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D3.0 – Product/Design Overview

THE BIGGEST PROBLEMS CONTRACTORS HAVE WITH RESTRAINTS

D3.1.1 – General:

Problem No. 1 – Knowing When Restraint is Required:

Section D2.1 of this manual covers the requirements for the various code years of the International Building Code (IBC). All of the states have adopted some version of the IBC. If the project in question has been assigned to Seismic Design Category A all of the non-structural components, architectural, mechanical, and electrical components, are exempt from the need for seismic restraint. If the Project has been assigned to Seismic Design Category B by, the mechanical and electrical components will not require seismic restraint. If the project is assigned to Seismic Design Category C, D, E, or F, some of all of the mechanical and electrical components will require seismic restraint; see Sections 2.1.4, 2.1.5, 2.1.6, and 2.1.7 of this manual.

Section D2.4 of this manual covers the requirements of the National Building Code of Canada (NBCC) and the Ontario Building Code (OBC). In general, if the 0.2 second period ground acceleration value for the project is less than 0.12; seismic restraint will be required for the non-structural components, mechanical, electrical, and plumbing components. There are no exemptions in the NBCC or the OBC. However, the specifications may spell out certain components and sizes that may be exempted from the need for seismic restraint.

Section D2.2 of this manual covers the wind provisions of the IBC for roof top equipment and components. Any equipment or components that are on the roof will need restraint of some type. Barrier walls and wind screens may not be used to reduce or eliminate the need for wind restraint.

Section D2.5 of this manual covers the requirements for restraint specified the Unified Facilities Criteria published by the DoD. The seismic and wind restraint requirements are similar to those spelled out in the IBC. However, there is a document, UFC-4-010-04, that deals with antiterrorism. In this document any suspend piece of equipment that weighs more than 31 lbs (14 kg) will require restraint to 0.5 G horizontal and 1.5 G total vertically down, this includes the dead weight of the component.

D3.2 – Anchorage Issues:

Problem No. 2 – Equipment Location in the Building:

The earthquake motion and the forces that the restraints must resist will increase as one moves up through the building. As far as the code is concerned, the total height of the building is not as important as the elevation of the equipment attachment relative to the mean roof height. The IBC and the NBCC/OBC recognize this with a factor that increases the design seismic forces in a linear fashion from a value of 1.0 at and below grade to 3.0 at the roof line.

This means that the contractor, who is generally responsible for obtaining the seismic restraints, will need more and/or larger restraints on the upper floors or roof of the building than in the basement. It is obvious that restraining equipment and components on the upper floors and roof of a building may be more expensive than restraining the same objects in the basement of the building. The contractors usually rely on the manufacturers of the seismic restraints to select and certify the restraint product for their projects. Unless information on the mean roof height above grade and the attachment elevation of the equipment or components is provided by the contractor, Kinetics Noise Control must assume that the equipment or components are attached to the roof of the building. This is a worst case assumption which will ensure that the right size and number of restraints are specified for each piece of equipment or component. The upshot of all of this is, the contractors can make sure they have the most economical restraint arrangements by providing accurate mean roof elevation and component attachment elevation to Kinetics Noise Control at the outset of the project.

Problem No. 3 – Anchorage to Concrete:

Anchorage of seismic restraints to concrete presents some unique and often serious problems. The major problem is that by the time the contractor is requesting the seismic restraint selection from Kinetics Noise Control; the concrete has been designed, specified, and often poured. That leaves very little room for Kinetics to recommend the appropriate anchorage. In lieu of being able to control the design of the concrete, Unless it is indicated otherwise, Kinetics Noise Control selects anchors based on the following parameters.

1. The concrete is normal-weight concrete with a density of 150 lbs/ft^3.

2. The concrete has a minimum compressive strength of 3,000 psi.

3. The minimum, or critical, edge distance in any direction as published in the Kinetics Noise Control anchor capacity data in Section P10 of this manual in maintained for each anchor. This edge distance is the one that will lead to a failure in the steel of the anchor before concrete fails.

