SELECTION AND INSTALLATION OF RAISED FLOORS FOR CRITICAL FACILITY EQUIPMENT IN SEISMIC ZONES

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ABSTRACT:

Raised floors for electronic equipment installation has three main advantages:
1. Clean room environment,
2. Effective cooling of the electronics, and
3. Easier cable management.
The structural integrity of the raised floor for equipment support is a major concern in seismic environments. The increased use of raised floor closely followed the change of technology from analog to digital equipment in the telecommunication and other industries. Raised floors are also found in control rooms in electric power, water, gas, and transportation facilities, and in banks and insurance companies. The rapid expansion of Internet services accelerated the use of raised floors.

This paper will discuss issues related to the selection and installation of raised floors for equipment used in telecommunication facilities, electric power facilities, emergency services, and other applications. A few engineered methods will be presented. Critical facilities include computer systems of very large companies and financial institutes that depend on these facilities to maintain business continuity after a damaging earthquake.

KEYWORDS:

Raised floor, bracing, electronic, emergency, retrofit

1. INTRODUCTION

Raised floor installation for critical facilities is becoming more popular for several reasons. The telecommunication central offices, the emergency control centers, operation control centers, banks, and insurance companies take advantage of raised floor when upgrading the facility with the most current electronic equipment. In addition to providing an aesthetically pleasing environment, it makes cables routing during refurbishment and expansion faster and less costly. Clusters of cables, both power and signal cables, can be organized for easy tracing during trouble-shooting. It can also act as an air plenum for cool air. Numerous problems with cables in cable trays are eliminated. Figure 1 shows communication switching equipment on a raised floor.

Figure 1. Switching equipment on raised floor during the final phase of installation. Due to fire regulations in this installation, the raised floor cannot be used as an air plenum, therefore cooling ducts and vents are installed in the ceiling.

Planning is the most important phase of a raised floor installation, particularly in a seismic environment. The key factors that affect the design are raised floor height, seismic zone, equipment weight and height, and height within the building it is installed.

The intent of this paper is to provide engineers with basic ideas to mitigate earthquake damage of equipment installed on raised floor.

2. COMMERCIAL RAISED FLOORS

There are more than a dozen major manufacturers of raised floor systems globally. They supply off the shelf raised floor systems with multiple optional items for customizing the installation to the purchasers' requirements.

A typical raised floor system consists of four elements that are always part of commercially available hardware and two components that are almost also needed for a seismically capable installation.

1. A pedestal with base plate,
2. A pedestal head that fits on top of the pedestal that supports the stringers, if used, and the floor tiles,
3. Stringers, if used, that bridge the pedestals supporting the edges of the floor tiles,
4. Floor tiles that form the raised floor
5. Custom braces that give selected pedestals added lateral resistance,

6. Custom structural platform that anchor heavy equipment directly to the building floor.

The basic considerations of choosing a structurally sound system are:

1. The pedestal base plate should have anchor holes and provide a strong moment-resisting connection to the pedestal,
2. There should be stringers with a positive connection to the pedestal head or anchored floor tiles, and
3. Pedestal head should not be made with brittle material such as cast aluminum,
4. Pedestals should be provided with supplemental bracing if needed.

Most commercially available systems that include the above important features may still not be good enough to support equipment subjected to seismic loads. In general raised floors are designed to handle vertical load, they are not designed to resist lateral loads and overturning moment of equipment mounted on the floor due to horizontal earthquake induced forces.

Therefore, a number of custom designs are used to strengthen the raised floor to resist these forces. A few of them are discussed in the next section. Figure 2 illustrates a snap on connection that should be avoided. Figure 3 shows two stringers that are bolted to the pedestal head before they are properly position to support the floor tile.

