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Building Records from 1984 Morgan Hill Earthquake

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Abstract

The dynamic response of 23 structures instrumented by the California Strong Motion Instrumentation Program was recorded during the magnitude 6.2 (ML) Morgan Hill earthquake of 24 April 1984. The structures range in complexity from a single-story warehouse to a 13-story office building. The number of acceleration sensors in the structures varied from 6 to 22, depending on structural complexity and specific measurement objectives. As an example, the Santa Clara County Office Building in San Jose was instrumented with a total of 22 sensors configured to record foundation rocking and the translational as well as torsional motion on five of the 13 stories.

The strong motion records from seven buildings and one bridge have been digitized and processed. Maximum horizontal ground accelerations at the buildings were in the range 0.03 - 0.11 g; maximum roof accelerations were 0.17 - 0.41 g. Processing of the digitized data indicates that the maximum horizontal displacements at roof level ranged from 1 to 19 centimeters. Significant structural response lasted for less than 35 seconds for most buildings. However, the steel-frame Santa Clara County Office Building had significant response for about 80 seconds. The records from this structure and from a single-story warehouse of tilt-up construction are considered in some detail in this paper.

Introduction

The Morgan Hill earthquake occurred on April 24, 1984 on the Calaveras fault southeast of San Jose, California with local magnitude (ML) of 6.2 (BRK). It triggered the strong-motion accelerographs at nearly 50 stations instrumented by the California Strong Motion Instrumentation Program (CSMIP). Twenty-three of those stations are extensively-instrumented structures. The records obtained at these structures as well as the instrumentation descriptions are given in Shakal et al. (1984). Additional information about the Morgan Hill earthquake and the associated damage is available in the compilation by Bennett and Sherburne (1984) and a special issue of Earthquake Spectra (1985).

The records obtained at 7 buildings have been digitized and processed. A listing of the buildings and the maximum amplitudes of motion at the base and the top of each is given in Table 1. The

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complete results of processing the records from these buildings are available in Huang et al. (1985). In the interests of brevity, this paper presents only the records obtained at the Santa Clara County Office Building in San Jose and the Glorietta Warehouse in Hollister. The records from the other buildings are only briefly discussed here.

Santa Clara County Office Building in San Jose

The 13-story Santa Clara County Office Bldg. in San Jose is about 21 km from the earthquake epicenter. The structure is 167 by 167 feet in plan and 187 feet in height. The exterior cores at the west and south ends extend from the lower level to 24 feet above the roof. The lateral load-resisting system of the building is composed entirely of moment-resisting steel frames. The vertical load-carrying system consists of concrete floor slabs overlying metal decks supported by the steel framing. The foundation is a concrete mat.

Twenty-two accelerometers were installed at locations throughout the building. The signals from the accelerometers were recorded by two central recorders on the lower level. The locations of the accelerometers are shown in Fig. 1. Sensors 1 - 3, on the lower level, are mounted vertically to record the vertical motion at the base as well as to indicate the presence of any foundation rocking. Channels 20 and 21 record the east-west translational motion of the foundation at the north and south ends. This east-west pair of sensors is repeated on the 2nd, 7th and 12th floors and on the roof. These sensor pairs allow analysis of translational as well as torsional motions at these levels. These pairs are complemented by pairs sensing north-south motion on the same levels.

The digitized records obtained during the 1984 Morgan Hill earthquake are plotted in Fig. 2. The records show that the building vibration lasted about 80 seconds with the last 50 seconds in almost purely fundamental mode motion. The period of this fundamental mode motion is about 2 seconds in both directions, which is 50% longer than the period given by T=0.1N for a steel frame building. The processing results included in Huang et al. (1985) indicate that the maximum relative displacement between the roof and lower level is about 16 centimeters. This is 5 to 6 times that at the other two 10-story reinforced concrete buildings in the same area (see Table 1). In addition, the duration of vibration of this building is about twice as long as that of the other two buildings.

