6th Canadian Conf. Earthquake Engineering / Toronto / 1991 / 6ème Conf. Canadienne Sismique

Experimental study on the seismic response of telecommunications equipment supported on access floor

C.M. Wong[1] and W.K. Tso[2]

ABSTRACT

An experimental study was carried out to investigate the dynamic properties and the seismic response of telecommunications equipment supported on access floors. A total of three access floor systems from three manufacturers were used in the test program. A commercially available telecommunications cabinet was used as a representative equipment. The test program consisted of three phases. First, static tests were performed to determine the lateral load-deflection characteristics of the access floors by themselves. Second, shake table tests were performed to determine the frequency and damping characteristics of the equipment cabinet and the combined equipment-access floor systems. Lastly, the equipment and the combined equipment-access floor systems were tested on a shake table under different level of excitation compatible with the building floor response spectra specified in the NEBS criteria of the telecommunications industry. The experimental results showed that the response motion of the equipment cabinet was amplified significantly by the access floor. Equipment units supported on access floors without stringers are more prone to be damaged due to the possibilities of collapse of the access floor in a strong earthquake.

INTRODUCTION

Access floor systems have been widely used to support equipment in telecommunications central offices. There are two major issues associate with the seismic safety of telecommunications equipment on access floors. First, most access floor systems are designed to support mainly gravity load; hence, their seismic performance which is dependent of their lateral strength and stiffness is unknown. Second, an access floor system tends to amplify the earthquake-induced building floor motion; as a result, the equipment supported on it would be subjected to a more severe shaking than if it were supported directly on a building floor. To address to the first issue, static tests were carried out to investigate the lateral strength and stiffness properties of three commercially available access floor systems. The second issue was addressed by carrying out shake table testing using a commercially available telecommunications equipment cabinet on different access floor systems.

In order to perform shake table testing to study the seismic response of the equipment cabinet on different access floors, it is necessary to use an input excitation which represents the upper-bound building floor motions induced by earthquakes. In North America, such input excitation can be derived from the floor

---

[1] Post Doctoral Fellow, Dept. of Civil Engineering and Engineering Mechanics, McMaster University, Hamilton, Ontario.

[2] Professor, Dept. of Civil Engineering and Engineering Mechanics, McMaster University, Hamilton, Ontario.

response spectra shown in Fig. 1a. These spectra are given in the NEBS (Network Equipment Building System) criteria (Bell Communications Research, 1988) which is the most commonly employed industry standard in the telecommunications industry. A typical artificially generated acceleration time history compatible with the NEBS 2% damped spectrum is shown in Fig. 1b. The time history has a duration of 31 seconds and a maximum acceleration of 1 g. This time history is a representative of the potential earthquake-induced floor motion at the top stories of buildings situated in zone 3 of Uniform Building Code. The associate displacement time history obtained from numerical integration of this acceleration time history is shown in Fig. 1c. This displacement time history was used as the input for the shake table in the experiment.

DESCRIPTION OF ACCESS FLOOR SYSTEMS AND EQUIPMENT CABINET

Access floor systems manufactured by three different suppliers (referred as supplier A, B, and C in the subsequent discussions) were used in this study. They all have a finished floor height of 20" (50.8 cm). Access floor systems of suppliers A and B are similar. They consist of an assembly of three components made of galvanized steel, pedestals, stringers and panels. Each pedestal has a square base plate to which a tubular stem is connected by spot-welding. The stringers are bolted onto the pedestals by means of screws. The stringers and the pedestals form a 2' (61 cm) square-grid understructure on which the floor panels are rested. The floor panels can either rest on the understructure or be bolted at its four corners on the understructure by means of screws. The access floor system of suppliers C is a stringerless system. It also has 2' (61 cm) square floor panels which rest on pedestals laid out in a 2' (61 cm) square pattern. The pedestals and panels are made of cast aluminum.

The equipment cabinet used in the study is a commercially available switching equipment used commonly in telecommunications central offices. The electronic gears in the cabinet were replaced by an equivalent amount of mass. The dimensions of the cabinet are 42x26" (107x66 cm) and 6' (1.83 m) in height. The entire cabinet weighs 1660lb (7.42 KN).

TESTING PROGRAM AND SET-UPS

To determine the lateral strength and stiffness properties of the access floors, static tests were done on a single-panel module of each of the access floor systems. An overview of the test set-up and the instrumentation involved is shown in Fig. 2. The lateral load was applied by means of a hydraulic jack. A load cell and two LVDT's (linear variable displacement transducer) were used to monitor the applied load and the lateral displacement of the access floor respectively. The loading history comprised of several cycles of loading and unloading followed by a monotonically increasing loading until the specimen had been failed.