4. When anchors are used to hard mount equipment and components to concrete, the minimum, or critical anchor spacing listed in the anchor capacity data published by Kinetics Noise Control in Section P10 of this manual must be maintained in order to maintain the maximum published anchor capacity.

5. The minimum concrete thickness for the recommended anchors as published in Section P10 of this manual will be maintained in all cases. This minimum concrete thickness includes the standard effective embedment for the anchor, any over drill requirement for the pilot hole, and the proper amount of cover over the end of the anchor to prevent moisture intrusion. It should be noted here that Kinetics Noise Control chooses the standard effective embedment depth for the manufacturer's published ICC-ESR data. Other standard embedments may produce acceptable results, but will need to be evaluated by the Structural Engineer of Record.

The effective embedment depth of the anchors in the concrete controls the capacity of the anchors. The 2000 and 2003 IBC and the NBCC/OBC require that the concrete anchors have an effective embedment depth that is equal to eight times the nominal anchor diameter, or use a greatly increased design horizontal seismic force. This will lead to the use of larger and/or more anchors. The 2006, 2009, and 2012 IBC codes do not have this restriction. However, the requirements for embedment depth published in the ICC-ESR for the anchors must be followed.

The 2000, 2003, 2006, and 2009 IBC do not allow standard wedge type anchors to be used for equipment that has a total of 10hp or greater on board. In this case either undercut type wedge anchors or adhesive anchors must be used. The undercut wedge type anchors are expensive, and require a great deal more labor to install than do standard wedge anchors. The adhesive anchors work well except in environments where the operating temperatures will normally exceed 100 °F for extended periods of time. This requirement for the undercut or adhesive anchors for equipment with 10 hp or greater on board has been lifted in 2012 IBC.

The isolator/restraints provided by Kinetics Noise Control and other manufacturers have been designed to maximize their performance when bolted or welded to structural steel. Thus the anchor hole locations in the isolator/restraint base plates may not optimize the performance of the concrete anchors, and additional capacity may be required. Typically the concrete anchor capacity increase is achieved through the use of an oversized base plate, see Sections D5.2.1 and 5.2.2 of this manual. The oversized base plate allows for the use of larger anchors, and spreads the anchor centers out far enough that maximum rated anchor capacity can be achieved. ***Please note***; pay attention to the submittal data issued with the recommended isolator/restraints to be sure that the recommended edge distance for the concrete anchors in the oversized base plate is maintained in all directions.

Where concrete of insufficient strength or thickness is provided, the only clear alternative will be to drill clear through the slab, and use through bolts, nuts and fish, spreader, plates. This solution is generally unacceptable because it penetrates a roof slab and compromises the roof integrity, or it leaves bolts showing which may be unsightly and/or cause interference.

The 2012 IBC will require that all concrete anchorage be designed per ACI 318 Appendix D which will require the failure of a ductile steel element at a force level below that required to fail the concrete. The alternative will be either a 2.5 increase in the design loads acting on the anchors, or a 60% reduction in the capacity of the concrete anchors. Unless the concrete anchor manufacturers redesign their products, or the code relaxes the requirements for concrete anchors, more and/or larger anchors will be required to attach equipment and components to concrete in building structures.

Problem No. 4 – Concrete Housekeeping Pads, Curbs, and Piers:

If concrete housekeeping pads are used, they must;

1. Be either dowled to the structural slab, or be a monolithic pour with the structural slab. This is to prevent the housekeeping pad from shifting position relative to the rest of the building during an earthquake, and breaking pipe, duct, and electrical connections.

2. Be steel reinforced to have enough strength to transmit the seismic loads from the equipment to the building structure, and to not be broken up into rubble under the earthquake motion.

3. Be normal-weight concrete with a standard density of 150 lbs/ft^3.

4. Have a minimum compressive strength of 3,000 psi.

5. Have a minimum concrete thickness that is compatible with the anchors specified by Kinetics Noise Control

6. Be large enough to provide the required edge distance in all directions for the anchors specified by Kinetics Noise Control and also any oversized base plates that may be required to achieve the necessary capacity.