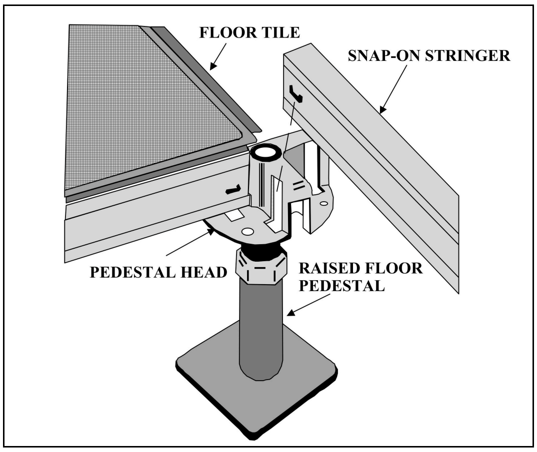

Figure 2 Snap-on type of stringer should be avoided in earthquake application.

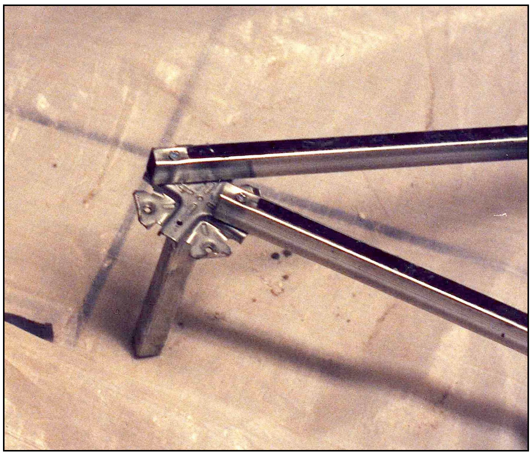

Figure 3 Positively secured stringers, as shown here, provides a better structural connection for earthquake application.

There are a few manufacturers specialized in isolation design of raised floor systems to reduce the earthquake load to the equipment mounted on the floor. This paper will not discuss these systems and their performance. The authors understand that many of these isolation systems were tested in the mid-1980.

4. SEISMIC DESIGN AND INSTALLATION CONSIDERATIONS

1. Raised floors must be capable of withstanding lateral loads.
2. Equipment supported on the raised floors must have some lateral restraint between the equipment and the raised floor.
3. Heavy equipment must be supported directly from the building floor.
4. Some methods of restraining equipment on the raised floor allow for some lateral movement, so that equipment must be prevented from hitting each other or structural elements such as walls and columns,

5. LATERAL RESTRAINT OF RAISED FLOORS

5.1 Anchoring Pedestals

Pedestals should be anchored by bolting the base plate to the building floor. Mastic and shot anchors should not be used to anchor the base plates. Adhesives should be avoided to secure the pedestals to the building floor unless they are braced as shown in Figures 4 and 5.

5.2 Diagonal Bracing to Strengthen Floor Structure

Some raised floor suppliers have developed simplified diagonal bracing components whenever lateral load resistance is called for. Figures 4 and 5 show the two designs commonly used to stiffen free standing raised floor systems. In Figure 4, the diagonal bracing is bolted to the stringer, very close to the pedestal head and anchored to the building floor. In he design shown in Figure 5, the diagonal bracing is terminated to the pedestal just below the pedestal head, and the other end is anchored to the building floor. Frequently, the pedestal base is secured to the building floor with adhesive, a practice that is not recommended.

For high and moderate earthquake zones, the raised floor with the diagonal bracing is generally adequate for an office environment with lightweight equipment, such as desks, office partitions, printers and copiers. A more rigid system is required when the floor is used for critical equipment or in critical facilities. The number of diagonal braces should be one floor tile length around the perimeter of the equipment footprint.

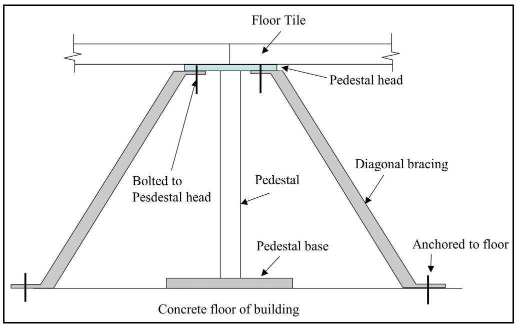

Figure 4 The diagonal bracing is secured to the pedestal head.