To study the dynamic amplification effect of the equipment cabinet on access floors, the cabinet by itself and the combined cabinet-access floor systems were tested dynamically on a shake table using random excitation and artificially generated earthquake excitation compatible with the 2% damped NEBS spectrum. For the random excitation test, a low level (maximum displacement of 0.05") random shaking was applied to the specimen. The transfer function for the acceleration signal measured by the accelerometers at the top of the cabinet and that at the shake table were monitored by a dual channel spectrum analyzer. The frequencies and damping ratios of the specimen were determined from the transfer function. For the NEBS excitation test, several levels of the NEBS excitation given by the time history shown in Fig.1b were used. The accelerations and displacements at various locations on the specimen and at the shake table were recorded by a microcomputer based data acquisition system.

For the shake table test carried out for the equipment cabinet alone, the equipment was anchored by four expansion fasteners on a concrete slab which was in turns mounted on the shake table. The set-up and instrumentation involved in the shake table tests for the combined cabinet-access floor systems are shown in Fig. 3. A 3 panel by 3 panel access floor was used to support the equipment cabinet. The cabinet's mounting on access floor was achieved by a through-bolting scheme which is shown also in Fig. 3. In this scheme, four 1/2" (12.7 mm) steel rods were passed through predrilled holes on the floor panels and anchored the cabinet directly to the shake table.

STATIC TEST ON ACCESS FLOOR SYSTEMS

The static test results for the three access floors are presented in terms of load-deflection curves shown in Fig. 4. All three systems exhibit linear behaviour at small loading. No well-defined yield point can be found on the three load deflection curves. The overall lateral behaviour of the access floors provided by suppliers A and B are very similar. Both systems failed in a very brittle manner from the tearing of welds which connect the pedestal stems and the base plates. After the initial tearing of the welds, no additional loading could be sustained. The static lateral behaviour of the access floor provided by supplier C was different from the other two. Under lateral load the system exhibits a ductile behaviour with large amount of displacement after yielding. The failure of the system was due to the yielding of the pedestal stems. Fig 5. shows the large distortion of the access floor of supplier C after the ultimate load had been reached.

The lateral stiffness and ultimate strength values for the three access floor systems tested are tabulated in Table 1. The stiffness values are similar for the two access floors with stringers (i.e., system A and B). The values of stiffness and strength of system C are much smaller than the other two systems. The reason for this is twofold. First, the access floor components of system C are made of a weaker material; namely, cast aluminum. Second, no stringer was used in the system to provide the frame action which can enhance the stiffness of the overall system; as a result, the lateral stiffness is only due to the individual stiffness of the pedestals acting as a cantilever.

RANDOM EXCITATION TESTS

Random excitation tests were performed to determine the natural frequencies and damping ratios of the equipment cabinet mounted on a concrete slab. The cabinet was tested in both the side-to-side and the back-to-front directions. The cabinet responded in a single mode in both directions and the frequencies and damping ratios for the two directions are tabulated in Table 2. The cabinet has a higher frequency in the back-to-front direction.

Random excitation tests were also performed for the various combination of the equipment cabinet and the three access floor systems. Two lateral response modes were found for each of the equipment-access floor configurations. Since the second mode frequency is in general higher than 15 Hz which is beyond the frequency range of the upper-bound floor motion described by NEBS, only the fundamental mode results will be discussed here. The fundamental frequencies and the damping ratios for each of the test configurations are tabulated in Table 2.

By comparing the frequency of the equipment cabinet on a concrete slab, it is apparent that the access floors cause the frequencies of the equipment cabinet to be reduced drastically. Additional experimental results for 12" FFH access floors presented in Ref. 2 shows that in general the reduction is larger for a more laterally flexible access floor system (Wong, 1990). The implication of such reduction is that even though the cabinet by itself is well designed such that its fundamental frequency is higher than the frequency range contained in the NEBS specified motion, when it is put on an access floor, its frequencies may be reduced such that it is vulnerable to the NEBS shaking. The cabinet's frequencies on the 20" FFH access floor are indifferent to the orientation of the cabinet although it has a much higher frequency in the back-to-front than the side-to-side orientation when it is supported on a concrete slab. The reason for this is that the equipment cabinet is much stiffer than the 20" access floors; as a result, the equipment cabinet behaves essentially as a rigid mass on the access floors.

