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AN EXPERIMENTAL PROGRAM FOR STUDYING THE DYNAMIC RESPONSE OF A STEEL FRAME WITH A VARIETY OF INFILL PARTITIONS

by

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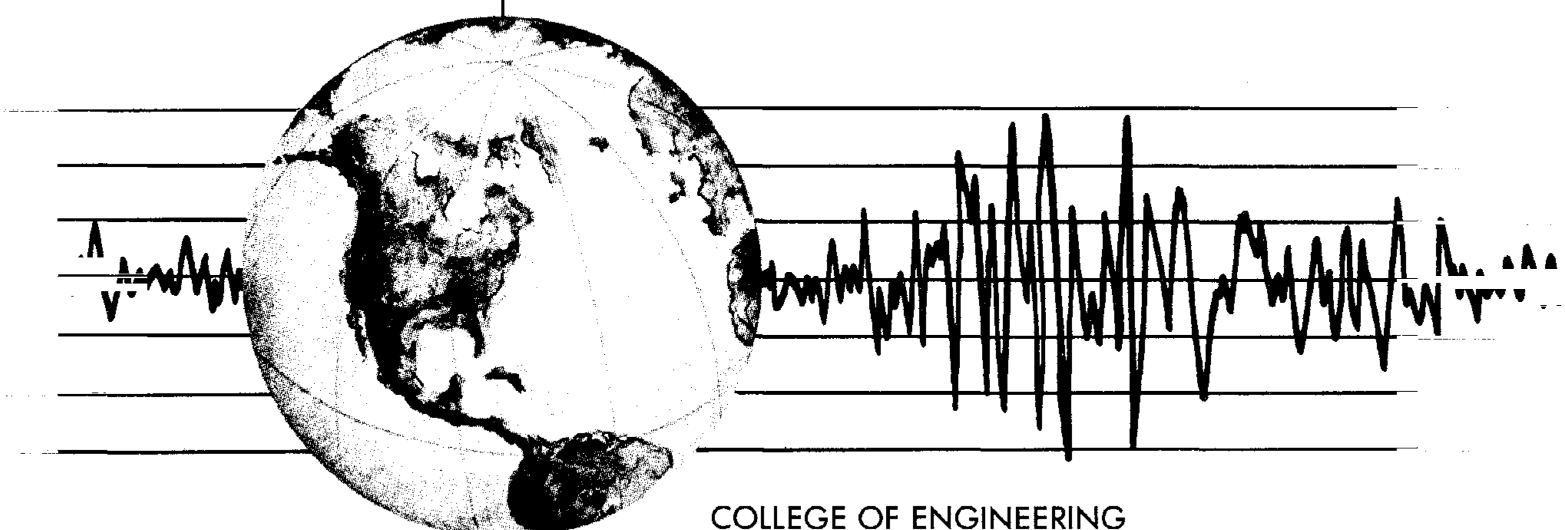
Report to the National Science Foundation



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AN EXPERIMENTAL PROGRAM FOR STUDYING THE DYNAMIC RESPONSE OF A STEEL FRAME WITH A VARIETY OF INFILL PARTITIONS

by

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Report to

The National Science Foundation

Report No. UCB/EERC-85/16
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ABSTRACT

The report describes an experimental program devoted to trying to establish the extend to which partitions in buildings influence the response of the fundamental frame of the building during an earthquake. On the flip side, we gain insight through the experiments, of the effect the deformation of the frame has on the fate of the partition.

Both of these influences depend on the partition, so the program includes those partitions common in practice. Masonry partitions of two sizes are tested including a variety of boundary conditions. Stud partitions both prefabricated and common timber are included.

The results are probably what one would anticipate. The stiff masonry partitions had a significant influence on the response of the frame but were destroyed by the frame when the intensity of the earthquake input was sufficient to create large deformations of the frame. The stud partitions on the other hand being flexible had little influence on the frame but a remarkable ability to survive.

Even though the results were predictable, the program leads to ideas for future research. Ideas on how both masonry and stud partitions can have not only an influence on the response but can be made to survive a strong earthquake.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

This report contains the results of an experimental program to study the behavior of frames with infill partitions under earthquake excitations. The investigation was carried out at the Earthquake Engineering Research Center, University of California at Berkeley.

Using present methods of analysis, the predicted response of a building to an earthquake input is considered to be the response of the bare frame of that building. Internal construction, such as partitions, is ignored. The neglect of interior construction in calculating the stiffness, resonant frequencies and damping of a building has been challenged many times in the past, but little substantive data have been available to show the nature and size of its influence. The purpose of the experimental program reported here is to provide some data that will help engineers to understand the advantages and disadvantages of constructing partitions in such a way that they interact with a frame.

The extent of the influence of partitions depends on the type of partition and how it is constructed to fit within the frame. Partitions in practice vary considerably in their composition, ranging from hollow brick masonry to timber stud. That is why in this study we investigate many types of partitions. The study will show that the contribution of a partition to the stiffness of the frame and the survival characteristics of a partition vary considerably from one type of partition to another. In fact we find that those that contribute most to the response of a frame are the ones that incur the most damage.

The partitions in this study all have the same infill characteristics. They are prevented from sustaining vertical load by being built free of the top of the framing. They are, however, built tightly against the frame columns and are, in some cases, sealed to them. Accordingly, the partitions are made to sustain the deformation characteristics of the frame during its response to earthquake motions.

Inspection of damaged buildings following an earthquake has shown that in many cases masonry partitions when present were in various stages of destruction. Some were merely cracked, others considerably damaged. All damage implies energy absorption, so that some of the energy absorbed by the building during the earthquake was absorbed by the partitions. Visual inspection gives no indication of the extent of the contribution from the partitions. This can only be ascertained by a careful experimental program that measures the responses of the bare frame and the infilled frame to the same excitation. Also, it is not possible, without experiments, to understand the interaction that damages the partition. One of the important findings of the program was the way in which the damage to the masonry partitions in particular was inflicted. Before excitation, the partition was bonded to the frame columns. During the early few seconds of the signal, the bond held so that the column and wall deformed together and no damage to the partition was evident. Soon, however, the bonding began to break down, leaving each element to deform independently. The partition was subsequently destroyed by the buffeting action between the frame and the partition. It was most evident from the response data that, even after buffeting began, the masonry partition contributed significantly to the response characteristics of the frame.

Many of the partitions were not masonry and showed quite different characteristics. All were gypsum board sheeted partitions in which the stud material varied. We tested partitions with both metal and timber studs. Their behavior differed somewhat but as a type they contributed little to the behavior of the frame. On the other hand, they showed great ability to survive considerable deformation with little damage.

The program, like many, raises more questions than answers. It does show that there is a real possibility for partitions of all kinds to have a significant influence on the seismic behavior of a building and, at the same time, survive a severe earthquake. The possibilities that emerge from this program and our conclusions indicate the need for further particular experiments which will be discussed at length in the conclusions.

2. THE TEST STRUCTURE

To our knowledge the work described herein represents the first time that a frame embracing an infill partition has been studied when subjected to a dynamic load. As will be found later, the response to dynamic loading is quite different than that to quasi-static.

The dynamic loading was accomplished by means of the shaking table at the Earthquake Engineering Research Center at the University of California at Berkeley. The table is 20 ft by 20 ft, can accommodate a load of 100,000 lbs and can impose simultaneous vertical and horizontal motions. There is available a library of earthquake signals both historical and synthetically generated, several of which were used in this program.

2.1 <u>The Frame</u>

For the test set-up we chose a steel frame for several reasons. We had had considerable experience with such a frame. Similar frames with the same top and base platforms had been used by Clough and Tang [1] and then by Matzen and McNiven [2]. The steel frame is more flexible than a comparable concrete one so that the assembly would accentuate interaction between the frame and the partition.

The top and base platforms were connected by four columns. The lightest section available (S 4 x 7.7) was selected for the frame columns. For the given overall dimensions of the frame it proved adequate in developing inelastic strains without local or global buckling. The column webs were aligned with the infill partitions. The frame was subjected to horizontal ground motions in the plane of the webs and the partitions thus causing column bending about the strong axis. The column ends were fixed. As expected from past experience, parabolic straps were necessary in order to obtain sufficient welding area between the columns and the end plates. Four bolts secured each end plate to the platforms allowing for adjustments in the height of the structure whenever this was required by the partitions.

Matzen and McNiven [2] reported that under the severe excitations designed to induce inelastic behavior, the experimental frame developed a twist. They attributed this to certain inaccuracies in the reproduction of the prescribed signal by the shaking table. Inelastic effects in the structure would contribute to the same result, and compound the twist. As a countermeasure, the X bracings shown in Figs. 1 and 2 were introduced. While acting against motions perpendicular to the ground excitation, the bracings did not interfere with the structural response in the direction of the signal.

2.2 The Partitions

We were anxious in this program to study a variety of partitions which we felt would behave and interact with the frame quite differently when subjected to earthquake forces. There

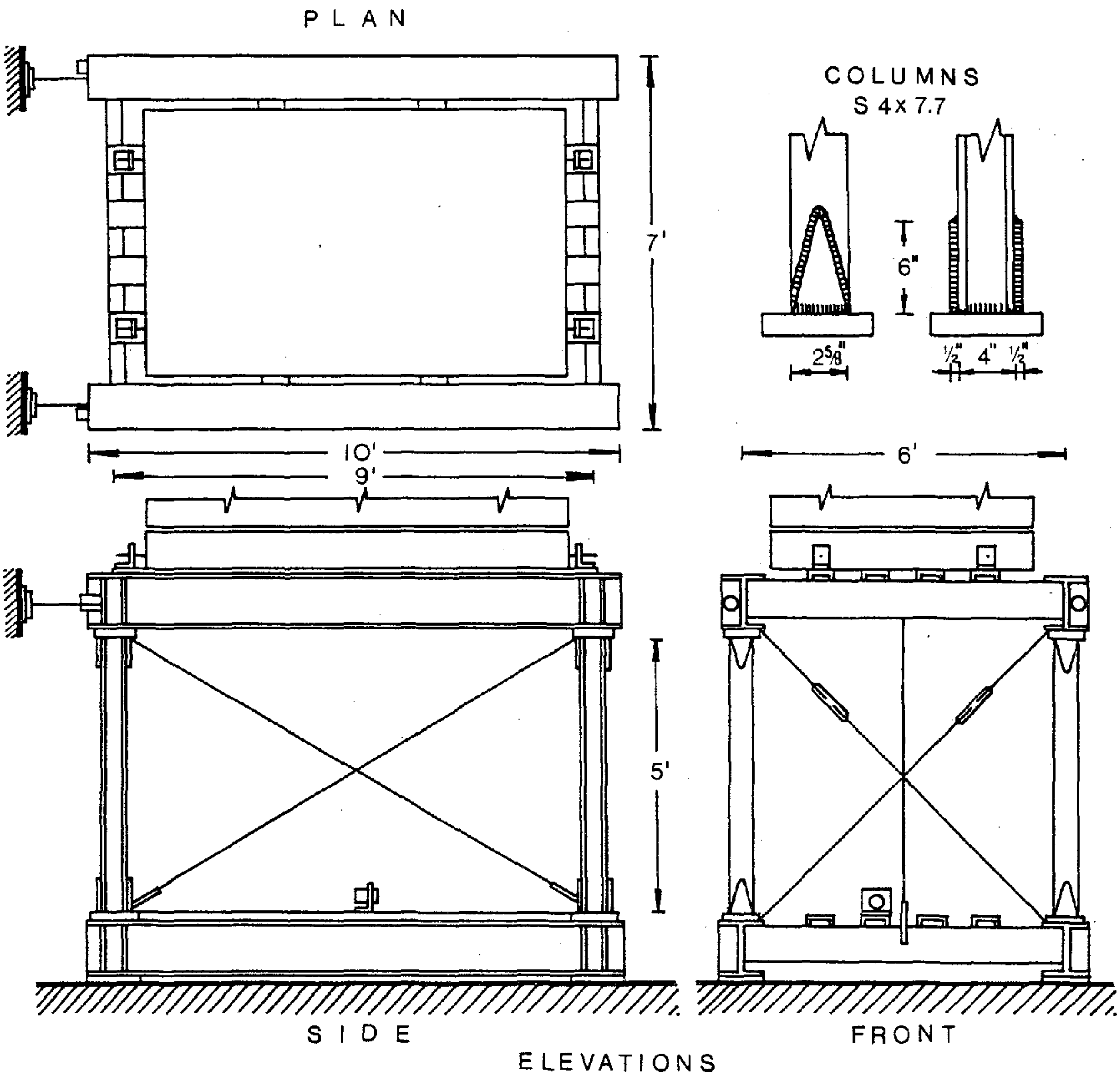


Figure 1: Details of the Bare Frame

were two basic types. First, hollow clay brick masonry which would be both stiff and brittle, and second, sheeted stud partitions which would be flexible and ductile. There were variations in each group. For the masonry partitions, the units were both full scale (3.6 in x 7.6 in x 3.8 in) and "half" scale (1.8 in x 3.8 in x 1.0 in). There were three kinds of stud walls. Two, which were furnished by the Finestone Co. of Detroit, had a common grid of metal studs, but two different types of cement composite sheeting. The sheeting attachment to the studs was a factory process. The final partition was the common half inch gypsum board nailed to 2 by 4 timber studs at 16 ins. on center.

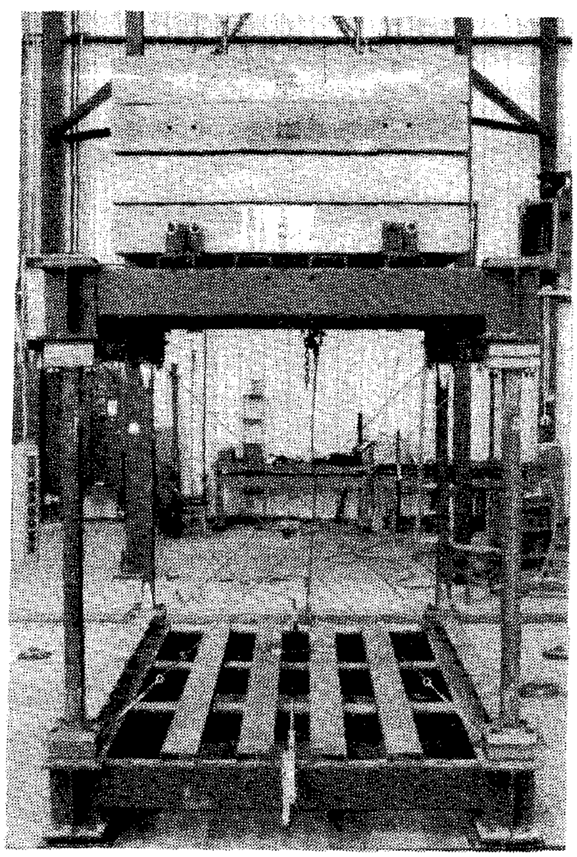


Figure 2: The Bare Frame Showing the Concrete Slab Load

2.3 Masonry Partitions

The masonry partitions were ungrouted and unreinforced, and as they had to be assembled away from the shaking table the chief concern was in transporting the partitions from their construction location to within the frame so that absolutely no cracks (at least visible cracks) would be created. The following method was used. Prior to the construction a base plate was laid down on which the partition was to be erected. Three long rods the height of the partition were welded to the base plate in a vertical position the top to accommodate nuts. The masonry was threaded over the rods so that the latter projected through the cavities in the masonry with the intent that they would not influence the behavior of the partition. The mortar (with common bond) was allowed to cure for 28 days. At the end of this period, a top plate was placed over the rods and nuts were used to put the partition in a slight state of compression. For details, see Fig. 3.

Once the partitions were in place in the frame, the nuts were removed. The rods served a further function of restraining fallout of the crushed units during some of the tests. Because the rods had to extend beyond the top plate, a space had to be left between the top plate and the top horizontal member of the frame. During installation the bottom plate was bolted to the shaking table. The partition size was such that a one-half inch gap existed on the sides between the partition and the frame columns. Some experiments were performed where this gap was others the gap was filled with a bonding material called Hydrocal which provided quick hardening and was easy to apply.

The compressive strength of each type of masonry was established through tests of individual bricks and prisms of brick and mortar. The prisms were tested at a higher rate of loading than the individual bricks. The results are tabulated in Table 1.

TABLE 1: Tests of Bricks and Prisms

Individual Full Scale Bricks

Specimen Number	Dimensions (in) W	L	H	Gross Area (in^2)	Ultimate Load (lb)	Compressive Strength (psi)
1	3.62	7.64	3.82	27.66	122800	4440
2	3.60	7.60	3.81	27.36	130800	4780
3	3.63	7.65	3.80	27.77	139400	5020
4	3.62	7.65	3.80	27.69	127600	4610
5	3.61	7.59	3.82	27.40	139600	5100
Avg.						4790

Prism Test

Type of Prism	Failure Load (lb)	Loading Rate (lb/min)
2 brick prism	92,000	20,000

Individual Half Scale Bricks

Specimen Number	Dimensions (in) W	L	H	Gross Area (in^2)	Ultimate Load (lb)	Compressive Strength (psi)
1	1.87	3.88	1.09	7.26	29400	4060
2	1.83	3.87	1.13	7.24	29450	4070
3	1.85	3.84	1.15	7.10	28250	3980
4	1.85	3.85	1.12	7.12	30550	4290
5	1.84	3.85	1.20	7.12	28650	4020
Avg.						4080

Prism Test

Type of Prism	Failure Load (lb)	Loading Rate (lb/min)
3 brick prism	12,000	20,000

2.4 Stud Partitions

The metal stud partitions supplied by the Finestone Co. were tailored to fit the steel frame. The panels were bolted to the floor platform and were attached to the frame with Hydrocal. Details of the panels are shown in Fig. 3.

The timber stud partitions were built inside the frame. They were bolted to both the top and base platforms; consequently bond was not applied to the vertical edges. Details of these partitions are shown in Fig. 3.

2.5 Instrumentation

Equally important in describing the test set-up is the instrumentation. In a set-up of this kind the responses sought are the acceleration and displacement time histories at strategic locations. Strain gages attached at various locations recorded the strain time histories.

Acceleration time histories are recorded using accelerometers. These have the advantage of needing no reference frame as they record acceleration at a point where the data is needed.

