EARTHQUAKE ENGINEERING RESEARCH CENTER

EARTHQUAKE SIMULATION TESTING OF A STEPPING FRAME WITH ENERGY-ABSORBING DEVICES

by

JAMES M. KELLEY
and
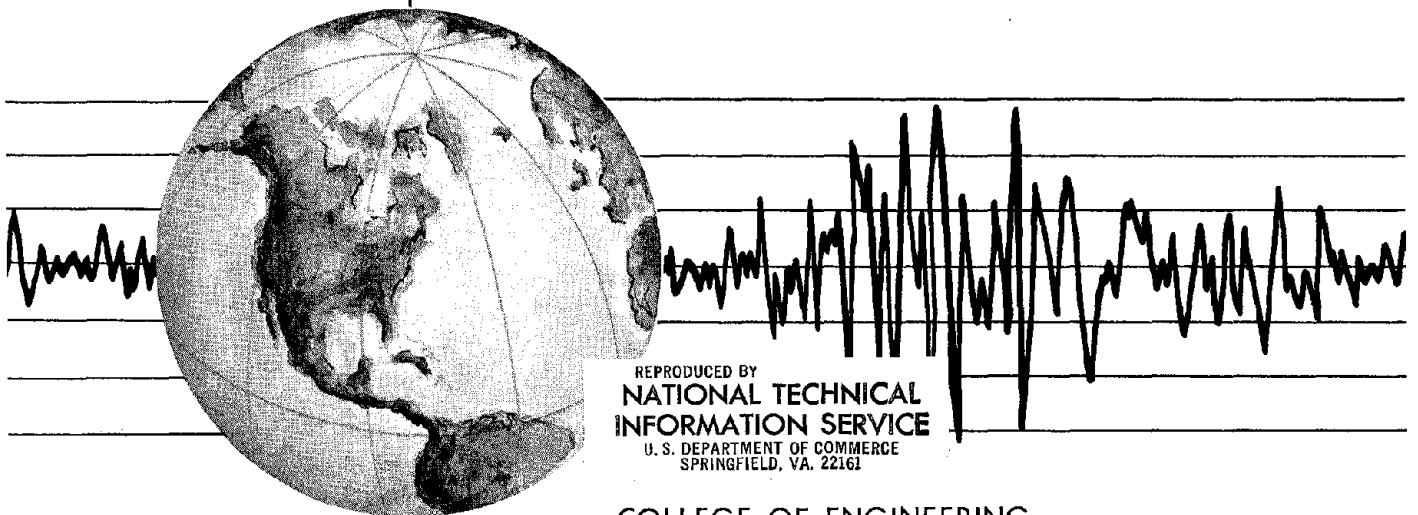DAVID F. TSZTOO

COLLEGE OF ENGINEERING

UNIVERSITY OF CALIFORNIA · Berkeley, California

BIBLIOGRAPHIC DATA SHEET	1. Report No. UCB/EERC-77/17	2.	3. Recipient's Accession No.

4. Title and Subtitle	5. Report Date
Earthquake Simulation Testing of a Stepping Frame with Energy-Absorbing Devices	August 1977
	6.

7. Author(s) James M. Kelley and David F. Tsztoo	8. Performing Organization Rept. No. 77/17

9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
Earthquake Engineering Research Center University of California, Berkeley 47th Street and Hoffman Blvd. Richmond, California 94804	11. Contract/Grant No. ENV76-04262

12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered
National Science Foundation 1800 G Street, N.W. Washington, D.C. 20550	14.

15. Supplementary Notes

16. Abstracts
Results are reported of earthquake simulation tests on a model frame with a partial base isolation system that includes energy-absorbing devices. The isolation system was modeled on a stepping bridge concept developed for New Zealand Railways, and the energy-absorbing devices, based on the plastic torsion of rectangular mild steel bars, functioned only when the frame base lifted off the foundation. Two series of tests using scaled accelerations from the El Centro N-S 1940 and Pacoima Dam 1971 earthquake ground motion records were used as input to the shaking table on which the tests were performed. Results from these tests are compared to those from earlier tests on an identical frame with the foundation (1) anchored as in conventional design, and (2) permitted to uplift freely. The response of the frame with the energy-absorbing devices installed was improved over that of both the fixed frame and the frame allowed to uplift freely for the El Centro accelerations. Although the results are not as favorable for the Pacoima Dam input, the feasibility of the energy-absorbing devices associated with a partial base isolation system is established as an alternative to anchored frames and frames allowed to uplift freely.

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21.
Release Unlimited	20. Security Class (This Page UNCLASSIFIED	22. Price A04 - A01

FORM NTIS-35 (REV. 10-73)   ENDORSED BY ANSI AND UNESCO.   THIS FORM MAY BE REPRODUCED   USCOMM-DC 8265-P74

EARTHQUAKE SIMULATION TESTING

OF A STEPPING FRAME WITH

ENERGY-ABSORBING DEVICES

by

J. M. Kelly

and

D. F. Tsztoo

ia

ABSTRACT

Results are reported of earthquake simulation tests on
a model frame with a partial base isolation system that
includes energy-absorbing devices. The isolation system
was modeled on a stepping bridge concept developed for the
New Zealand Railways, and the energy-absorbing devices,
based on the plastic torsion of rectangular mild steel bars,
functioned only when the frame base lifted off the foundation.
Two series of tests using scaled accelerations from the El
Centro N-S 1940 and Pacoima Dam 1971 earthquake ground motion
records were used as input to the shaking table on which the
tests were performed. Results from these tests are compared
to those from earlier tests on an identical frame with the
foundation (1) anchored as in conventional design, and
(2) permitted to uplift freely. The response of the frame
with the energy-absorbing devices installed was improved
over that of both the fixed frame and the frame allowed
to uplift freely for the El Centro accelerations. Although
the results are not as favorable for the Pacoima Dam input,
the feasibility of the energy-absorbing devices associated
with a partial base isolation system is established as an
alternative to anchored frames and frames allowed to uplift
freely.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

1. INTRODUCTION

Normally, structural elements that support pseudo-static loads must also absorb dynamic loadings from lateral force-producing phenomena such as earthquakes. Both the normal load-carrying capacity and the seismic resistance of such elements may be reduced during an earthquake by structural mechanisms such as yielding of beam-column joints, buckling or inelastic deformation of structural members, and cracking of partitions or walls. Repaired structural elements cannot be assumed to have recovered original strength properties.

In the work reported here, a different approach is proposed in which structural earthquake and load-carrying capacity may be provided separately. A structure would be designed to resist gravity and wind loads, and seismic resistance would be provided by energy-absorbing devices associated with a partial isolation system. When an earthquake occurs, the structure itself will be protected at the expense of energy-absorbing devices that can easily and inexpensively be replaced if damaged. The effectiveness of such devices is enhanced when they are incorporated into a base isolation system [1,2] that not only isolates a structure from seismic forces, but also channels such energy into the devices.

A partial isolation system that can accommodate energy-absorbing devices [3,4] is the stepping support foundation system, generalized from the stepping bridge concept developed by Beck, Skinner, et al., for a viaduct of the New Zealand Railways [5]. In this system relatively light mechanical devices serve as the only means of restraint against uplift of the railway bridge piers during intense ground shaking. The mechanical devices absorb energy during uplift by mechanical moment arms coupled to the base of each pier. This partial isolation system can also be applied to general structural frames not designed to be bolted to foundations, but allowed to step off their footings. The primary purpose of such a design is to minimize the cost of providing the down anchorage necessary to resist overturning forces that can develop under specified ground accelerations.

As a result of interest in the stepping bridge concept, a feasibility study on energy-absorbing devices was carried out by Kelly, Skinner, and Heine [6,7,8]. Among the mechanisms of energy absorption investigated in that study, the more important were found to be load displacement relationship, energy-absorption capacity, and low-cycle fatigue resistance. Steel bars with a rectangular cross section to facilitate external clamping without slippage were used to show that the plastic torsion of mild steel is an extremely efficient mechanism for absorbing energy and that the mode of

failure in torsion is favorable for use in an energy-absorbing device because it takes the form of a gradual decay.

Later work by Kelly, Tsztoo, and Ozdemir [9,10,11] more accurately defined the energy-absorption mechanism of the torsion devices experimentally and analytically. The devices were shown not only to have a substantial damping capacity over a prolonged service life, but also to deteriorate very gradually and in a predictable manner independent of loading rate. A correlation between device response to sinusoidal and random loading was found, allowing sinusoidal loading input to be used as the basis for designing an energy-absorbing device. Most importantly, it was noted that the useful life of such devices was in excess of 300 cycles, far exceeding any loading anticipated from an earthquake.

In this report, experiments designed to establish the feasibility of the energy-absorbing device-stepping frame system under earthquake excitations are described. In a recent series of tests, a three-story, four column model steel frame [3,4,12,13] designed to uplift from its footings was fitted with energy-absorbing devices and subjected to several earthquake simulation loadings on the twenty-foot square shaking table at the Earthquake Simulator Laboratory at the Earthquake Engineering Research Center, University of California, Berkeley. The El Centro N-S 1940 horizontal record and a horizontal component of the Pacoima Dam records

from the 1971 San Fernando Valley Earthquake, each scaled to various amplifications, were used as input to the shaking table. Results from these tests are compared to those for similar El Centro and Pacoima Dam tests on the frame with the base anchored, and with the frame free to uplift [5,14].

The tests were intended to show that overturning moment and column tension force when the energy-absorbing devices were installed were reduced as opposed to response when the frame was bolted down. Uplift and lateral story displacement were also reduced with the devices installed when compared to the case where the frame was free to uplift. It is proposed that the use of the energy-absorbing devices be considered as a compromise between the concepts of a fixed base frame and a frame totally free to uplift.

2. MODEL FRAME

A steel frame [3,4,12,13] designed to rest on either a conventional fixed base fully anchored to foundation supports (Fig. 1) or on a base support permitting vertical uplift and decoupling of the frame from the foundation (Fig. 2) was used in the present study. The A36 steel frame, standing 18 feet high and measuring 12 feet longitudinally and 6 feet transversely between column centerlines, was approximately a half-scale model of an actual structure. The frame consisted of three stories with floor diaphragms of W6x12 beams and girders, and four columns with W5x16 steel sections. To simulate structural dead weight, each floor was loaded by concrete blocks to 8000 lb (3630 Kg), yielding a total weight of approximately 27,500 lb (12,500 Kg). The structure had an overall moment of inertia of 190,600 lb-ft-sec^2 (2,635,000 Kg-cm-sec^2) about the lower 6-foot transverse edge, or 21,900 lb-ft-sec^2 (30,400 Kg-cm-sec^2) about the centroid of the frame when tested in the longitudinal direction.

The uplift footing design is shown in detail in Fig. 3. Stiffened wide flanges provided the main supports under the column footings. Stiff laminated pads were placed directly under each column foot to cushion the supports from the impact following each uplift. The pads were constructed of alternate layers of steel plate and neoprene rubber epoxied together, yielding a composite vertical stiffness of

about 400 kips/in (71,000 Kg/cm) per pad. Each column shoe
was fitted with a metal shoe and ankle that allowed full
surface contact on the bearing pads while providing a
momentary rotational hinge as the frame rocked. Restraints
along each column coupled the frame with the horizontal
motion of the shaking table, but did not prevent free vertical
uplift displacement. Roller guides centered each foot on its
support and restricted uplift so that vertical displacement
could be measured easily.

In the later phase of the testing program, fixtures
were attached to the column support interface to permit the
energy-absorbing devices to be installed (Fig. 4). These
fixtures were T-shaped tabs bolted to the exterior side of
each column shoe and fixed outer arms welded to the supporting
wide flange beams. The devices were bolted in place between
the outer arms and pin-connected to the tabs that moved with
each uplift of the columns. Thus, the uplift displacement
of the columns loaded the devices.

3. ENERGY-ABSORBING DEVICES

The key element in the energy-absorbing device used
in the present study (Fig. 5) is a mild steel torsion bar
with ductility characteristics enabling the device to with-
stand large plastic deformation and to absorb seismic forces.
The rectangular cross section of the torsion bars used in the
device facilitates external clamping of the bar to frame
models [6,7]. Torque is transferred to the bars by means of
outer moment arms that clamp the bar ends in a stationary
position relative to torque action. The inner moment arms
are pin-connected to active frame elements by a 1-in.(2.54 cm)
diameter high-strength steel pin, thereby achieving bar torque
without displacing the pin out-of-plane. The device is inte-
grated with foundation and/or structural frame elements by
means of 3/4-in.(1.91 cm) diameter high-strength nuts and
bolts on the outer arms.

Three-eighths-inch (.95 cm) diameter fillet welds were
used to connect all device elements (Fig. 5), since screwed
connections would not have ensured contact interaction
between torsion bars and the moment arm and clamp pieces,
and heavier fillet welds might have led to cracking in
welds due to increased concentration of stress and/or joint
stiffness [9,10]. The device was designed to be flat in
order to minimize overall dimensions and simplify design.
Common centerlines of symmetry coupled with the fact that
device elements can be cut from a single thickness of A36

mild rolled steel plate facilitate and minimize the cost of fabricating the device.

Tests on the energy-absorbing device [9,10] indicated its feasibility under both sinusoidal and random loadings. The device was shown not only to have substantial energy-absorbing capacity over an extended period of time, but also to deteriorate in a gradual, predictable manner independent of loading rate. The useful life of the device was estimated to be in excess of 300 cycles, far exceeding any anticipated seismic loading.

In tests on an identical device under similar conditions, the hysteresis loops that developed under sinusoidal loading effectively bounded those that developed under random loading. Sinusoidal loading was therefore deemed to be satisfactory for use as a basis for design, with a reasonable safety factor for rating loading and damping characteristics. The typical pin displacement vs. force hysteresis diagrams shown in Figs. 6 and 7 for the torsion devices used in these tests were produced using sinusoidal loading calibrated to displace the pin position ± 1/2 in. (± 1.27 cm) out-of-plane. The device hysteresis prior to testing is shown in Fig. 6, while that for the device after ten earthquake simulations is shown in Fig. 7.

Comparison of the hysteresis loops in these two figures indicates that no deterioration of the devices resulted from the very substantial plastic deformation that they sustained

during the ten simulated earthquakes of the test program.
The area of the hysteresis loop, representing the energy
displaced per cycle, is in fact slightly larger after the
test program than before. This result is the more note-
worthy when it is realized that the maximum displacement of
the device during the test program was approximately 2-1/4 in.,
representing a plastic shear strain in excess of 10%.

After the test program had been completed, a lateral
bending deformation (Fig. 8) of approximately 1/8 in. (.32 cm)
parallel to the axis of the inner moment arms was noted. This
additional lateral deformation occurred when the inner moment
arms rotated sufficiently to cause the torsion bars to bend.
The devices were nonetheless able to dissipate energy with
no signs of cracking or deterioration at these large displace-
ments.

4. TESTING PROGRAM

Two earthquake records were used to produce the ten ground motion simulations used in the testing program: six scaled signals based on the El Centro N-S 1940 horizontal component, and four based on a horizontal component of the Pacoima Dam record of the 1971 San Fernando Valley Earthquake. The maximum acceleration of the scaled El Centro records was 0.786g, and that for the Pacoima Dam records was 0.955g. In order to simplify input loading and thus analysis and interpretation of test results, no vertical component was used. An effort was made to duplicate the command signals used in the earlier tests on the fixed frame and the frame free to uplift [3]. Thus, results from the present series of tests with the energy-absorbing devices installed in the frame could be compared easily to those obtained in the earlier tests.

The shaking table functions and frame response were monitored by 128 separate data channels in discrete sampling intervals, and the digital data were stored on the disk of a mini-computer [15]. Thirty-six table functions and ninety transducer and two blank reserve channels on the frame were monitored with a sampling rate of approximately 50 points per second for each channel. The data were later transferred from disk to magnetic tape for reduction and analysis.

Electrical transducers used during testing and their functions were as follows:

1. Accelerometers monitored the shaking table and horizontal accelerations at each floor of the frame.

2. Potentiometers and Direct Current Linear Varying Displacement Transducers (DC LVDT's) monitored table displacements, horizontal displacements of each floor relative to fixed references off the table, vertical uplifts or displacements at each column foot relative to the table, and selected frame member and joint displacements.

3. Strain gages epoxied to various frame members monitored strain distribution throughout the frame, enabling the complete force distribution and levels of column tension to be determined.

4. Electrical contact switches embedded in each support pad monitored each uplift when the bearing surface of the column foot was completely free of the support pad.

5. EXPERIMENTAL RESULTS

In this section, results of tests run using the scaled accelerations from the El Centro and Pacoima Dam ground motion records are compared for the three model frame base conditions considered in this report: fixed, free to uplift, and free to uplift with energy-absorbing devices installed. For all earthquake intensities up to the respective peak accelerations used in the tests, the uplift of the frame footings was significantly less than that when the frame was unanchored. In Figs. 10 and 11, where the rocking motion of the frame is shown with the uplift of the north side of the frame in the top grid and that of the south side in the bottom grid, the effect of the energy-absorbing devices is clearly apparent.

For the El Centro test with peak input acceleration of 0.768g, third floor displacements were substantially less with the devices installed than when the frame was free to uplift (Fig. 12). The relative story displacements of the frame with devices were similar to those when the base frame was fixed except that the peak displacements were slightly larger with the devices. The influence of the devices on the overall displacement history is, however, apparent in that considerably more damping of the motion is shown.

The greatest third floor displacement for the Pacoima Dam test with peak input acceleration of 0.955g (Fig. 13) occurred in the frame with the devices installed, the next

largest in the unanchored frame, and the least in the fixed base frame. Although this result is clearly not in favor of the device application, top story displacements, especially in the latter portion of the time history following the most intense portion of the input motion, do show the beneficial effect of device damping.

First floor column tension in the frame with devices for both earthquake series was greater than in the unanchored frame, but substantially less than that in the fixed base frame for both north and south columns (Figs. 14-17). First floor column compression during these tests was not critical (Figs. 14-17). Because column force histories were not corrected for a static compression of approximately -7000 lb (-3200 Kg) in each column, all tension levels shown in Figs. 14-17 should be reduced and all compression levels increased by 7.0 kips. In the fixed frame, remaining tension was due to the column foundation anchorages, while such tension in the frame with devices was primarily due to the restraint offered by the devices. Tension in the unanchored frame was probably due to a combination of imperfect base conditions and inertial effects during dynamic uplift.

Base and upper level story shears in the frame with devices were far lower than in the fixed frame (Figs. 18 and 19). In some cases, the peak shear values in the frame with devices were comparable to if not smaller than those for the unanchored frame. The preceding comments apply equally

to base and story overturning moments for the three cases
(Figs. 20 and 21).

Test results are summarized for both the El Centro and
Pacoima Dam series of earthquake simulations in Tables 1 and
2, respectively. Peak response for average column uplift,
relative third floor displacement, first floor column axial
force, base shear, and base overturning moment are given for
the three test conditions considered in this report.

