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NEW CHALLENGES/APPROACHES IN CENTRAL OFFICE EQUIPMENT BRACING

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SUMMARY

Presented in this paper are methodologies for the seismic restraint of digital telecommunications equipment cabinets that are being installed in central office environments. The paper identifies the needs imposed on the earthquake engineering profession by today's new technology in the design of the equipment along with current approaches anchoring the cabinets. It presents concepts for anchoring the equipment directly on the structural floor of the switchroom and the evolution of designs for the seismic restraint of equipment placed on raised access flooring systems (computer floors).

INTRODUCTION

Historically, it has been the practice of the telephone industry to brace switching equipment to resist seismic forces induced by earthquakes. In the United States, the criteria most commonly employed as an industry standard ($NEBS_1$) far exceeds the requirements of typical building codes such as the UBC_2 and the U.S. Armed Services Tri-Service Manual $_3$. Of particular significance is the requirement in NEBS that "Central Office (CO) equipment shall remain operational when subjected to earthquake environments".

Today, there is an industry-wide transformation from mechanical relay equipment to digital electronic switches. The digital switches are more compact and offer much greater sophistication and versatility in the telecommunications field. With this greater sophistication, there is a trend for the larger organization, either private or public, to establish its own internal central office. This paper's reference to central office environments encompasses the traditional CO of the telecommunications utility as well as the CO of the larger organizations with their own internal system.

The NEBS performance criteria stated above, coupled with the current evolution of the telecommunications switching equipment and usage, has raised several new issues with regard to bracing; most noteworthy are the following:

1. What strength and deformation limits are required to satisfy the NEBS performance criteria?

2. Is anchorage of the switch base sufficient, or must the equipment be braced overhead?

3. How should equipment placed on raised access flooring systems (computer floors) be dealt with?

Prior to answering these questions, a brief synopsis of the NEBS general design criteria is appropriate. The NEBS criteria is based on a design spectrum intended to be applicable to any building, regardless of size or type of construction. The spectrum addresses installations on the upper floors of buildings located in the most active seismic zones of the United States. For installations in the lower portions of a building, or in areas of less seismic activity, reduction coefficients are provided in the criteria. The design spectrum from NEBS is shown in Figure 1. The natural frequencies of the designs discussed in this paper have been targeted for the range of ten hertz (10 hz.) or greater, which is well away from the maximum acceleration plateau contained in the NEBS design spectrum.

The answer to the first question, strength and deformation limitations, is best addressed by the individual designers and manufacturers of today's telecommunication switching equipment. It involves a detailed examination of the switch cabinet construction, including static and dynamic testing of the whole switch assemblies to determine natural frequency and stiffness. The new cabinet being used to house the fragile line cards of the new digital equipment must be able to protect the internal works from excessive vibrations during a seismic event and be stiff enough that deformations of the cabinet itself, during the event, do not cause the line cards and other electronic circuitry to become dislodged and malfunction. Experience and testing of the tall, slender cabinets[4] indicate that deformations must be limited to about two inches (2") of sway at the top.

The second and third questions most likely will be addressed by the engineer responsible for the anchorage of the cabinet.

Given the physical characteristics and limitations of the cabinet by the manufacturer, the engineer must now provide a design that will keep the cabinet in place during a seismic event. The use of base anchorage as the sole means of lateral support may only work in specific environments. There must be a floor system present which is adequate to carry the anchorage forces and overturning moments generated at the base of the switch frame. This floor must be thick enough to develop the capacity of the anchor used. Further, the physical relationships between the top of the cabinets and overhead cabling must be maintained so that out-of-phase deformations of the two elements during a seismic event do not result in excessive damage to either. Alternative designs that must be employed if either of these two conditions can not be met have been developed and implemented by the authors and their clients in several Central Office installations in the US.

One obvious solution is to place a series of diagonal braces from the top of the equipment to the building structure overhead. While this appears to be a simple solution, it usually involves the use of many long braces which become entangled with each other and the overhead cabling. The simple solution becomes awkward.

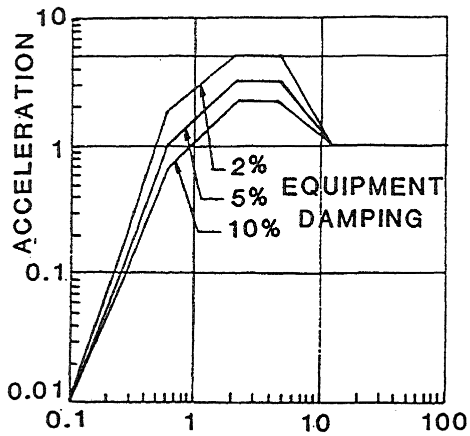
For equipment installed on a structural floor (without the capacity to resist anchorage and overturning forces), a system has been developed employing a horizontal member which captures the tops of the equipment and transfers the seismic force to end-posts. The end-posts carry the seismic forces to the floor and to the structural building elements above. (See Figure 2) For larger central offices, the main switching equipment usually is configured in lineups of six to eight units. This results in horizonal member spans up to twenty feet (20'-0"). The overall system is designed so that the natural frequency of the equipment and bracing combined will remain in the range of 10 hz. or greater, assuming that the bottoms of the equipment are pinned at the floor (no resistance to overturning).