Displacement time histories are more complicated in this test set-up because the reference frame is remote from the table. Our first choice was to use an LVDT to record the displacement at the top of the frame and a linear potentiometer to record the displacement at the base. What was required was the relative

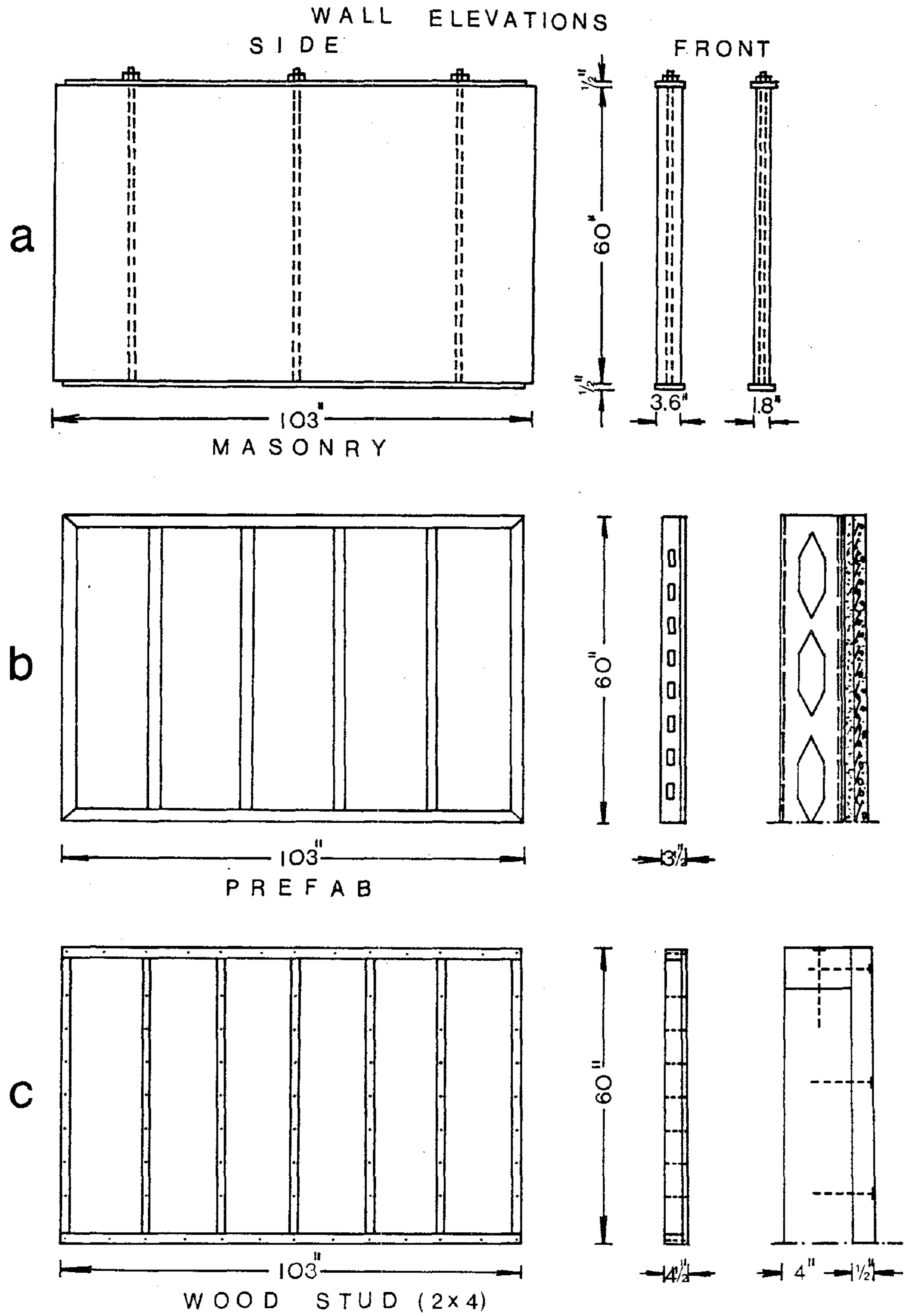


Figure 3: The Details of the Three Types of Partitions Tested

displacement at the base. What was required was the relative displacement of the top of the frame to the bottom; that is, the difference of the two readings. In some experiments this difference was so small that it fell below the sensitivity of the potentiometers. An alternative scheme had to be adopted. The ideal scheme would be to ignore the reference frame and measure the relative displacement between the top and bottom by measuring the changes in length of a diagonal spanning from the bottom at one end to the top of the other end. The change in length of the diagonal would be recorded by transducers. This idea led to difficulties of its own. The length of the diagonal was approximately 125 inches. A rigid diagonal was ruled out because of the weight of such an element and the inaccuracy introduced by its end connections. The idea of a wire was offered but it had to satisfy the following criteria:

(a) the weight of the wire should not create a substantial sag;

(b) the counteracting spring, while keeping the wire taut, should not affect its length appreciably.

We found, as have others, using a piano wire which is thin and stiff, and with a spring of the appropriate stiffness, that when the diagonal changes length, the wire and spring account for no more than three of four percent of the change, and that the rest is accommodated by the transducer as it should be. The choice of transducer remained. We tried transducers of three sensitivities. In the most sensitive, the rotation of the wire during the motion tended to jam the transducer and it was

Another response characteristic measured during some of the tests was the strain in the columns. The locations of the strain gages are shown in Fig. 4. The flange areas in the zones of maximum deflection were monitored on the inside flange surface since it is better protected. Care was taken to avoid the effect of the parabolic straps.

The choice of the gage type was motivated by the need for a sensitivity range covering both the elastic response ($\pm$1%) and the post yield response ($\pm$3%) of the steel.

Initially the output of the measuring equipment was recorded at a scanning rate of 50 Hz. After a few experiments, however, this was changed to 100 Hz in order to avoid omitting peak values when the natural period of the structure was particularly small.

Figure 4 shows the location of each of the recording devices. Accelerometer 1 recorded the acceleration time history of the base or table; accelerometers 2 and 3 the time histories of each side of the top. LVDTs 1 and 2 recorded the time histories of the changes in length of the piano wires resulting in the relative displacements of the top and bottom of the frame. Sixteen strain gages recorded the strain histories at the top and bottom of each of the four columns.

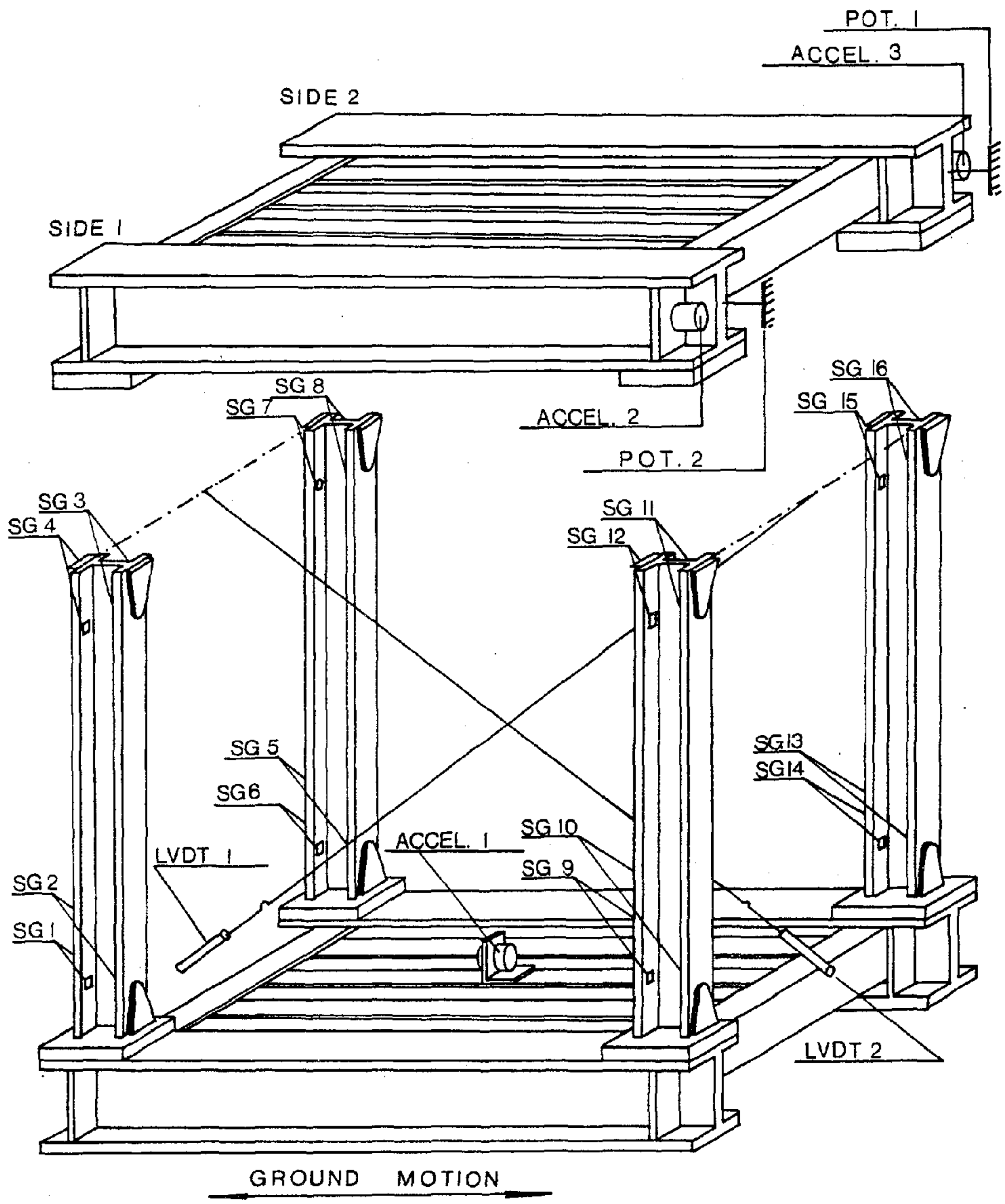


Figure 4: The Location of the Instrumentation

2.6 Free Vibration Tests

Free vibration tests were carried out before the test program with earthquake inputs, partly to obtain a qualitative feeling for the influence of the partitions on the natural frequency of the frame but mainly to establish their influence on damping when the amplitude of motion is small. Only those partitions were tested that were attached to the frame by Hydrocal, and care was taken to make sure the amplitudes of motion were such that the seal was not broken.

The free vibrations were induced by pullback tests. A cable was attached to the top platform of the frame. Tension was applied to the cable and monitored using a load cell. At a load of either two or three kips, depending on the assembly stiffness, the cable was cut allowing the frame to vibrate freely. A reading of the displacement prior to release corresponding to the load cell reading gave an estimate of the frame stiffness.

The motion following release was recorded using potentiometers, DCDTs and accelerometers. The potentiometers did not work well and their data was discarded. The best data were obtained using the transducers. The accelerometers were used to check the natural frequency of the bare frame.

This testing program involved tests of the bare frame, a masonry wall (one-half scale brick) and one stud wall (timber studs). When the bare frame was tested the natural period was 0.2612 sec and the damping coefficient was .0051. This checked exactly using data from the accelerometers. The masonry wall was tested next. The natural period was reduced to .0538 and the damping coefficient increased to .0114. The last to be tested was the timber stud partition, again attached to the column by Hydrocal, and the results were much the same as with the masonry partition. The natural period was reduced to .0514 sec and the damping coefficient increased to .0148. We must keep in mind that these tests all involved very small displacement amplitudes.

Figure 5 shows the acceleration time history of the response of the bare frame. The best data was the displacement time history of the response recorded by the DCDTs. These are shown in Fig. 6.

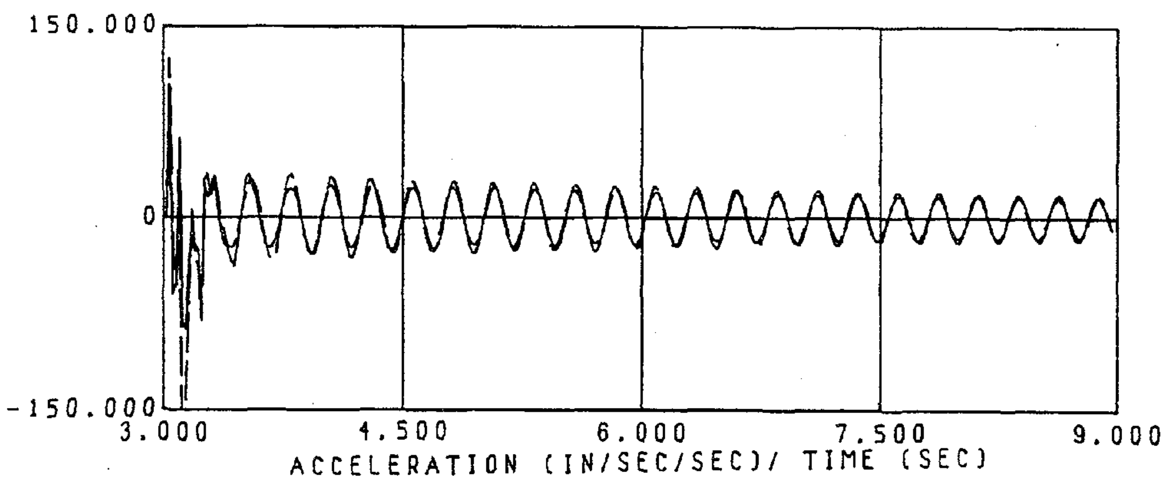


Figure 5: Free Vibration Response of the Bare Frame

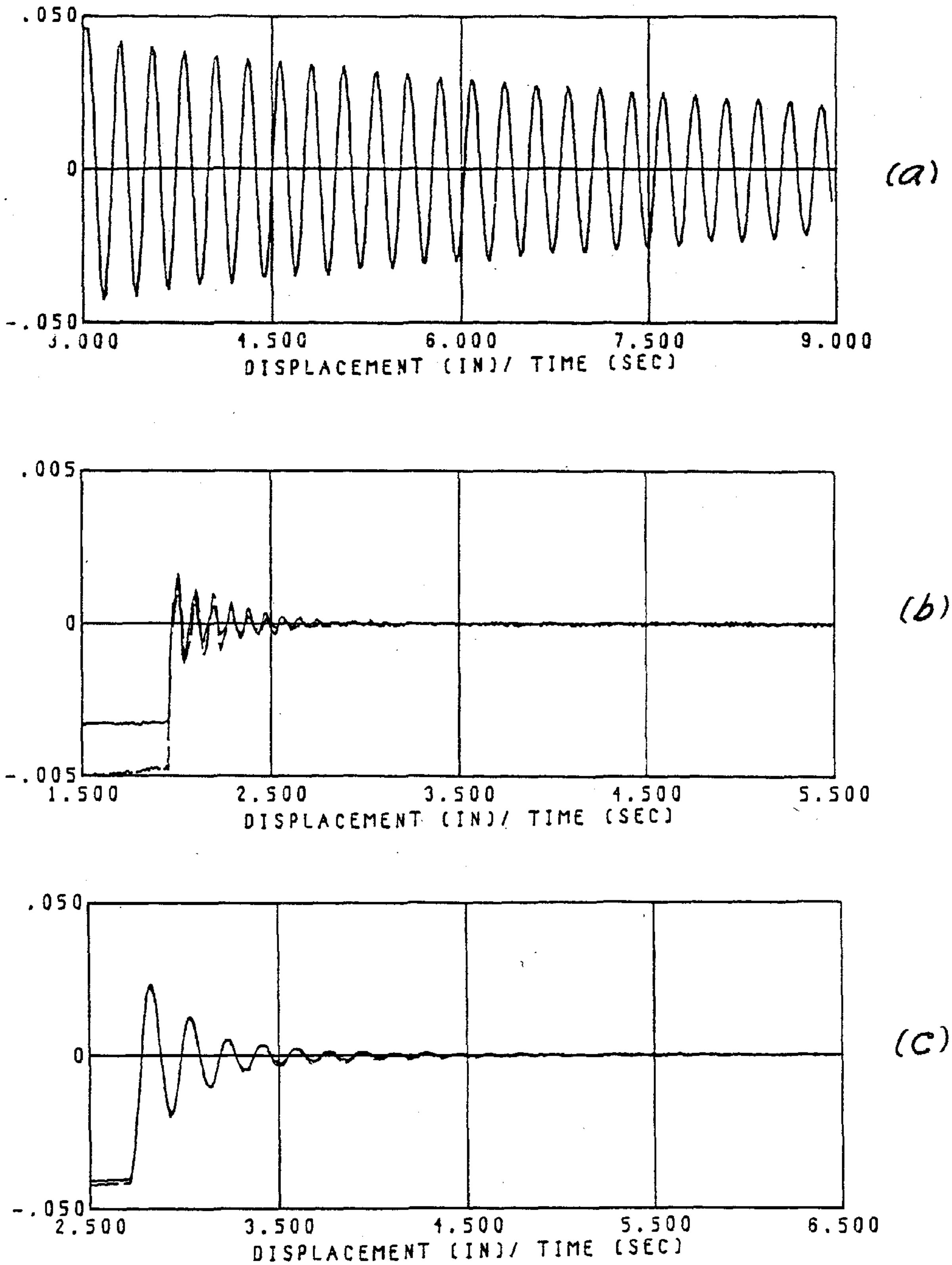


Figure 6: Displacement Responses of the Free Vibration Tests of (a) The Bare Frame, (b) Half-Scale Masonry Partition, and (c) The Wood Stud Partition

3. THE GENERAL EXPERIMENTAL PROGRAM

Whereas the free vibration tests gave indications of the influences of the different partitions on the natural frequencies and damping coefficients of the frame when the amplitude of vibration is small, the main experimental program was directed to studying the response of the structure to an earthquake input of an intensity that would be considered "strong" and that would damage the assembly. The control system of the shaking table is capable of imposing any earthquake signal. They can be either derived from the records of a recent earthquake or the signal can be concocted. Here we decided to use three separate historical signals from earthquakes that had occurred at El Centro, Taft and Pacoima Dam.

A large number of low intensity signals were used and we found that the most significant responses resulted when we applied both the El Centro and Taft to the base frame, the Pacoima Dam to the full-scale masonry partition infill, the Pacoima Dam and the Taft to the half-scale masonry partition, the Pacoima Dam to the two types of prefabricated partitions, and the Pacoima Dam to the timber stud partition.

With the load on the shaking table being rather small, the input time history and the time history recorded on the table differed by an insignificant amount. The weight of concrete slabs on the top deck of the structure was increased from that of the bare frame when the infill partitions were inserted. The slight twist of the structure experienced with the free vibration experiments did not occur with the earthquake inputs. An outline of the tests is shown in Table 2.

TABLE 2: LIST OF TESTS

TEST	TYPE OF PARTITION	SUPER IM-POSED LOAD (KIPS)	SCAN-NING RATE	EXCITATION	MAX. ACCEL. g
1	BARE STEEL FRAME	19	50	TAFT	0.36
2	DO	19	50	EL CENTRO	0.67
3	MASONRY HYDROCAL BOUNDARY	26.6	100	PACOIMA DAM	1.65
4	½ SCALE MASONARY HYDROCAL BOUNDARY	22.8	100	PACOIMA DAM	1.68
5	½ SCALE MASONARY FREE BOUNDARY	22.8	100	TAFT	0.63
6	PREFABRICATED MODEL "A"	26.6	100	PACOIMA DAM	0.89
7	PREFABRICATED MODEL "B"	26.6	100	PACOIMA DAM	1.05
8	TIMBER STUD	22.8	100	PACOIMA DAM	0.88

For each experiment the following data were recorded:

(a) table acceleration time history;

(b) table displacement time history;

(c) acceleration time history of the top of the structure;

(d) the relative displacement time history of the top versus the base;

(e) the strain time histories at selected points on each column.

The DCDT-100 transducers yielded poor results. In the other cases, wherever comparison was possible, there was close agreement between the transducer and potentiometer readings.

Yield did not occur simultaneously at corresponding points in different columns.

3.1 The Bare Steel Frame

Even though the steel frame used in these tests was similar to one used previously, the sections used for columns were sufficiently different from the ones which were part of the frame tested previously, to require a study of the response characteristics of the new frame. It was decided to restrict these tests to the linear response of the frame, reserving the nonlinear response for the tests involving infill partitions.

Strain gages were used to signal the approach of yield. Both earthquake inputs from the Taft and El Centro earthquakes were used. The intensity reflected by the maximum acceleration for the El Centro earthquake could be almost double that for the Taft while preserving a linear response.

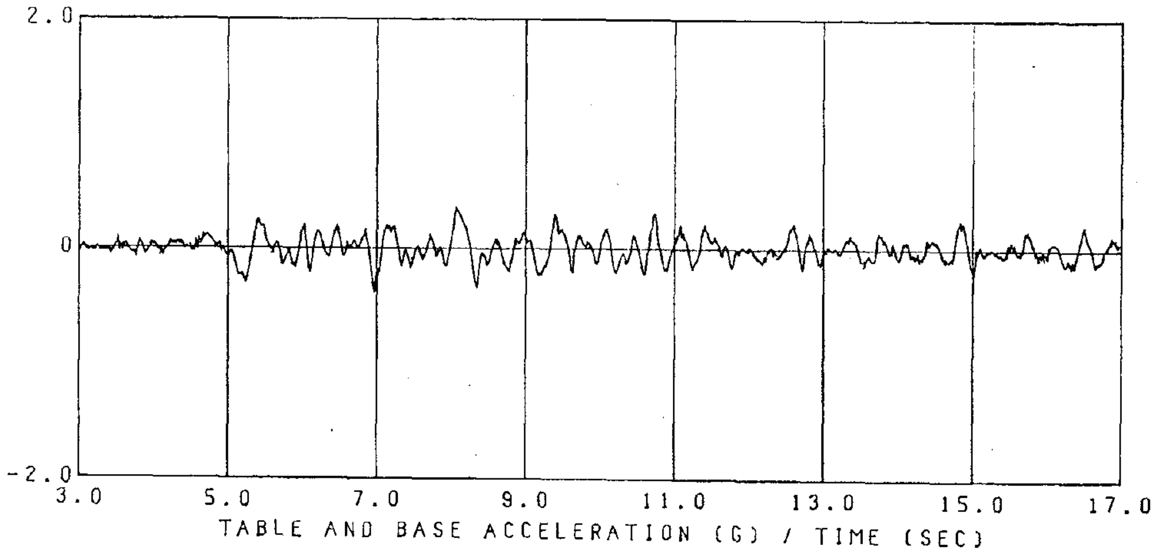
The tests were necessary to ascertain the influence of each type of partition on the response characteristics of the frame within the linear domain. The extreme earthquake motions resulting in nonlinear frame behavior were used in later tests to incur severe damage to partitions similar to that seen following a severe earthquake.

The tests are listed as 1 and 2 in Table 2. Figure 7 shows the Taft input and Fig. 8 the response of the bare frame to it, while Fig. 9 shows the El Centro input and Fig. 10 the response of the bare frame to it.