NEBS TIME HISTORY TESTS

NEBS time history tests were performed for the equipment cabinet supported on a concrete slab and on the three access floor systems. Shown in Fig. 6 are two acceleration traces for the response at the top of the equipment cabinet. These traces were obtained from the tests done for the equipment cabinet mounted in the side-to-side orientation on a concrete slab and on access floor A. Both acceleration traces were obtained using an input excitation of 25% of the full NEBS time history given in Fig. 1. It can be seen from Fig. 6 that the equipment cabinet's response on the access floors is much larger than that on the concrete slab. The level of amplification of the response depends largely on the fundamental frequencies of the systems considered. The fundamental frequency for the equipment on the concrete slab alone is 8.5 Hz and on the access floor is 4.6 Hz. As indicated by the NEBS spectra in Fig. 1a, a decrease in fundamental frequencies from 8.5 Hz to 4.6 Hz is associated with an increase of spectral acceleration values. As a result, the equipment response is higher when supported on the access floor than on the concrete slab.

The equipment cabinet on the various access floors was tested until the access floors were damaged by gradually increasing the intensity of the NEBS shaking. None of the access floor systems could sustain more than a 50% intensity of NEBS shaking without damage while supporting the equipment cabinet. The access floors of suppliers A and B failed under the NEBS shaking in a similar manner as the failure depicted in the static tests. The failure was due to the tearing of the spot-welds at the base plate of the pedestals. A typical damaged pedestal is shown in Fig. 7. System A can sustain a slightly higher NEBS shaking than system B due to stronger spot-welded based plate connections. Although in some tests more than half the pedestal stems were completely severed from the base plates, no collapse of the access floor occurred because the stringers were holding all the pedestal stems together. Access floor system C failed under the NEBS shaking in a totally different way from the failure observed in the static tests. The failure was due to the sharing off of the pedestal heads as shown in Fig. 8. Since the pedestal heads were the only support for the floor panels, the shearing off of several pedestal heads directly underneath the equipment cabinet led to a collapse of the access floor under the weight of the equipment cabinet. The collapsed access floor can be seen in Fig. 9. Such catastrophic failure was primary due to the lack of a stringer system which stabilizes the pedestal and provides a more even distribution of the imposed seismic force to the pedestals. It was observed in the tests for one of the access floors with a stringer system that in spite of 90% of the pedestal stems were severed from their base plates no collapse occurred.

In order to relate the results of the NEBS time history test to that of the static test, the maximum floor displacements under different level of NEBS shaking are indicated on the static lateral-load displacement curves. Fig. 10 shows the load-deflection curve for the access floor system A. The maximum floor displacement denoted in the figure were obtained from the NEBS test performed for the equipment cabinet in the back-to-front direction on the access floor system A. For the 50% NEBS excitation test where the access floor was damaged, the load induced by the maximum displacement was very close to the ultimate load. The correlation with the dynamic test results implies that it is viable to use the static test results of a simple one-panel access floor module to evaluate the seismic safety margin of an access floor system given that the upper-bound access floor displacement can be estimated with reasonable accuracy.

CONCLUSIONS

In this paper the results of an experimental study undertaken to investigate the seismic response of telecommunications equipment supported on access floors were presented. Several conclusions can be drawn from the results.

1. Access floors utilize spot-welded base plate connections are in general lack of the ductility and strength to support heavy telecommunications equipment in region with high seismic risk.
2. Stringerless access floors systems should not be employed for seismic applications because they are prone to catastrophic collapse. A stringer system helps to prevent the collapse of an access floor even when

majority of the pedestals were severed from their base plates.
3. It is viable to use the static test results of a simple one-panel access floor module, to evaluate the seismic safety margin of an access floor system given that the upper-bound access floor displacement can be estimated with reasonable accuracy.
4. Only the fundamental mode of response of the combined equipment-access floor system is important in earthquake consideration.
5. The dynamic response of an equipment cabinet can be amplified significantly when it is mounted on an access floor. This implies that equipment which has been seismically qualified to a certain level of NEBS shaking on a concrete slab may not be qualified for the same level of shaking on access floors.

REFERENCES

1. Bell Communications Research, "Network Equipment Building System (NEBS) - General Equipment Requirements", Technical Reference TR-EOP-000063, Issue 3, Morristown, New Jersey, March 1988.

2. C.M. Wong, Seismic Response of Telecommunications Equipment Supported on Access Floors, Ph.D. Thesis, McMaster University, Hamilton, Ontario, Canada, 1990.