Concrete curbs and piers represent an enormous headache. They are typically designed and poured before Kinetics is approached to select restraints and anchors. The design of concrete curbs and piers almost never;

1. Takes into account the size and configuration of the isolator/restraints that are to be mounted on them.

2. Leaves enough edge distance for the concrete anchors required to attach the isolator/restraints to the curb or pier to resist the design seismic and wind loads. This often means that a special steel frame must be fabricated to encapsulate part or the entire top of the concrete curb or pier so that the anchors can be installed along the sides rather than the top of the curb.

D3.3 – Equipment Issues:

Problem No. 5 – Equipment Durability and Interfacing Support Members:

For designated seismic systems in essential facilities, the IBC requires that the durability of the equipment be certified by the manufacturer of the equipment. It must continue to function after an earthquake that is equal to the design level for the project location. It is becoming more common for this certification must be performed by shake table testing. The usual testing protocol is ICC AC156.

Interfacing support members must have sufficient strength and stiffness to transfer the earthquake and wind loads from the equipment to the isolator/restraints. Unless these are being designed and manufactured by Kinetics Noise Control, Kinetics can not comment on their suitability for a particular application. If Kinetics Noise Control does provide the interfacing support members, Kinetics can not guarantee the performance of the equipment structure. That must be by the equipment manufacturer. Kinetics can only certify that the interfacing support members meet the force requirements of the code in force for the project.

Problem No. 6 – Restraint of Tall, Narrow Floor/Roof Mounted Equipment:

Tall, narrow pieces of equipment are difficult to restrain, and all the more so if they are isolated. The restraint points at the floor or roof are relatively close together when compared to the elevation of the center of gravity, seismic loads, or the center of pressure, wind loads. This produces very large overturning moments which will require very large vertical forces at the restraint points. While restraints might be sized to properly resist these vertical loads, the frame of the equipment most likely has not been so designed.

There are several design schemes that can be employed to restrain equipment that is tall and narrow.

1. Restrain the equipment rigidly to a wall, and loosely at the base to keep the base from kicking out.

2. Fabricate a frame to which the equipment would be mounted, and adequately brace the equipment to the frame. The frame is used to spread the restraint points out reducing the vertical forces required to resist the overturning moment.

3. Attach the equipment to an inertia base to lower the center of gravity and spread the restraint points out.

4. Limit the lateral motion of the equipment with cable restraints. The cables should be attached to the equipment somewhere above the center of gravity/pressure, and anchored to the floor or roof.

Problem No. 7 – Adequate Attachment Locations on Equipment:

Frequently the equipment to be restrained does not have adequate attachment location possibilities. This can be due to a number of reasons.

1. The equipment base rails are inaccessible for attaching the required isolator/restraints.

2. The equipment base rails or attachment points are constructed from a material that is not compatible with galvanized or painted steel restraint components normally used. Some of these materials are aluminum and fiber reinforced plastics.

3. There are times when there are no base rails, and the restraints would need to be attached to the sheet metal panels of the equipment. This is undesirable because the panels were not designed to take concentrated loads, and the restraints may block access to maintenance doors and panels.

D3.4 – Distribution System Issues – Pipe, Duct, Conduit, and Cable Trays:

All of the following issues are covered fully in the **Kinetics Pipe & Duct Seismic Application Manual** which is available from www.kineticsnoise.com. Throughout the rest of this manual, the Kinetics Pipe & Duct Application Manual will be referred to as the Pipe & Duct Manual.

Problem No. 8 – Room for Restraints:

The most frequent issue relative to suspended distribution systems is that there is almost never enough room for running the seismic restraints from the suspended distribution components to the building structure. Most of this interference comes from adjacent distribution system components that have been installed by other trades. It is typical procedure for the distribution systems to be installed first, and then the seismic restraints for those systems are installed at a later date. During the intervening time other trades are installing their systems. By the time the restraints are to be installed there are many components in the way making it difficult if not impossible to properly install the seismic restraints. This issue is discussed in Sections I1.0 and I2.0 of the Pipe & Duct Manual.