3.2 Masonry Partitions

As many partitions in practice are masonry and many have been damaged severely during an earthquake, testing masonry partitions was mandatory. The masonry here was brick rather than clay tile, and the bricks were of two sizes. Because masonry partitions are both stiff and brittle their behavior as infill partitions in a steel frame could be predicted. There were variations in the behavior, but in general the pattern was very much the same for each test set-up.

The partition significantly changed the seismic response of the frame by making it much stiffer, but, during excitation, the more flexible frame began to buffet the partition, eventually destroying it.



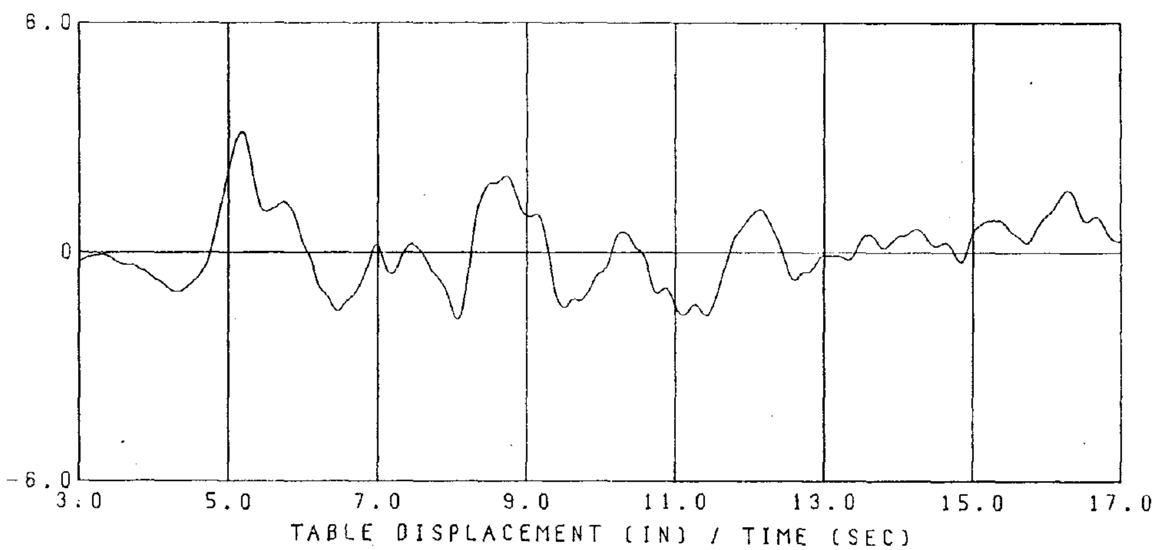


Figure 7: Taft Input to the Bare Frame

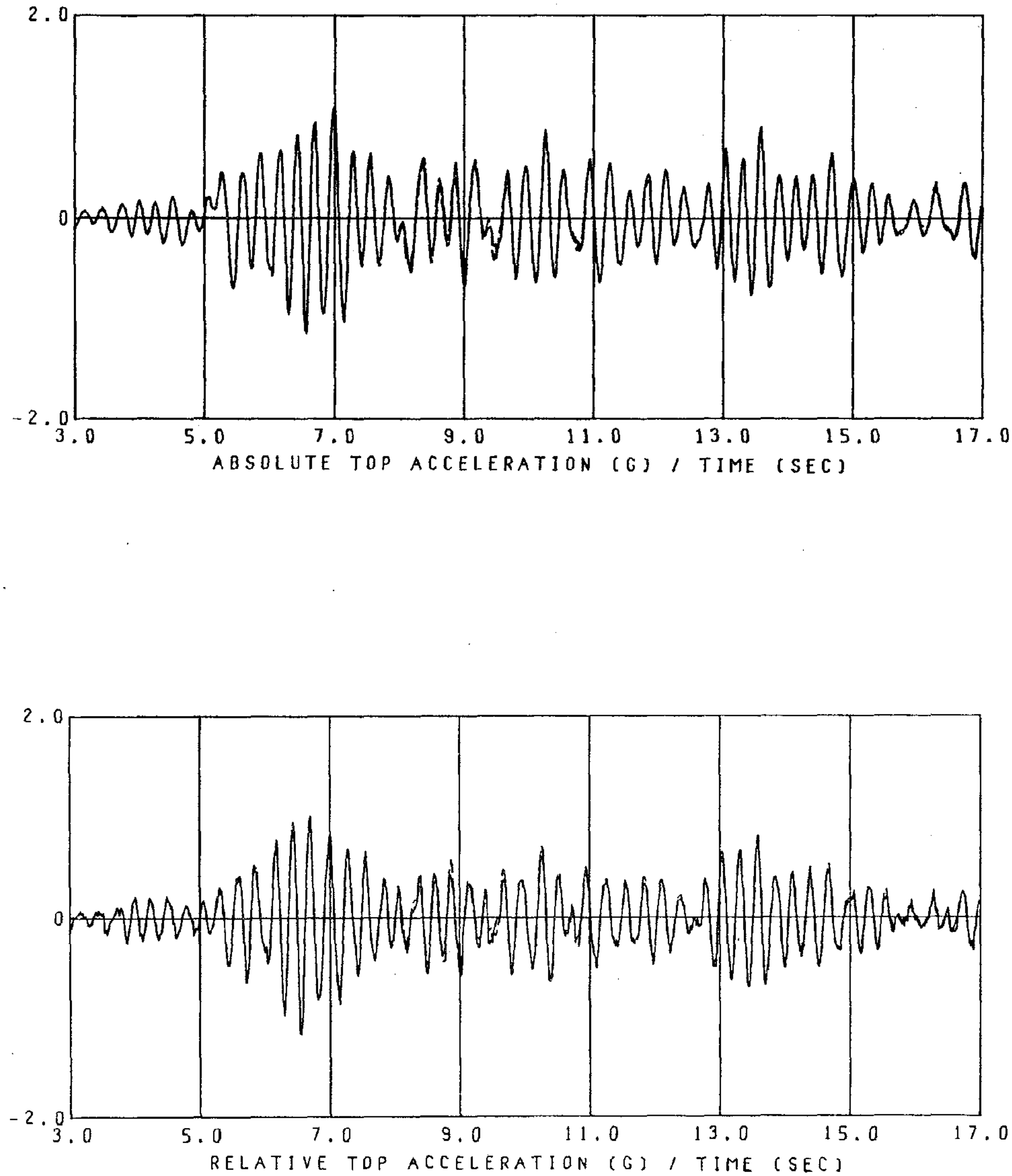


Figure 8: Response of Bare Frame to Taft Input

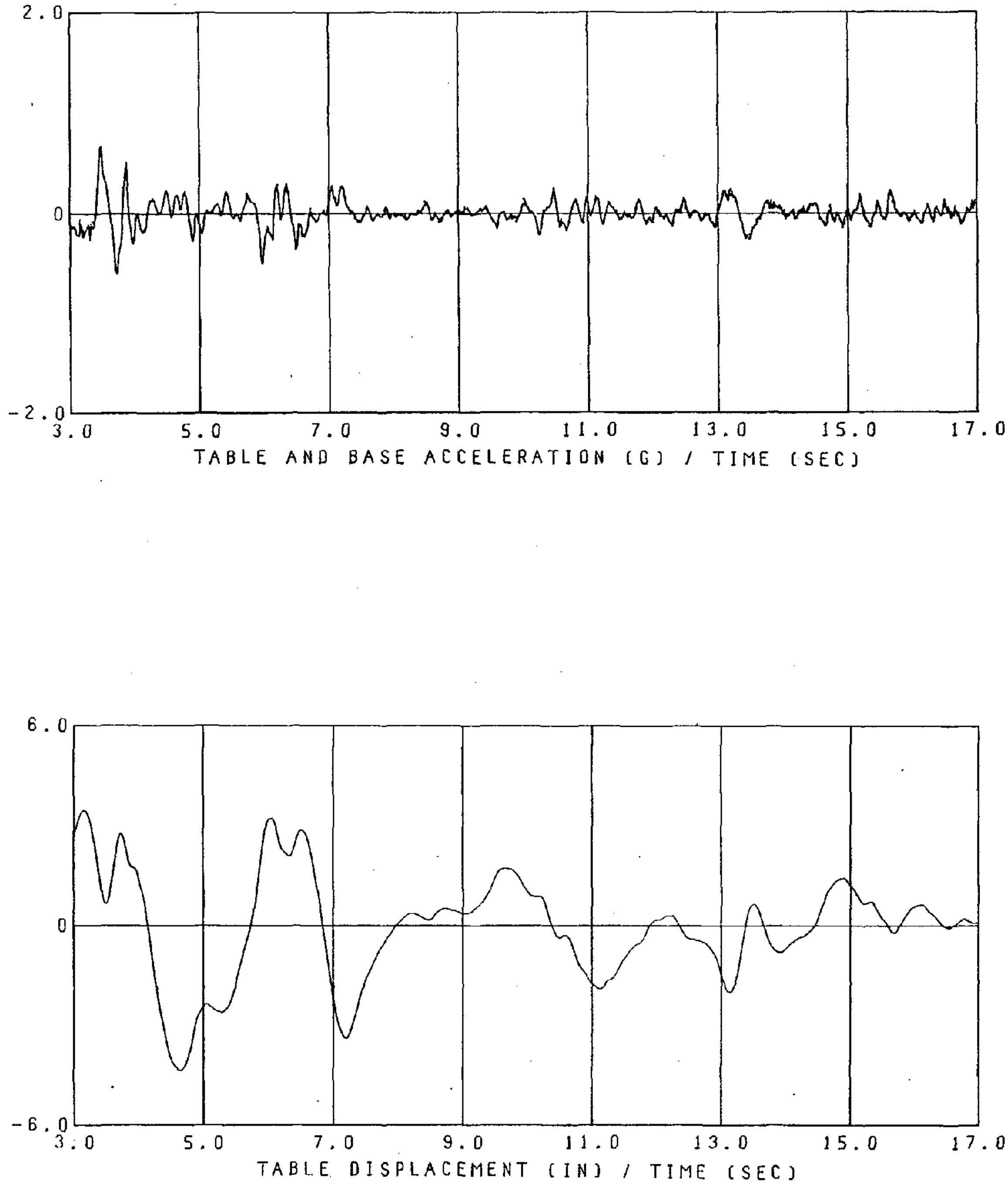
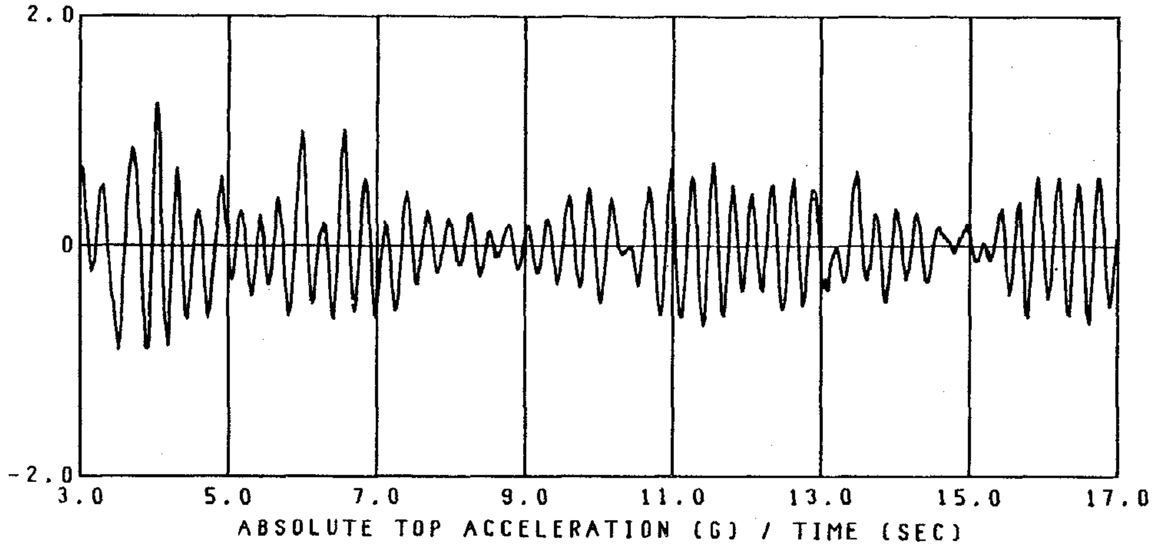


Figure 9: El Centro Input to The Bare Frame



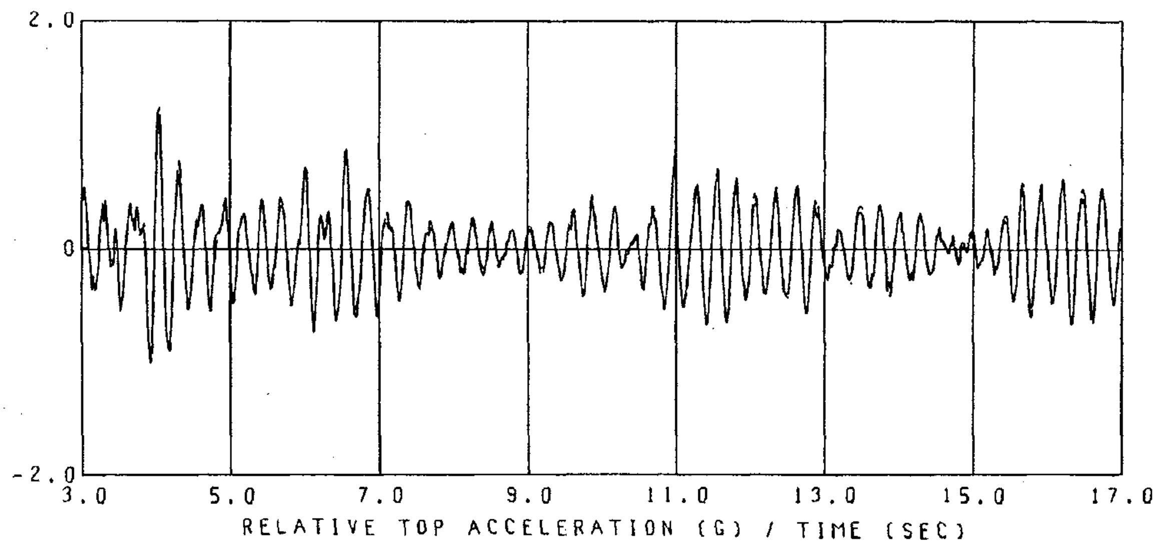


Figure 10: Response of Bare Frame to El Centro Input

3.3 Full Size Bricks

One of the purposes of this series of tests was to ascertain the significance of the loading being dynamic as opposed to quasi-static. As quasi-static testing is much more widely performed and the results are often used to demonstrate how a structure would behave under dynamic loading, it was considered important to question this kind of extrapolation. So identical test set-ups were subjected to dynamic and quasi-static loadings. The responses to the two types of loading were quite different.

3.4 Quasi-Static Loading

In these tests the partitions were made snug to the frame along their boundaries and sealed along these boundaries with Hydrocal. The load was applied by a hydraulic jack in both forward and backward motions. Even though the loading was applied with relatively high speed, the Hydrocal bonding remained unbroken along the complete boundary. The partition initially offered significant stiffness but when the length of travel of the jacks was increased the partitions began to fail in shear, or more correctly, in diagonal tension, along lines at 45 degrees with the horizontal. The mortar was weaker in tension than the bricks so the 45 degree crack followed the mortar line forming a step type crack. From our work with free masonry walls, and given the geometry of the partition, we speculate that there might have been some evidence of a flexural failure if the partition had not been confined. Figure 11 shows the progressive failure of the partition during the test showing the failure of

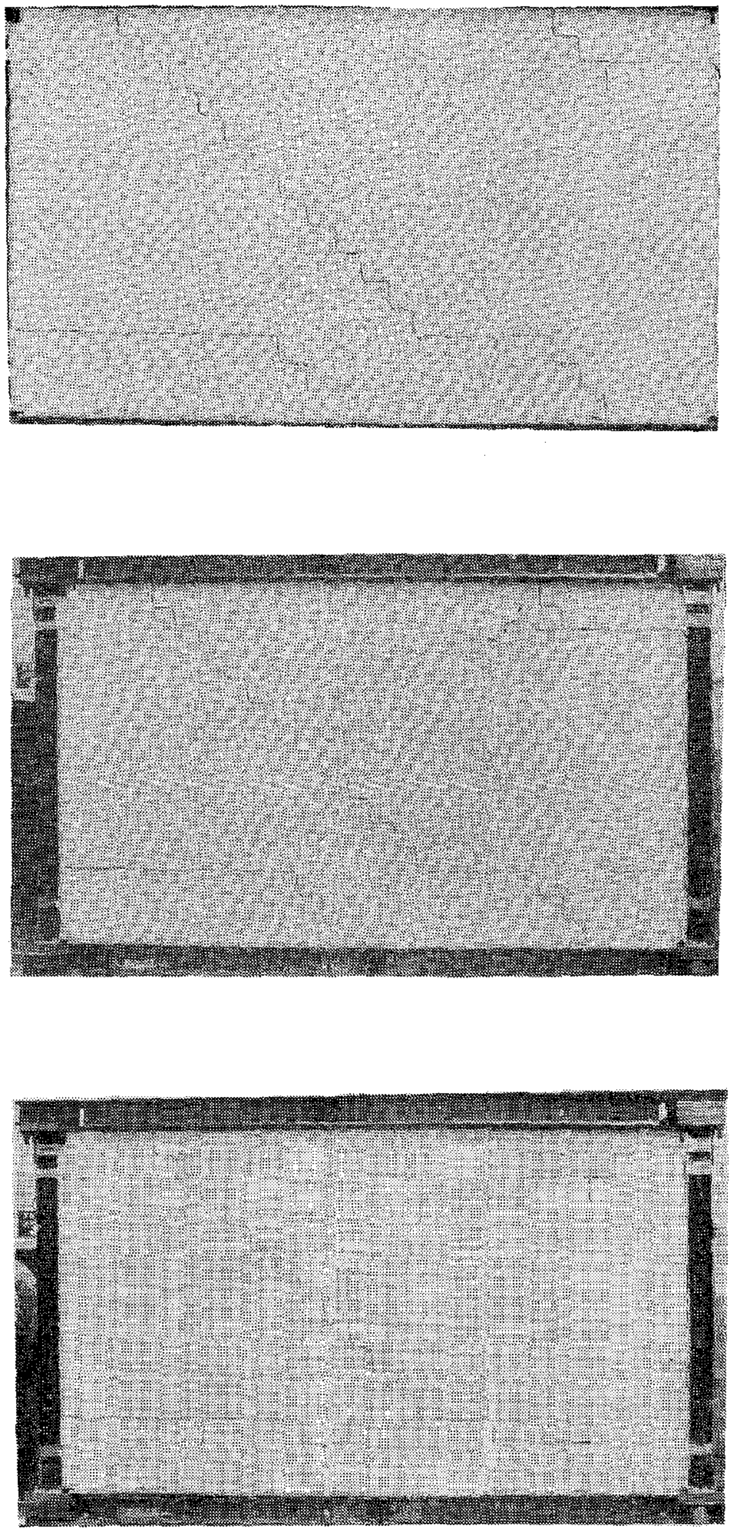


Figure 11: Progressive Failure of the Masonry Partition due to Quasi-Static Loading

the mortar in the step crack at approximately 45 degrees.

3.5 Dynamic Loading

The set-up was identical to the previous test with the Hydrocal seal around the complete perimeter. Figure 12 shows the full size masonry partition within the frame ready for testing. The test is listed as 3 in table 2.

