels are listed in Table 4. The ratios listed represent the average of 12 cases, all for 20-story walls, with fundamental periods ranging from 0.8 sec. to 2.4 sec. and yield levels from 500,000 to 1,500,000 in.-kips.

A total of some 170 cases were considered in preparing Figs. 18 through 20. These represent fundamental period values from 0.5 to 3.0 seconds, yield levels from 300,000 to 2,500,000 in.-kips and wall heights from 10 to 40 stories. Six input motions with intensities varying from 0.75 to 1.5 of the reference intensity, $SI_{ref.}$ were considered.

Sequence of Large-Amplitude Cycles

To obtain detailed data on specimen behavior for design applications, the loading program most commonly used in tests of large-size specimens under slowly reversed loads consists of deformation cycles of progressively increasing amplitudes until failure occurs(9-29). This type of loading program is shown schematically in Fig. 22. The maximum forces and deformations sustained are then noted as indicating capacity. It has been suggested by Bertero(37-38) that such a loading program may not be as conservative as a program in which the peak deformation is imposed early in the test.

An examination of response histories of nodal rotations near the base of isolated walls indicates that in many cases, the maximum amplitude, or an amplitude of deformation close to the maximum, occurs early in the response, with hardly any inelastic cycle preceding it. Large-amplitude cycles also occur later in the response. This is evident in Fig. 15, which shows nodal rotation histories for walls having different fundamental periods, yield levels and stiffness degrading characteristics subjected to the E-W component of the 1940 El Centro record. Because this observed early occurrence of the maximum amplitude cycle differs from the usual sequence of loading, it was decided to examine the response histories obtained in the course of this investigation(8) in greater detail. Rotation histories were obtained for the two nodes closest to the base of the models used, as well as the horizontal displacement histories of nodes located at or near midheight of the walls. Figure 9 shows a plot of all three response quantities for a particular case. Since the time variation of these three response quantities are very similar, it was decided to consider in detail only the rotation history of the node closest to the base.

In examining the sequence of large-amplitude cycles, attention was focused on the first response peak of large amplitude, i.e., with a value between 0.75 and 1.0 of the calculated maximum. Particular emphasis was placed on the number and relative magnitude of the inelastic cycles preceding this large-amplitude peak.

For the purpose of this examination, the deformation cycles preceding the first large-amplitude peak are referred to as "B cycles". "Fully reversed cycles", in relation to B-cycles, are defined as complete cycles (+ and -) with the amplitude of the greater peak denoted by B and the other, on reversal, between 0.5 and 1.0 of B. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of B and the other 0.5 or less of B.

The results of this examination are listed in Tables A5 through A8 for the 170 cases considered. Data on "fully reversed" and "partially reversed" inelastic B-cycles preceding the first large-amplitude response peak are listed under the last two columns of these tables.

For the purpose of determining the number of fully reversed and partially reversed inelastic B-cycles, a cycle where one peak was inelastic and the reverse cycle was elastic (i.e., with amplitude less than the initial yield rotation) was considered as equivalent to one-half of an inelastic cycle. Cycles where both peaks were elastic were not counted. However, even when the only B-cycles occurring were all elastic (i. e., No. of inelastic B-cycles = 0), the ratio of the amplitudes, B/A, was still noted. In this case, B is the largest applicable amplitude. In Fig. 23 for example, the ratio of the amplitude, B, of the inelastic cycle preceding the first large-amplitude peak, A (here, A is equal to the maximum), is $3\,\theta_y/7\,\theta_y$ = 0.43. In this case, the number of fully reversed B-cycles is zero and of partially reversed cycles is 1/2, since the B-cycle does not reverse itself. It will be noted in Tables A5 through A8 that in most of the cases considered, there are no fully reversed inelastic B-cycles.

The data on number of inelastic B-cycles listed in Tables A5 through A8 are summarized in Fig. 24. The abscissa in Fig. 25 indicates the sum of fully reversed and partially reversed inelastic cycles noted in the last two columns of Table A5 through A8. In Fig. 24, data points along the vertical line corresponding to zero inelastic B-cycles represent cases where the largest amplitude B-half cycle was elastic. The figure shows that in the majority of cases, there are no inelastic cycles preceding the first large-amplitude response peak. In a number of cases, mainly for those where the first large-amplitude peak, A, is itself close to the yield amplitude, (indicating low ductility demands), the ratio B/A exceeds 0.50.

The information relating to the number of inelastic B-cycles preceding the first large-amplitude peak in Fig. 24 has been replotted in the form of a histogram in Fig. 25. The important thing to note in Figs. 24 and 25, with particular reference to the question of sequence of load cycles, is that in many instances, the maximum deformation (or a deformation close to the maximum) can occur early in the response, with hardly any inelastic cycle preceding it. Because of the probable sensitivity of structural behavior under reversed loading with high shears to the manner in which the maximum deformation is approached, i.e., whether through progressively increasing amplitudes of loading or by a relatively sudden increase to the maximum, this observation is significant and should be considered if a realistic loading program is to be developed.

Preliminary results of tests at PCA to verify the effect of sequence of loading(36) indicate that under shearing stresses of the order of 8 $\sqrt{f'_c}$ or greater, a loading program where the maximum deformation is imposed early in the test can be more severe than when the loading is progressively increased to the maximum.

The tests involved two companion isolated wall specimens. The first of these was loaded following the usual program of progressively increasing amplitudes of deformation as shown in Fig. 26a and 26b. The second, essentially identical specimen, was loaded using a program based on the results of this study as shown in Fig. 26c and 26d. For this specimen, the maximum deformation was imposed early in the test, with only one small inelastic cycle preceding it.

Results indicate that the first specimen could sustain a particular maximum deformation through at least three cycles when this maximum deformation was imposed after a series of progressively increasing load cycles. However, the second, essentially identical, specimen could not sustain the same maximum deformation through three cycles when the maximum deformation was applied early. Details of the tests are described in Ref. 36. While no definite conclusions can be drawn on the basis of a comparison of only two specimens, this subject is certainly one that merits further investigation.

The observed difference in behavior between the two specimens can be explained in major part by the greater deformation capacity under the same lateral load, or the lesser stiffness, of a specimen that has been appreciably cracked and "softened" by earlier cycles of loading when compared to a "stiff" specimen that has only a few cracks. A specimen with well-distributed flexural and diagonal cracks produced by earlier cycles of loading can accommodate a particular total rotation by inelastic deformations over a longer hinging length than a specimen that has less cracking. In one case, the rotation in the critical region is spread over a longer hinging length. In the second case the inelastic rotation tends to be concentrated over a much shorter length with consequent high curvatures and strains.

REPRESENTATIVE LOADING HISTORY - AN EXAMPLE

The procedure for selecting a loading program to be used in testing isolated structural wall specimens under slowly reversed loads will be illustrated below. Such a loading can be considered as "representative" of conditions associated with structures having fundamental periods and yield levels within certain ranges when subjected to a particular ground motion intensity. The loading is representative in the sense of being as severe or more severe than the response that might be expected in a particular group of structures to the specific ground motion intensity.

Number of Fully-Reversed Large-Amplitude Cycles and Sequence

It was shown in the preceding section that for a 20-second duration of strong ground motion and a wide range of values of the fundamental period and yield level, the number of "fully-reversed" cycles of response (or loading) rarely exceeds six. The maximum total number of inelastic cycles, both large and small, is ten. For over 95% of the cases considered, the corresponding values are four and eight, respectively. Examination of a large number of response histories also showed that the occurrence of the first large-amplitude cycle very early in the response is a very strong possibility. In view of the adverse effect that early occurrence of a large-amplitude cycle can have on the behavior of reinforced concrete walls, a representative loading history for use in testing should incorporate this aspect of response.

Figure 27 shows a rotational deformation loading program for the hinging region of isolated walls incorporating aspects of response relating to number and sequence of large-amplitude cycles.

Examination of a rotation response history such as shown in Fig. 16 shows that the positive and negative peaks of any response cycle generally are not of the same amplitude. Also, the "fully-reversed" cycle as defined in this study may have the higher peak ranging from 0.75 to 1.0 of the calculated maximum deformation. The other peak, on reversal, may be anywhere between 0.50 and 1.0 of the maximum. To reflect these variations in amplitude of response cycles, the five fully-reversed cycles in Fig. 27 have been divided into three cycles with amplitudes equal to the maximum deformation and two cycles with amplitude equal to 0.80 of the maximum. The first large-amplitude cycle occurs after a single inelastic cycle with amplitude close to yield. Smaller inelastic cycles equal to about 1.5 to 2 times the yield amplitude occur between the fully-reversed large-amplitude cycles. The effect of these small-amplitude inelastic cycles on structural behavior is generally not significant (9,36). In all cases, the cycles are made up of positive and negative peaks of the same amplitude.

The loading program shown in Fig. 27 applies generally to the entire range of isolated walls considered in this study. It is important to note, however, that a particular loading history, in all its details, cannot be thought of as being generally applicable. The actual magnitude of the maximum rotation, θ_{max}, as well as the maximum shear, will vary depending upon the combination of parameter values represented by the loading. These parameters include earthquake intensity and structure period and yield level.

Maximum Rotation, θ_{max}, and Maximum Shear

To determine the value of the rotational ductility requirement, $\mu = \theta_{max}/\theta_{yield}$, to be used in a particular loading program, a decision has to be made on the range of values of the structure period and yield level as well as the earthquake intensity represented by the test. Referring to Fig. 10, for instance, a maximum rotational ductility of 4.0 would represent or cover 20-story isolated walls with periods ranging from about 1.0 sec. or greater and yield levels of about 1,500,000 in.-kips or greater when subjected to an earthquake with intensity SI = 1.5 ($SI_{ref.}$). Also covered are walls with periods ranging from about 1.7 sec. or greater and yield levels of 1,000,000 in.-kips or greater. Walls with M_y = 750,000 in.-kips will be covered by the same ductility requirement provided the period is 1.8 sec or greater. It is clear from Fig. 10 that the higher the ductility ratio used in a test, the broader the range of parameter values represented or covered by the results.

Similar observations apply to the maximum shear which should accompany the imposed deformations. Figure 12 can be used as a guide in selecting the appropriate shear force. Here again, the distinction must be made between the maximum dynamic shear and the shear applied to specimens in quasi-static tests which is in phase with the accompanying moment and rotation. As indicated in the subsequent section on "Comments on Character of Shear Loading," some adjustment may be required in either the dynamic shears or the shear capacity obtained from quasi-static tests before a valid comparison can be made between these two quantities.

Laboratory tests using a loading program based on dynamic analysis results, such as shown in Fig. 27, with specific values of θ_{max} and the accompanying maximum shear, will have the character of proof tests. A specimen that sustains such a loading program without significant loss of strength can be said to be adequate with respect to design and details for the particular combination or range of values of the significant parameters represented by the loading program.

COMMENTS ON CHARACTER OF SHEAR LOADING

In correlating capacity values obtained from experiments with demands estimated from dynamic inelastic analyses(8), it is essential that the capacity values be derived under conditions closely approximating those prevailing under dynamic conditions. This, of course, assumes that the mathematical idealization used in the dynamic analyses represents a realistic approximation of the actual structure, i.e., with the significant variables adequately modelled.

The need for close correspondence between laboratory test conditions and those obtaining under dynamic conditions is particularly important with respect to factors that have significant influence on the behavior of reinforced concrete elements. The validity of any correlation between demand as determined from analysis and capacity as obtained from laboratory tests will depend on how representative the test conditions are of actual dynamic response. While there are many aspects to the problem(38), only one, related to loading history as used in quasi-static tests to simulate earthquake loading, will be discussed here. This has to do with the time variation of the shear force relative to that of the accompanying moment and rotational deformation. The question is important because of the significant influence shear can have on specimen behavior.

As far as the shear force used in tests is concerned, two aspects have to be considered. First is the magnitude of the maximum shear force. The second is its variation with time, and particularly in relation to the accompanying moment and deformation. Most quasi-static tests that have been conducted to date have been concerned mainly with the magnitude of the expected shear forces. The loading imposed on test specimens has been characterized by the moment, shear and deformation in the critical region being all in phase. This results from the application of a single horizontal load or a series of proportionally changing horizontal loads to a specimen.

Dynamic response studies of isolated structural walls undertaken at PCA(8), however, indicate that the shear in the critical region at the base is more sensitive to higher mode response and thus fluctuates more rapidly with time than either the moment or the rotation. This is illustrated in Fig. 28a through 28d which show time-history plots of the shear, rotation and moment in the first story of an isolated wall subjected to four different input motions.

It is significant to note in Fig. 28 that the shear force in the critical region fluctuates more rapidly than either the moment or the rotation. The maximum shear generally acts over a shorter duration relative to the accompanying moment. In addition, the direction of the shear force reverses itself several times during a single half-cycle of moment and rotational response.

The behavior of the shears shown in Fig. 28 may be partly due to the fact that the model of the hinging region allowed yielding in flexure only, while remaining linearly inelastic with respect to shear throughout the response. Experimental studies(9,36) have shown that this is generally not the case.

The shear distortion in the hinging region can be significant and contributes appreciably to the total displacement at the top(9,36) even before the onset of flexural yielding. Whatever the effect of this modelling assumption may be*, it is important, in correlating experimental data on capacity with analytical data on demand, to allow for any differences in the manner in which shear is induced under dynamic response conditions and in the typical quasi-static test. It is believed that a shear force that fluctuates rapidly and reaches its peak value only for very short durations relative to the associated moment and rotation represents a less severe loading condition than one in which the shear, moment and deformation are all in phase.

The question involved here relates not only to the effects of out-of-phase forces but also possible shear strain-rate effects on the behavior of reinforced concrete members. The determination of the sensitivity of reinforced concrete member behavior to these differences in loading needs further investigation. An indication of significant effects would suggest an adjustment either in the dynamic shear demand or in the quasi-statically determined shear capacity in order to allow a valid comparison.

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*A model which will allow yielding in shear in the hinging region, based on uncoupled behavior relative to moment, has been developed to study this and related questions concerning shear yielding.

SUMMARY

A total of 170 rotational response history plots for isolated walls, representing a broad range of structural and ground motion parameter values, were examined in this study. The primary objective of the examination was to determine the number and sequence of large-amplitude cycles of rotational response in the hinging region of isolated structural walls. Response corresponding to 20 seconds of strong ground motion is suggested as adequate for the purpose of establishing design requirements. This information is essential in developing a representative loading program for testing laboratory specimens under slowly reversed loads to simulate earthquake loading. Such a loading program can be considered as representative of the response of a particular group of structures to ground motions of specific intensity.

In addition to the number and sequence of large-amplitude cycles of rotation, other equally important parameters characterizing the response history are the magnitudes of the total rotation in the hinging region and the accompanying shear. Information on the latter two parameters has been developed in detail in Ref. 8. The relevant results have been reproduced here for completeness.

Significant observations made in this study are summarized below. These apply strictly to isolated walls having properties within the ranges indicated in Table 1.

1. An estimate of the maximum amplitude of rotational deformation, i.e., rotational ductility requirement,

that can be expected for a particular earthquake intensity and combination of structure period and yield level may be obtained from charts such as shown in Figs. 10a to 10d. These charts were developed in Ref. 8. For 20-story structural walls with fundamental period of 0.8 sec. or greater, for example, a maximum ductility requirement of about 5 is indicated provided the yield level at least 1,500,000 in.-kips (170,000 kN•m).

2. The maximum dynamic shears corresponding to a particular combination of earthquake intensity and structural parameters (i.e., period and yield level) may be estimated using Figs. 12a to 12d, also developed in Ref. 8. For a rotational ductility demand of 4 and a structure period equal to 0.06 N, where N is the number of stories, the maximum nominal shear stress at the critical section near the base can vary from $4\sqrt{f'_c}$ to $7.5\sqrt{f'_c}$. These values correspond to an earthquake intensity SI = 1.5 ($SI_{ref.}$) and yield level values ranging from 600,000 to 2,350,000 in.-kips.

   Because the critical shears shown in Figs. 12a to 12d are often produced by ground motions that are not the same as those producing the critical ductility demand shown in Figs. 10a to 10d, a conservatism beyond that associated with using the largest value for each response quantity is implied when using both quantities and assuming that they occur simultaneously.

3. The maximum number of "fully-reversed cycles of large amplitude"* that can be reasonably expected for strong ground motions of 20-second duration is six. The maximum total number of inelastic cycles, of small and large amplitude, for the same duration of strong ground motion, is ten. More than ninety-five percent of the cases considered had less than four fully reversed cycles of large amplitude. The corresponding number of inelastic cycles was eight.

4. The study relating to sequence of loading indicates that a realistic loading program must reflect the fact that in a large number of cases, the first maximum amplitude of deformation can occur fairly early in the response, with hardly any inelastic cycles preceding it.

5. A loading program incorporating conclusions (3) and (4) is shown in Fig. 27. The value of the maximum rotation in the hinging region, θ_{max}, and the maximum dynamic shears corresponding to a particular earthquake intensity and combinations of structure period and yield level may be obtained from Fig. 10 and Fig. 12 respectively. In application, laboratory tests using a loading history such as developed in this study will have the character of proof tests. A specimen that sustains such a loading program without significant

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*See page 24 and Fig. 16 for definition.

loss of strength can be said to be adequate with respect to strength and deformation capacity for the particular combination or range of values of the significant design variables represented by the loading program. These variables include earthquake intensity, structure period and yield level.

6. A loading characterized by moments, shears and rotations all occurring in phase, such as is commonly used in laboratory tests under slowly reversed loading, differs from typical dynamic inelastic response in respect to the variation of the shear force with time. Under dynamic conditions, the shears, which are more sensitive to the higher modes of response, change direction much more rapidly with time than the moment and rotation. It is believed that in this particular respect, the commonly used laboratory program represents a more severe loading condition when compared to typical dynamic response.

Because of the difference in character of the shear loading under dynamic conditions and that obtaining under commonly used quasi-static tests, some adjustment may be required in either the estimated dynamic shears or the shear capacities determined from tests using slowly reversed loading before a valid comparison can be made between these two quatities.

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TABLES AND FIGURES

APPENDIX A

This Appendix presents tables giving detailed data obtained from an examination of the 170 response histories considered in this investigation. The compiled data relate mainly to the number and sequence of large-amplitude cycles of response.

Also included is a sampling of the normalized rotation histories for 10-, 20-, 30- and 40-story isolated walls. The plots are for rotations of the nodes closest to the base in each of the lumped-mass models shown in Fig. 2 of the main body of this report. In each plot, the calculated nodal rotation has been divided by the corresponding rotation at first yield.

In Tables A1 through A8, the following abbreviations are used under the column "Earthquake Input" to denote the corresponding input accelerograms:

EC-E - 1940 El Centro, E-W component (10-sec. duration)
EC-E** - 20-second composite accelerogram based on EC-E
EC-N - 1940 El Centro, N-S component (10-sec. duration)
EC-N** - 20-second composite accelerogram based on EC-N
P.D. - 1971 Pacoima Dam, S16E component (10-sec. duration)
P.D.** - 20-second composite accelerogram based on P.D.
H.O. - 1971 Holiday Orion, E-W component (10-sec. duration)
H.O.** - 20-second composite accelerogram based on H.O.
T - 1952 Taft, S69E component (10-sec. duration)
S1 - Artificially generated accelerogram

The intensity factor, f, shown in the tables, represents the ratio of the 5%-damped spectrum intensity of the particular input motion to the reference spectrum intensity, $SI_{ref.}$, i.e., the 5%-damped spectrum intensity - between periods 0.1 and 3.0 seconds - corresponding to the first 10 seconds of the N-S component of the 1940 El Centro record.

Table 1 Values of Parameters Characterizing Isolated Wall Models

Parameter	Value
STRUCTURAL	
No. of Stories	10 - 40
Fundamental Period, T_1	0.5 - 3.0 sec.
Yield Level, M_y	16,950 - 339,000 kN·m (150,000 - 3,000,000 in-kips)
Yield Stiffness Ratio, r_y*	0.05 for most
Parameters characterizing Hysteretic M-θ Curve:*	
Unloading parameter, α	0.10 for most
Reloading parameter, β	0.0 for most
Damping (stiffness-and mass-proportional)	0.05 of critical for initial first and second modes
Stiffness Variation with Height	Uniform for most
Strength Variation with Height	Uniform, except for adjustments to reflect effect of axial load -for most
Base Fixity Condition	Fully fixed
INPUT MOTION	
Intensity	SI = 1.5 ($SI_{ref.}$)# for most
Frequency Characteristics ("peaking" and "broad band")	1940 El Centro, E-W 1940 El Centro, N-S 1971 Pacoima Dam, S16E 1971 Holiday Orion, E-W 1952 Taft, S69E Artificial Accelerogram, S1
Duration	10 sec. for most 20 sec. for some

*See Figure 3.

#-$SI_{ref.}$ (reference spectrum intensity)=area under 5% damped velocity response spectrum, between periods 0.1 and 3.0 seconds, corresponding to the first 10 seconds of the N-S component of the 1940 El Centro record.

Table 2 Composition and Intensity of 20-Second Composite Accelerograms

Basic Accelerogram	Composition		Spectrum Intensity, (in.)@		$\frac{SI_{ref.}}{SI_{10}}$ x 1.50	$\frac{SI_{ref.}}{SI_{20}}$ x 1.50
	1st Part	2nd Part	First 10 Sec. SI_{10}	20-Second SI_{20}		
1940 El Centro, E-W	First 12.48 sec. as recorded*	From 0.98 to 8.5 se of record*	55.97	68.16	1.88	1.54
1940 El Centro, N-S	First 10.08 sec. as recorded*	From 2.90 sec. to 12.82 sec. of record*	70.15#	77.44	1.5	1.36
1971 Holiday Orion,E-W	First 10.08 sec. as recorded*	From 1.70 sec. to 11.62 sec. of record*	32.67	42.86	3.22	2.46
1971 Pacoima Dam, S16E	First 10.08 sec. as recorded*	From 2.42 sec. to 12.34 sec. of record*	177.25	206.07	0.594	0.511

*See Reference 30.

@Based on 5%-damped velocity spectrum, for period range 0.1 to 3.0 seconds.

#Reference spectrum intensity, $SI_{ref.}$

Table 3a - Approximate Nominal Shearing Stresses for Different Wall Heights

Isolated Structural Walls - <u>Rectangular Sections</u>

No. of Stories	Fundamental Period, T_1 (sec)	Effective Moment of Inertia* I_e (in.^{4})	Section Dimensions		Effective Shear Area = 0.8h ℓ_w (in.^{2})	Flexural Yield Level, # M_y x10^6 in-k	Corresponding Reinforcement Ratio ρ@	Critical Shear at Base (kips)	Nominal Shear Stress - x$\sqrt{f'_c}$	
			Thickness h (in.)	Width ℓ_w (ft)					f'_c = 4 ksi	f'_c = 6 ksi
10	0.6	23 x 10^6	10	25.2	2420	0.51	0.05	932	6.1	5.0
20	1.2	77 x 10^6	12	35.4	4080	1.15	.039	1440	5.6	4.6
30	1.8	163 x 10^6	14	43.2	5810	1.66 (1.90) $	.021 (.033) $	1745 (1908) $	4.8 (5.2) $	3.9 (4.3) $
40	2.4	285 x 10^6	16	49.8	7650	2.45 (2.92) $	.018 (.033) $	2315 (2592) $	4.8 (5.4) $	3.9 (4.4) $

* I_e based on gross area of section. E_c assumed = 3600 ksi in calculating T_1.

\# M_y chosen to correspond to a rotational ductility demand of about 4 at the base under an earthquake intensity, SI = 1.5 ($SI_{ref.}$). See Fig.

@ Relative to an assumed "flange area" at each end of the section equal in length to $0.10\ell_w$. Thus, $\rho = A_s/h(0.1\ _w)$, based on f_y = 60 ksi and f'_c = 4 ksi.

$ Correspond to ACI Code requirements for min. steel area in shear walls.

Note: 1 in. = 25.4 mm; 1 ft = 0.305 m; 1 kip = 4.45 kN

Table 3b - Approximate Nominal Shearing Stresses for Different Wall Heights

Isolated Structural Walls - Flanged Sections

No. of Stories	Fundamental Period, T_1 (sec)	Effective Moment of Inertia* I_e ($in.^4$)	Section Dimensions				Effective Shear Area $= 0.8h\ \ell_w$ ($in.^2$)	Flexural Yield Level, ♯ M_y $x10^6$ in-k	Corresponding Reinforcement Ratio ρ@	Critical Shear at Base (kips)	Nominal Shear Stress - $x\sqrt{f'_c}$	
			Total Depth of Section (ft)	Web Thickness (in.)	Flange						$f'_c = 4$ ksi	$f'_c = 6$ ksi
					Width (in.)	Thickness (in.)						
10	0.6	23×10^6	24.2	10	14	20	2320	0.51	.071	932	6.4	5.2
20	1.2	77×10^6	34.4	12	16	22	3960	1.15	.074	1083	5.7	4.7
30	1.8	163×10^6	42.2	14	18	24	5670	1.66	0.56	1745	4.9	4.0
40	2.4	285×10^6	48.9	16	20	26	7510	2.45 (2.65) \$	0.05 (.062) \$	2315 (2414) \$	4.9 (5.1) \$	4.0 (4.2) \$

* I_e based on gross area of section. E_c assumed = 3600 ksi in calculating T_1.

♯ M_y chosen to correspond to a rotational ductility demand of about 4 at the base under an earthquake intensity, SI = 1.5 ($SI_{ref.}$). See Fig.

@ Relative to an assumed "flange area" at each end of the section.

\$ Correspond to ACI Code requirements for min. steel area in shear walls.

Note: 1 in. = 25.4 mm; 1 ft = 0.305 m; 1 kip = 4.45 kN

Table 4 - Average Ratios* of Maximum and Cumulative Response Values Corresponding to 20- and 10-Second Duration Input Motions 20-Story Isolated Structural Walls

Response Parameter	Average Ratio, R_{20}/R_{10}		
	Yield Level, M_y (in-kips)**		
	500,000	1,000,000	1,500,000
Deformation Measures Based on Nodal Rotations at 1st floor level			
Cum. Cyclic Rotational Ductility, $\Sigma\mu_{r1}$	2.33	2.14	1.99
Cum. Rotational Energy, ΣA_{r1}	2.18	1.97	1.78
Deformation Measures Based on Nodal Rotations at 2nd Floor Level			
Cum. Cyclic Rotational Ductility, $\Sigma\mu_{rc2}$	2.32	2.11	2.00
Cum. Rotational Energy, ΣA_{r2}	2.18	1.95	1.82

* Usin four different accelerograms as input with SI = 1.5 (SI_{ref}). Fundamental period range: 0.8 to 2.4 sec.

** 1 in-kip = 0.1129792 kilonewton·meter (kN·m)

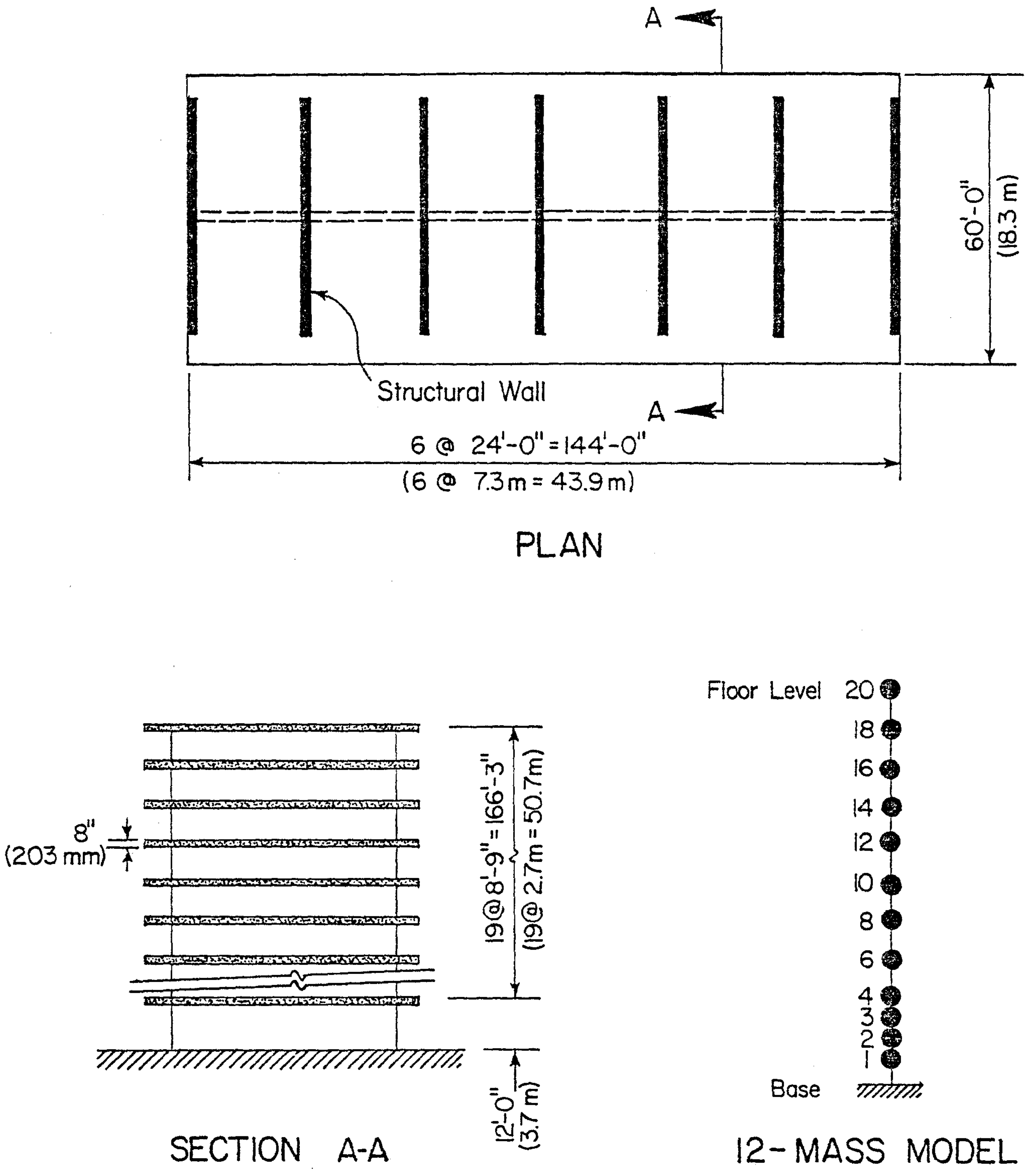


Fig. 1 Twenty-Story Building with Isolated Structural Walls

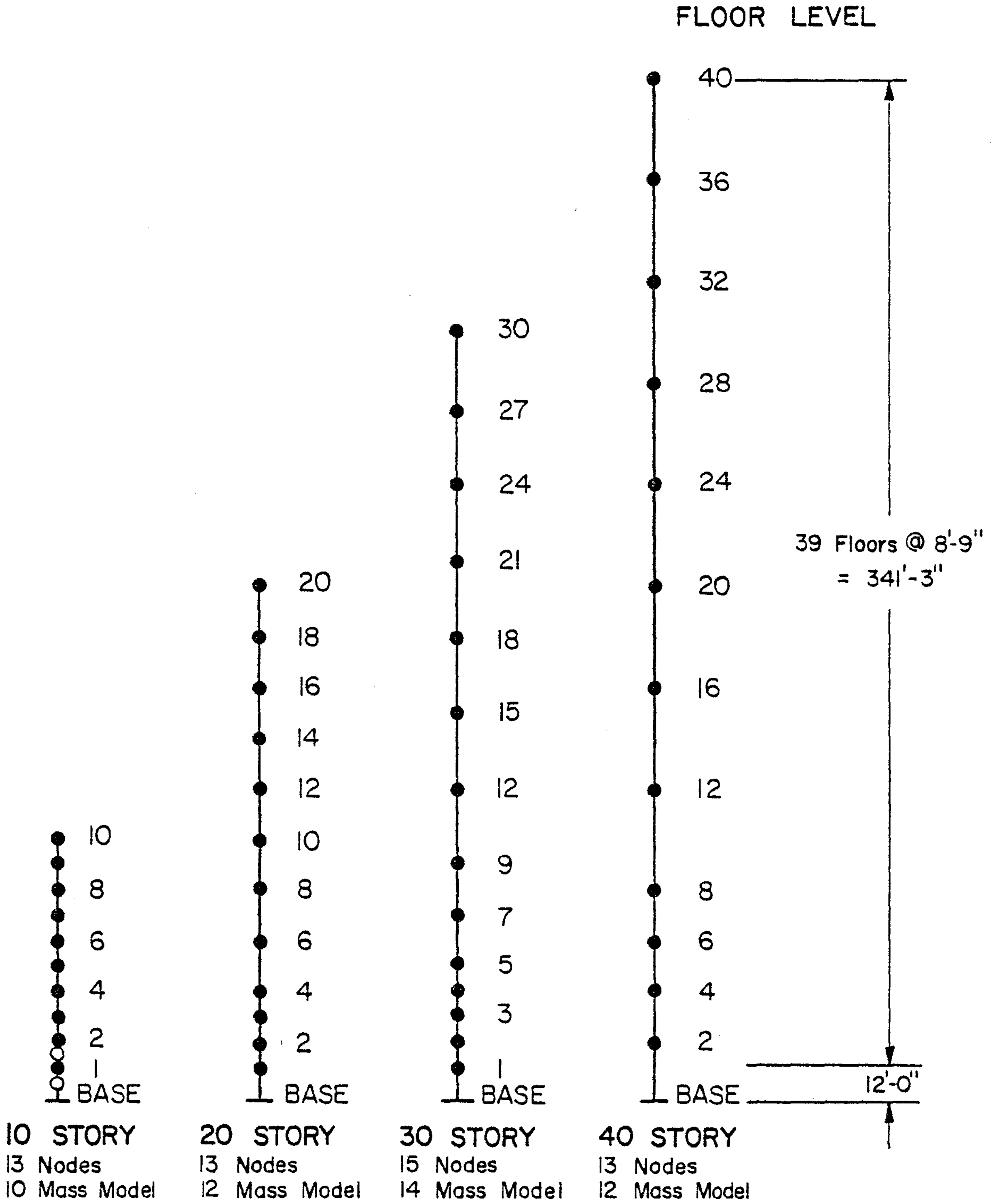


Fig. 2 Lumped-Mass Models of Isolated Walls Investigated

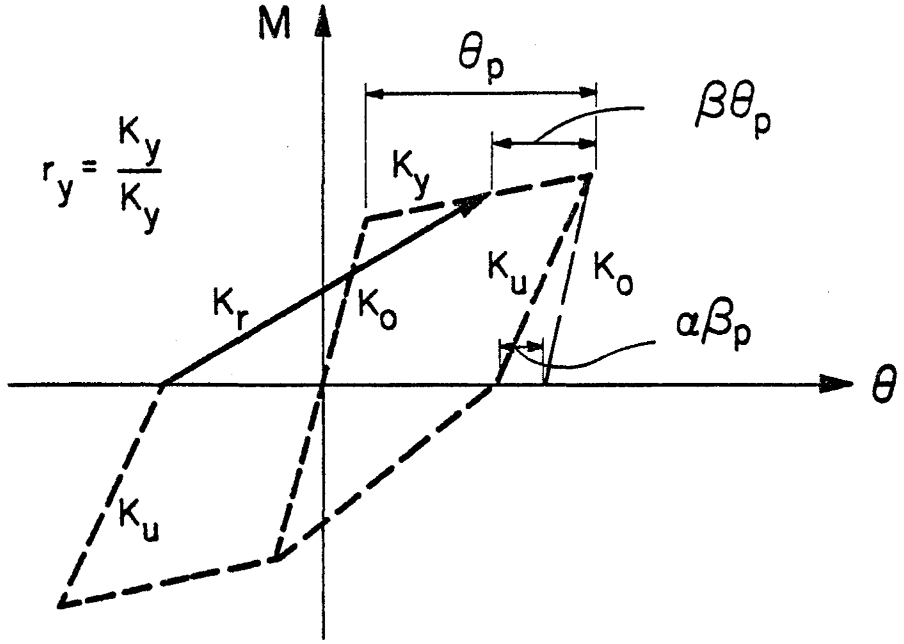


Fig. 3a Unloading and Reloading Parameters α and β Characterizing Hysteretic Loop of Decreasing Stiffness Model

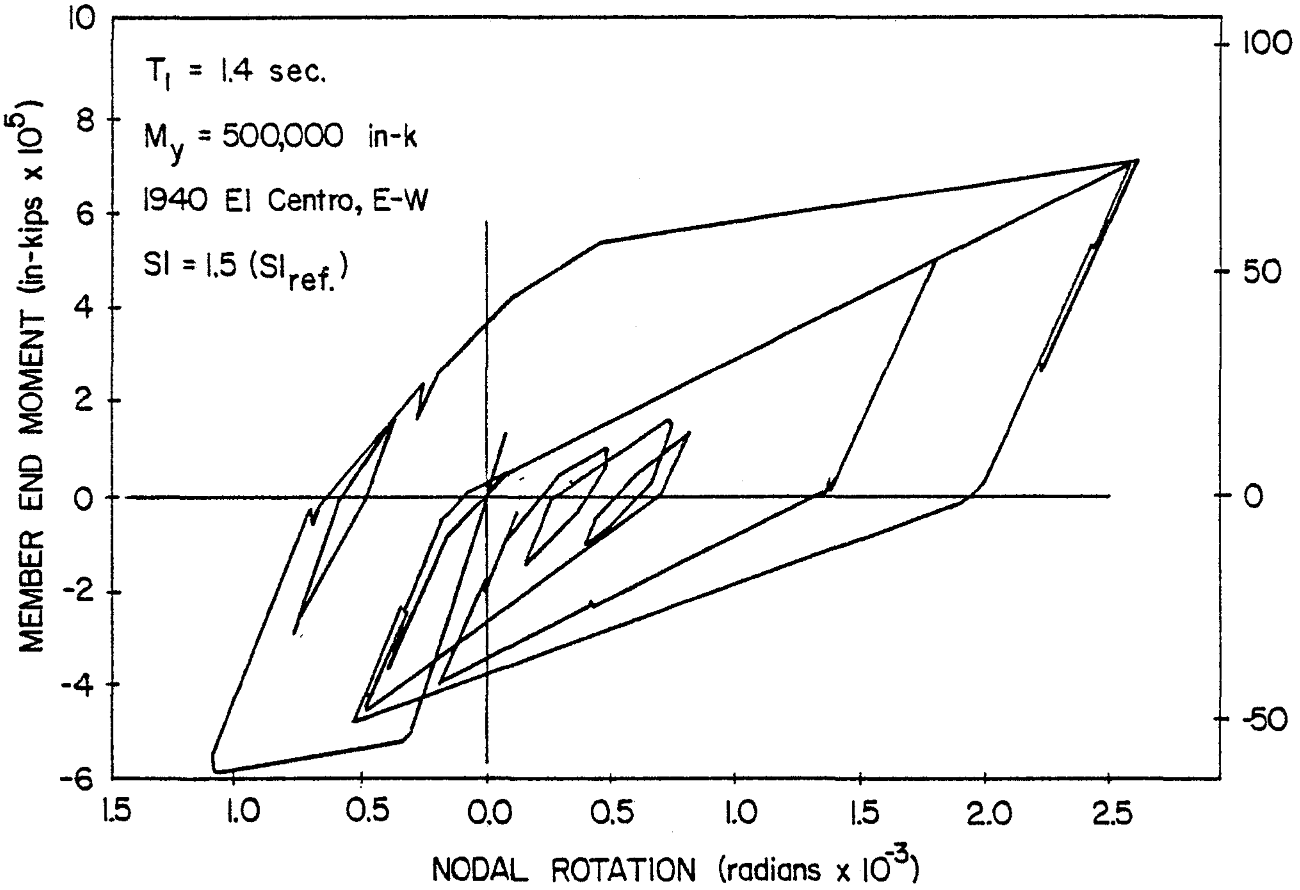


Fig. 3b Base Moment versus Nodal Rotation at First Floor Level - 20 Story Isolated Wall