The extensive instrumentation of this building warrants thorough and detailed studies of the records. Studies could include estimation of modal periods and damping, investigations of the torsional response, of the relationship between design loads and structural response, and of the performance of the building if subjected to stronger shaking than that during the Morgan Hill earthquake. Preliminary analysis of the data indicates the presence of torsion in the building response. Further, the foundation torsional motion appears to be relatively small compared to that on the higher floors. Thus, most of the torsional motion at the upper levels of the structure represents torsional response to translational input motion, or alternatively, amplification of the torsional input motion.

Glorietta Warehouse in Hollister

The Glorietta (now Tri-Valley Growers) warehouse in Hollister is a single-story structure approximately 300 by 100 feet in plan and 30 feet in height, and is approximately 37 km from the Morgan Hill earthquake fault. The lateral force-resisting system consists of concrete shear walls on the perimeter and a plywood roof diaphragm. The glu-lam roof beams, interior steel pipe columns, and concrete perimeter walls carry vertical loads. The structure is of tilt-up construction.

Thirteen accelerometers were installed on the walls and roof of the structure, as shown in Fig. 3. The record obtained during the 1984 Morgan Hill earthquake is also shown in Fig. 3. Some important observations and preliminary interpretations can be made through direct inspection of this record. The transverse in-plane vibration of the roof diaphragm is readily apparent by comparing the record from sensor 4, at the middle of the roof, with those from sensors 2 and 3, at the end walls. Similarly, comparison of the record from sensor 11 with those from 10 and 12 indicates the in-plane longitudinal vibration of the roof diaphragm. The side-wall out-of-plane motion can be noted by comparing the record from sensors 5 and 6 with the base motion indicated by sensor 7.

The in-plane vibration of the roof diaphragm in the transverse direction, indicated by sensor 4, suggests that the principal mode of vibration of the structure is that shown in Fig. 4a. From the response spectrum it is estimated that this mode has a frequency of about 1.7 Hz. Comparison of the records from sensors 5, 6 and 7, on the sidewall, indicates that much of the high-frequency motion present at the mid-height (sensor 6) did not occur at the top of the wall (sensor 5). This may reflect structural response in the vibration mode shown in Fig. 4b, in which the center line of the roof is a node. Analysis of the spectrum indicates this mode has a frequency of about 4.2 Hz.

The record obtained at this warehouse is the first strong motion record obtained from a tilt-up building. Many tilt-up structures were heavily damaged in the 1971 San Fernando earthquake. Most failures arose from a weak connection between the roof diaphragm and tilt-up wall. The building code was revised after that earthquake. This warehouse was designed and constructed in 1979 with the roof diaphragm built according to the new code. It performed well during the Morgan Hill earthquake. Detailed study of this record will provide guidance in code revision.

Features of Records From Other Buildings

The Town Park Tower Apartment building and the Great Western S & L building in San Jose are both 10-story reinforced concrete buildings. The records from these buildings, quite close to the Santa Clara County Bldg., have been digitized and are included in Huang et al. (1985). The records from the gymnasium at West Valley College in Saratoga indicate large in-plane vibrations of the roof diaphragm. Another building, the 4-story Watsonville Telephone building, is important because, constructed in 1948, it predates most of the modern code

provisions. Study of that record can lead to a better understanding of ways of retrofitting old buildings. Finally, the record from the Kaiser Medical Center in South San Francisco is of interest because of the large response amplitudes of this 4-story steel-frame hospital, nearly 80 km from the earthquake source.

Data Availability

The 1984 Morgan Hill earthquake generated an important set of records for the analyses of structural response. Although the instrumented buildings did not suffer structural damage, the extensive instrumentation provided detailed data on the response of several types of structures. For each structure, the raw and processed data, copies of the structural drawings, and details on the locations of each sensor can be obtained upon request to: Office of Strong Motion Studies, Division of Mines and Geology, California Department of Conservation, 630 Bercut Drive, Sacramento, California 95814.