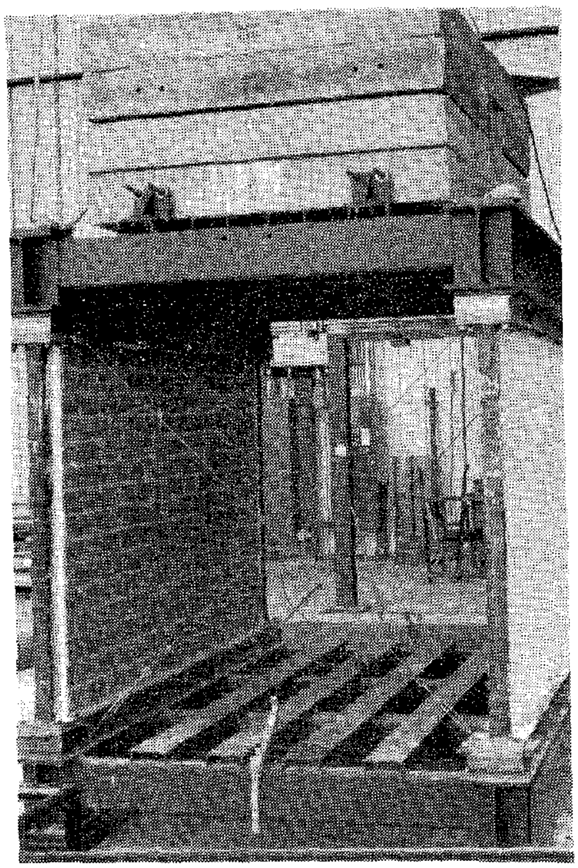


Figure 12: Masonry Partition within the Frame Ready for Dynamic Loading

It is appropriate to note here that the superimposed mass on the bridge between frames was increased over that used in the free vibration tests to increase the force exerted by identical intensities. The signal for this test was the Pacoima Dam acceleration time history. The response of the frame and partition was quite different from that induced by the quasi-static load. Very early in the excitation, the seal along the boundaries began to break down and buffeting began. The stiffness of the set-up was very large at the beginning and became progressively less as the cracking of the partition spread. The crack pattern was also different from the quasi-static test. Here the cracks occurred in the layers of mortar but parallel to the base. This started near the bottom of the partition and as damage progressed horizontal cracks would form elsewhere. Figure 13 shows the virgin partition and the progression of damage. The horizontal cracks are quite visible. With the buffeting which occurred with the dynamic tests the breakdown of the resistance of the partitions was more rapid than with the quasi-static tests. Figure 14 shows the shaking table input to the full scale masonry partition and Fig. 15 the partition responses.

3.6 Half-Size Bricks

We had access to one-quarter-size bricks and even though these would be used infrequently in practice we decided to carry out a separate series of tests devoted to these partitions. The choice was motivated by the relatively smaller stiffness of these bricks, providing a distinct contrast to the full size ones. This series was also designed to study an additional variation in

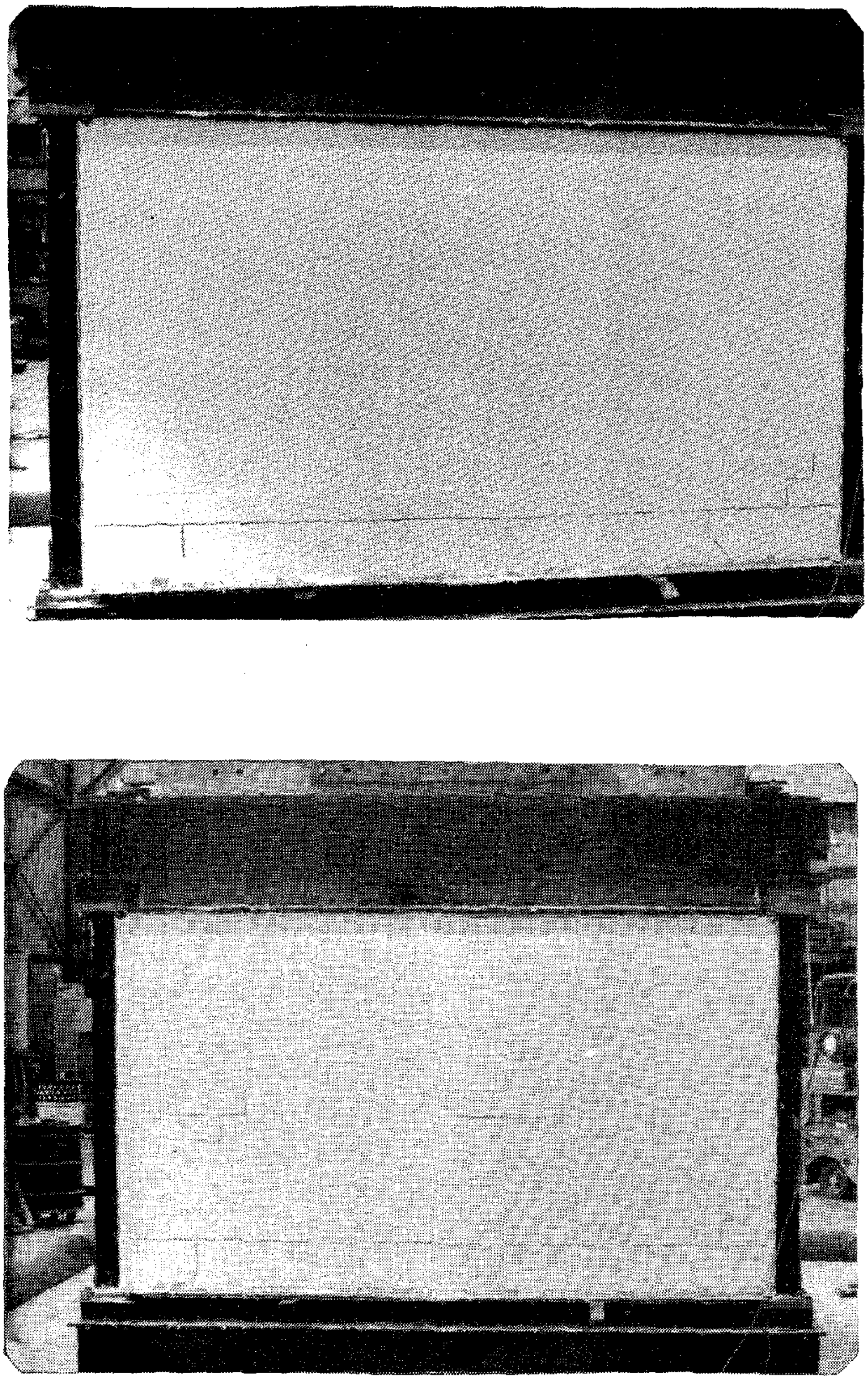


Figure 13: Progressive Damage to the Masonry Partition caused by Dynamic Loading

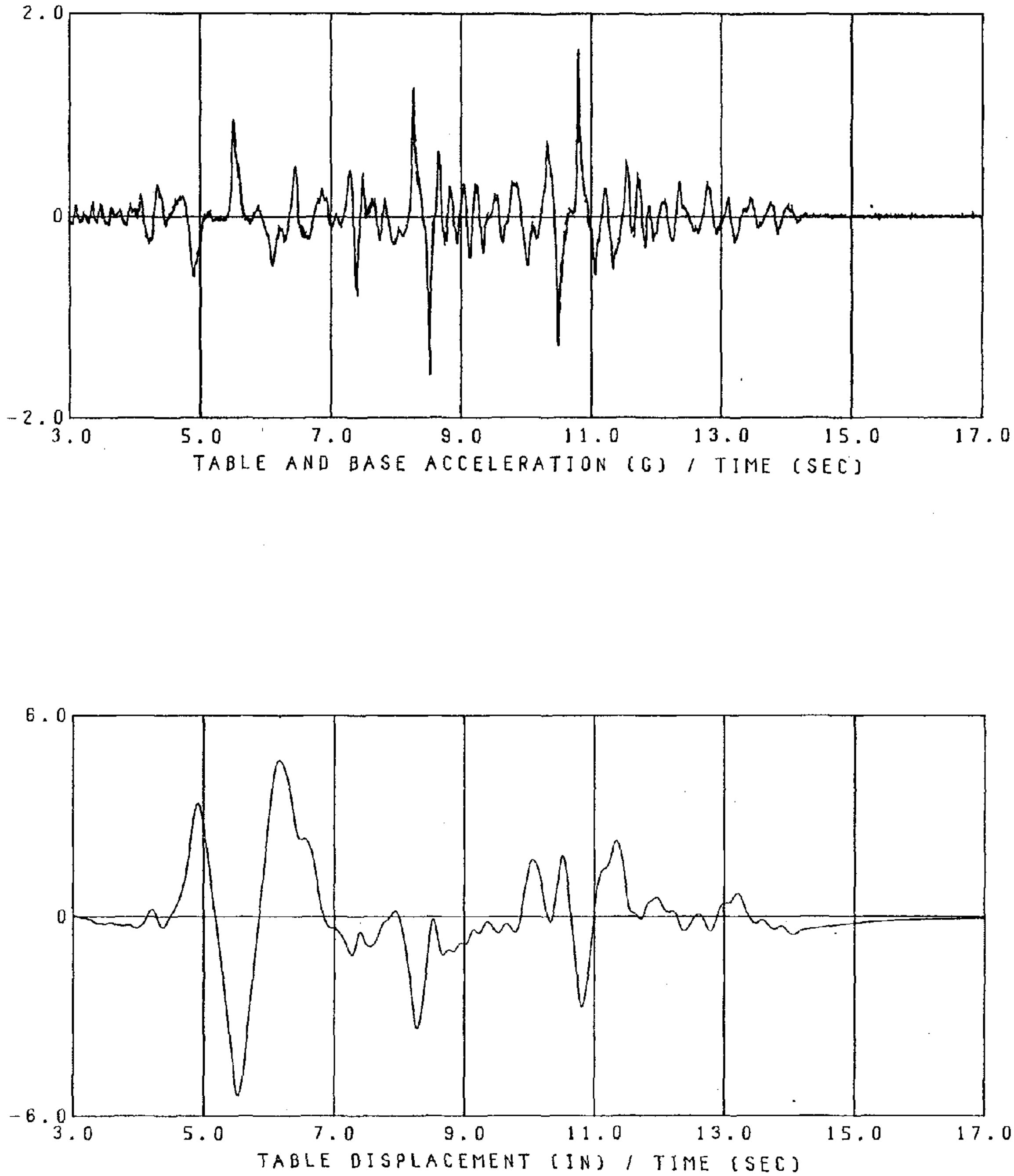
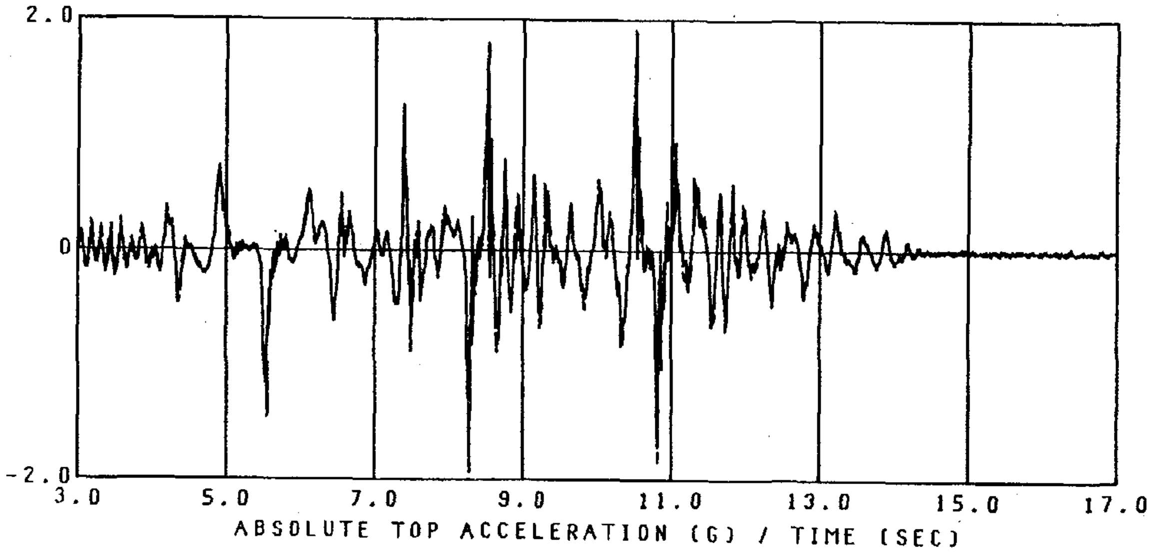


Figure 14: Input to the Frame and Masonry Partition



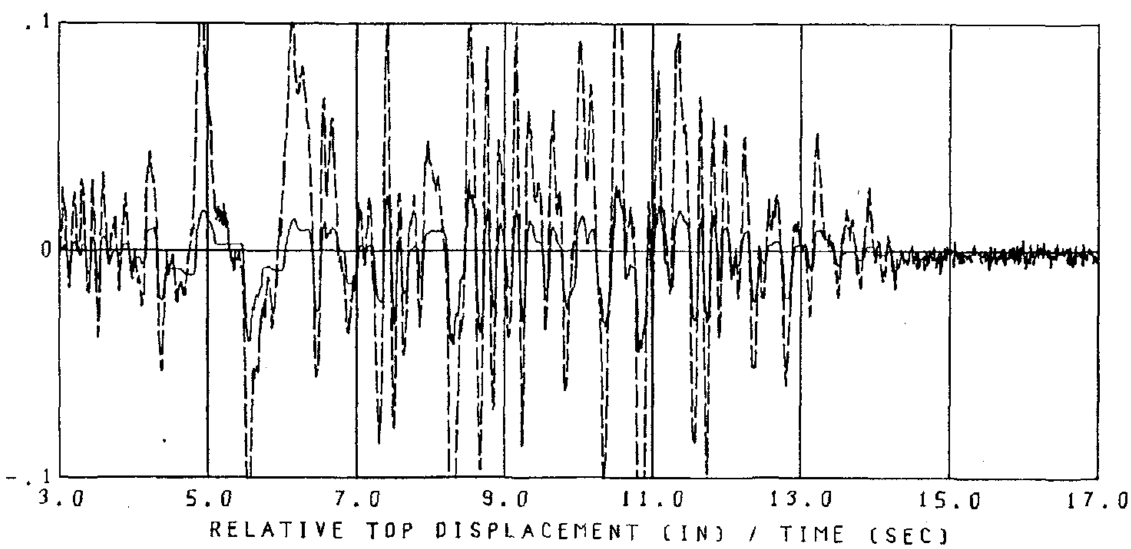


Figure 15: Responses of the Frame and Masonry Partition

the test set-up. One set-up had the boundary of the partition sealed to the frame using Hydrocal, as before. In the other set-up, a one-half inch gap was left between the partition and the frame. For both of these series, the superimposed mass was reduced by about sixteen percent, as we anticipated that the partitions would be more fragile than those made using full size bricks. For the sealed boundary set-up the excitation was the Pacoima Dam signal; for the free boundary we used the Taft signal.

3.7 <u>Sealed Boundaries</u>

The one-quarter scale partition with sealed boundaries is shown within the frame ready for testing in Fig. 16. This test is listed as 4 in Table 2.

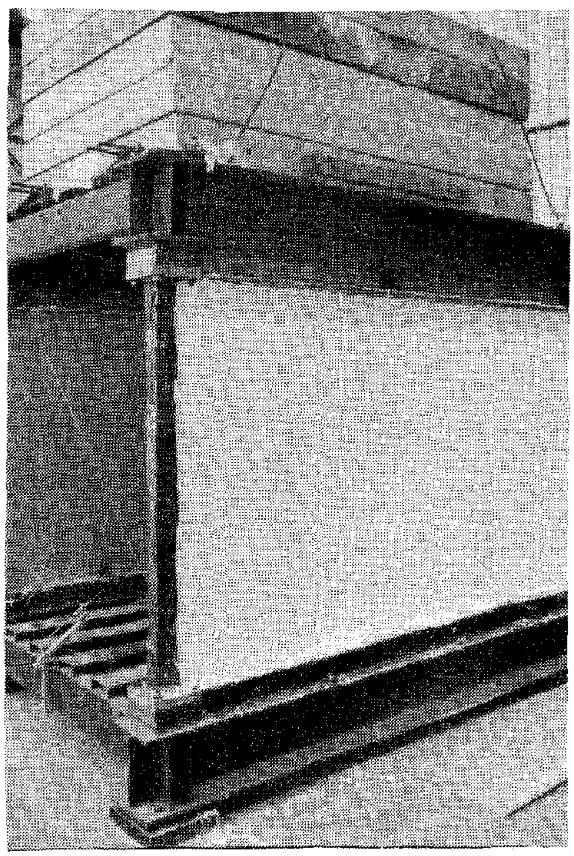


Figure 16: Half-Scale Masonry Partition within Frame Ready for Dynamic Testing

The behavior of this set-up differed somewhat from the similar set-up with the full size bricks. The first cracks formed around the boundary, but here there was no spalling off of the boundary material so no gaps formed around the perimeter. Shortly thereafter, cracking of the masonry began. Here again the pattern was different. The cracks formed a "bell shape" which gradually enlarged as the resistance of the partition lessened.

Figure 17 shows the progressive damage to the partition when subjected to the dynamic load. Figure 18 shows the table input time histories and Fig. 19 shows the partition responses.

The data from strain gages was abundant and space does not permit including all of the data. We choose to show the time history of strains for gages 4, 12, 7, 15 for the half scale masonry partition when the partition is attached to the frame using Hydrocal. Figure 20 shows the time histories of gages 4 and 12, Fig. 21 gages 7 and 15.

The hysteretic behavior is divided for clarity into two time intervals; 7.5 to 12.5 seconds and 12.5 to 16 seconds, all for strain gage number 2. Figure 22 shows column strain versus top displacement and Fig. 23 shows column strain versus lateral

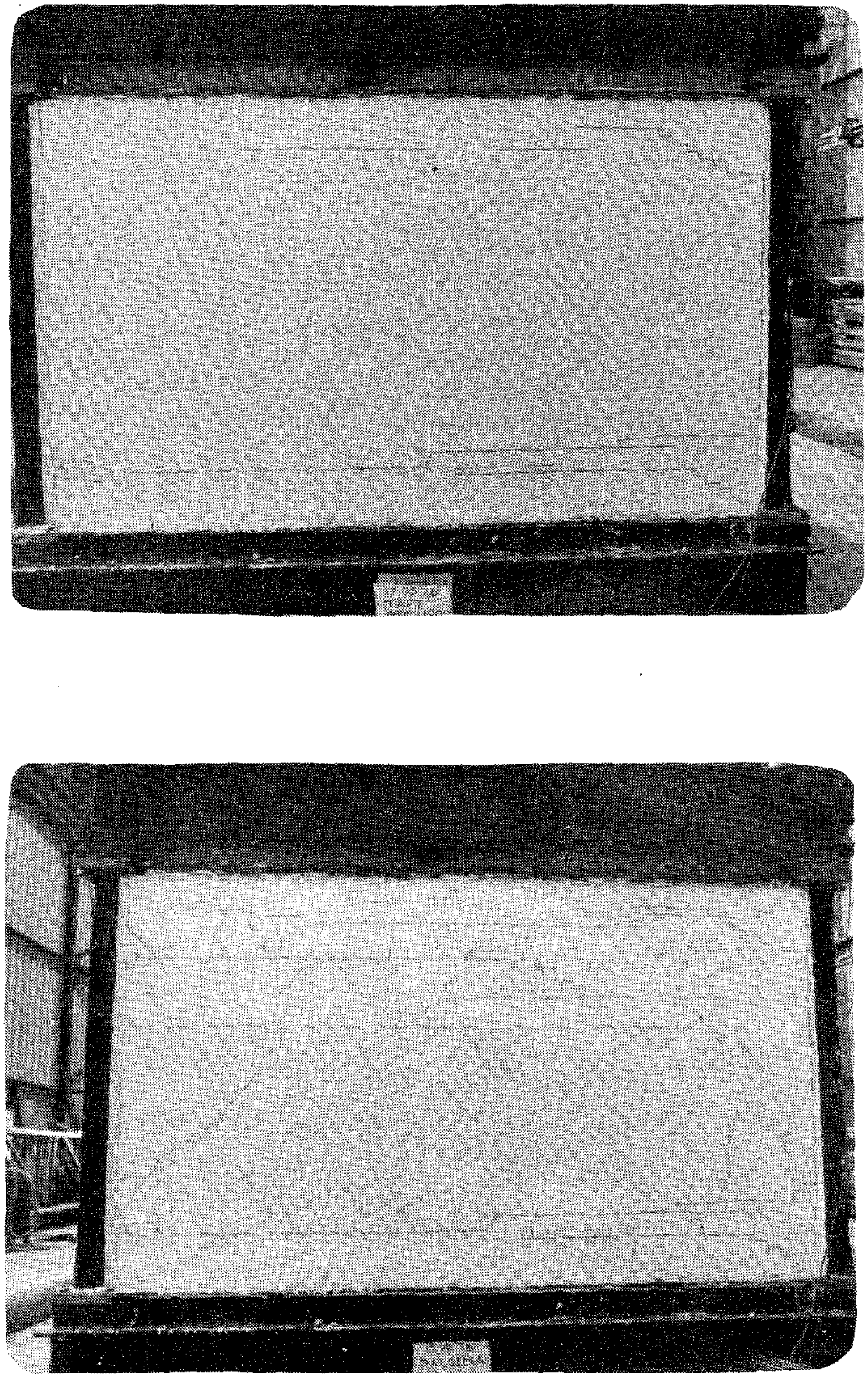
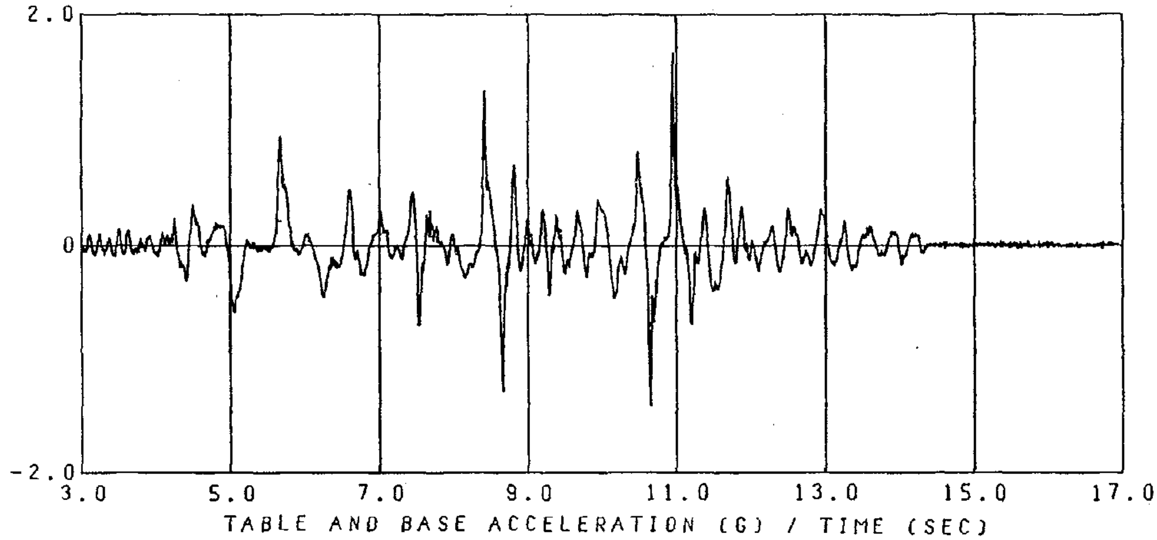