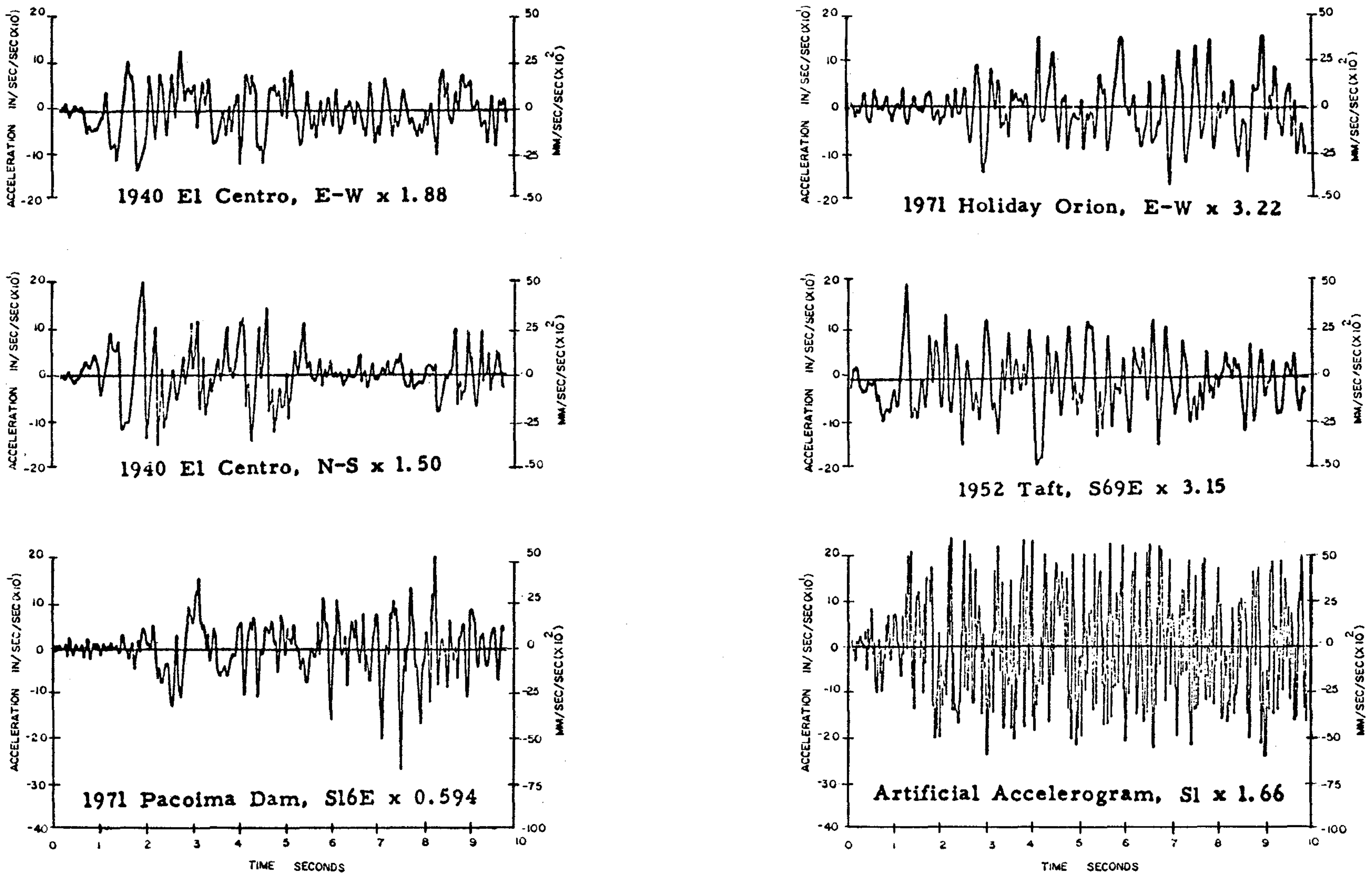


Fig. 4 Ten-Second Duration Normalized Accelerograms

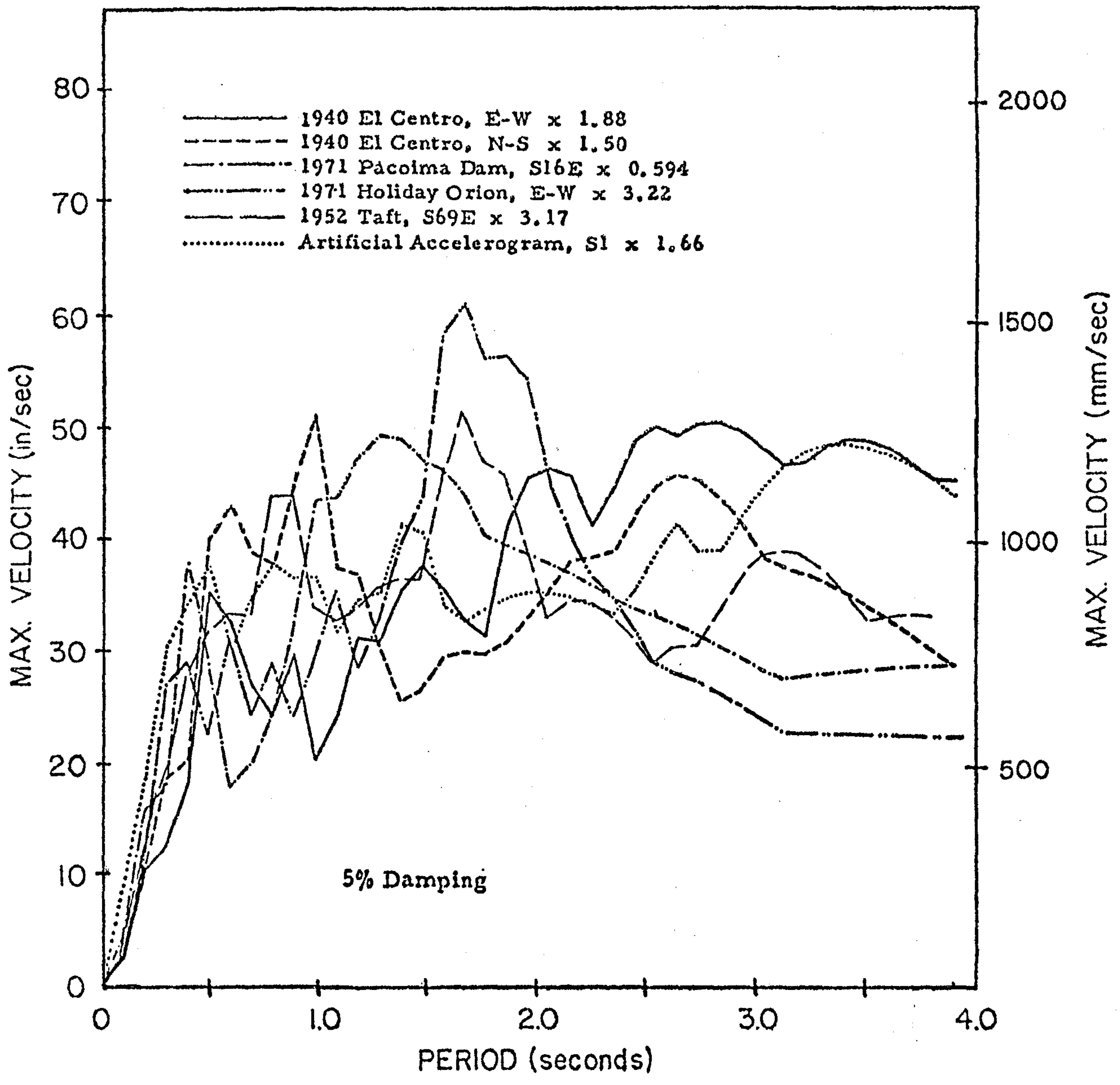


Fig. 5 Relative Velocity Response Spectra for First 10-Seconds of Normalized Input Motions

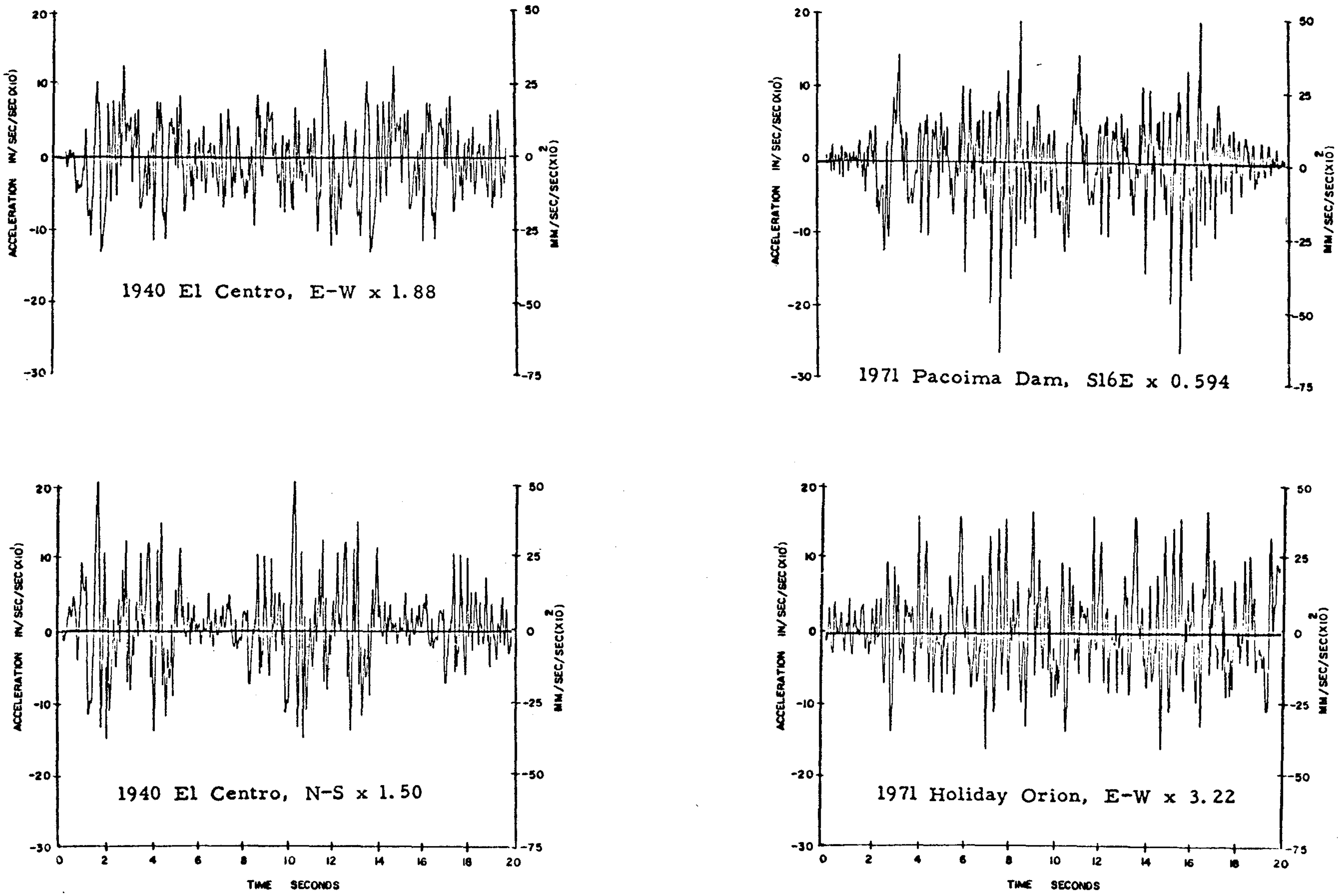


Fig. 6 Normalized 20-Second Duration Composite Accelerograms

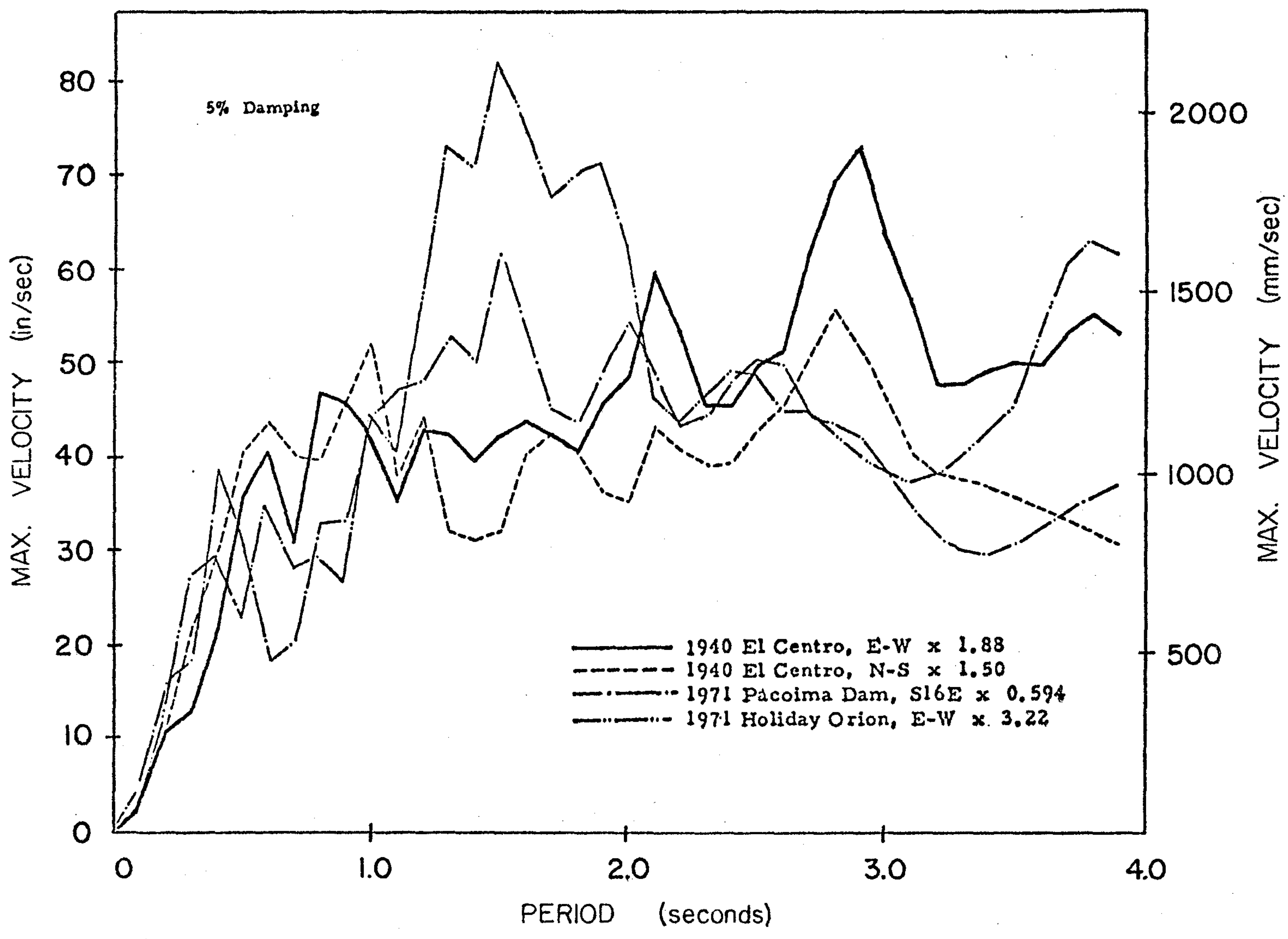


Fig. 7 Relative Velocity Response Spectra for Normalized 20-Second Composite Accelerograms

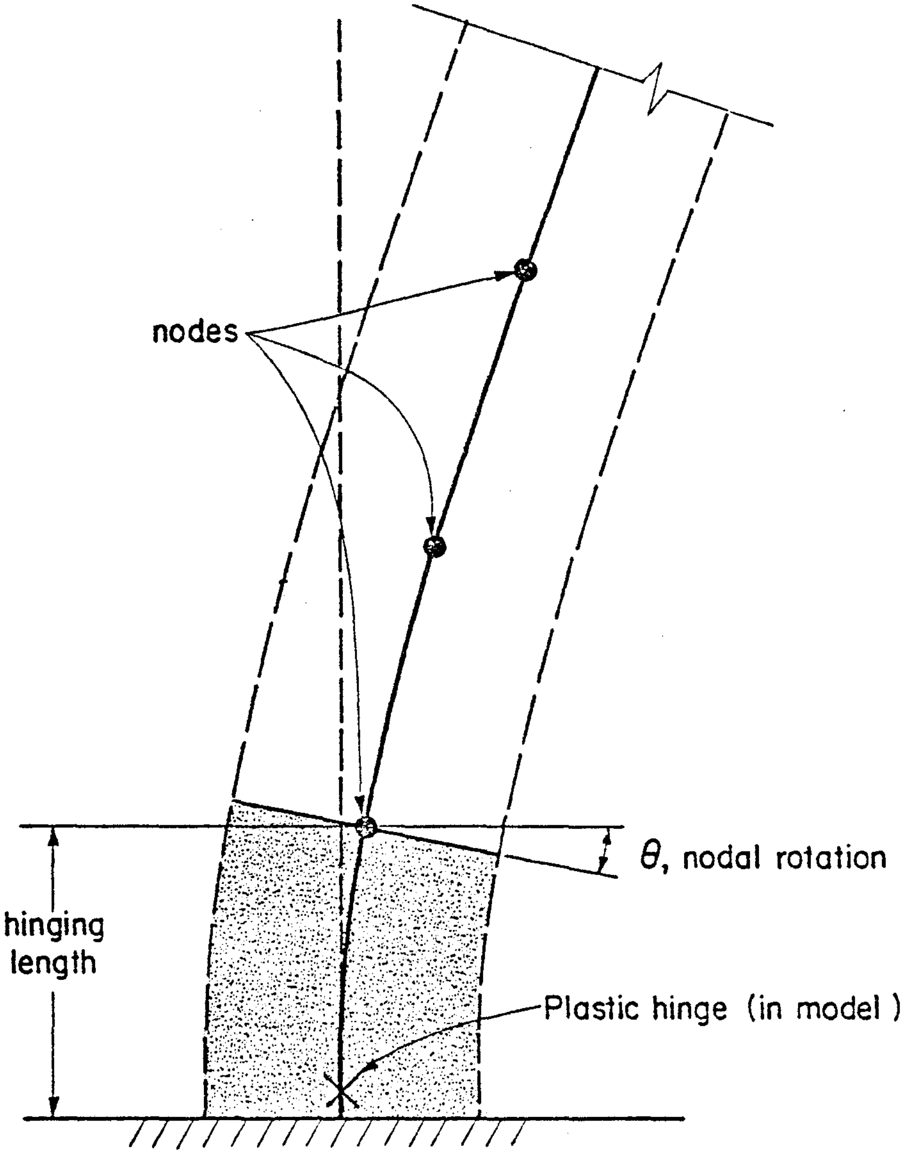


Fig. 8 Nodal Rotation as a Measure of Total Rotation in Hinging Region

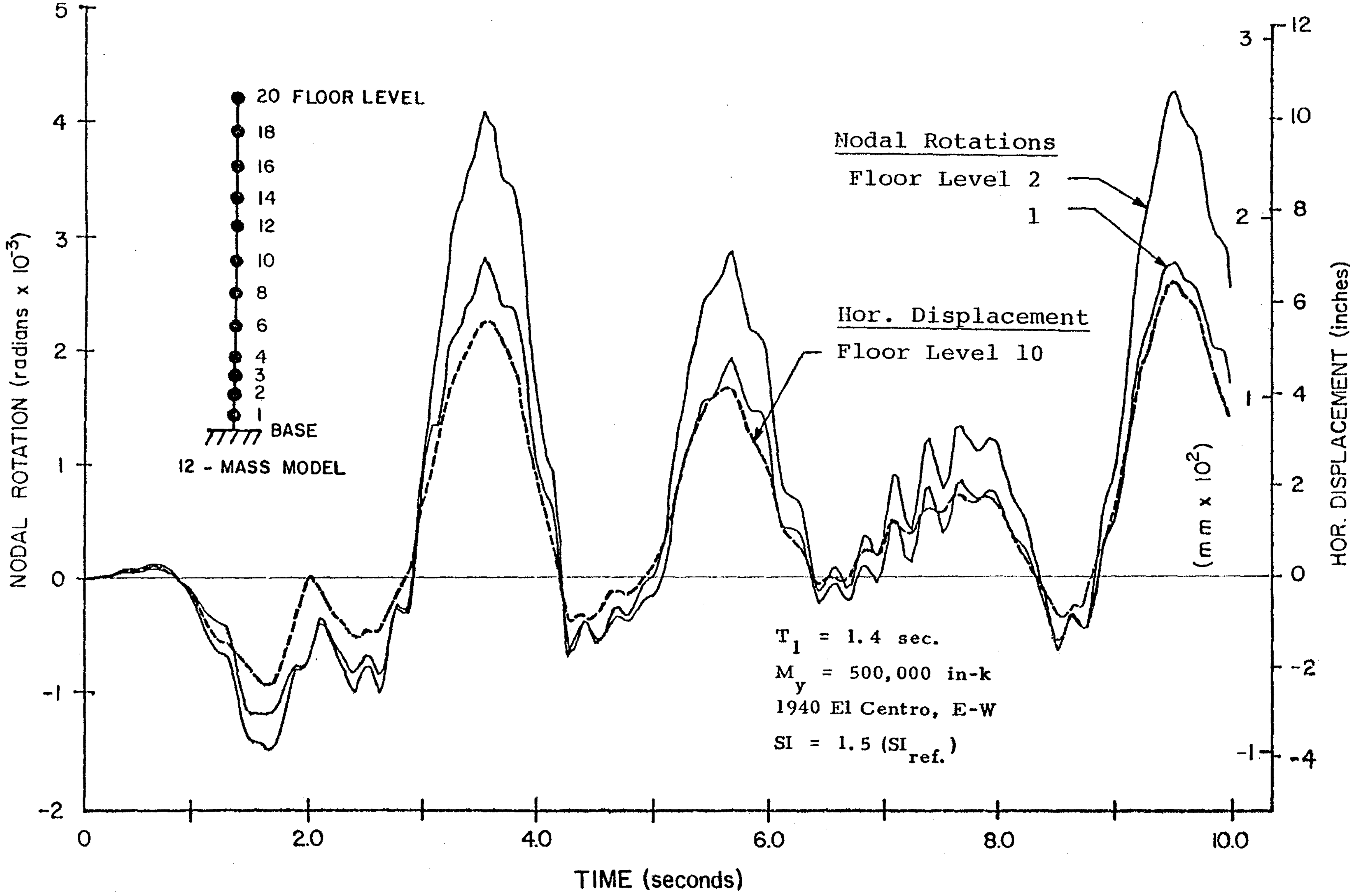


Fig. 9 Nodal Rotation and Horizontal Displacement Histories of Nodes at Different Heights from Base - 20-Story Isolated Wall

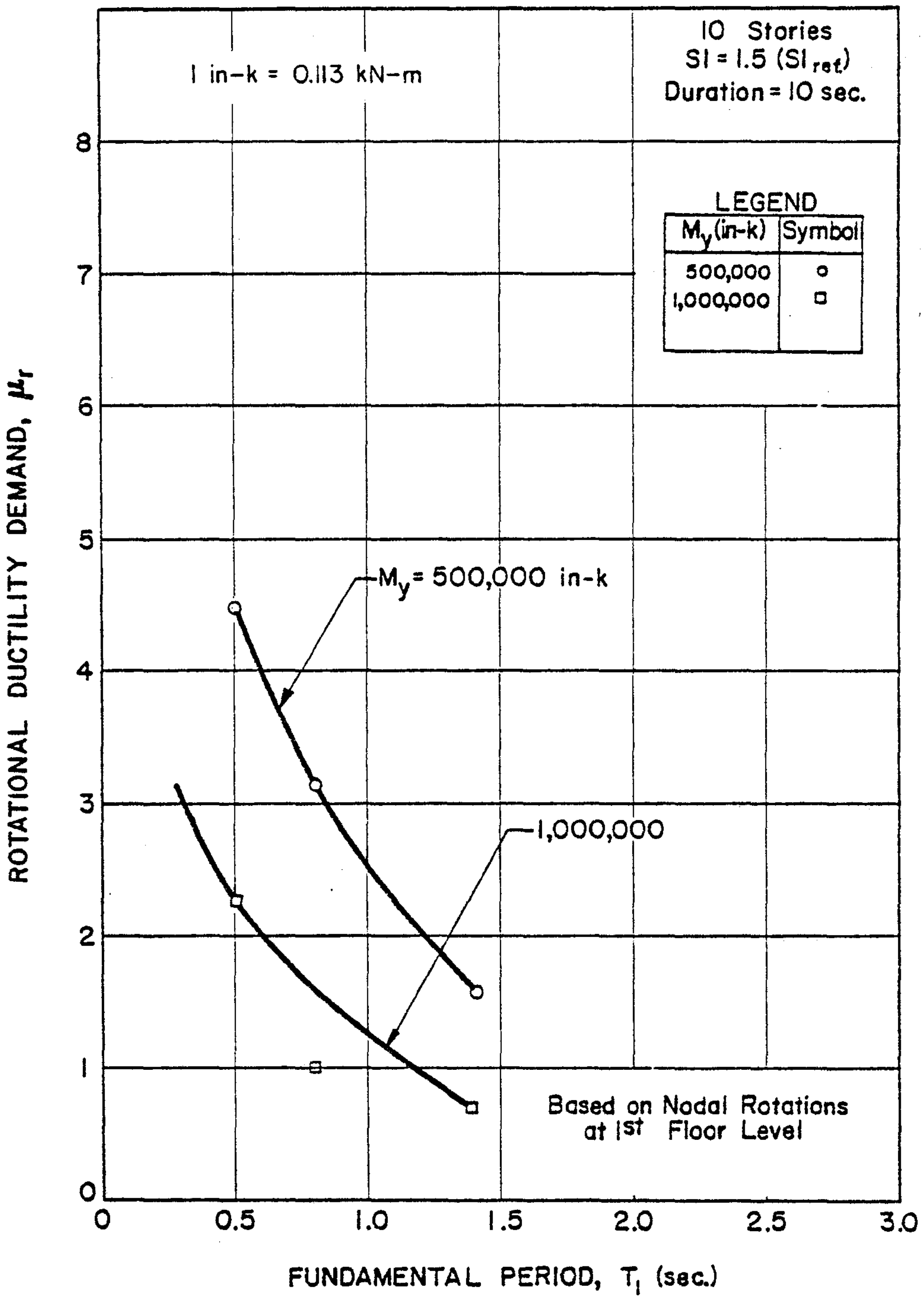


Fig. 10a Critical Rotational Ductility Ratio at Base as a Function of Fundamental Period, T_1, and Yield Level, M_y
10-Story Isolated Structural Walls

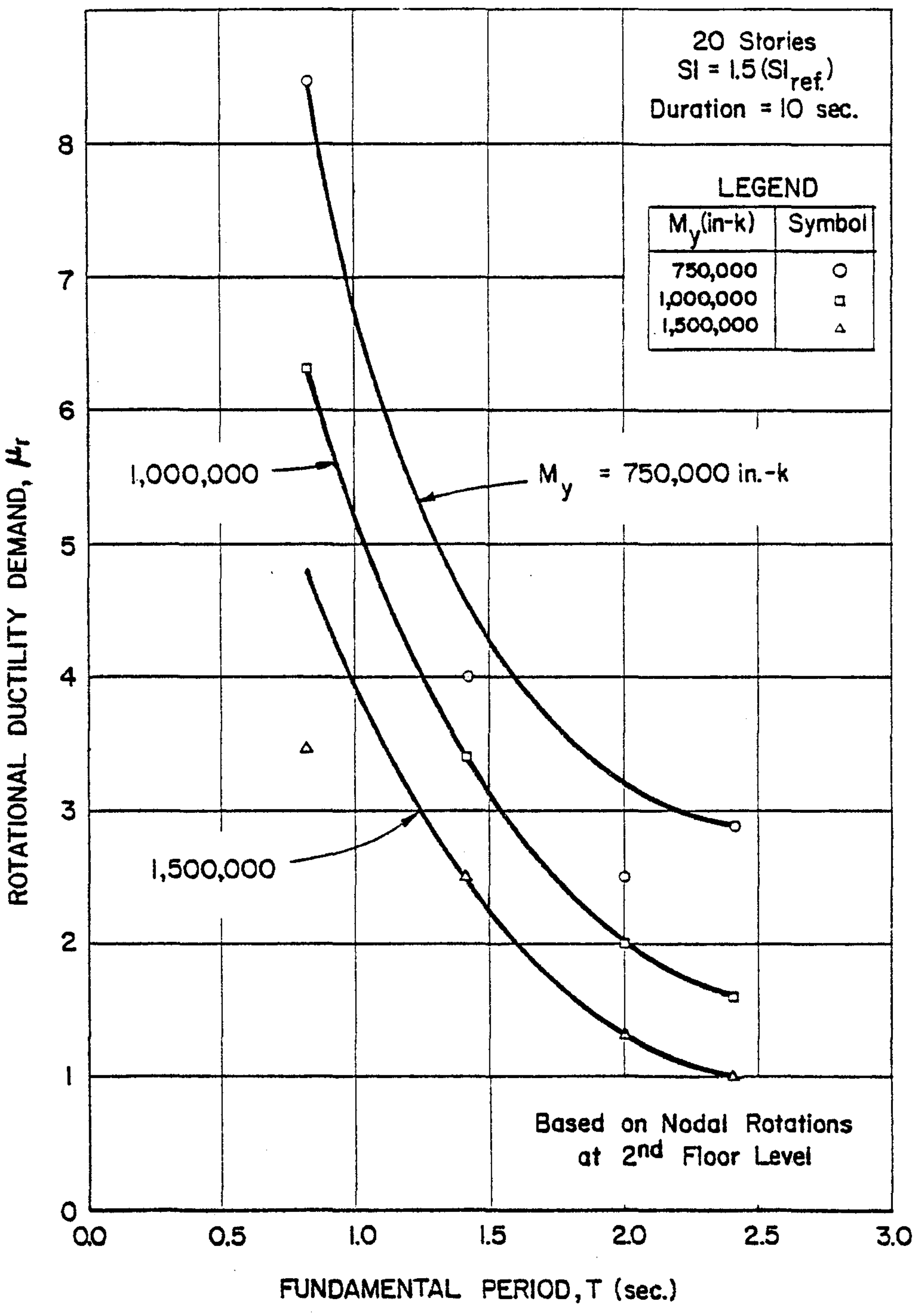


Fig. 10b Critical Rotaional Ductility Ratio at Base as a Function of Fundamental Period, T_1, and Yield Level, M_y 20-Story Isolated Structural Walls

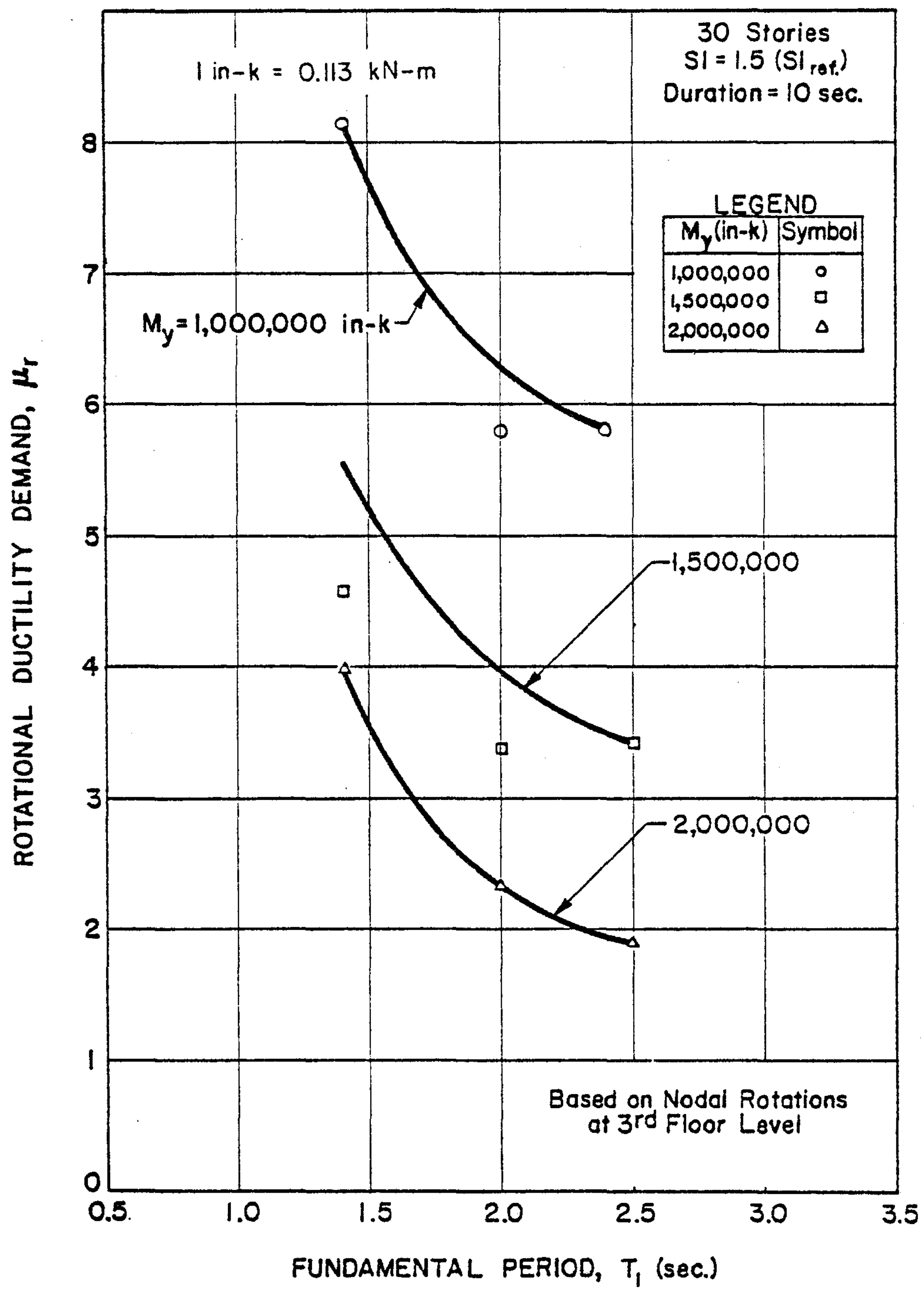


Fig. 10c Critical Rotational Ductility Ratio at Base as a Function of Fundamental Period, T_1, and Yield Level, M_y
30-Story Isolated Structural Walls

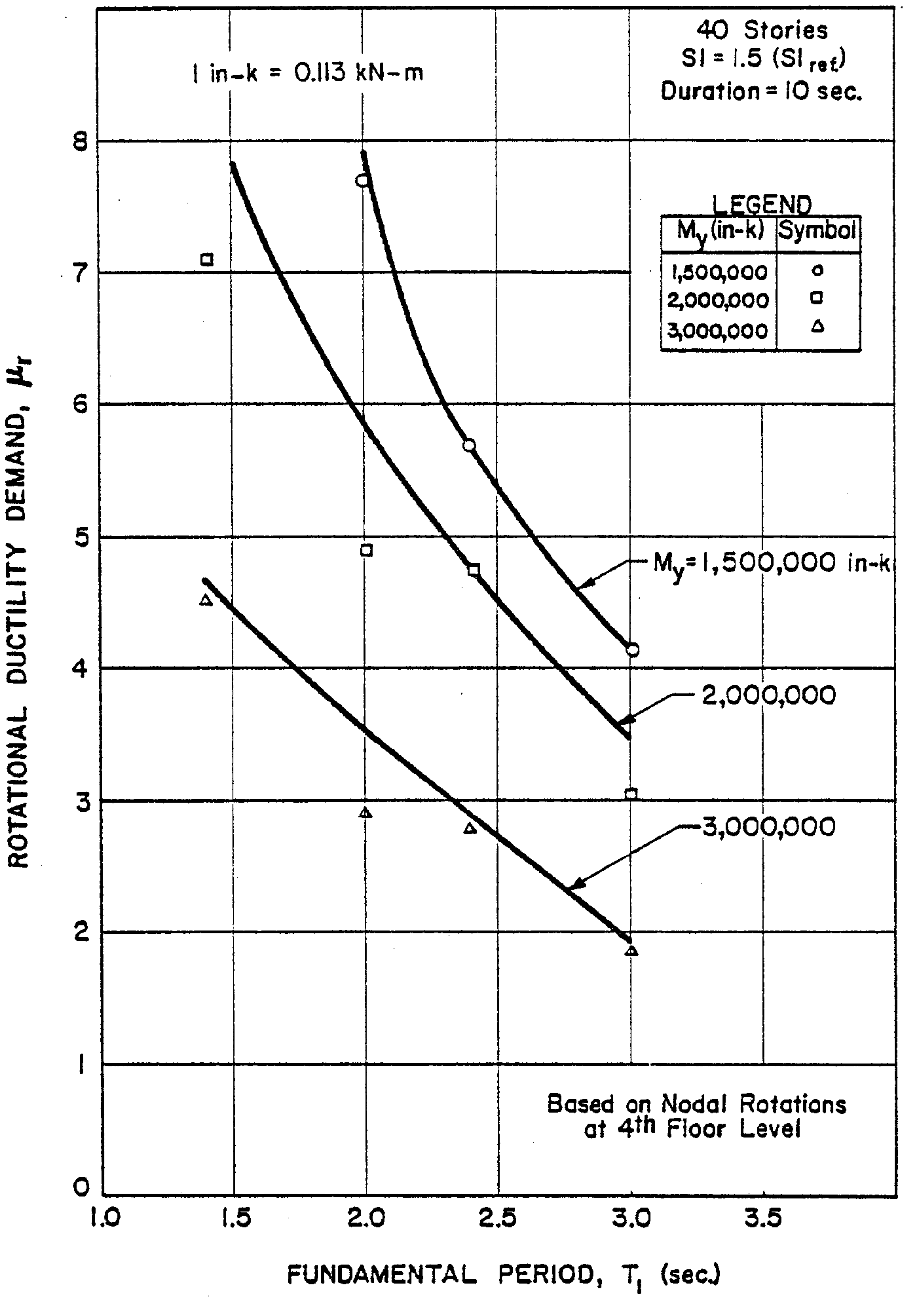


Fig. 10d Critical Rotational Ductility Ratio at Base as a Function of Fundamental Period, T_1, and Yield Level, M_y 40-Story Isolated Structural Walls