Table 1 - Summary of Processed Building-Response Records from the 1984 Morgan Hill Earthquake

Structure	No. Stories (above/below ground)	No. of Sensors	Type of Bldg.	Epicentral Distance (km)*	Peak Acceleration** Ground	Peak Acceleration** Structure	Peak Velocity (cm/sec) Ground	Peak Velocity (cm/sec) Structure	Peak Displacement (cm) Ground	Peak Displacement (cm) Structure
San Jose - Town Park Tower Apartment Bldg.	10/0	13	RC Shear Walls	19 [19]	0.06g H 0.04g V	0.21g H	11.5 H 3.5 V	23.6 H	3.0 H 1.1 V	5.2 H
San Jose - Great Western S & L	10/1	13	RC Frame & Shear Walls	19 [19]	0.06g H 0.03g V	0.22g H	11.9 H 3.9 V	27.4 H	3.6 H 0.9 V	6.4 H
San Jose - Santa Clara County Bldg.	12/1	22	Steel Frame	21 [21]	0.04g H 0.02g V	0.17g H	9.2 H 3.4 V	57.4 H	3.2 H 1.0 V	19.2 H
Saratoga - West Valley College Gym	1/0	11	RC Columns & Shear Walls	30 [30]	0.10g H 0.03g V	0.41g H	5.8 H 2.5 V	18.2 H	1.0 H 0.6 V	1.1 H
Watsonville - Telephone Bldg.	4/0	13	RC Shear Walls	45 [30]	0.11g H 0.08g V	0.33g H	9.1 H 3.9 V	16.2 H	1.8 H 0.7 H	2.2 H
Hollister - Glorietta Warehouse	1/0	13	Perimeter Shear Walls	57 [37]	0.08g H 0.30g V	0.25g V	7.3 H 11.7 V	22.4 H	3.1 H 0.8 V	3.5 H
So. San Francisco - Kaiser Medical Center	4/0	11	Steel Frame	78 [78]	0.03g H 0.02g V	0.26g H	3.9 H 1.3 V	19.5 H	0.7 H 0.3 V	2.4 H

* - Distance given relative to the epicenter, 37.309 N, 121.678 W. Bracketed number is the distance to the nearest point on the fault inferred from the aftershock distribution.
** - Corrected acceleration, H - horizontal component, V - vertical.