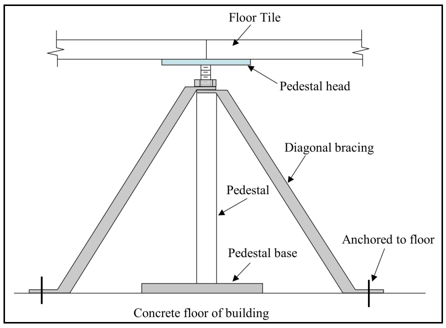

Figure 5 The diagonal bracing is terminated on the pedestal close to the base of the pedestal head.

For low earthquake zones, these types of braced raised floor will be sufficient when the equipment is anchored directly to the concrete floor of the building.

5.3 Perimeter Restraint Around Raised Floor

In general, there should be a restraint around the perimeter of the raised floor that is capable of restraining lateral loads. From tests, it was shown that one floor tile length around the perimeter of equipment footprint provided sufficient lateral load resistance for equipment less than 300 Kg weight.

5.4 The Raised Floor as a Diaphragm

The diaphragm action of the raised floor is an important element is resisting lateral loads and retaining the structural integrity of the raised floor. Stringers play a critical role in maintaining the raised floor as a diaphragm. Some raised floor systems do not have stringers and depend on the floor tiles remaining in place to form a structurally viable diaphragm. In general, this would not be an acceptable practice unless the corners of each floor tile is held to the pedestal head with a fastener. By securing the floor tiles with fasteners defeat the purpose of easy access to the cables below the raised floor. As will be seen below, some methods of securing equipment to raised floors tends to cause floor tiles to be lifted.

6. RESTRAINING EQUIPMENT TO RAISED FLOORS

Several methods are used to restrain equipment to raised floors. One of the most common methods is to allow the power and signal cables to the equipment to serve as a tether. In some cases there may be a cable restraint anchored to the equipment frame that roughly follows the power and signal cables, but is anchored to the building floor near the equipment. This procedure tends to cause floor tiles to pop up when the restrain cables are brought into play. A better method is to provide a cable from the equipment frame directly to the floor, where it is secured by raising an adjacent floor tile. This is illustrated in Figure 9, below. Equipment should not be anchored directly to the floor tiles, as these systems are not designed to resist overturning moments. Most methods of restraining equipment will add lateral loads to the raised floor system.

To prevent adjacent equipment from hitting each other, they should be bolted together. Adequate space should be provided between equipment and building walls and columns.

7. SUPPORTING HEAVY EQUIPMENT

Heavy equipment should not be supported on a raised floor but should have a structural frame below the equipment to anchor it to the building floor. The basic engineering concept is to design a structural platform that the equipment will be anchored with a very high stiffness. That is, the natural frequency of the platform is high compared to that of the raised floor. This platform is designed to raise the heavy equipment to the level of the raised floor, but it is structurally independent of the raised floor. It was shown in References #2 (Figure 6) that the higher the stiffness of the platform the amplification factor would become lower. Figure 7 shows one of the many designs of a platform with high stiffness for the supported equipment. Figure 7 shows a bolted assembly, a welded assembly will have a high stiffness. The draw back of a welded assembly is it takes a lot space in shipping. The equipment as shown has an extension for cable exit and entry. Some equipment cabinets are designed with an open base for cables. The size of anchor for the structural platform depends on the equipment height and weight.

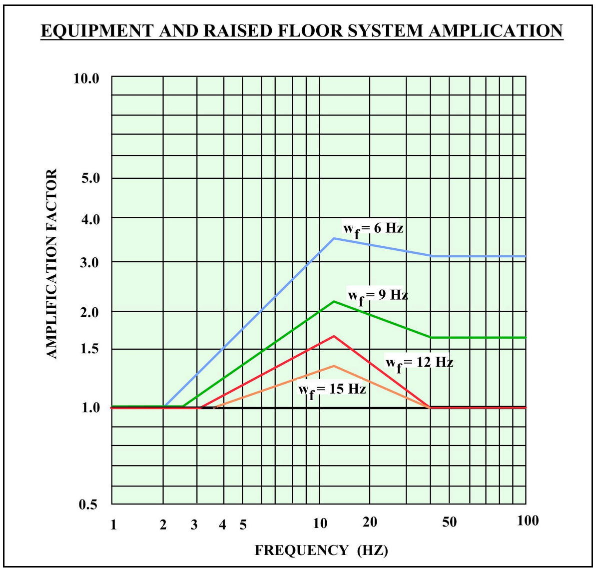

Figure 6 Straight-line approximation of amplification curve for different effective raised floor frequencies.