It is sometimes necessary to be very creative with the restraints and their installation. Some of the various restraint schematics normally used for suspended distribution are found in Sections I3.0, I4.0, and I7.0 of the Pipe & Duct Manual.

Problem No. 9 – Mixing Cable and Strut Type Restraints:

It is important that cable type restraints and strut type restraints are not used on the same run of a suspended distribution system. It has to do with the way the two different types of restraints load the pipe, duct, conduit, or other distribution component. For example, if all of the restraints on a run were to be cable type restraints, and an interference issue required the use of a strut type restraint for one location, all of the restraints in that run would need to be changed to struts.

Problem No. 10 – Problems with Strut Type Restraints:

Cables are the preferred type of restraints. This is because they are small and easily routed past other components. ***Note: cable restraints must not touch any other component or the building structure along their path from the components being restrained and the attachment point to the structure.*** Also, cable restraints are preferred because they apply only compressive reaction loads to the hanger rods.

Strut type restraints, on the other hand, will induce tension reaction loads in the hangers in addition to the dead weight of the component. There are cases when the tensile reaction loads from the struts can equal or exceed the dead weight load of the component. If struts must be used for a particular run, the hangers and hanger attachments to the building must be reevaluated to see if they have enough capacity to carry the additional tension loads. Also, struts are more difficult to route past other components. See Section I7.0 of the Pipe & Duct Manual for additional information regarding the application of strut type restraints.

Problem No. 11 – Rod Stiffeners:

Rod stiffeners may be required for hanger rods that are small in diameter and/or relatively long. Also, they are more often required when the distribution components are supported by a trapeze bar. They are required only at the seismic restraint locations, and are used to carry the net compressive reaction loads from the seismic restraints to prevent the buckling of the hanger rod. Section I8.0 of the Pipe & Duct Manual will provide some guidance on when rod stiffeners may be required, and how to apply them. The actual sizing of the rod stiffeners is discussed in Section S8.0 of the Pipe & Duct Manual. There is also a web based tool on Kinetics' web site that will assist in determining whether rod stiffeners are required for a particular location, sizing the stiffener, and recommending the number of clamps required.

Problem No. 12 – Implementing the 12″ Rule:

The 12″ Rule is defined in Sections S4.0 and S12.0 of the Pipe & Duct Manual. Basically any pipe or duct that is suspended within 12 inches of the supporting structure, and is supported by non-moment generating, free swinging, hangers does not require seismic restraint provided that the pipe or duct can swing freely without striking another object or the building, and that any interfaces with equipment are designed to tolerate the expected motion. There are some issues that must be dealt with when trying to implement the 12″ Rule.

1. The trade(s) that are on site first have the best opportunity to implement the 12″ Rule. The best and most cost effective way to use the 12″ Rule is by plan. The MEP coordinator should decide which system will give the building owner the most benefit from utilizing the 12″ Rule, and then schedule that trade in to the job first making sure they follow the guidelines for implementing the 12″ Rule completely.

2. Each and every hanger location on a run must meet the requirements for the 12″ Rule or the entire run must be restrained.

3. Non-moment generating, free swinging, connections between the hangers and the structure must be used at each hanger location.

4. The distribution system components must be free to swing without contacting any other components or the building structure.

5. Interfaces, connections, with equipment must be designed to accommodate the expected relative motion between the pipe or duct and the equipment.

Problem No. 13 – Small Duct Exemptions:

The SMACNA Seismic Restraint Manual 2nd Edition[1] allows all ducts with a cross-sectional area of 6 ft^2 or less to be exempt regardless of the Component Importance Factor. The SMACNA Seismic Restraint Manual 3rd Edition[2] only allows this exemption for Duct with a Component Importance Factor of 1.0. 2000 IBC directly references the SMACNA Seismic Restraint Manual 2nd Edition, so the 6 ft^2 or less exemption will apply regardless of the Component Importance Factor. 2003 and 2006 IBC do not allow the 6 ft^2 or less exemption for duct whose Component Importance Factor is 1.5. However, 2009 and 2012 IBC will allow the 6 ft^2 or less exemption regardless of the Component Importance Factor.