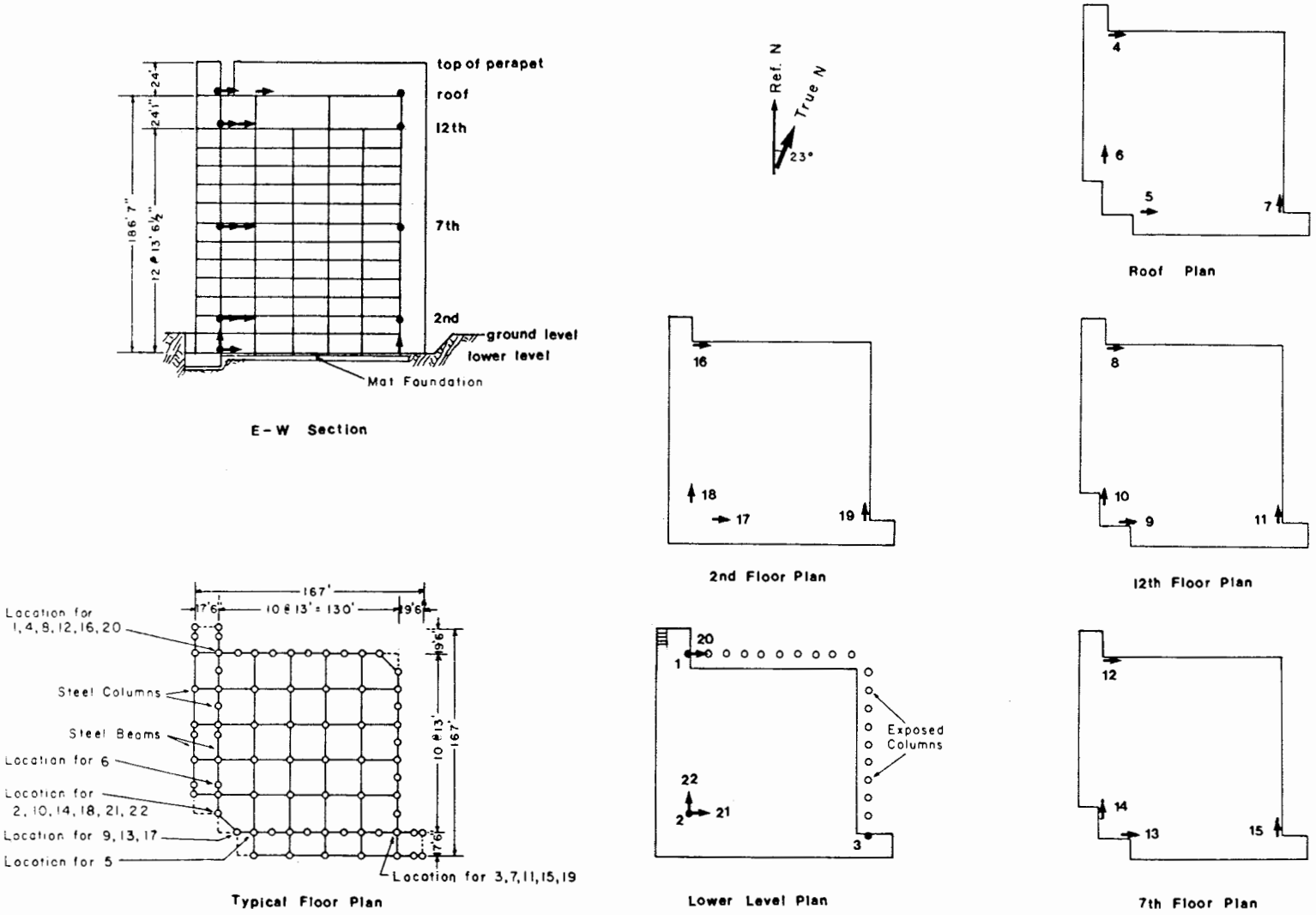

Figure 1. Location of Acceleration Sensors in the Santa Clara County Office Bldg. in San Jose during the 1984 Morgan Hill Earthquake.

