

Firming up the Framing Why and How to Stiffen the Telecommunications Cabling Infrastructure

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Abstract - The intent of this paper is to show the need for adequate bracing and framing of cable trays in the central office environment, particularly cable racks bearing power cables. Power busbars and cabling are the densest conductors in the telecommunications environment and everything in the central office is dependant on power. The paper will cover seismic influences on the cabling structures and the ways in which seismic displacement could result in systemic failure of the telecommunications systems if the mechanical support for the cabling or buswork is inadequate.

The paper also will cover bracing and framing for busbars and busduct systems with text and illustrations. The paper will cover bracing and framing for cable trays including primary and secondary power cables, communication cables (often called "Switchboard cable) and optical fiber cable trays.

Most telecommunications huts and CEVs are equipped with adequate cableways and so this paper is intended to speak mainly to central office cabling whether for wireline or wireless use and for data centers with dc powered systems.

Finally, the paper will socialize an idea in the telecom community. To date, no cable manufacturer makes a plenum-rated dc power cable. Telcos with raised floors would gain more robust systems if the power cables were run beneath that floor. Unfortunately, the way the National Fire Protection Association (NFPA) has written the codes, only plenum rated cables may be run beneath the floor if that floor also is used as a cooling air plenum.

The requirement is because toxic gasses from burning cabling insulation being pushed into the working space occupied by employees were a fire to ignite beneath the floor.

However, telcos now have a twenty year history of successfully using Very Early Smoke Detection Alarm (VESDA) systems. Many of these systems are designed to sample room air through PVC pipes placed under partial vacuum and then route that sampled air past a particle counter. The substance perceived as smoke is a cloud of soot and other particles formed during combustion. By counting these particles, the VESDA system is able to detect overheating equipment or cabling in the incipient stage of a fire, long before visible smoke is present.

Most VESDA systems are capable of several levels of alarm state depending on the particle-count (smoke density) of the sampled air. By using one alarm level to automatically shutdown the fans forcing air into the plenum, smoke that might be generated by the non-plenum rated dc power cable for the most part would remain in the plenum while the dc power was disconnected. The advantage of using this arrangement is that the central office gains the seismic reliability associated with

under-floor cabling while using a known reliable smoke detection system to maintain a safe environment by shutting down the pressurization airflow if fire broke out. This author intends to approach the NFPA with this concept for the next code cycle and wishes to see the telecom industry's reaction to the idea.

INTRODUCTION

Overhead cabling systems are a feature of most telecom buildings including central offices, huts, remote, and Controlled Environmental vaults (CEV) whether used for wireline or wireless telecommunications. Usually, the heaviest cabling includes the dc power cable and the dc busbars in power plants so equipped. Overhead support needs to accomplish two key objectives:

- Support the weight of the conductors and racking so that sagging and deflection are within limits
- Provide sufficient lateral bracing so that the cable racks do not act as a pendulum if a seismic event causes ground displacement.

Often, the framing and cable tray systems provided for telecommunications systems are inadequate for the task; or they were adequate initially but became overloaded as later jobs piled on more cabling than the system was designed to support. Such conditions can lead to the catastrophic collapse of the cable racks or cable tearing failures during seismic ground displacement.

Powerful earthquakes are a relatively rare occurrence; but when they do happen the increased demand for reliable communications is a key element of public safety. Of all the measures taken by telephone companies to save money on capital expansion, the proper provisioning and bracing of cable tray systems is an area where skimping should not be condoned. The relative difference between adequate and inadequate support is usually less than 1.5% of the overall capital investment in any central office equipment addition. Placing the entire investment in peril to save 1% isn't good risk management.

What are the seismic forces involved?

Generally, when seismic events such as earthquakes occur in an area the mechanical forces are in predictable directional planes. In general terms the waves are called P (primary) and S (Secondary) waves.

These P and S waves are generated by the motion between plates of rock deep within the earth's crust in areas called subduction zones (Figure 1).

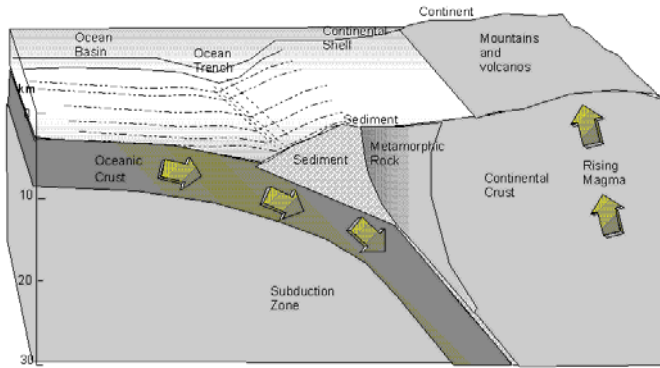


Figure 1 Coastal Subduction Zones

The rocks forming the Oceanic crust typically are Bassalt and are much heavier and denser than Granite which makes up most of the continental crust. These crusts are called "Tectonic plates" that grind against one another and shift. The heavier Oceanic plates tend to push below the lighter continental plates forming mountain ranges. Some of those mountains are volcanos fed by magma rising under the pressure of the geologic activity.