Figure 17: Progressive Damage to the Half-Scale Masonry Partition due to the Earthquake Input



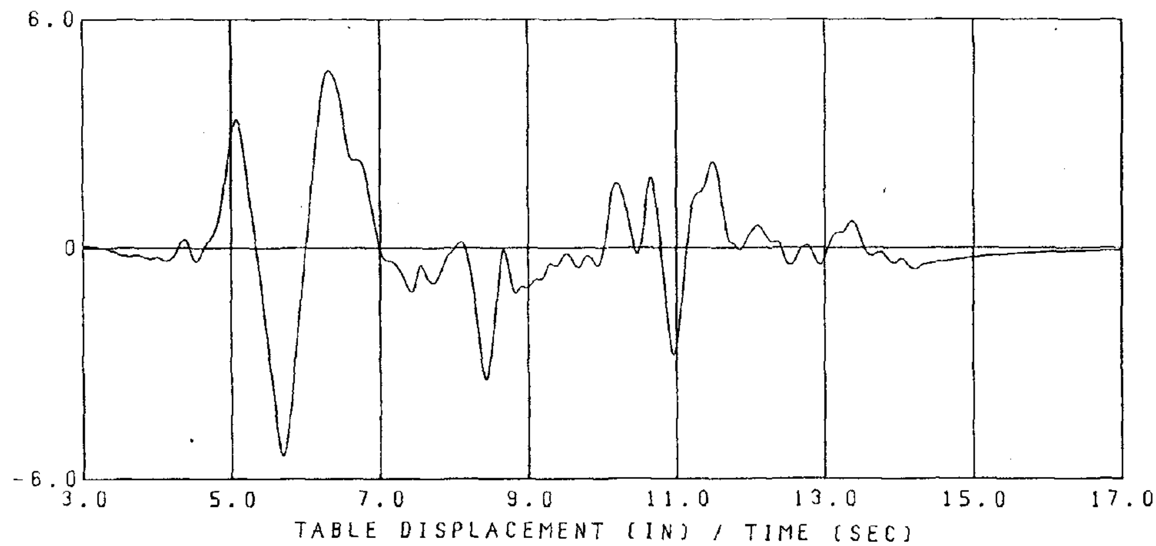
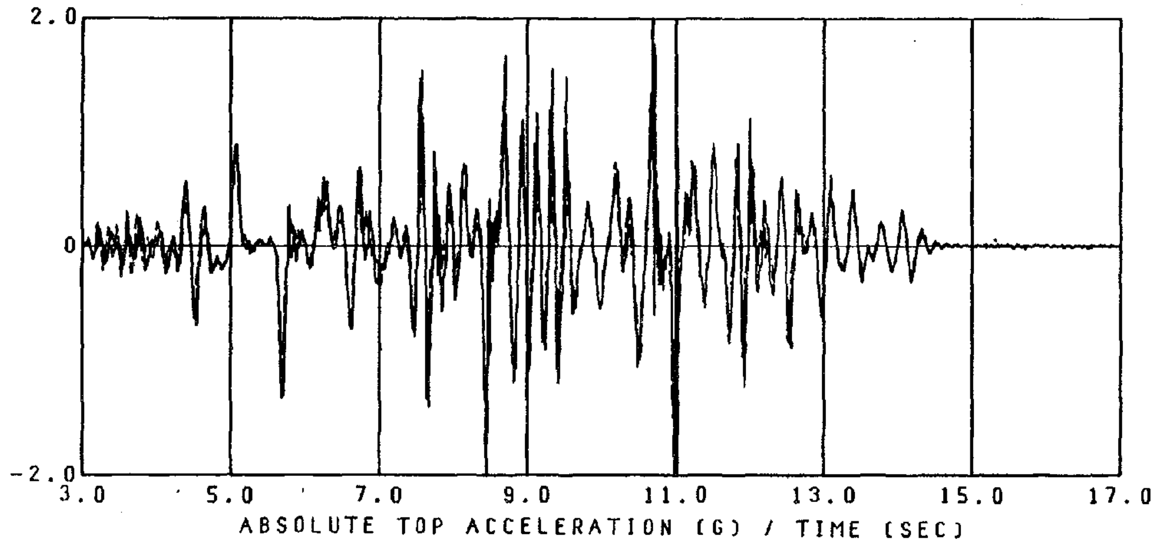


Figure 18: Earthquake Input to the Half-Scale Masonry Partition



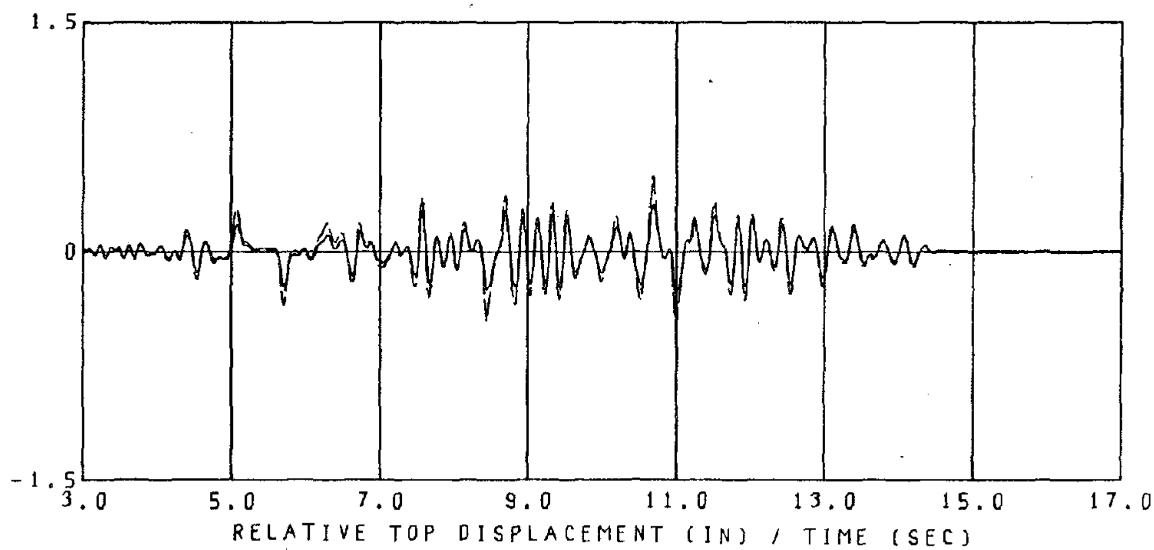


Figure 19: Responses of the Half-Scale Masonry Partition

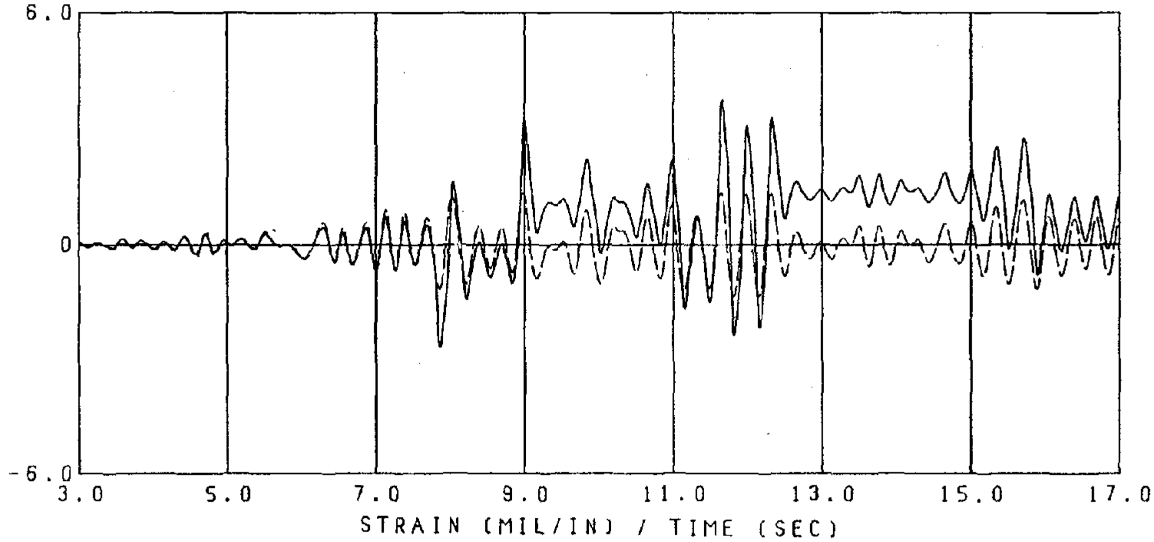


Figure 20: Strain Time History Responses of Gages 4 and 12

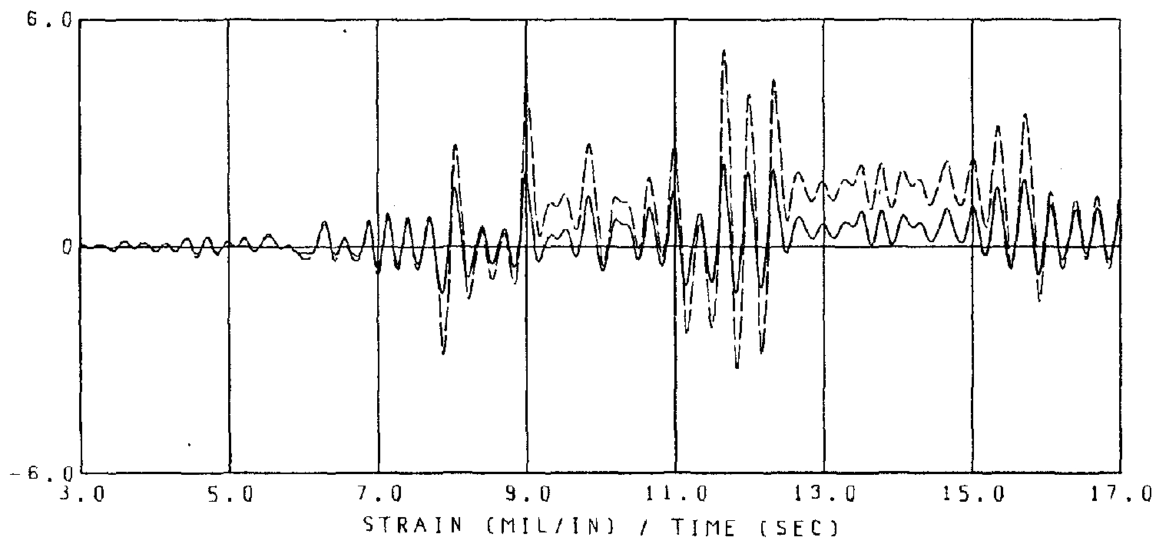
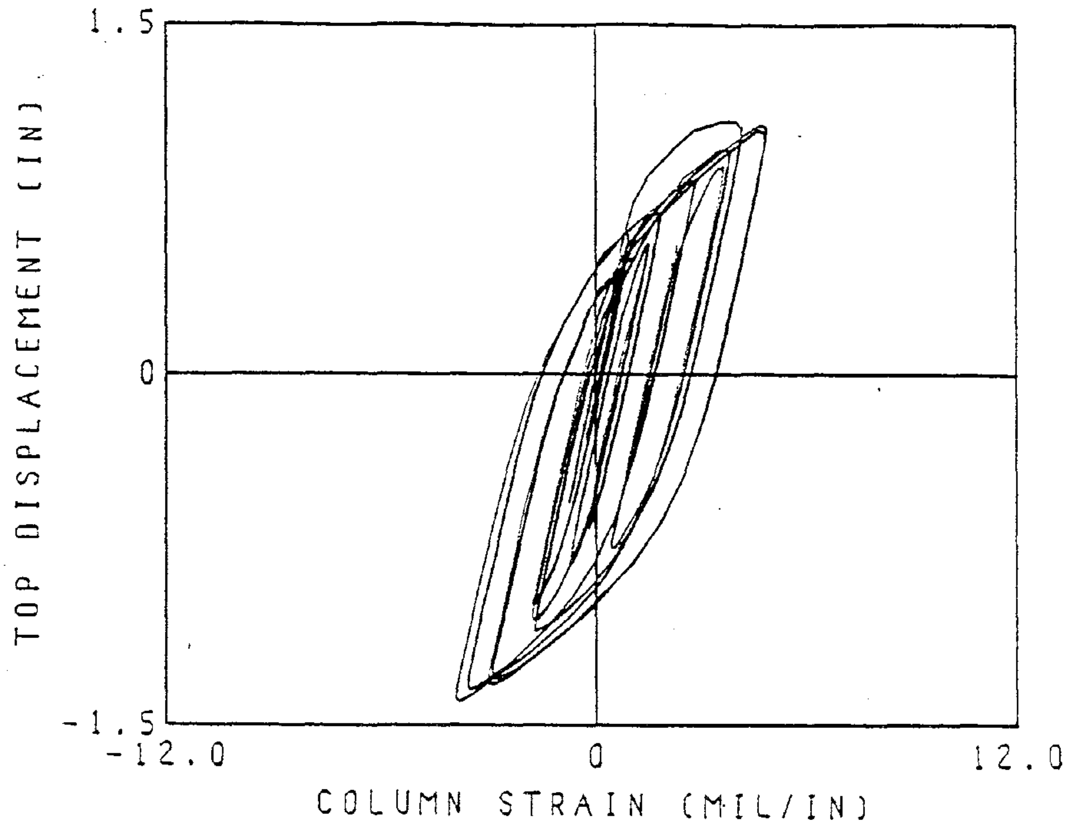


Figure 21: Strain Time History Responses of Gages 7 and 15



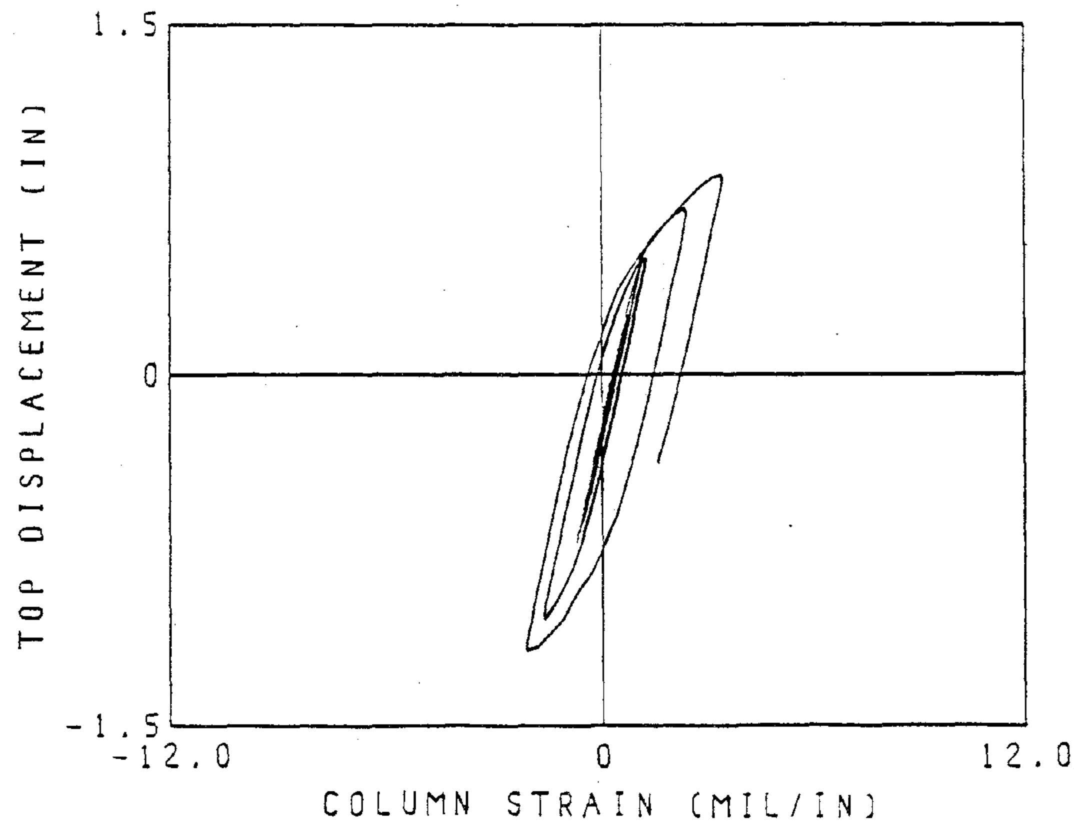
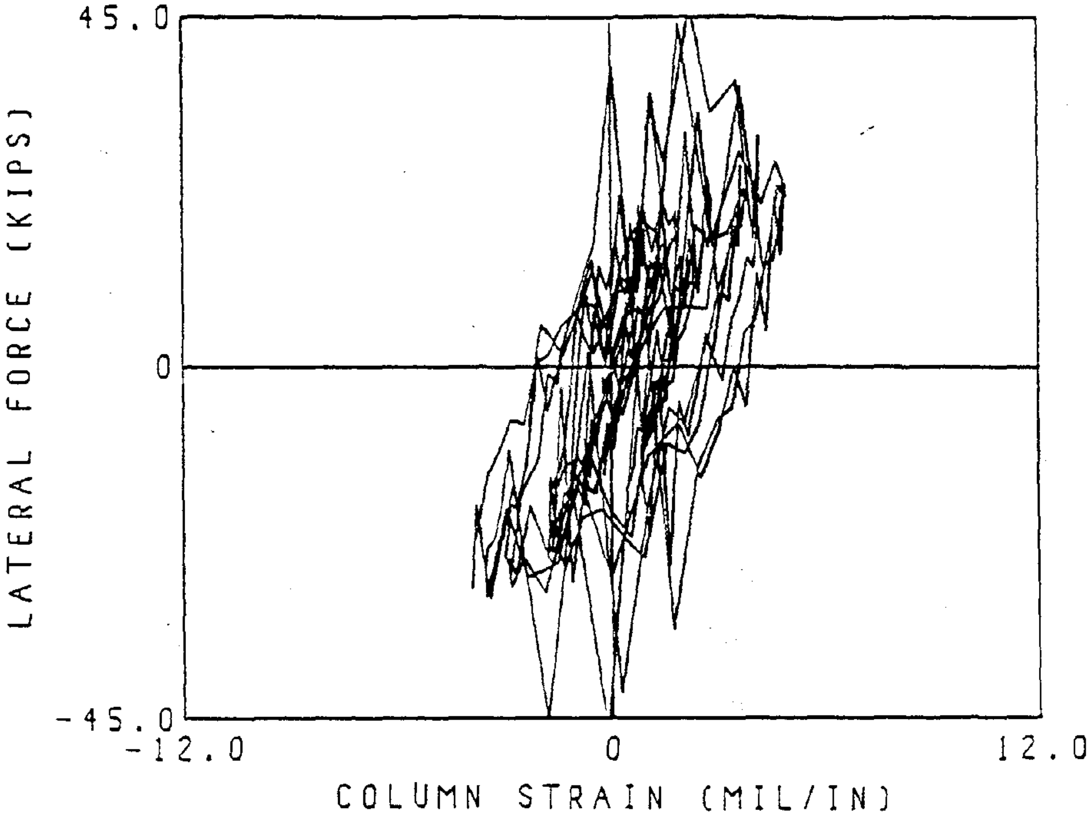


Figure 22: Column Strains Versus Top Displacement for Gage 2 for (a) 7.5 to 12.5 secs. and (b) 12.5 to 16 secs.