Early designs used two parallel channels four to five inches wide, with webs horizontal, as top members spanning between posts. While this configuration was feasible, it was found that the channels obstructed critical air flow at the top of the equipment, besides becoming quite large in the longer span configuration, because of the stiffness requirements. An overhead truss is now being using in lieu of the channel members. The truss, similar to that shown in Figure 3, is constructed of structural steel tubing. The overhead truss system was shown to be quite feasible in earlier installations on computer floors where top bracing was required due to the narrow design of the cabinets.

In some of the earlier bracing designs for cabinets on computer floors, the same truss and end-post arrangement was employed. In earlier installations of computer floors designed by the authors, the equipment cabinets were tall and, without the advantage of solid base anchorage, were highly susceptible to overturning. The lateral support system employed secured the cabinet at the top and bottom. Using the truss to laterally support the tops of the cabinets and transfer the lateral loads to the end-post was quite feasible. The lateral load, or base shear, developed at the bottom of the cabinet during an earthquake can result in lateral loads to the computer floor in the range of 60 to 70 psf. It is the experience of the authors that the lateral forces considered in the design of computer floors is in the 50 psf range. The design process is further complicated since the computer floors are usually existing and information on their design for lateral forces is not available. It was concluded that it is more prudent to totally support the telecommunications equipment laterally, independently of the lateral system of the computer floor[5]. Thus, an under-floor tube was designed to laterally support the base of the equipment and transfer lateral loads to end-post; the same end-post that laterally supported the overhead truss. The systems is shown by the section presented in Figure 3.

The tube is installed tight to the underside of the computer floor. The tube is sized with significant depth (top to bottom) so that high strength bolts installed vertically through the tube can cantilever the depth of the computer floor to transfer shears from the bottom of the cabinet into the support system. High strength bolts have been used to resist the large bending stresses developed within the system. The tubes are sized for both direct lateral loads and the torsion imposed on the tube by the cantilevered bolts. The tubes are supported from the floor by gusset plates which transfer the lateral forces and torsion from the tubes down to the structural floor system. Again, this bracing was designed to keep the natural frequency of the total system, equipment and bracing, in the range of 10 hz. or greater.

The equipment used in these initial installation was designed for the typical central office environment. The cabinets were originally designed to be rigidly mounted to a structural floor. The manufacturer has acknowledged that this cabinet configuration is not appropriate for the computer floor applications, and has developed a new cabinet configuration.



NEBS SPECTRUM

FIGURE 1

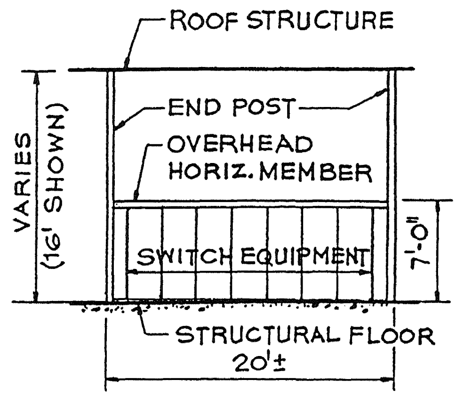
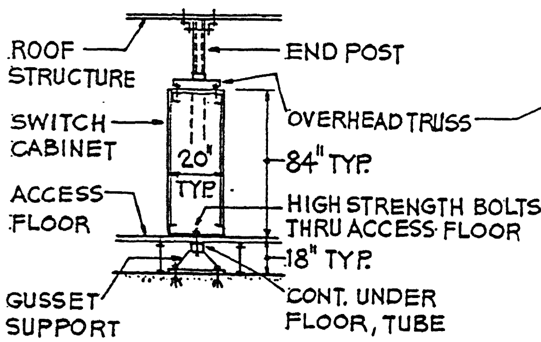
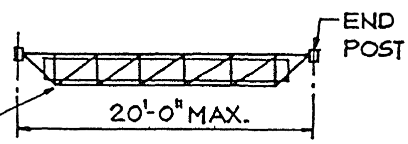