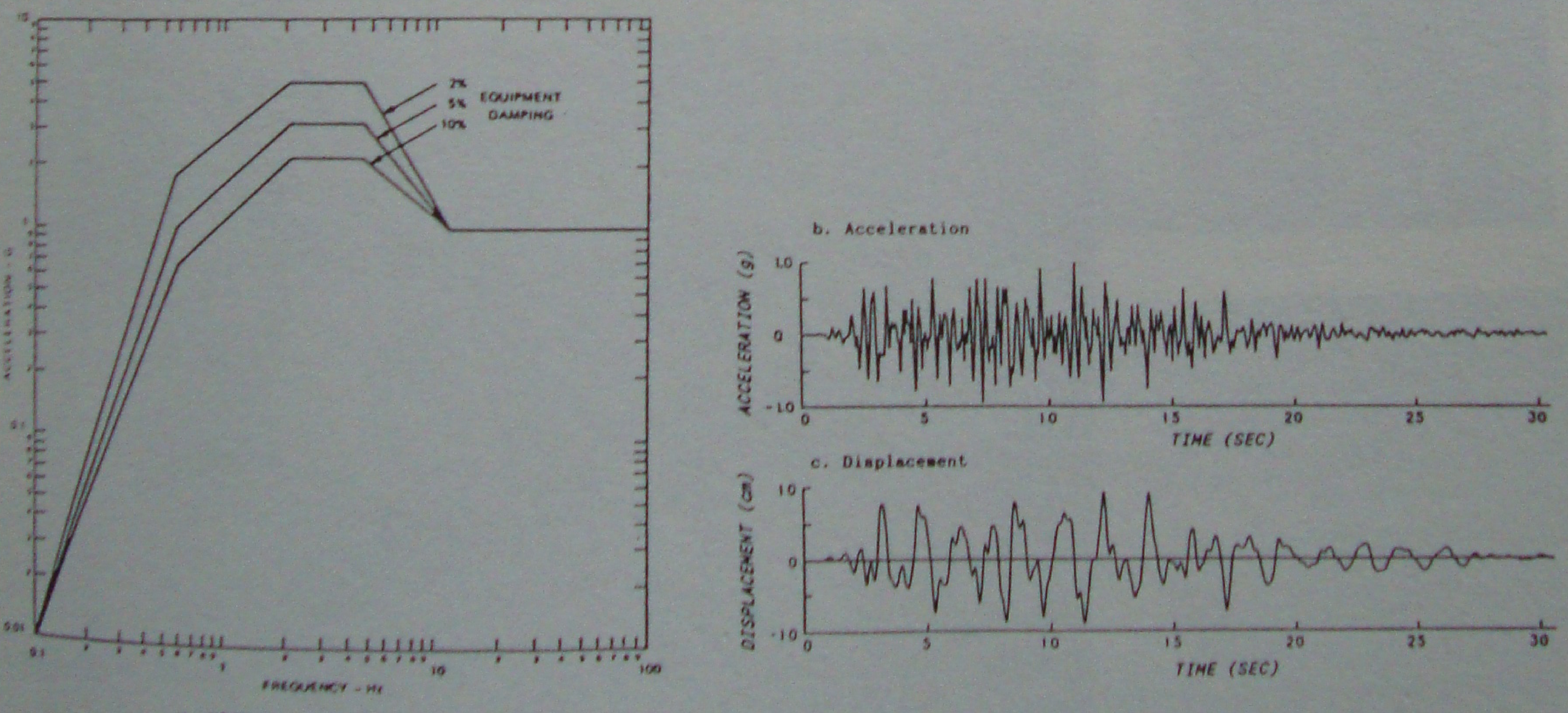
Table 1. Lateral stiffness and strength of different access floor systems

System	A20	B20	C20
Stiffness (KN/mm)	0.16	0.15	0.093
Ultimate strength (KN)	2.8	2.1	2.0

Table 2. Fundamental frequencies and damping ratios

	Side-to-side				Back-to-front			
System	Cabinet alone	A20	B20	C20	Cabinet alone	A20	B20	C20
Freq. (Hz)	8.91	4.7	4.5	4.09	13.2	4.6	4.53	4.03
Damp. (%)	0.70	1.6	1.7	3.0	1.23	1.7	1.9	3.4

Fig. 1 NEBS spectra criteria and time histories compatible with the 2% damped NEBS spectrum