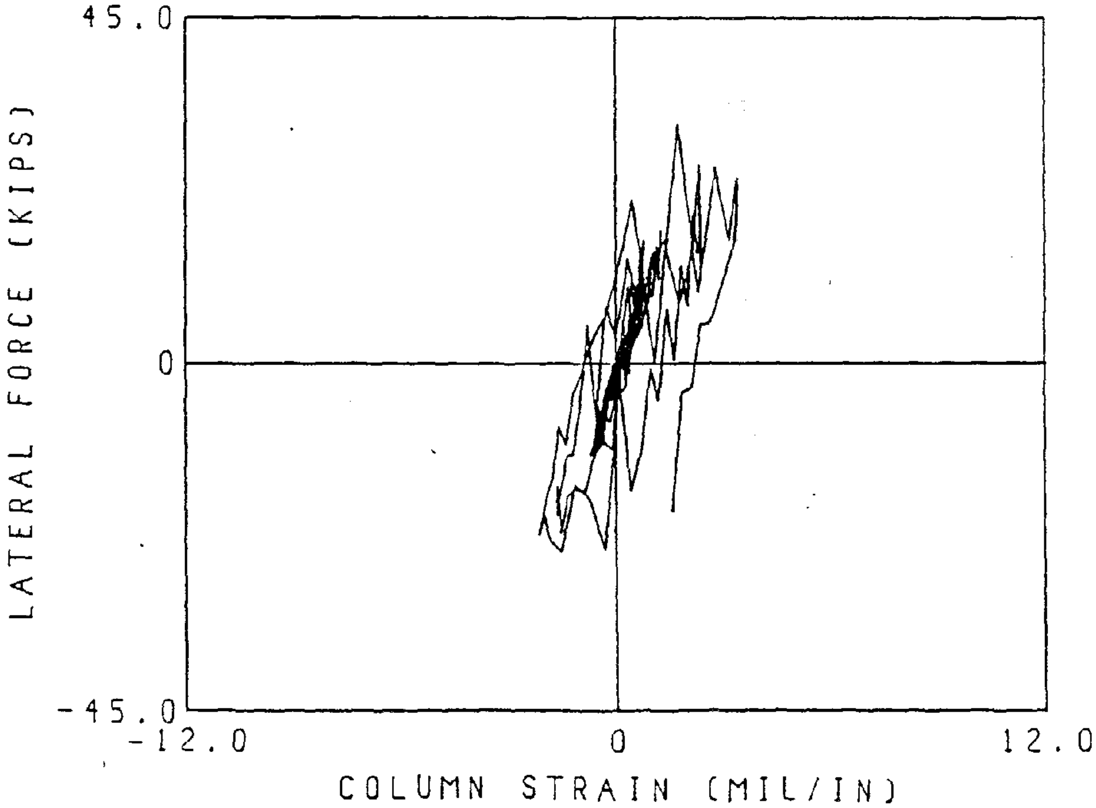


Figure 23: Column Strains Versus Lateral Force for Gage 2 for (a) 7.5 to 12.5 secs. and (b) 12.5 to 16 secs.

force.

It is noted that the traditional force - strain relationship graphs were marred by multiple disturbances caused by buffeting. The less common, but analogous strain - displacement graphs, in contrast, proved useful in depicting the hysteresis behaviour during the yielding of the columns.

3.8 Gap in the Boundary

This is test 5 shown on Table 2. Here it was intended that the partition would offer no contribution to the stiffness of the frame but would remain intact. This was true as long as the intensity of the motion was small. However, when the intensity applied corresponded to a major earthquake, the base frame deformed significantly, buffeting began, and the partition was readily destroyed. Foam rubber was tried as a filler for the gap, but its influence on the response behavior was minimal. The type of damage incurred is shown in Fig. 24.

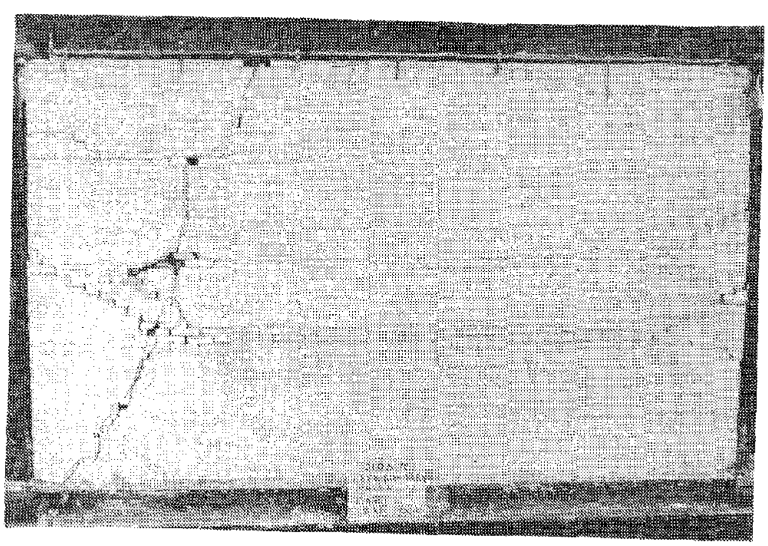


Figure 24: Damage to the Half-Scale Partition from an Earthquake Input When a Gap is Left Between Partition and Frame

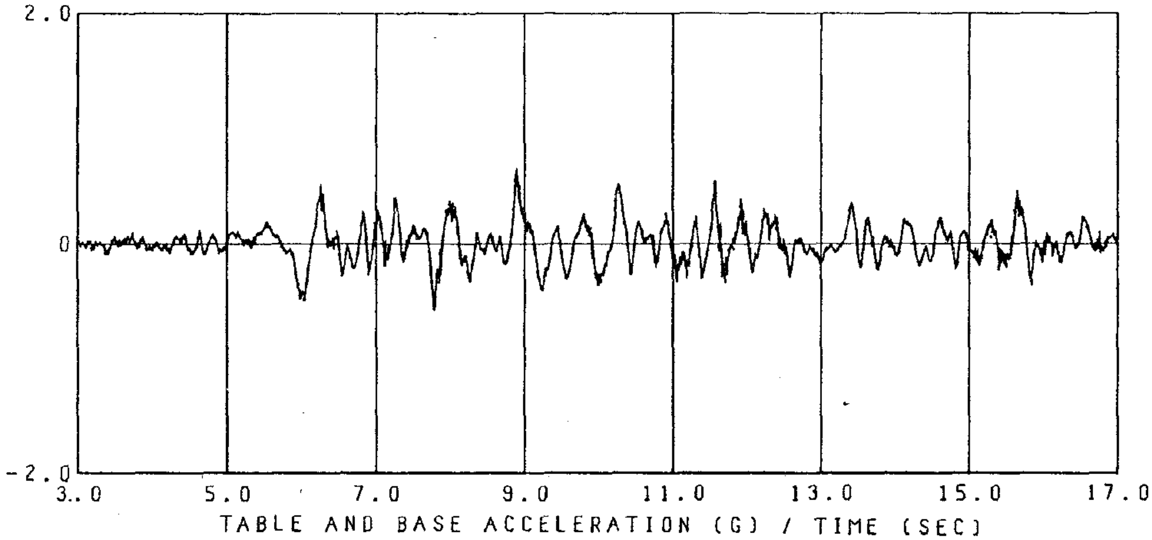
Figure 25 shows the table input for this test and Fig. 26 shows the partition responses.

3.9 Prefabricated Partitions

When the experimental program was being designed, we received a request from the Finestone Corporation of Detroit asking that we test a prefabricated partition which they manufacture. They were anxious to find out how the partition behaved when subjected to earthquake loading. We were pleased to accede to this request and at the appropriate time sent the Finestone Corporation the inner dimensions of the frame.

The partitions consisted of a steel perimeter with vertical metal studs at about twenty inch centers. See Fig. 3b. Figure 27 shows the backside of the panel. There were two models distinguished only by the cladding. For model "A" only one layer of gypsum board was used; for model "B" two layers of board were used. The tests are listed as 6 and 7 respectively in Table 2.

As they were made-to-measure, the partitions fit snugly into the frame. They were bolted to the frame at the base and were attached to the sides and top with Hydrocal. To ascertain the influence of the second layer of gypsum board, both partition experiments used the same superimposed mass and the same Pacoima Dam excitation. For both models, cracking along the perimeter started early in the excitation, the seal spalled off leaving a slight gap between frame and partition. The influence of the



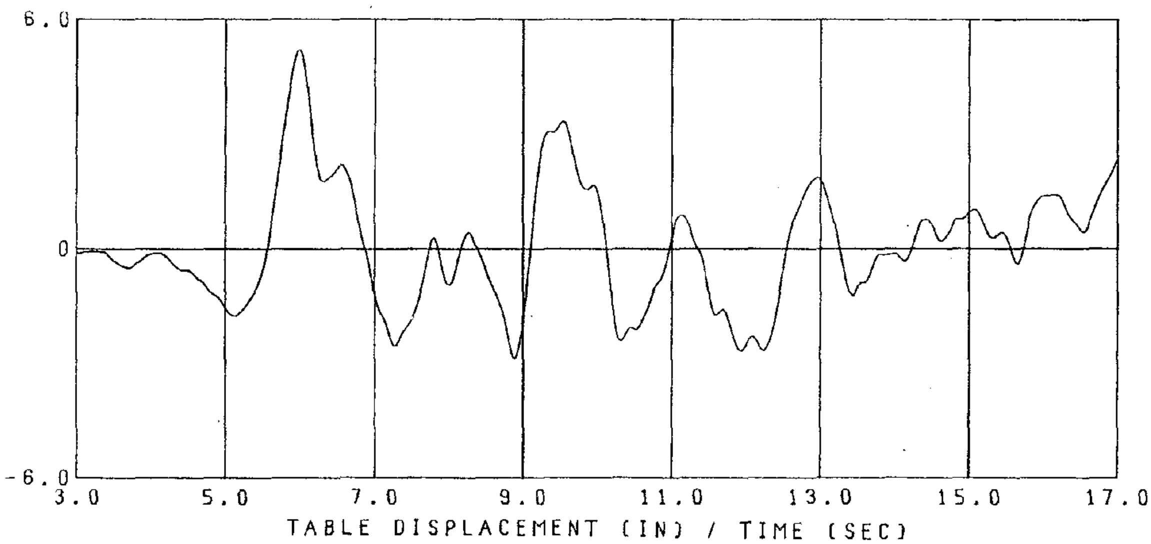
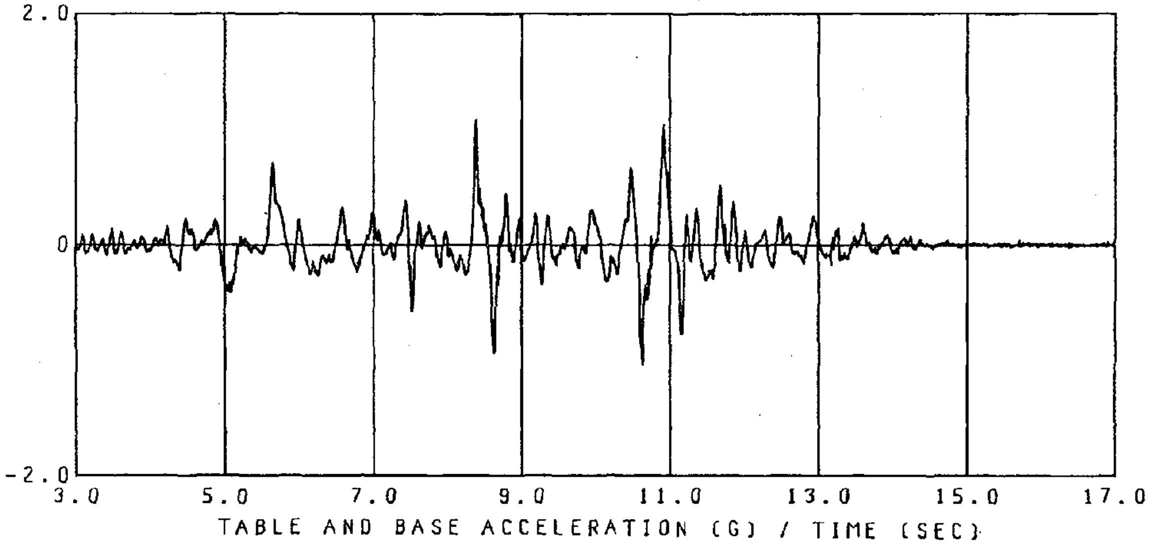


Figure 25: Table Inputs for the Half-Scale Partition with Gap



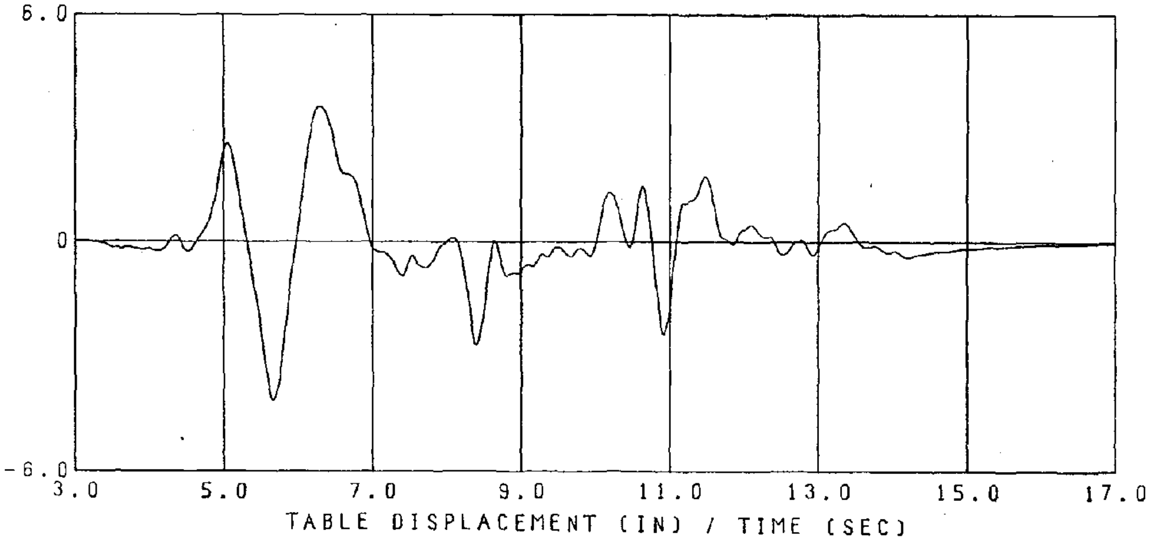


Figure 26: Partition Responses to the Earthquake Input

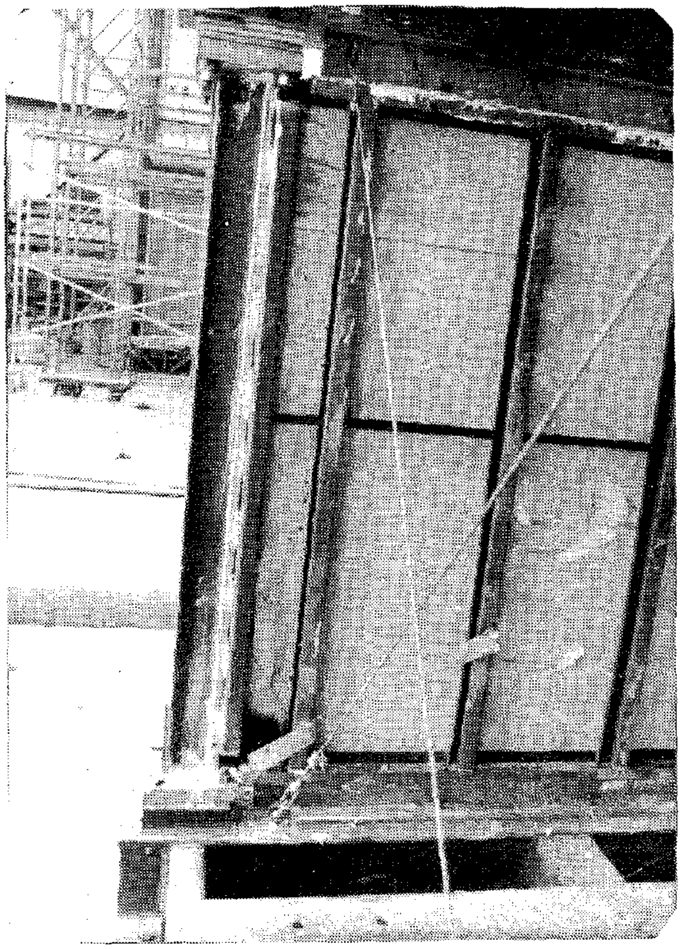


Figure 27: The Prefabricated Partition Showing the Perimeter Members and the Metal Studs

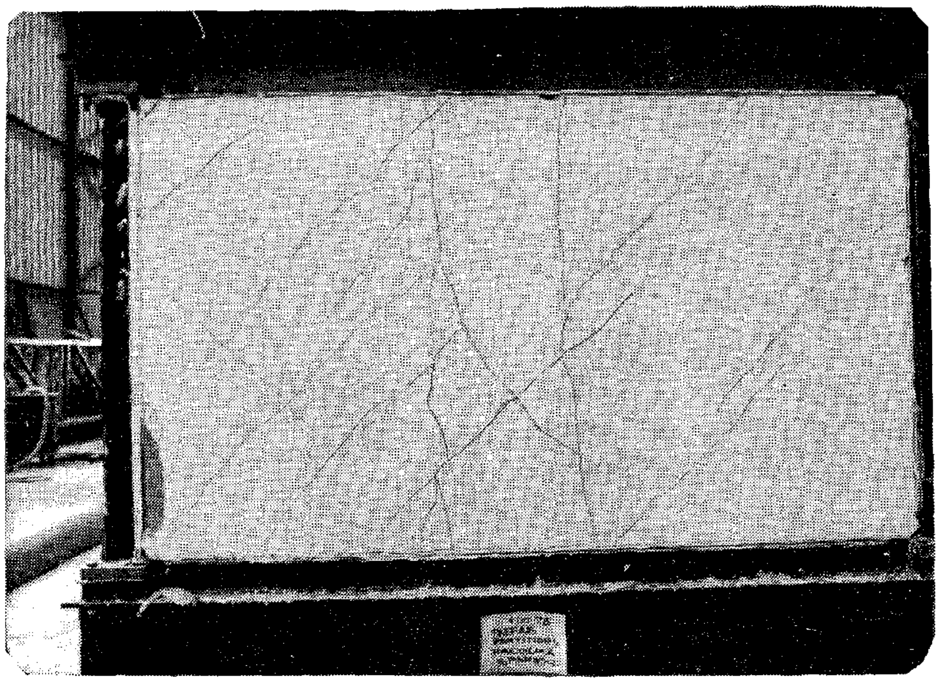


Figure 28: Damage to the Prefabricated Partition Due to an Earthquake Input

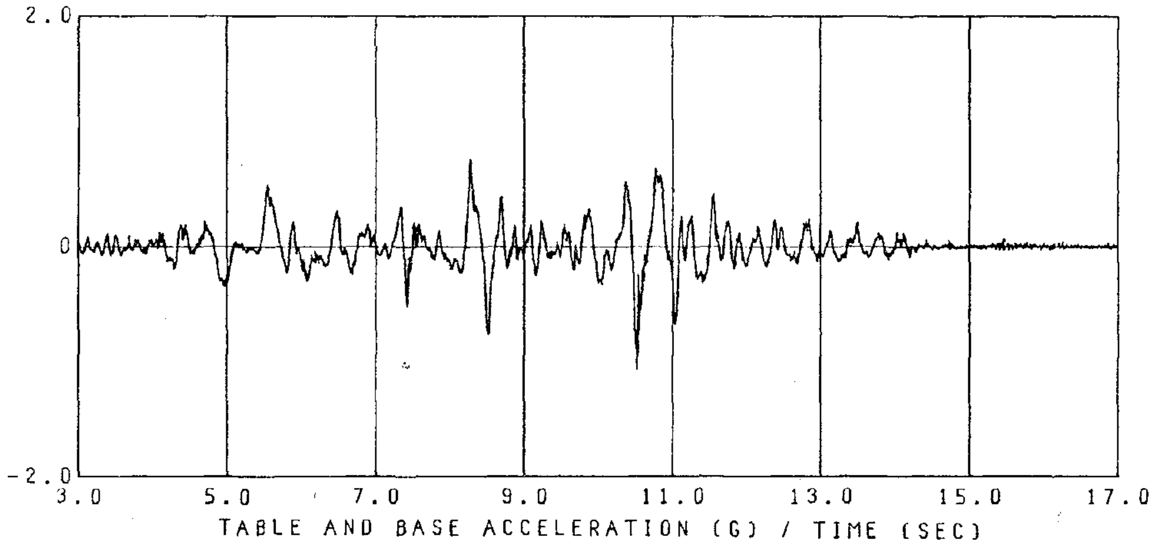
partitions was noticed early but quickly deteriorated as the partitions were forced to deform. The perimeter steel frame was sizable but not designed to withstand horizontal loads.