P waves generally are short-duration jolts of motion in the vertical plane. Often the first motions detected in an earthquake are the P waves and the vertical jolt sometimes is confusing to people in the first moments of an earthquake. S waves are more sinusoidal and they are a result of the edges of the tectonic plates grinding against each other. S waves result in a side-to-side ground motion. So, what earthquake victims experience is a violent side to side ground motion with periodic vertical bumps or jolts.

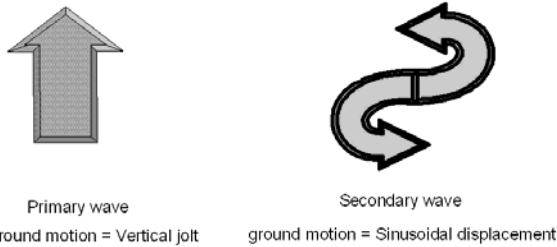


Figure 2 P and S waves and soil displacement

The same seismic forces that affect cable systems affect buildings, highways and all other structures. It's been said that earthquakes don't kill people, faulty buildings do. What that means is that structures that are not designed to withstand seismic forces may collapse, thus trapping the occupants. Two earthquakes exactly a year apart,

one in North Ridge, California and the other in Kobe, Japan proved this fact very dramatically. The North Ridge earthquake killed a handful of people while a year later the earthquake at Kobe killed thousands. Considering the forces that earthquakes place onto buildings will help to understand how those forces act on cabling systems.

Buildings and the systems within them usually are built plumb with respect to the earth, because gravity helps hold the building together. Buildings that are out of plumb eventually may fail because gravity is pushing them down. Perhaps the most recognized example of this is the Leaning Tower of Pisa. Figure 3 compares the effects of gravity on a sketch of the Leaning Tower of Pisa with the forces against a similar structure that is plumb. Note that gravity is pushing against the tower in a plane that could cause catastrophic collapse whereas gravitational forces against the plumb structure tend to hold it more tightly to the earth.

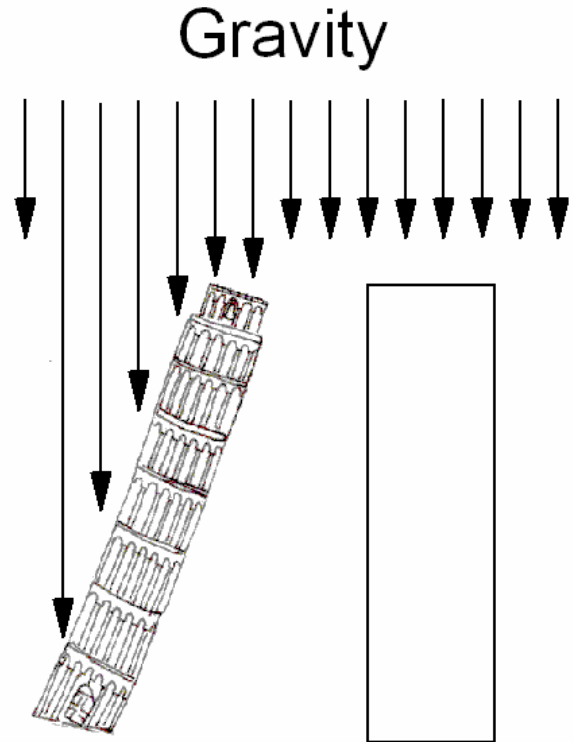


Figure 3, the effects of gravity on structures that are off-plumb with respect to structures that are plumb.

The more top-heavy a structure is the more likely it is to collapse during an earthquake. This is because the ground motion will move the base of the structure. The laws of inertia tend to "hold" the heaviest part of the structure in one place. If ground displacement moves the base of the structure while inertia holds the top in one place then the structure becomes out of plumb and then gravity collapses it. This situation is what caused the terrible loss of life at Kobe. Traditional Japanese homes were built with heavy clay tile roofs that shed rain easily and their thermal mass helps to

maintain an even temperature within the dwelling. These roofs often are supported by wooden members similar to post and beam construction techniques. When the earthquake struck, inertia held the roof steady while the earth displaced beneath it taking the walls in the direction the soil moved. With the walls now at a dramatic angle with respect to the weight of the roof, gravity brought the structures to collapse.



Figure 4 failed homes during the 1995 Hyogoken-Nanbu earthquake in Kobe Japan caused by the top-heavy nature of their construction that could not withstand soil displacement taking the structure out of plumb.