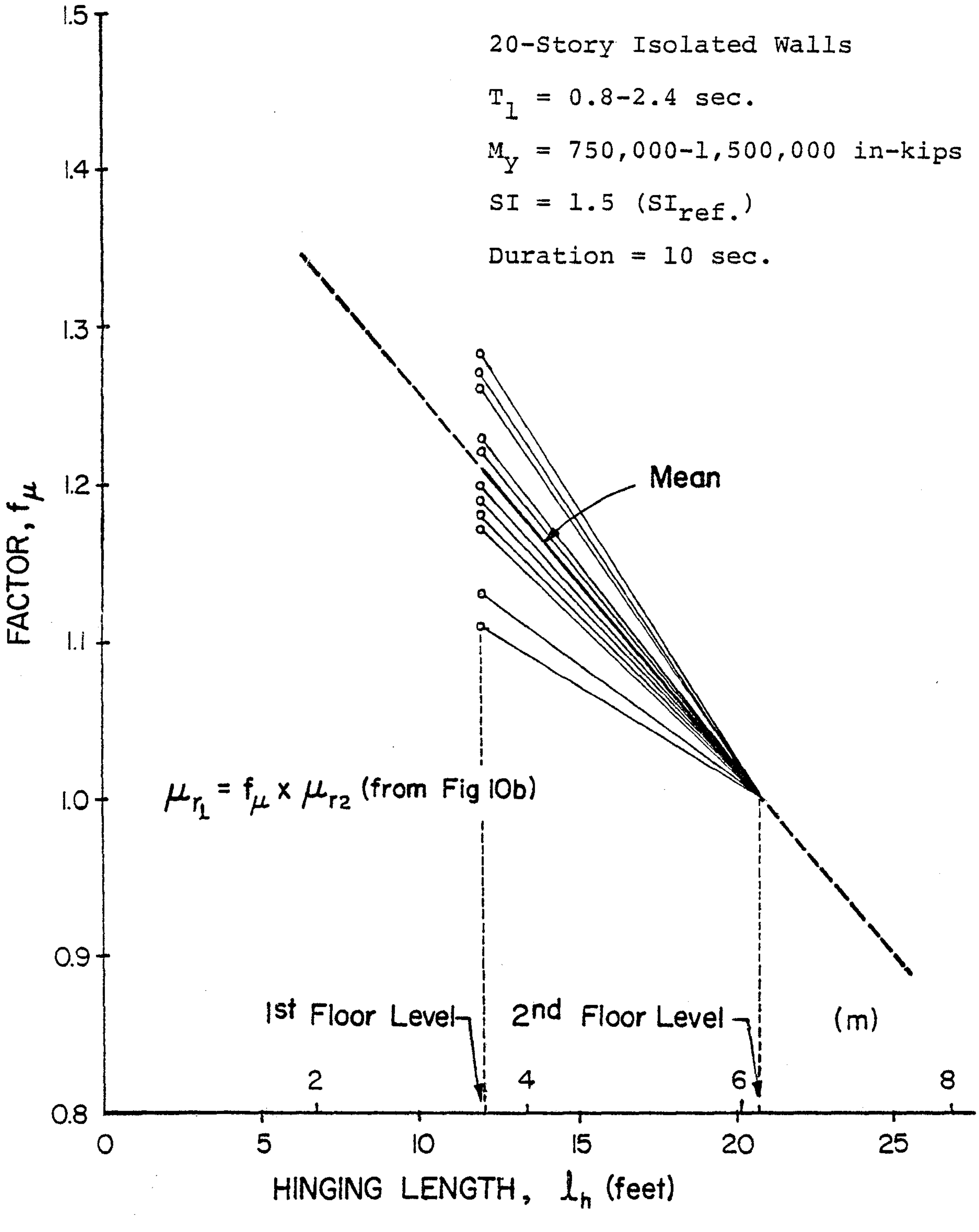


Fig. 11 Variation of Ductility Demand with Assumed Hinging Length

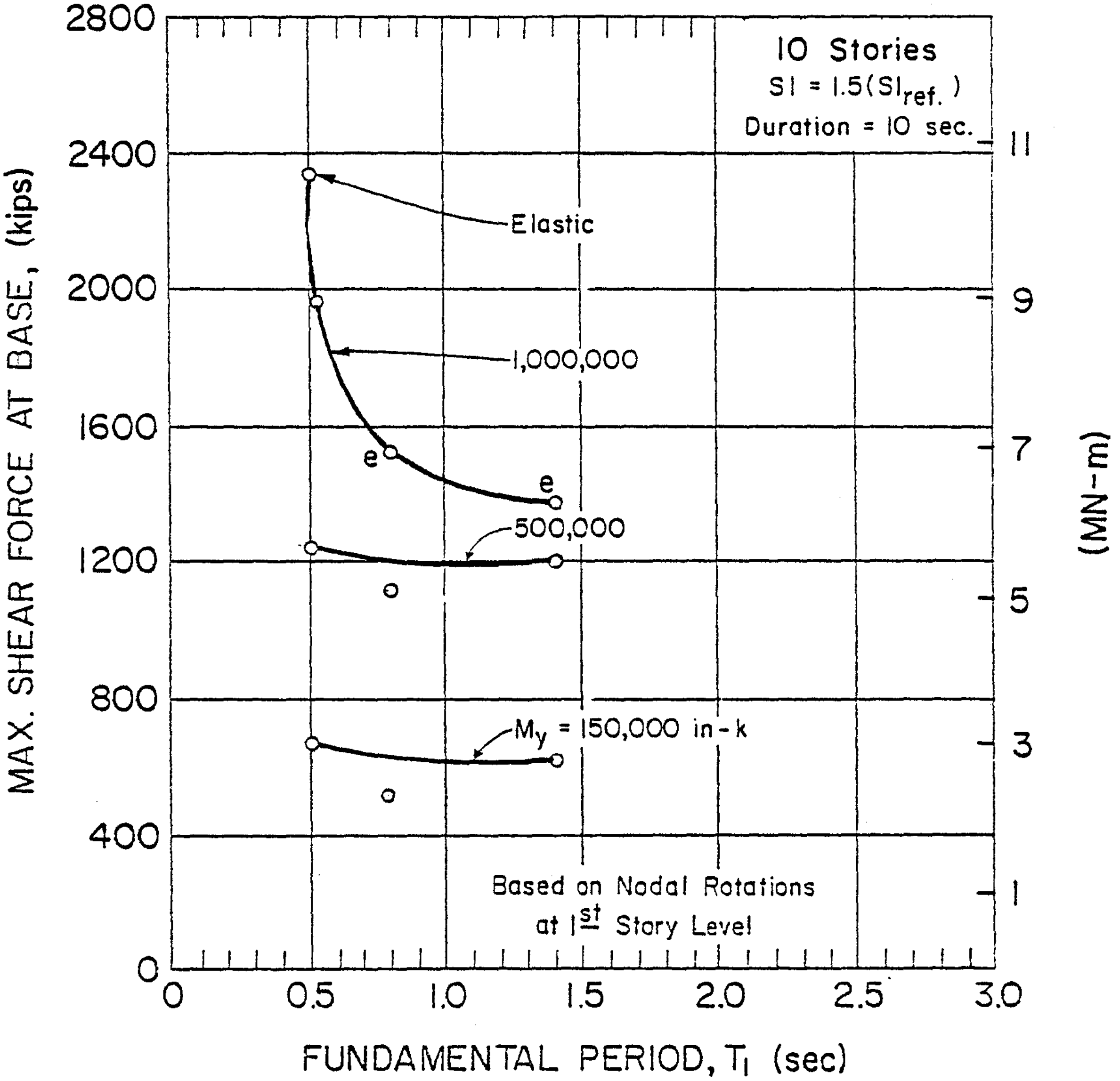


Fig. 12a Critical Base Shear, V_T^{dyn}, as a Function of Fundamental Period, T_1, and Yield Level, M_y 10-Story Isolated Walls

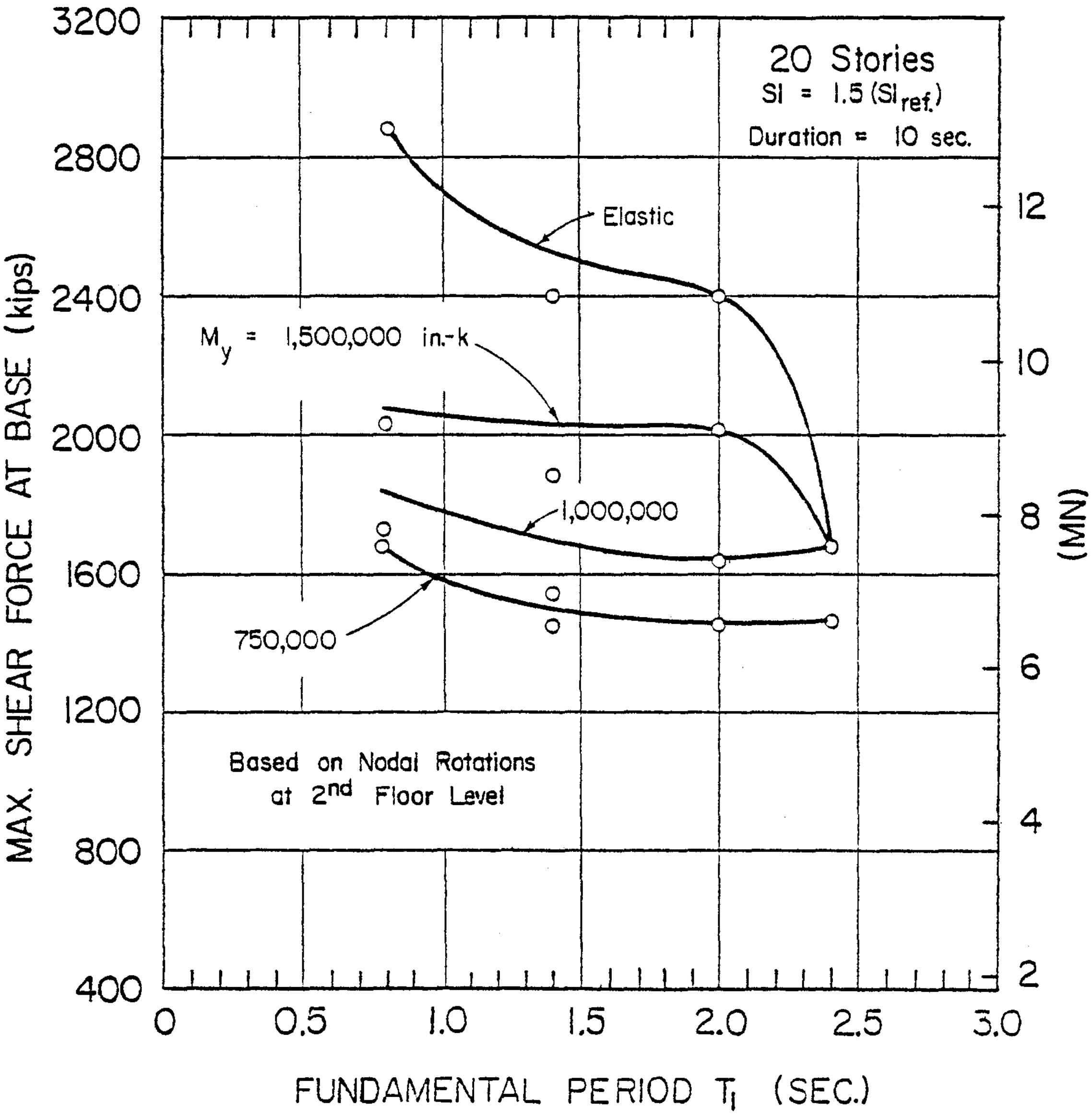


Fig. 12b Critical Base Shear, V_T^{dyn}, as a Function of Fundamental Period, T_1, and Yield Level, M_y 20-Story Isolated Walls

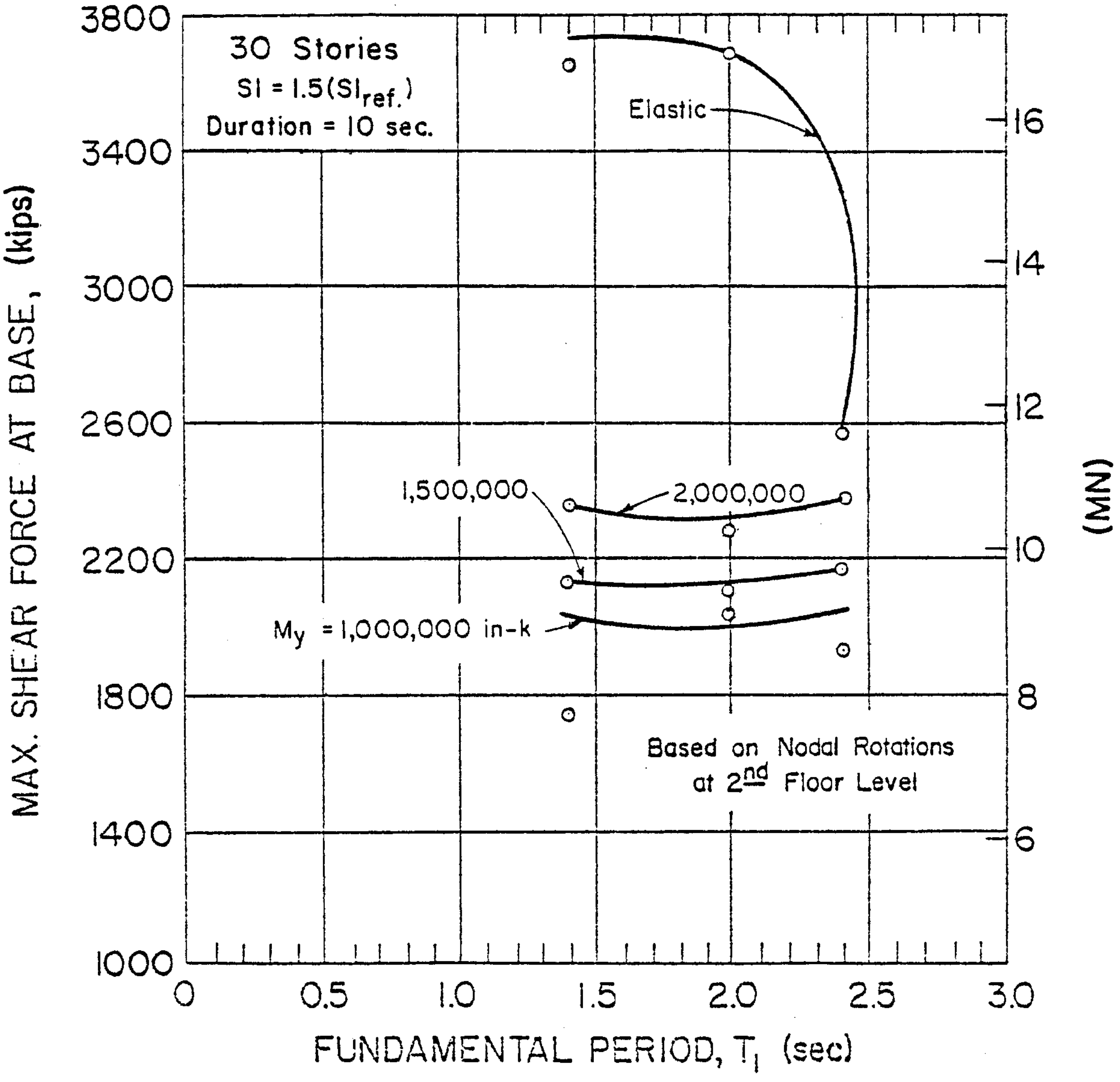


Fig. 12c Critical Base Shear, V_T^{dyn}, as a Function of Fundamental Period, T_1, and Yield Level, M_Y 30-Story Isolated Walls

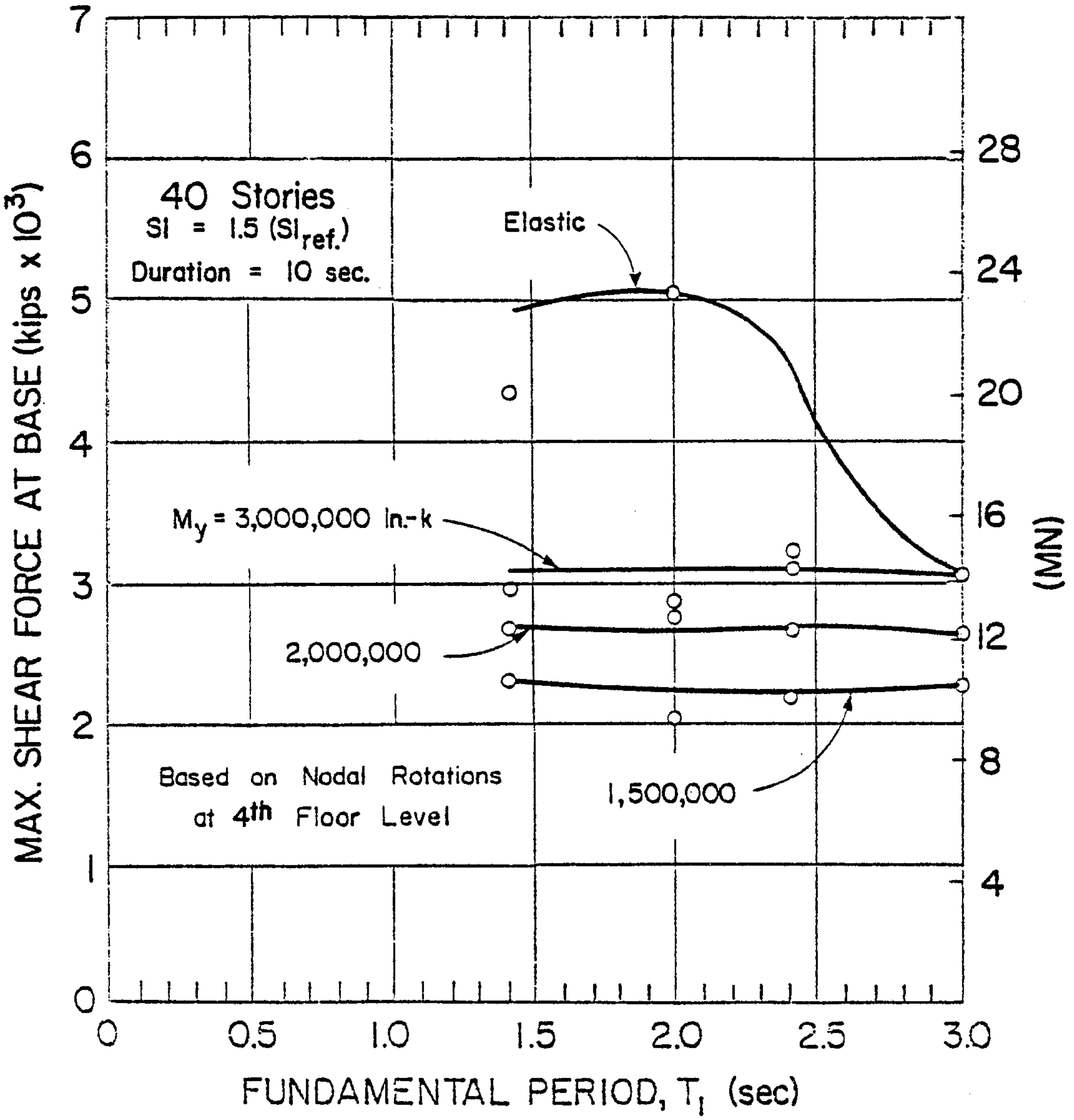


Fig. 12d Critical Base Shear, V_T^{dyn}, as a Function of Fundamental Period, T_1, and Yield Level, M_y 40-Story Isolated Walls

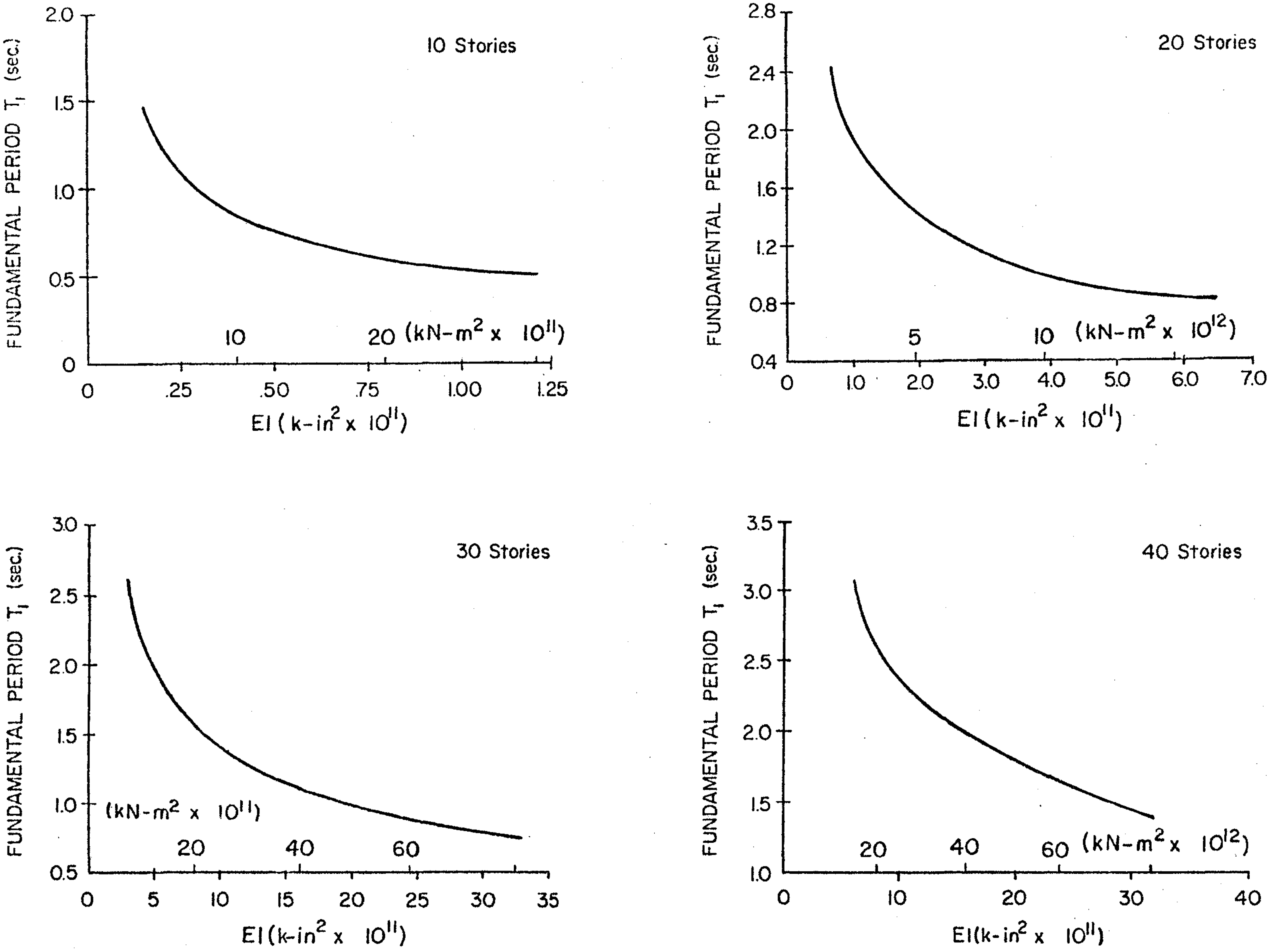


Fig. 13 Stiffness Factor, EI, versus Fundamental Period for the Four Different Wall Heights Considered

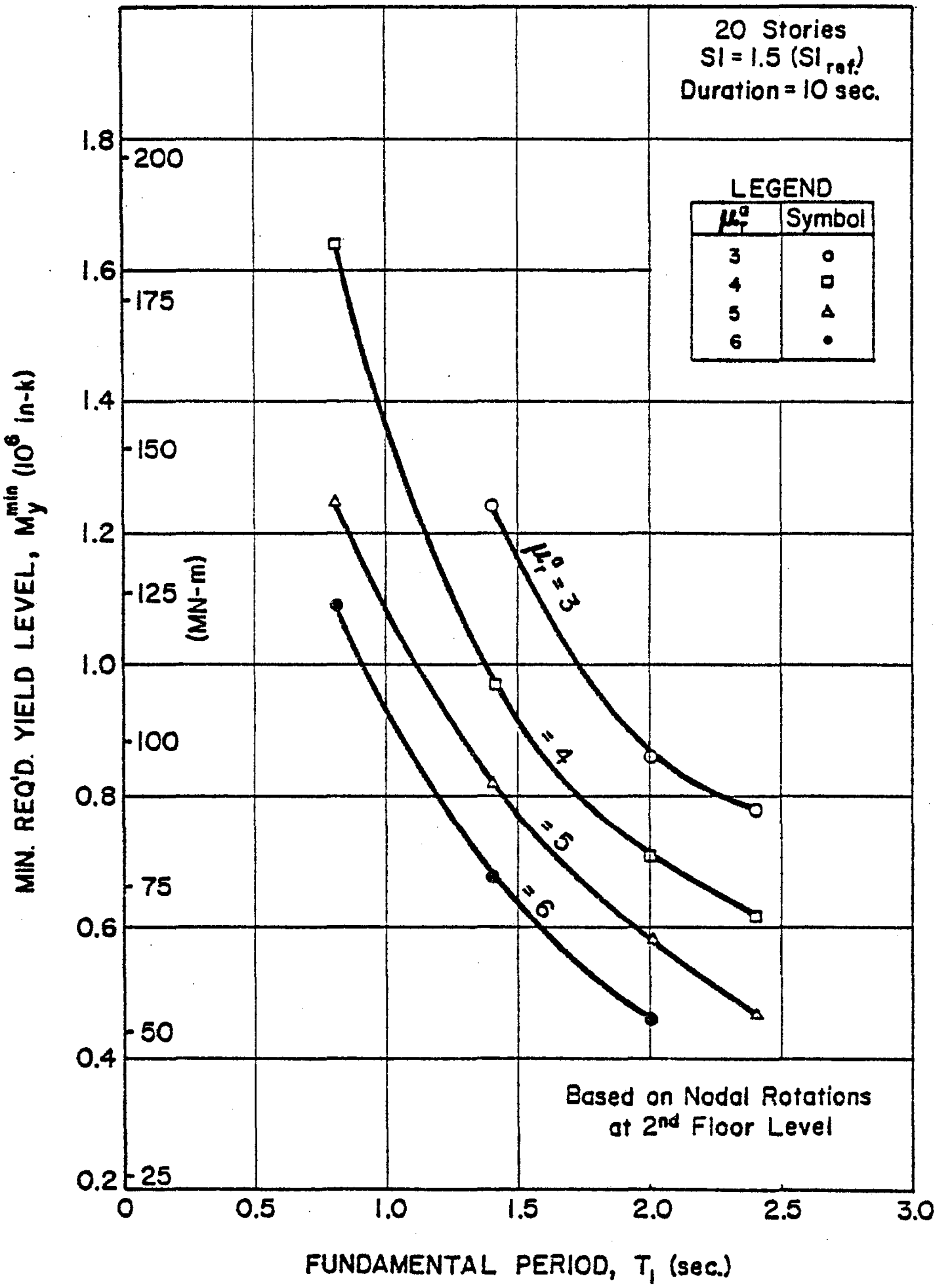


Fig. 14 Minimum Yield Level, M_y^{min}, Required at Base as a Function of Available Rotational Ductility Ratio, μ_r^a, and Fundamental Period, T_1 - 20-Story Isolated Walls

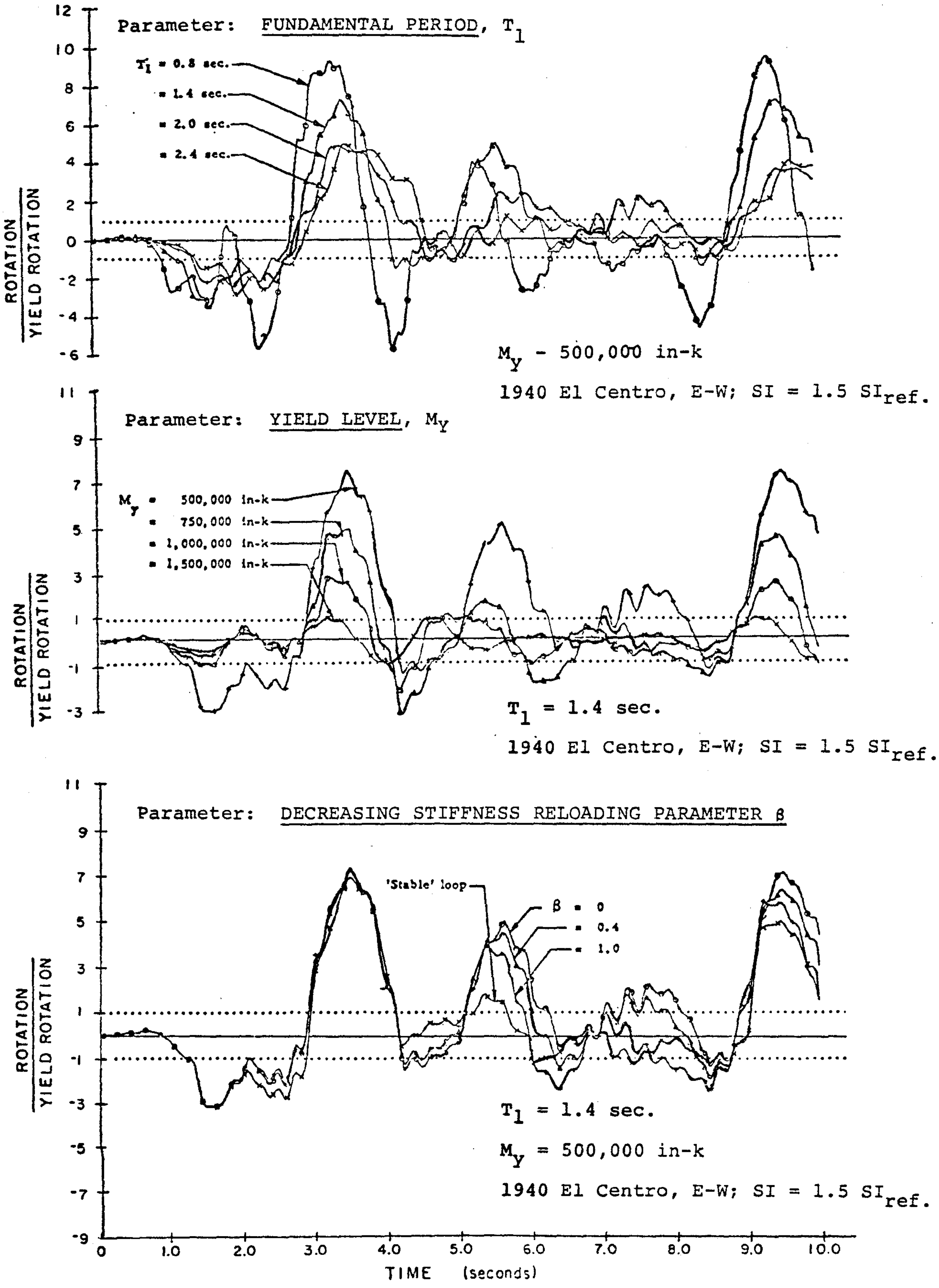
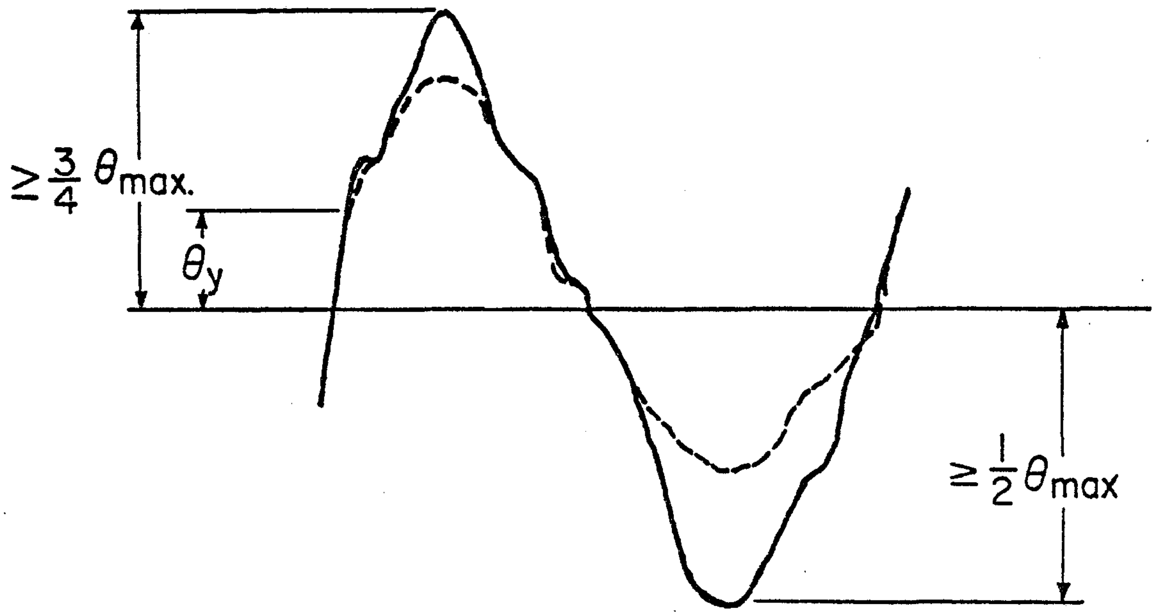
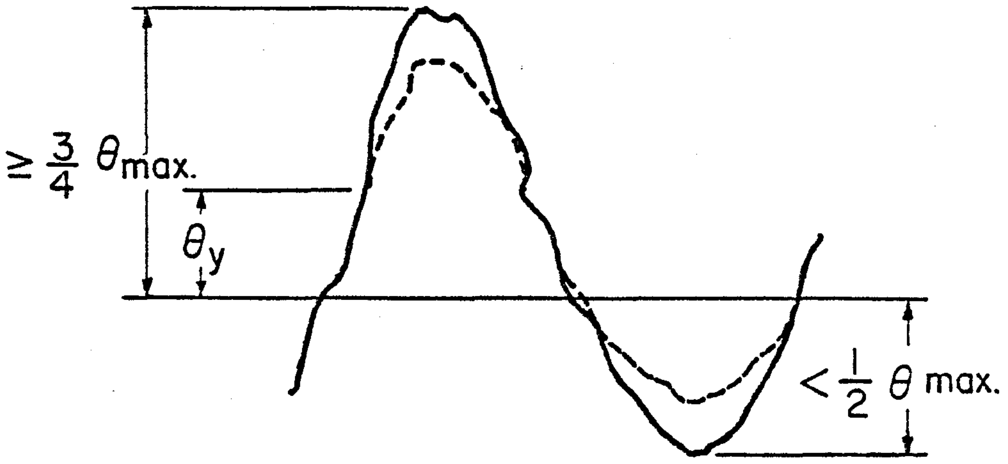


Fig. 15 Samples of Normalized Nodal Rotation History Plots

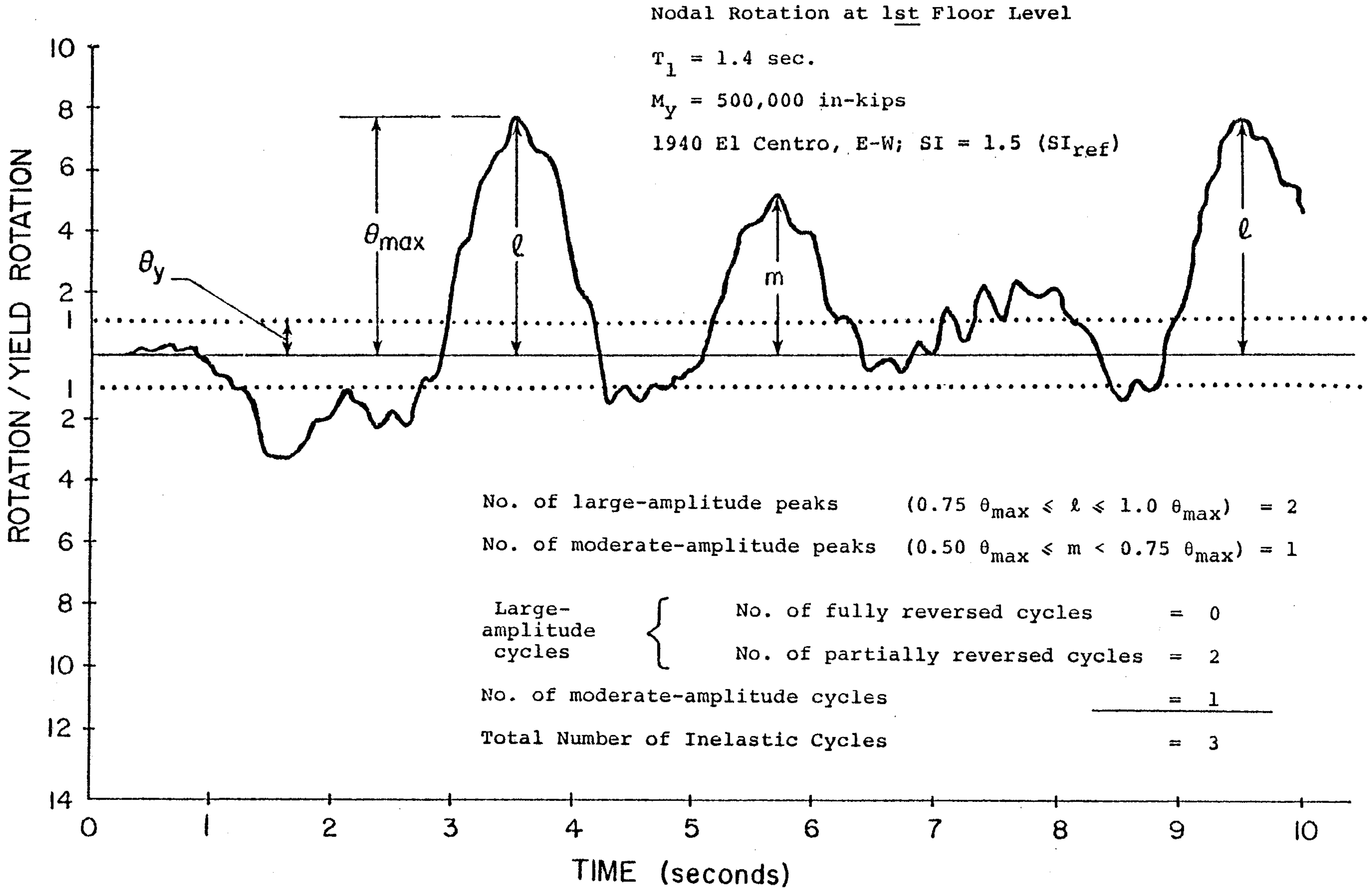


(a) "FULLY REVERSED" CYCLE



(b) "PARTIALLY REVERSED" CYCLE

Fig. 16 "Fully Reversed" and "Partially Reversed" Large Amplitude Cycles of Rotational Deformation Defined



No. of large-amplitude peaks ($0.75\ \theta_{max} \leqslant \ell \leqslant 1.0\ \theta_{max}$) = 2

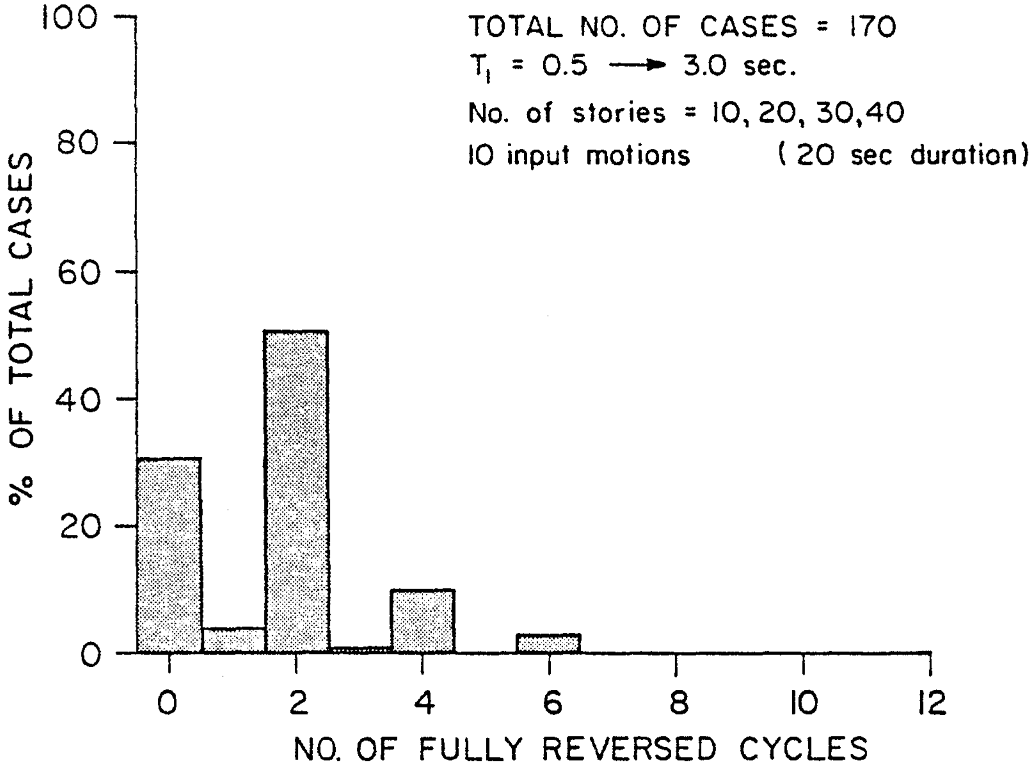
No. of moderate-amplitude peaks ($0.50\ \theta_{max} \leqslant m < 0.75\ \theta_{max}$) = 1

Large-amplitude cycles $\left\{ \begin{array}{ll} \text{No. of fully reversed cycles} & = 0 \\ \text{No. of partially reversed cycles} & = 2 \end{array} \right.$

No. of moderate-amplitude cycles = 1

Total Number of Inelastic Cycles = 3

Fig. 17 Example Showing Determination of Fully Reversed and Partially Reversed Cycles of Deformation