6. SUMMARY AND CONCLUSIONS

Comparisons of results from the El Centro and Pacoima
Dam earthquake simulations for the fixed frame and for
the frame free to uplift to results for the frame with the
energy-absorbing devices installed indicate that the concept
of such devices associated with a partial isolation system
as a form of aseismic design should be considered as an
alternative to the concepts of fixed base design and design
in which structures are uncoupled vertically from foundations.

In the El Centro tests the devices offered sufficient
base restraint to reduce uplift substantially from levels
observed when the frame was free to uplift. Relative story
displacements were at a level similar to that observed in
the fixed base case, but were substantially lower than when
the frame was uncoupled vertically from its foundation.
At the same time, the devices absorbed significant amounts
of energy and permitted partial base uncoupling, resulting
in reductions of column forces, especially column tension,
to levels far lower than those for the fixed base case and
comparable to those for the unanchored case. The base and
story shears and story overturning moments were reduced when
the devices were installed to values less than those recorded
for both the fixed and unanchored cases.

On the other hand, results obtained using the peak
acceleration scaled from the Pacoima Dam records were
conspicuously less favorable. For certain critical responses,

such as base uplift and relative floor displacement, the
frame with devices installed did not perform better than did
the frame free to uplift without devices. However, other
responses, such as first floor column axial force, base and
story level shear, and base and story overturning moment,
were noticeably improved when the devices were installed as
opposed to results obtained when the frame was permitted to
uplift freely.

The discrepancy between the results for the El Centro
and Pacoima Dam excitations can perhaps be explained by
the dissimilarity of the records. The Pacoima Dam records
represent an unusual type of earthquake with impulsive
loading on the order of 1.0g acceleration. The energy-
absorbing devices act to dissipate energy and to prevent
increasing resonance. Under impulsive loading such as
that in the Pacoima Dam record, the devices will be rendered
less effective and maximum structural response will be
determined primarily by inertial characteristics of the
system. Thus, the peak displacement response of the frame
during the Pacoima Dam inputs was not effectively damped
by the devices. The devices did, however, damp frame
response after the initial impulse, thus mitigating overall
damage.

The initial tests of the energy-absorbing device
described in this report have established the feasibility
of such devices for aseismic design. Energy-absorbing

devices incorporating stainless steel alloys, and isolation systems with natural rubber bearing pads that allow partial horizontal isolation of structural frames from earthquakes are being designed and tested in an attempt to improve on the results reported herein.

REFERENCES

1. K. Matsushita and M. Izumi, "Some Analysis on Mechanisms to Decrease Seismic Forces Applied to Buildings," Proceedings of the Third World Conference on Earthquake Engineering, Vol. III, 1965, pp. 342-389.

2. A. K. Chopra, D. P. Clough, and R. W. Clough, "Earthquake Resistance of Buildings with a Soft First Story," Earthquake Engineering and Structural Dynamics, Vol. 1, 1973, pp. 347-385.

3. R. W. Clough and A. A. Huckelbridge, Jr., "Earthquake Simulation Tests of a Steel Frame Allowed to Uplift," Dynamic Response of Structures: Instrumentation, Testing Methods, and System Identification, ASCE/EMD Speciality Conference, March 30 and 31, 1976, University of California, Los Angeles, pp. 318-329.

4. A. A. Huckelbridge, Jr., "An Analytical Study of the Seismic Response of a Three Story Frame Allowed to Uplift," Master of Science Research Report, Structural Engineering and Structural Mechanics, Department of Civil Engineering, University of California, Berkeley, June 1975.

5. J. L. Beck and R. I. Skinner, "The Seismic Response of a Proposed Reinforced Concrete Railway Viaduct," Technical Report No. 369, Physics and Engineering Laboratory, Department of Scientific and Industrial Research, Lower Hutt, New Zealand, 1974.

6. J. M. Kelly, R. I. Skinner, and A. J. Heine, "Mechanisms of Energy Absorption in Special Devices for Use in Earthquake Resistant Structures," Bulletin of the New Zealand Society of Earthquake Engineering, Vol. 5, 1972, pp. 63-88.

7. R. I. Skinner, J. M. Kelly, and A. J. Heine, "Hysteretic Dampers for Earthquake Resistant Structures," Earthquake Engineering and Structural Dynamics, Vol. 3, 1975, pp. 287-296.

8. R. I. Skinner, J. M. Kelly, and A. J. Heine, "Energy Absorption Devices for Earthquake-Resistant Structures," Proceedings of the Fifth World Conference on Earthquake Engineering, Rome, Italy, 1973.

9. D. F. Tsztoo, "The Development of Mechanical Torsion Devices to Absorb Seismic Energy," Master of Engineering Research Report, Structural Engineering and Structural Mechanics, Department of Civil Engineering, University of California, Berkeley, December 1976.

10. J. M. Kelly and D. F. Tsztoo, "Energy Absorbing Devices for Earthquake Resistant Design," Earthquake Engineering Research Center Report, College of Engineering, University of California, Berkeley, 1977 (in preparation).

11. H. Ozdemir, "Nonlinear Transient Dynamic Analysis of Yielding Structures," Ph.D. Thesis, Structural Engineering and Structural Mechanics, Department of Civil Engineering, University of California, Berkeley, 1976.

12. R. W. Clough and D. T. Tang, "Shaking Table Tests of a Steel Frame - A Progress Report," Report No. EERC 74-8, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, July 1974.

13. R. W. Clough and D. T. Tang, "Earthquake Simulator Study of Steel Frame Structure, Vol. I: Experimental Results," Report No. EERC 75-6, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, April 1975.

14. J. M. Kelly and D. F. Tsztoo, "Energy Absorbing Devices in Structures Under Earthquake Loading," Proceedings of the Sixth World Conference on Earthquake Engineering, New Delhi, India, January 10-14, 1977.

15. D. Rea and J. Penzien, "Dynamic Response of a 20 ft x 20 ft Shaking Table," Proceedings of the Fifth World Conference on Earthquake Engineering, Rome, Italy, 1973.
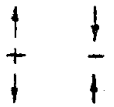
	FIXED BASE	WITH DEVICES	WITHOUT ANCHORAGES	
AVE. UPLIFT				
NORTH COLS.	0"	1.26"	1.99"	
SOUTH COLS.	0"	1.10"	3.03"	
REL. 3RD. FLR. DISPL.	+2.43" −2.02"	+2.29" −2.74"	+5.34" −3.72"	
1ST. FLR. COL. AXIAL FORCE				
NORTH COL.	+20.76 K −22.14 K	+11.64 K −19.93 K	+7.85 K −18.44 K	
SOUTH COL.	+22.10 K −18.93 K	+14.42 K −13.33 K	+8.99 K −20.50 K	
BASE SHEAR	+35.21 K −35.53 K	+19.57 K −24.11 K	+26.90 K −25.25 K	
BASE OVERTURN- ING MOMENT	+471.3 K-FT −434.3 K-FT	+278.7 K-FT −297.7 K-FT	+323.2 K-FT −296.1 K-FT	

TABLE 1. SUMMARY OF EL CENTRO PEAK RESPONSES.

Preceding page blank
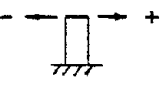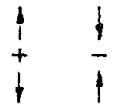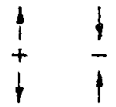
	FIXED BASE	WITH DEVICES	WITHOUT ANCHORAGES	
AVE. UPLIFT				
NORTH COLS.	0"	2.24"	2.40"	
SOUTH COLS.	0"	1.65"	2.05"	
REL. 3RD. FLR. DISPL.	+3.12" −2.36"	+3.47" −4.31"	+3.27" −3.44"	
1ST. FLR. COL. AXIAL FORCE				
NORTH COL.	+22.96 K −25.15 K	+14.20 K −22.59 K	+7.94 K −21.03 K	
SOUTH COL.	+25.72 K −20.89 K	+15.73 K −31.36 K	+10.20 K −21.18 K	
BASE SHEAR	+37.58 K −32.72 K	+27.80 K −31.35 K	+24.32 K −30.72 K	
BASE OVERTURN-ING MOMENT	+563.8 K-FT −481.1 K-FT	+358.3 K-FT −431.8 K-FT	+343.3 K-FT −398.4 K-FT	

TABLE 2. SUMMARY OF PACOIMA PEAK RESPONSES.
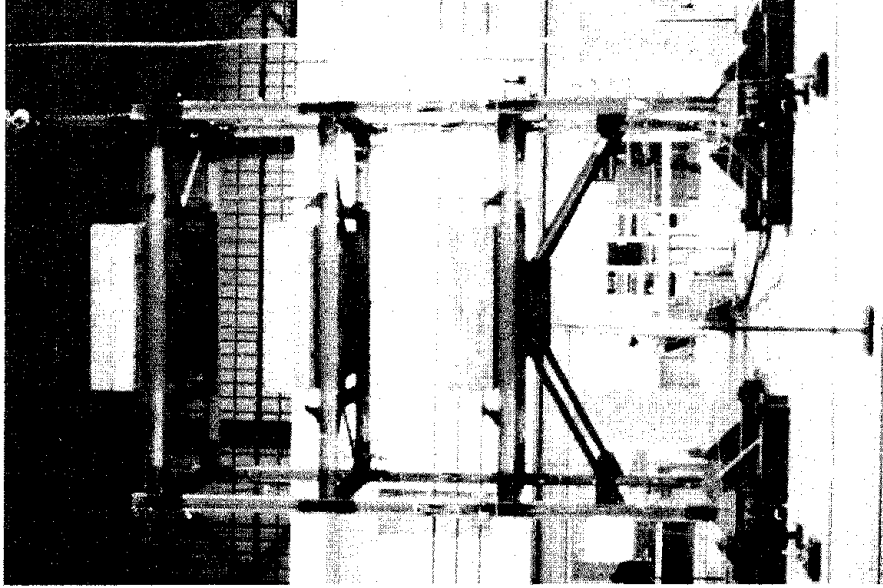
FIG. 2. FRAME MODIFIED TO ALLOW UPLIFT.