a. NEBS floor response spectra

b. Acceleration

c. Displacement

Fig. 2 Static test set-up

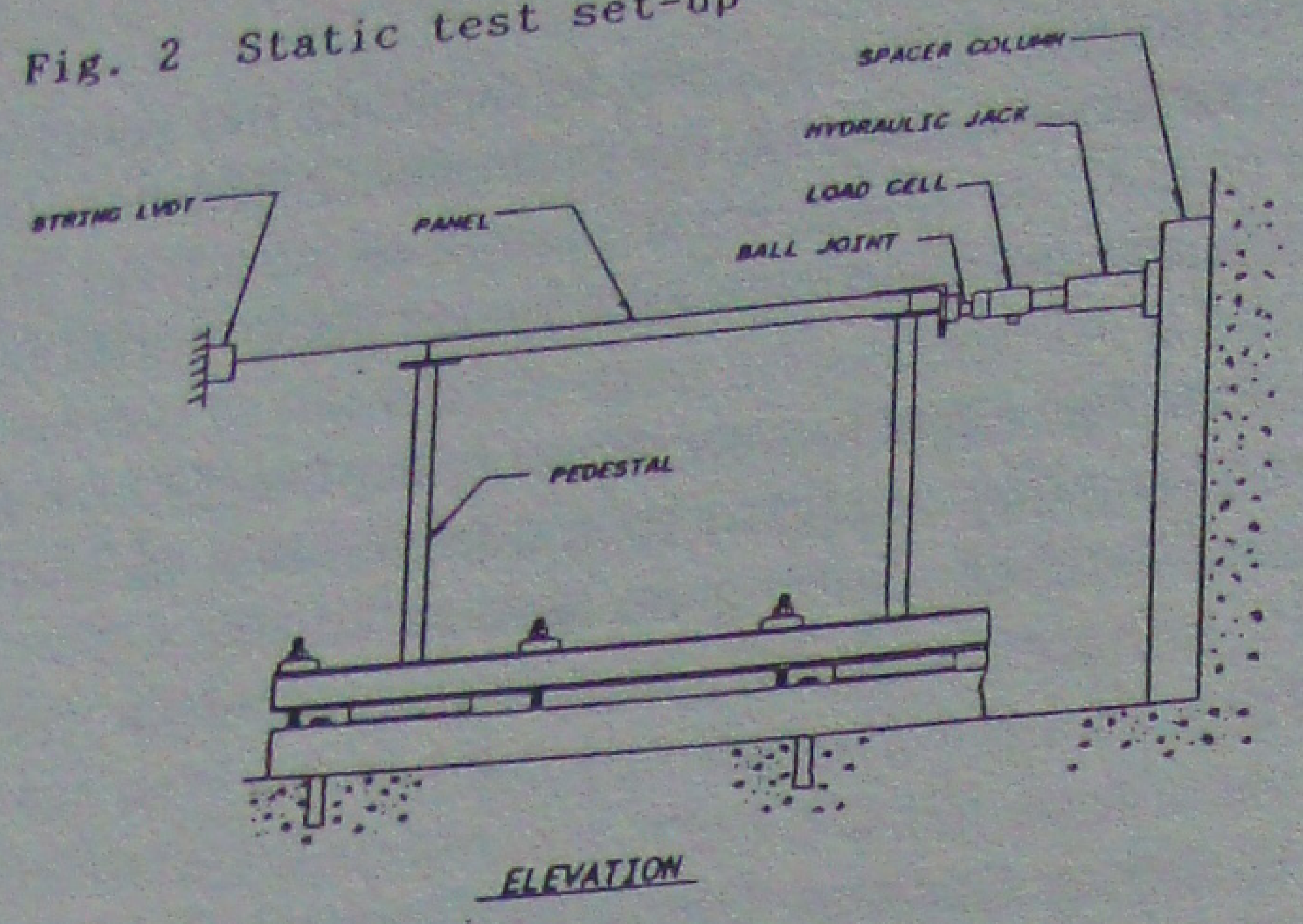