(Photo used with permission Professor Mitsutoshi Yoshimine Tokyo Metropolitan University)

Also, the taller an object is the more that S waves tend to affect it. Figure 5 shows the effect of a small amount of ground motion on a tall structure. Note that the top of the structure though moves further away from the reference line than the bottom for a given displacement at the bottom. The same physical nature affects elements within a building. The taller these elements are or the higher they are placed within the building, the more that the amplitude of ground level displacement or vibration will be experienced higher up. Stated simply, the horizontal displacement is mechanically amplified proportionate to the height of the structure.

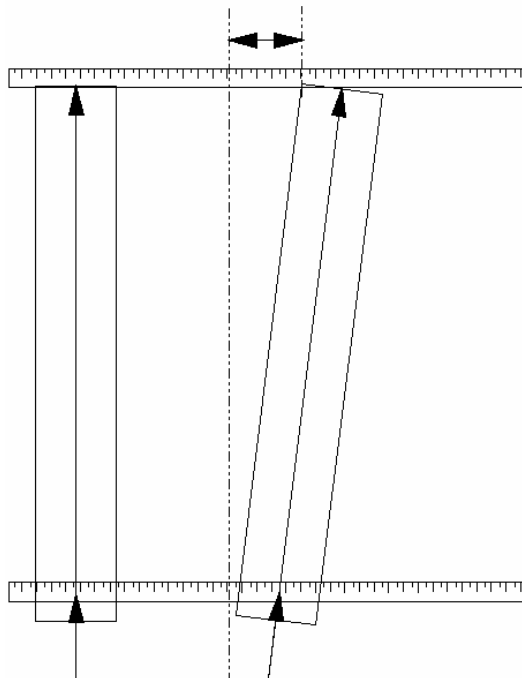


Figure 5 shows the amplification effect of horizontal displacement upon a tall structure. The structure to the left is on stable soil while the structure to the right is on soil that is experiencing horizontal displacement. A small amount of displacement at the base results in significantly more displacement at the top.

Aren't earthquakes just a west coast thing?

Actually, no. While the San Andreas Fault is the best known, of the seismic faults in North America, seismologists predict significant activity along the New Madrid Fault between St. Louis and Memphis Tennessee and Charlotte NC has seen earthquakes with significant ground displacement. It's important to specify buildings and the structures within them to survive at least the earthquake zone in which that building resides. Some telephone companies specify the Zone plus one level for robust reliability.

Figure 6 shows the tearing of a street in San Francisco experienced during an earthquake and Figure 7 shows how an S-curve was bent into a previously straight stretch of railroad track in Charlotte, NC. In addition to P and S waves, Geologists also refer to Love Waves and Rayleigh Waves named for the Geologists who identified them. Love waves typically leave a trench-like split in the earth similar to the San Francisco example below and Rayleigh waves typically result on ground displacement without large splits such as the Charlotte example.



Figure 6 Ground displacement evident during a 1906 earthquake in San Francisco.



Figure 7 Railroad track displacement from an earthquake in Charlotte, NC. The track was straight before the event.

OK how does all this tie into cable racks?

The first tenet of cable support is that the overhead system must be strong enough to take the weight of the auxiliary framing, or strut system plus the weight of the cable tray and cabling. Generally the fasteners, threaded rods, anchors, beam clamps etc. are derated for a safe working load of approximately 25% of their ultimate load capability. The reason for this is that the vertical thrust from the P wave of an

earthquake causes inertia to act on the hanging load suddenly increasing the load on the system dramatically.

An experienced structural engineer should be consulted to determine the safe working load of a ceiling and support system. Generally, for concrete ceilings cast-in-place anchors are best and where they cannot be used other anchors such as drop-ins may be used. Experience shows that zinc anchors have a high rate of failure and so it's best if they are avoided. They're cheap but failure prone.

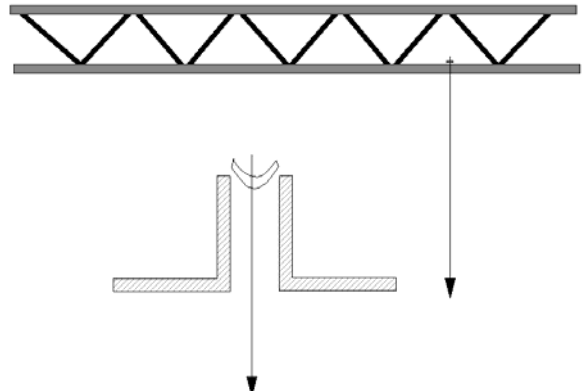


Figure 8 when supporting from overhead truss joists fender washers are inadequate and thick rugged washers are needed to prevent pull through failures. Note the bowing evident in the washer pictured and in the illustration.