FIG. 1. FIXED BASE FRAME.
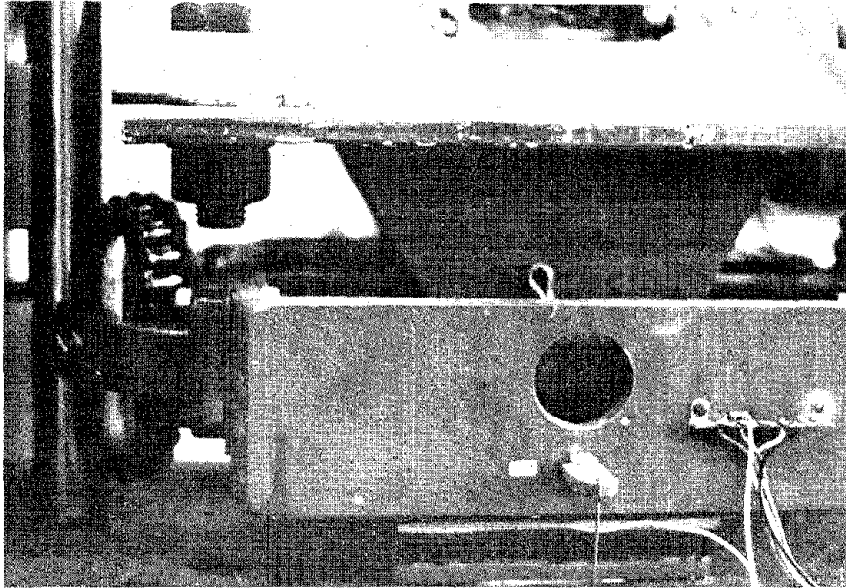
FIG. 3. COLUMN FOOT ROLLER GUIDE DETAIL.
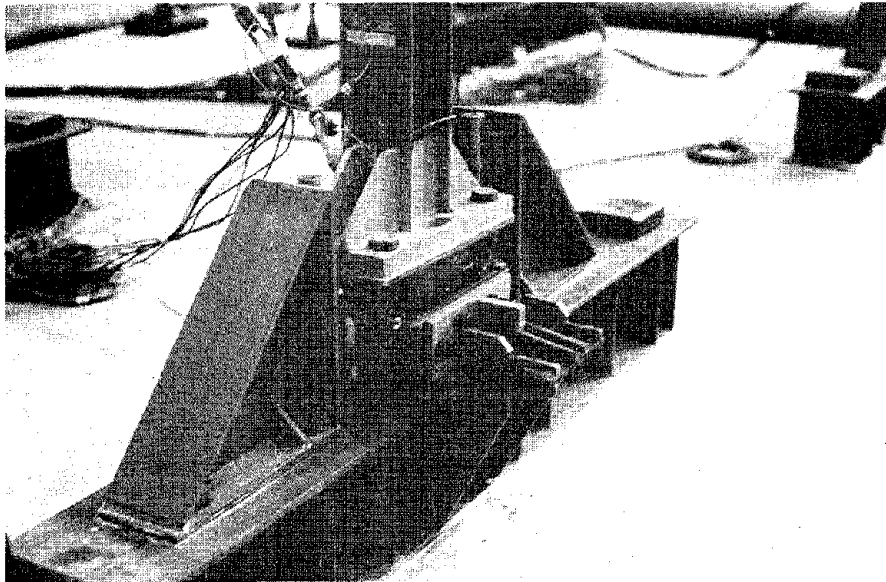
FIG. 4. COLUMN FOOT/DEVICE INTEGRATION.
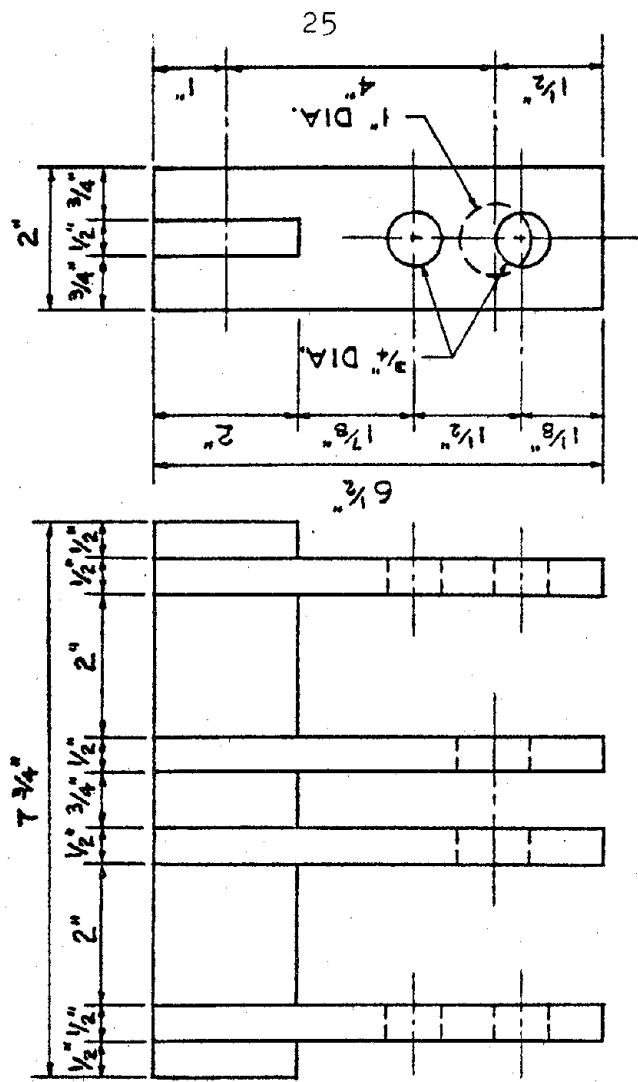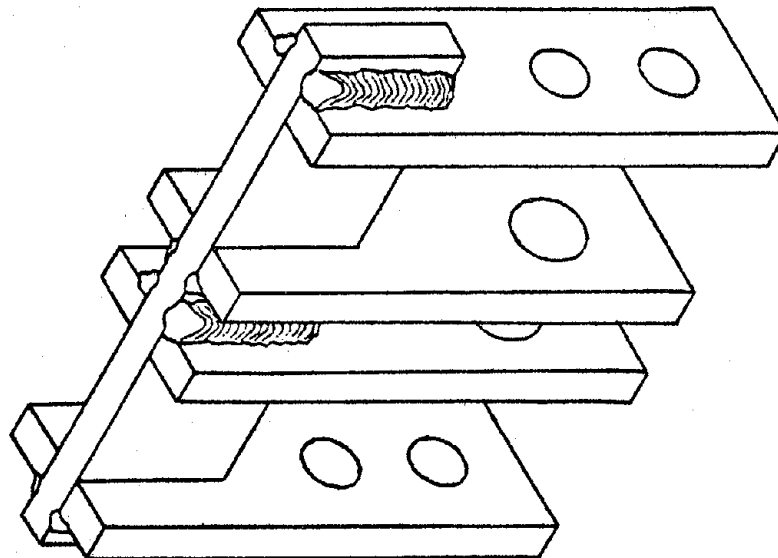
FIG. 5. TORSION DEVICE.
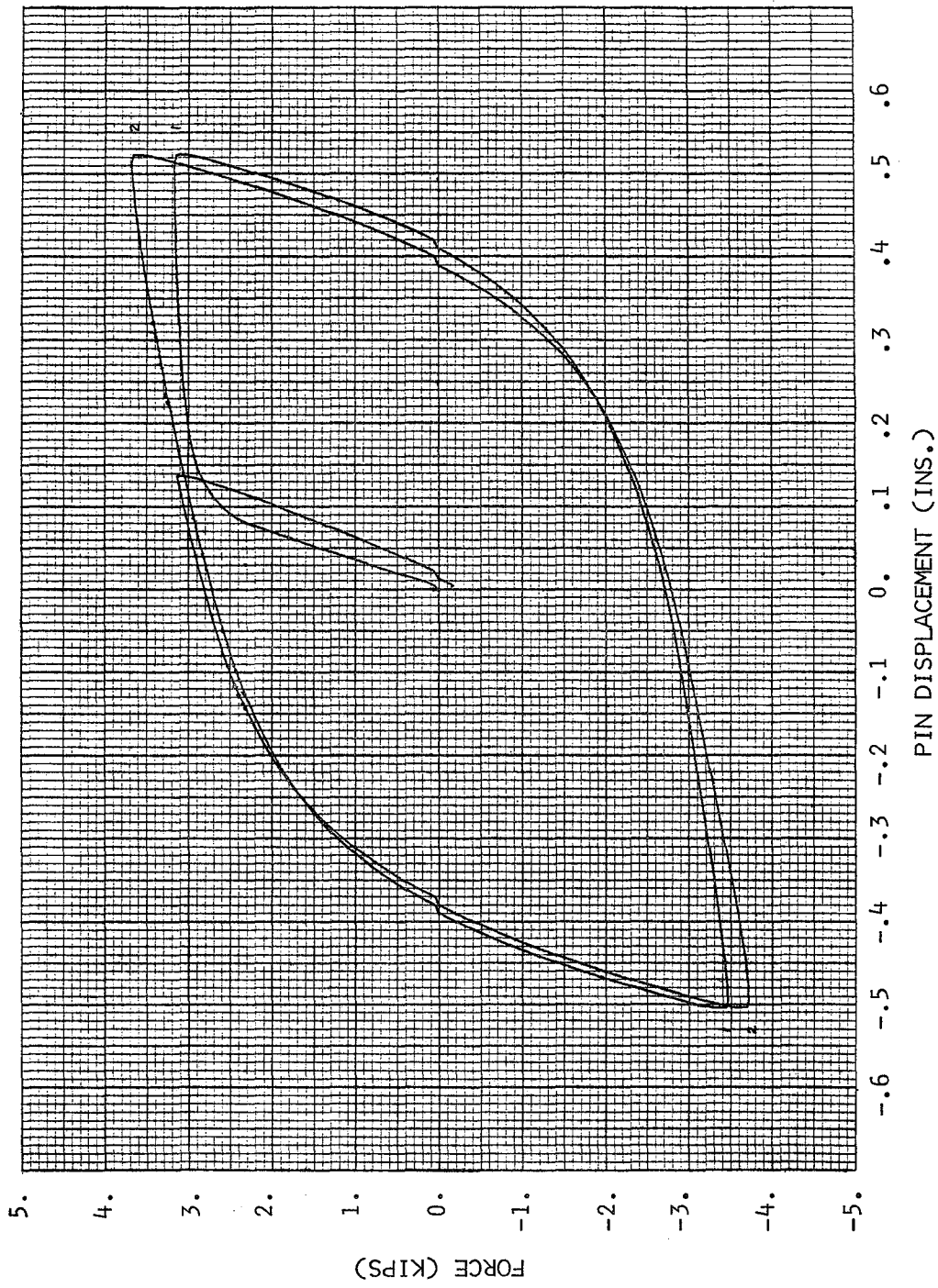
FIG. 6. DEVICE HYSTERESIS BEFORE EARTHQUAKE SIMULATION TESTS.
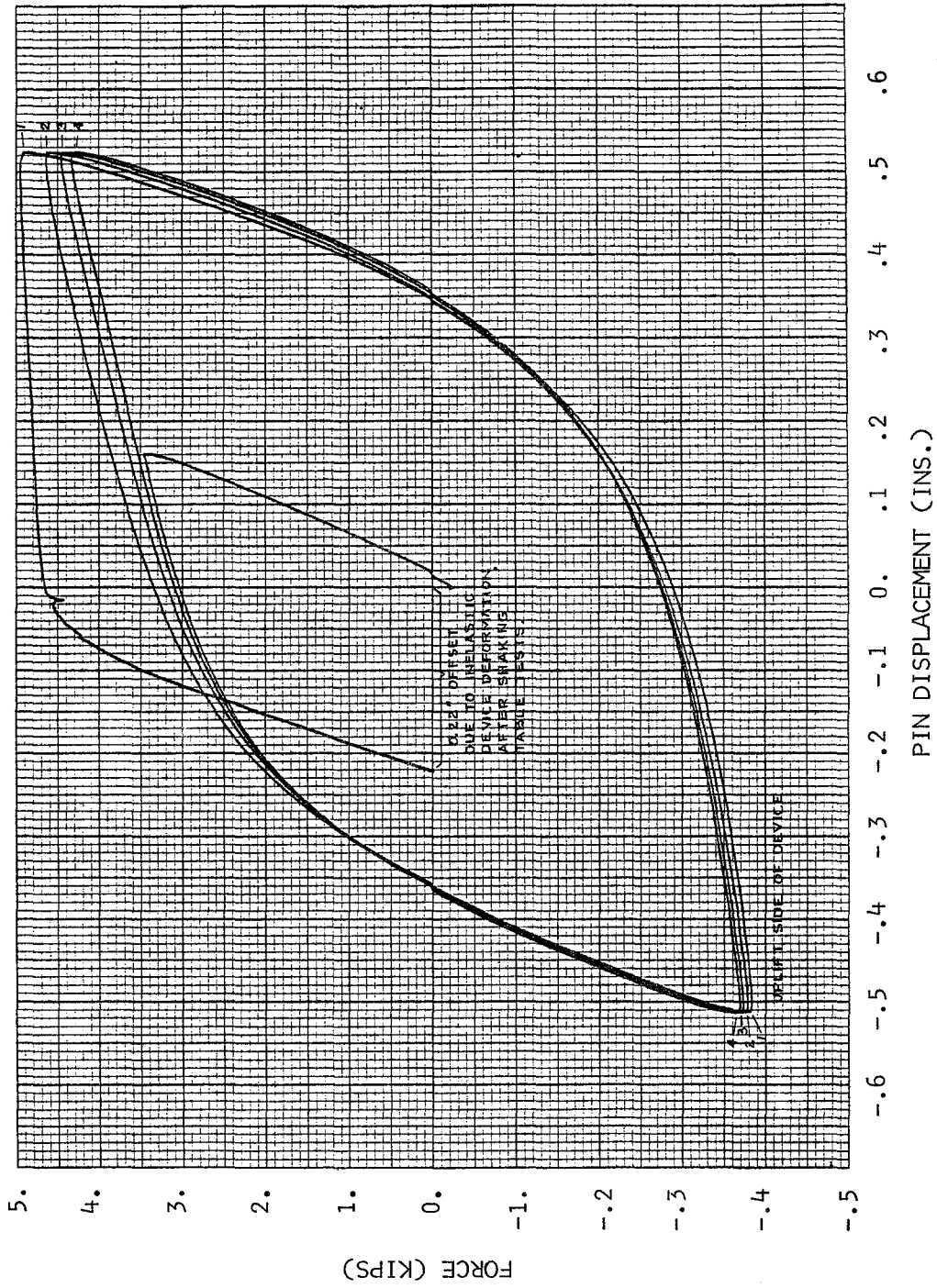
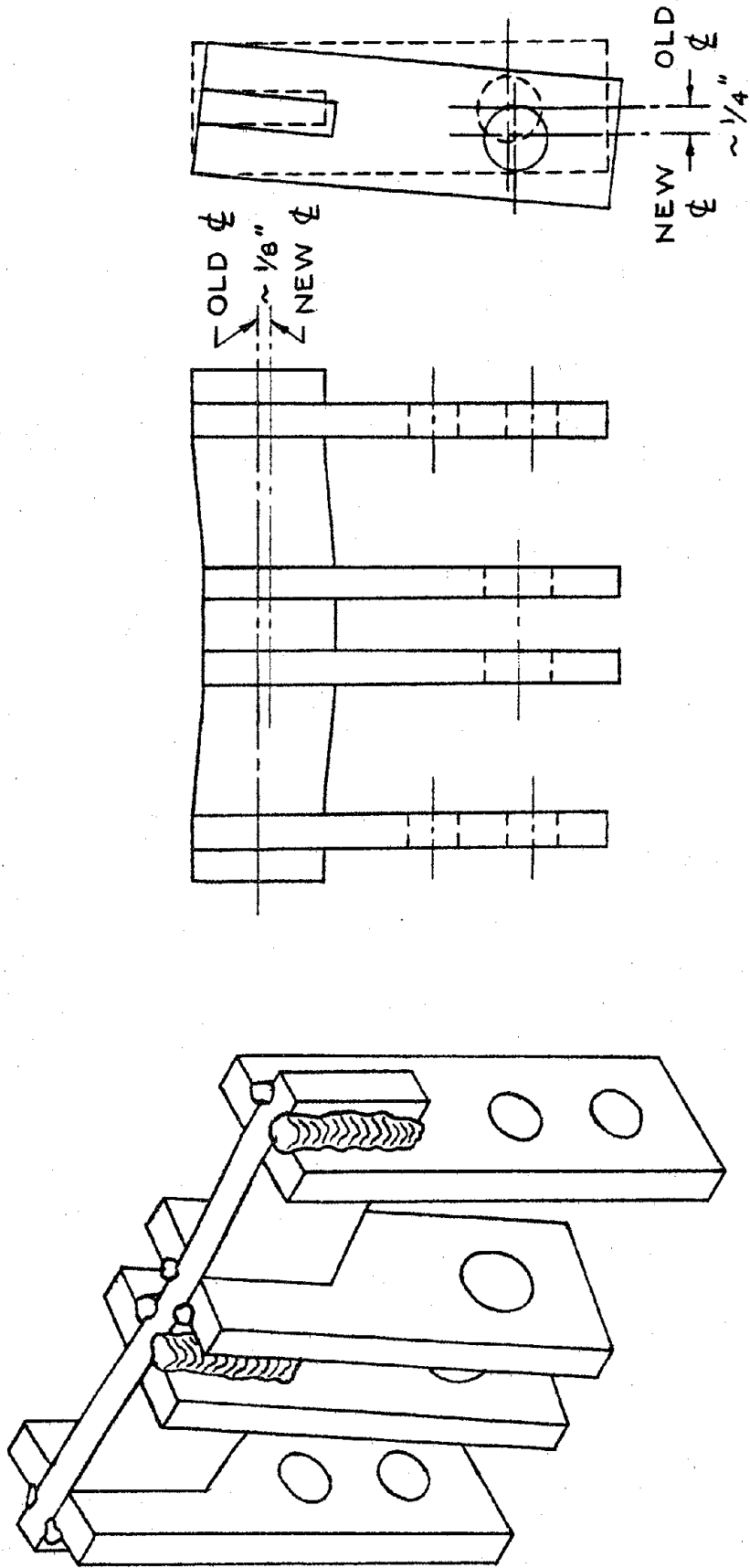FIG. 7. DEVICE HYSTERESIS AFTER TEN EARTHQUAKE SIMULATION TESTS.

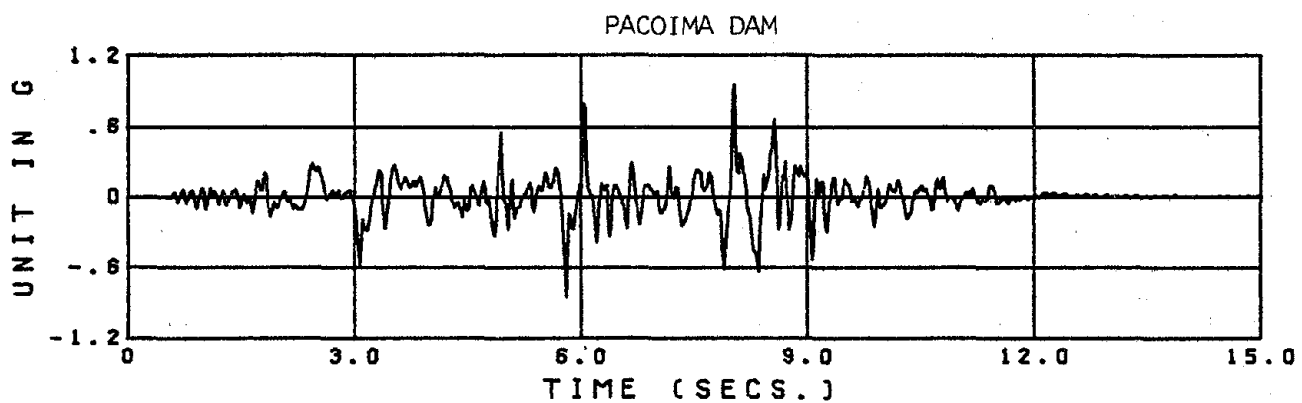FIG. 8. DEVICE INELASTIC DEFORMATIONS AFTER SIMULATION TESTS.

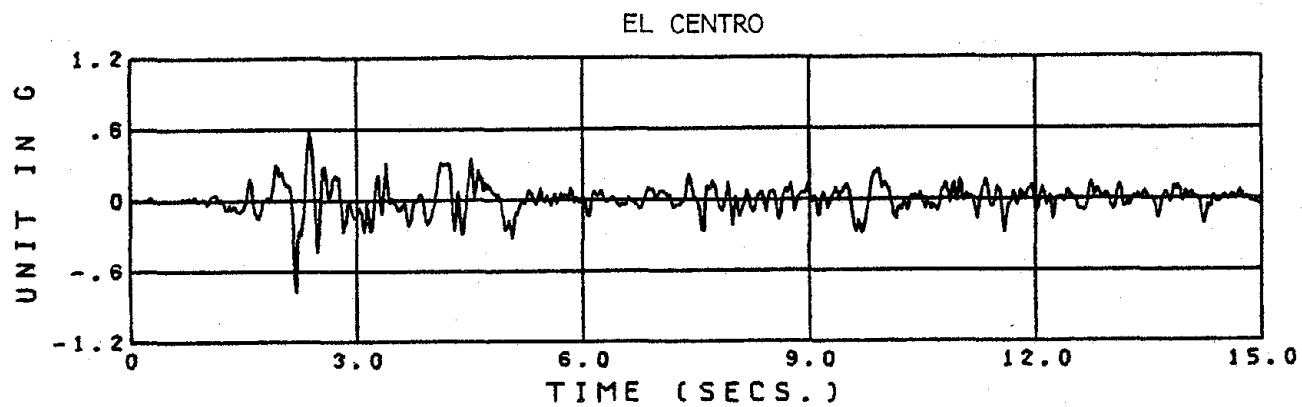FIG. 9. EL CENTRO AND PACOIMA DAM PEAK AMPLIFICATION
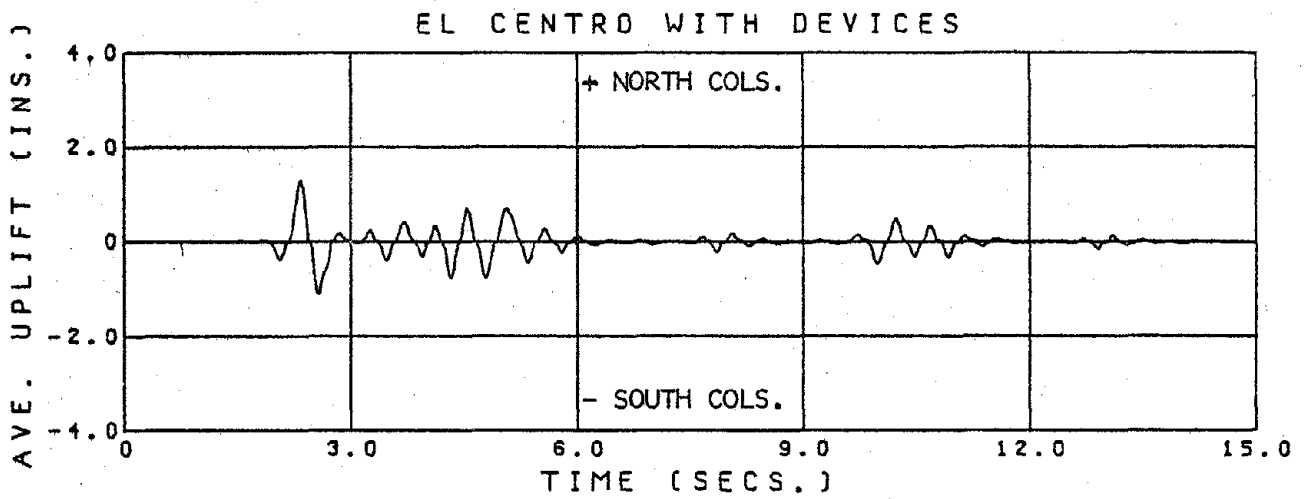TABLE ACCELERATION INPUTS FOR TEST FRAME.
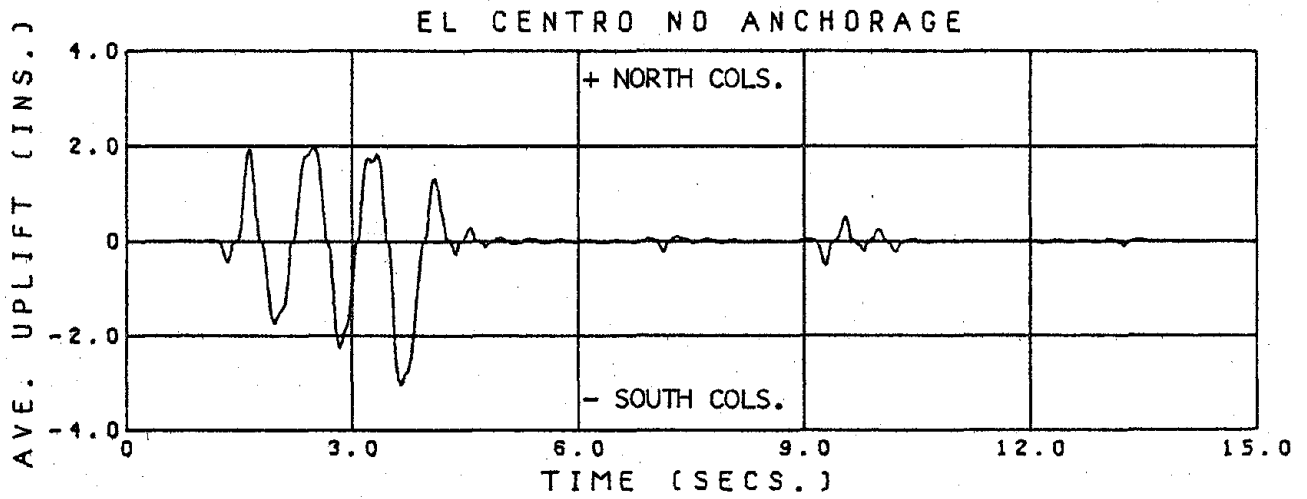
EL CENTRO NO ANCHORAGE

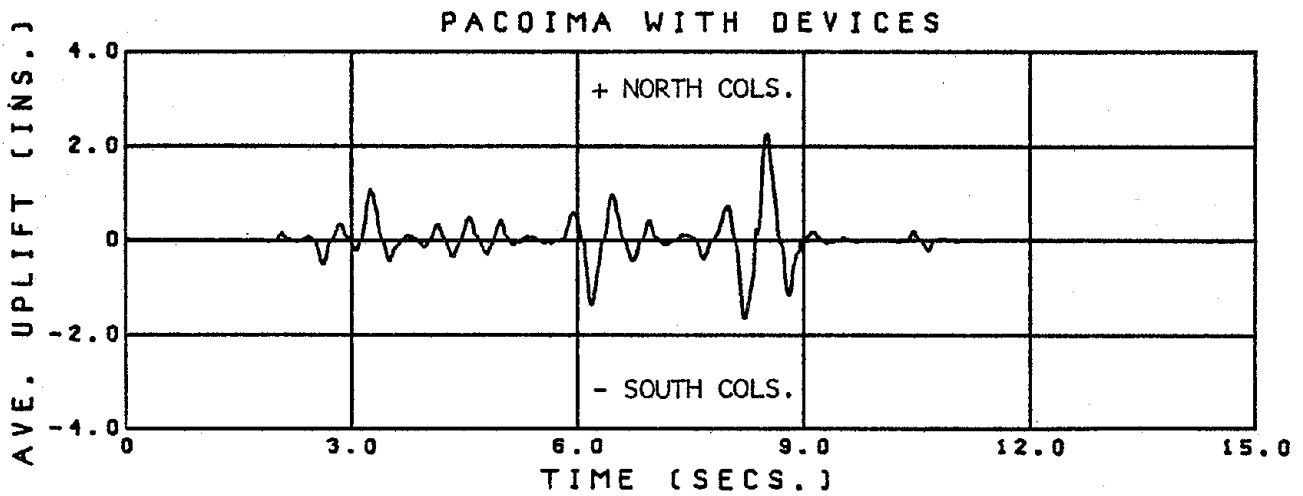EL CENTRO WITH DEVICES

FIG. 10. EL CENTRO VERTICAL UPLIFT DISPLACEMENT COMPARISONS.