The drop-off of resistance of the partitions coincided with crack patterns in the siding. The model "B", with two layers of board, withstood about thirteen percent larger input than model "A." Model "A" lost resistance at an intensity of 0.891 g whereas model "B" required 1.045 g. The prefabricated partitions both survived the earthquake with damage that could easily be repaired by replacing the gypsum board, but affected the stiffness of the frame very little.

The damage to the prefabricated partition can be seen in Fig. 28. Figure 29 shows the table input to the prefabricated partition model "A", and Fig. 30 shows the partition responses. Figure 31 shows the table input to partition model "B" and Fig. 32 shows its responses.

3.10 <u>Wood Stud Partitions</u>

The wood stud partitions were constructed following standard practice. The 2 in. by 4 in. studs were spaced 16 in. center to center with a 2 in. by 4 in. wood perimeter. Gypsum board was nailed to the studs and perimeter using nails and spacing recommended by the Uniform Building Code. See Figure 3c. When they were placed within the steel frame, the partitions were bolted along the top edge and the base,



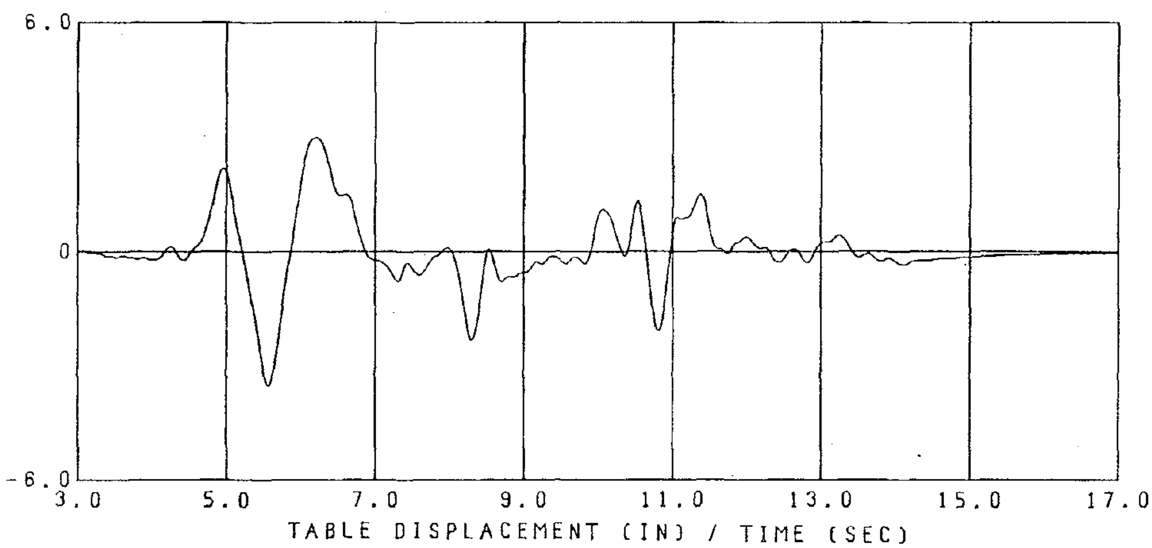
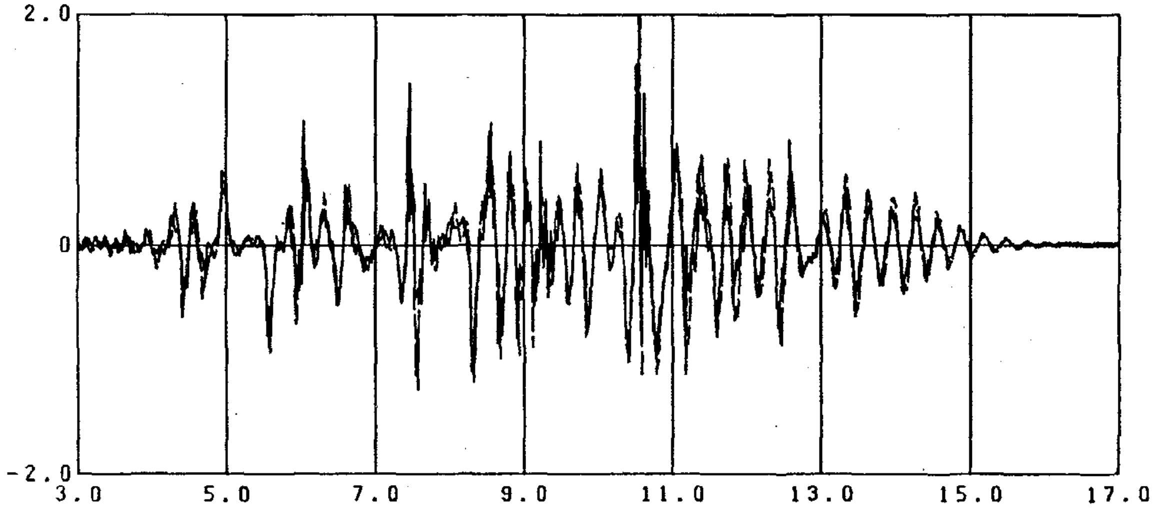


Figure 29: Earthquake Inputs to the Prefabricated Partition, Model "A"



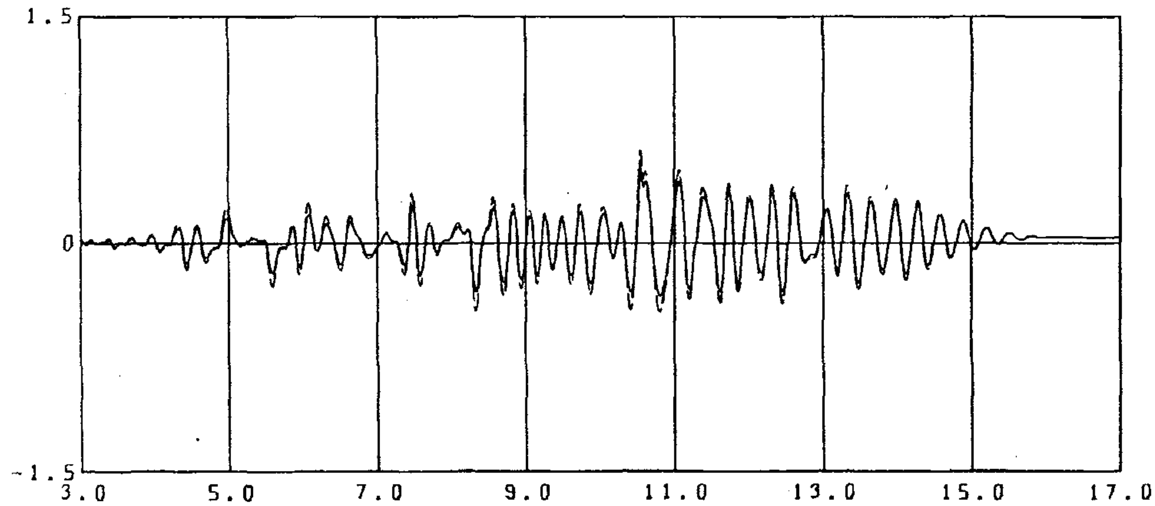
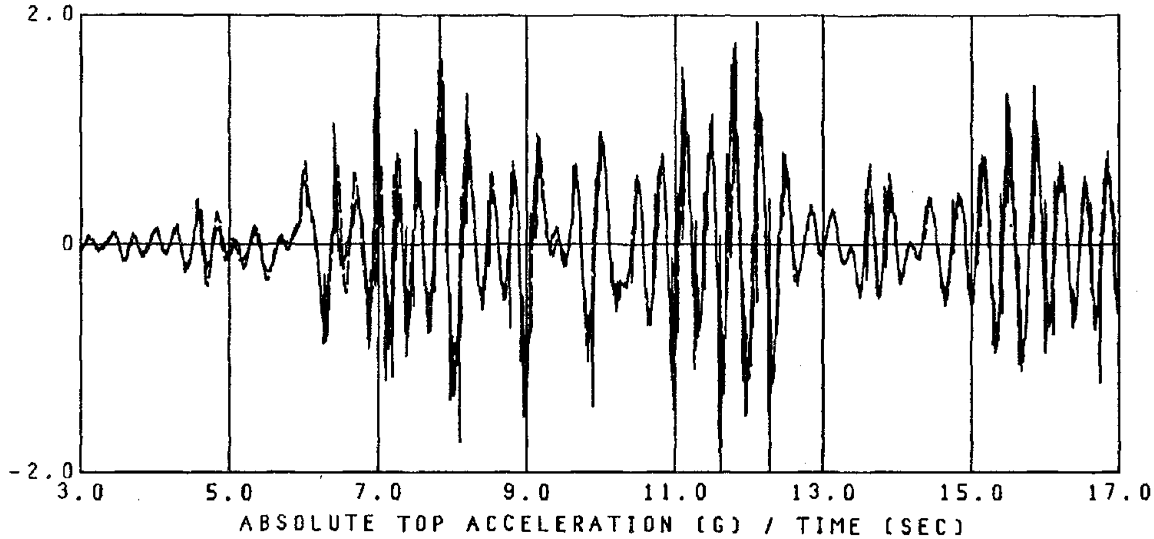


Figure 30: Responses of Partition, Model "A", to the Earthquake Input



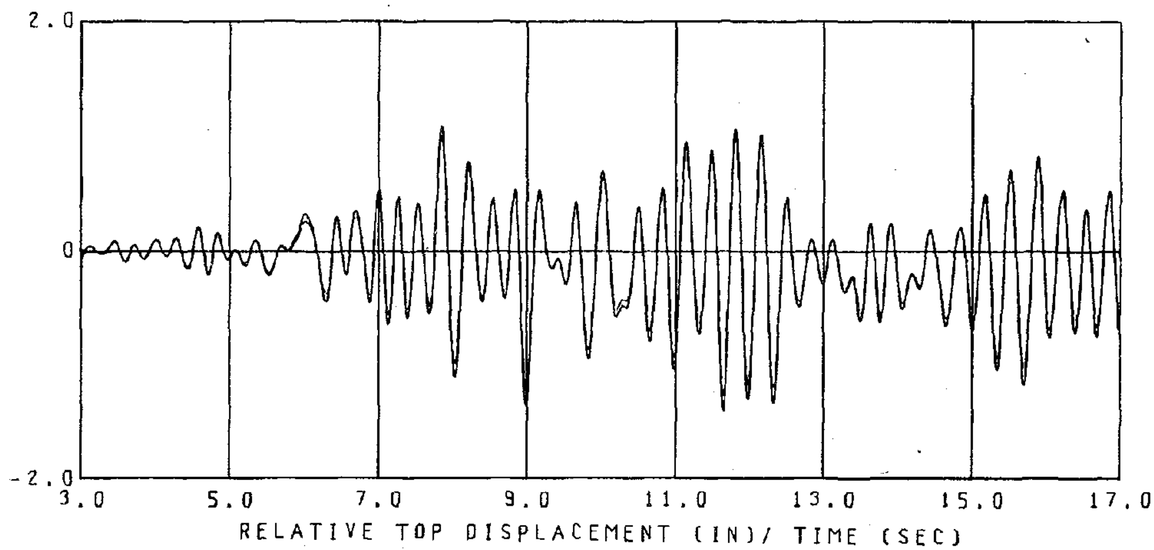
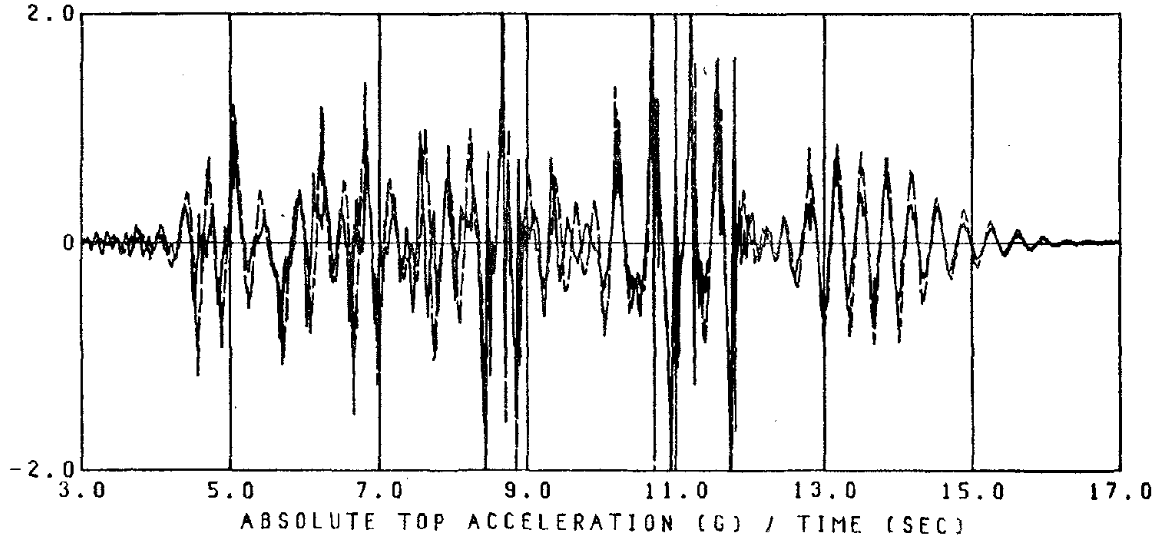


Figure 31: Earthquake Inputs to the Prefabricated Partition, Model "B"



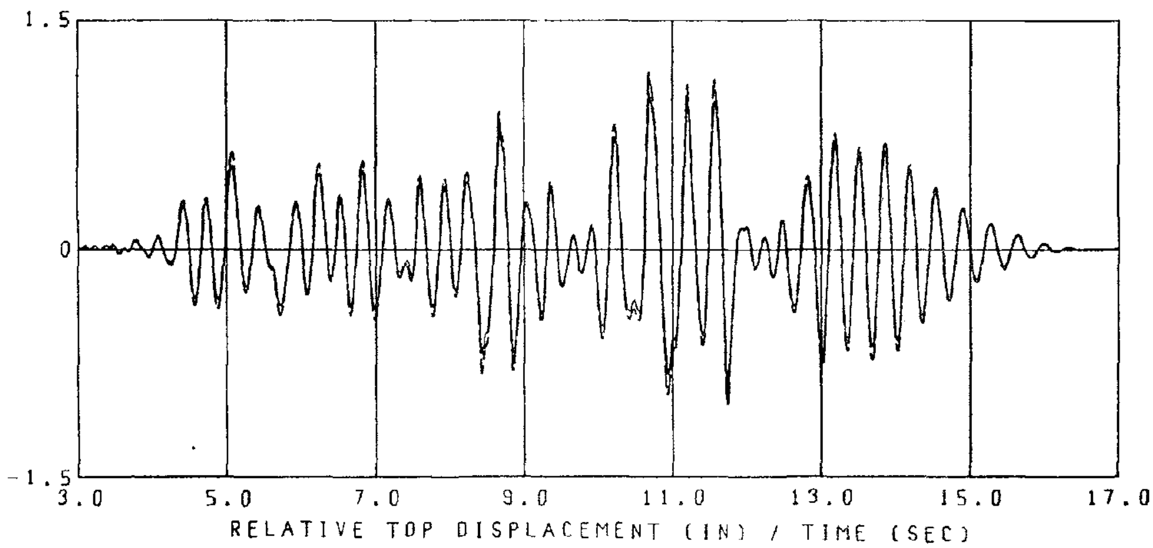


Figure 32 Responses of Partition, Model "B", to the Earthquake Input

leaving the vertical edges free.

The assembly was subjected to the Pacoima Dam earthquake. The response of the assembly resembled closely that of the bare frame, meaning that the partition had very little influence on the response of the frame. Even though the influence of the partition was small, the deformation of the assembly tended to damage the partition. The damage was probably not what was expected. The gypsum board did not crack as it did with the prefabricated panels; instead it sprang free of the studs by releasing itself from the nails, leaving holes where the nails had held it.

Figure 33 shows the wood stud partition in the frame ready for testing.

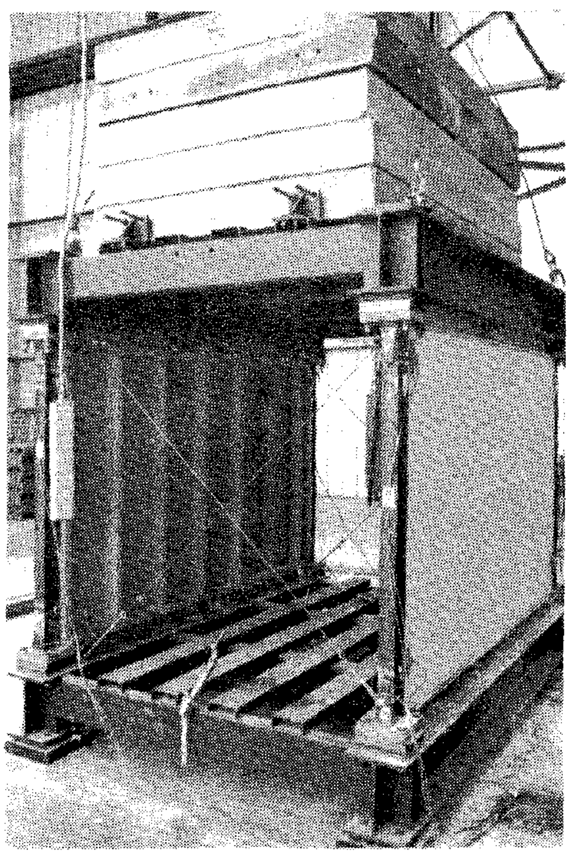


Figure 33: Wood Stud Partition in Place in Frame Ready for Testing

This test is listed as 8 in Table 2. Figure 34 shows the table input for the timber stud partitions and Fig. 35 shows the partition responses. Figures 36 and 37 show the time histories of column strains recorded by gages 4 and 12, and 7 and 15, respectively. Figure 38 shows the hysteretic behavior of top displacement versus strain and Fig. 39 shows the same but for lateral force versus strain.

Once again the hysteresis of the strain vs. displacement is smoother than the one of strain vs. force. However, the wood stud partition minimized the buffeting to such an extent that a comparison between the two hystereses graphs was easy to draw.