Most telcos use Telcordia GR-1275 as the basis for their framing systems and that document specifies 5/8 by 11 thread per inch threaded rods for overhead cabling support. Some vendors try to skimp by with 1/2" rods and this nearly always is a costly mistake discovered a few years later.

When overhead steel bar joists are used to support the roof many engineers drop threaded rods from the lower chord of the truss. If the truss is able to support the weight this is a suitable arrangement however the cabling engineer should be wary of supporting the load from common fender washers as they tend to bend and pull through the truss between the angle irons. Washers used for this purpose should be at least

3/8" thick and a good deal wider than the truss to avoid pull through.

Tile-Arch buildings present a special challenge. Multistory office buildings built between approximately 1910 and 1930 often used a method of construction called "Tile Arch" and the floors are hollow terracotta palates set into I beams as shown in Figure 9. Usually the terracotta supports a gravel fill and thin concrete floor above and is coated with a veneer of plaster below.

Anchoring mistakes with this system have caused failures and serious injuries to installers. Conventional anchors are not designed to hold in terracotta and the preferred method is to use beam clamps that attach to both sides of an I-Beam as shown.

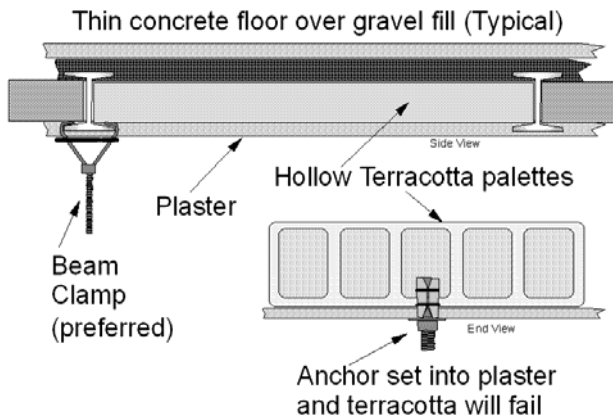


Figure 9 Tile Arch buildings require beam clamps or other arrangement. Anchors set into plaster or terracotta are prone to catastrophic failure.

FRAMING SYSTEMS

The earliest framing systems used in central offices were bar-stock steel. Later, 2-inch channel bars became the standard and sometimes a much more robust product called "3-inch 4 pound" channel was the framing member of choice when spans between supports exceed 6 feet. Increasingly, strut systems such as are offered by Hilti and Unistrut are finding a welcome place in the central office. Generally, strut costs about the same for material but the installation cost is greatly reduced because assembly time is drastically reduced.



Figure 10, 2-7/16" strut for central office framing (Courtesy Hilti Corp.)

For support spans less than 6' the 2-7/16" strut is adequate. For greater spans the use of back to back strut is recommended (see figure 11).



Figure 11, Back-to-back strut for central office framing (Courtesy Hilti Corp.)

One caution, it's best not to mix strut and channel type framing in any given system. Use one or the other. For example, one might finish framing one building bay with channel framing and then switch to strut in the next and future building bays. Connecting the two together mechanically can lead to problems as the two technologies have different characteristics.

HIGH AND LOW TYPE FRAMING

When ceilings are very high with respect to the relay racks that typically are 6 or 7 feet tall the cable racks are placed a considerable distance from the ceiling. It is imprudent to place very long threaded rods hanging from the ceiling and so multiple levels of framing are prudent, often called high type and low type framing. When high and low type framing are used they should be oriented perpendicular to each other.

The Telcordia standard design of framing supported by a grid of 5/8 threaded rods on 60-inch centers is based around a 25 pounds per square foot ultimate load. Many engineers are finding that their cabling density has grown and so something more robust is needed. It would be prudent to consult a structural engineer and design a threaded rod grid of

something less than 5-feet to support the heavier cable load. It is prudent to cover the threaded rods with insulating tube to protect cabling from damage.

CABLE RACK

GR-1275 allows the use of various types of cable tray system including solid stringer racks, tubular stringer racks and “C” type stringer racks. These racks are available in a variety of sizes and finishes. It’s up to the user which type of stringer they wish to use; however, if the system must support heavy power cable, the solid stringer is the safest choice. Further, if the rack will support power cable it’s prudent to specify continuity clips, bonding jumpers or other methods so that a continuous electrical connection to Ground is present the length of the cable rack. If an energized cable becomes short circuited to the rack, a low impedance electrical Ground is needed to operate the feeder circuit breaker or fuse for safety. Some engineers specify cable racks that are protected from corrosion with an electroplated coating of yellow Chromate of Zinc rather than powder-coat paint. This type of cable rack offers improved grounding and RFI/EMI characteristics.

Generally it’s best to place power cables on the highest tier of cable racks. The reason for this is that power cables are the most likely conductors in the central office to catch fire. By placing power cables on the highest tier, there isn’t other cabling just above them where heat from the electrical fire would find more fuel to burn and spread the fire.