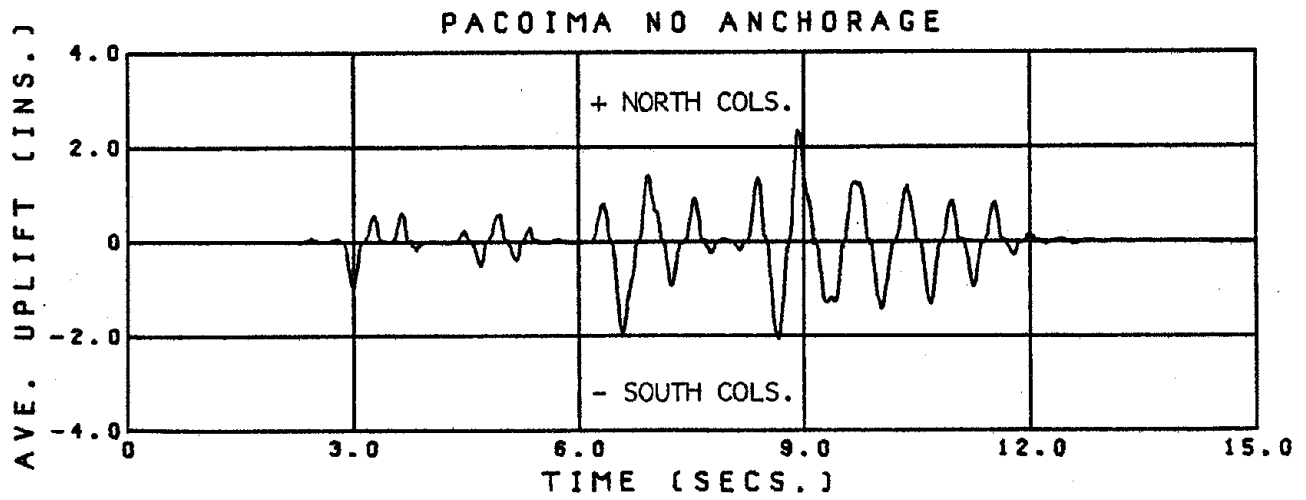FIG. 11. PACOIMA VERTICAL UPLIFT DISPLACEMENT COMPARISONS.

EL CENTRO FIXED BASE
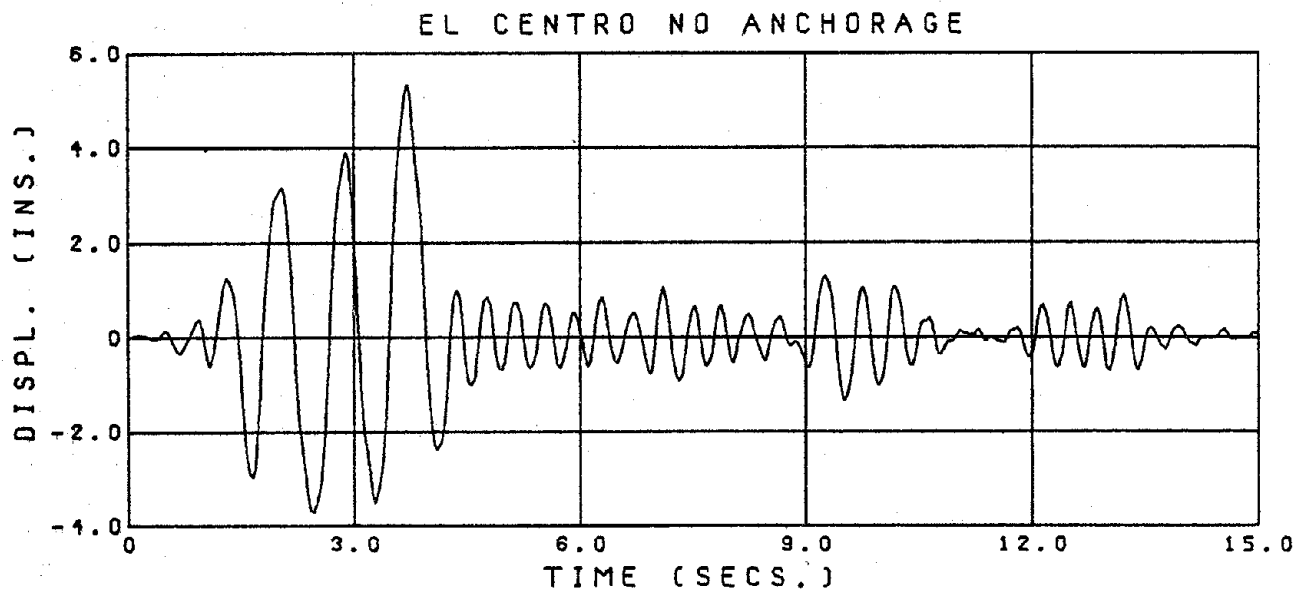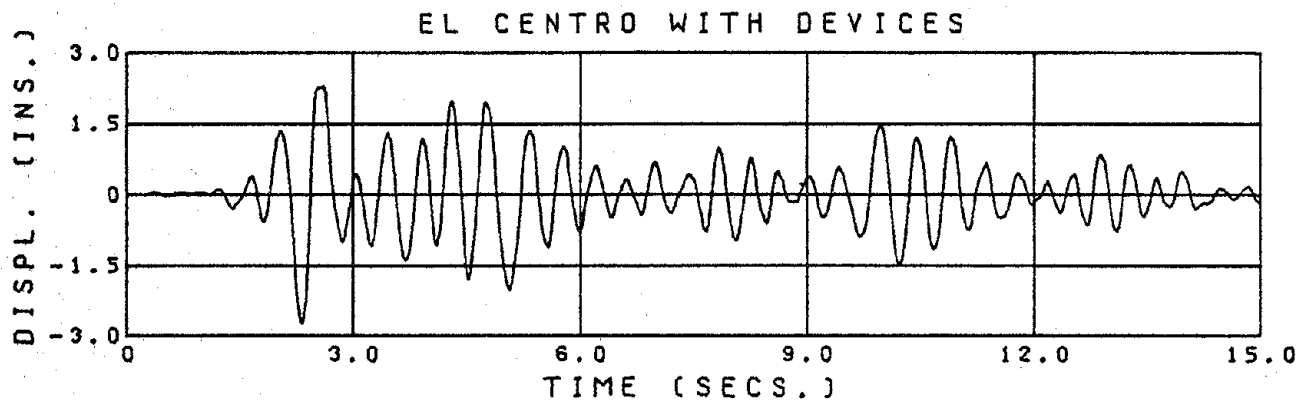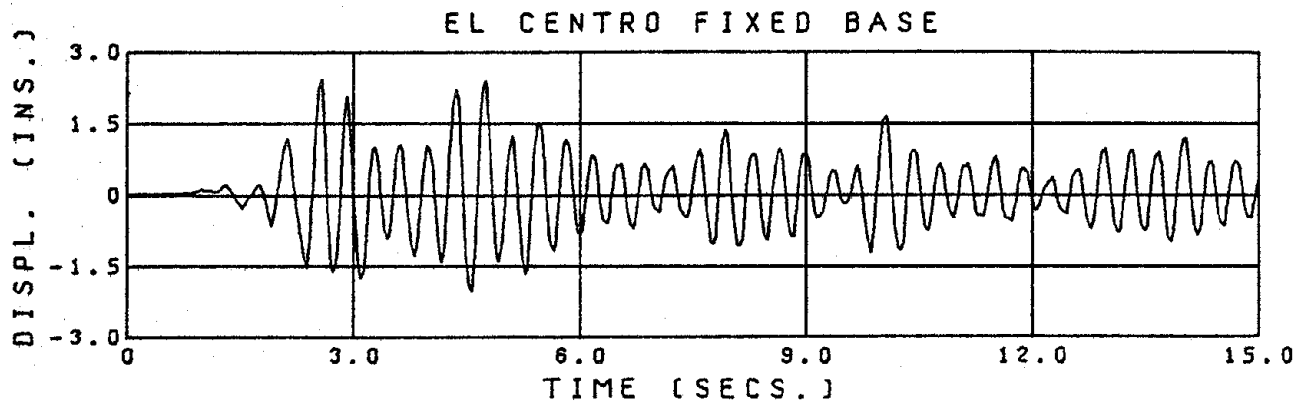

EL CENTRO WITH DEVICES

EL CENTRO NO ANCHORAGE

FIG. 12. EL CENTRO RELATIVE THIRD FLOOR HORT. DISPL. COMPARISONS.