FIGURE 2

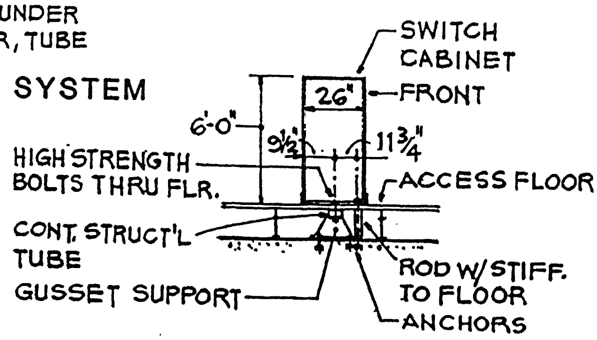


OVERHEAD-BRACED SYSTEM



PLAN-OVERHEAD BRACED SCHEME

FIGURE 3



CANTILEVER SYSTEM

FIGURE 4

The new cabinet configuration is more adaptable to computer floor applications. It is lower, has a wider base (front to back), and as a free standing unit, has a higher natural frequency than its predecessor. It was still susceptible to overturning in a seismic event, and to lateral movement, if not rigidly anchored to a structural floor. Based on the seismic design standards adopted for the central office environment, the new generation cabinet installed on a computer floor still needs to be rigidly anchored. The challenge was to develop a lateral support system that could be totally concealed beneath the computer floor.

The new lateral system, with a telecommunication equipment cabinet cantilevered off a computer floor, can be compared to a cantilevered beam with a spring support. The under-floor system, represented by the spring support, has to be stiff enough as not to significantly reduce the natural frequency of the total system.

The bracing system evolved from an initial system employing two parallel under-floor tubes to a system with one tube and an series of stiffened threaded rod anchors as seen in Figure 4. In each scheme, the under-floor tube configuration was similar to that used in the earlier top and bottom support system.

The under-floor lateral bracing system was conceived for a basement installation, where the lateral force demand is reduced accordingly. The installation is in California (USA).

The two tube system resists the overturning on the cabinets in flexure in the tubes. While a bracing scheme could be developed for the lower floor installation (reduced force demand) based on this system, it was not cost effective. The relationship of the tube size and gusset spacing became critical. The combined configuration required to keep the frequency of the cabinet line-up near its natural frequency (when rigidly anchored) resulted in larger members and more gussets to reduce spans, hence, a costly anchorage system. Furthermore, if the two tube concept were applied to upper floor installations where the lateral force demand is greater, the cost would be prohibitive. The two tube system provided too flexible of a spring support for the system.

A combination of under-floor tubes and threaded rods solved several problems. The single tube provides one component of the overturning resistance couple, and is used to transfer the shear from the system from above the computer floor to the structural floor below. The bracing system can still remain laterally independent from the computer floor system. The stiffened threaded rods provide the other component of the overturning resistance couple. With the combination of the two elements, the natural frequency of the entire system was kept within the desired range of 10 hertz. (The frequency of a rigidly anchored cabinet is 16 hertz.) In addition, the installed cost of the hybrid system is approximately half of the two tube concept.

What should the future bring? In analyzing the bracing designs discussed in this paper, it became evident that if seismic design criteria, such as NEBS, are to remain standard, and if today's central office telecommunications equipment is to be placed on the raised access floor, more research and development is needed on the cabinet frame and contents. The frames must become stiffer (higher natural frequency) to allow for the flexible (spring) base connection which reduces the frequency of the overall system. Testing is required, either static or dynamic, to determine the true distribution of overturning forces to the base anchors. The base of the structural frame of the equipment needs to be evaluated to insure that overturning forces can be resisted at that level and delivered to the anchor bolts. And finally, there is a need to determine the effect of interconnecting frames in series has on the longitudinal frequency of the system. Further research and development in this area will allow greater compatibility between the actual equipment and seismic anchorage methods and should lead to more efficient and cost effective systems.

REFERENCES AND NOTES

1. Bell System's Technical Reference New Equipment - Building Systems - General Equipment Requiremnts, dated August 1985, published by American Telephone and Telegraph Company.

2. The Uniform Building Code, published by the International Conference of Building Officials, Whittier CA USA

3. Entitled Seismic Design For Buildings, a technical manual and design guideline used by the United States Departments of The Army, The Navy and The Air Force.

4. The cabinet referred to has a base width of 28", and depth varying between 18" and 26". The cabinet height vary between six and seven feet.

5. It is appropriate to state that the engineer and the supplier of the telecommunications equipment, by contract, were not responsible for the evaluation of the computer floor, nor did they have controls over its future use. It was their determination that keeping the lateral resistant system of the base of the equipment independent from the computer floor lateral system was a prudent solution.