BRACING

Bracing auxiliary framing and strut systems is necessary because seismic ground motion will transmit through the building and amplified by the height of the building. This motion more than likely will cause unbraced framing and cable racks to behave like a pendulum swinging to and fro and rip the cable “drop” connections from the relay racks or cabinets beneath them.

Figure 13 shows cable racks and relay racks next to illustrations of pendulums, one hanging from the ceiling and one above the floor representing the relay rack. How much the pendulum will swing when ground displacement sets the building into motion is a function of the mass (weight) and the distance from the ceiling or floor. Called the “Moment of Inertia,” this force will cause the two mechanical structures to swing. How much each one swings is determined by each one’s Moment of Inertia and their stiffness. It is very unlikely that the cable rack and the relay rack will have the same Moment of Inertia and so it is possible that the two structures could mechanically be out of phase with respect to each other. When out of phase, the cable rack might be swinging to the right while the relay rack is either still or moving slightly to the left.

Obviously this out of phase condition has the potential to tear out the cabling. Some engineers opt to install threaded rods between the cable racks and relay racks to prevent this damage as shown in Figure 12. Unfortunately, the Moment

of Inertia of a heavily laden cable rack can sometimes be transmitted through to the relay rack by such braces and tear the rack apart.

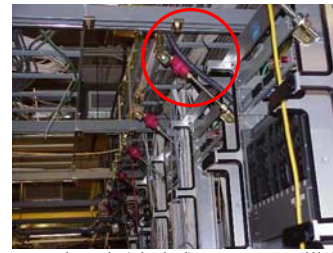


Figure 12 Bracing on weak rack (circled) structures will fail.

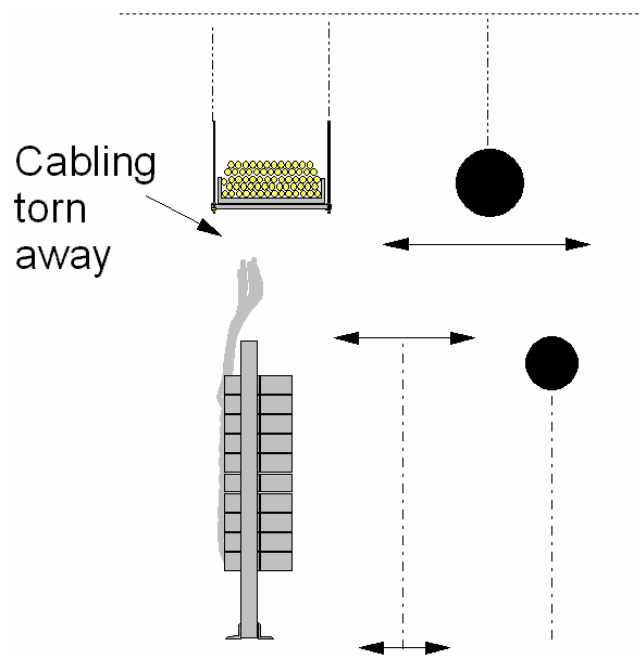


Figure 13, cable racks and relay racks represented as pendulums and their behavior during ground displacement.

How to brace

Bracing should run in both directions to prevent side to side motion as well as longitudinal motion. If the aux framing is close enough to the ceiling or the high type framing and the lateral bracing is 18 or fewer inches long then 5/8” threaded rod may be used as the lateral brace. If the brace is longer than 18” threaded rods should not be used, because they would only be strong enough if the direction of motion placed the rod in a tension mode. If the motion was in the opposite direction the rod would bow and fold uselessly. For lateral braces longer than 18” one of two accepted methods should be used.

Steel angle iron, 2” X 2” X 1/8” bolted to flat 3/8” X 2” bar stock steel “Shoe-braces” bent to the appropriate angle for the application may be used. The second method would be strut the same size as the strut used for the framing may be used for lateral bracing and the angles obtained by the use of a steel bracing “shoe” as described above or the use of a

“Seismic Hinge” product from the strut supplier and rated for the task.

The same need to brace cable racks against lateral movement also is true of overhead bus bars. Overhead bars are very heavy and therefore have a high Moment of Inertia. Additionally, as a seismic tremor runs through a building laterally, long runs of bus bar could undulate out of phase and strike each other causing system failure and a very serious short circuit condition on the central office battery. For example, each string of 4,000 Ampere hour battery cells has the short circuit potential to deliver as much as 26,000 amperes into a fault.