PACOIMA FIXED BASE

PACOIMA WITH DEVICES

PACOIMA NO ANCHORAGE
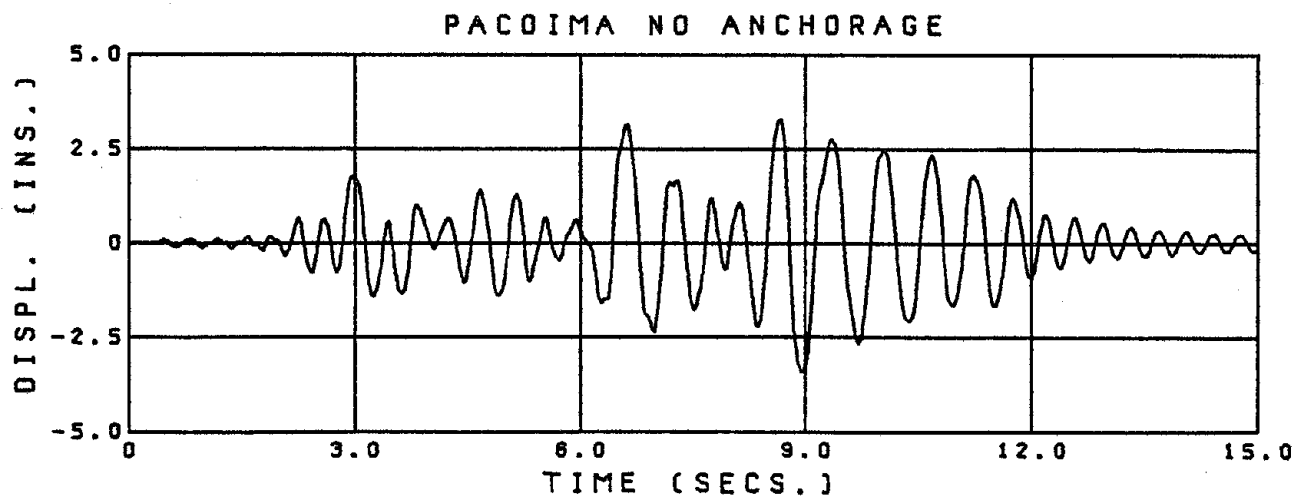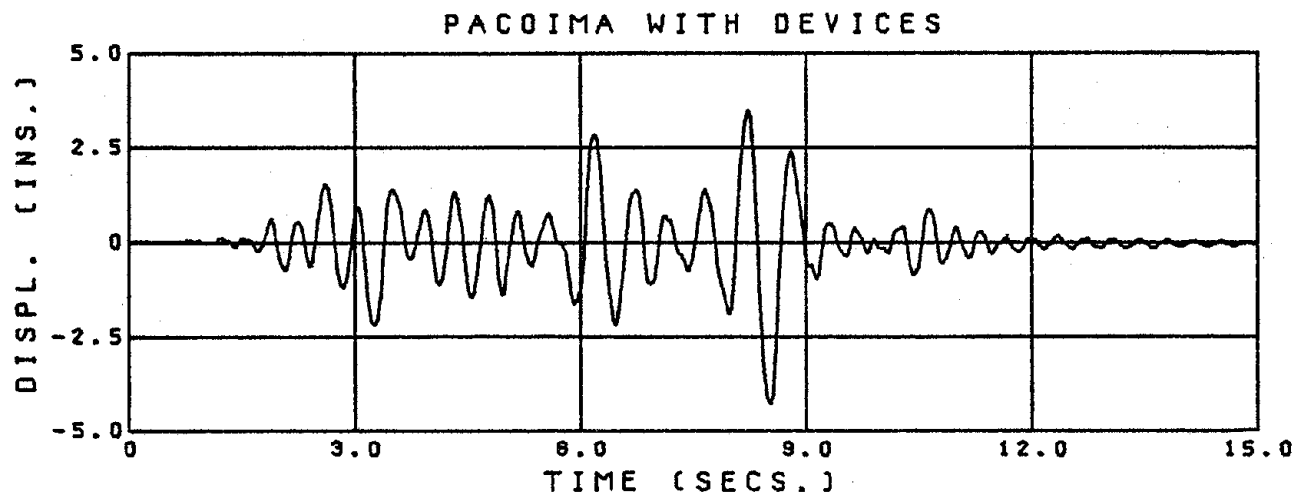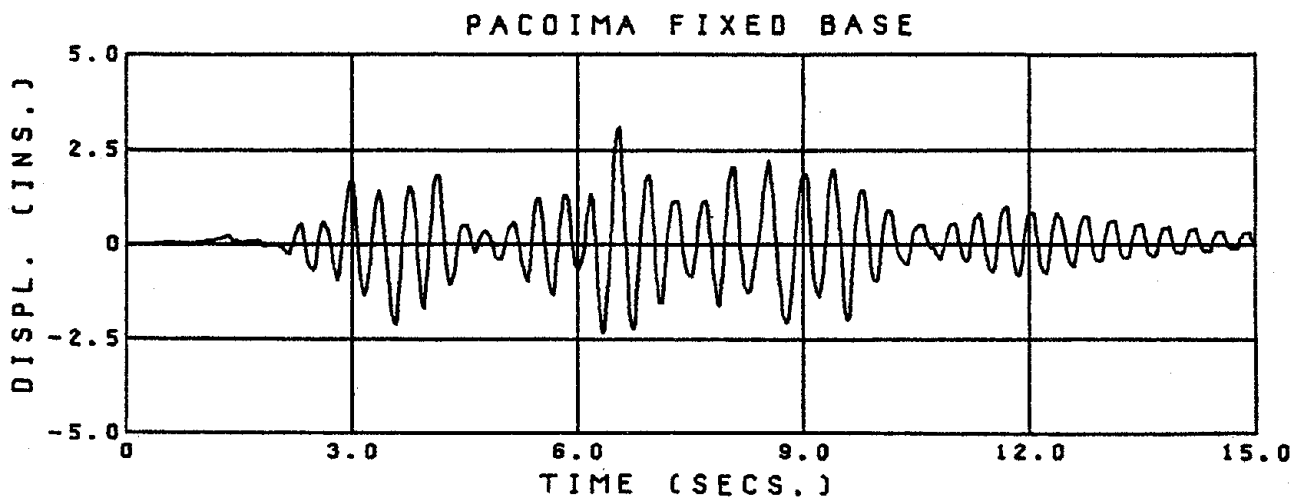
FIG. 13. PACOIMA RELATIVE THIRD FLOOR HORT. DISPL. COMPARISONS.
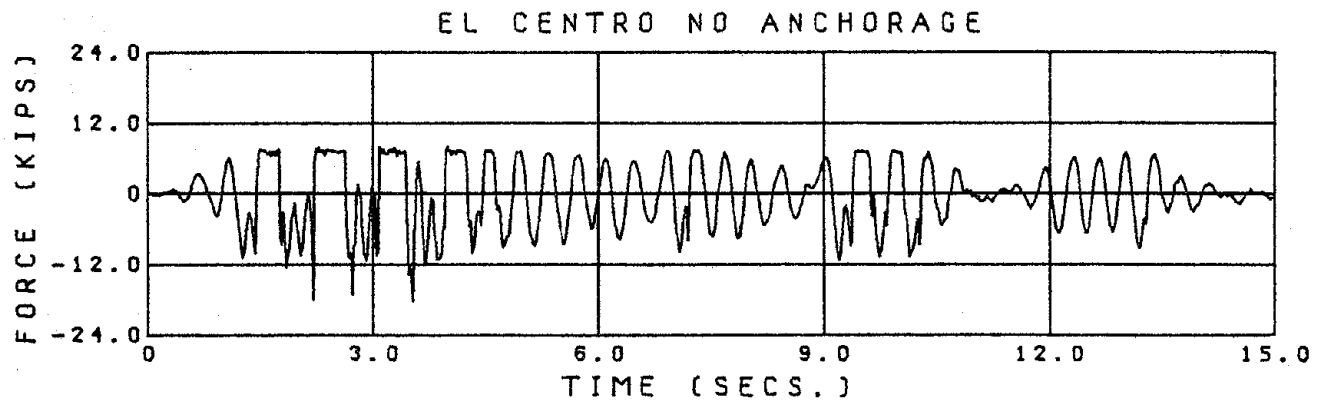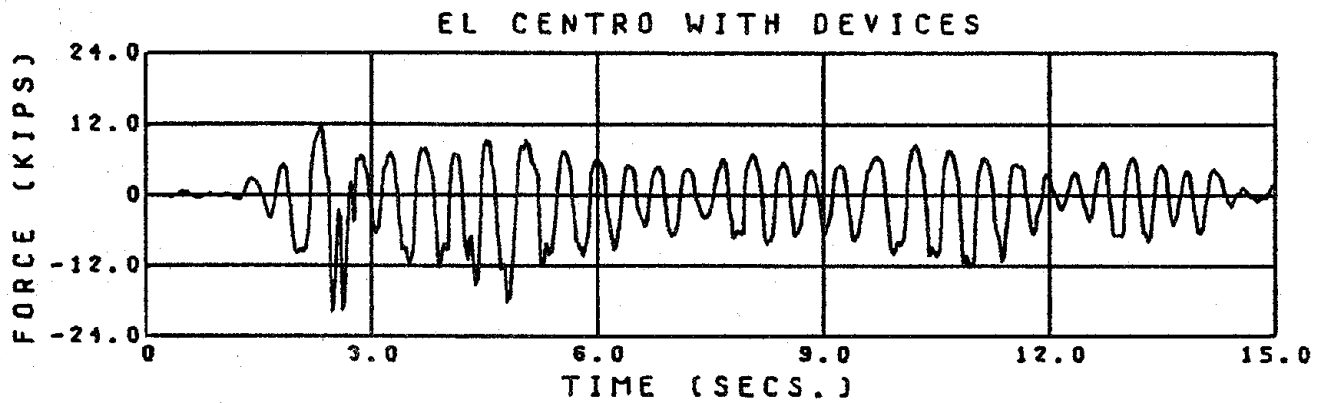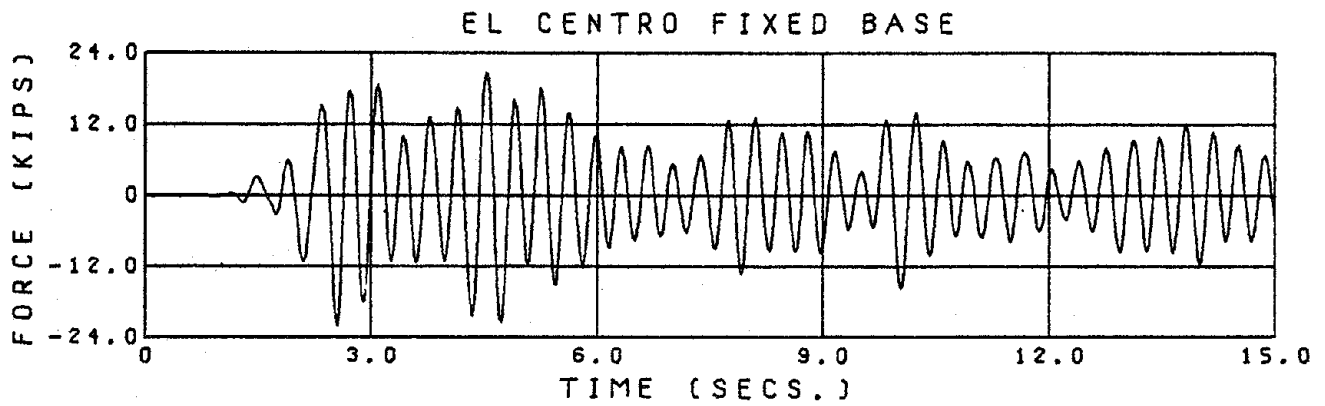
FIG. 14. EL CENTRO FIRST FLOOR NORTH COLUMN AXIAL FORCE COMPARISONS.
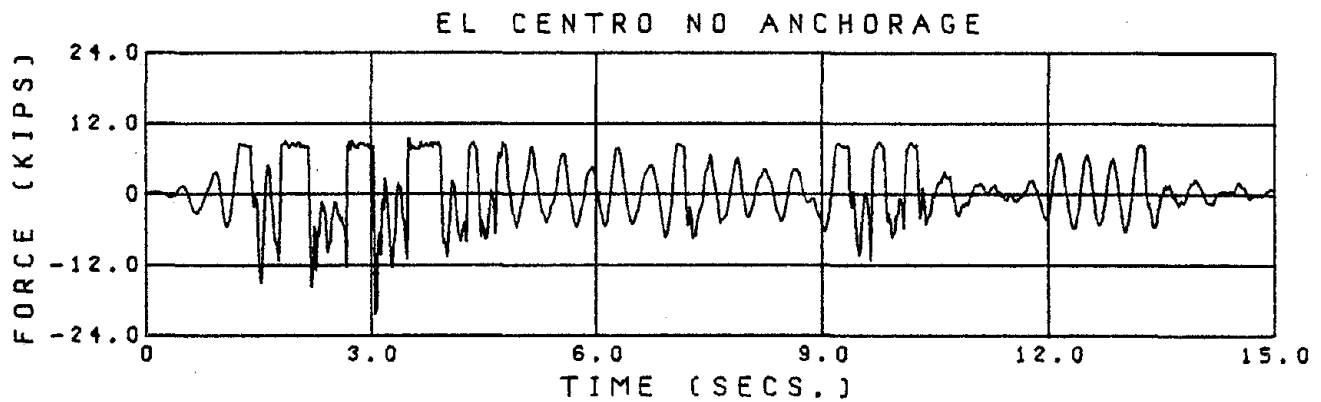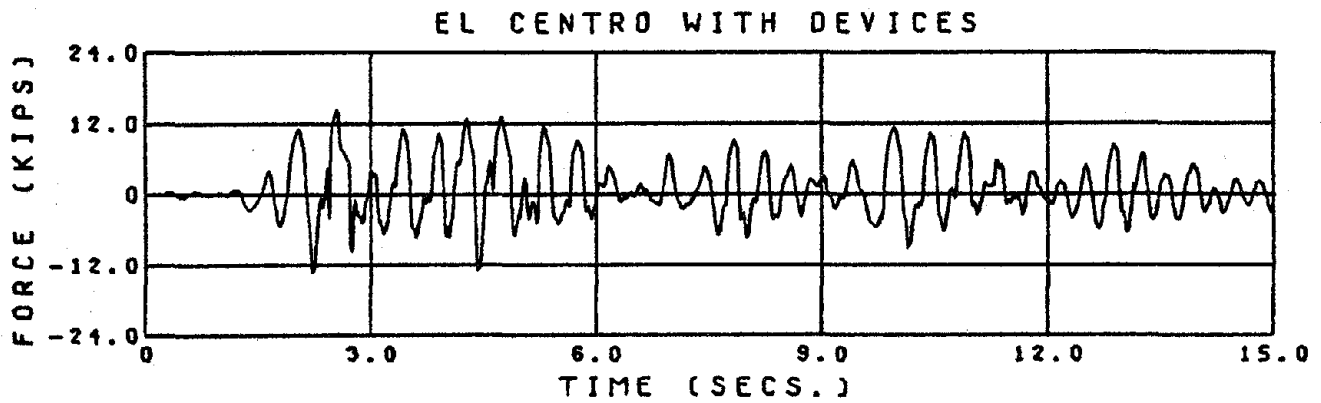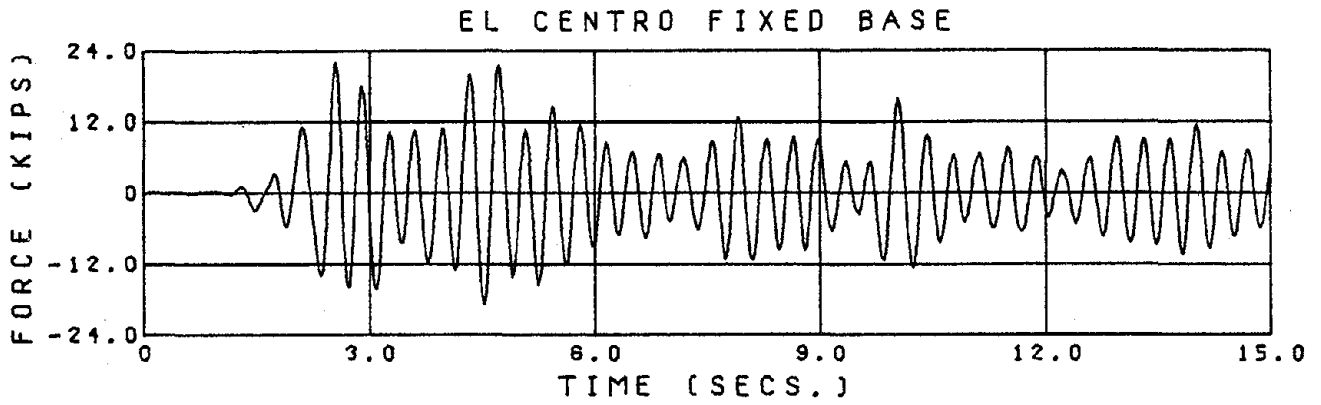
FIG. 15. EL CENTRO FIRST FLOOR SOUTH COLUMN AXIAL FORCE COMPARISONS.
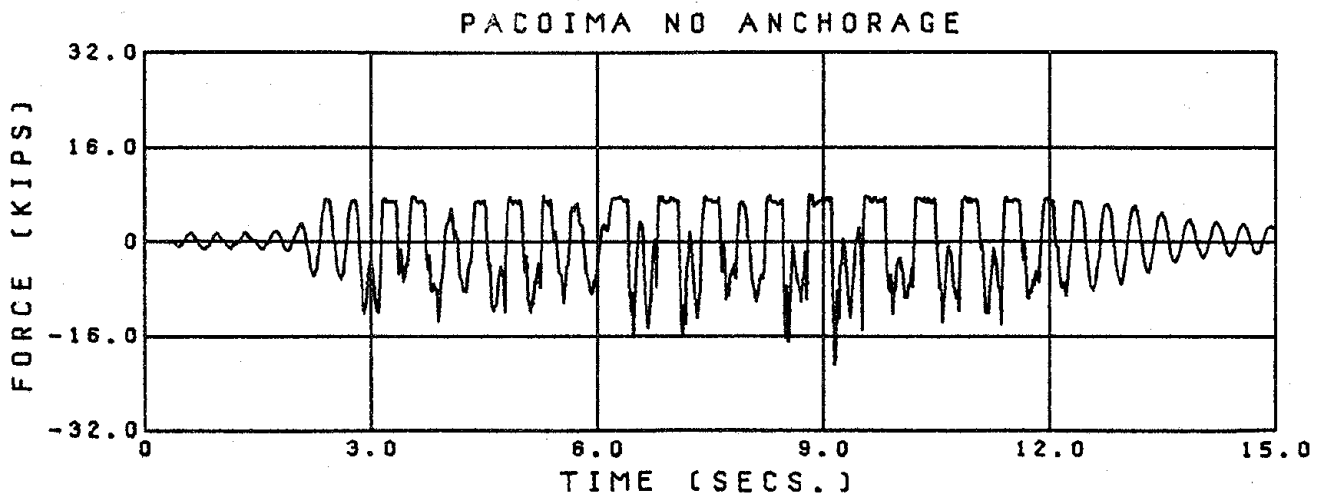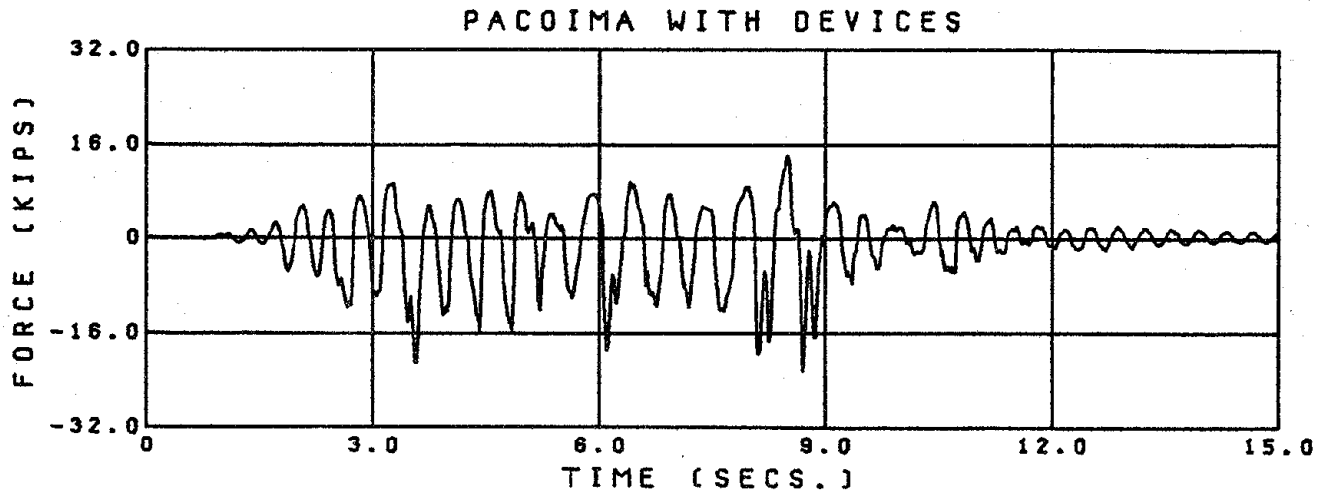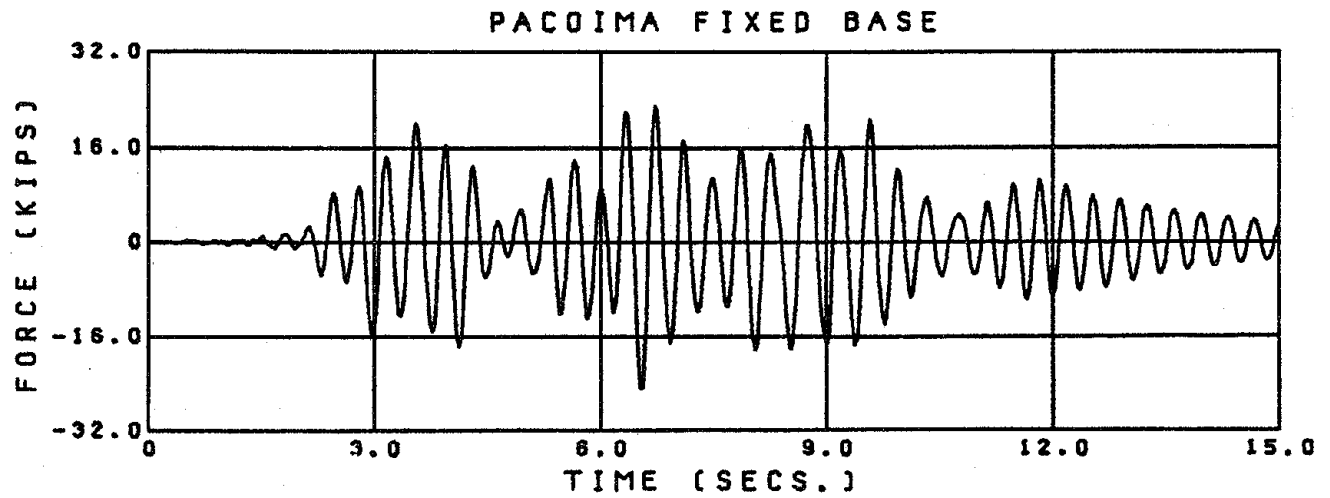
FIG. 16. PACOIMA FIRST FLOOR NORTH COLUMN AXIAL FORCE COMPARISONS.

FIG. 17. PACOIMA FIRST FLOOR SOUTH COLUMN AXIAL FORCE COMPARISONS.

FIG. 18. EL CENTRO BASE SHEAR COMPARISONS.

FIG. 19. PACOIMA BASE SHEAR COMPARISONS.

FIG. 20. EL CENTRO BASE OVERTURNING MOMENT COMPARISONS.

FIG. 21. PACOIMA BASE OVERTURNING MOMENT COMPARISONS.