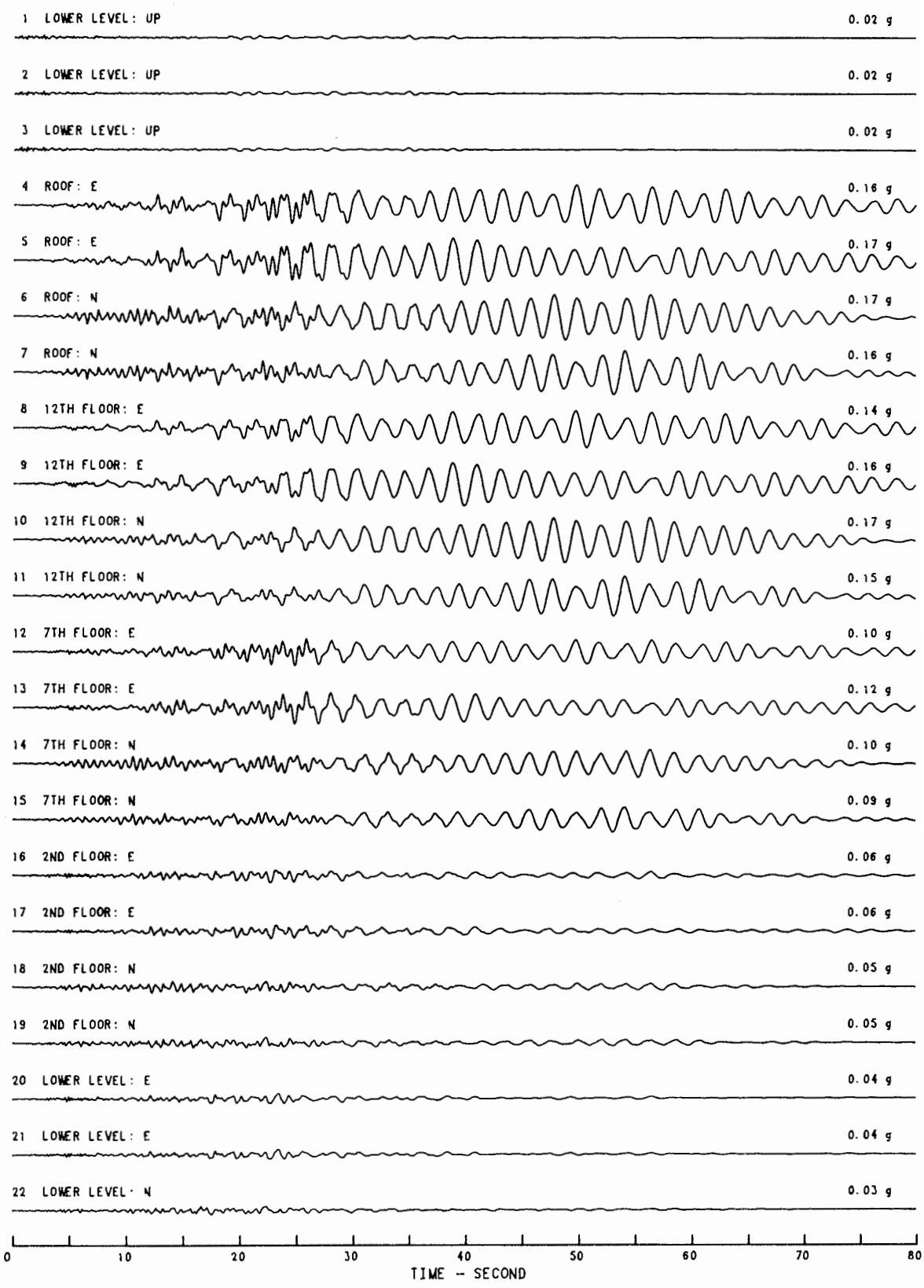

Figure 2. Acceleration Records from the Santa Clara County Office Bldg. in San Jose during the 1984 Morgan Hill Earthquake.