Fig. 3 Shake table test set-up for equipment-access floor system

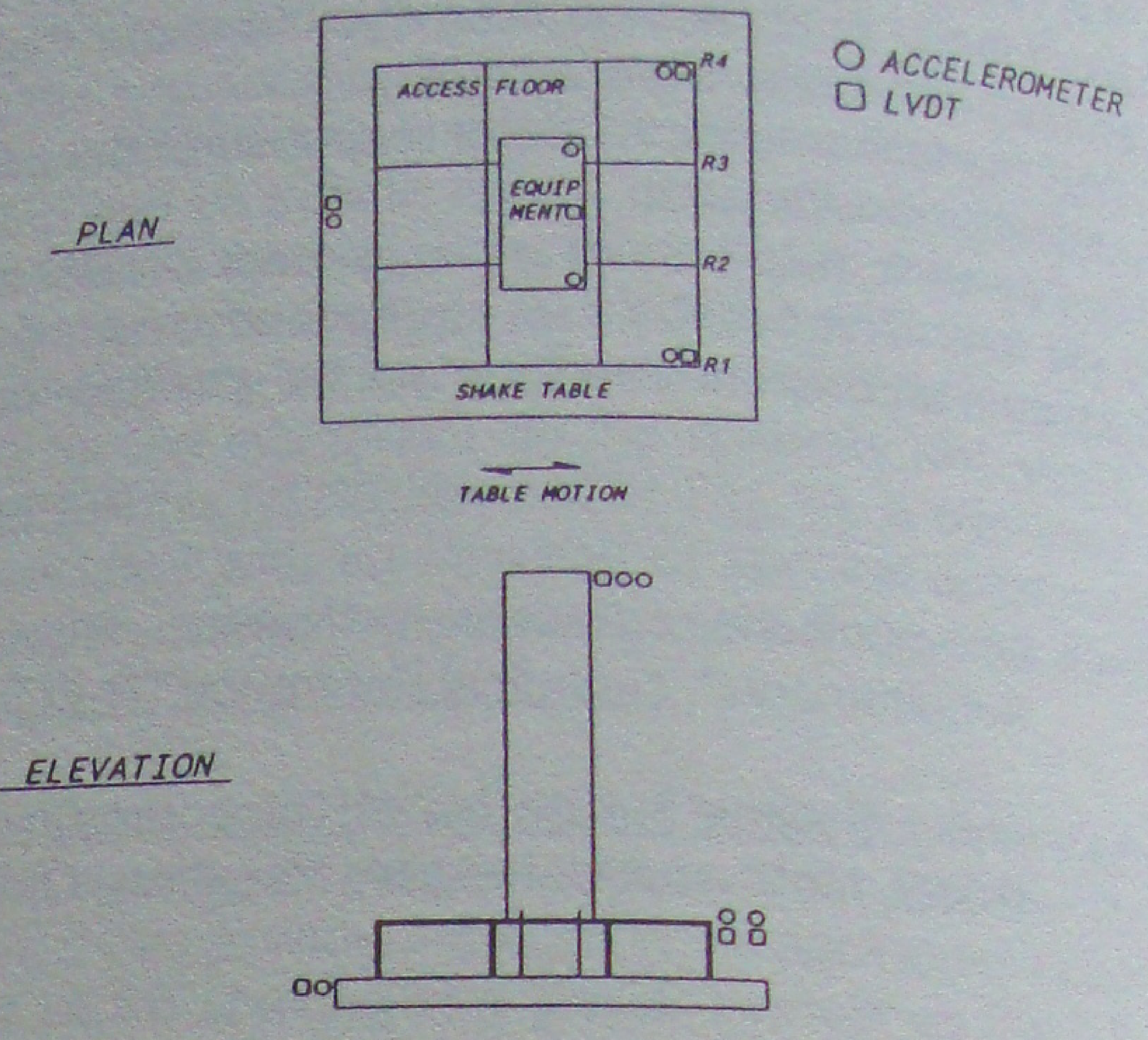
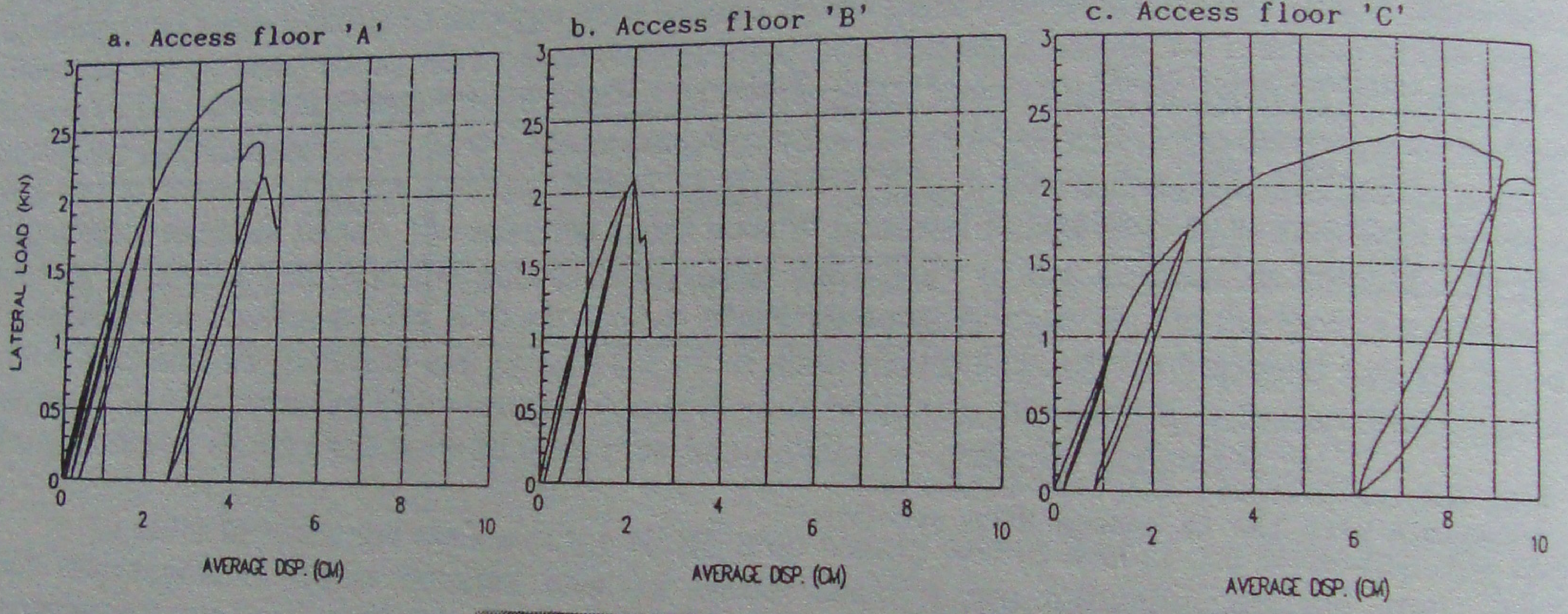