EARTHQUAKE ENGINEERING RESEARCH CENTER REPORTS

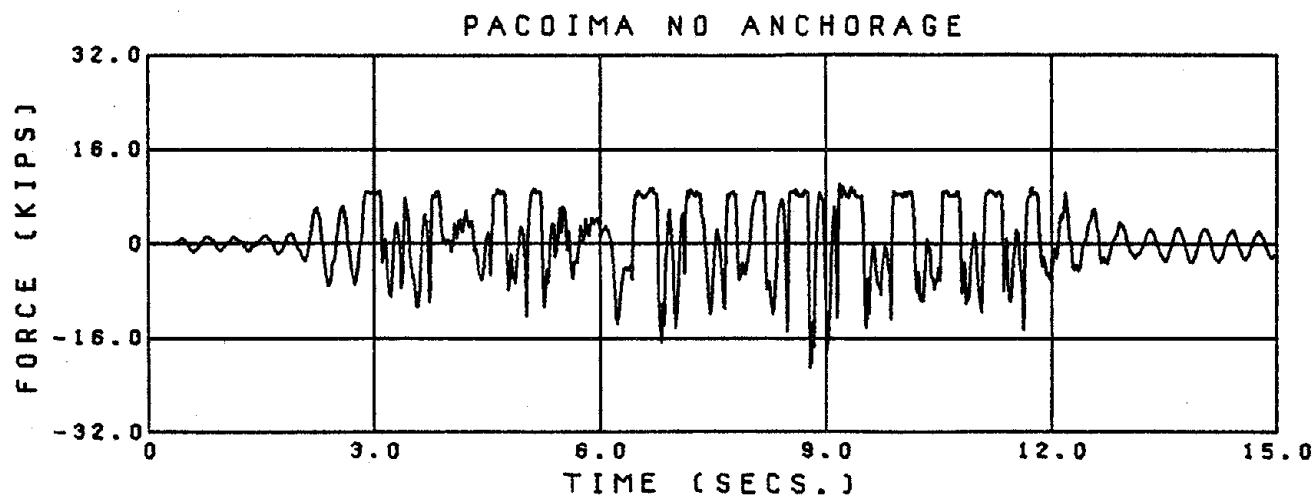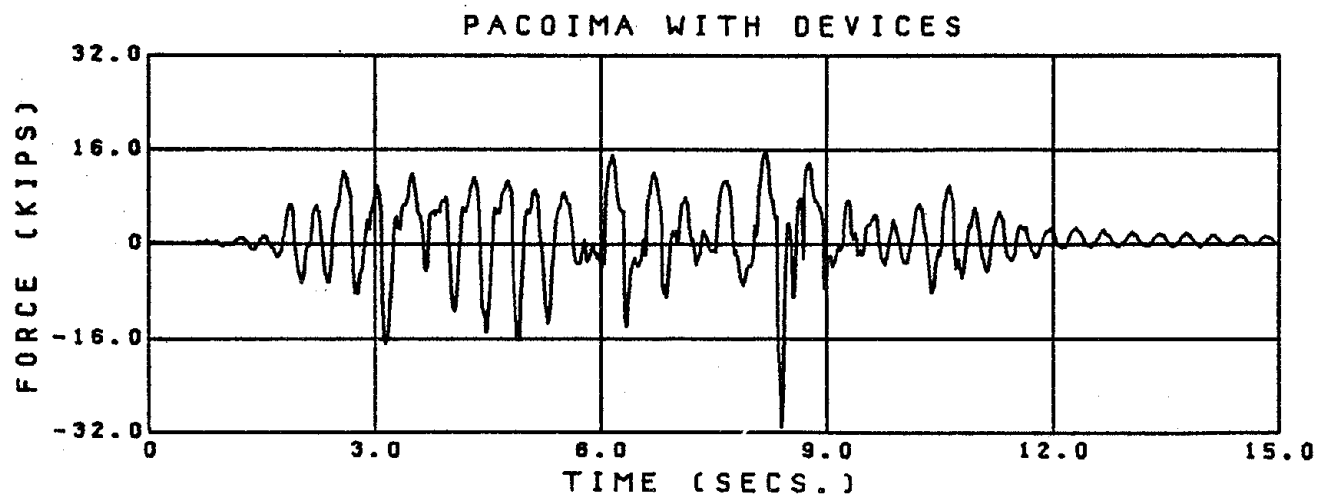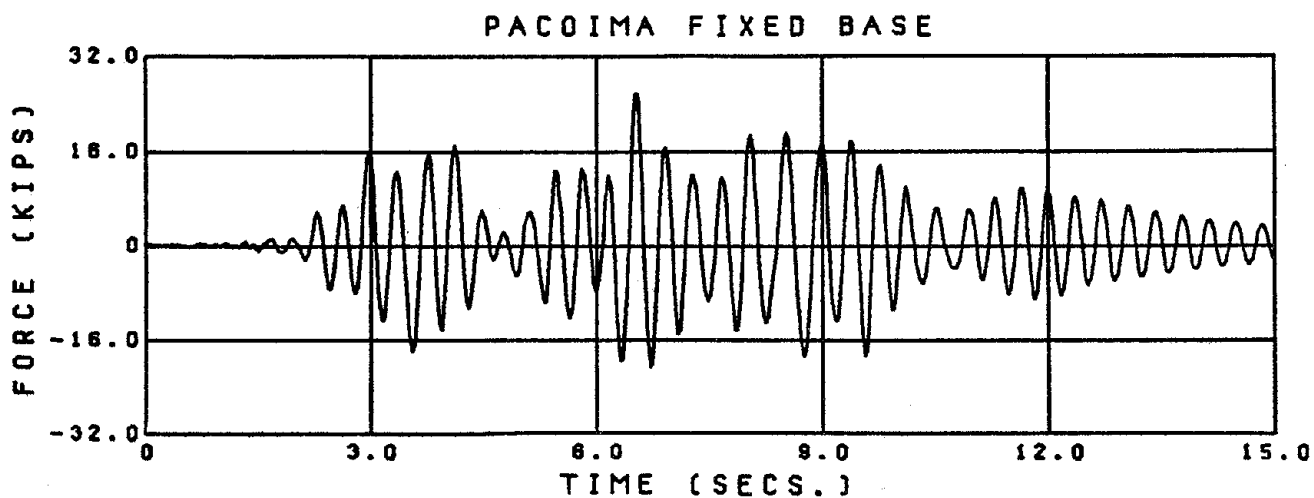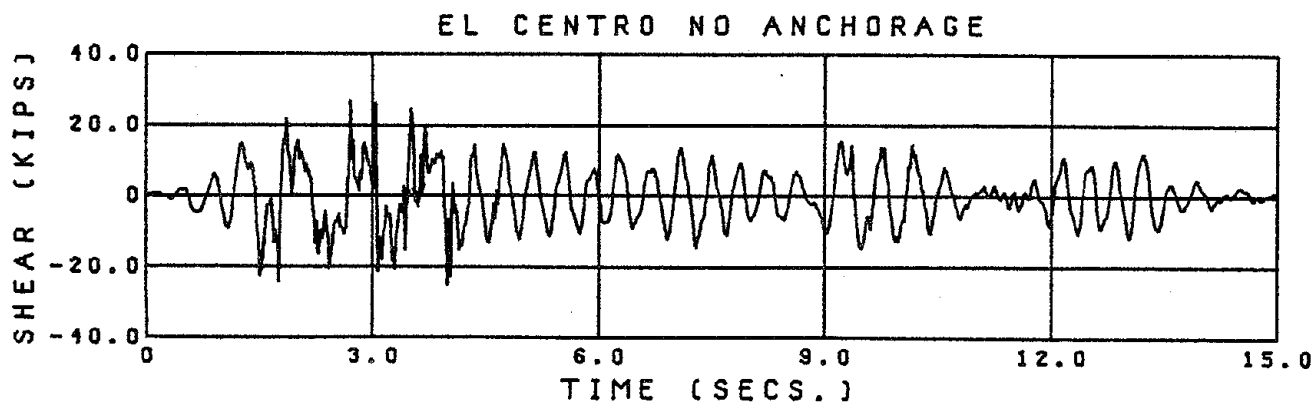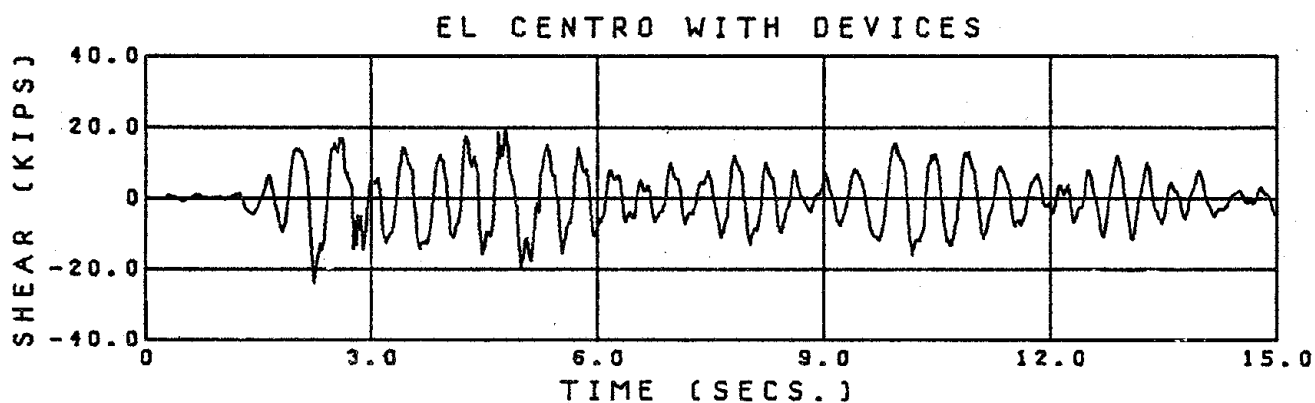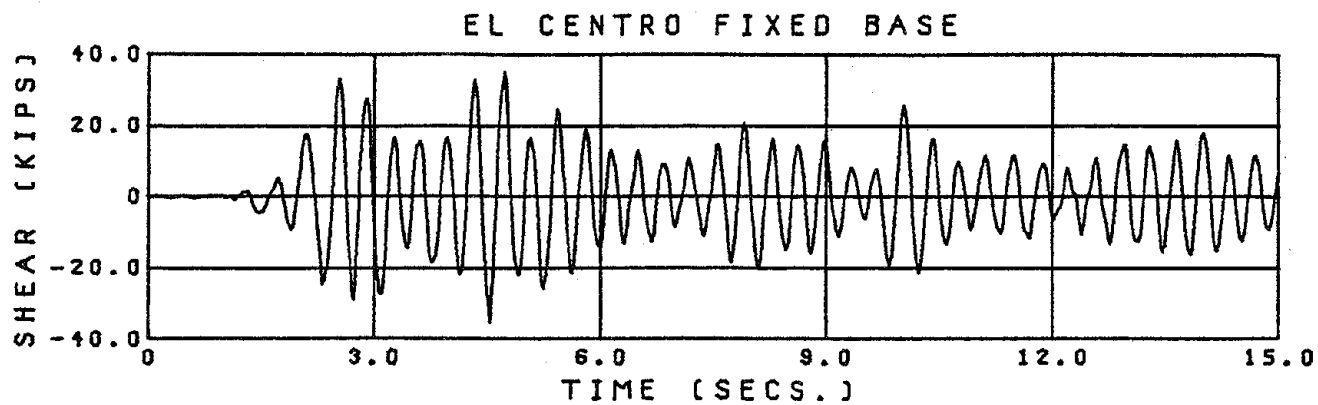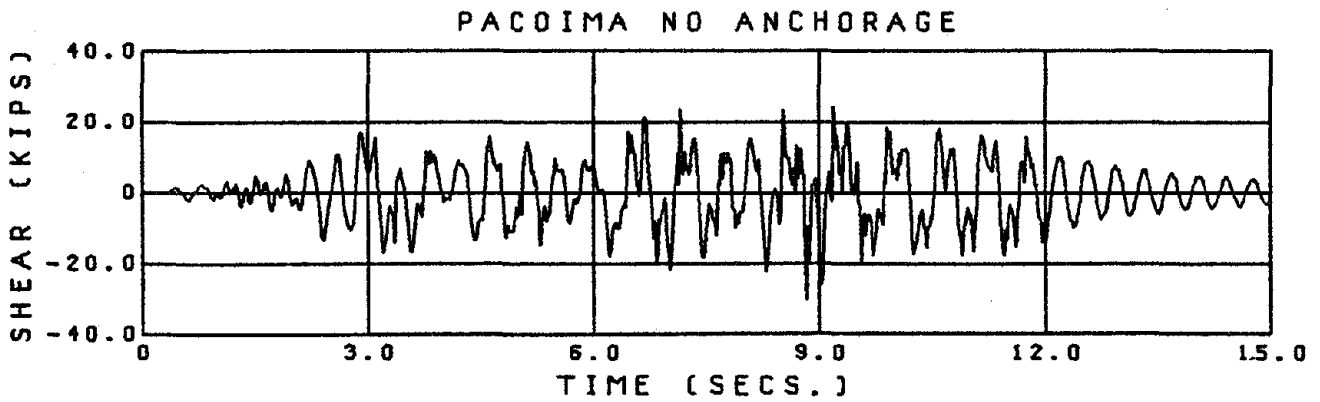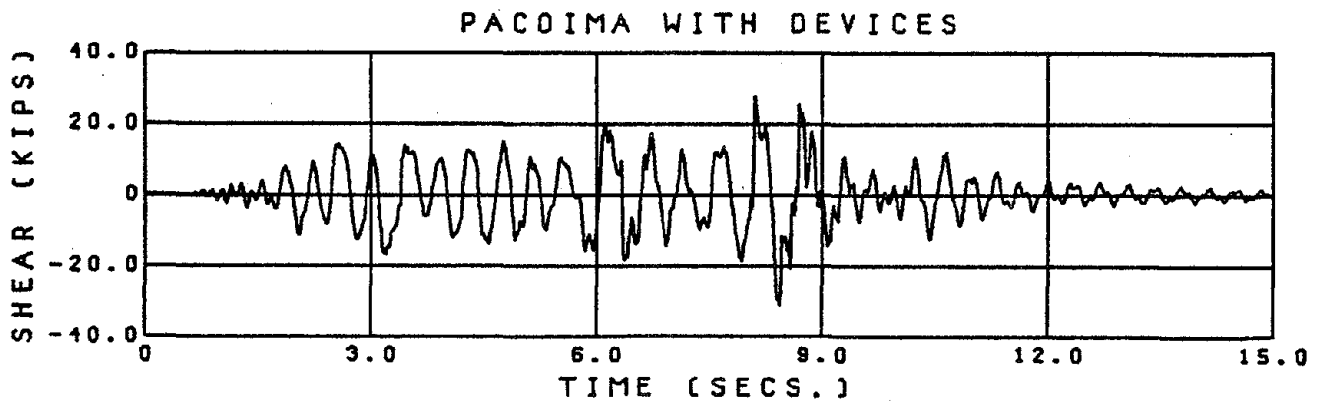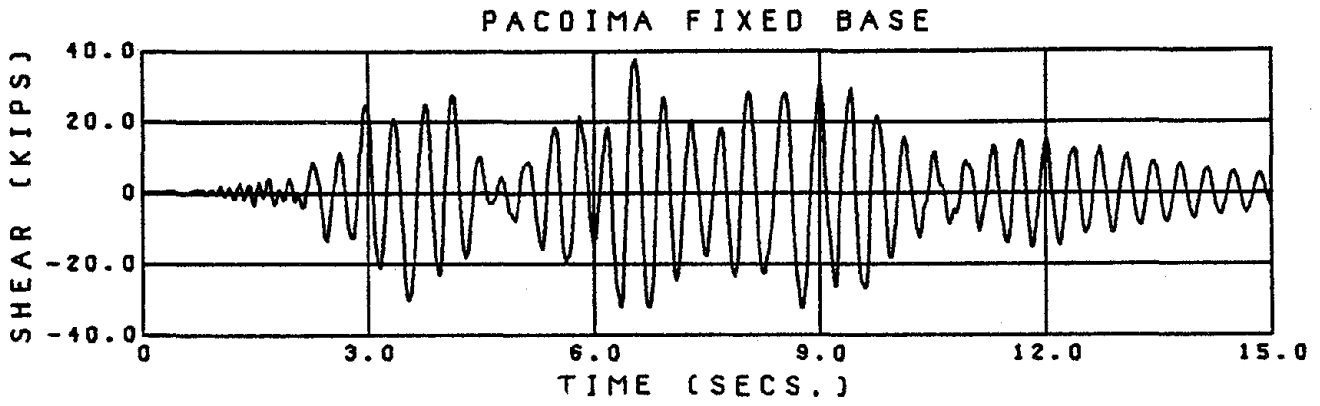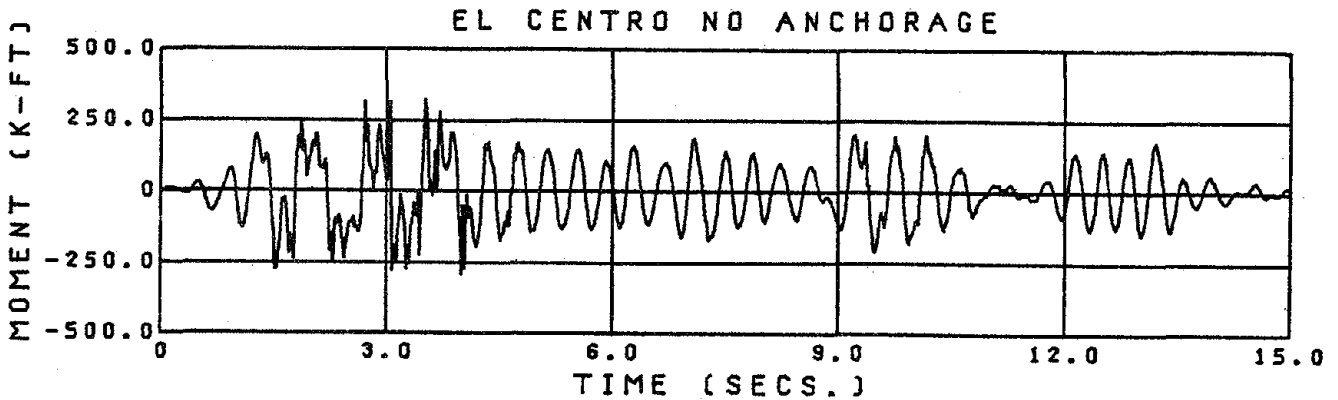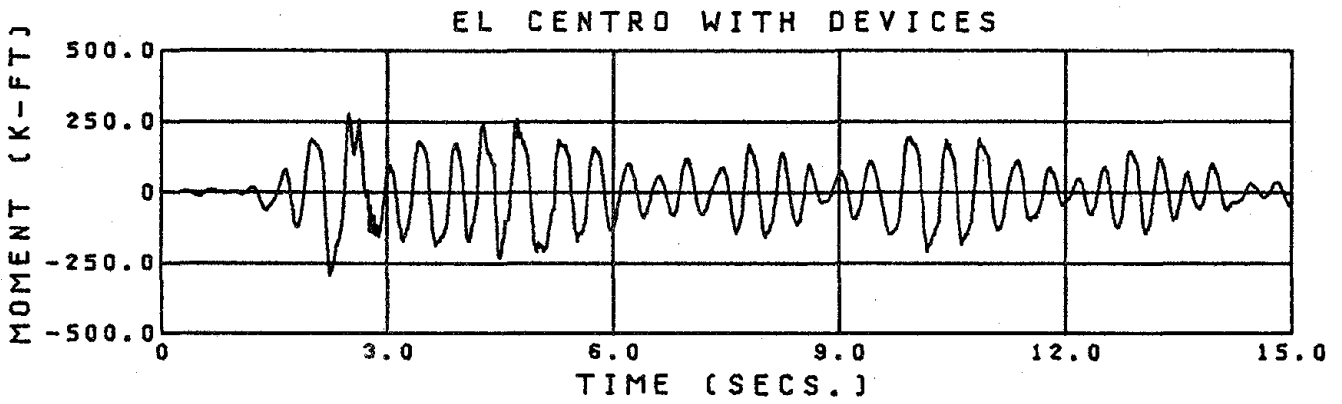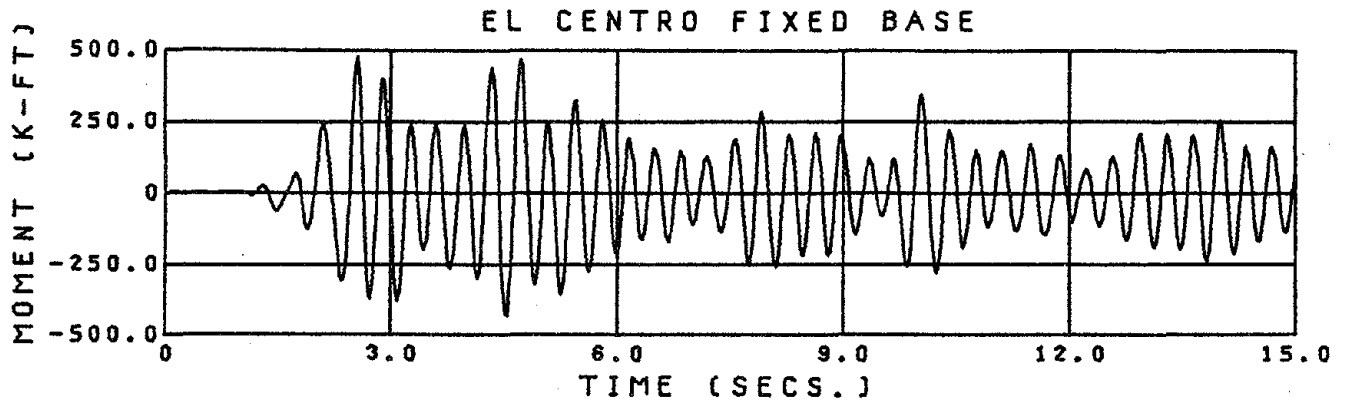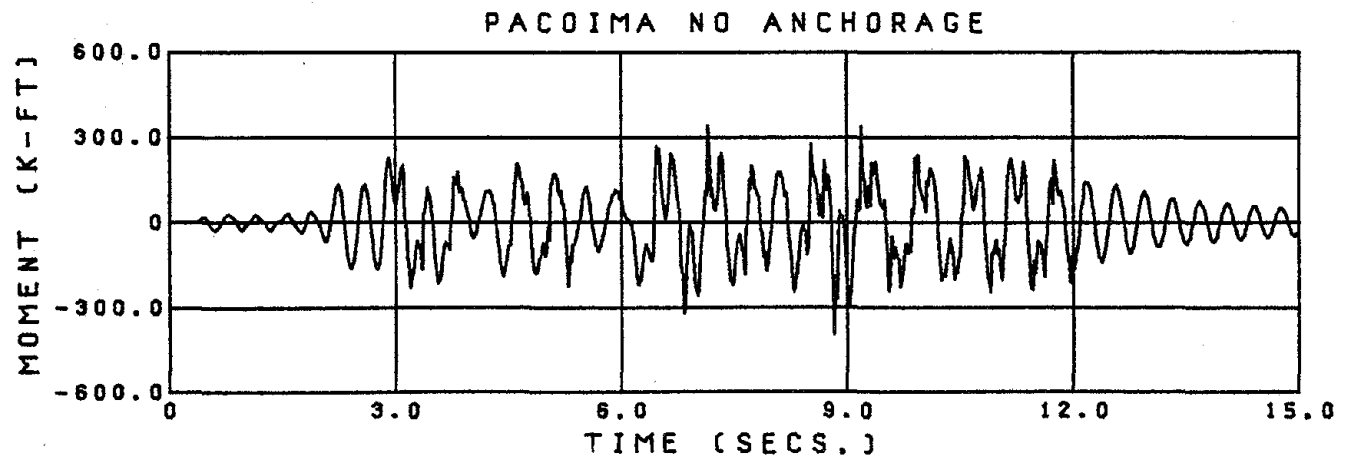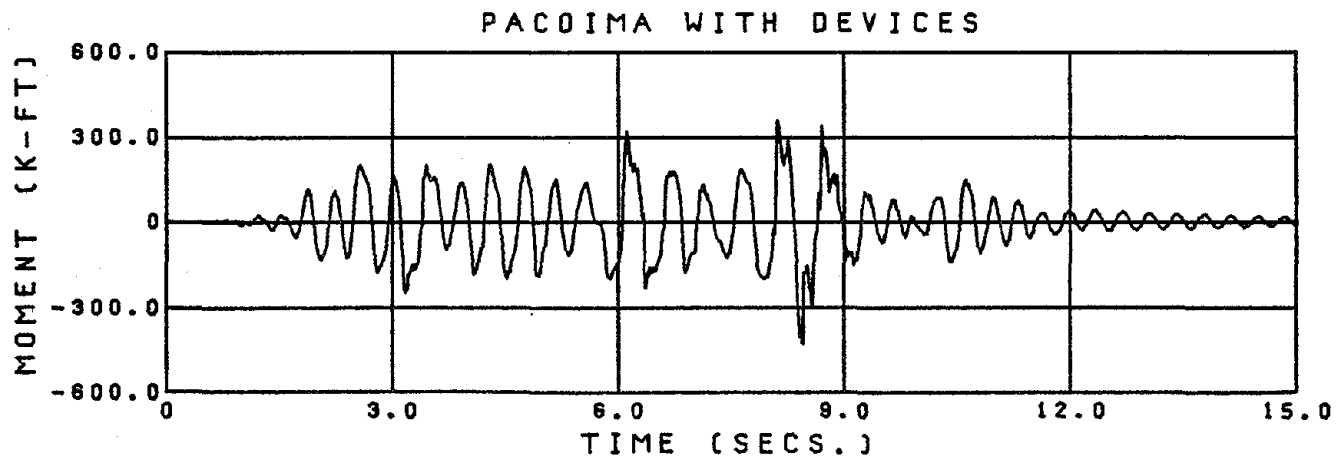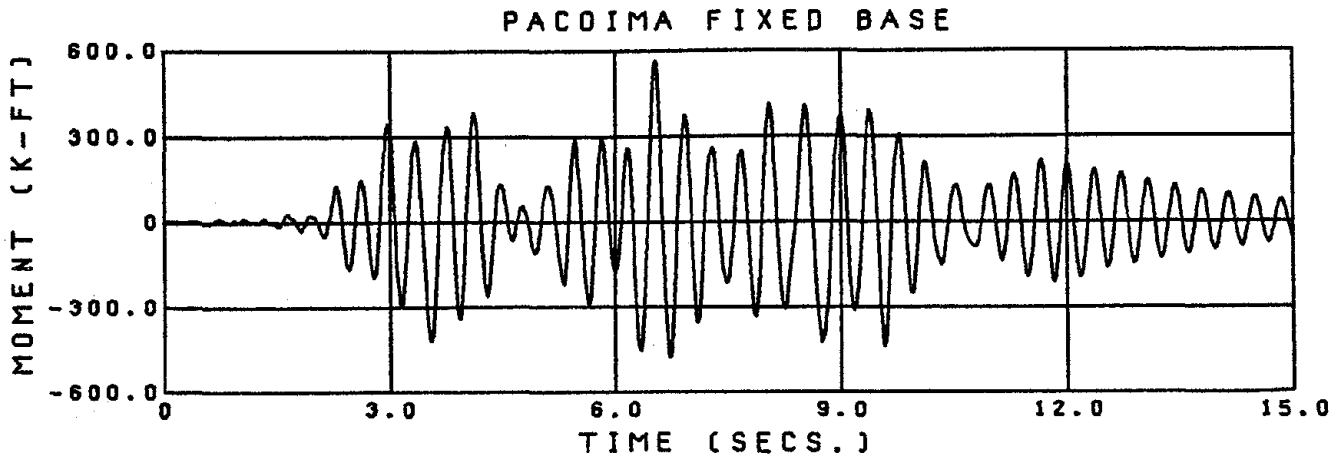NOTE: Numbers in parenthesis are Accession Numbers assigned by the National Technical Information Service; these are followed by a price code. Copies of the reports may be ordered from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia, 22161. Accession Numbers should be quoted on orders for reports (PB --- ---) and remittance must accompany each order. Reports without this information were not available at time of printing. Upon request, EERC will mail inquirers this information when it becomes available.