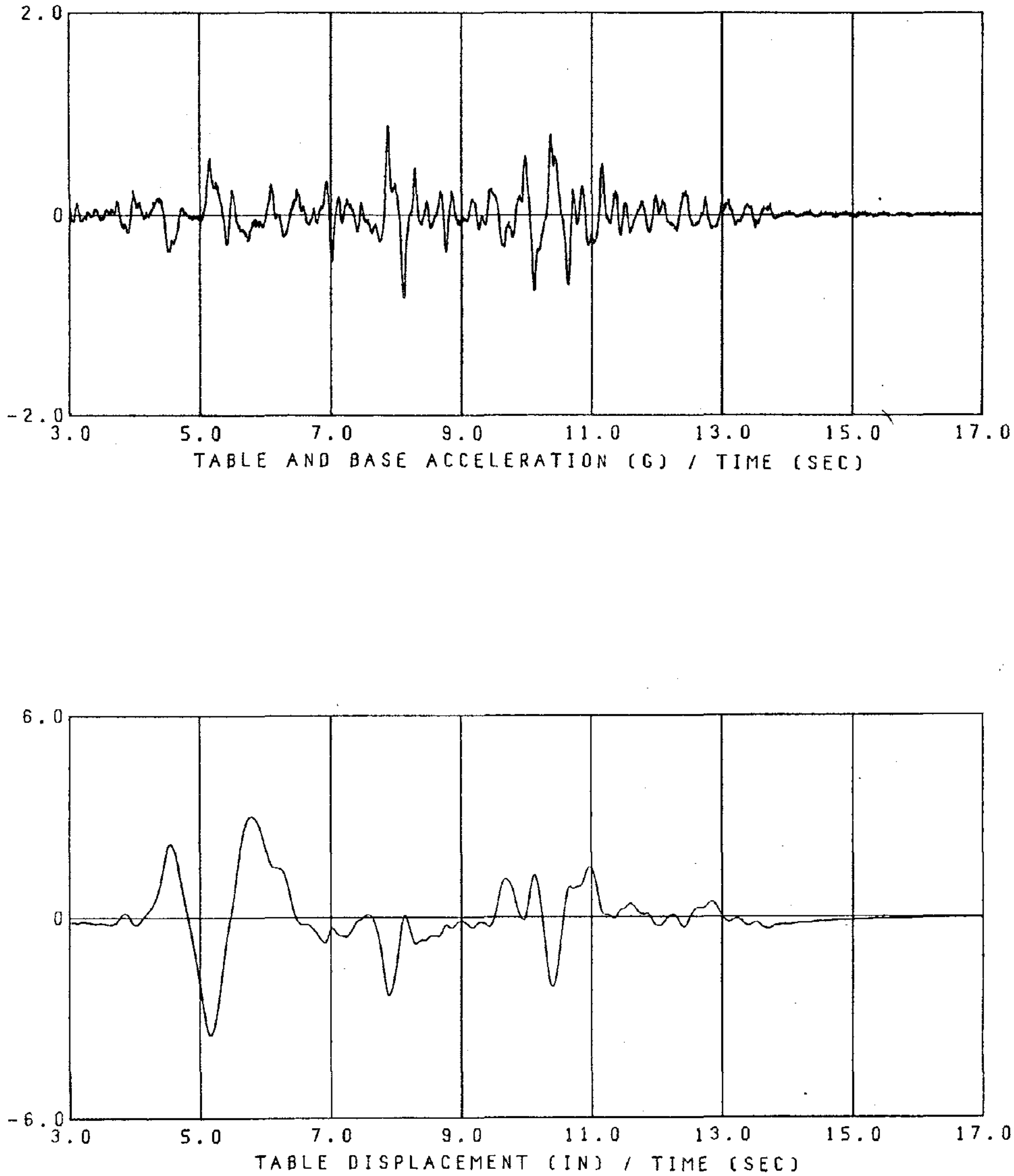


Figure 34: Earthquake Inputs to the Timber Stud Partition

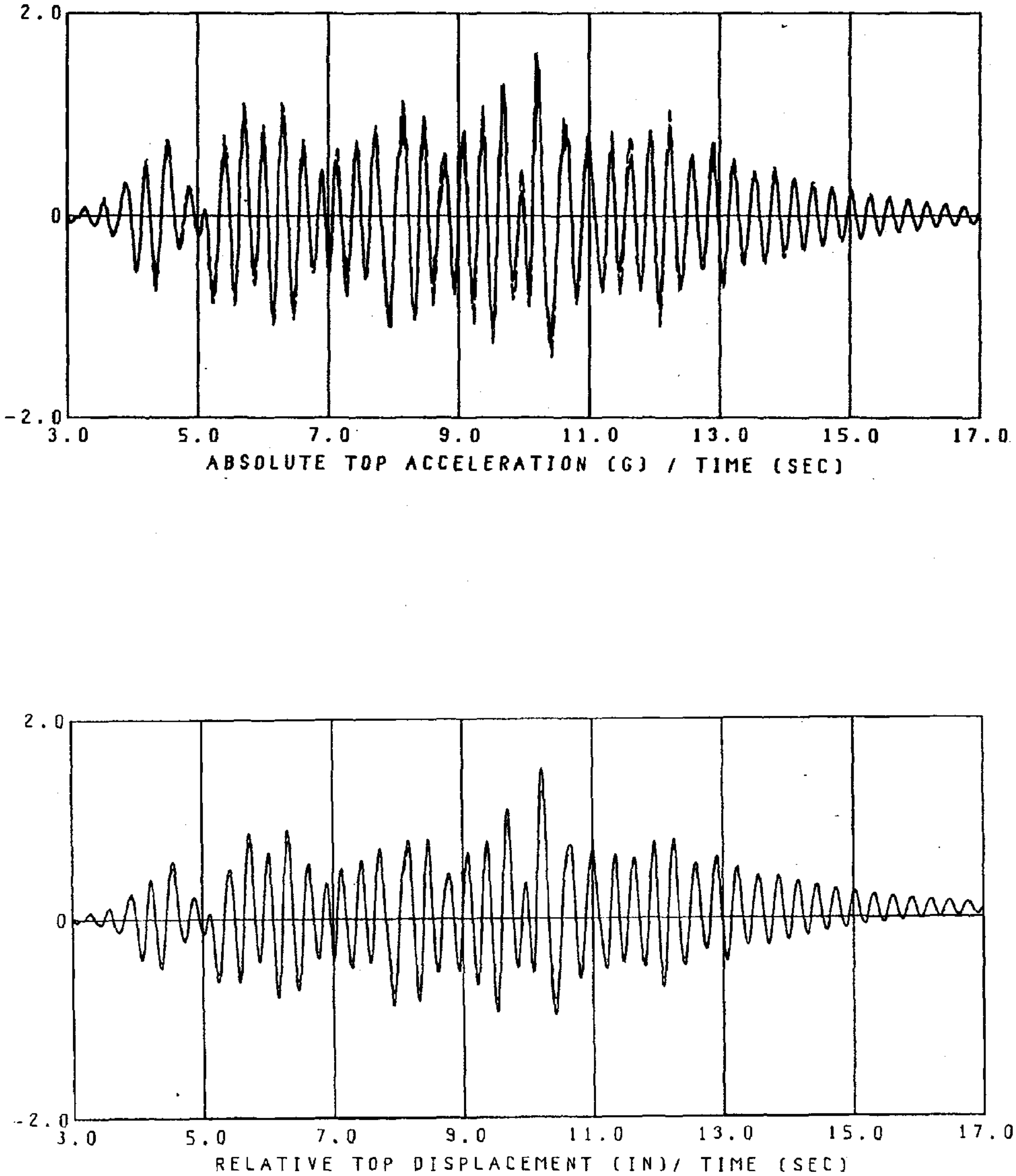


Figure 35: Partition Responses to the Earthquake Input

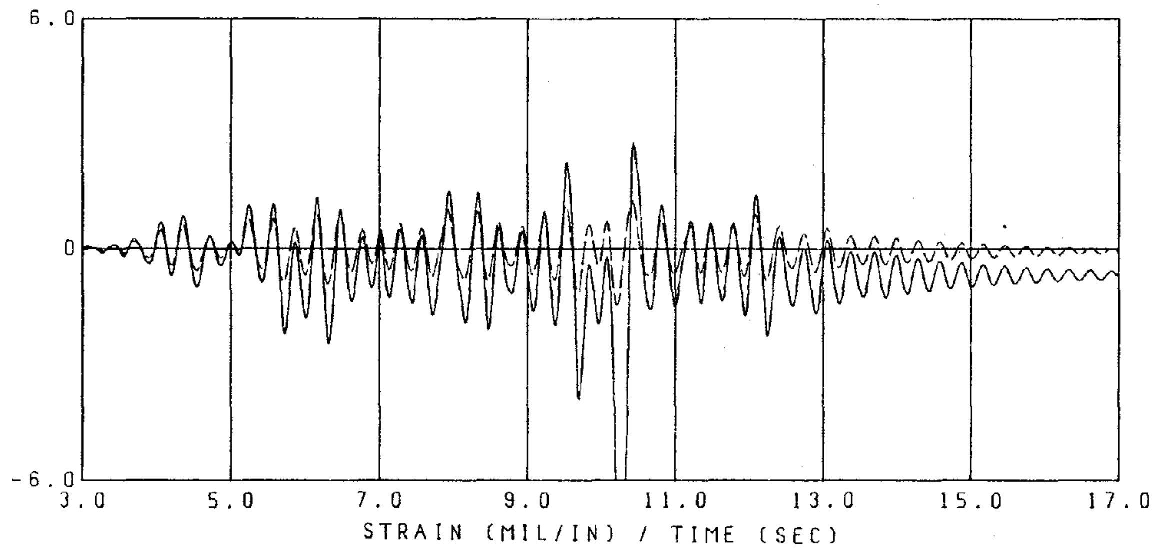


Figure 36: Strain Time History Responses for Gages 4 and 12

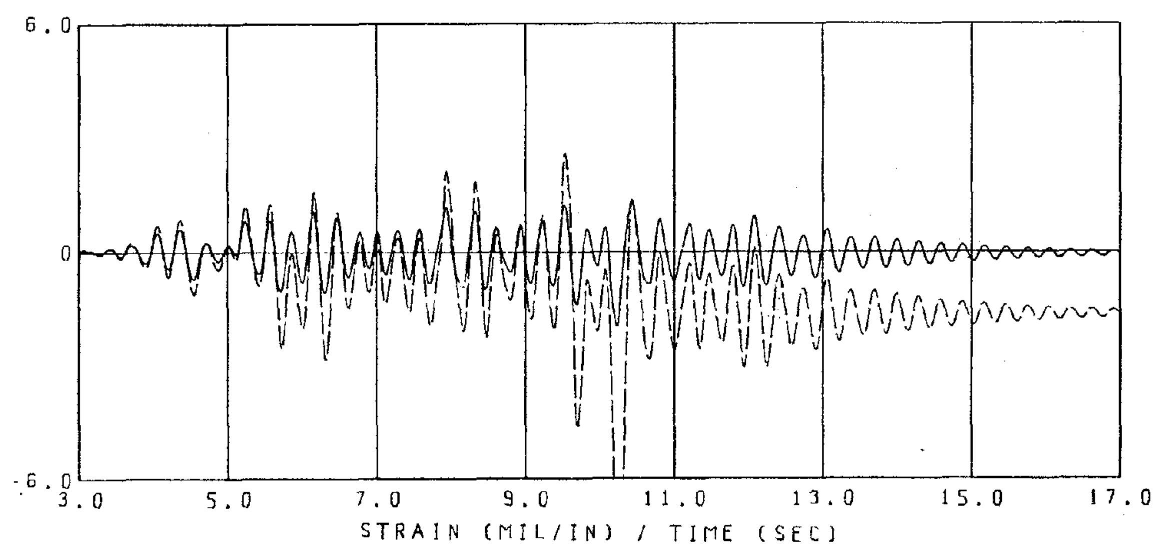


Figure 37: Strain Time History Responses for Gages 7 and 15

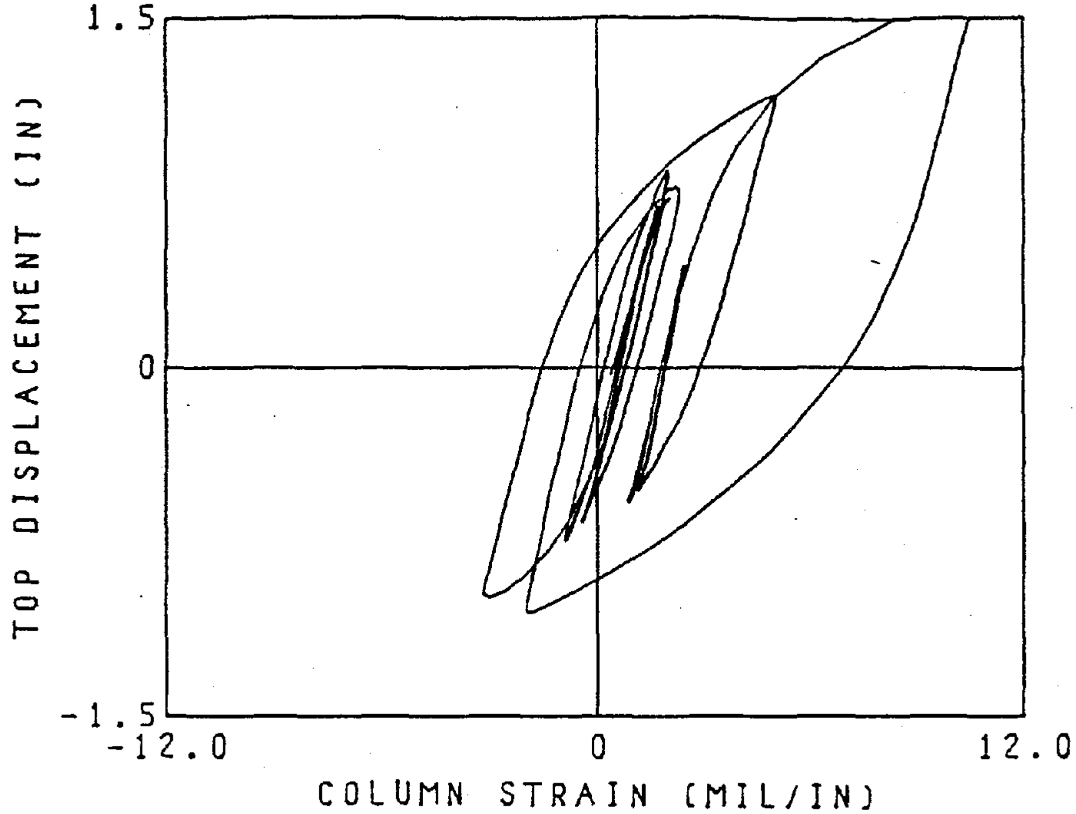


Figure 38: Column Strain Versus Top Displacement for Gage 6

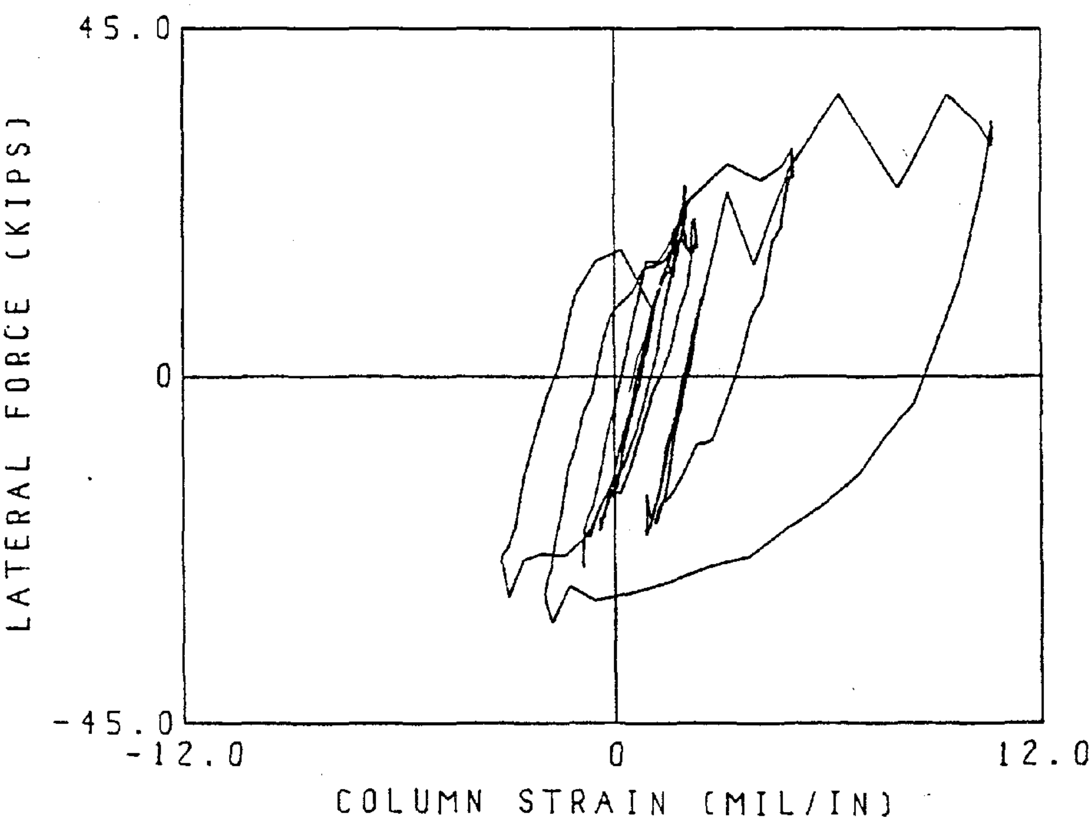


Figure 39: Column Strain Versus Lateral Force for Gage 6

4. CONCLUSIONS

Reviewing the test program and its results leads to several conclusions.

The first has to do with quasi-static versus dynamic testing. When the material being tested is brittle, such as masonry, the failure patterns for the two types of loading are quite different. This can be concluded from the failure patterns of the masonry partitions when separately subjected to quasi-static and dynamic inputs.

The program, as it should, stimulates ideas for future research. From the tests on masonry partitions, we learn that the partition adds significantly to the stiffness of the frame and alters its dampening characteristics. We also learn that the partition cannot accommodate large frame deformations with the result that the partition is destroyed by buffeting from the frame. What is indicated here is a program of research where a gap is left between partition and frame, and in that gap, at intervals to be established, there should be some kind of spring mechanism whose stiffness is such that it exerts a force on the frame to stiffen it an effective amount, but so that the size of this force is less than that required to destroy the partition.

For the stud partition a different kind of research is indicated. This program found that whereas the partitions survived, they had an insignificant influence on the frame behavior. The lack of influence can be laid to the gypsum board cladding. In one case it cracked readily and in the other it sprang free leaving the stud frame to deform easily.

What is indicated is a series of tests to ascertain precisely how much the resistance to deformation would be increased if the cladding were plywood rather than gypsum board. A series of tests is indicated where gypsum board is compared to different thicknesses of plywood. Different ways of attaching the plywood should be studied, including nails, screws, glue and then nails.

It is the plan to use the data from this program to construct mathematical models of the various test set-ups. A report devoted to the construction of these models will follow in due course.

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UCB/EERC-80/12 "Hydrodynamic Pressure and Added Mass for Axisymmetric Bodies.," by Nilrat, F., May 1980, (PB81 122 343)A08.

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UCB/EERC-80/20 "The Design of Steel Energy-Absorbing Restrainers and their Incorporation into Nuclear Power Plants for Enhanced Safety (Vol 1C): Numerical Method for Dynamic Substructure Analysis," by Dickens, J.M. and Wilson, E.L., June 1980.

UCB/EERC-80/21 "The Design of Steel Energy-Absorbing Restrainers and their Incorporation into Nuclear Power Plants for Enhanced Safety (Vol 2): Development and Testing of Restraints for Nuclear Piping Systems," by Kelly, J.M. and Skinner, M.S., June 1980.

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UCB/EERC-80/24 "U-Bar Restraint Element (Type 11) for the ANSR-II Program," by Oughourlian, C. and Powell, G.H., July 1980, (PB81 122 293)A03.

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UCB/EERC-80/30 "Dynamic Properties of an Eight-Story Prefabricated Panel Building," by Bouwkamp, J.G., Kollegger, J.P. and Stephen, R.M., October 1980, (PB81 200 313)A05.

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UCB/EERC-80/32 "The Design of Steel Energy-Absorbing Restrainers and their Incorporation into Nuclear Power Plants for Enhanced Safety (Vol 3): Testing of Commercial Steels in Low-Cycle Torsional Fatigue," by Spanner, P., Parker, E.R., Jongewaard, E. and Dory, M., 1980.

UCB/EERC-80/33 "The Design of Steel Energy-Absorbing Restrainers and their Incorporation into Nuclear Power Plants for Enhanced Safety (Vol 4): Shaking Table Tests of Piping Systems with Energy-Absorbing Restrainers," by Stiemer, S.F. and Godden, W.G., September 1980, (PB82 201 880)A05.

UCB/EERC-80/34 "The Design of Steel Energy-Absorbing Restrainers and their Incorporation into Nuclear Power Plants for Enhanced Safety (Vol 5): Summary Report," by Spencer, P., 1980.

UCB/EERC-80/35 "Experimental Testing of an Energy-Absorbing Base Isolation System," by Kelly, J.M., Skinner, M.S. and Beucke, K.E., October 1980, (PB81 154 072)A04.

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