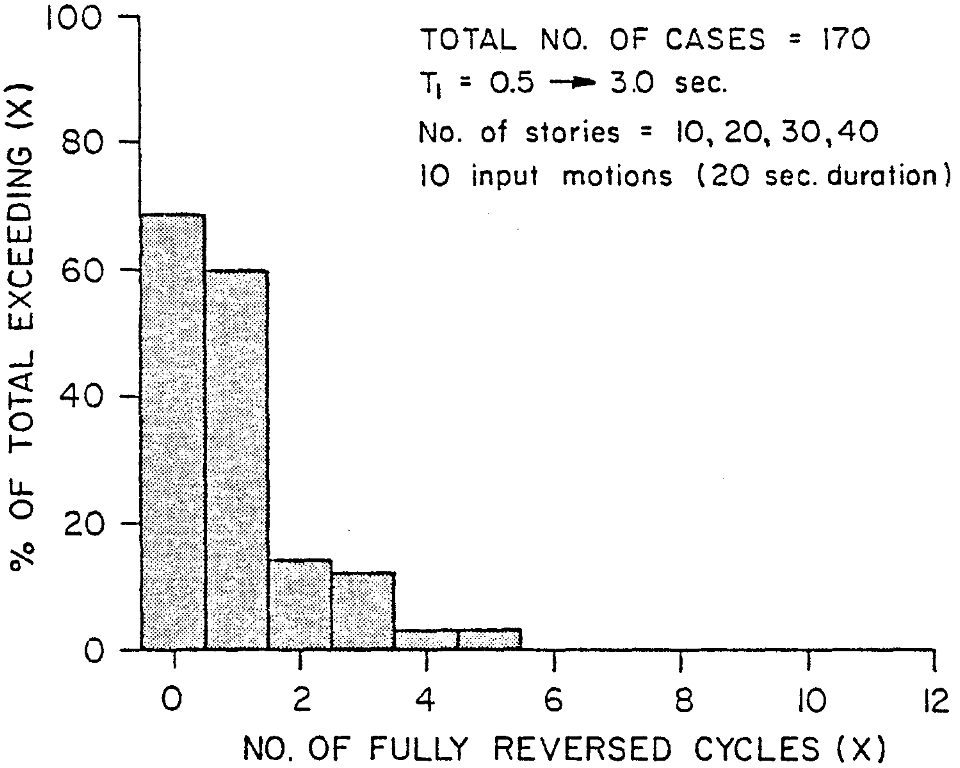
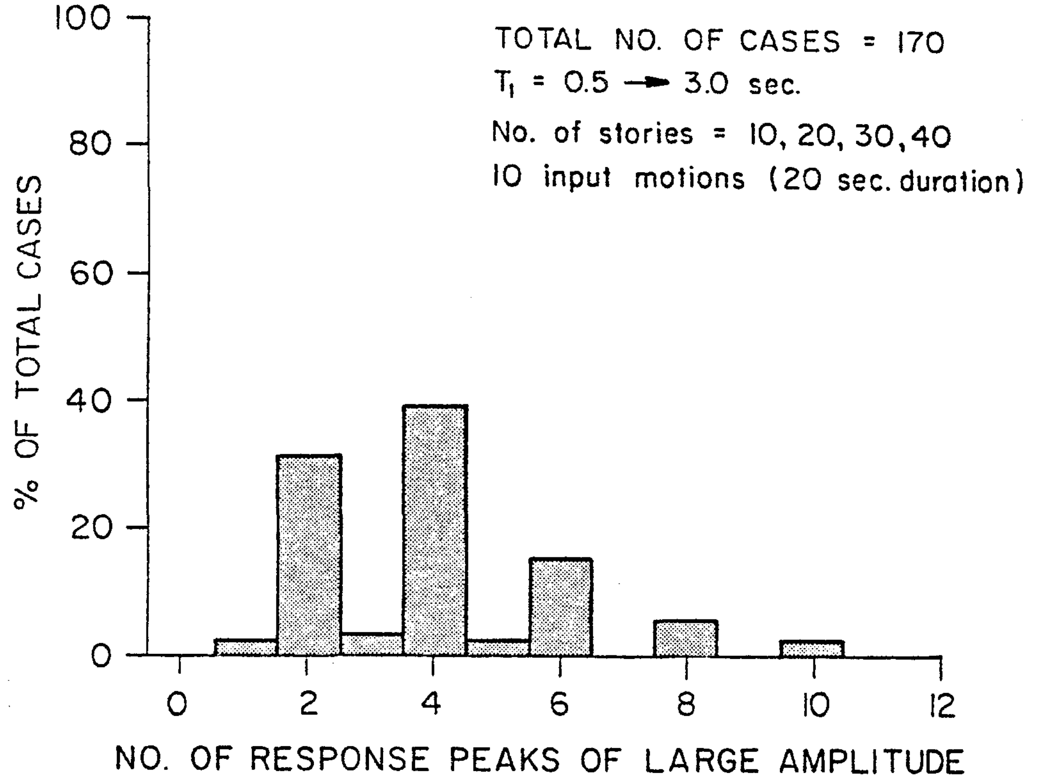


Fig. 18 Distribution of Number of Fully Reversed Large-Amplitude Cycles



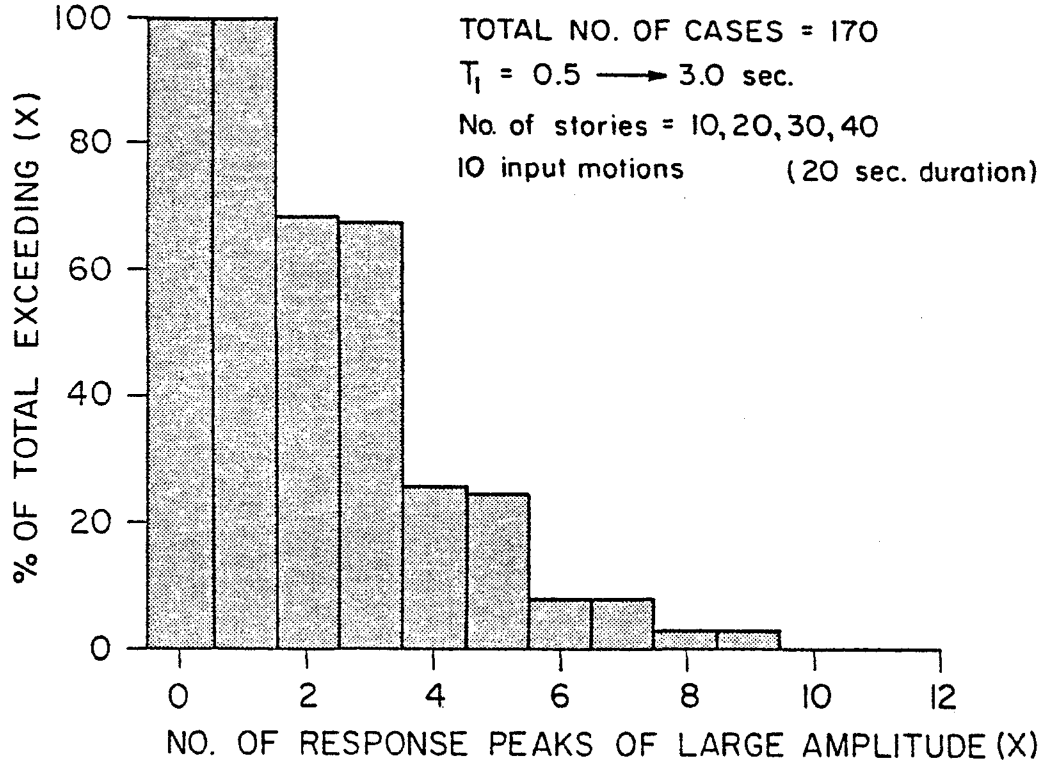


Fig. 19 Distribution of Number of Peaks of Large Amplitude

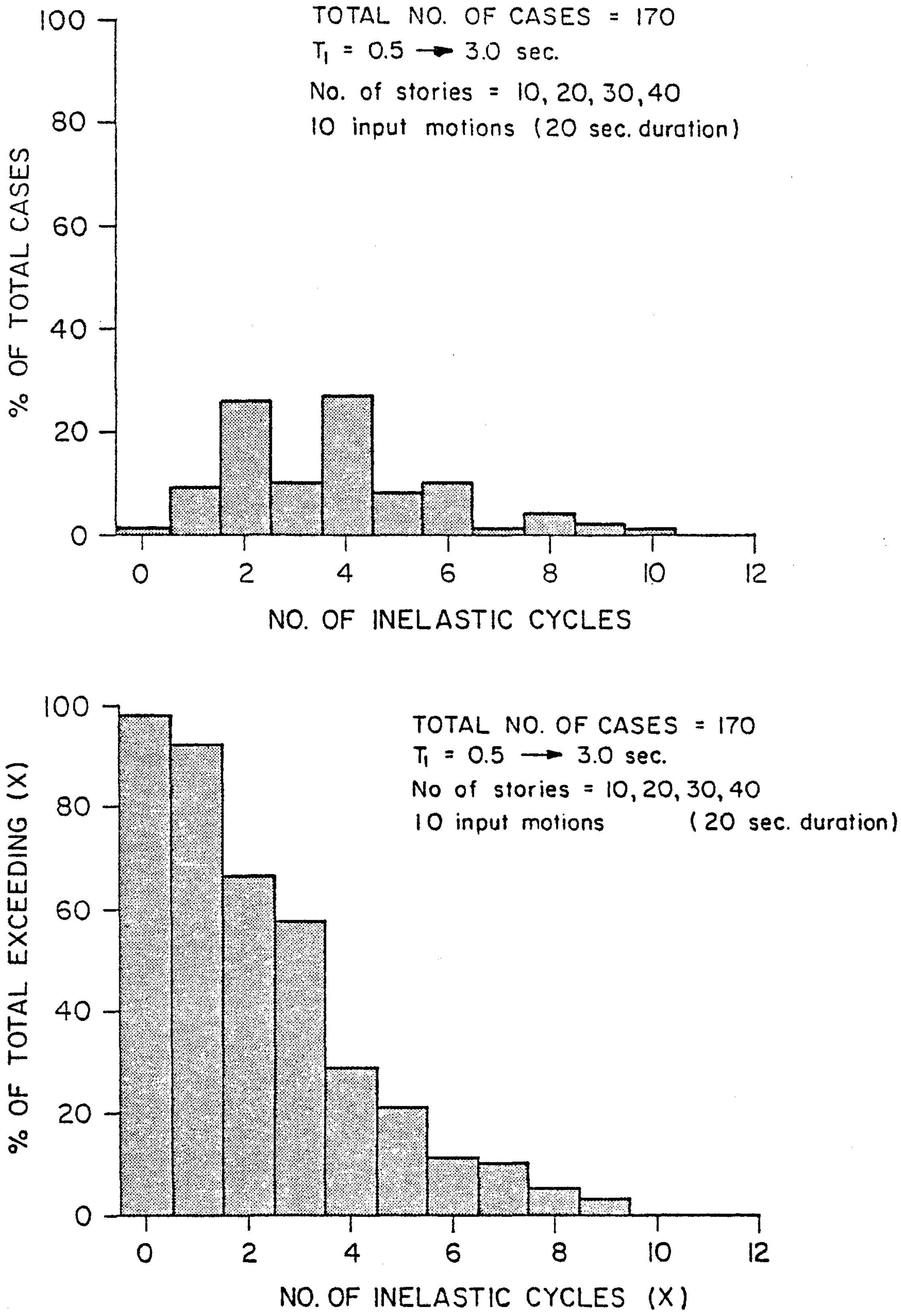
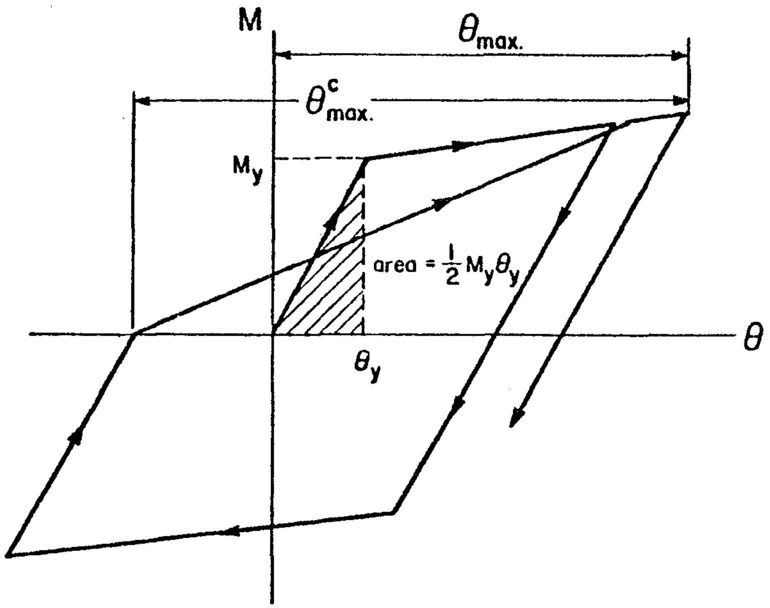
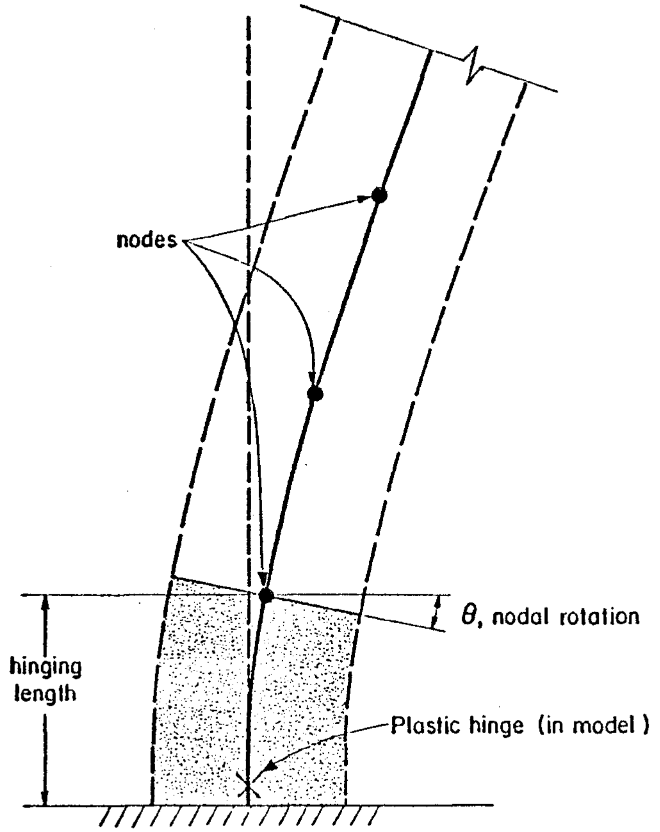


Fig. 20 Distribution of Total Number of Inelastic Cycles





Measures of Deformation:

rotational ductility, $\mu_r = \dfrac{\theta_{max.}}{\theta_y}$

cyclic rotational ductility, $\mu_{rc} = \dfrac{\theta^c_{max.}}{\theta_y}$

cumulative rotational ductility, $\sum\mu_{rc} = \dfrac{\sum\theta^c_{max.}}{\theta_y}$

cumulative rotational energy, $\sum A_r = \dfrac{\text{cumulative area under } M-\theta \text{ loops}}{\frac{1}{2}M_y\theta_y}$

Fig. 21 Different Measures of Rotational Deformation in Hinging Region

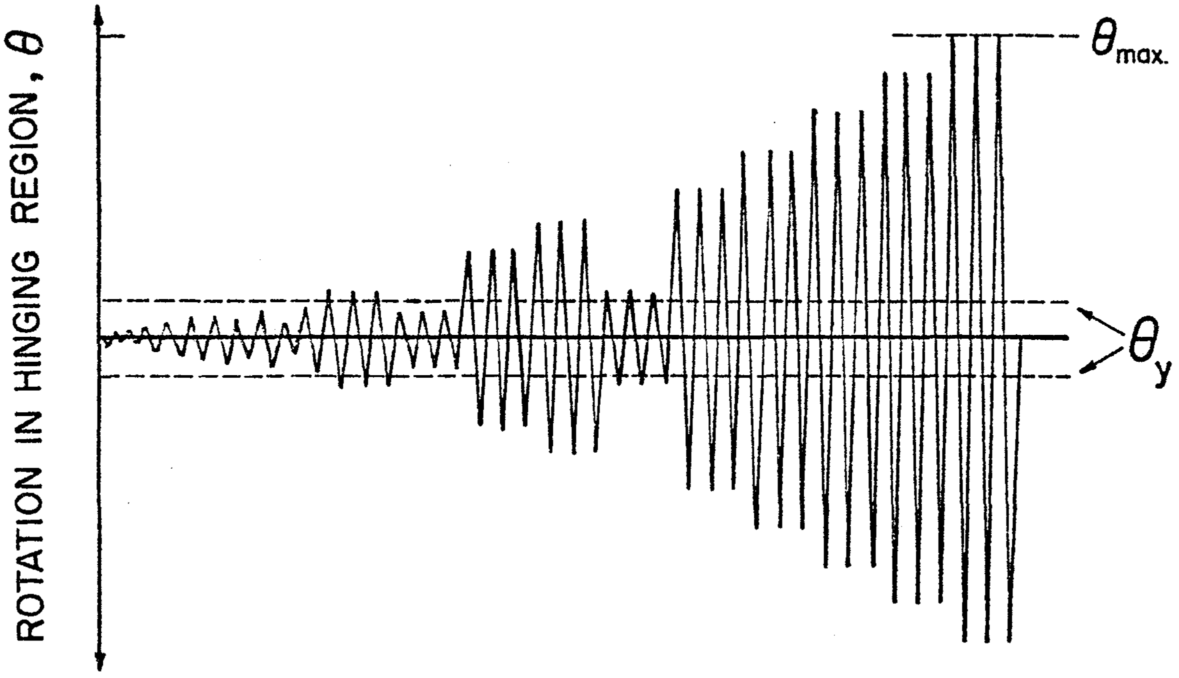


Fig. 22 Typical Sequence of Loading Used In Testing Specimens Under Slowly Reversed Loads

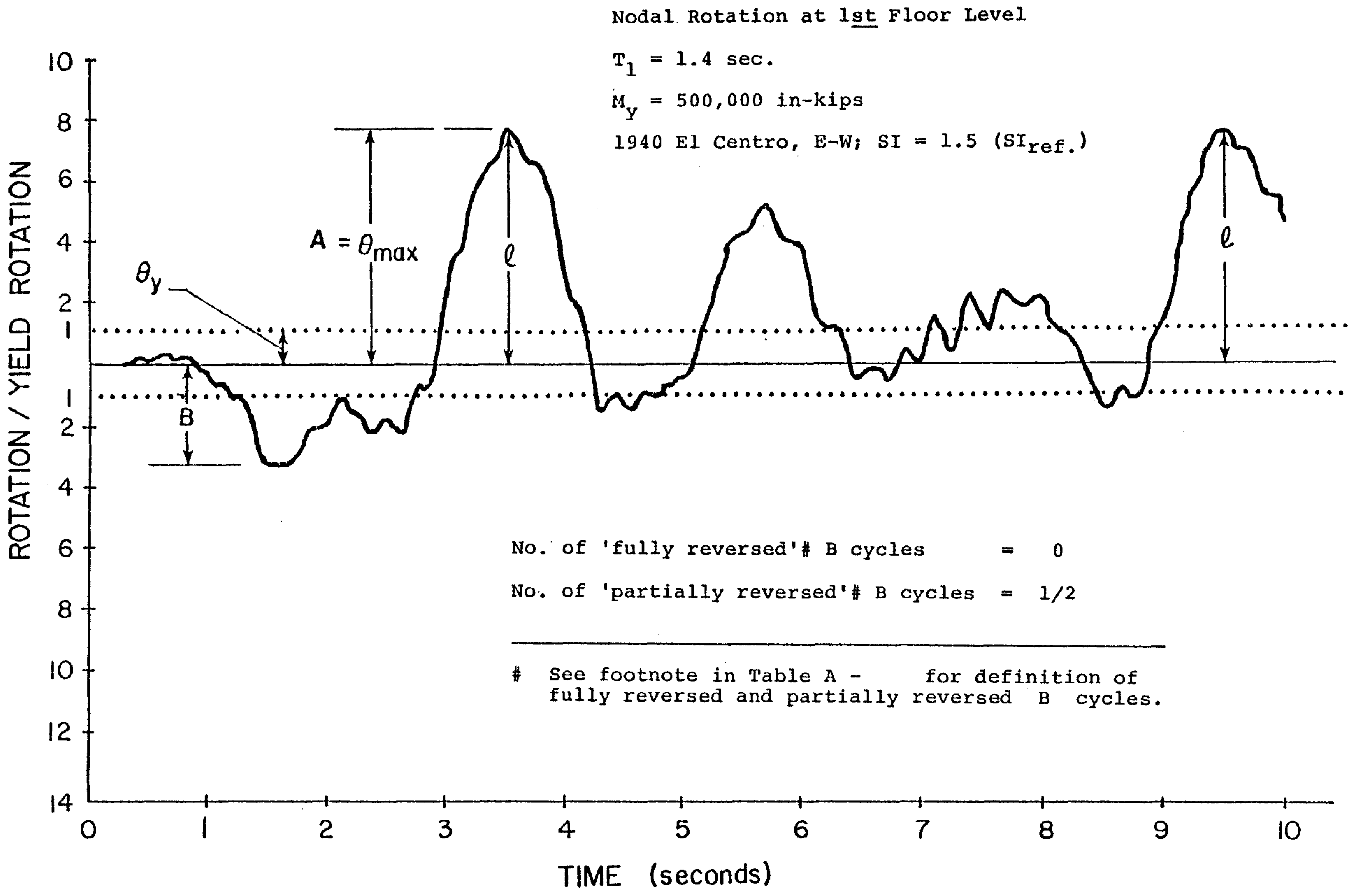


Fig. 23 Example Showing Determination of Inelastic Cycles Preceding Large-Amplitude Response Peak

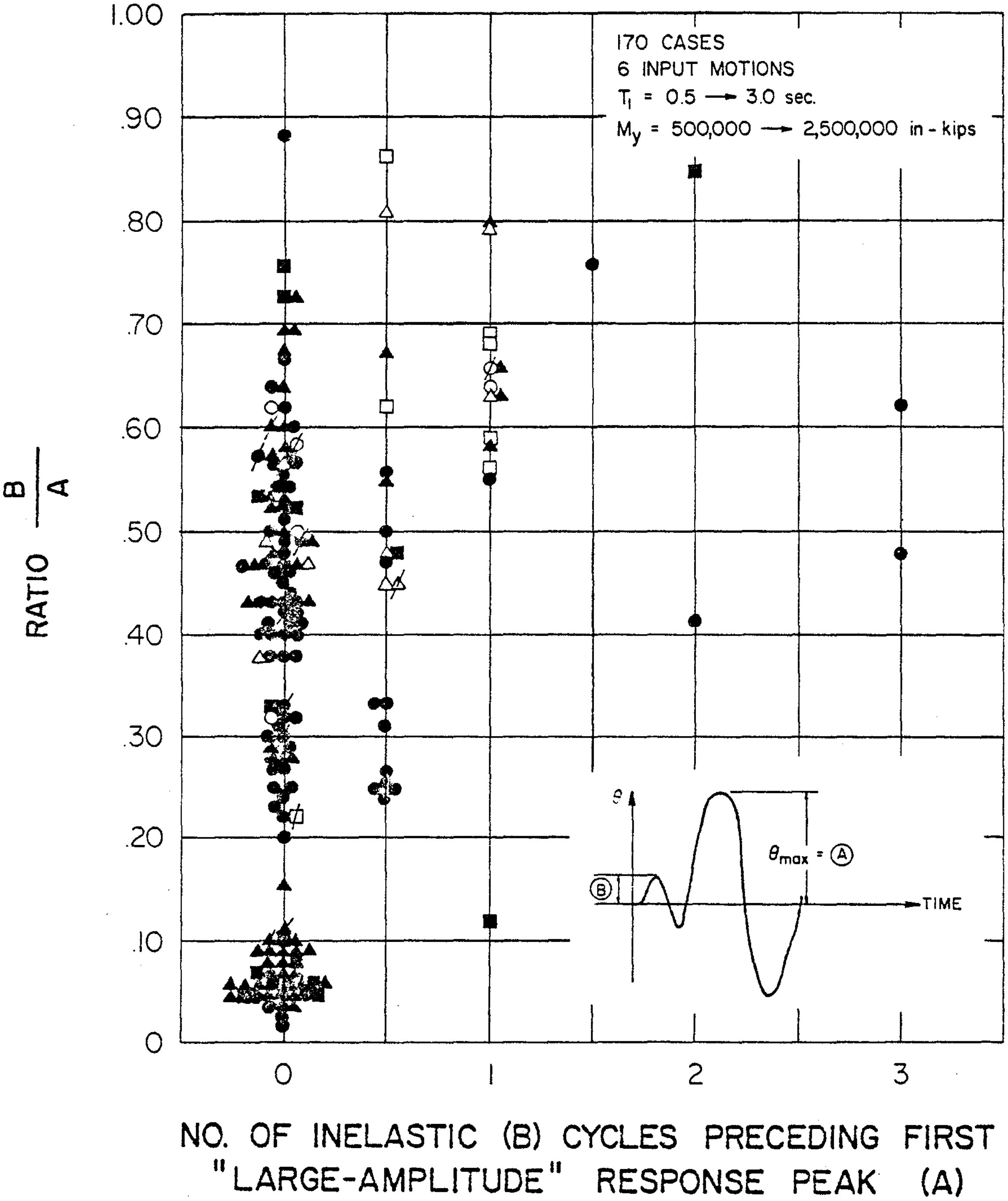


Fig. 24 Number of Inelastic (B) Cycles Preceding First Large-Amplitude Response Peak (A), versus Ratio B/A

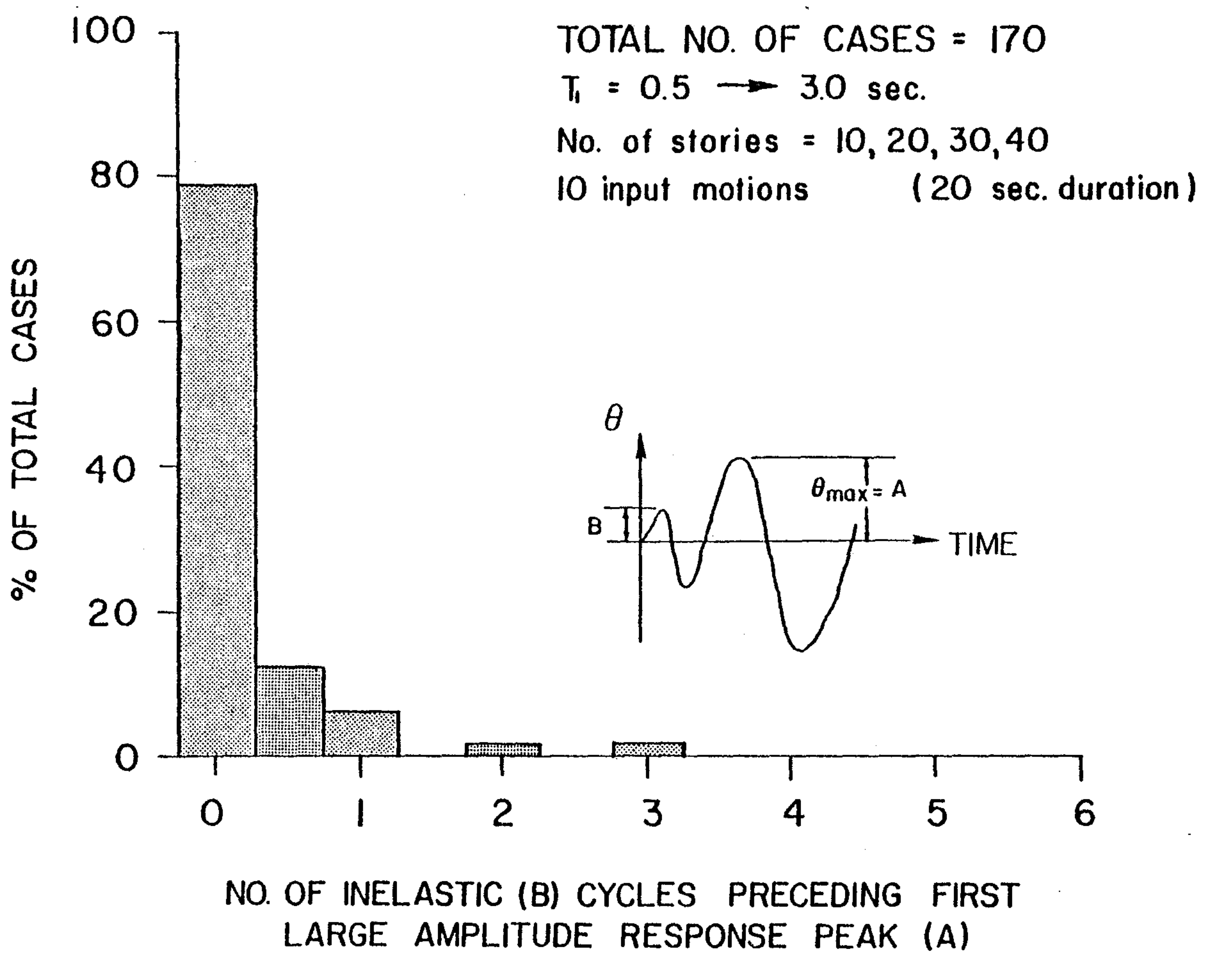


Fig. 25 Distribution of Inelastic (B) Cycles Preceding First Large-Amplitude Response Peak (A)

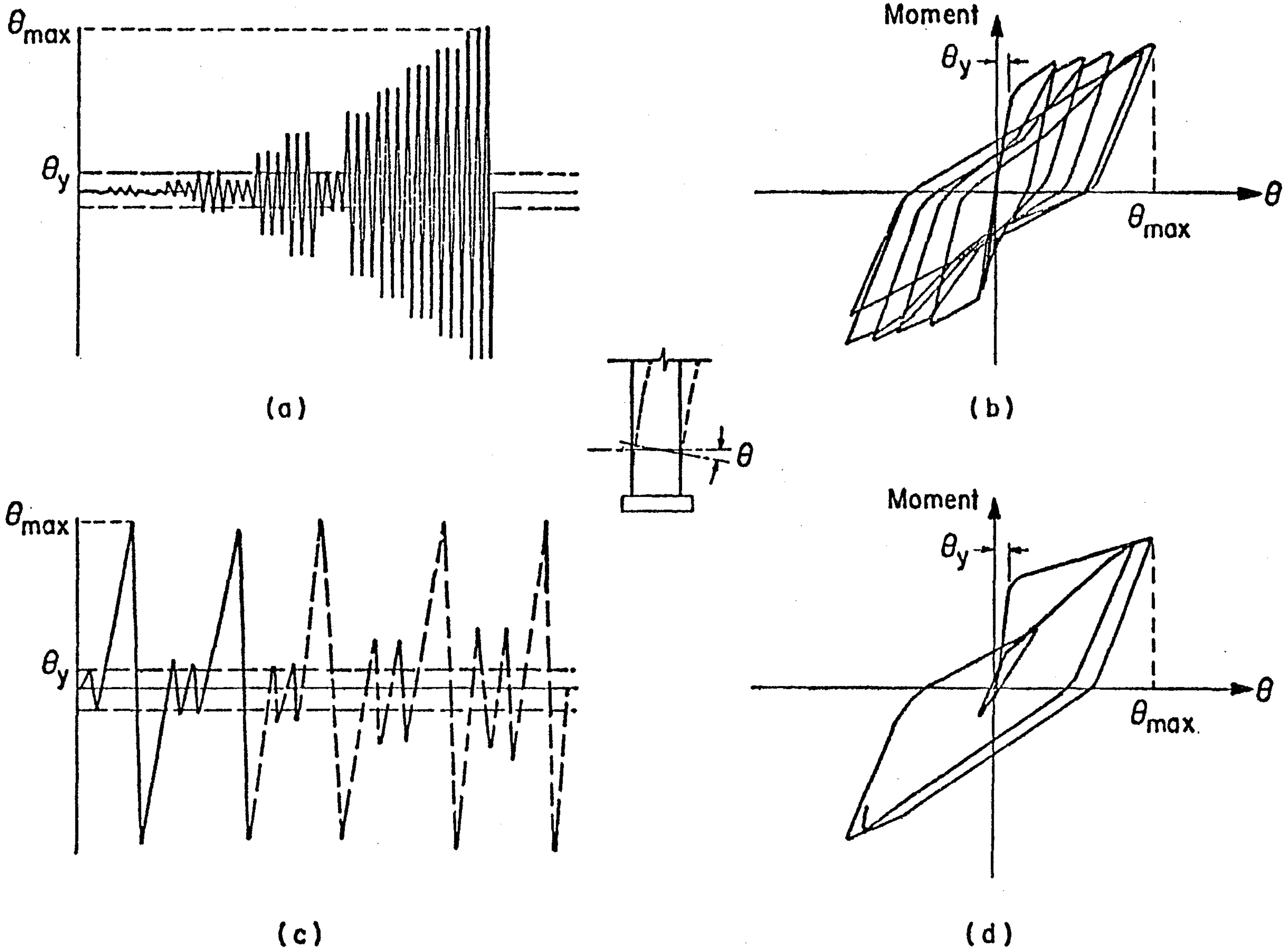


Fig. 26 Effect of Sequence of Application of Large-Amplitude Deformations on Specimen Behavior

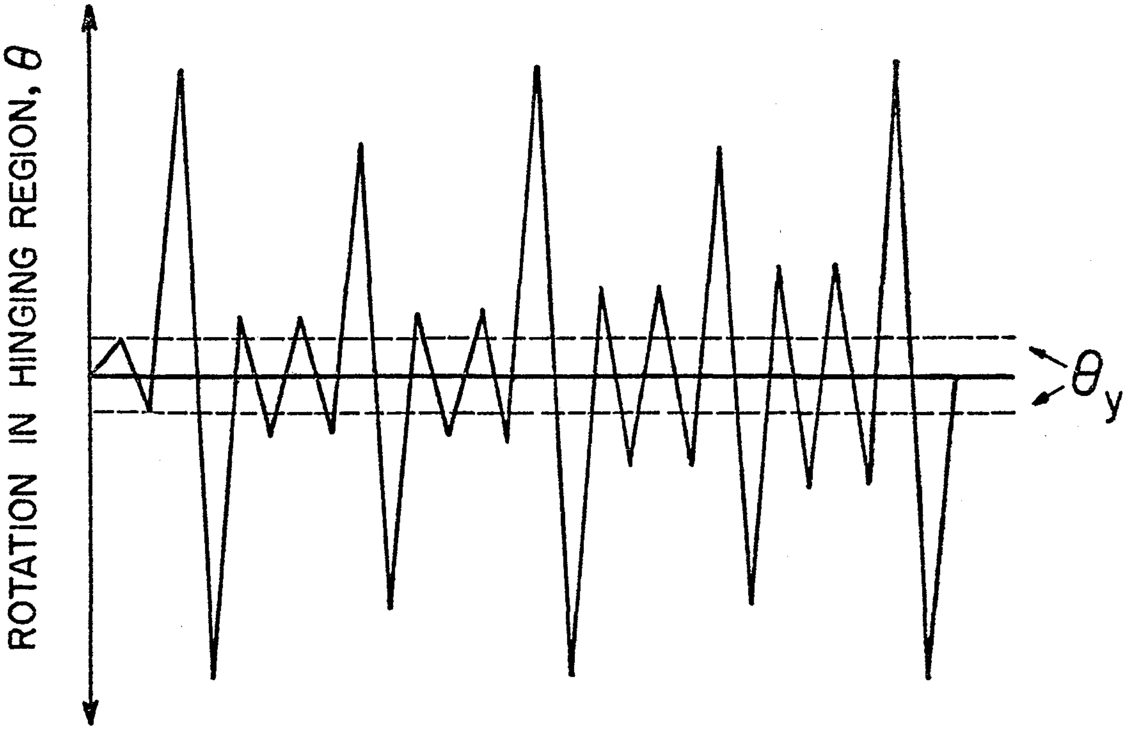


Fig. 27 Representative Deformation History for Hinging Region of Isolated Walls

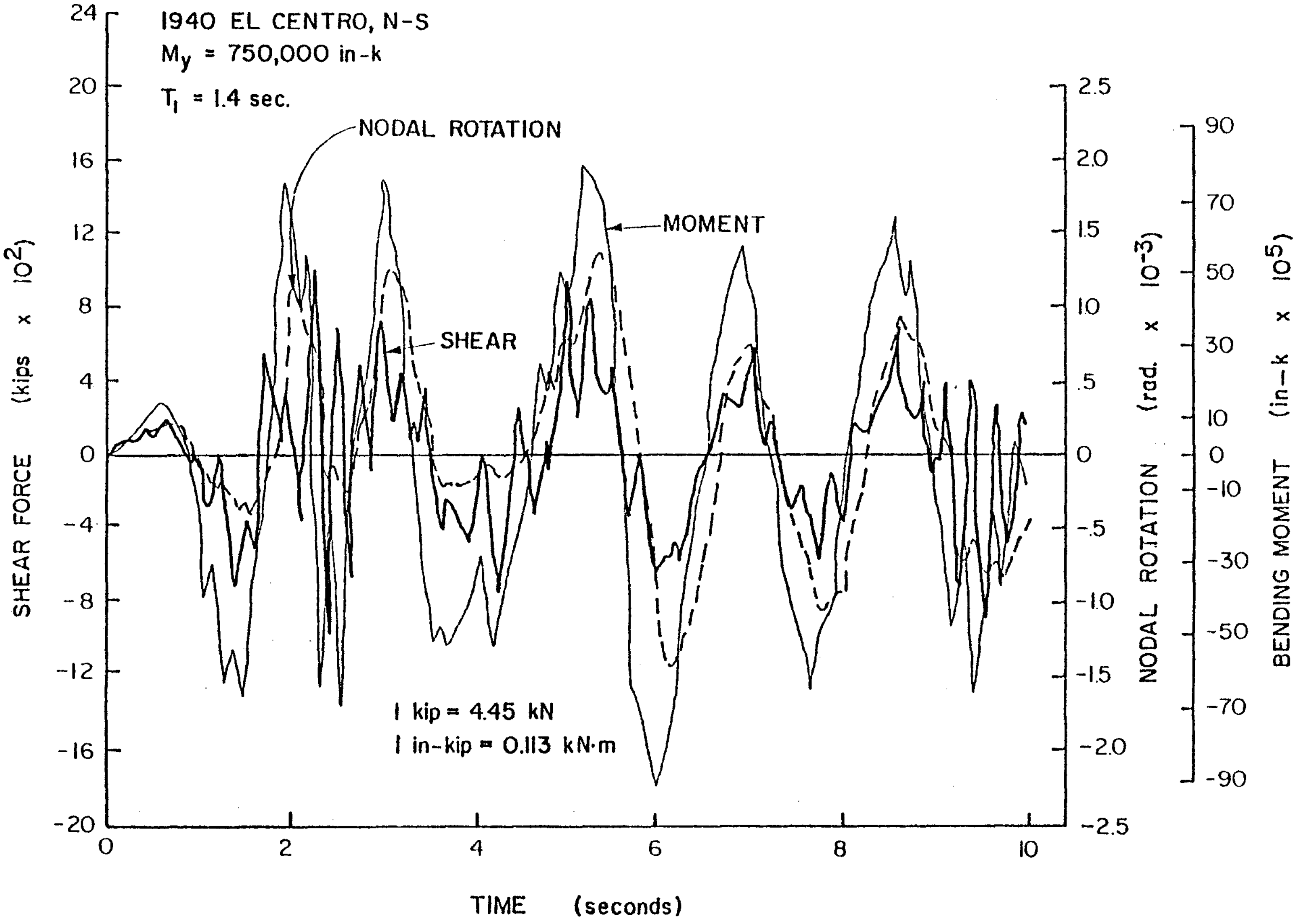


Fig. 28a Relative Variation with Time of Shear, Moment and Rotation in Hinging Region - 20-Story Isolated Wall