EERC 67-1 "Feasibility Study Large-Scale Earthquake Simulator Facility," by J. Penzien, J.G. Bouwkamp, R.W. Clough and D. Rea - 1967 (PB 187 905)A07

EERC 68-1 Unassigned

EERC 68-2 "Inelastic Behavior of Beam-to-Column Subassemblages Under Repeated Loading," by V.V. Bertero - 1968 (PB 184 888)A05

EERC 68-3 "A Graphical Method for Solving the Wave Reflection-Refraction Problem," by H.D. McNiven and Y. Mengi - 1968 (PB 187 943)A03

EERC 68-4 "Dynamic Properties of McKinley School Buildings," by D. Rea, J.G. Bouwkamp and R.W. Clough - 1968 (PB 187 902)A07

EERC 68-5 "Characteristics of Rock Motions During Earthquakes," by H.B. Seed, I.M. Idriss and F.W. Kiefer - 1968 (PB 188 338)A03

EERC 69-1 "Earthquake Engineering Research at Berkeley," - 1969 (PB 187 906)A11

EERC 69-2 "Nonlinear Seismic Response of Earth Structures," by M. Dibaj and J. Penzien - 1969 (PB 187 904)A08

EERC 69-3 "Probabilistic Study of the Behavior of Structures During Earthquakes," by R. Ruiz and J. Penzien - 1969 (PB 187 886)A06

EERC 69-4 "Numerical Solution of Boundary Value Problems in Structural Mechanics by Reduction to an Initial Value Formulation," by N. Distefano and J. Schujman - 1969 (PB 187 942)A02

EERC 69-5 "Dynamic Programming and the Solution of the Biharmonic Equation," by N. Distefano - 1969 (PB 187 941)A03

EERC 69-6 "Stochastic Analysis of Offshore Tower Structures," by A.K. Malhotra and J. Penzien - 1969 (PB 187 903)A09

EERC 69-7 "Rock Motion Accelerograms for High Magnitude Earthquakes," by H.B. Seed and I.M. Idriss - 1969 (PB 187 940)A02

EERC 69-8 "Structural Dynamics Testing Facilities at the University of California, Berkeley," by R.M. Stephen, J.G. Bouwkamp, R.W. Clough and J. Penzien - 1969 (PB 189 111)A04

EERC 69-9 "Seismic Response of Soil Deposits Underlain by Sloping Rock Boundaries," by H. Dezfulian and H.B. Seed 1969 (PB 189 114)A03

EERC 69-10 "Dynamic Stress Analysis of Axisymmetric Structures Under Arbitrary Loading," by S. Ghosh and E.L. Wilson 1969 (PB 189 026)A10

EERC 69-11 "Seismic Behavior of Multistory Frames Designed by Different Philosophies," by J.C. Anderson and V. V. Bertero - 1969 (PB 190 662)A10

EERC 69-12 "Stiffness Degradation of Reinforcing Concrete Members Subjected to Cyclic Flexural Moments," by V.V. Bertero, B. Bresler and H. Ming Liao - 1969 (PB 202 942)A07

EERC 69-13 "Response of Non-Uniform Soil Deposits to Travelling Seismic Waves," by H. Dezfulian and H.B. Seed - 1969 (PB 191 023)A03

EERC 69-14 "Damping Capacity of a Model Steel Structure," by D. Rea, R.W. Clough and J.G. Bouwkamp - 1969 (PB 190 663)A06

EERC 69-15 "Influence of Local Soil Conditions on Building Damage Potential during Earthquakes," by H.B. Seed and I.M. Idriss - 1969 (PB 191 036)A03

EERC 69-16 "The Behavior of Sands Under Seismic Loading Conditions," by M.L. Silver and H.B. Seed - 1969 (AD 714 982)A07

EERC 70-1 "Earthquake Response of Gravity Dams," by A.K. Chopra - 1970 (AD 709 640)A03

EERC 70-2 "Relationships between Soil Conditions and Building Damage in the Caracas Earthquake of July 29, 1967," by H.B. Seed, I.M. Idriss and H. Dezfulian - 1970 (PB 195 762)A05

EERC 70-3 "Cyclic Loading of Full Size Steel Connections," by E.P. Popov and R.M. Stephen - 1970 (PB 213 545)A04

EERC 70-4 "Seismic Analysis of the Charaima Building, Caraballeda, Venezuela," by Subcommittee of the SEAONC Research Committee: V.V. Bertero, P.F. Fratessa, S.A. Mahin, J.H. Sexton, A.C. Scordelis, E.L. Wilson, L.A. Wyllie, H.B. Seed and J. Penzien, Chairman - 1970 (PB 201 455)A06

Preceding page blank

EERC 70-5   "A Computer Program for Earthquake Analysis of Dams," by A.K. Chopra and P. Chakrabarti - 1970 (AD 723 994)A05

EERC 70-6   "The Propagation of Love Waves Across Non-Horizontally Layered Structures," by J. Lysmer and L.A. Drake 1970 (PB 197 896)A03

EERC 70-7   "Influence of Base Rock Characteristics on Ground Response," by J. Lysmer, H.B. Seed and P.B. Schnabel 1970 (PB 197 897)A03

EERC 70-8   "Applicability of Laboratory Test Procedures for Measuring Soil Liquefaction Characteristics under Cyclic Loading," by H.B. Seed and W.H. Peacock - 1970 (PB 198 016)A03

EERC 70-9   "A Simplified Procedure for Evaluating Soil Liquefaction Potential," by H.B. Seed and I.M. Idriss - 1970 (PB 198 009)A03

EERC 70-10 "Soil Moduli and Damping Factors for Dynamic Response Analysis," by H.B. Seed and I.M. Idriss - 1970 (PB 197 869)A03

EERC 71-1   "Koyna Earthquake of December 11, 1967 and the Performance of Koyna Dam," by A.K. Chopra and P. Chakrabarti 1971 (AD 731 496)A06

EERC 71-2   "Preliminary In-Situ Measurements of Anelastic Absorption in Soils Using a Prototype Earthquake Simulator," by R.D. Borcherdt and P.W. Rodgers - 1971 (PB 201 454)A03

EERC 71-3   "Static and Dynamic Analysis of Inelastic Frame Structures," by F.L. Porter and G.H. Powell - 1971 (PB 210 135)A06

EERC 71-4   "Research Needs in Limit Design of Reinforced Concrete Structures," by V.V. Bertero - 1971 (PB 202 943)A04

EERC 71-5   "Dynamic Behavior of a High-Rise Diagonally Braced Steel Building," by D. Rea, A.A. Shah and J.G. Bouwkamp 1971 (PB 203 584)A06

EERC 71-6   "Dynamic Stress Analysis of Porous Elastic Solids Saturated with Compressible Fluids," by J. Ghaboussi and E. L. Wilson - 1971 (PB 211 396)A06

EERC 71-7   "Inelastic Behavior of Steel Beam-to-Column Subassemblages," by H. Krawinkler, V.V. Bertero and E.P. Popov 1971 (PB 211 335)A14

EERC 71-8   "Modification of Seismograph Records for Effects of Local Soil Conditions," by P. Schnabel, H.B. Seed and J. Lysmer - 1971 (PB 214 450)A03

EERC 72-1   "Static and Earthquake Analysis of Three Dimensional Frame and Shear Wall Buildings," by E.L. Wilson and H.H. Dovey - 1972 (PB 212 904)A05

EERC 72-2   "Accelerations in Rock for Earthquakes in the Western United States," by P.B. Schnabel and H.B. Seed - 1972 (PB 213 100)A03

EERC 72-3   "Elastic-Plastic Earthquake Response of Soil-Building Systems," by T. Minami - 1972 (PB 214 868)A08

EERC 72-4   "Stochastic Inelastic Response of Offshore Towers to Strong Motion Earthquakes," by M.K. Kaul - 1972 (PB 215 713)A05

EERC 72-5   "Cyclic Behavior of Three Reinforced Concrete Flexural Members with High Shear," by E.P. Popov, V.V. Bertero and H. Krawinkler - 1972 (PB 214 555)A05

EERC 72-6   "Earthquake Response of Gravity Dams Including Reservoir Interaction Effects," by P. Chakrabarti and A.K. Chopra - 1972 (AD 762 330)A08

EERC 72-7   "Dynamic Properties of Pine Flat Dam," by D. Rea, C.Y. Liaw and A.K. Chopra - 1972 (AD 763 928)A05

EERC 72-8   "Three Dimensional Analysis of Building Systems," by E.L. Wilson and H.H. Dovey - 1972 (PB 222 438)A06

EERC 72-9   "Rate of Loading Effects on Uncracked and Repaired Reinforced Concrete Members," by S. Mahin, V.V. Bertero, D. Rea and M. Atalay - 1972 (PB 224 520)A08

EERC 72-10 "Computer Program for Static and Dynamic Analysis of Linear Structural Systems," by E.L. Wilson, K.-J. Bathe, J.E. Peterson and H.H.Dovey - 1972 (PB 220 437)A04

EERC 72-11 "Literature Survey - Seismic Effects on Highway Bridges," by T. Iwasaki, J. Penzien and R.W. Clough - 1972 (PB 215 613)A19

EERC 72-12 "SHAKE-A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites," by P.B. Schnabel and J. Lysmer - 1972 (PB 220 207)A06

EERC 73-1   "Optimal Seismic Design of Multistory Frames," by V.V. Bertero and H. Kamil - 1973

EERC 73-2   "Analysis of the Slides in the San Fernando Dams During the Earthquake of February 9, 1971," by H.B. Seed, K.L. Lee, I.M. Idriss and F. Makdisi - 1973 (PB 223 402)A14

EERC 73-3 "Computer Aided Ultimate Load Design of Unbraced Multistory Steel Frames," by M.B. El-Hafez and G.H. Powell 1973 (PB 248 315)A09

EERC 73-4 "Experimental Investigation into the Seismic Behavior of Critical Regions of Reinforced Concrete Components as Influenced by Moment and Shear," by M. Celebi and J. Penzien - 1973 (PB 215 884)A09

EERC 73-5 "Hysteretic Behavior of Epoxy-Repaired Reinforced Concrete Beams," by M. Celebi and J. Penzien - 1973 (PB 239 568)A03

EERC 73-6 "General Purpose Computer Program for Inelastic Dynamic Response of Plane Structures," by A. Kanaan and G.H. Powell - 1973 (PB 221 260)A08

EERC 73-7 "A Computer Program for Earthquake Analysis of Gravity Dams Including Reservoir Interaction," by P. Chakrabarti and A.K. Chopra - 1973 (AD 766 271)A04

EERC 73-8 "Behavior of Reinforced Concrete Deep Beam-Column Subassemblages Under Cyclic Loads," by O. Küstü and J.G. Bouwkamp - 1973 (PB 246 117)A12

EERC 73-9 "Earthquake Analysis of Structure-Foundation Systems," by A.K. Vaish and A.K. Chopra - 1973 (AD 766 272)A07

EERC 73-10 "Deconvolution of Seismic Response for Linear Systems," by R.B. Reimer - 1973 (PB 227 179)A08

EERC 73-11 "SAP IV: A Structural Analysis Program for Static and Dynamic Response of Linear Systems," by K.-J. Bathe, E.L. Wilson and F.E. Peterson - 1973 (PB 221 967)A09

EERC 73-12 "Analytical Investigations of the Seismic Response of Long, Multiple Span Highway Bridges," by W.S. Tseng and J. Penzien - 1973 (PB 227 816)A10

EERC 73-13 "Earthquake Analysis of Multi-Story Buildings Including Foundation Interaction," by A.K. Chopra and J.A. Gutierrez - 1973 (PB 222 970)A03

EERC 73-14 "ADAP: A Computer Program for Static and Dynamic Analysis of Arch Dams," by R.W. Clough, J.M. Raphael and S. Mojtahedi - 1973 (PB 223 763)A09

EERC 73-15 "Cyclic Plastic Analysis of Structural Steel Joints," by R.B. Pinkney and R.W. Clough - 1973 (PB 226 843)A08

EERC 73-16 "QUAD-4: A Computer Program for Evaluating the Seismic Response of Soil Structures by Variable Damping Finite Element Procedures," by I.M. Idriss, J. Lysmer, R. Hwang and H.B. Seed - 1973 (PB 229 424)A05

EERC 73-17 "Dynamic Behavior of a Multi-Story Pyramid Shaped Building," by R.M. Stephen, J.P. Hollings and J.G. Bouwkamp - 1973 (PB 240 718)A06

EERC 73-18 "Effect of Different Types of Reinforcing on Seismic Behavior of Short Concrete Columns," by V.V. Bertero, J. Hollings, O. Küstü, R.M. Stephen and J.G. Bouwkamp - 1973

EERC 73-19 "Olive View Medical Center Materials Studies, Phase I," by B. Bresler and V.V. Bertero - 1973 (PB 235 986)A06

EERC 73-20 "Linear and Nonlinear Seismic Analysis Computer Programs for Long Multiple-Span Highway Bridges," by W.S. Tseng and J. Penzien - 1973

EERC 73-21 "Constitutive Models for Cyclic Plastic Deformation of Engineering Materials," by J.M. Kelly and P.P. Gillis 1973 (PB 226 024)A03

EERC 73-22 "DRAIN - 2D User's Guide," by G.H. Powell - 1973 (PB 227 016)A05

EERC 73-23 "Earthquake Engineering at Berkeley - 1973," (PB 226 033)A11

EERC 73-24 Unassigned

EERC 73-25 "Earthquake Response of Axisymmetric Tower Structures Surrounded by Water," by C.Y. Liaw and A.K. Chopra 1973 (AD 773 052)A09

EERC 73-26 "Investigation of the Failures of the Olive View Stairtowers During the San Fernando Earthquake and Their Implications on Seismic Design," by V.V. Bertero and R.G. Collins - 1973 (PB 235 106)A13

EERC 73-27 "Further Studies on Seismic Behavior of Steel Beam-Column Subassemblages," by V.V. Bertero, H. Krawinkler and E.P. Popov - 1973 (PB 234 172)A06

EERC 74-1 "Seismic Risk Analysis," by C.S. Oliveira - 1974 (PB 235 920)A06

EERC 74-2 "Settlement and Liquefaction of Sands Under Multi-Directional Shaking," by R. Pyke, C.K. Chan and H.B. Seed 1974

EERC 74-3 "Optimum Design of Earthquake Resistant Shear Buildings," by D. Ray, K.S. Pister and A.K. Chopra - 1974 (PB 231 172)A06