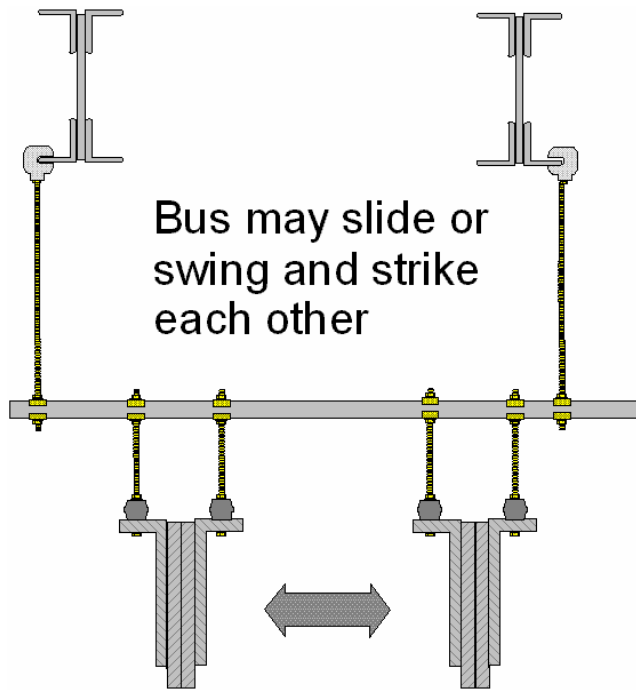


Figure 14 during an earthquake bus bars may shift and strike each other causing a serious electrical fault. Or, because “C-Clamp” type beam clamps may be used as shown, lateral motion may cause one of the clamps to pull away from the beam dropping the bus.

It is prudent to use beam clamps that hold both sides of I-beams as shown earlier in Figure 8 and either to use back to back strut to support the bus. If conventional channel framing is used to support the bus it is prudent to fashion a rugged brace atop the support channels to maintain the distance between the bus bars and/or to insulate the bar that is at battery potential with a rugged thermoset insulating board bearing a NEMA rating of GPO-3.

STANCHION SUPPORT

Many cable rack systems are floor supported on stanchions because the overhead building structures cannot bear the weight of framing and cabling. Stanchions are a suitable method for supporting cable providing the stanchions are adequate for the load, adequately braced against seismic forces and adequately secured to the floor. Some vendors

think they can save money by securing the tops of floor stanchions but not the bottom. They believe that the cable system weight will hold the structure together and some even use double stick foam tape on the base plate rather than anchors and bolts thinking that this is sufficient.

Tape fasteners are ridiculously inadequate for systems that will have overturning Moments of Inertia in the tons and proper anchors, bolts and lateral bracing must be in place for the system to survive seismic displacement..



Figure 15 Stanchion lacks floor connection

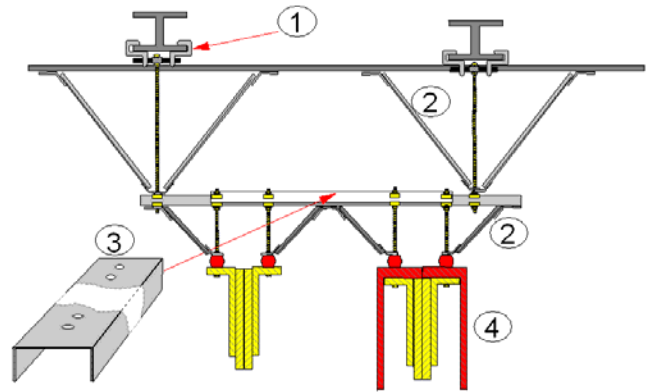


Figure 16 (1) Proper beam clamps “grab” both sides of the I-Beam (2) Lateral bracing in both planes is provided (3) a drilled channel atop the framing prevents bars from sliding together during an earthquake (4) NEMA GPO-3 insulation protects the bar that is at Battery potential.

Stanchion cable support systems require a site-specific design by a competent architect or structural engineer. The system should be carefully braced to protect against displacement.

For example, some bus manufacturers are offering a dc bus-duct product comprised of plated copper bus bars supported by insulating combs and suspended from a single 1-inch threaded rod. When suitable overhead framework is available the bus-duct may be suspended from them. Unfortunately, over head framing often can’t handle the weight of the bus and stanchions are used. The stanchions are vertical steel members anchored to the floor.

The busduct is quite heavy and 200 pounds per lineal foot is not unusual. Figure 13 shows a stanchion supported busduct system and illustrates some of the seismic stresses that could influence the structure. Assuming 200 pounds per lineal foot, spans of 6 feet and a stanchion height of 9 feet the overturning Moment of Inertia imposed on the top of the stanchions could be as high as 97,000 pounds. With the stanchions secured to the floor with concrete anchors consider the prying action of a 9 foot lever being pushed by 97,000 pounds as illustrated by the claw hammer. Floor anchors will likely pull out permitting this structure to fall over thus faulting a powerful dc bus and causing the catastrophic failure of the facility if not a very serious Class C fire.