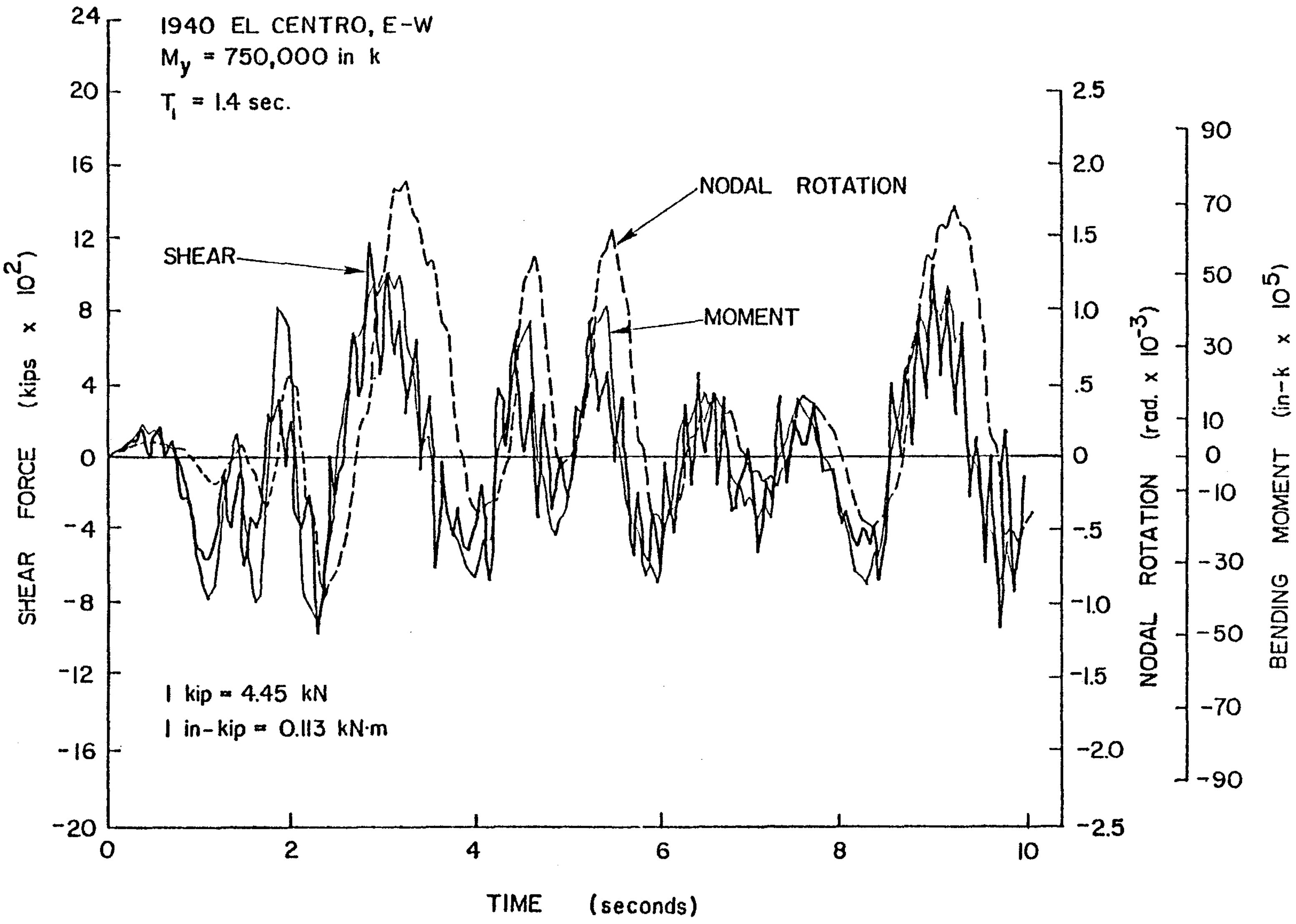


Fig. 28b Relative Variation with Time of Shear, Moment and Rotation in Hinging Region
- 20-Story Isolated Wall

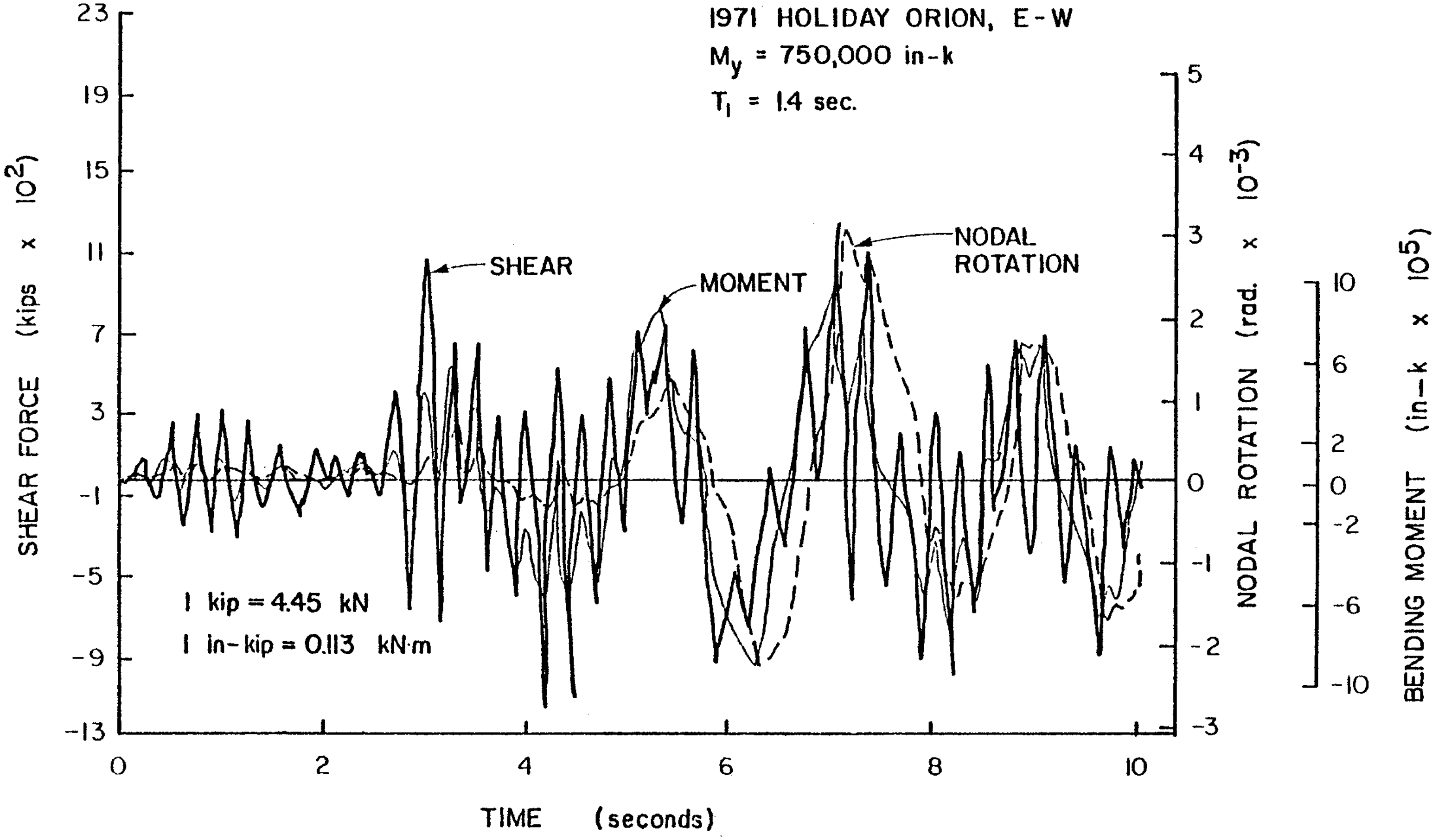


Fig. 28c Relative Variation with Time of Shear, Moment and Rotation in Hinging Region - 20-Story Isolated Wall

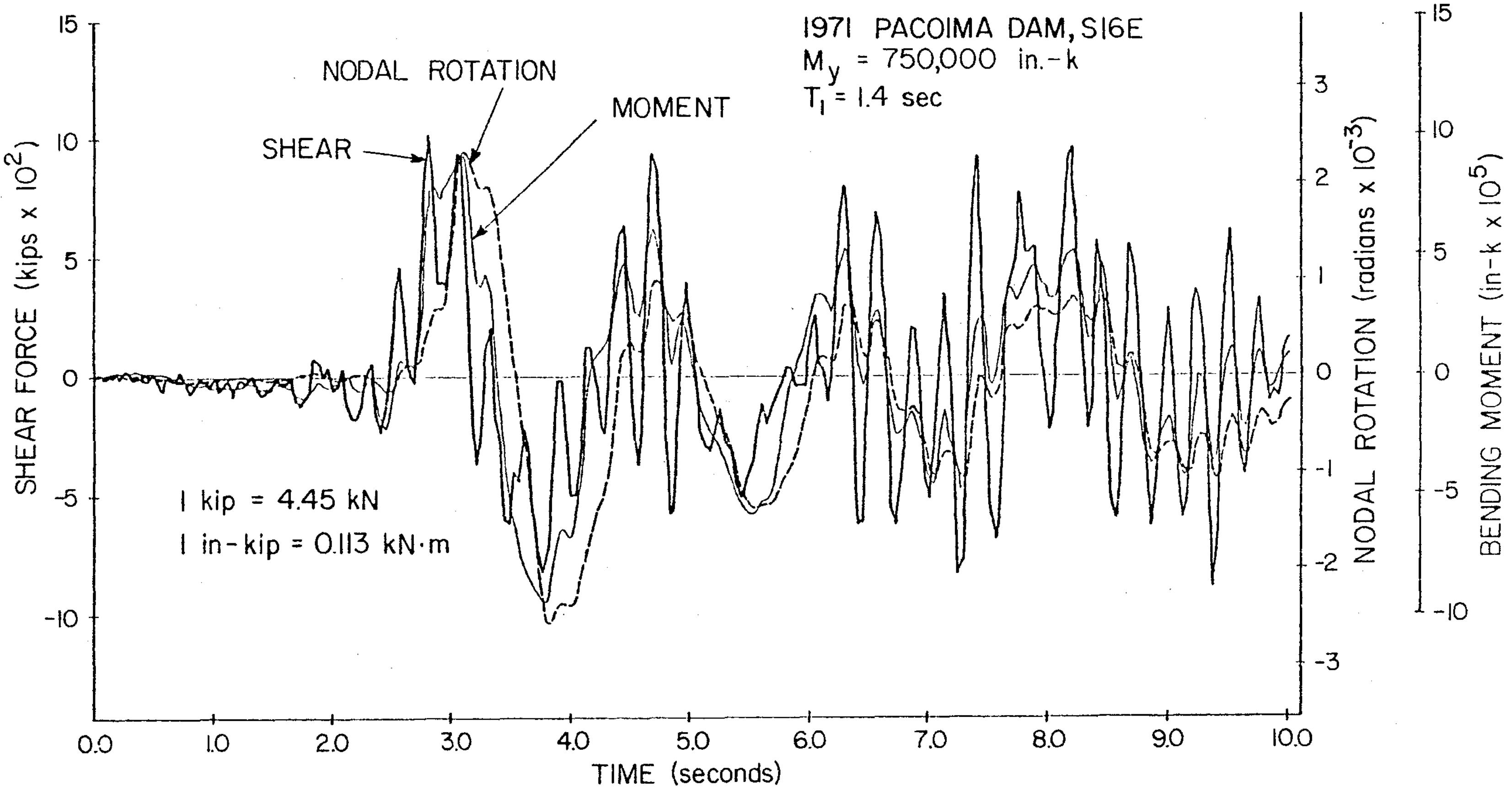


Fig. 28d Relative Variation with Time of Shear, Moment, and Rotation in Hinging Region - 20-Story Isolated Wall

APPENDIX A

This Appendix presents tables giving detailed data obtained from an examination of the 170 response histories considered in this investigation. The compiled data relate mainly to the number and sequence of large-amplitude cycles of response.

Also included is a sampling of the normalized rotation histories for 10-, 20-, 30- and 40-story isolated walls. The plots are for rotations of the nodes closest to the base in each of the lumped-mass models shown in Fig. 2 of the main body of this report. In each plot, the calculated nodal rotation has been divided by the corresponding rotation at first yield.

In Tables A1 through A8, the following abbreviations are used under the column "Earthquake Input" to denote the corresponding input accelerograms:

EC-E - 1940 El Centro, E-W component (10-sec. duration)
EC-E** - 20-second composite accelerogram based on EC-E
EC-N - 1940 El Centro, N-S component (10-sec. duration)
EC-N** - 20-second composite accelerogram based on EC-N
P.D. - 1971 Pacoima Dam, S16E component (10-sec. duration)
P.D.** - 20-second composite accelerogram based on P.D.
H.O. - 1971 Holiday Orion, E-W component (10-sec. duration)
H.O.** - 20-second composite accelerogram based on H.O.
T - 1952 Taft, S69E component (10-sec. duration)
S1 - Artificially generated accelerogram

The intensity factor, f, shown in the tables, represents the ratio of the 5%-damped spectrum intensity of the particular input motion to the reference spectrum intensity, $SI_{ref.}$, i.e., the 5%-damped spectrum intensity - between periods 0.1 and 3.0 seconds - corresponding to the first 10 seconds of the N-S component of the 1940 El Centro record.

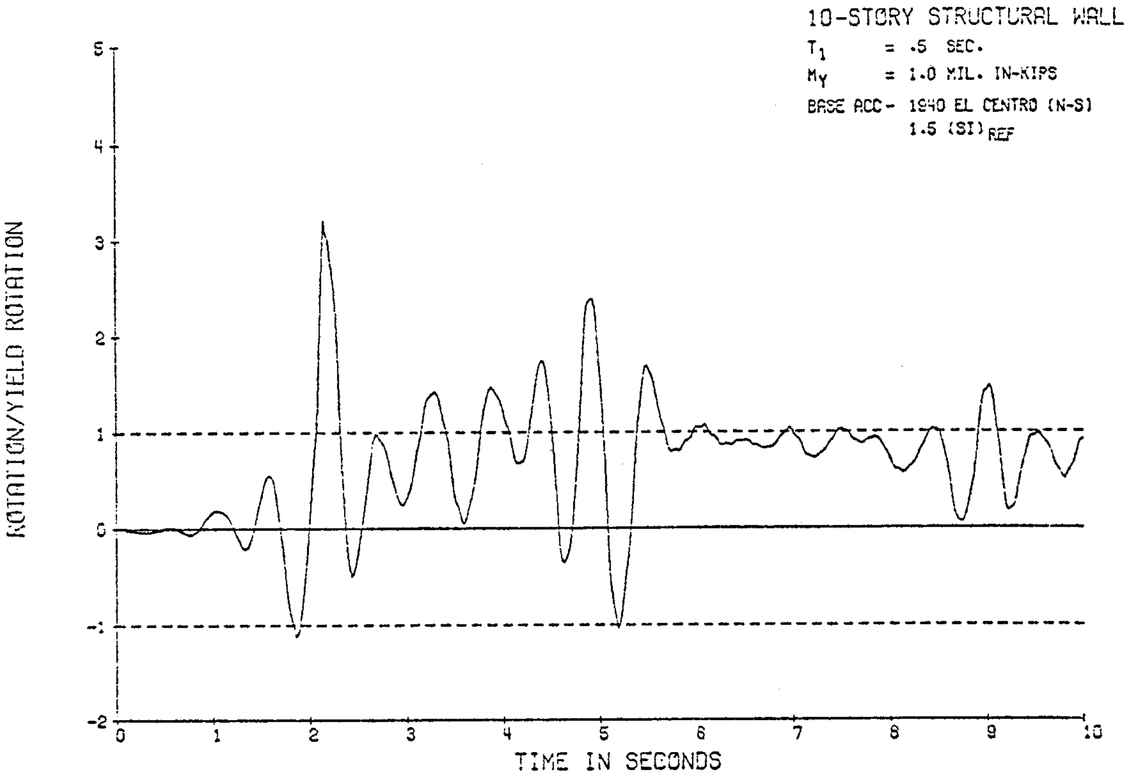

10-STORY STRUCTURAL WALL
T$_1$ = .5 SEC.
M$_Y$ = 1.0 MIL. IN-KIPS
BASE ACC- 1940 EL CENTRO (N-S)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
5
4
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A1

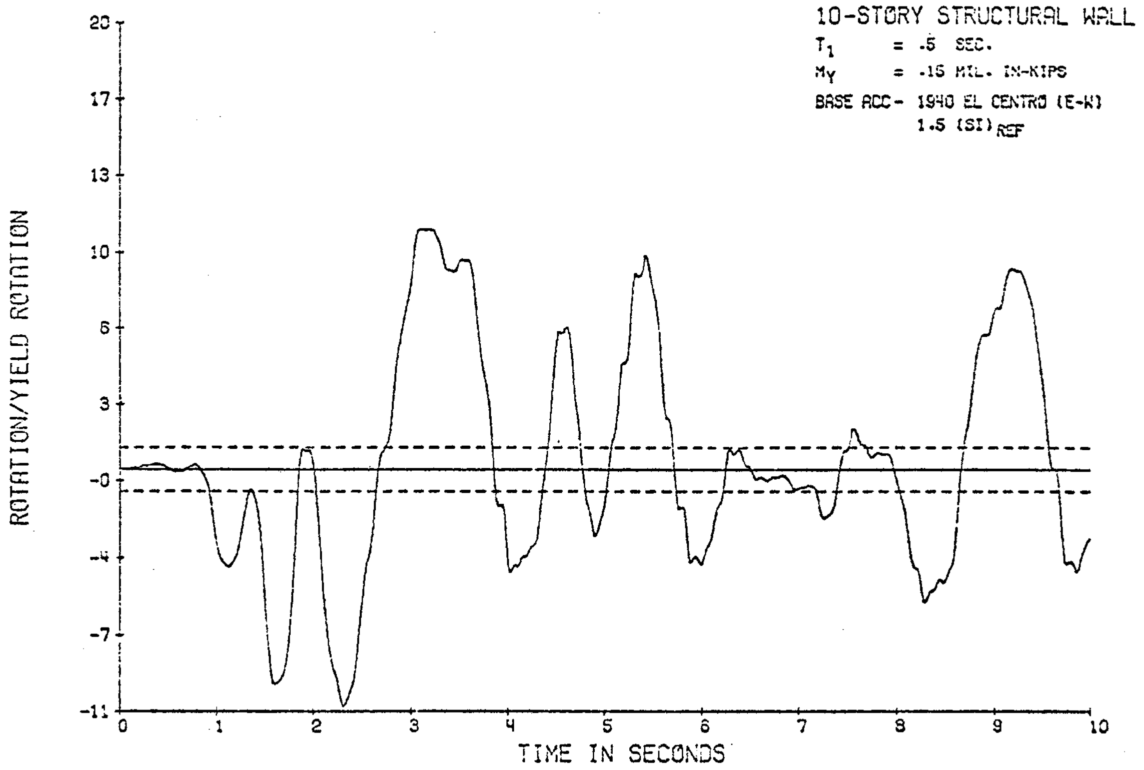

10-STORY STRUCTURAL WALL
T$_1$ = .5 SEC.
M$_Y$ = .15 MIL. IN-KIPS
BASE ACC- 1940 EL CENTRO (E-W)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
20
17
13
10
6
3
-0
-4
-7
-11
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A2

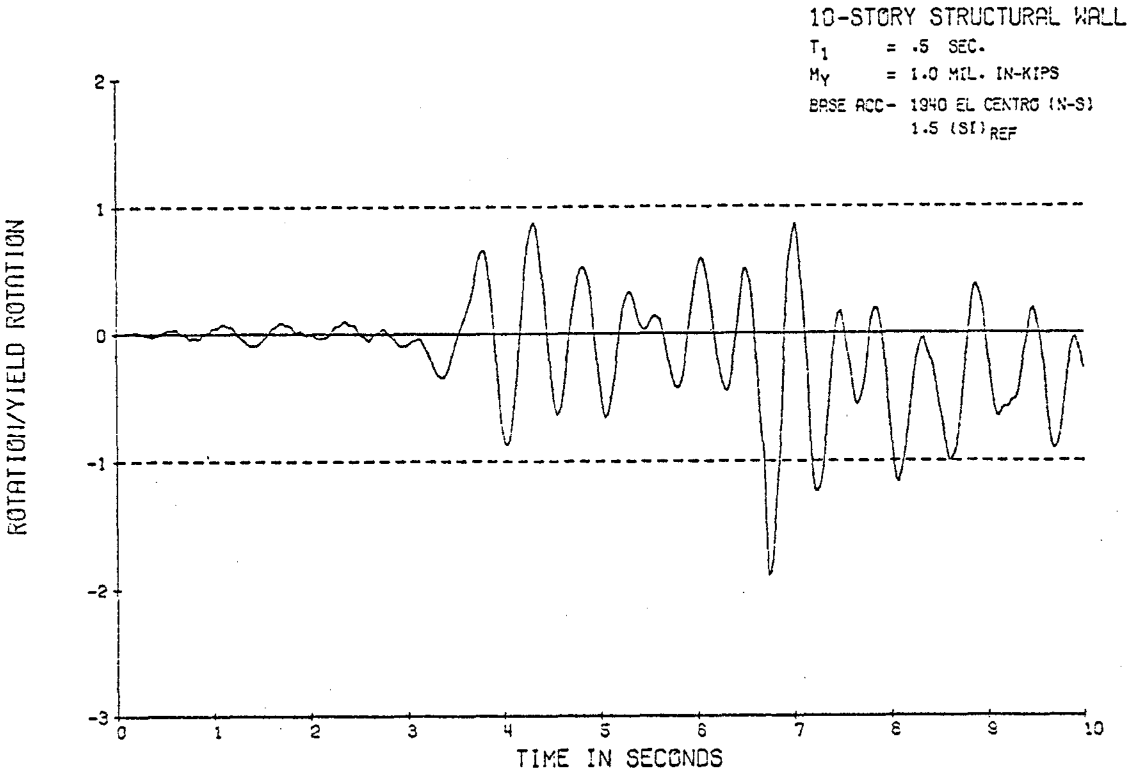

10-STORY STRUCTURAL WALL
T_1 = .5 SEC.
M_Y = 1.0 MIL. IN-KIPS
BASE ACC- 1940 EL CENTRO (N-S)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
2
1
0
-1
-2
-3
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A3

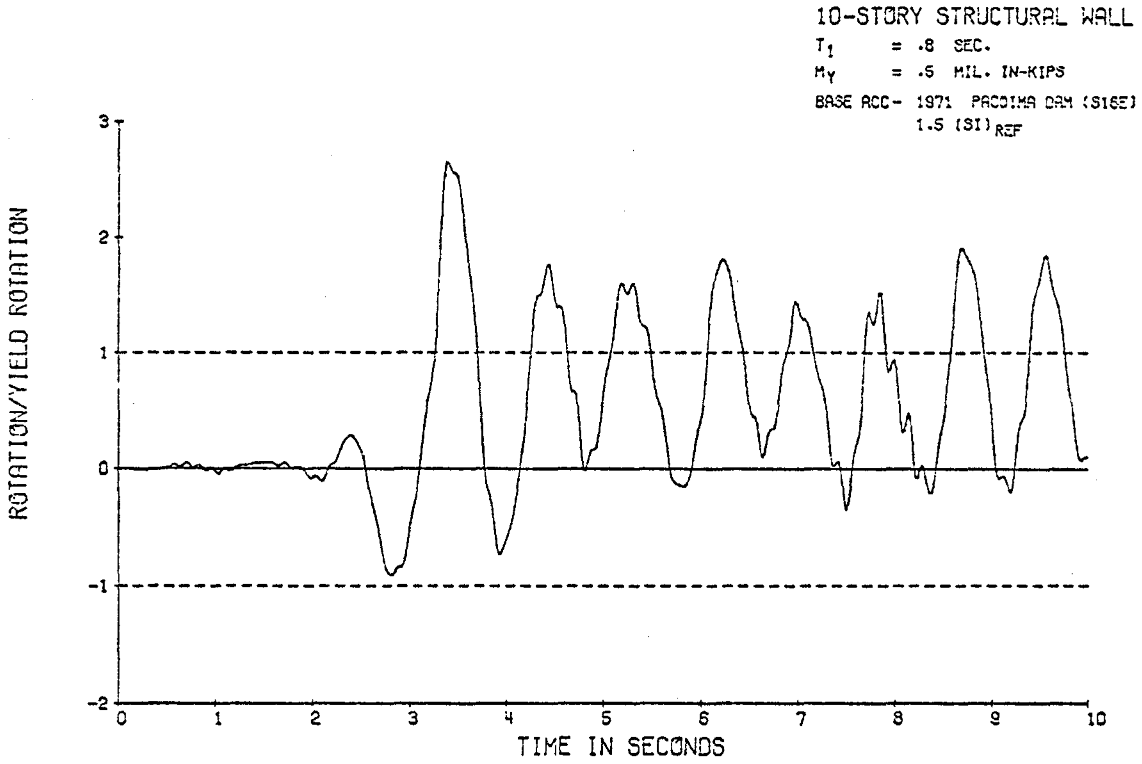

10-STORY STRUCTURAL WALL
T_1 = .8 SEC.
M_Y = .5 MIL. IN-KIPS
BASE ACC- 1971 PACOIMA DAM (S16E)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A4

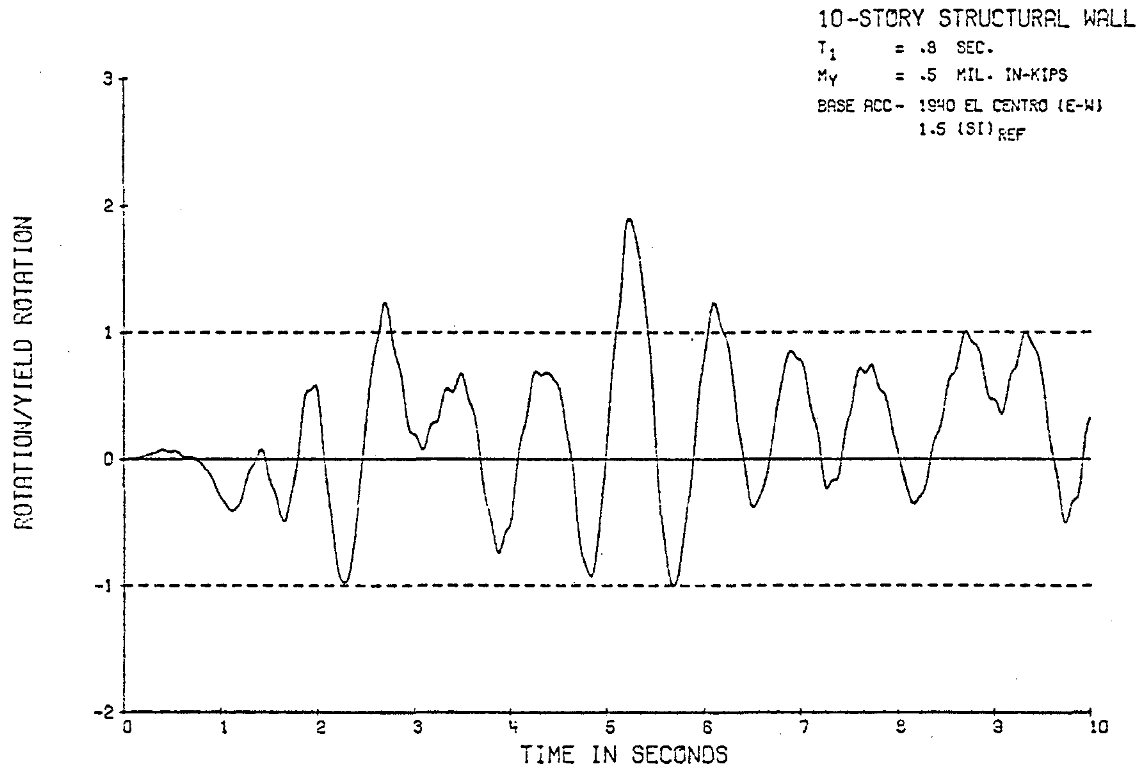

10-STORY STRUCTURAL WALL
T_1 = .8 SEC.
M_Y = .5 MIL. IN-KIPS
BASE ACC- 1940 EL CENTRO (E-W)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
3
2
1
0
-1
-2
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A5

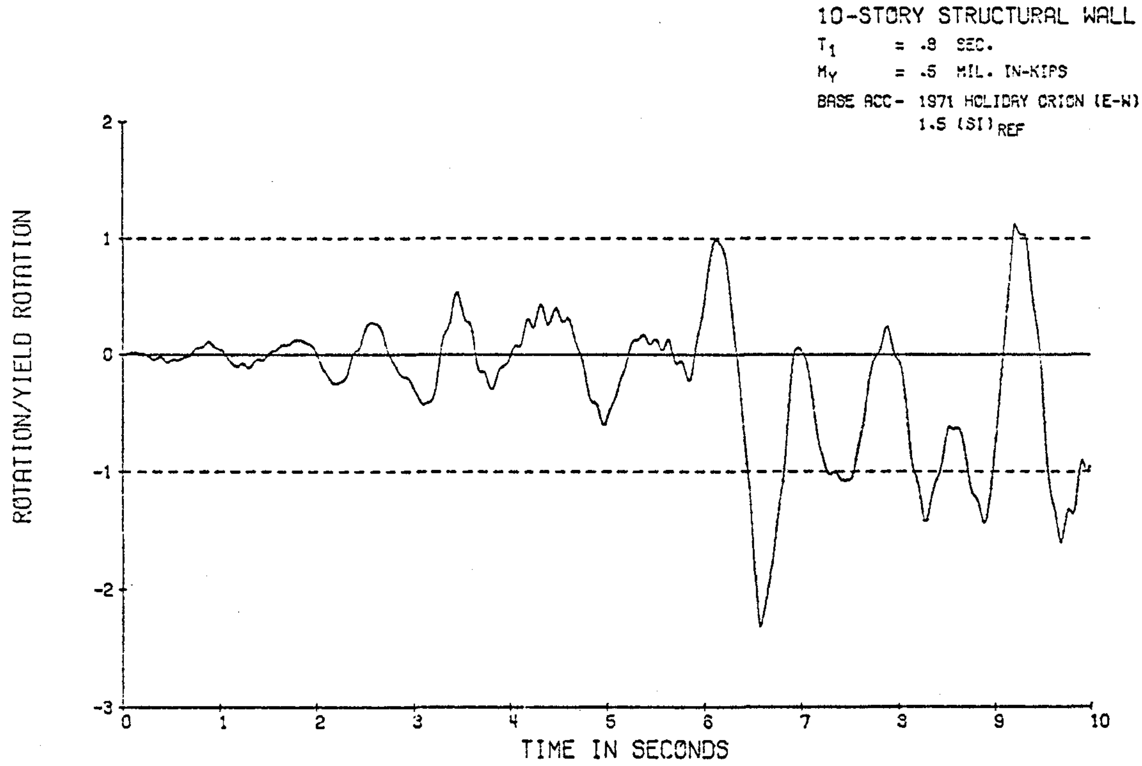
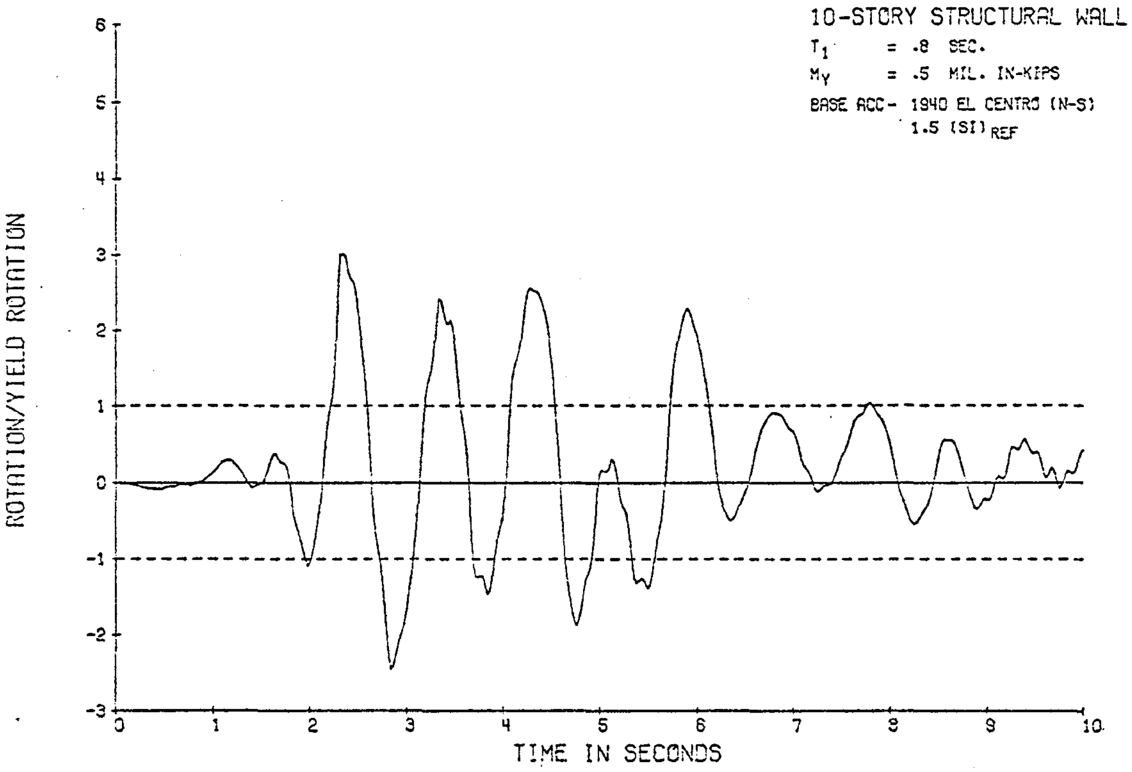
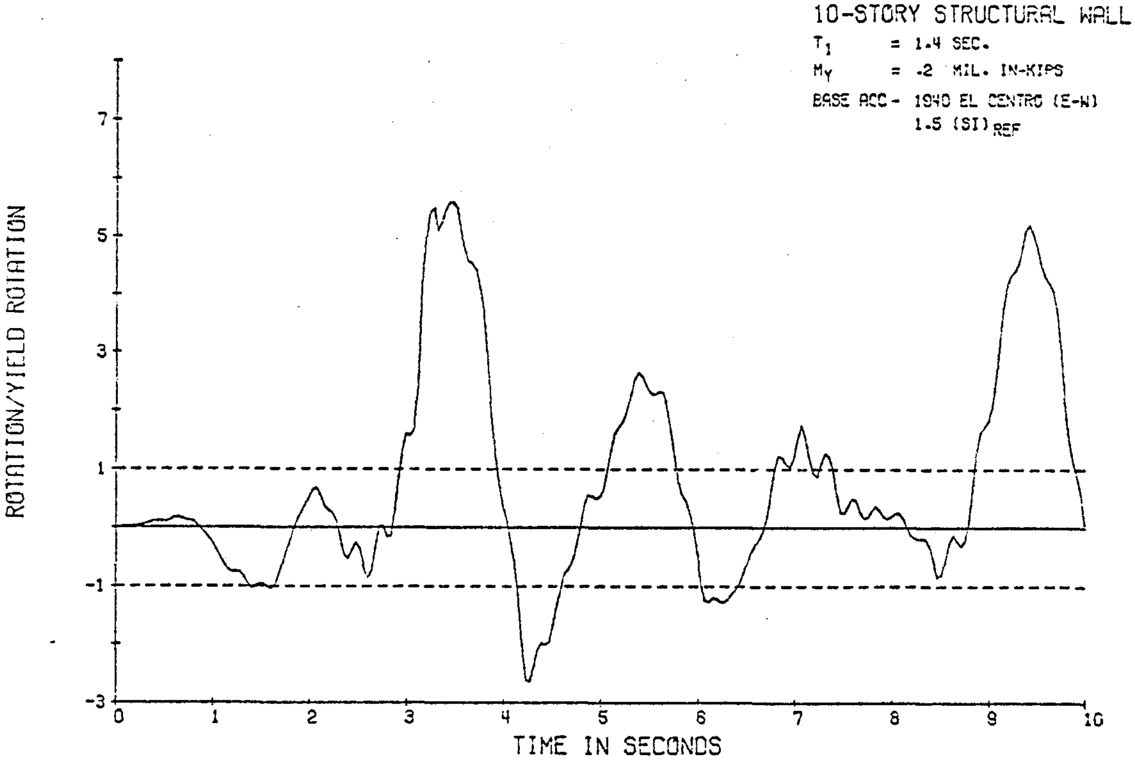

10-STORY STRUCTURAL WALL
T_1 = .8 SEC.
M_Y = .5 MIL. IN-KIPS
BASE ACC- 1971 HOLIDAY ORION (E-W)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
2
1
0
-1
-2
-3
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A6



10-STORY STRUCTURAL WALL
T_1 = .8 SEC.
M_Y = .5 MIL. IN-KIPS
BASE ACC- 1940 EL CENTRO (N-S)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
6
5
4
3
2
1
0
-1
-2
-3
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A7



10-STORY STRUCTURAL WALL
T_1 = 1.4 SEC.
M_Y = .2 MIL. IN-KIPS
BASE ACC- 1940 EL CENTRO (E-W)
1.5 (SI)$_{REF}$
ROTATION/YIELD ROTATION
7
5
3
1
-1
-3
0
1
2
3
4
5
6
7
8
9
10
TIME IN SECONDS