Fig. 4 Load-deflection curves for different access floors


a. Access floor 'A'

b. Access floor 'B'

c. Access floor 'C'

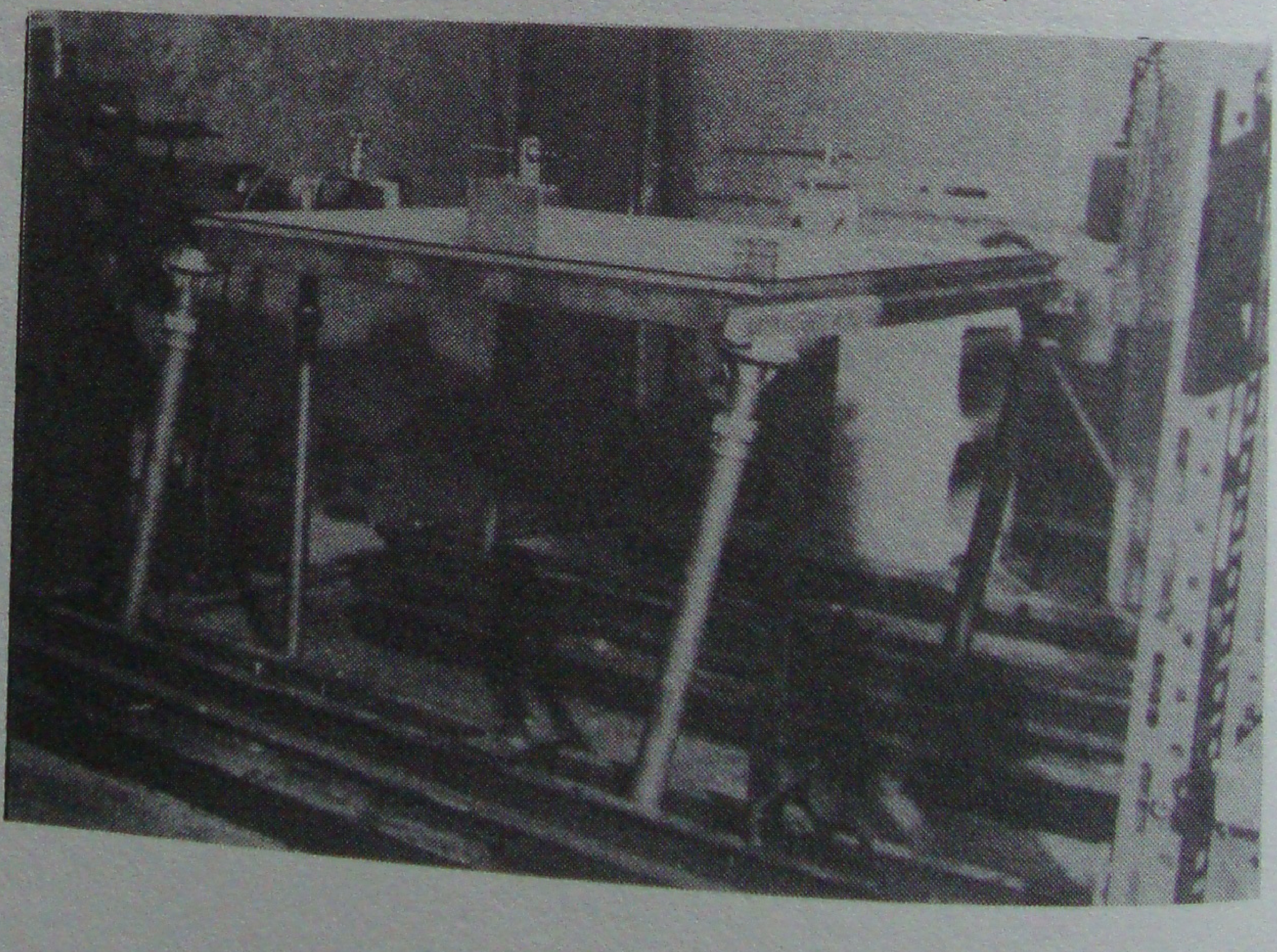


Fig. 5 Damaged access floor 'C' after static test

Fig. 6 Acceleration response at the top of the equipment-cabinet under 25% NEBS excitation