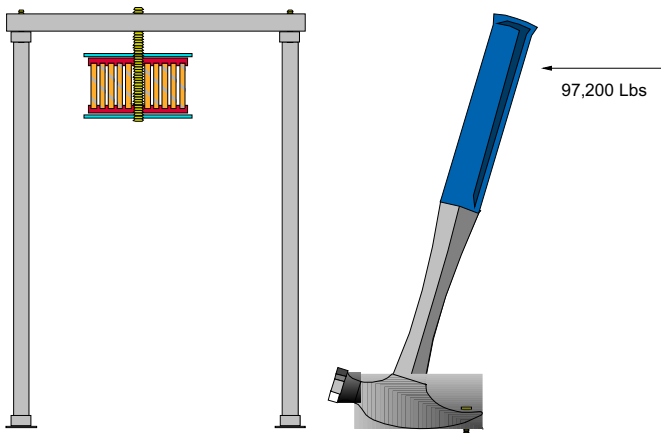


Figure 17 a high "Overturning Moment of Inertia can act like a pry bar to pull out floor anchors.

For stanchions to be safe they need adequate lateral bracing to resist seismic forces. An example is shown in Figure 15 of a stanchion system braced with "K-Bracing."

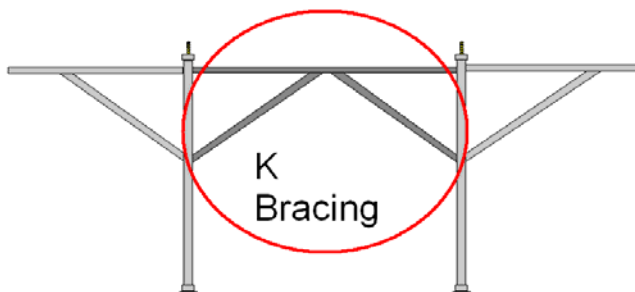


Figure 18 Stanchions with "K-Bracing"

When structural engineers design framing systems they typically follow formulas outlined in the Uniform Building Code, International Building Code or other model code adopted in the location where the construction will take place.

Unless the architects or engineers are given direction from their telephone company clients, they may not design the system as robust as it should be for services so critical as telecommunications. It would be prudent if the design

criteria given to the structural engineers specified that framing systems shall be "rigid structures" designed using a minimum Seismic Importance Factor of 1.5 and Category 3 Peak Ground Accelerations used for the seismic calculations. When those criteria are "plugged-into" the IBC structural formula it forces the engineer to use very stiff bracing to meet the engineering goals and is best for central offices.

Removing existing cable rack systems

Care should be taken when doing central office tear outs. Often the cable racks were supported by relay racks and if too many of the relay racks are removed the system could collapse resulting in very dangerous conditions for installers and serious operational issues for the telephone company.



Figure 19, a serious cable rack collapse can occur if too many of the supporting frames are removed.

Underfloor cable systems offer advantages and yet have some disadvantages too. When cable trays are placed beneath a raised floor, they are lower in height and closer to the relay racks and cabinets they serve. This means there is less Moment of Inertia acting on the racks and less opportunity for mechanical out of phase conditions to exist between the cables and the telecommunications equipment. This especially is true of power cables because they are the heaviest and densest cables in telecommunications.

Some engineers like to use the space beneath an access floor system (sometimes called a "computer floor") for cooling air. Essentially the space beneath the access floor is pressurized by the Heating Ventilating and Air Conditioning (HVAC) system and used as a large air plenum. Air registers are placed into cutouts in the access floor panels and cooling air flows upwards past the telecommunications equipment so that it can cool more efficiently.

Because most cabling insulations burn with a toxic, corrosive smoke the National Electrical Code requires plenum rated cabling insulations for any cables that share the space inside an access floor that doubles as an air plenum. Usually, the outer insulation on plenum rated cable is made of Teflon or similar insulation compounds. The problem with dc power is that there is no North American cable manufacturer that makes a plenum rated power cable. There are many manufacturers of low smoke non-halogenated cables but these are not plenum rated.

Because of the limitations imposed by the unavailability of plenum rated dc power cable, many telephone companies either run the power cable overhead which is expensive and fraught with seismic bracing issues or run the air ducts overhead which limits ceiling space and also causes the room volume to grow a great deal which raises the cost of gaseous fire suppression dramatically in offices so equipped.

Is there another way?

At present the only code-sanctioned way to run dc power in a plenum floor is to place it in some sort of conduit which is impractical. A proposal is being floated for consideration in NFPA-76 that would permit low-smoke non-halogenated cables to be placed in plenums providing that a suitable incipient smoke detection system be installed in the plenum and automatically shut down the HVAC fans if smoke is detected, thus reducing the transference of smoke from beneath the plenum to the equipment space above.