Problem No. 14 – Restraint of Hot & Cold Pipes:

Pipes that undergo significant expansion or contraction from installation state to operational state present unique problems for seismic restraint designers and installers. Wherever a longitudinal restraint is placed, an anchor is created. If anchors already exist on a run of pipe, placing the longitudinal restraint anywhere but the anchor location will place the pipe in tension or compression which can be sever enough to either fail the pipe, or fail the restraints. How to handle hot and cold piping is discussed and illustrated in Sections S9.0 and I13.0 of the Pipe & Duct Manual.

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[1] SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 2nd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209; March, 1998.

[2] SMACNA; Seismic Restraint Manual – Guidelines for Mechanical Systems 3rd Edition; Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209; March, 2008.

CABLES vs. STRUTS IN SEISMIC RESTRAINT APPLICATIONS

Cable and strut restraints perform the same function in very different ways. Cable restraints are often called tension only braces. Because of their flexible nature, they can carry loads only in tension. So, for each direction being restrained, two cables are required located 180° apart. And, to completely restrain a component, four cables are required located 90° apart Struts, on the other hand, are referred to as rigid braces. They are capable of carrying both tension and compression loads. For each direction being restrained, only one strut is required. To completely restrain a component two struts spaced 90° apart are required.

Cables represent a more flexible and easily installed restraint system. Even though four cables are needed to fully restrain a component, it is generally easier to route the cables past any adjacent components to achieve a clear load path from the component to the building structure. Cables are light weight and can be easily cut to a proper length while at the restraint location. Struts, on the other hand, being rigid may prove difficult to route past other component. Also, struts are heavy and inflexible. Generally they must be cut on the ground, and perhaps more than one try may be required in certain instances.

When the equipment, pipe, or duct must be isolated, it is not good practice to use strut type restraints. The struts are rigid by definition which will “short circuit” the isolation. Cable type restraints are more flexible which will lead to better isolation performance.

Both types of restraints will place the hanger rod in compression. The cable restraints will ***only*** place the hanger rod on compression. The strut restraint will place the hanger rod in compression, and then in tension as the component being restrained tries to swing back and forth. This is a serious draw back of the strut type restraints. They can place additional tension loads on the hanger rod beyond the dead weight load of the component. Any hanger rod design and selection of its attachment to the structure must be sized to include the tensile reaction loads due to the design horizontal seismic force.

Occasionally, a component was designed to be restrained with cables, but an unforeseen interference required a strut type restraint to be used. In this case, the following practices ***must*** be used.

1. All restraints on this component must be changed to struts. If the component is a run of pipe, duct, conduit, or cable tray, all of the restraints on that run must be converted to struts. This is because they behave completely differently than the cables, and the reaction loads on the equipment and hangers are different.

2. All of the hanger rods and their attachments must be re-evaluated for the increased tensile loads due to the seismic reactions from the struts. If they are undersized, they must be changed. If the hanger rods are attached to concrete, the anchors used for the attachment must be prequalified per ACI 355.2 (ICC-AC193) for use in cracked concrete, and have an

ICC-ESR stating they are suitable for applications in Seismic Design Categories C, D, E, or F. This is because with the tensile component due to the struts, the hanger rod and its attachment are part of the seismic load path.

This is detailed more thoroughly in Sections S8.0 and I7.0 of the Pipe & Duct Manual.

ISOLATOR/RESTRAINTS – COMBINED OR SEPARATE

D3.3.1 – Introduction:

In the world of vibration isolation and seismic restraint for floor mounted equipment, there are two routes that may be taken.

1. **Combination Isolator/Restraints:** Where the restraint component is incorporated in the same housing as the isolation component.

2. **Separate Isolators and Restraints:** Where the restraint component and isolation component are self contained separate entities.

