DYNAMIC TESTING AND ANALYSIS OF
IMPROVED COMPUTER/CLEAN ROOM RAISED FLOOR SYSTEM

I. K. Chang (I)
Presenting Author: I. K. Chang

SUMMARY

This paper discusses the significant aspects of a dynamic testing and analysis program performed on a prototype computer or clean room raised floor base isolation system. The seismic problems inherent in the construction of a conventional computer or clean room are identified. The design of a new isolation system which adresses these problems is then discussed. Procedures and results of tests performed on a prototype design are discussed. Recommendations are made to further improve the isolation design studied.

INTRODUCTION

Raised floor systems are widely used in computer operating rooms and electronic manufacturing process clean room facilities throughout the world. This type of floor system provides service space and air circulation necessary for operation of electronic equipment. Raised floor systems are commonly referred to as "floating floors" because of the unsecured manner in which the floor connects to supporting structures (Fig. 11 - 13 of Ref. 1). The floating characteristic of raised floor systems seriously diminishes their ability to withstand seismic loadings, and is therefore a serious concern among structural engineers.

Traditionally, except for vibration sensitive or self vibrating machines, most electrical and mechanical equipment is secured to the floor in a rigid manner to avoid seismic problems. Unfortunately, this rigid support is of no value when dealing with raised floor systems, since the floor panels must be unsecured. As a consequence, currently equipment resting on most raised floor systems is virtually unsupported against seismic motions. However, recently developed shock and vibration isolators now make it possible to provide protection of sensitive equipment residing on raised floor systems by protecting the total floor system against destructive seismic motion. To date, the potential inherent in these new types of isolators have largely been ignored, and most existing and proposed computer facilities employing raised floor systems are seriously vulnerable to major damage in the event of serious seismic motions. For example, computer damages were reported in Miyagi-ken-oki Earthquake of Japan in 1978 (Ref. 2) and Middle Japan Sea Earthquake in 1983 (Ref. 3).

In the past isolators have been used in providing shock and vibration isolation for individual pieces of equipment. This technique is effective when the floor system underlying the equipment is secured. However when the floor system is unsecured, as in raised floor systems, isolation of individual components is of limited value, and in some cases may aggrevate the structural response. A much better solution to providing shock and vibration isolation involves protecting the entire floor system by isolating the underlying floor

(I) Graduate Student, John Blume Earthquake Engineering Center, Stanford University, California, USA; and Staff Engineer, IBM, San Jose, CA, USA

support structure. The same principles apply to isolating the floor support system as apply to isolating individual components. The idea is to decouple the structure from the ground or base motion during an earthquake so that the accelerations or motions which the ground or the supporting base transmits to the structure are not amplified. This response reduction is achieved through load-supporting and energy-dissipating devices, that is, through springs and dampers.

Isolators like Aeroflex and Barry Controls for single computer or equipment and isolation systems, such as suspended floor system and others developed in Japan had been discussed in detail in Reference 1. This paper only discusses the computer or clean room raised floor isolation system recently developed by IBM and Stanford University.

IDENTIFICATION OF THE PROBLEM

Basically, the most important characteristics of seismic ground motion are that peak accelerations, velocities and displacements occur randomly in time and frequency contents. A raised floor or an equipment room can be located anywhere in a building. If located on the ground floor, the input motion would be the ground motion modified by the structure-soil-foundation interaction. If the system is located at higher floor levels, the input motion to the floor will be the response of the building at that level due to some ground motion. Design of isolation system should be such that all the relevant frequencies are considered and that the response is significantly reduced at the frequencies of interest.

If an isolation solution is desired for a single problem, for example, reducing the acceleration or displacement from a given motion, the problem would be straight-forward. Unfortunately, it is usually required to reduce both the acceleration and displacement at the same time with a single isolation system. The problem is further complicated by the random characteristic of seismic vibrations. Typically, earthquakes contain high acceleration and displacement components, and motions are three dimensional. These characteristics magnify the shortcomings of many isolators for single equipment currently in market. For example, natural or synthetic rubber mounts or metal spring isolators designed with uni-axial isolation capability in acceleration often fail to respond to displacement input as seen in 1971's San Fernando Earthquake (Ref. 4).