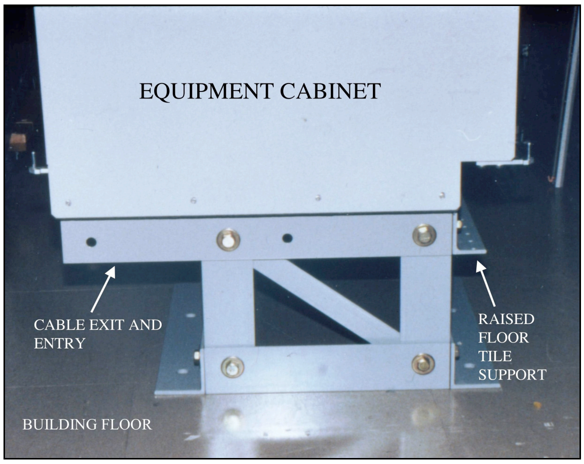

Figure 7 The structural platform is designed to the raised floor height and the extension at the back is for cable entry and exit.

8. RETROFIT DESIGNS

For critical facilities the upgrading the raised floor or equipment support should be considered to reduce earthquake damage. The concept is again to stiffen the floor, on which the equipment is installed or anchored the equipment to the building floor.

Unsecured equipment will tend to tip over or slide and strike other equipment in an earthquake. When a piece of equipment is not anchored, retrofitting with anchors is a very difficult task especially with cabling. Most of this type of retrofit requires external anchor brackets bolted to the equipment base as shown in Figure 8. Steel cable with a turnbuckle can also be used to secure the equipment to prevent overturning, as shown in Figure 9.

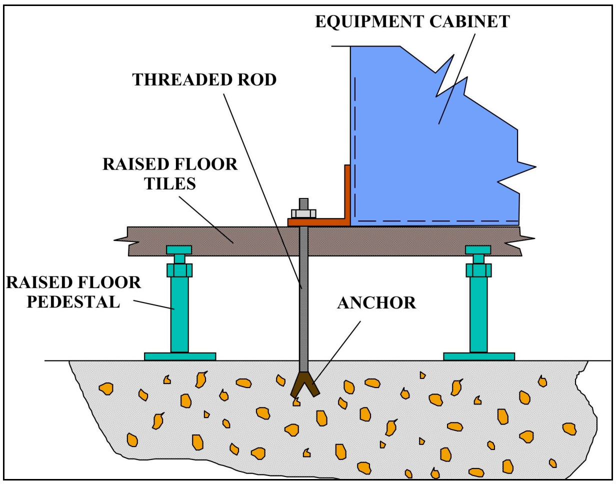

Figure 8 This shows an external anchoring method when access under the base of the cabinet is limited.

Figure 9 This shows one corner of the cabinet with a cable anchoring method. A turnbuckle below the raised floor allows the cable to be tightened to reduce movement.

For important equipment in areas subjected to earthquakes, particularly in upper floors of multistory structures, the raised floor around the equipment must be stiffened to reduce amplification and the chance for collapse. The raised floor pedestals are tied horizontally and braced diagonally to create a structural platform. One of the designs to achieve a stiff structure is shown in Figure 10 and 11. With bolted assembly, the connection may become loose after a few cycles of shaking; the designers have to take that into consideration when calculating the seismic load on the equipment.