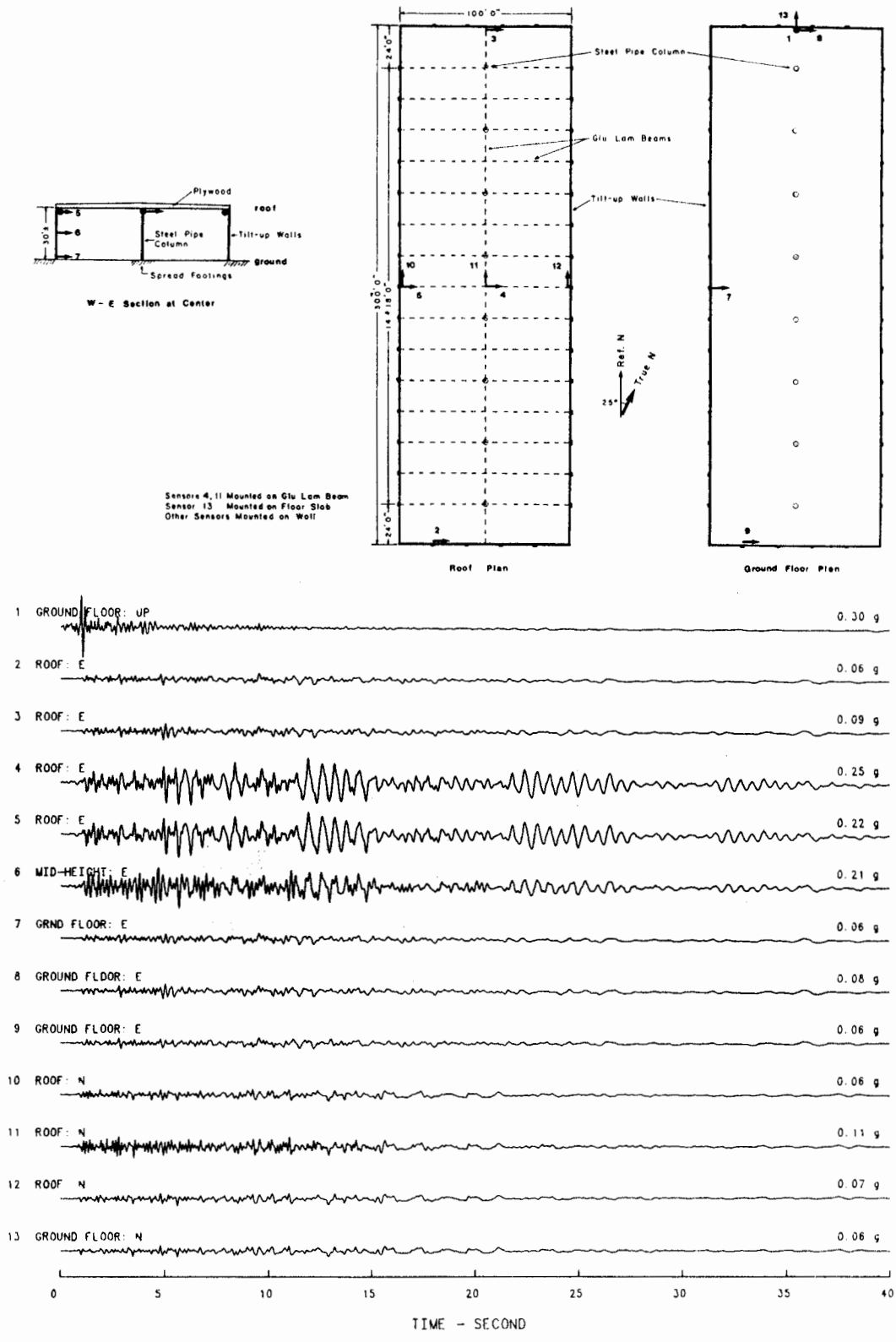

Figure 3. (Upper) Location of Acceleration Sensors in the Glorietta Warehouse in Hollister. (Lower) Record Obtained during the 1984 Morgan Hill Earthquake.

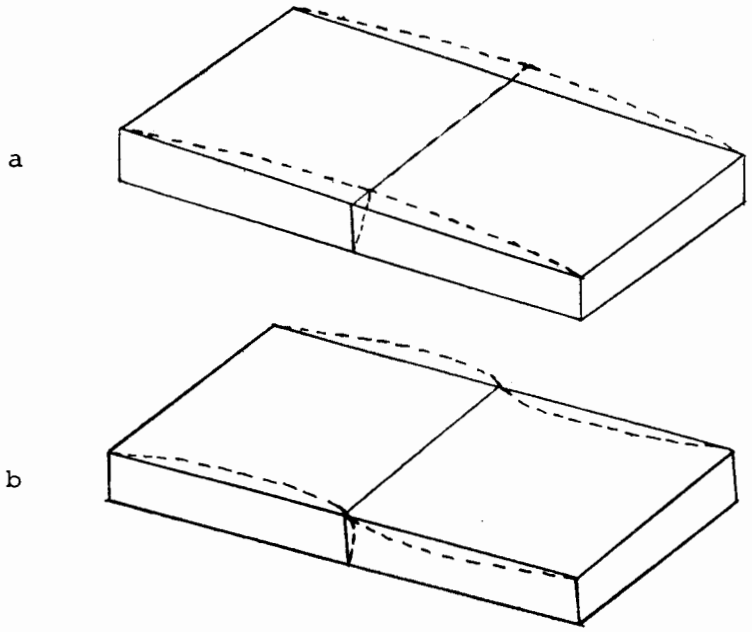

Figure 4. Inferred Mode Shapes of Vibration of the Glorietta Warehouse during the 1984 Morgan Hill Earthquake.

References

Bennett, J.H. and R.W. Sherburne (1985) (eds.) The Morgan Hill, California earthquake, Calif. Div. Mines and Geol., Report SP-68, 271 pp.

Earthquake Spectra, issue devoted to Morgan Hill earthquake, Vol. 1, No. 3, 1985, Earthq. Eng. Res. Inst., Berkeley, California.

Huang, M.J., A.F. Shakal, D.L. Parke, R.W. Sherburne and R.V. Nutt (1985), Processed Data from the Strong-Motion Records of the Morgan Hill Earthquake of 24 April 1984, Part II. Structural-Response Records, Calif. Div. Mines and Geol., Office of Strong Motion Studies, Report OSMS 85-05.

Shakal, A.F., R.W. Sherburne and D.L. Parke (1984) CDMG strong-motion records from the Morgan Hill, California earthquake of 24 April 1984, Calif. Div. Mines and Geol., Office of Strong Motion Studies, Report OSMS 84-7.