Fig. A8

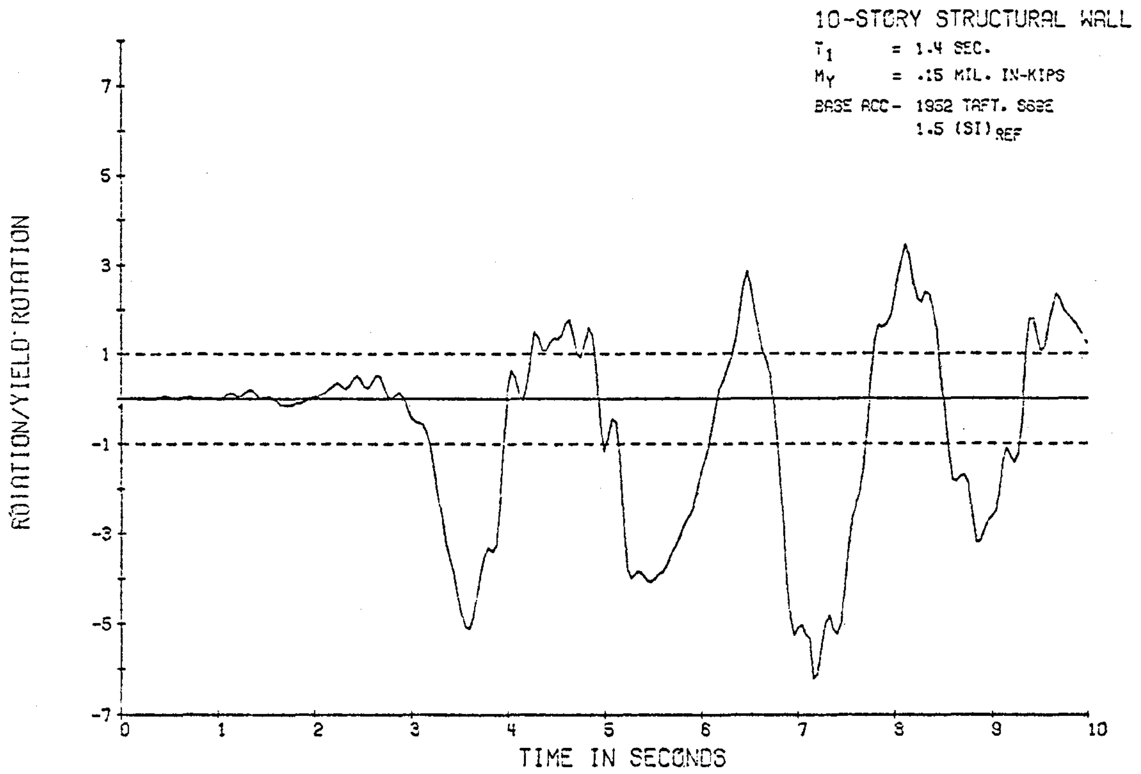


Fig. A9

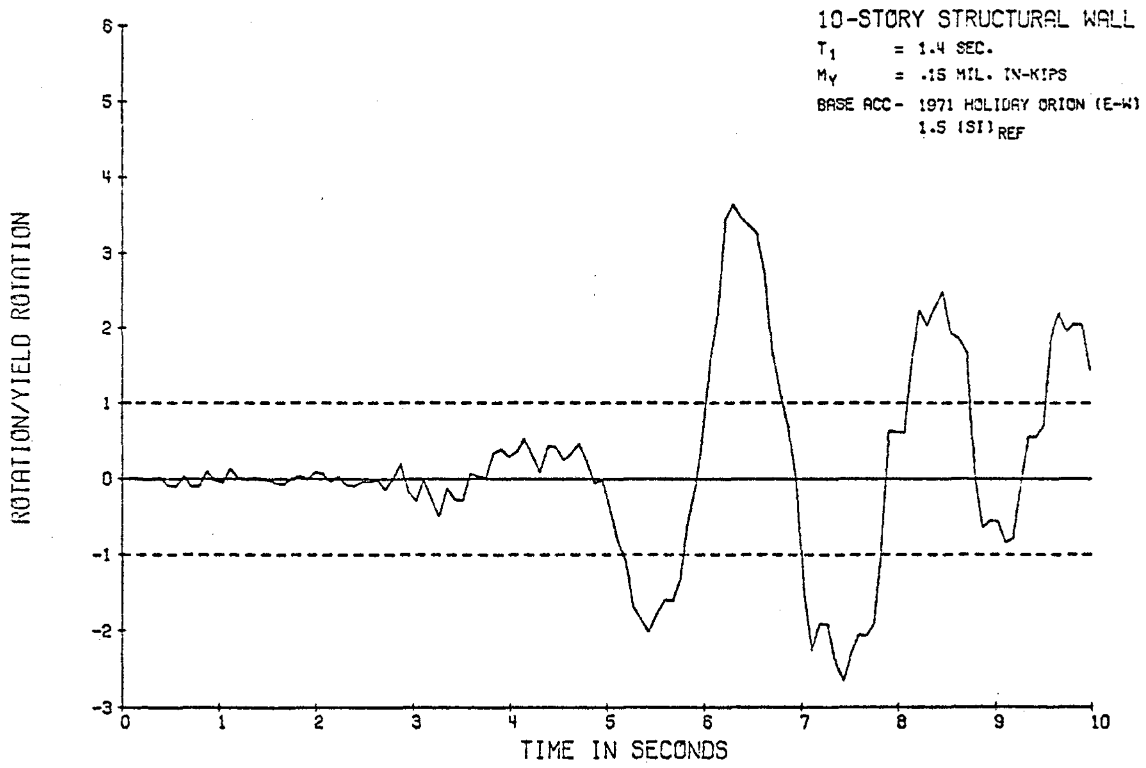


Fig. A10

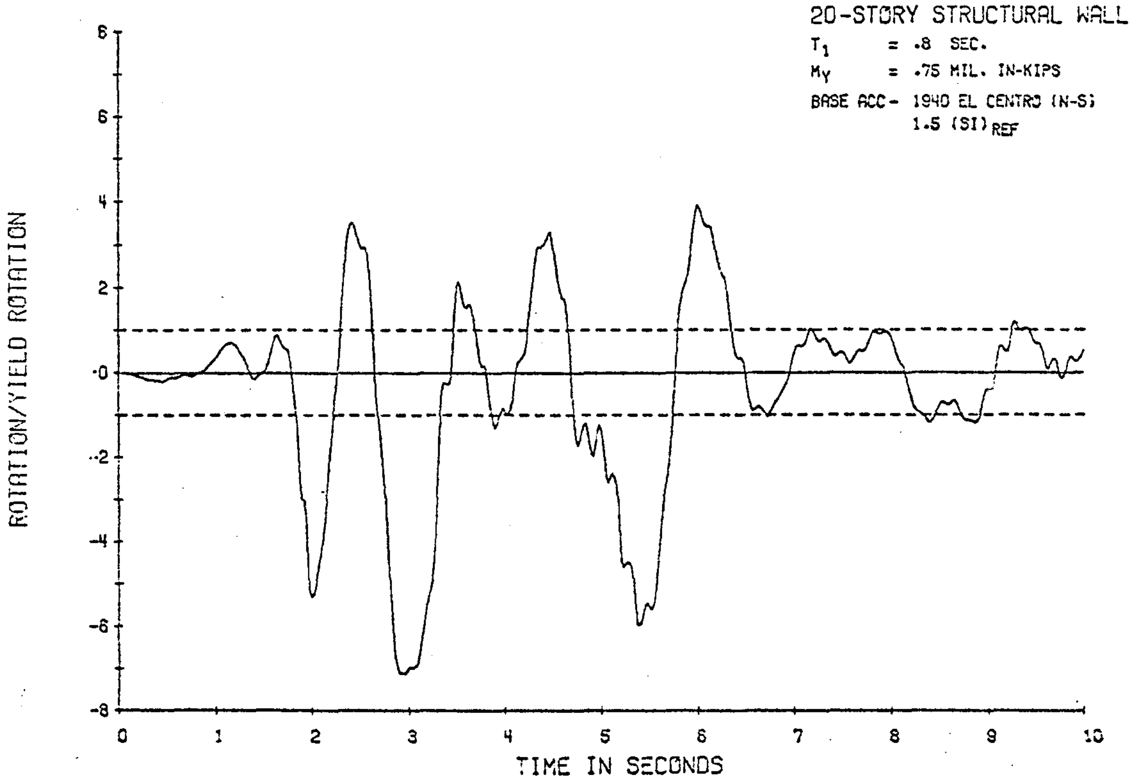


Fig. A11

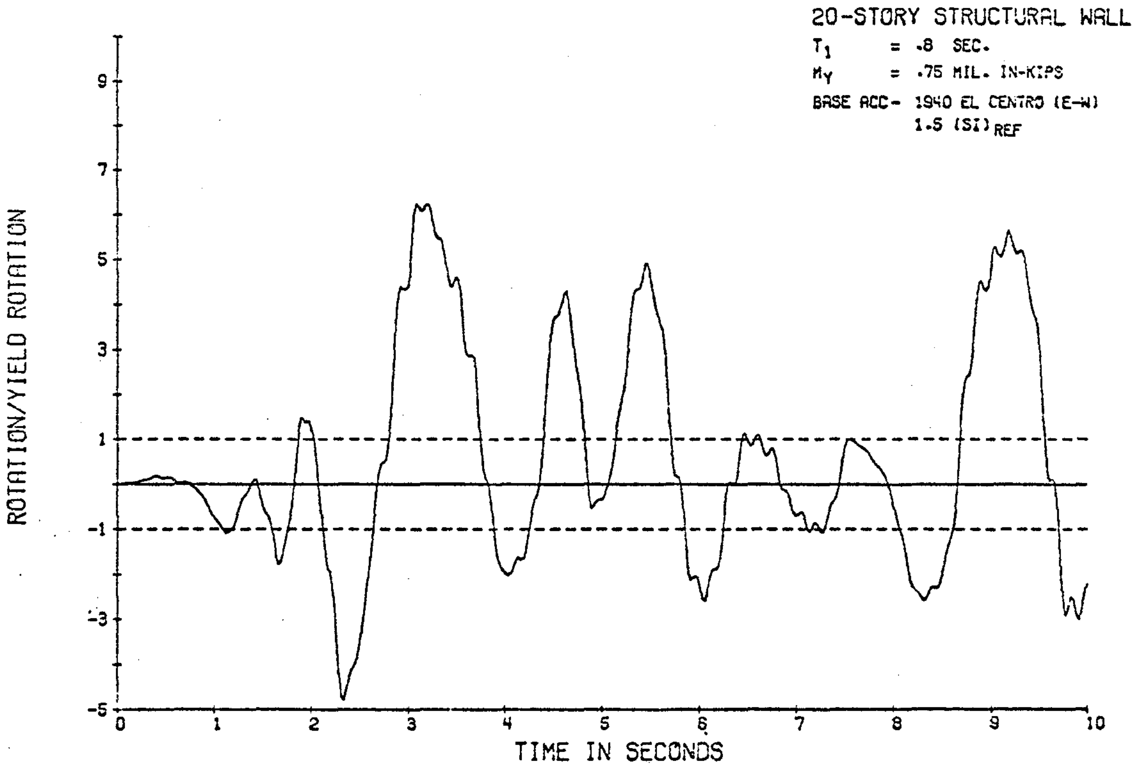


Fig. A12

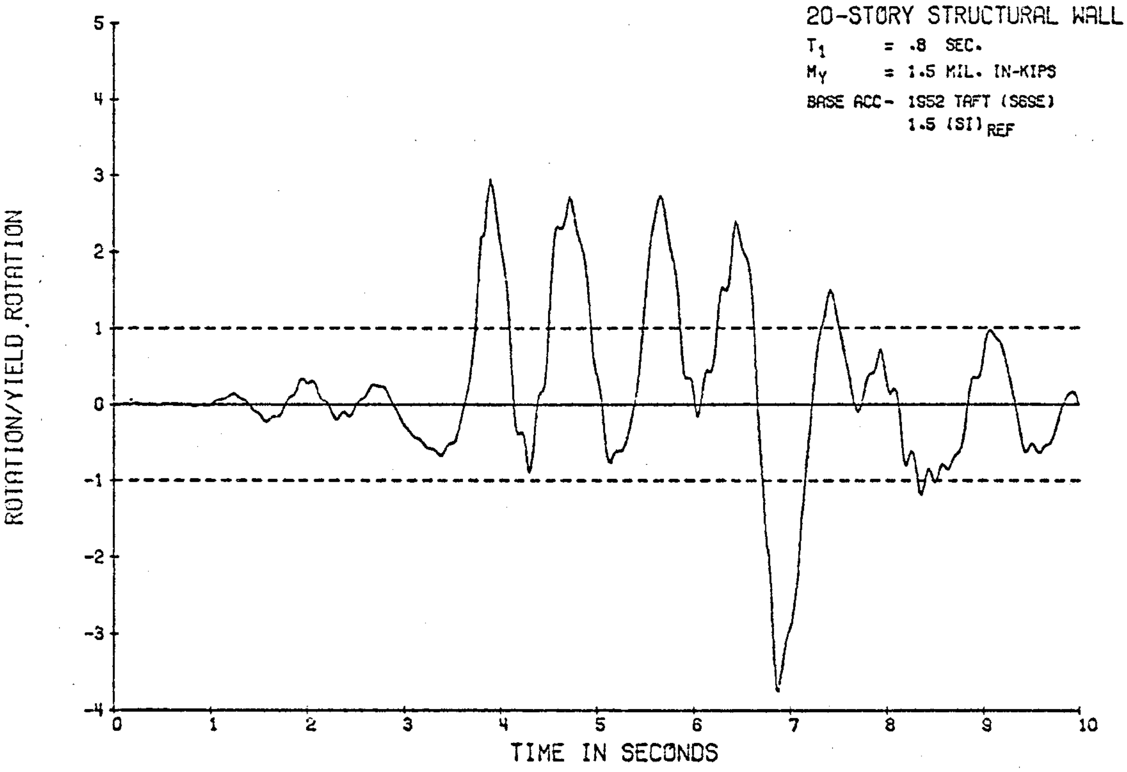


Fig. A13

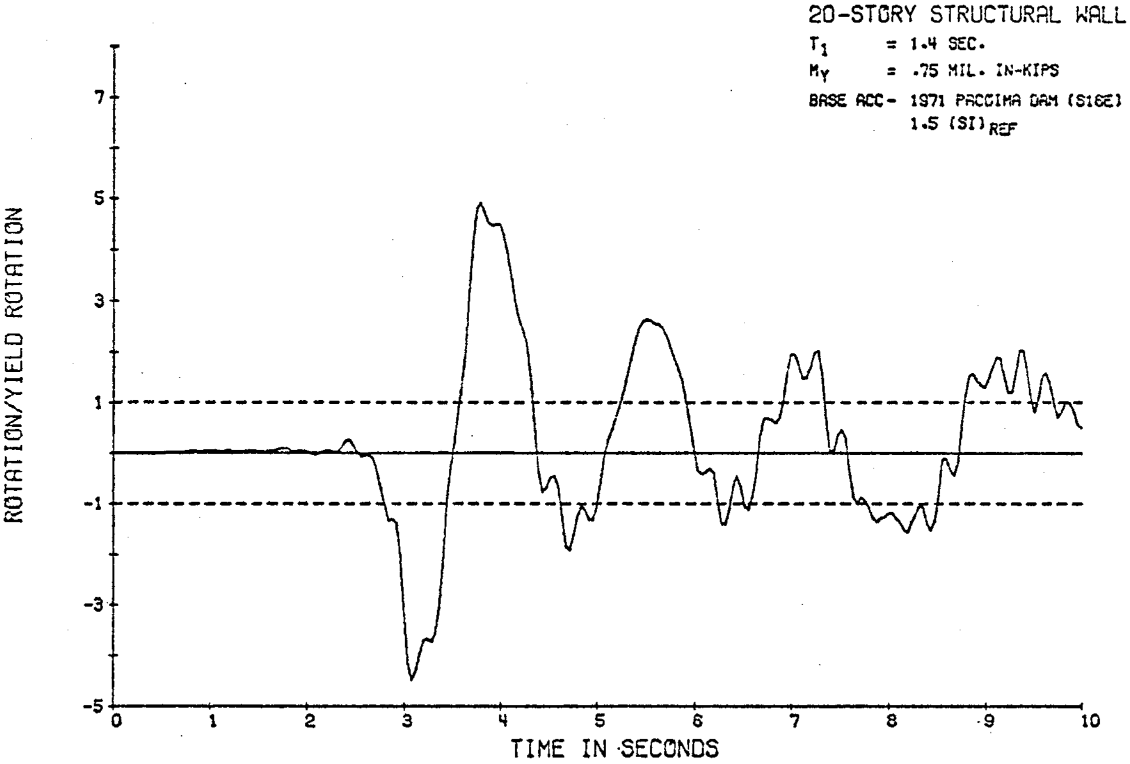


Fig. A14

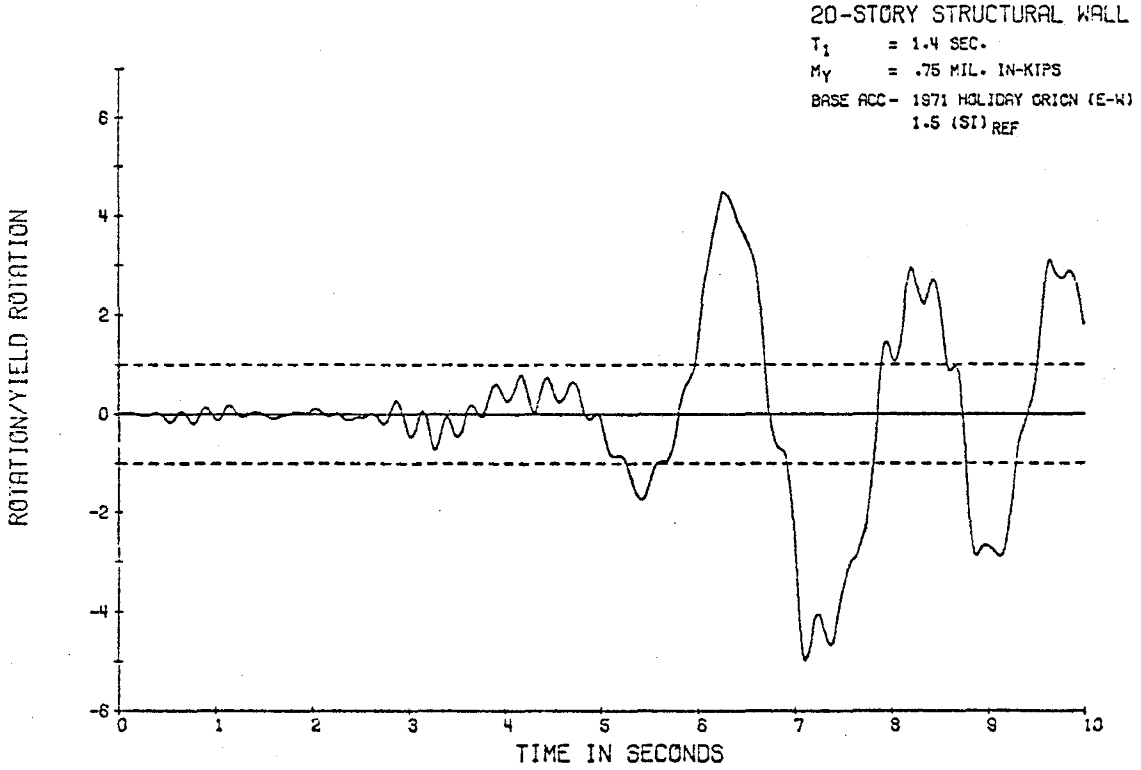


Fig. A15

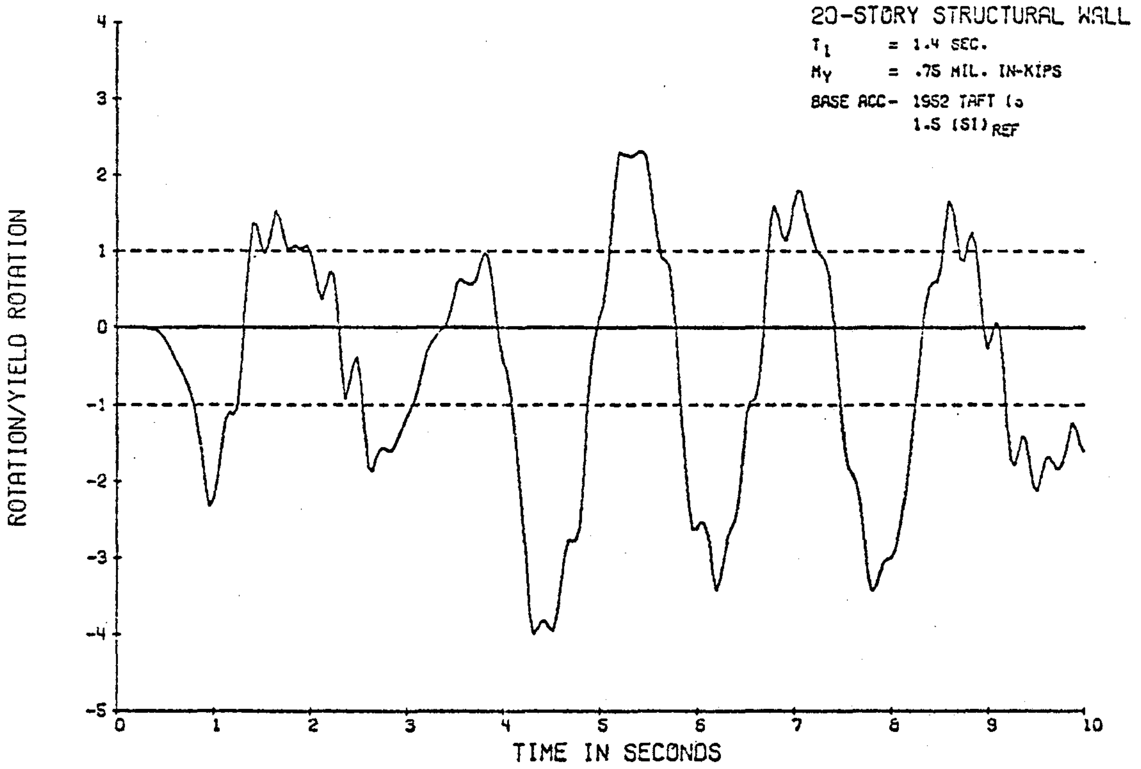


Fig. A16

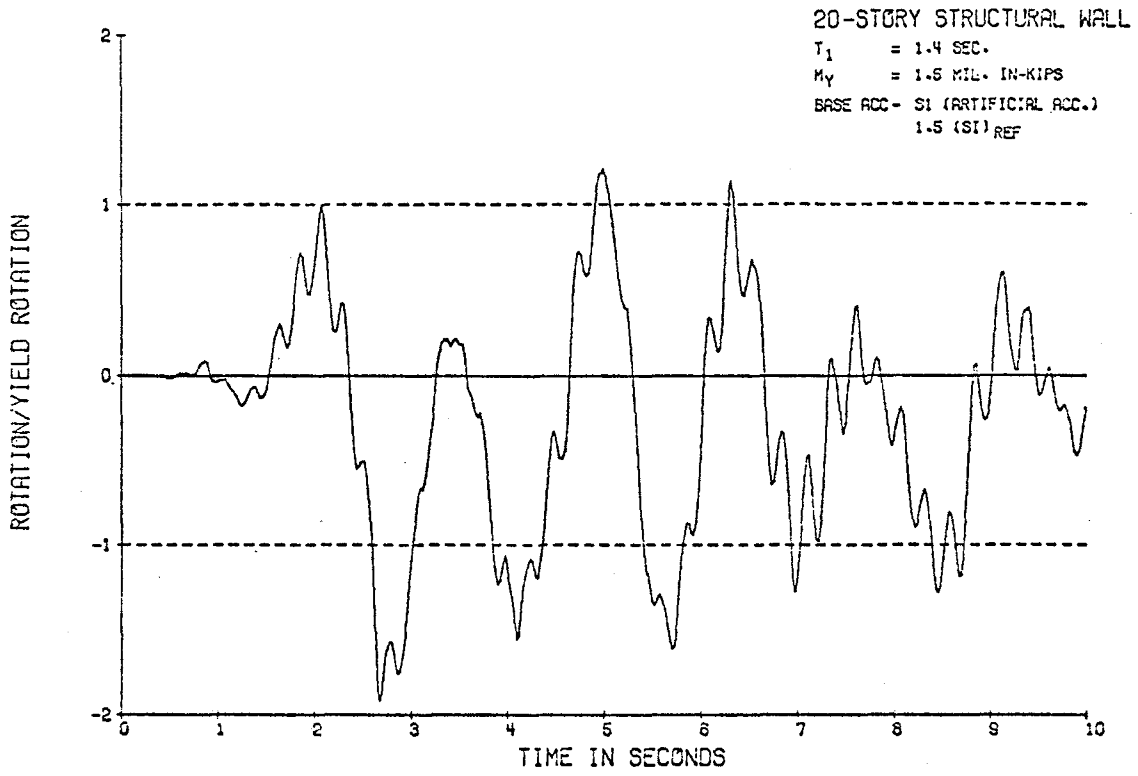


Fig. A17

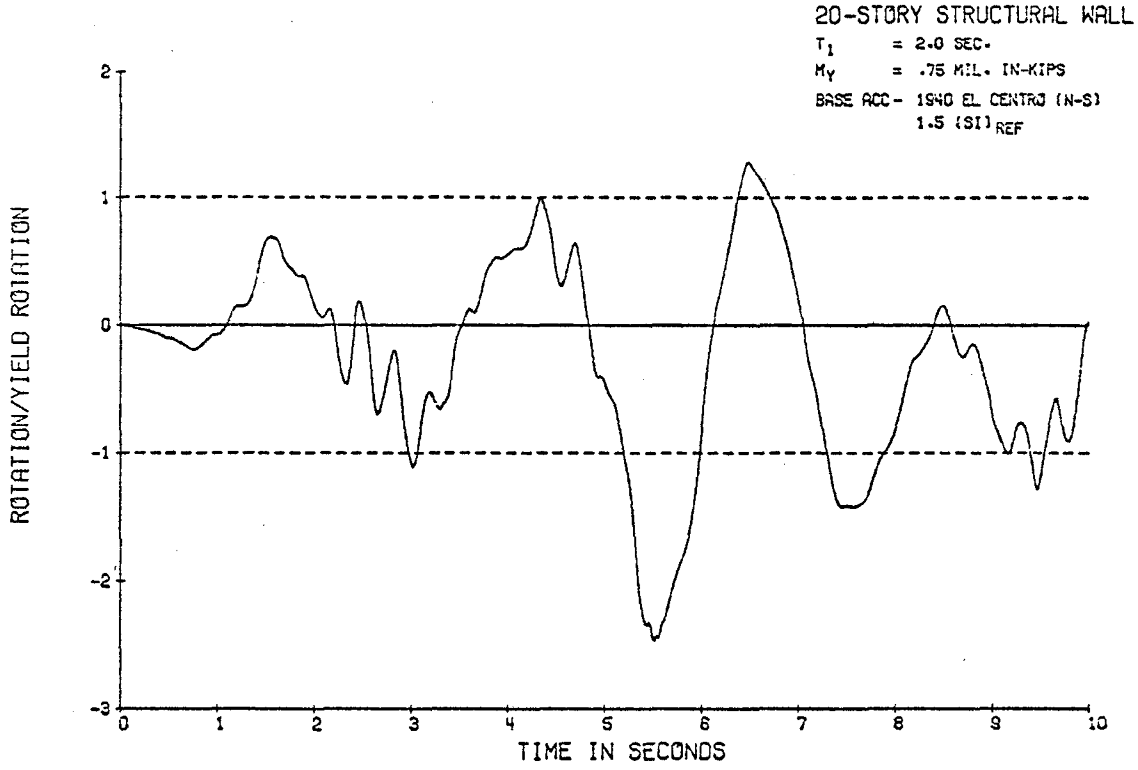


Fig. A18

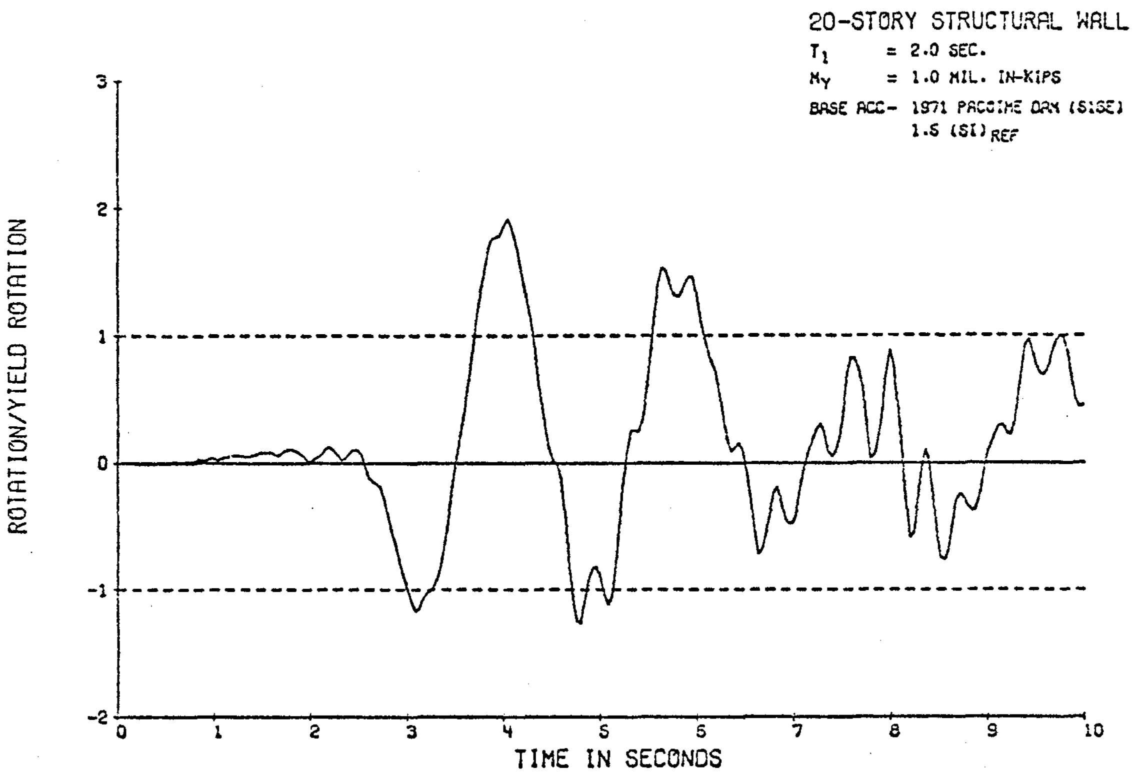


Fig. A19

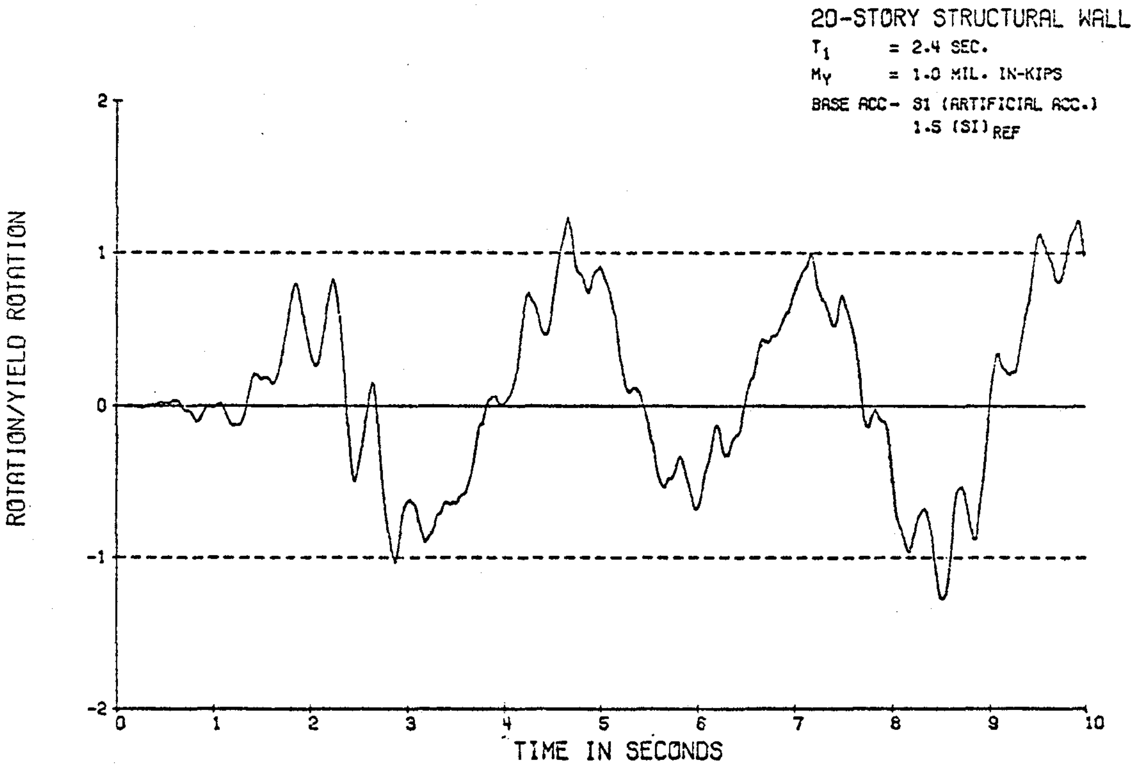


Fig. A20

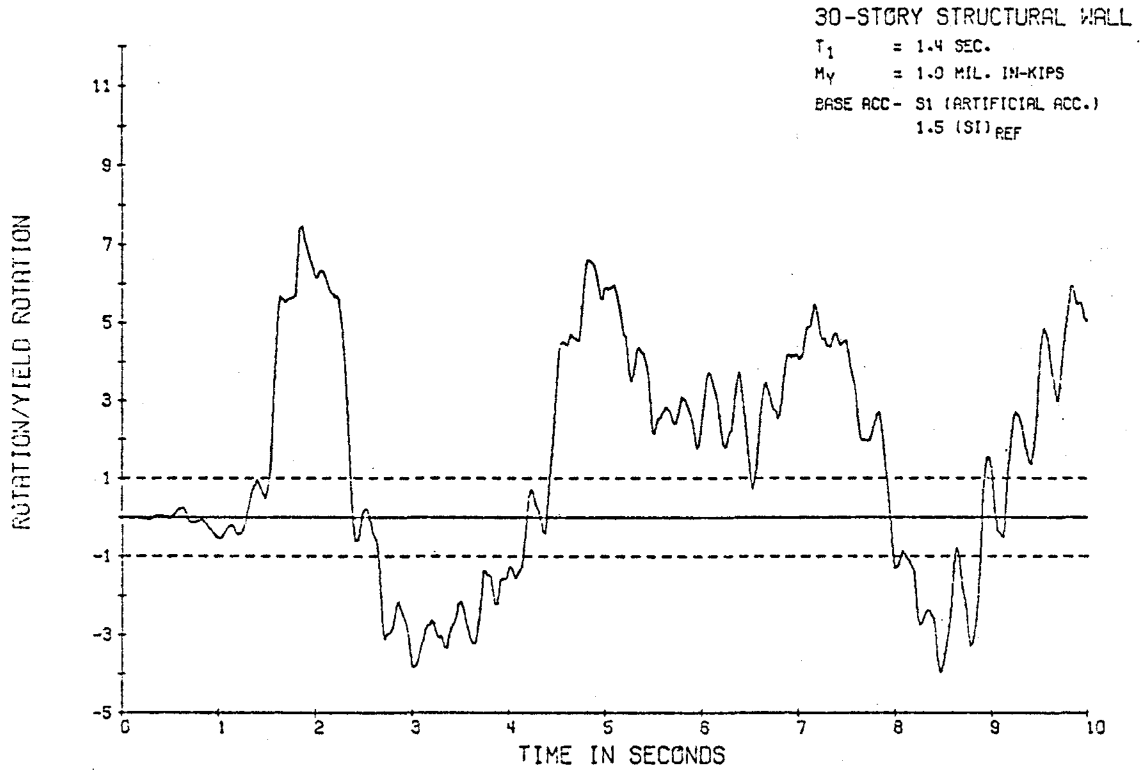


Fig. A21

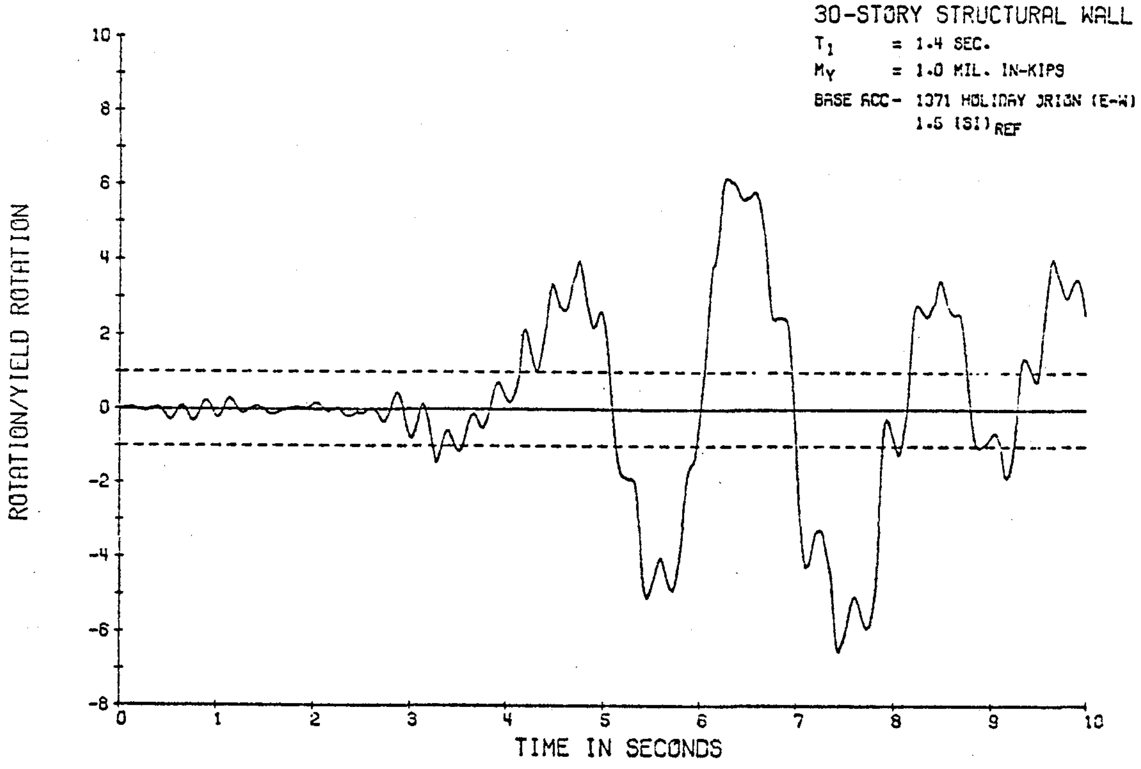


Fig. A22

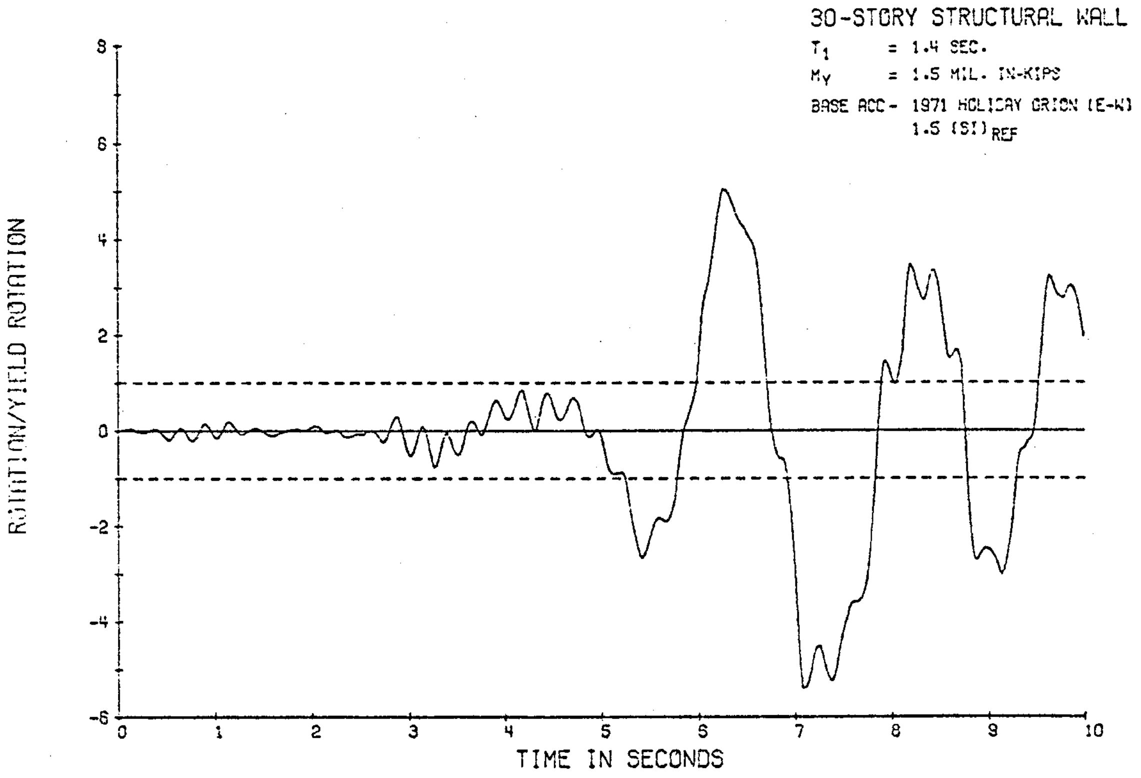


Fig. A23

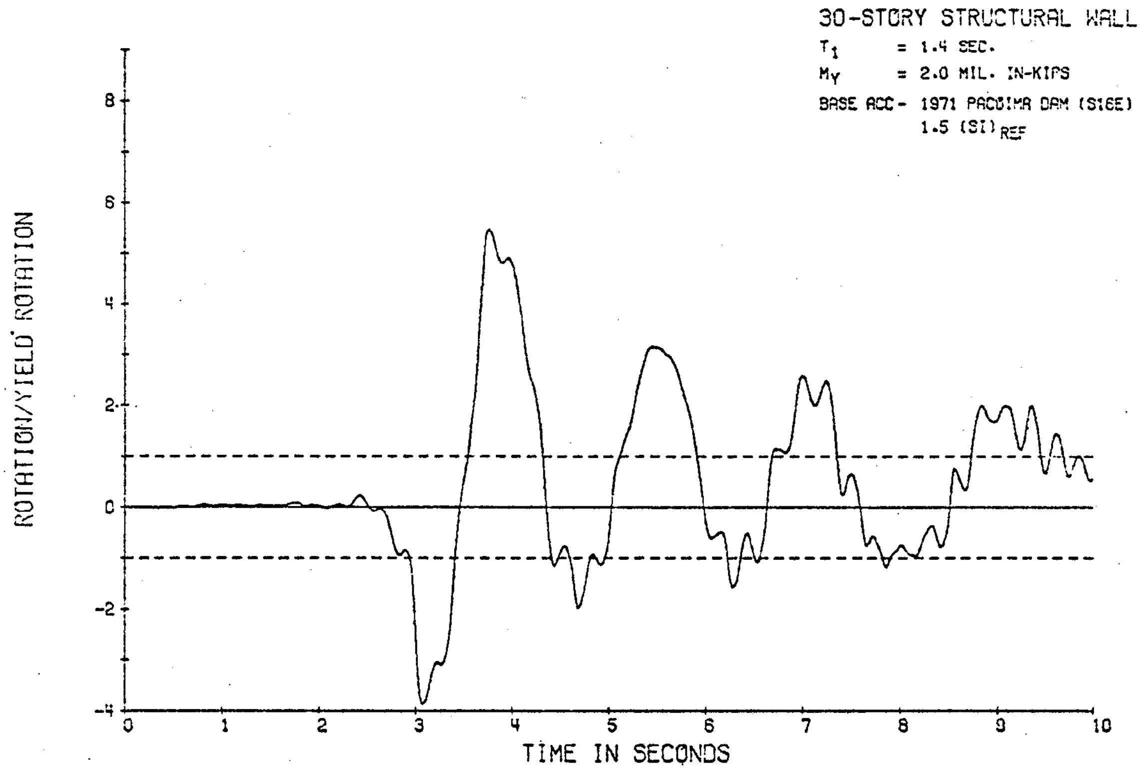


Fig. A24

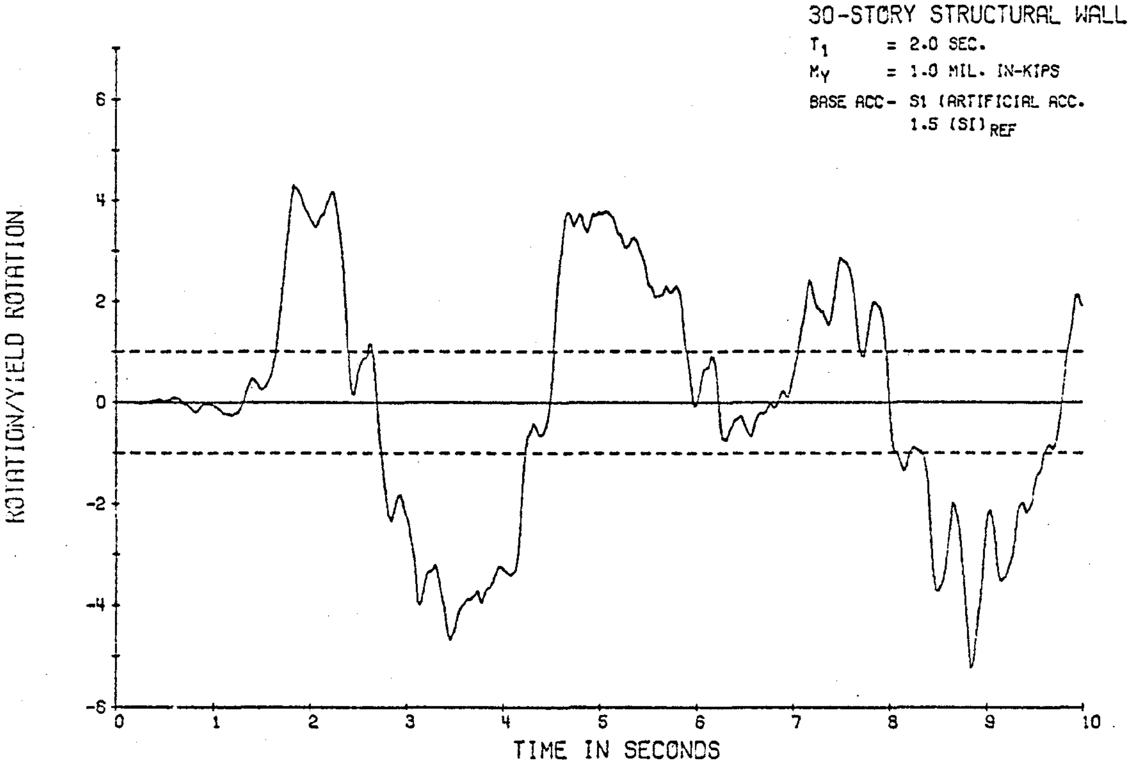


Fig. A25

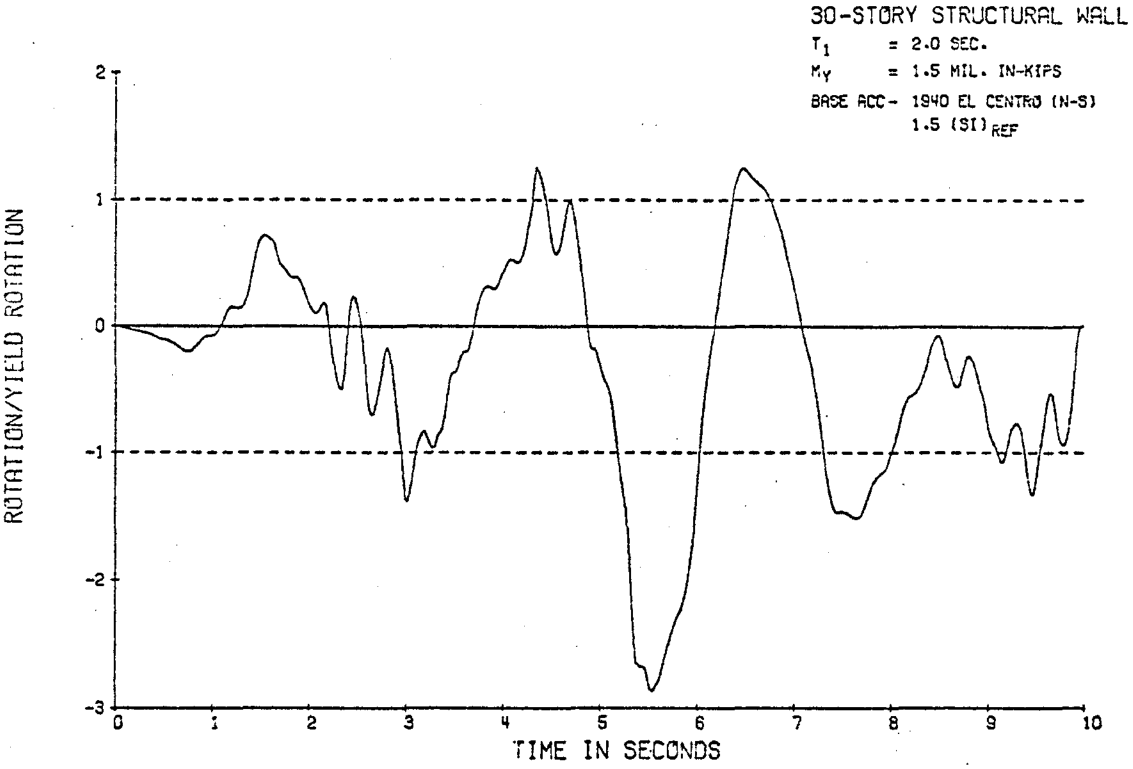


Fig. A26

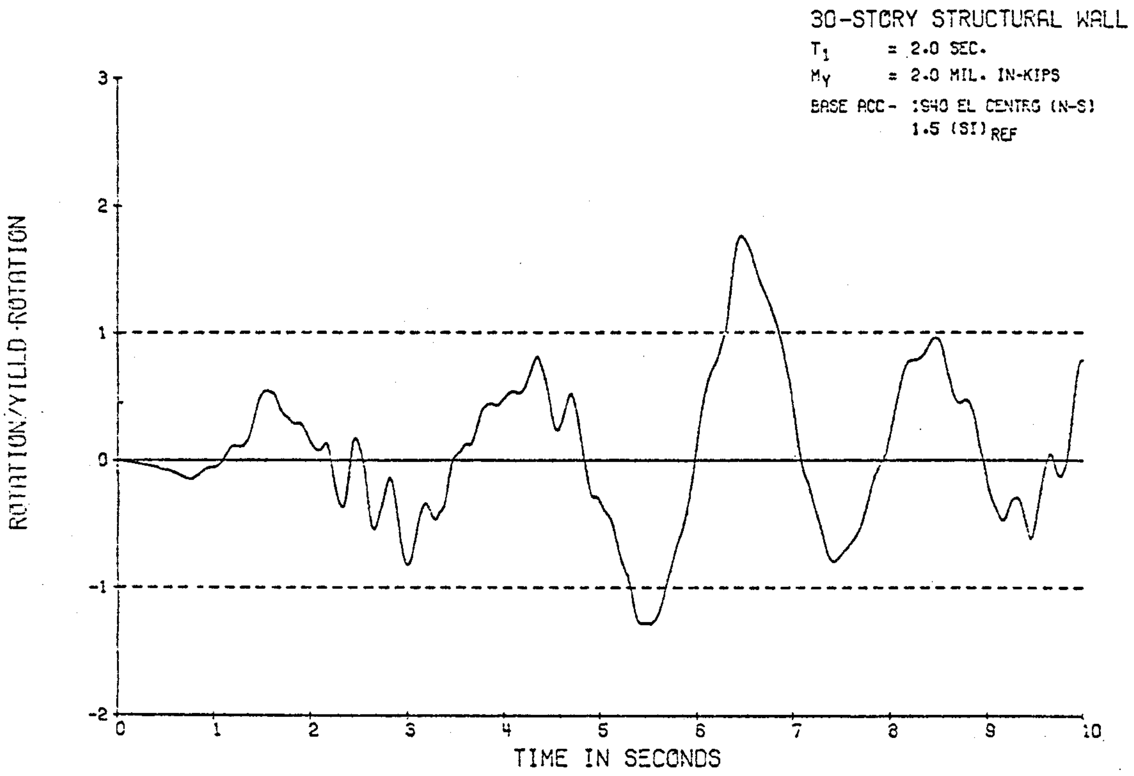


Fig. A27

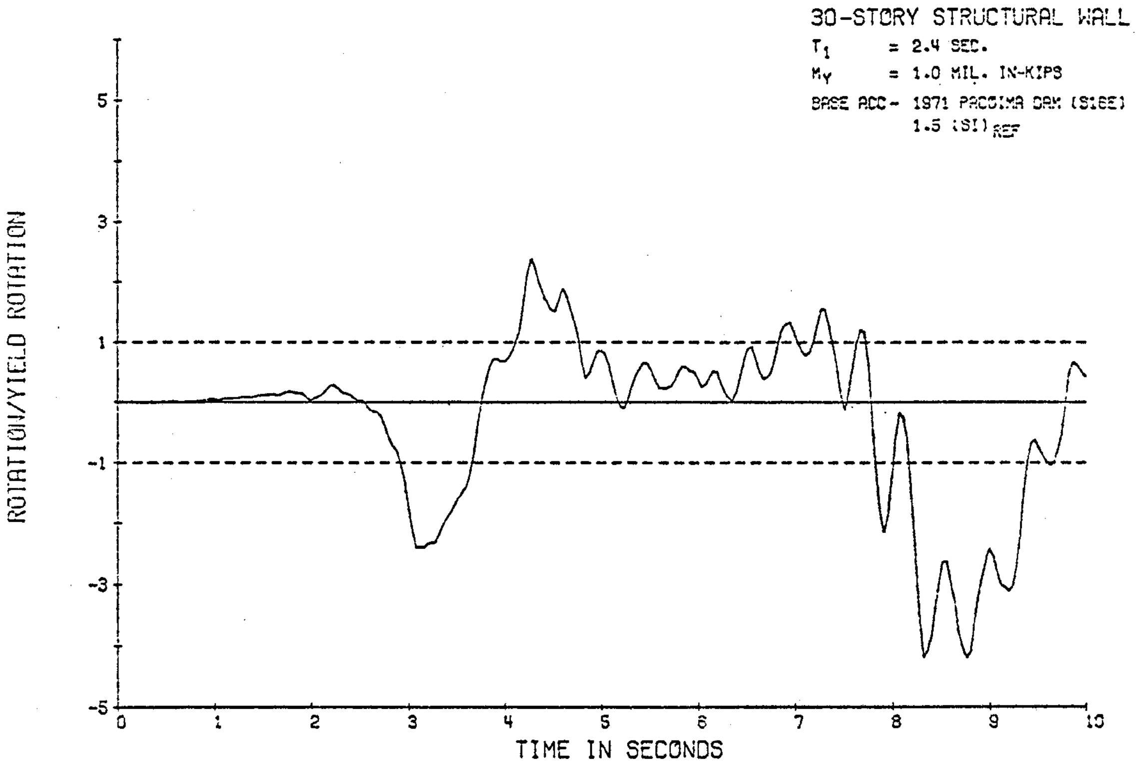


Fig. A28

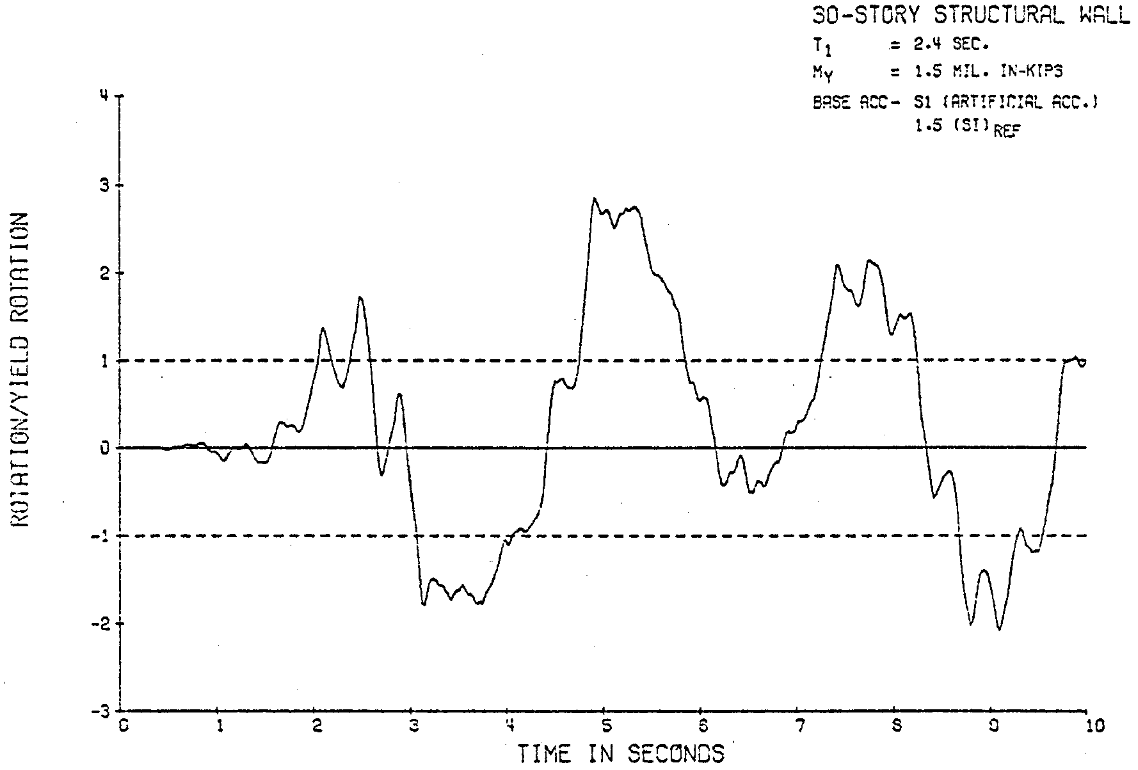


Fig. A29

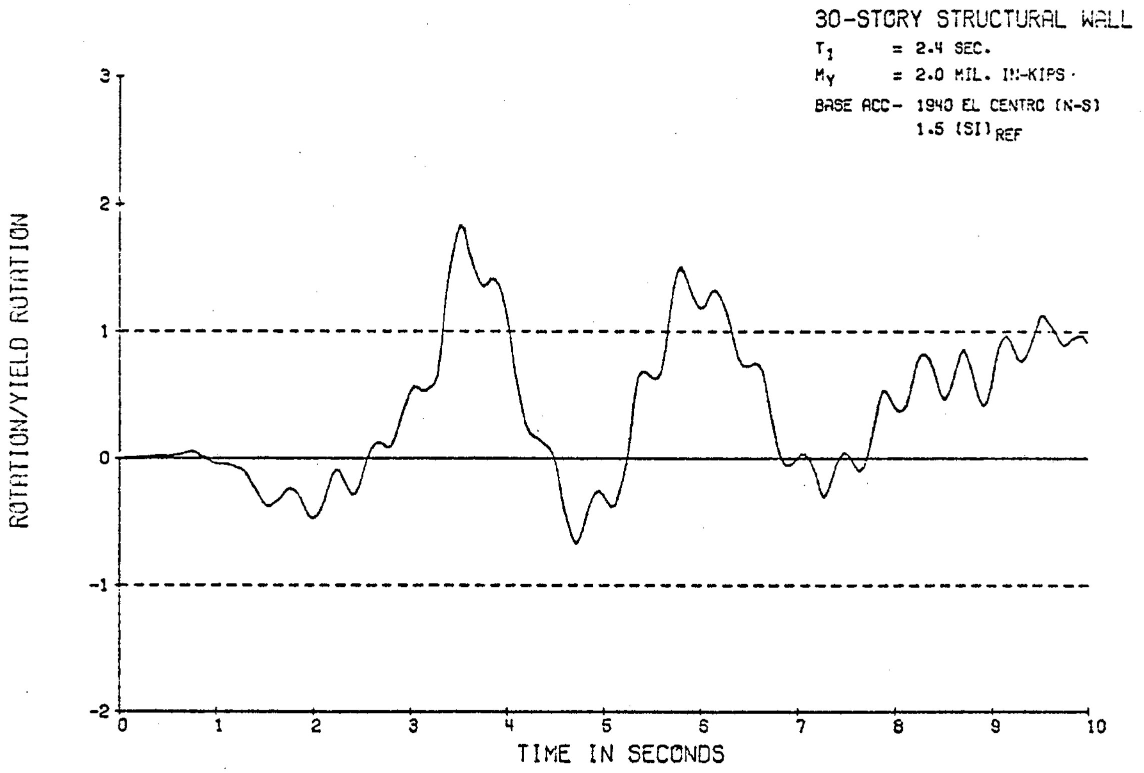


Fig. A30

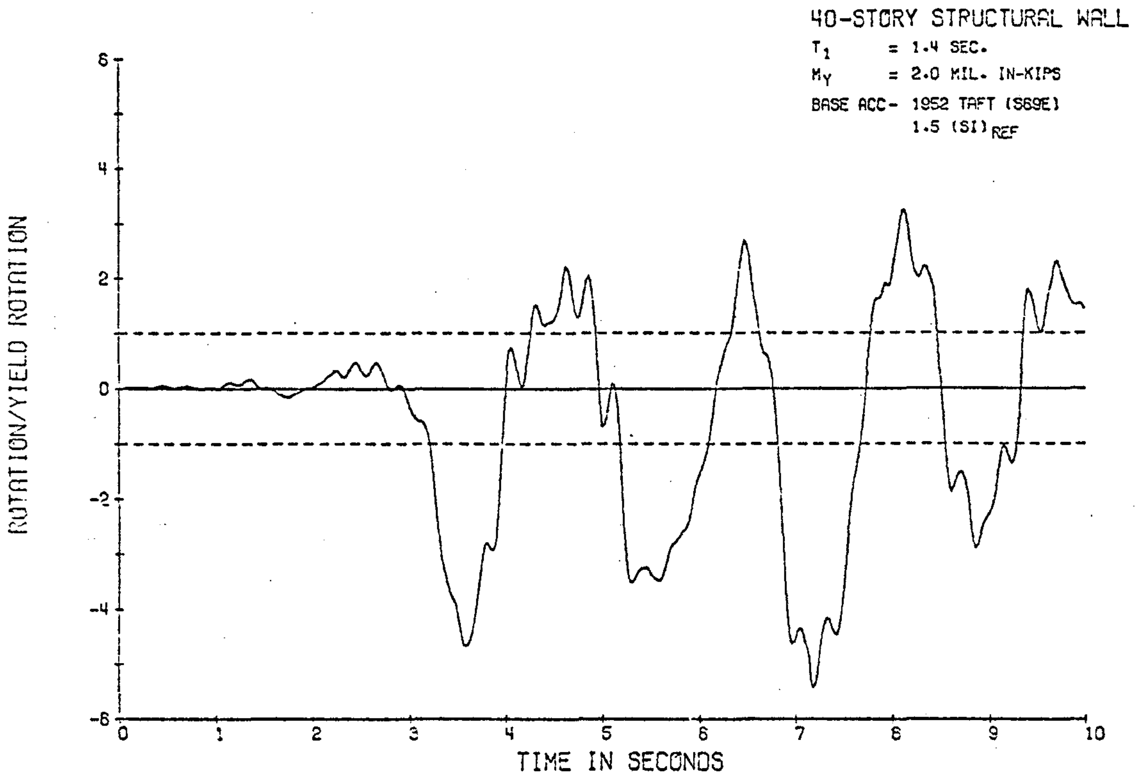


Fig. A31

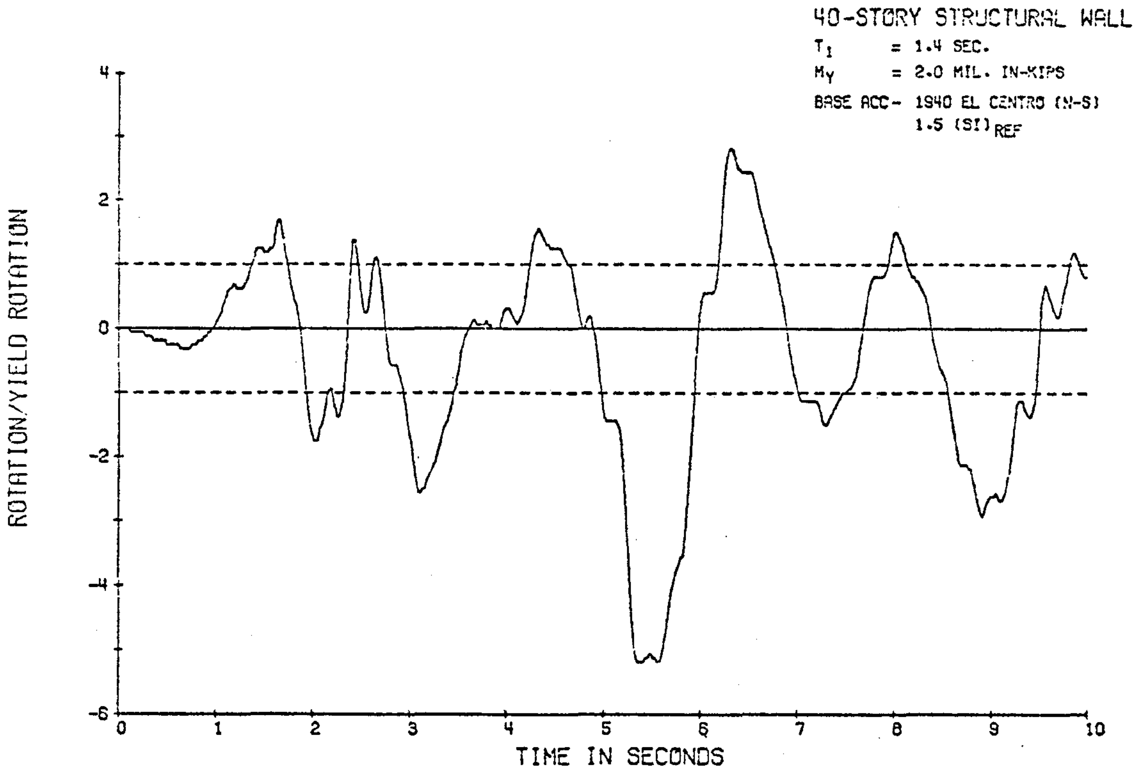