EERC 74-4 "LUSH - A Computer Program for Complex Response Analysis of Soil-Structure Systems," by J. Lysmer, T. Udaka, H.B. Seed and R. Hwang - 1974 (PB 236 796)A05

EERC 74-5   "Sensitivity Analysis for Hysteretic Dynamic Systems: Applications to Earthquake Engineering," by D. Ray
1974 (PB 233 213)A06

EERC 74-6   "Soil Structure Interaction Analyses for Evaluating Seismic Response," by H.B. Seed, J. Lysmer and R. Hwang
1974 (PB 236 519)A04

EERC 74-7   Unassigned

EERC 74-8   "Shaking Table Tests of a Steel Frame - A Progress Report," by R.W. Clough and D. Tang - 1974 (PB 240 869)A03

EERC 74-9   "Hysteretic Behavior of Reinforced Concrete Flexural Members with Special Web Reinforcement," by
V.V. Bertero, E.P. Popov and T.Y. Wang - 1974 (PB 236 797)A07

EERC 74-10   "Applications of Reliability-Based, Global Cost Optimization to Design of Earthquake Resistant Structures,"
by E. Vitiello and K.S. Pister - 1974 (PB 237 231)A06

EERC 74-11   "Liquefaction of Gravelly Soils Under Cyclic Loading Conditions," by R.T. Wong, H.B. Seed and C.K. Chan
1974 (PB 242 042)A03

EERC 74-12   "Site-Dependent Spectra for Earthquake-Resistant Design," by H.B. Seed, C. Ugas and J. Lysmer - 1974
(PB 240 953)A03

EERC 74-13   "Earthquake Simulator Study of a Reinforced Concrete Frame," by P. Hidalgo and R.W. Clough - 1974
(PB 241 944)A13

EERC 74-14   "Nonlinear Earthquake Response of Concrete Gravity Dams," by N. Pal - 1974 (AD/A 006 583)A06

EERC 74-15   "Modeling and Identification in Nonlinear Structural Dynamics - I. One Degree of Freedom Models," by
N. Distefano and A. Rath - 1974 (PB 241 548)A06

EERC 75-1   "Determination of Seismic Design Criteria for the Dumbarton Bridge Replacement Structure, Vol. I: Description,
Theory and Analytical Modeling of Bridge and Parameters," by F. Baron and S.-H. Pang - 1975 (PB 259 407)A15

EERC 75-2   "Determination of Seismic Design Criteria for the Dumbarton Bridge Replacement Structure, Vol. II: Numerical
Studies and Establishment of Seismic Design Criteria," by F. Baron and S.-H. Pang - 1975 (PB 259 408)A11
(For set of EERC 75-1 and 75-2 (PB 259 406))

EERC 75-3   "Seismic Risk Analysis for a Site and a Metropolitan Area," by C.S. Oliveira - 1975 (PB 248 134)A09

EERC 75-4   "Analytical Investigations of Seismic Response of Short, Single or Multiple-Span Highway Bridges," by
M.-C. Chen and J. Penzien - 1975 (PB 241 454)A09

EERC 75-5   "An Evaluation of Some Methods for Predicting Seismic Behavior of Reinforced Concrete Buildings," by S.A.
Mahin and V.V. Bertero - 1975 (PB 246 306)A16

EERC 75-6   "Earthquake Simulator Study of a Steel Frame Structure, Vol. I: Experimental Results," by R.W. Clough and
D.T. Tang - 1975 (PB 243 981)A13

EERC 75-7   "Dynamic Properties of San Bernardino Intake Tower," by D. Rea, C.-Y. Liaw and A.K. Chopra - 1975 (AD/A008 406)
A05

EERC 75-8   "Seismic Studies of the Articulation for the Dumbarton Bridge Replacement Structure, Vol. I: Description,
Theory and Analytical Modeling of Bridge Components," by F. Baron and R.E. Hamati - 1975 (PB 251 539)A07

EERC 75-9   "Seismic Studies of the Articulation for the Dumbarton Bridge Replacement Structure, Vol. 2: Numerical
Studies of Steel and Concrete Girder Alternates," by F. Baron and R.E. Hamati - 1975 (PB 251 540)A10

EERC 75-10   "Static and Dynamic Analysis of Nonlinear Structures," by D.P. Mondkar and G.H. Powell - 1975 (PB 242 434)A08

EERC 75-11   "Hysteretic Behavior of Steel Columns," by E.P. Popov, V.V. Bertero and S. Chandramouli - 1975 (PB 252 365)A11

EERC 75-12   "Earthquake Engineering Research Center Library Printed Catalog," - 1975 (PB 243 711)A26

EERC 75-13   "Three Dimensional Analysis of Building Systems (Extended Version)," by E.L. Wilson, J.P. Hollings and
H.H. Dovey - 1975 (PB 243 989)A07

EERC 75-14   "Determination of Soil Liquefaction Characteristics by Large-Scale Laboratory Tests," by P. De Alba,
C.K. Chan and H.B. Seed - 1975 (NUREG 0027)A08

EERC 75-15   "A Literature Survey - Compressive, Tensile, Bond and Shear Strength of Masonry," by R.L. Mayes and R.W.
Clough - 1975 (PB 246 292)A10

EERC 75-16   "Hysteretic Behavior of Ductile Moment Resisting Reinforced Concrete Frame Components," by V.V. Bertero and
E.P. Popov - 1975 (PB 246 388)A05

EERC 75-17   "Relationships Between Maximum Acceleration, Maximum Velocity, Distance from Source, Local Site Conditions
for Moderately Strong Earthquakes," by H.B. Seed, R. Murarka, J. Lysmer and I.M. Idriss - 1975 (PB 248 172)A03

EERC 75-18   "The Effects of Method of Sample Preparation on the Cyclic Stress-Strain Behavior of Sands," by J. Mulilis,
C.K. Chan and H.B. Seed - 1975 (Summarized in EERC 75-28)

EERC 75-19 "The Seismic Behavior of Critical Regions of Reinforced Concrete Components as Influenced by Moment, Shear and Axial Force," by M.B. Atalay and J. Penzien - 1975 (PB 258 842)A11

EERC 75-20 "Dynamic Properties of an Eleven Story Masonry Building," by R.M. Stephen, J.P. Hollings, J.G. Bouwkamp and D. Jurukovski - 1975 (PB 246 945)A04

EERC 75-21 "State-of-the-Art in Seismic Strength of Masonry - An Evaluation and Review," by R.L. Mayes and R.W. Clough 1975 (PB 249 040)A07

EERC 75-22 "Frequency Dependent Stiffness Matrices for Viscoelastic Half-Plane Foundations," by A.K. Chopra, P. Chakrabarti and G. Dasgupta - 1975 (PB 248 121)A07

EERC 75-23 "Hysteretic Behavior of Reinforced Concrete Framed Walls," by T.Y. Wong, V.V. Bertero and E.P. Popov - 1975

EERC 75-24 "Testing Facility for Subassemblages of Frame-Wall Structural Systems," by V.V. Bertero, E.P. Popov and T. Endo - 1975

EERC 75-25 "Influence of Seismic History on the Liquefaction Characteristics of Sands," by H.B. Seed, K. Mori and C.K. Chan - 1975 (Summarized in EERC 75-28)

EERC 75-26 "The Generation and Dissipation of Pore Water Pressures during Soil Liquefaction," by H.B. Seed, P.P. Martin and J. Lysmer - 1975 (PB 252 648)A03

EERC 75-27 "Identification of Research Needs for Improving Aseismic Design of Building Structures," by V.V. Bertero 1975 (PB 248 136)A05

EERC 75-28 "Evaluation of Soil Liquefaction Potential during Earthquakes," by H.B. Seed, I. Arango and C.K. Chan - 1975 (NUREG 0026)A13

EERC 75-29 "Representation of Irregular Stress Time Histories by Equivalent Uniform Stress Series in Liquefaction Analyses," by H.B. Seed, I.M. Idriss, F. Makdisi and N. Banerjee - 1975 (PB 252 635)A03

EERC 75-30 "FLUSH - A Computer Program for Approximate 3-D Analysis of Soil-Structure Interaction Problems," by J. Lysmer, T. Udaka, C.-F. Tsai and H.B. Seed - 1975 (PB 259 332)A07

EERC 75-31 "ALUSH - A Computer Program for Seismic Response Analysis of Axisymmetric Soil-Structure Systems," by E. Berger, J. Lysmer and H.B. Seed - 1975

EERC 75-32 "TRIP and TRAVEL - Computer Programs for Soil-Structure Interaction Analysis with Horizontally Travelling Waves," by T. Udaka, J. Lysmer and H.B. Seed - 1975

EERC 75-33 "Predicting the Performance of Structures in Regions of High Seismicity," by J. Penzien - 1975 (PB 248 130)A03

EERC 75-34 "Efficient Finite Element Analysis of Seismic Structure - Soil - Direction," by J. Lysmer, H.B. Seed, T. Udaka, R.N. Hwang and C.-F. Tsai - 1975 (PB 253 570)A03

EERC 75-35 "The Dynamic Behavior of a First Story Girder of a Three-Story Steel Frame Subjected to Earthquake Loading," by R.W. Clough and L.-Y. Li - 1975 (PB 248 841)A05

EERC 75-36 "Earthquake Simulator Study of a Steel Frame Structure, Volume II - Analytical Results," by D.T. Tang - 1975 (PB 252 926)A10

EERC 75-37 "ANSR-I General Purpose Computer Program for Analysis of Non-Linear Structural Response," by D.P. Mondkar and G.H. Powell - 1975 (PB 252 386)A08

EERC 75-38 "Nonlinear Response Spectra for Probabilistic Seismic Design and Damage Assessment of Reinforced Concrete Structures," by M. Murakami and J. Penzien - 1975 (PB 259 530)A05

EERC 75-39 "Study of a Method of Feasible Directions for Optimal Elastic Design of Frame Structures Subjected to Earthquake Loading," by N.D. Walker and K.S. Pister - 1975 (PB 257 781)A06

EERC 75-40 "An Alternative Representation of the Elastic-Viscoelastic Analogy," by G. Dasgupta and J.L. Sackman - 1975 (PB 252 173)A03

EERC 75-41 "Effect of Multi-Directional Shaking on Liquefaction of Sands," by H.B. Seed, R. Pyke and G.R. Martin - 1975 (PB 258 781)A03

EERC 76-1 "Strength and Ductility Evaluation of Existing Low-Rise Reinforced Concrete Buildings - Screening Method," by T. Okada and B. Bresler - 1976 (PB 257 906)A11

EERC 76-2 "Experimental and Analytical Studies on the Hysteretic Behavior of Reinforced Concrete Rectangular and T-Beams," by S.-Y.M. Ma, E.P. Popov and V.V. Bertero - 1976 (PB 260 843)A12

EERC 76-3 "Dynamic Behavior of a Multistory Triangular-Shaped Building," by J. Petrovski, R.M. Stephen, E. Gartenbaum and J.G. Bouwkamp - 1976

EERC 76-4 "Earthquake Induced Deformations of Earth Dams," by N. Serff and H.B. Seed - 1976

EERC 76-5   "Analysis and Design of Tube-Type Tall Building Structures," by H. de Clercq and G.H. Powell - 1976 (PB 252 220) A10

EERC 76-6   "Time and Frequency Domain Analysis of Three-Dimensional Ground Motions, San Fernando Earthquake," by T. Kubo and J. Penzien (PB 260 556)A11

EERC 76-7   "Expected Performance of Uniform Building Code Design Masonry Structures," by R.L. Mayes, Y. Omote, S.W. Chen and R.W. Clough - 1976

EERC 76-8   "Cyclic Shear Tests on Concrete Masonry Piers," Part I - Test Results," by R.L. Mayes, Y. Omote and R.W. Clough - 1976 (PB 264 424)A06

EERC 76-9   "A Substructure Method for Earthquake Analysis of Structure - Soil Interaction," by J.A. Gutierrez and A.K. Chopra - 1976 (PB 257 783)A08

EERC 76-10   "Stabilization of Potentially Liquefiable Sand Deposits using Gravel Drain Systems," by H.B. Seed and J.R. Booker - 1976 (PB 258 820)A04

EERC 76-11   "Influence of Design and Analysis Assumptions on Computed Inelastic Response of Moderately Tall Frames," by G.H. Powell and D.G. Row - 1976

EERC 76-12   "Sensitivity Analysis for Hysteretic Dynamic Systems: Theory and Applications," by D. Ray, K.S. Pister and E. Polak - 1976 (PB 262 859)A04

EERC 76-13   "Coupled Lateral Torsional Response of Buildings to Ground Shaking," by C.L. Kan and A.K. Chopra - 1976 (PB 257 907)A09

EERC 76-14   "Seismic Analyses of the Banco de America," by V.V. Bertero, S.A. Mahin and J.A. Hollings - 1976

EERC 76-15   "Reinforced Concrete Frame 2: Seismic Testing and Analytical Correlation," by R.W. Clough and J. Gidwani - 1976 (PB 261 323)A08

EERC 76-16   "Cyclic Shear Tests on Masonry Piers, Part II - Analysis of Test Results," by R.L. Mayes, Y. Omote and R.W. Clough - 1976

EERC 76-17   "Structural Steel Bracing Systems: Behavior Under Cyclic Loading," by E.P. Popov, K. Takanashi and C.W. Roeder - 1976 (PB 260 715)A05

EERC 76-18   "Experimental Model Studies on Seismic Response of High Curved Overcrossings," by D. Williams and W.G. Godden - 1976

EERC 76-19   "Effects of Non-Uniform Seismic Disturbances on the Dumbarton Bridge Replacement Structure," by F. Baron and R.E. Hamati - 1976

EERC 76-20   "Investigation of the Inelastic Characteristics of a Single Story Steel Structure Using System Identification and Shaking Table Experiments," by V.C. Matzen and H.D. McNiven - 1976 (PB 258 453)A07

EERC 76-21   "Capacity of Columns with Splice Imperfections," by E.P. Popov, R.M. Stephen and R. Philbrick - 1976 (PB 260 378)A04

EERC 76-22   "Response of the Olive View Hospital Main Building during the San Fernando Earthquake," by S. A. Mahin, R. Collins, A.K. Chopra and V.V. Bertero - 1976

EERC 76-23   "A Study on the Major Factors Influencing the Strength of Masonry Prisms," by N.M. Mostaghel, R.L. Mayes, R. W. Clough and S.W. Chen - 1976

EERC 76-24   "GADFLEA - A Computer Program for the Analysis of Pore Pressure Generation and Dissipation during Cyclic or Earthquake Loading," by J.R. Booker, M.S. Rahman and H.B. Seed - 1976 (PB 263 947)A04

EERC 76-25   "Rehabilitation of an Existing Building: A Case Study," by B. Bresler and J. Axley - 1976

EERC 76-26   "Correlative Investigations on Theoretical and Experimental Dynamic Behavior of a Model Bridge Structure," by K. Kawashima and J. Penzien - 1976 (PB 263 388)A11

EERC 76-27   "Earthquake Response of Coupled Shear Wall Buildings," by T. Srichatrapimuk - 1976 (PB 265 157)A07

EERC 76-28   "Tensile Capacity of Partial Penetration Welds," by E.P. Popov and R.M. Stephen - 1976 (PB 262 899)A03

EERC 76-29   "Analysis and Design of Numerical Integration Methods in Structural Dynamics," by H.M. Hilber - 1976 (PB 264 410)A06

EERC 76-30   "Contribution of a Floor System to the Dynamic Characteristics of Reinforced Concrete Buildings," by L.J. Edgar and V.V. Bertero - 1976

EERC 76-31   "The Effects of Seismic Disturbances on the Golden Gate Bridge," by F. Baron, M. Arikan and R.E. Hamati - 1976

EERC 76-32   "Infilled Frames in Earthquake Resistant Construction," by R.E. Klingner and V.V. Bertero - 1976 (PB 265 892)A13

UCB/EERC-77/01   "PLUSH - A Computer Program for Probabilistic Finite
                  Element Analysis of Seismic Soil-Structure Interaction,"
                  by M.P. Romo Organista, J. Lysmer and H.B. Seed - 1977

UCB/EERC-77/02   "Soil-Structure Interaction Effects at the Humboldt Bay
                  Power Plant in the Ferndale Earthquake of June 7, 1975,"
                  by J.E. Valera, H.B. Seed, C.F. Tsai and J. Lysmer - 1977
                  (PB 265 795)A04

UCB/EERC-77/03   "Influence of Sample Disturbance on Sand Response to
                  Cyclic Loading," by K. Mori, H.B. Seed and C.K. Chan
                  1977 (PB 267 352)A04

UCB/EERC-77/04   "Seismological Studies of Strong Motion Records," by
                  J. Shoja-Teheri - 1977

UCB/EERC-77/05   "Testing Facility for Coupled-Shear Walls," by L. Li-
                  Hyung, V.V. Bertero and E.P. Popov - 1977

UCB/EERC-77/06   "Developing Methodologies for Evaluating the Earthquake
                  Safety of Existing Buildings," No. 1 - B. Bresler;
                  No. 2 - B. Bresler, T. Okada and D. Zisling; No. 3 - T.
                  Okada and B. Bresler; No. 4 - V.V. Bertero and B. Bresler
                  1977 (PB 267 354)A08

UCB/EERC-77/07   "A Literature Survey - Transverse Strength of Masonry
                  Walls," by Y. Omote, R.L. Mayes, S.W. Chen and R.W. Clough
                  1977

UCB/EERC-77/08   "DRAIN-TABS: A Computer Program for Inelastic Earthquake
                  Response of Three Dimensional Buildings," by R. Guendelman-
                  Israel and G.H. Powell - 1977

UCB/EERC-77/09   "SUBWALL: A Special Purpose Finite Element Computer
                  Program for Practical Elastic Analysis and Design of
                  Structural Walls with Substructure Option," by D.Q. Le,
                  H. Peterson and E.P. Popov - 1977

UCB/EERC-77/10   "Experimental Evaluation of Seismic Design Methods for
                  Broad Cylindrical Tanks," by D.P. Clough - 1977

UCB/EERC-77/11   "Earthquake Engineering Research at Berkeley - 1976,"
                  1977

UCB/EERC-77/12   "Automated Design of Earthquake Resistant Multistory
                  Steel Building Frames," by N.D. Walker, Jr. - 1977

UCB/EERC-77/13   "Concrete Confined by Rectangular Hoops Subjected to
                  Axial Loads," by D. Zallnas, V.V. Bertero and E.P. Popov
                  1977

UCB/EERC-77/14   "Seismic Strain Induced in the Ground During Earthquakes,"
                  by Y. Sugimura - 1977

UCB/EERC-77/15   "Bond Deterioration Under Generalized Loading," by V.V. Bertero, E.P. Popov and S. Viwathanatepa - 1977

UCB/EERC-77/16   "Computer Aided Optimum Design of Ductile Reinforced Concrete Moment Resisting Frames," by S.W. Zagajeski and V.V. Bertero - 1977

UCB/EERC-77/17   "Earthquake Simulation Testing of a Stepping Frame with Energy-Absorbing Devices," by J.M. Kelly and D.F. Tsztoo 1977