THE NEW DESIGN OF RAISED FLOOR ISOLATION SYSTEM

The basic requirements of isolation system for raised floor where computers and/or equipment are supported should be as follows:

i. The floor isolation system should isolate the input vibrations in the three orthogonal directions.

ii. Both acceleration and displacement components should be considered, and an efficient compromise should be reached.

iii. The floor system must be able to deal with large variations in vertical loads during normal operating conditions and that the isolation system should be effective for such variations in loads during periods of strong vibrational motion.

iv. The floor system should maintain constant level and not sway under normal operating conditions. A trigger should activate the isolation system only when strong motion occurs.

v. Service space below the floor should not be reduced or hampered.

vi. The cost of manufacturing and maintaining such floor isolation system should not be prohibitively expensive.

vii. The operational requirements of the floor must be met during and after the strong motion.

The new raised floor isolation system developed by IBM and Stanford University consists of a rigid floor grid system supporting conventional movable raised floor panels. The floor grid system bears on a series of vertical springs and dampers cased in a steel column. There is one module assembly for every one hundred square feet of floor area. This module absorbs and neutralizes most of the vertical seismic shock. To counteract horizontal seismic motions each module has a mechansim that permits sliding. This mechansim consists of a teflon-coated steel shoe at the base of the module, and four horizontal springs secured between the column and the fixed floor which return the module to the original position. Alternately, the entire floor system is guided along its perimeter by an energy absorbing bumper system. To prevent the floor from responding with spring action to live loads on the raised floor, the floor grids bear on steel rods housed inside the modules. The floor release from these rods is triggered by the impact of a vertical or horizontal shock. The floor's weight is then transferred to the springs and dampers. Changes in floor loads are accomodated by a series of springs and dampers built into each isolator module. These springs and dampers are preset to fixed gaps and become active only as loads are developed. The conceptual designs of the raised floor isolation system are illustrated in Reference 5.

PROTOTYPE TEST MODELS AND PRELIMINARY RESULTS

A prototype of the system described above has been designed, fabricated and subjected to series of tests involving both sine wave and simulated earthquake motions. Horizontal and vertical motion tests were conducted in the United States at Stanford University and at IBM San Jose Plant last spring (Ref. 1 and 5). The specimen used for the above two tests is 6 ft. x 6 ft. in size. Due to shake table limitations, four isolator modules were used in the horizontal test while two isolator modules were used in the vertical shake test. This arrangement created very high stifness in the vertical direction, however, significant results were still achieved from these two tests.

A 16 ft. x 16 ft. floor specimen was used in a three dimensional simultaneous shake test conducted by Stanford University and Ishikawajima-Harima Heavy Industries Research Institute (IHI) in September, 1983 at Yokohama, Japan (Ref. 5). Because nine isolator modules were used, the vertical stiffness of the isolation system assembled was about 8 Hz. Since the sine-wave sweep ranged from 0.2 Hz to 10.0 Hz, the vertical acceleration response of the specimen showed amplification at all frequencies tested while the displacement response was relatively low. The design vertical fundamental natural frequency of the system should be between 2 and 3 Hz.

Although preliminary test results obtained confirm the performance of the system in reducing the overall seismic response, three areas discussed below are proposed for further improvement on the raised floor isolation design.

i. The module should be equipped with the adjustable vertical stiffness control capability. This will enhance the flexibility of placing modules at variable spacings when necessary.

ii. Energy absorbing horizontal bumper system should be used to replace the four horizontal springs made with each module. As observed from tests, these horizontal springs not only decrease the efficiency of sliding action of the module base but also significantly reduce the usable space needed below the floor.

iii. Electronic automatic triggering system should be developed to replace the mechanical trigger system used. Tests have proven that the reliability of simultaneous triggering action in every module can not be assured.

A special computer program containing a gap element is used for analytical study of the system. The gap elements contained in the program permit the modeling of the necessary gaps of the raised floor and mechanical support system, and they further permit efficient direct integration of the system equations of motion. Due to page limitation, the three dimensional shake table test study on the isolation system conducted in Japan in September, 1983 along with the analytical study results are presented in a separate report shown in Reference 5. Reference 5 will be available for distribution during the presentation of this paper in the coming Eighth World Conference on Earthquake Engineering.

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