Fig. A32

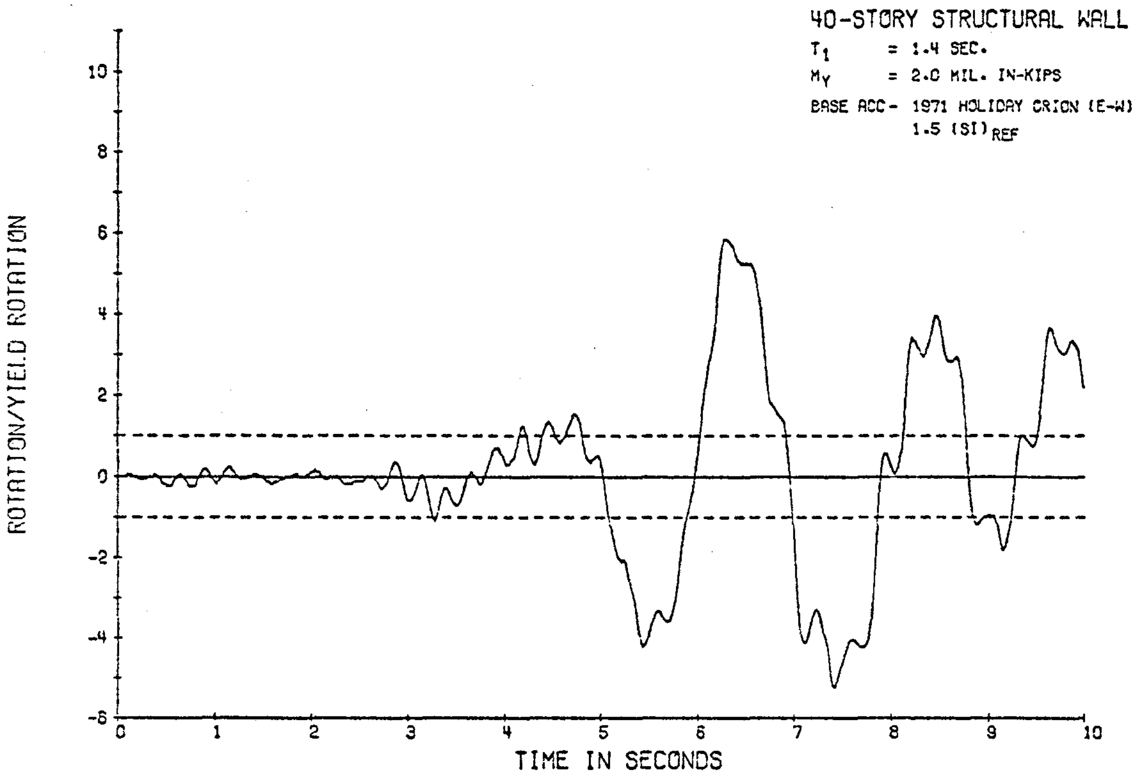


Fig. A33

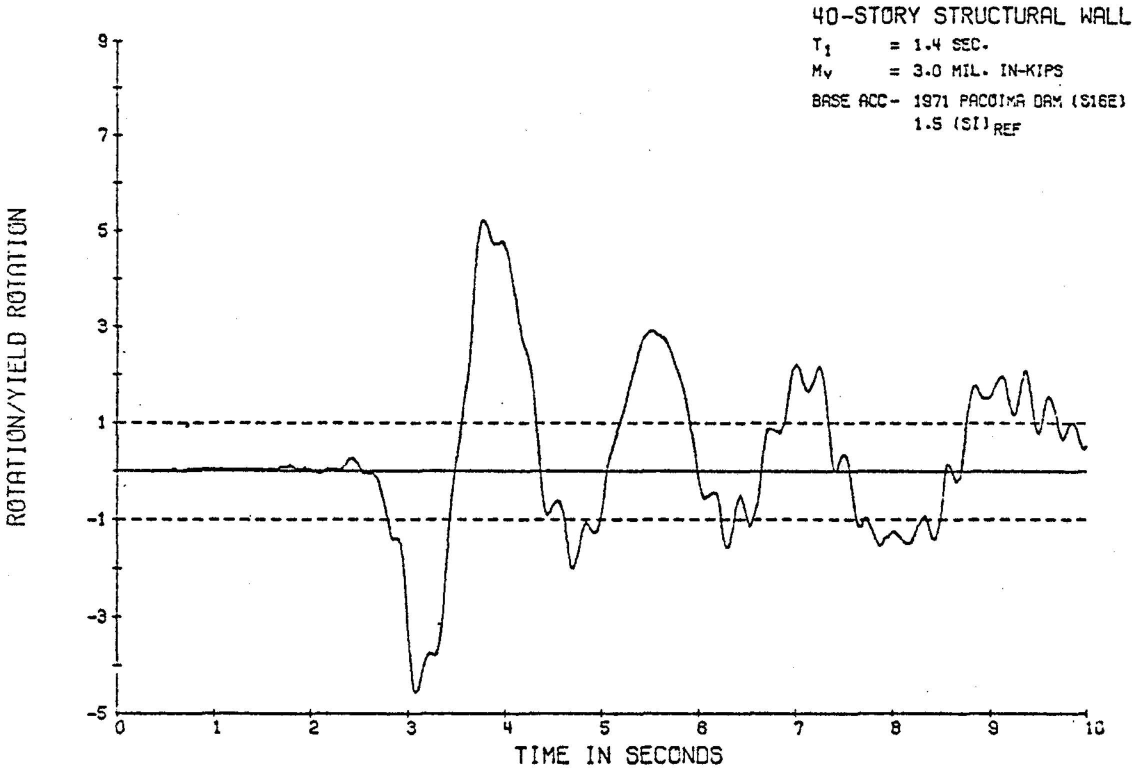


Fig. A34

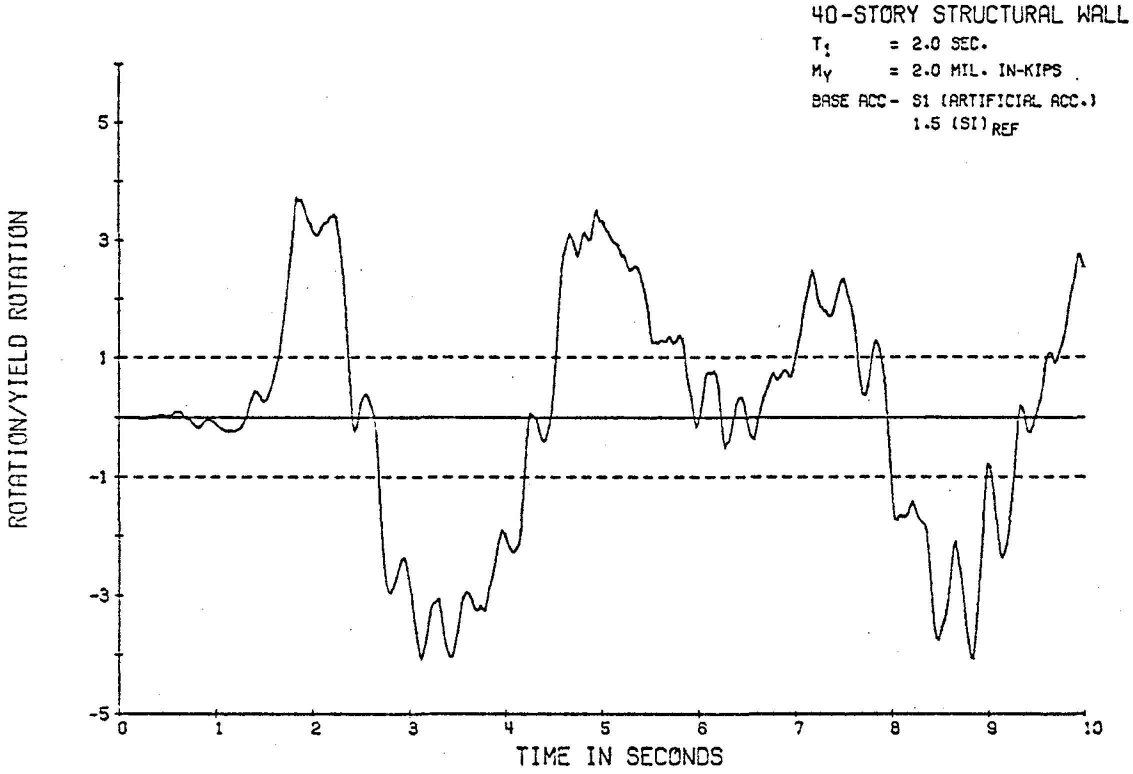


Fig. A35

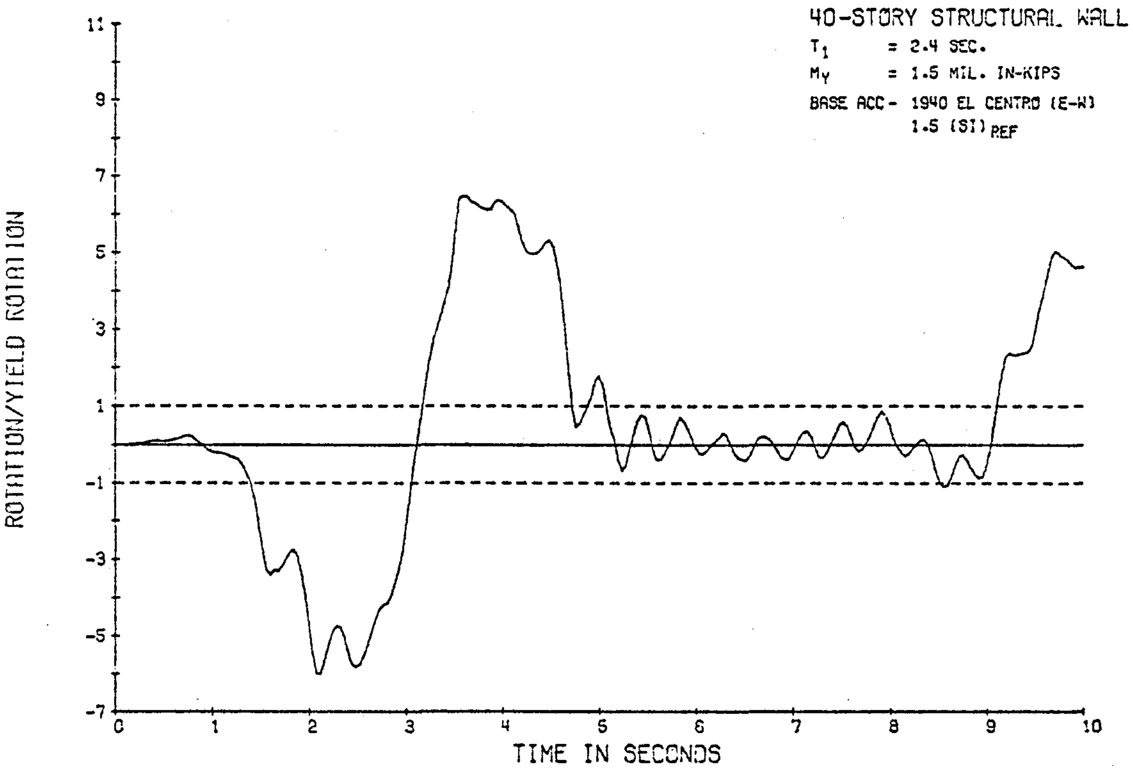


Fig. A36

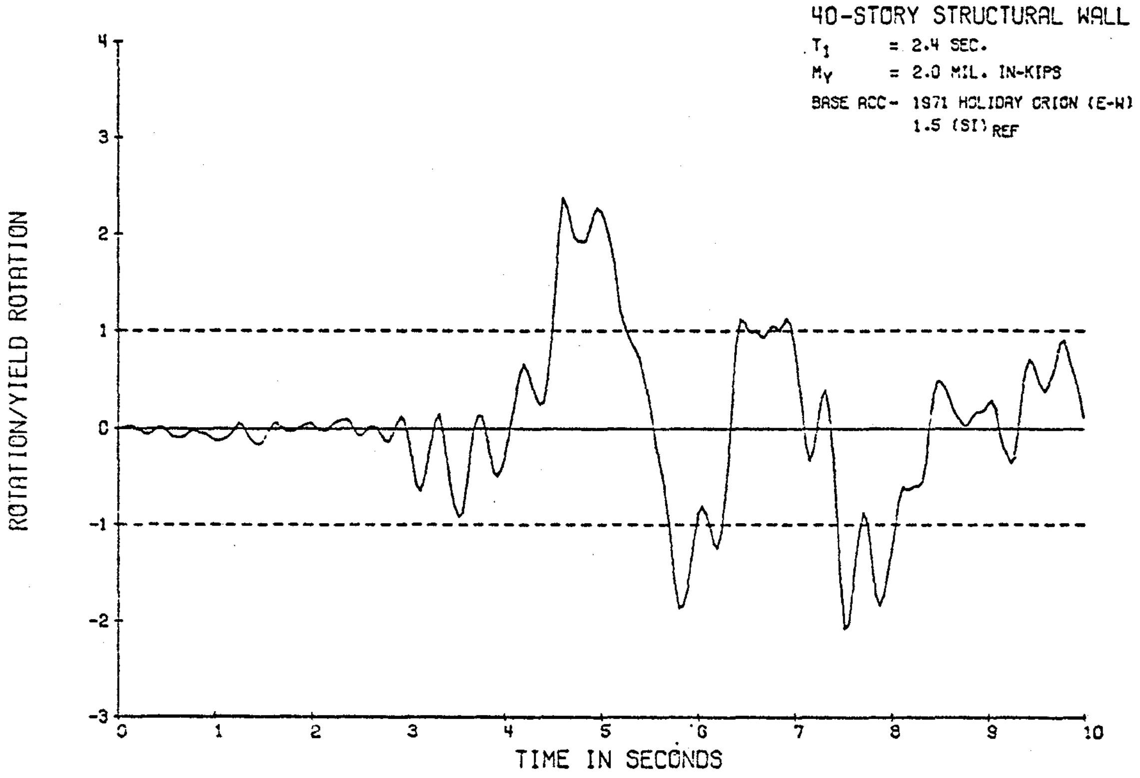


Fig. A37

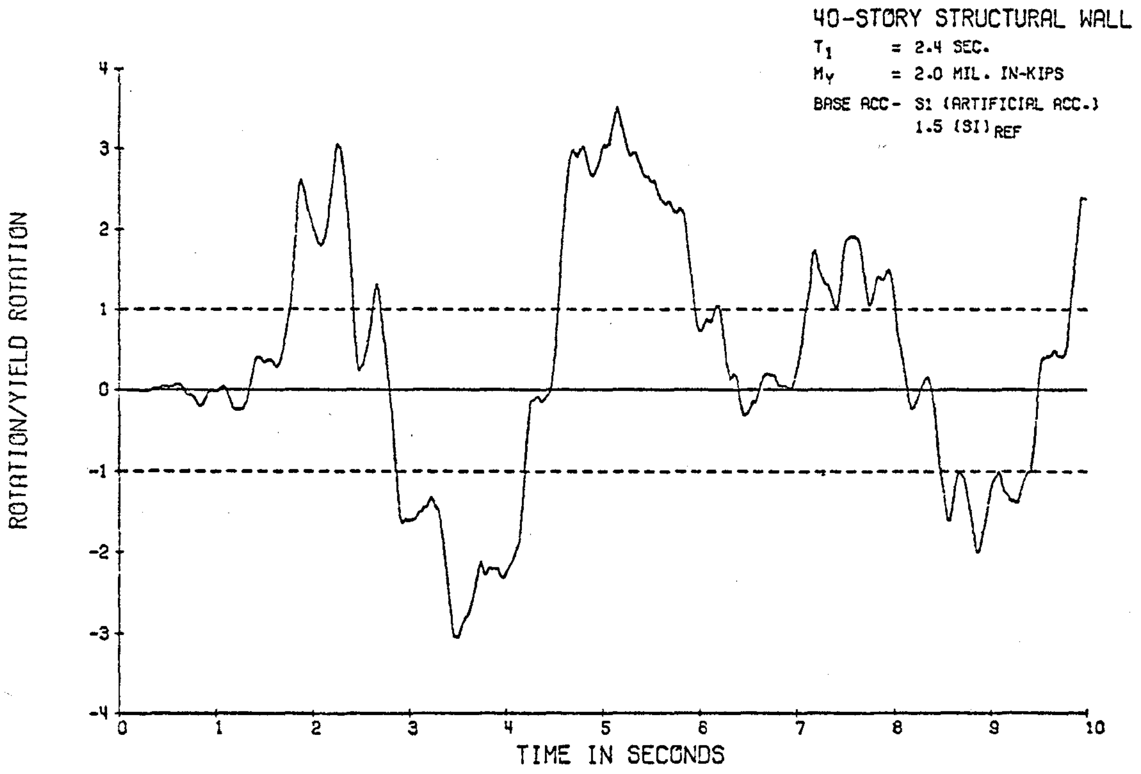


Fig. A38

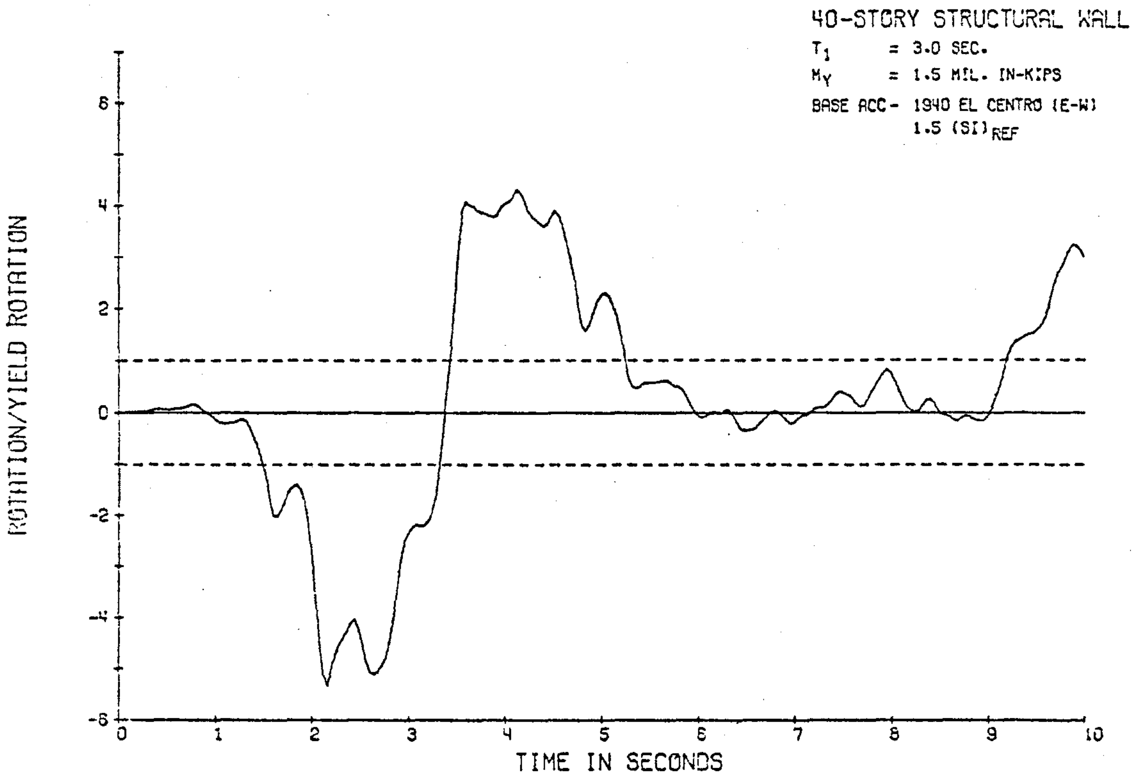


Fig. A39

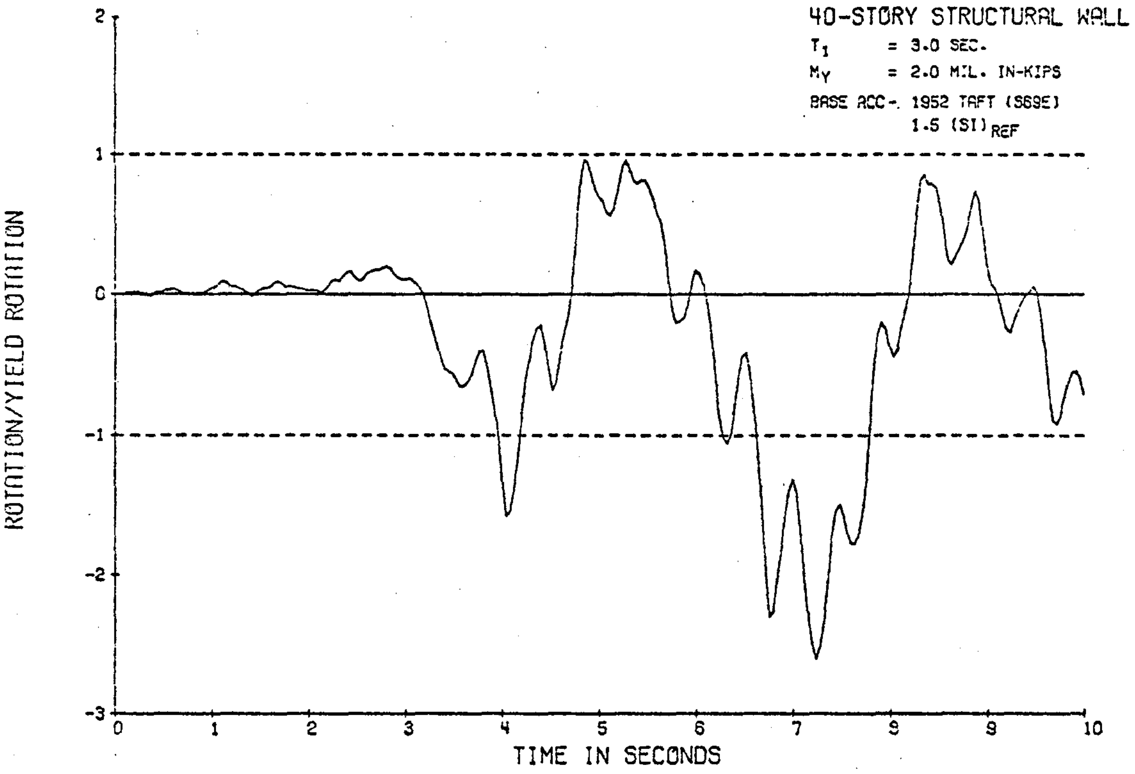


Fig. A40

Table A1 Data on Number of Cycles Based on Nodal Rotations at Midheight of 1st Story 10-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f $SI = f \times SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
1003	0.5	.15	EC-E	1.5	11.4	4	2	1	1½	2	4½
1037	0.5	.15	P.D.	1.5	19.9	1	1	1	0	0	1
1010	0.5	.50	EC-E	1.5	4.0	1	2	1	0	1	2
1036	0.5	.50	P.D.	1.5	1.9	4	6	2	½	2	4½
1007	0.5	1.0	EC-E	1.5	2.1	2	3	0	1	1	2
1024	0.5	1.0	S1	1.5	2.3	5	5	3	0	2	5
1031	0.5	1.0	P.D.	1.5	1.3	1½	2½	½	0	0	½
1004	0.8	.15	EC-E	1.5	8.7	2	1	1	1	0	2
1038	0.8	.15	P.D.	1.5	10.5	2	0	1	0	0	1
1009	0.8	.50	EC-E	1.5	1.9	2	7	1	0	0	1
1035	0.8	.50	P.D.	1.5	2.0	1	7	0	½	3½	4
1002	1.4	.15	EC-E	1.5	6.6	2	1	0	1	1	2
1034	1.4	.15	P.D.	1.5	5.6	1	2	1	0	1	2
1041	1.4	.20	EC-E	1.5	3.9	2	1	0	1½	½	2
1040	1.4	.25	EC-E	1.5	1.9	2	1	1	½	0	1½
1033	1.4	.50	P.D.	1.5	1.5	2	3	1½	0	½	2