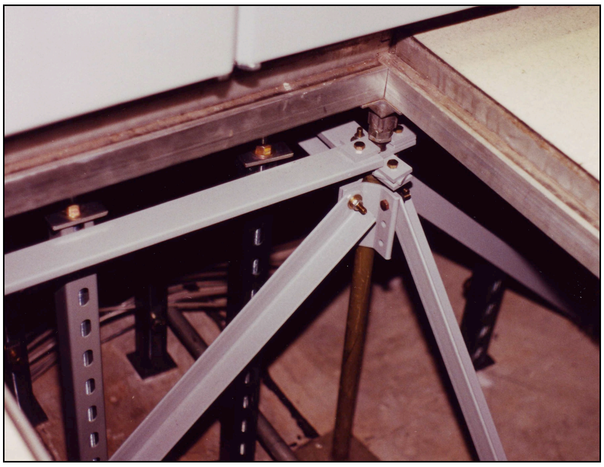

Figure 10 This shows the pedestal top arrangement and the anchoring method of the equipment.

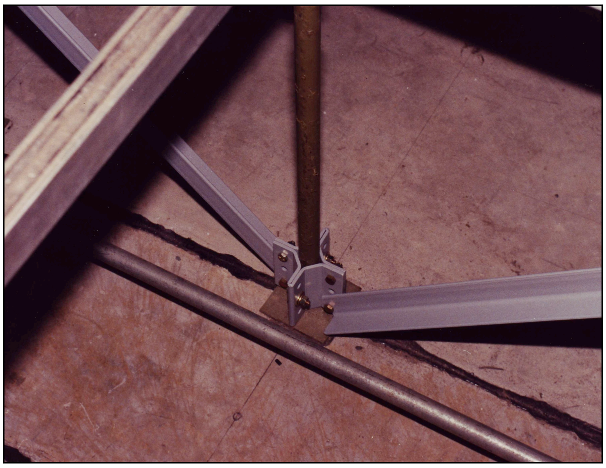

Figure 11 This shows the base of the pedestal arrangement. The brackets allow the two direction diagonal bracing termination.

9. SELECTION AND INSTALLATION CONSIDERATIONS

Prior to selecting a raised floor system, the equipment to be installation is the key element in your decision making process. That includes the footprint, the weight and the cable interconnection between the equipment. In addition to the equipment, environmental control system, fire protection system, power entry, lighting, electric grounding, and static electricity requirements must be part of the criteria of the raised floor system to be installed.

From the tests and research results presented in References #2, the structural platform for installing equipment in a raised floor environment is the best choice.

A raised floor system with stringers connecting the pedestals is a structurally sound system, although the pedestals should be properly anchored. The stringers allow horizontal load to be distributed within the floor system even when tiles are dislocated due to earthquake shaking. A pedestal assembly with the rod welded to a base plate is more flexible than an assembly with gussets welded to the rod and the base plate.

In a new installation, when a structural platform is needed for heavy equipment, these platforms should be installed before the raised floor. This allows easy handling and anchoring the heavier and bulkier structural platform.

Environmental system for the raised floor room is an important element in space planning of the raised floor. Using the raised floor as air plenum has its advantages and disadvantages. The advantage is allowing cool air to displace the heat generated from the equipment towards the top of the equipment. As cables, both power and signal, are routed in the same space, any smoke due to electrical fire becomes a problem. It will cost more to enclose the cables in cable raceways. A drop ceiling with lighting and air vents can be more cost effective.

When cutting holes in the raised floor for cable to enter the equipment, attempt to locate them so that an equipment support will not fall into the hole if the equipment shifts.

Fire protection is another key element in the decision process.

10. CONCLUSION

Raised floors have been found to be very useful for supporting collections of electronic equipment because they allow easy routing of power and signal cables and cooling infrastructure. However, it is important that in areas subjected to earthquakes that the raised floor be designed to take into account lateral loads imposed by earthquake motions. This can be accomplished by the selection of structural sound pedestals and bolting them to the building floor, providing pedestal braces, where called for, using stringers that have mechanical connections to the pedestal head. Equipment should be secured to the raised floor and interconnected or provided with adequate separation so that they do not impact each other. Heavy equipment should be supported on a support structure that is anchored to the building floor independent of the raised floor.

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