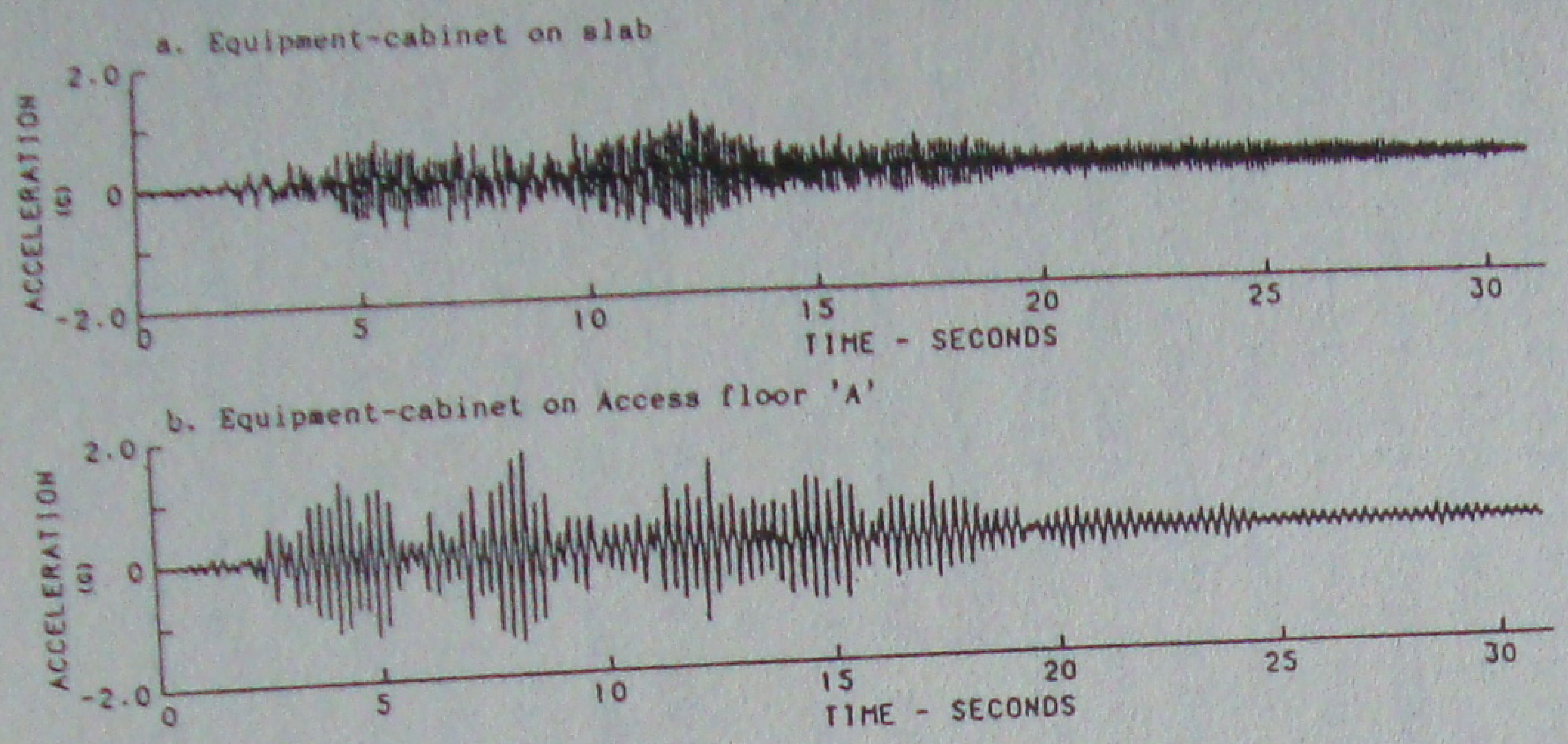


Fig. 7 Damaged pedestal of access floor 'B' after NEBS time history test

Fig. 8 Sheared off pedestal head

Fig. 9 Collapsed access floor 'C'

Fig. 10 Correlation of results between static test and dynamic test for access floor 'A'