+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

- "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between p.50 - 1.0 of the maximum. "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

Table A2 Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level
20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)$^+$	Earthquake Input	Intensity Factor, f $SI = f \times SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
1	0.8	.5	EC-E	1.5	9.6	2	2	1	1	½	2½
116	0.8	.5	P.D.	1.5	12.6	1	1	1	0	0	1
156	0.8	.5	P.D.**	1.5	12.3	1	1	1	0	0	1
169	0.8	.5	P.D.	.75	5.8	2	1	1	0	1	2
7	0.8	.75	EC-E	1.5	5.9	4	1	1	2	1	4
115	0.8	.75	P.D.	1.5	7.9	2	0	1	0	0	1
117	0.8	.75	P.D.	.75	4.6	1	2	0	1	2	3
121	0.8	.75	P.D.	1.0	6.0	1	1	1	0	0	1
135	0.8	.75	H.O.	1.5	7.6	3	1	2	0	0	2
143	0.8	.75	S1	1.5	3.3	2	9	2	0	3	5
149	0.8	.75	T	1.5	5.3	2	4	1	1	1	3
4	0.8	1.0	EC-E	1.0	1.4	3	1	1	½	0	1½
5	0.8	1.0	EC-E	1.5	4.0	3	4	2	½	1	3½
6	0.8	1.0	EC-E	1.5	3.0	5	3	3	0	1	4
90	0.8	1.0	EC-E**	1.5	4.4	1	6	1	0	2½	3½

\+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

\# - "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between 0.50 - 1.0 of the maximum "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

** - 20 sec. duration input motions.

Table A2 (cont'd.) Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level 20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
91	0.8	1.0	T**	1.5	4.1	3	2	1	1	1	3
103	0.8	1.0	EC-E	1.5	4.1	2	3	2	0	1	3
104	0.8	1.0	EC-E	1.5	4.0	3	2	2	1	0	3
105	0.8	1.0	EC-E	1.5	3.7	3	4	0	2½	2	4½
110	0.8	1.0	P.D.	1.5	5.5	2	0	1	0	0	1
125	0.8	1.0	EC-E	1.5	2.8	2	2	1	½	½	2
153	0.8	1.0	EC-N	.75	2.8	4	2	2	2	0	4
157	0.8	1.0	P.D.**	1.5	3.8	1	2	1	0	1	2
2	0.8	1.5	EC-E	1.5	2.7	3	3	1	1	2½	4½
3	0.8	1.5	EC-N	1.5	3.0	3	3	3	1	0	4
109	0.8	1.5	P.D.	1.5	4.2	1	0	0	1	0	1
139	0.8	1.5	EC-E	1.5	1.0	5	1	½	0	0	½
142	0.8	1.5	EC-E	1.5	1.1	4	4	½	0	0	½
147	0.8	1.5	EC-N**	1.5	2.5	3	5	3	0	1	4
154	0.8	1.5	P.D.**	.75	1.3	4	1½	1	1	0	1

+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

- "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between 0.50 - 1.0 of the maximum "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

** - 20 sec. duration input motions.

Table A2 (cont'd.) Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level 20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
12	1.4	.5	H.O.	1.5	4.7	3	2	2	0	1	3
13	1.4	.5	EC-E	1.5	7.0	2	1	0	2	1	3
14	1.4	.5	S1	1.5	6.2	3	3	1	1½	½	3
15	1.4	.5	P.D.	1.5	7.0	1	2	1	0	1	2
16	1.4	.5	EC-E	1.5	4.7	2	2	1	0	1	2
18	1.4	.5	EC-E	1.5	2.5	2	1	0	1	½	1½
21	1.4	.5	EC-E**	1.5	6.0	3	3	1	2	2	5
22	1.4	.5	EC-E	1.0	5.0	2	1	1	1	0	3
23	1.4	.5	EC-E	.75	2.8	3	0	1	1	0	2
24	1.4	.5	EC-E	1.5	7.5	3	0	0	3	0	3
25	1.4	.5	EC-E	1.5	7.5	2	1	0	2	1	3
26	1.4	.5	EC-E	1.5	7.5	2	1	0	2	1	3
27	1.4	.5	EC-E**	1.5	8.9	5	2	1	4	1	6
42	1.4	.5	EC-E	1.5	8.5	2	2	1	1	1	3
45	1.4	.5	EC-E	1.5	7.0	2	1	0	2	1	3

+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

- "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between 0.50 - 1.0 of the maximum "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

** - 20 sec. duration input motions.

Table A2 (cont'd.) Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level 20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f $SI = f \times SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
46	1.4	.5	EC-E	1.5	7.8	2	1	0	2	1	3
50	1.4	.5	EC-E	1.5	3.3	3	1	1	1	0	2
51	1.4	.5	EC-E	1.5	2.8	2	1	1	½	½	2
80	1.4	.5	EC-E	1.5	11.0	2	1	0	1½	½	2
106	1.4	.5	P.D.	.75	4.5	1	3	1	0	1½	2½
126	1.4	.5	EC-E	1.5	7.1	1	1	0	1	0	1
130	1.4	.5	EC-E	1.5	7.5	2	1	0	1	1	2
133	1.4	.5	EC-E	1.5	2.2	1	1	0	1	0	1
141	1.4	.5	EC-E	1.5	2.8	2	2	1	0	½	1½
151	1.4	.5	P.D.	.75	2.0	1	3	1	0	1	2
171	1.4	.5	S1	.75	3.2	2	2	1	1	1	3
11	1.4	.75	EC-E	1.5	5.1	2	1	1	1	0	2
123	1.4	.75	P.D.	.75	3.2	2	1	0	1	½	1½
124	1.4	.75	P.D.	1.0	3.2	1	2	0	1	1	2
127	1.4	.75	P.D.	1.5	4.9	2	1	1	0	1	2

+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

- "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between 0.50 - 1.0 of the maximum "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

** - 20 sec. duration input motions.

Table A2 (cont'd.) Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level 20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
128	1.4	.75	H.O.	1.5	4.5	2	3	1	0	1	2
131	1.4	.75	S1	1.5	3.3	2	2	1	½	½	2
132	1.4	.75	EC-E	1.5	2.5	1	4	1	0	1½	3
146	1.4	.75	T	1.5	3.9	3	2	1	2	1	4
165	1.4	.75	S1	.75	1.9	3	5	3	0	1	4
10	1.4	1.0	EC-E	1.5	3.0	3	0	1	1	0	2
113	1.4	1.0	P.D.	1.5	4.5	1	3	1	0	2	3
148	1.4	1.0	P.D.**	1.5	4.5	1	3	1	0	1	2
152	1.4	1.0	P.D.	.75	1.0	2½	1	½	0	0	½
20	1.4	1.5	EC-E	1.5	1.1	4	1	½	0	0	½
114	1.4	1.5	P.D.	1.5	3.2	2	1	0	1	½	1½
162	1.4	1.5	P.D.**	1.5	3.5	2	1	0	1½	½	2
31	2.0	.5	EC-E	1.5	6.4	1	2	0	1	1	2
34	2.0	.5	EC-E	1.5	3.5	1	3	1	0	1½	2½
35	2.0	.5	EC-E	1.0	2.9	3	1	0	2½	½	3

+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

- "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between 0.50 - 1.0 of the maximum "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

** - 20 sec. duration input motions.

Table A2 (cont'd.) Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level 20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
36	2.0	.5	EC-E	1.5	4.2	2	2	1	0	1	2
150	2.0	.5	H.O.	.75	2.9	2	0	1	0	0	1
163	2.0	.5	EC-E	1.5	5.0	2	1	0	1	0	1
32	2.0	.75	EC-E	1.5	3.0	3	1	0	2	½	2½
119	2.0	.75	EC-E	.75	1.4	1	3	0	0	0	0
120	2.0	.75	EC-E	1.0	2.7	1	0	0	0	0	0
129	2.0	.75	T	1.0	2.7	1	4	1	0	1½	2½
136	2.0	.75	S1	1.5	2.9	2	1	1	½	0	1½
137	2.0	.75	H.O.	1.5	3.6	2	1	1	0	1	2
140	2.0	.75	P.D.	1.0	2.3	1	2	1	0	½	1½
167	2.0	.75	H.O.	.75	1.8	1	1	0	½	½	1
33	2.0	1.0	EC-E	1.5	2.5	1	2	0	1	1	2
111	2.0	1.0	H.O.	1.5	3.1	1	1	1	0	0	1
164	2.0	1.0	H.O.**	1.5	2.9	2	0	1	0	0	1
112	2.0	1.5	H.O.	1.5	1.7	1	1	0	½	½	1

\+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

\# - "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between 0.50 - 1.0 of the maximum "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

** - 20 sec. duration input motions.

Table A2 (cont'd.) Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level 20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
40	2.4	.5	EC-E	1.5	5.0	2	2	1	1	½	2½
158	2.4	.5	EC-E**	1.5	5.1	2	1	1	0	0	1
102	2.4	.75	EC-E	1.5	4.1	1	2	0	½	½	1
122	2.4	.75	EC-E	1.0	1.6	2	2	2	0	0	2
134	2.4	.75	S1	1.5	2.1	4	2	2	½	0	2½
138	2.4	.75	P.D.	1.5	1.5	2	3	0	½	½	1
144	2.4	.75	H.O.	1.5	1.9	3	2	2	0	0	2
145	2.4	.75	T	1.5	1.3	1½	3	½	0	0	½
107	2.4	1.0	EC-E	1.5	2.1	2	2	1	½	0	1½
159	2.4	1.0	EC-E**	1.5	1.5	2	1	½	½	0	1
176	2.0	.25	S1	.75	4.0	4	1	2	½	0	2½
174	2.4	.2	EC-E	.75	5.2	3	0	1	0	0	1
175	2.4	.2	T	.75	2.8	2½	4	1	0	1	2
173	2.4	.25	T	.75	2.8	3	4	1	1	1	2½

\+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

\# - "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between 0.50 - 1.0 of the maximum "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

** - 20 sec. duration input motions.

Table A3 Data on Number of Cycles Based on Nodal Rotations at 1st Floor Level 30-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
3004	1.4	1.0	EC-E	1.5	4.2	3	1	1	½	0	1½
3013	1.4	1.0	P.D.	1.5	6.3	1	1	0	1	1	2
3008	1.4	1.5	EC-E	1.5	3.3	2	1	1	0	0	1
3014	1.4	1.5	P.D.	1.5	5.8	2	0	1	0	0	1
3012	1.4	2.0	EC-E	1.5	3.9	3	1	1	1	½	2½
3015	1.4	2.0	P.D.	1.5	5.5	1	2	1	0	1	2
3005	2.0	1.0	EC-E	1.5	6.7	2	1	1	0	0	1
3017	2.0	1.0	P.D.	1.5	4.1	2	3	1½	0	½	2
3006	2.0	1.5	EC-E	1.5	4.0	3	1	0	2	½	2½
3018	2.0	1.5	P.D.	1.5	2.3	1	2	1	0	½	1½
3007	2.0	2.0	EC-E	1.5	2.6	1	5	0	0	3	3
3019	2.0	2.0	P.D.	1.5	1.8	1	1	0	½	½	1
3009	2.4	1.0	EC-E	1.5	7.0	2	1	1	0	0	1
3021	2.4	1.0	P.D.	1.5	4.2	1	2	0	1	1	2
3010	2.4	1.5	EC-E	1.5	5.2	1	2	0	1	1	2
3022	2.4	1.5	P.D.	1.5	1.4	1	½	0	½	0	½
3011	2.4	2.0	EC-E	1.5	3.2	2	1	0	1½	0	1½
3023	2.4	2.0	P.D.	1.5	1.3	1	1	0	½	0	½

+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

- "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

**** "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between p.50 - 1.0 of the maximum. "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

Table A4 Data on Number of Cycles Based on Nodal Rotations at 2nd Floor Level 40-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
4008	1.4	1.0	EC-E	1.5	9.2	1	2	1	0	0	1
4021	1.4	1.0	S1	1.5	15.0	2	2	2	0	0	2
4034	1.4	1.0	P.D.	1.5	12.2	2	0	0	1½	0	1½
4001	1.4	1.5	EC-E	1.5	9.5	2	1	0	2	½	2½
4039	1.4	1.5	P.D.	1.5	9.0	1	1	0	1	0	1
4006	1.4	2.0	EC-E	1.5	3.4	2	1	0	1½	½	2
4045	1.4	2.0	P.D.	1.5	7.0	1	2	1	0	1	2
4051	1.4	2.5	EC-E	1.5	5.7	2	1	1	1	0	2
4016	2.0	1.0	EC-E	1.5	4.4	2	0	1	0	0	1
4022	2.0	1.0	S1	1.5	6.5	2	2	2	0	0	2
4043	2.0	1.0	P.D.	1.5	8.5	2	1	0	½	0	½
4015	2.0	1.5	EC-E	1.5	4.2	1	1	1	0	0	1
4024	2.0	1.5	S1	1.5	5.75	4	0	2	0	0	2
4040	2.0	1.5	P.D.	1.5	5.1	2	0	0	1	0	1
4046	2.0	2.0	P.D.	1.5	3.2	2	1	1	½	0	1½

\+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

\# - "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

==== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between p.50 - 1.0 of the maximum. "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

Table A4 (cont'd.) Data on Number of Cycles Based on Nodal Rotations at 2nd Floor Level 40-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Maximum Amplitude of Deformation (in terms of Correspdg Value at First Yield)	Total No. of Peaks		No. of CYCLES OF LARGE AMPLITUDE		No. of cycles of Moderate Amplitude	Total No. Inelastic Cycles
						Large Amplitude @	Moderate Amplitude #	Fully Reversed Cycles	Partially Reversed Cycles		
4050	2.0	2.0	EC-E	1.5	5.6	2	2	1	½	½	2
4009	2.4	1.0	EC-E	1.5	5.7	1	2	1	0	0	1
4023	2.4	1.0	S1	1.5	6.3	3	1	2	0	0	2
4042	2.4	1.0	P.D.	1.5	6.3	2	0	0	½	0	½
4020	2.4	1.5	EC-E	1.5	6.5	3	0	1	0	0	1
4027	2.4	1.5	S1	1.5	6.8	3	0	1	1	0	2
4041	2.4	1.5	P.D.	1.5	3.8	1	1	0	0	1	1
4004	2.4	2.0	EC-E	1.5	5.4	2	1	1	0	0	1
4047	2.4	2.0	P.D.	1.5	3.2	1	2	0	1	1	2
4012	3.0	1.0	EC-E	1.5	4.6	1	2	1	0	0	1
4031	3.0	1.0	S1	1.5	6.7	2	1	1	1	0	2
4038	3.0	1.0	P.D.	1.5	3.3	1	1	0	½	½	1
4005	3.0	1.5	EC-E	1.5	5.8	2	1	1	0	½	1½
4032	3.0	1.5	S1	1.5	5.4	1	1	1	0	0	1
4037	3.0	1.5	P.D.	1.5	2.1	1	2	0	0	0	0
4003	3.0	2.0	EC-E	1.5	3.3	2	1	1	0	0	1
4048	3.0	2.0	P.D.	1.5	2.0	1	1	0	½	½	1

+ - 1 in.-kip = 0.113 kN·m.

@ - "Large" amplitudes are those inelastic deformations between 0.75 - 1.0 of the corresponding maximum amplitude.

- "Moderate" amplitudes are those between 0.50 - 0.75 of the corresponding maximum.

*=== "Fully reversed cycles" of large amplitude are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the maximum amplitude and the other - on reversal - between p.50 - 1.0 of the maximum. "Partially reversed cycles" are cycles with one large amplitude peak and the other 0.50 or less of the maximum. "Moderate amplitude cycles" are those with one peak value between 0.50 - 0.75 of the maximum while the other is 0.50 or less.

Table A5 Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at Midheight of 1st Story 10-Story Isolated Structural Walls - 10-sec. Duration Input Motion

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @ Fully Reversed Cycles	No. of Ⓑ Cycles @ Partially Reversed Cycles
1003	0.5	.15	EC-E	1.5	9.4*	1.6	3.8	0.40	1	0	½
1037	0.5	.15	P.D.	1.5	14.0*	3.0	2.3	0.16	1	0	½
1010	0.5	.50	EC-E	1.5	2.9*	1.6	1.6	0.55	1	1	0
1036	0.5	.50	P.D.	1.5	1.7*	3.4	0.8	0.47	1	0	½
1007	0.5	1.0	EC-E	1.5	2.1	2.1	1.0	0.47	½	0	0
1024	0.5	1.0	S1	1.5	1.9*	4.1	1.6	0.84	2	2	0
1031	0.5	1.0	P.D.	1.5	1.3	8.6	0.9	0.69	1½	0	0
1004	0.8	.15	EC-E	1.5	8.0*	3.4	4.5	0.56	1	0	1
1038	0.8	.15	P.D.	1.5	10.5	3.0	0.9	0.09	½	0	0
1009	0.8	.50	EC-E	1.5	1.1*	2.7	0.97	0.88	½	0	0
1035	0.8	.50	P.D.	1.5	2.0	3.4	1.0	0.50	½	0	0
1002	1.4	.15	EC-E	1.5	6.1*	3.5	2.0	0.33	1	0	1
1034	1.4	.15	P.D.	1.5	5.6	3.1	0.4	0.07	½	0	0
1041	1.4	.20	EC-E	1.5	3.9	3.6	1.0	0.26	1½	½	0
1040	1.4	.25	EC-E	1.5	1.9	3.2	0.6	0.32	½	0	0
1033	1.4	.50	P.D.	1.5	1.5	3.7	0.8	0.53	½	0	0

+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

- with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

Table A6 Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level 20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ ‡	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
1	0.8	.5	EC-E	1.5	9.4*	3.4	5.8	0.62	1	0	½
116	0.8	.5	P.D.	1.5	12.6	3.0	1.1	0.09	1	0	½
156	0.8	.5	P.D.	1.5	12.3**	3.0	1.2	0.10	1	0	1
169	0.8	.5	P.D.	.75	4.4*	3.0	0.4	0.09	½	0	0
7	0.8	.75	EC-E	1.5	4.5*	2.4	1.4	0.31	1	0	1
115	0.8	.75	P.D.	1.5	7.0*	3.0	0.6	0.09	½	0	0
117	0.8	.75	P.D.	.75	4.6	3.5	2.0	0.43	1	0	½
121	0.8	.75	P.D.	1.0	6.0	3.6	4.0	0.67	1	0	½
135	0.8	.75	H.O.	1.5	6.1	6.8	4.8	0.79	2	1	0
143	0.8	.75	S1	1.5	3.3	2.4	2.4	0.73	1	0	½
149	0.8	.75	T	1.5	4.2*	1.3	3.6	0.86	1	½	0
4	0.8	1.0	EC-E	1.0	1.0*	2.3	0.4	0.40	1½	0	0
5	0.8	1.0	EC-E	1.5	4.0	2.3	1.0	0.25	2	½	0
6	0.8	1.0	EC-E	1.5	3.0	2.3	1.0	0.33	2	½	0
90	0.8	1.0	EC-N	1.5	4.4*	2.9	2.9	0.66	2	1	0

+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

‡ - with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

** - 20 sec. duration input motions.

Table A6 (cont'd.) Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level

20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
91	0.8	1.0	T	1.5	4.1**	4.1	0.9	0.22	½	0	0
103	0.8	1.0	EC-E	1.5	4.1	2.3	1.0	0.24	2	½	0
104	0.8	1.0	EC-E	1.5	4.0	2.3	1.0	0.25	2	½	0
105	0.8	1.0	EC-E	1.5	3.7	2.3	1.0	0.27	1½	½	0
110	0.8	1.0	P.D.	1.5	4.5*	3.0	0.4	0.09	½	0	0
125	0.8	1.0	EC-E	1.5	2.8	2.3	0.8	0.29	2	0	0
153	0.8	1.0	EC-N	.75	2.8	2.3	0.9	0.32	½	0	0
157	0.8	1.0	P.D.	1.5	2.8***	3.0	0.3	0.11	½	0	0
2	0.8	1.5	EC-E	1.5	2.1*	2.3	0.8	0.38	1½	0	½
3	0.8	1.5	EC-N	1.5	3.0	2.3	1.5	0.50	1	0	½
109	0.8	1.5	P.D.	1.5	4.2	3.5	1.8	0.43	1	0	½
139	0.8	1.5	EC-E	1.5	0.9*	3.2	0.5	0.56	½	0	0
142	0.8	1.5	EC-E	1.5	1.1	3.1	0.5	0.45	1½	0	0
147	0.8	1.5	EC-N	1.5	2.4***	2.4	1.4	0.58	1	0	½
154	0.8	1.5	P.D.	.75	1.3**	2.8	0.8	0.62	½	0	0

+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

- with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

** - 20 sec. duration input motions.

Table A6 (cont'd.) Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level
20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
12	1.4	.5	H.O.	1.5	3.6*	5.5	2.0	0.56	1	0	½
13	1.4	.5	EC-E	1.5	7.0	3.5	3.0	0.43	1	0	½
14	1.4	.5	S1	1.5	6.2	2.1	0.4	0.06	½	0	0
15	1.4	.5	P.D.	1.5	7.0	3.0	0.5	0.07	½	0	0
16	1.4	.5	EC-E	1.5	4.7	3.5	2.4	0.51	1	0	½
18	1.4	.5	EC-E	1.5	2.5	3.5	1.0	0.40	1	0	½
21	1.4	.5	EC-E	1.5	6.0**	3.6	1.8	0.30	1	0	½
22	1.4	.5	EC-E	1.0	5.0	3.5	1.0	0.20	1½	0	½
23	1.4	.5	EC-E	.75	2.8	3.3	0.7	0.25	½	0	0
24	1.4	.5	EC-E	1.5	7.5	3.5	3.2	0.43	1	0	½
25	1.4	.5	EC-E	1.5	7.5	3.5	3.2	0.43	1	0	½
26	1.4	.5	EC-E	1.5	7.5	3.5	3.2	0.43	1	0	½
27	1.4	.5	EC-E	1.5	7.4***	3.6	3.1	0.42	1	0	½
42	1.4	.5	EC-E	1.5	8.5	3.4	4.2	0.49	1	0	½
45	1.4	.5	EC-E	1.5	7.0	3.5	3.2	0.46	1	0	½

\+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

\# - with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

** - 20 sec. duration input motions.

Table A6 (cont'd.) Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level

20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
46	1.4	.5	EC-E	1.5	7.8	3.5	3.2	0.41	1	0	½
50	1.4	.5	EC-E	1.5	3.3	3.5	1.8	0.55	1	0	½
51	1.4	.5	EC-E	1.5	2.8	3.5	1.3	0.46	1	0	½
80	1.4	.5	EC-E	1.5	11.0	3.5	5.2	0.47	1	0	½
106	1.4	.5	P.D.	.75	4.5	3.8	2.7	0.60	1	0	½
126	1.4	.5	EC-E	1.5	7.1	3.5	3.0	0.42	2	0	½
130	1.4	.5	EC-E	1.5	7.5	3.5	3.1	0.41	1	0	½
133	1.4	.5	EC-E	1.5	2.2	3.5	1.1	0.50	1	0	½
141	1.4	.5	EC-E	1.5	2.8	3.5	1.5	0.54	1	0	½
151	1.4	.5	P.D.	.75	2.0	3.8	1.1	0.53	1	0	½
171	1.4	.5	S1	.75	2.5*	1.9	0.3	0.12	1	0	0
11	1.4	.75	EC-E	1.5	5.1	3.5	1.1	0.22	1	0	½
123	1.4	.75	P.D.	.75	3.2	3.7	0.9	0.28	½	0	0
124	1.4	.75	P.D.	1.0	3.2	3.7	1.5	0.47	1	0	½
127	1.4	.75	P.D.	1.5	4.5*	3.1	0.3	0.07	½	0	0

+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

- with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

** - 20 sec. duration input motions.

Table A6 (cont'd.) Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level
20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ ‡	No. of Ⓑ Cycles @ Fully Reversed Cycles	Partially Reversed Cycles
128	1.4	.75	H.O.	1.5	4.2*	6.3	1.6	0.38	1	0	½
131	1.4	.75	S1	1.5	3.1*	1.8	0.3	0.10	½	0	0
132	1.4	.75	EC-E	1.5	2.5	6.1	1.6	0.64	3	0	1½
146	1.4	.75	T	1.5	3.9	4.3	2.3	0.59	2	1	½
165	1.4	.75	S1	.75	1.9	2.4	1.0	0.53	1	0	½
10	1.4	1.0	EC-E	1.5	3.0	3.3	0.72	0.24	1	0	0
113	1.4	1.0	P.D.	1.5	4.5	3.9	2.6	0.58	1	0	½
148	1.4	1.0	P.D.	1.5	4.5**	3.8	2.7	0.60	1	0	½
152	1.4	1.0	P.D.	.75	1.0	3.8	0.5	0.48	½	0	0
20	1.4	1.5	EC-E	1.5	.96*	3.2	0.5	0.52	½	0	0
114	1.4	1.5	P.D.	1.5	3.2	3.7	0.9	0.28	½	0	0
162	1.4	1.5	P.D.	1.5	3.5**	3.7	1.0	0.29	1	0	½
31	2.0	.5	EC-E	1.5	6.4	3.5	3.1	0.48	1	0	½
34	2.0	.5	EC-E	1.5	3.5	3.4	1.9	0.54	1	0	½
35	2.0	.5	EC-E	1.0	2.6*	3.4	1.0	0.38	1	0	½

\+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

‡ - with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

** - 20 sec. duration input motions.

Table A6 (cont'd.) Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level

20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
36	2.0	.5	EC-E	1.5	4.2	7.5	3.2	0.76	3	1	1
150	2.0	.5	H.O.	.75	2.2*	6.6	1.0	0.45	1½	½	0
163	2.0	.5	EC-E	1.5	5.0	3.5	2.5	0.49	1	0	½
32	2.0	.75	EC-E	1.5	2.5*	3.3	1.0	0.40	1	0	½
119	2.0	.75	EC-E	.75	1.4	9.4	0.8	0.57	3	0	0
120	2.0	.75	EC-E	1.0	2.7	9.5	1.1	0.41	5	2	0
129	2.0	.75	T	1.0	2.7	3.1	1.5	0.56	1	1	0
136	2.0	.75	S1	1.5	2.9	3.1	1.5	0.52	1	0	½
137	2.0	.75	H.O.	1.5	3.2*	6.4	2.0	0.63	1	1	0
140	2.0	.75	P.D.	1.0	2.3	4.0	1.3	0.57	1	0	½
167	2.0	.75	H.O.	.75	1.8	7.5	0.9	0.49	½	0	0
33	2.0	1.0	EC-E	1.5	2.5	9.5	1.2	0.48	6	3	0
111	2.0	1.0	H.O.	1.5	2.3	6.6	1.1	0.48	1	0	1
164	2.0	1.0	H.O.	1.5	2.2***	6.6	1.0	0.45	1½	½	0
112	2.0	1.5	H.O.	1.5	1.7	7.5	0.8	0.47	1	0	0

\+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

\# - with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

** - 20 sec. duration input motions.

Table A6 (cont'd.) Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level
20-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ ‡	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
40	2.4	.5	EC-E	1.5	5.0	3.5	2.2	0.44	1	0	0
158	2.4	.5	EC-E	1.5	5.1**	3.5	2.9	0.57	1	0	½
102	2.4	.75	EC-E	1.5	4.1	3.5	1.1	0.27	1	0	½
122	2.4	.75	EC-E	1.0	1.5*	3.5	0.7	0.47	½	0	0
134	2.4	.75	S1	1.5	1.7*	2.9	1.3	0.76	1	0	½
138	2.4	.75	P.D.	1.5	1.5	8.3	1.2	0.80	2	1	0
144	2.4	.75	H.O.	1.5	1.6*	5.8	1.3	0.81	1	½	0
145	2.4	.75	T	1.5	1.3	3.5	0.9	0.69	2	1	0
107	2.4	.75	EC-E	1.5	2.1	3.5	0.8	0.38	½	0	0
159	2.4	1.0	EC-E	1.5	1.5**	3.5	0.5	0.33	½	0	0
176	2.0	.25	S1	.75	3.2*	1.9	0.2	0.06	½	0	0
174	2.4	.2	EC-E	.75	4.4*	2.1	0.2	0.05	½	0	0
175	2.4	.2	T	.75	2.8	4.5	1.9	0.68	2	1	0
173	2.4	.25	T	.75	2.1*	2.2	1.3	0.62	1	½	0

\+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

‡ - with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

** - 20 sec. duration input motions.

Table A7 Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 1st Floor Level
30-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
3004	1.4	1.0	EC-E	1.5	4.2	3.5	2.1	0.50	1	0	1
3013	1.4	1.0	P.D.	1.5	6.3	3.1	0.4	0.06	½	0	0
3008	1.4	1.5	EC-E	1.5	3.3	3.5	0.9	0.27	½	0	0
3014	1.4	1.5	P.D.	1.5	5.8*	3.1	0.3	0.05	½	0	0
3012	1.4	2.0	EC-E	1.5	3.9	3.3	0.9	0.23	½	0	0
3015	1.4	2.0	P.D.	1.5	3.9*	3.1	0.3	0.08	½	0	0
3005	2.0	1.0	EC-E	1.5	6.7	3.4	4.0	0.60	1	0	½
3017	2.0	1.0	P.D.	1.5	3.7*	3.1	0.2	0.05	½	0	0
3006	2.0	1.5	EC-E	1.5	3.8*	3.4	1.2	0.32	1	0	½
3018	2.0	1.5	P.D.	1.5	1.7*	3.1	0.13	0.08	½	0	0
3007	2.0	2.0	EC-E	1.5	2.6	9.6	1.6	0.62	5	3	0
3019	2.0	2.0	P.D.	1.5	1.8	4.0	0.9	0.49	½	0	0
3009	2.4	1.0	EC-E	1.5	5.0*	2.1	0.2	0.04	½	0	0
3021	2.4	1.0	P.D.	1.5	4.2	8.7	2.4	0.58	2	1	0
3010	2.4	1.5	EC-E	1.5	5.2	3.5	0.8	0.25	½	0	0
3022	2.4	1.5	P.D.	1.5	1.4	8.3	0.9	0.64	½	0	0
3011	2.4	2.0	EC-E	1.5	3.2	3.5	0.8	0.25	½	0	0
3023	2.4	2.0	P.D.	1.5	1.3	8.3	0.9	0.69	½	0	0

+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

- with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

Table A8 Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 2nd Floor Level 40-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @	
										Fully Reversed Cycles	Partially Reversed Cycles
4008	1.4	1.0	EC-E	1.5	9.2	3.5	6.1	0.66	1	0	½
4021	1.4	1.0	S1	1.5	15.0	2.1	1.2	0.08	1	0	½
4034	1.4	1.0	P.D.	1.5	12.2	3.1	0.8	0.06	½	0	0
4001	1.4	1.5	EC-E	1.5	9.5	3.5	4.5	0.47	1	0	½
4039	1.4	1.5	P.D.	1.5	9.0	3.1	0.5	0.06	½	0	0
4006	1.4	2.0	EC-E	1.5	3.4	3.5	1.4	0.41	1	0	½
4045	1.4	2.0	P.D.	1.5	7.0	3.1	0.4	0.06	½	0	0
4051	1.4	2.5	EC-E	1.5	5.7	3.5	1.6	0.28	2	0	1
4016	2.0	1.0	EC-E	1.5	4.4	2.1	0.2	0.05	½	0	0
4022	2.0	1.0	S1	1.5	6.5	2.1	0.3	0.05	½	0	0
4043	2.0	1.0	P.D.	1.5	8.0*	3.0	0.4	0.05	½	0	0
4015	2.0	1.5	EC-E	1.5	4.2	3.5	2.7	0.64	1	0	½
4024	2.0	1.5	S1	1.5	5.75	2.1	0.3	0.05	½	0	0
4040	2.0	1.5	P.D.	1.5	4.8*	3.1	0.2	0.04	½	0	0
4046	2.0	2.0	P.D.	1.5	3.2	3.1	0.2	0.06	½	0	0

+ - 1 in.-kip = 0.113 kN-m.

$ - equal to calculated maximum response peak, except where noted.

- with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.

Table A8 (cont'd.) Data on Number and Relative Magnitude of Cycles Preceding First Large-Amplitude Response Peak Based on Nodal Rotations at 2nd Floor Level

40-Story Isolated Structural Walls - 10-sec. Duration Input Motions

Run No. ISW-	Fundamental Period, T_1 (sec.)	Yield Level, $M_y/10^6$ (in-kips)+	Earthquake Input	Intensity Factor, f SI = f x $SI_{ref.}$	Ⓐ First Large Amplitude Response Peak $ (in terms of Correspdg. Value at First Yield)	Time to Maximum Displst. Amplitude T_{mxd}	Ⓑ Amplitude of Largest Displst. Preceding Max. A (in terms of Yield Amplitude)	Ⓑ / Ⓐ	No. of Peaks between 0-sec. and T_{mxd} of amplitude to Ⓑ #	No. of Ⓑ Cycles @ Fully Reversed Cycles	No. of Ⓑ Cycles @ Partially Reversed Cycles
4050	2.0	2.0	EC-E	1.5	5.6	3.4	2.9	0.52	1	0	½
4009	2.4	1.0	EC-E	1.5	5.7	2.1	0.2	0.04	½	0	0
4023	2.4	1.0	S1	1.5	6.3*	2.1	0.4	0.06	½	0	0
4042	2.4	1.0	P.D.	1.5	5.2*	3.1	0.5	0.10	½	0	0
4020	2.4	1.5	EC-E	1.5	6.0*	2.1	0.3	0.05	½	0	0
4027	2.4	1.5	S1	1.5	5.8*	2.5	0.4	0.07	1	0	0
4041	2.4	1.5	P.D.	1.5	3.8	8.8	2.5	0.66	1	1	0
4004	2.4	2.0	EC-E	1.5	5.4	3.8	3.0	0.56	1	0	½
4047	2.4	2.0	P.D.	1.5	3.2	8.3	2.0	0.63	2	1	0
4012	3.0	1.0	EC-E	1.5	4.6	2.2	0.1	0.02	½	0	0
4031	3.0	1.0	S1	1.5	6.7	4.2	3.2	0.48	1	0	½
4038	3.0	1.0	P.D.	1.5	3.3	8.5	2.4	0.73	1	0	½
4005	3.0	1.5	EC-E	1.5	5.8	2.2	0.2	0.03	½	0	0
4032	3.0	1.5	S1	1.5	5.4	4.2	1.8	0.33	1	0	½
4037	3.0	1.5	P.D.	1.5	2.1	8.9	1.4	0.67	2	½	½
4003	3.0	2.0	EC-E	1.5	3.3	2.1	1.0	0.30	½	0	0
4048	3.0	2.0	P.D.	1.5	2.0	8.9	1.1	0.55	2	½	0

\+ - 1 in.-kip = 0.113 kN·m.

$ - equal to calculated maximum response peak, except where noted.

\# - with amplitude equal to at least 0.85 of that of Ⓑ.

@ - "Fully reversed cycles" are complete cycles (+ and -) with at least one peak value between 0.75 - 1.0 of the amplitude of Ⓑ and the other - on reversal - between 0.50 - 1.0 of Ⓑ. "Partially reversed cycles" are cycles with one peak amplitude equal to at least 0.75 of Ⓑ and the other 0.50 or less of Ⓑ.

* - 75% of maximum amplitude of deformation.