Very Early Smoke Detection Alarms (VESDA) systems have been in use for some twenty years and have earned a solid reputation for reliability. Such systems are available from a number of manufacturers and use different hardware schemes but essentially all of them are laser-particle counters. Smoke is a cloud of gasses and particles released during combustion. With electronic systems and Class C (electrical) fires the usual progression is for some part of the system to overheat and then begin burning. Particles are released long before visible smoke is present. This is called the incipient phase of a fire and can precede smoke and fire by hours or even days in some circumstances. The VESDA type systems detect and alarm at this incipient phase of combustion. Many such VESDA systems are multilevel systems reacting to varying levels of particle density with as many as four or more levels of alarm.

If such a system was sampling air in the plenum and was connected to automatically shut down the HVAC fans at visible smoke, perhaps at the 0.5 to 1% Obscuration level (smoke density) then the fire would be discovered and personnel evacuated long before insulation toxicity became an issue. First responders today wear Self Contained Breathing Apparatus (SCBA) and so the Non-Halogenated cable insulations would pose no serious threat to them.

If the NFPA accepts such a proposal what the industry gains is reliability and a modest cost savings. Few if any fire departments still maintain fire alarm pull-boxes on street corners because the telephone network is considered the most

reliable means for alerting first-responders to an emergency. The telecommunications network is so interconnected that a power failure in one central office can cut a wide swath through telecommunications services in a city or even isolate major portions of a state in the case of cellular telephone switches. The more robust these central office installations are with respect to earthquakes and other disaster, the safer is the entire community around them. From an intuitive viewpoint cable racks secured to a concrete floor slab will move around less than will cables on an overhead trapeze. The fact that plenum rated dc power cable is unavailable but that alarms with a twenty year track record for reliability hopefully will be accepted as a viable alternative.

BATTERY STANDS

Lead-acid storage batteries are usually the most dense, heavy equipment in a telecommunications facility. As such, the racks that support those batteries must be sufficiently robust to withstand seismic forces.

Several battery stand failures were experienced during the 1989 earthquake in San Francisco. This damage caused engineers to rethink battery stand design. The traditional steel battery stands used until then were a series of frameworks supporting a three-sided folded steel shelf as shown in Figure 17. Essentially the weight of the batteries and the associated inertia caused the stand to buckle close to the feet as ground motion (S-Wave energy) displaced the floor slab onto which the battery stand was anchored.



Figure 20 a type of battery stand that experienced failures during a US earthquake. The failure points are identified by circles.

Virtually any “top-heavy” structure has the potential for failure unless it’s sufficiently robust to withstand the seismic motion. The buckled-leg damage observed in battery stands in the US is not unlike the damage seen on the Hanshin Expressway collapse in Kobe, Japan during a magnitude 6.9 earthquake in 1995.

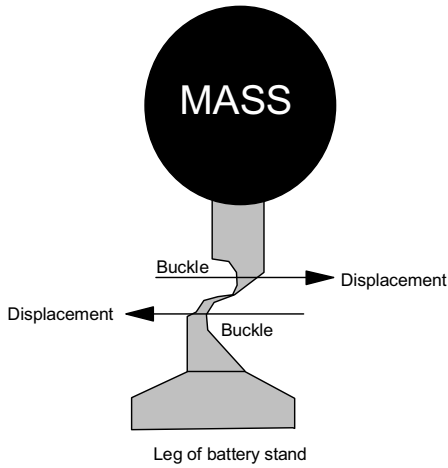


Figure 21 Damage to battery stand legs in San Francisco is similar to the damage experienced in the columns of the collapsed sections of the Hanshin Expressway during the 1995 earthquake in Kobe, Japan.

Battery stands rated for seismic applications are much more robust than stands that are not seismic rated.

SUMMARY

Summing up, the key elements of a robust overhead bus or cable tray system include:

1. The overhead system should have sufficient strength to support 400% of the actual hanging load to compensate for the vertical acceleration effects of P-Wave seismic activity.
2. The overhead and underfloor systems cable tray system should be adequately braced in all four lateral planes to resist the horizontal acceleration effects of seismic S-Wave forces.
3. Bus and cable systems supported via 7' foot cabinets and relay racks are more likely to resist seismic forces than ceiling hung systems.

Cabling under raised floors has better seismic stability than overhead systems providing that the cable trays are adequately secured to the floor. Of course, the raised floor itself must be sufficiently robust to withstand the lateral forces imposed upon it. Telecommunications equipment is significantly heavier than data center computer systems and

so the floor loading needs to be specified for the floor provider.

In keeping with today's electrical codes, the unavailability of plenum-rated dc power cabling prevents it from being installed in access floors also used as an air plenum. Hopefully, the track record of very early smoke detection systems and Zoned Disconnect plans may influence code officials to rethink the requirement for plenum rated power cable.

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