Whether combination isolator/restraints or separate isolators and restraints are to be used will depend on the application. For highly sensitive isolation applications, when the vibration consultant is concerned about the restraints shorting out the isolation, the isolators and restraints are installed as separate stand alone devices. However, when the application does not highly sensitive to occasional shorting of the isolation, the combined isolator/restraints will generally be the most cost effective. Normally, isolator/restraints require less floor space than the separate isolators and restraints, and they are usually more cost effective since they can be combined into a single package.

D3.3.2 – Combination Isolator/Restraints:

Combination isolator/restraints are devices that incorporate the vibration isolation function and the seismic/wind restraint function in one device. Kinetics Noise Control manufactures several types of these combination isolator/restraints. All of the combination isolator/restraints have three axis restraint capabilities.

1. **Model FHS:** This is a post type isolator with one spring coil, and one leveling bolt assembly. The leveling bolt assembly serves three purposes; levels the equipment, is part of the restraint, and is tapped for a bolt to attach the equipment to the isolator/restraint. The restraint is a three axis restraint. This product is detailed in Section P3.2.4 of this manual.

2. **Model FLS, FLSS, FTS, Titan:** These are plate type isolator/restraints with one or more spring coil sets and leveling bolts. The top plate of the isolator restraint is flat with through holes that will allow the equipment to be bolted or welded to the isolator/restraint. These devices are detailed in Sections P3.2.2, P3.2.1, and P3.2.3 of this manual respectively.

3. **Model FMS:** This is a hybrid isolator/restraint. It combines the best of both the isolator/restraints and the separate isolators and restraints. The restraint portion can be used by itself or in conjunction with a freestanding isolator. The freestanding isolator can be combined with the restraint as part of the assembly, or it can be completely separate from the **FMS** restraint. For more details for the **FMS** system, see Section P2 of this manual.

4. **Model KRMS:** This is a neoprene isolator/restraint. This type of isolator can be used for floor, walls, and ceiling mounted equipment because it is basically a zero clearance isolator/restraint, see Sections P4.1 and 4.2.1 of this manual.

5. **Model ESR, KSR, KSCR, HD-KSR, Kinetics Curb, MegaCurb:** These are roof curbs that incorporate isolators and restraints in the same package. The Model **ESR** has pedestals that operate as combined isolator/restraints, see Sections P6.1 and P6.2.1 of this manual. The Model **KSR** and **KSCR** have isolators and restraints that are separate, but that share the same supporting members, see Sections P6.1, P6.2.2, and P6.2.3 of this manual. The **Kinetics Curb** also has separate isolators and restraints, but is has zero clearance horizontal restraints, see Sections P6.1 and P6.2.4 of this manual. The HD-KSR is fitted with independent high capacity restraints in each corner and optional restraints on the sides, see Sections P6.1 and P6.2.5 of this manual. The MegaCurb is a High Wind/High Seismic structural steel curb fitted with modular spring/isolator elements, see Sections P6.1 and P6.2.6 of this manual.

D3.3.3 – Separate Isolators and Restraints:

When separate isolators and restraints are specified, the Kinetics Noise Control Model **FDS** isolator is used. This is a free standing coils spring isolator sitting on a neoprene high frequency barrier. The restraint devices normally used with the freestanding isolators are described below.

1. **Single Axis Snubbers – Model HS-1:** The **HS-1** snubber, restraint, only acts against a horizontal force in one direction. A piece of equipment would require at least one Model **HS-1** on each side to be fully restrained. This restraint ***does not*** accommodate any uplift load conditions. See Section P5.2.1 of this manual for a complete description of this product.

2. **Two Axis Snubbers – Model HS-2:** The **HS-2** snubber, restraint, acts against a horizontal force in any horizontal direction. A piece of equipment to be restrained using the **HS-2** would require at least two of these devices on opposite sides. This restraint also ***does not*** accommodate any uplift load conditions. See Section P5.2.2 of this manual for a complete description of the **HS-2**.

3. **Three Axis Snubbers – Model HS-5 and FMS:** Both of these snubbers, restraints, act against forces in any horizontal and vertical direction, and so may be used for uplift load conditions. See Section P5.2.3 of this manual for a complete description of the HS-5, and Section P2 of this manual for a description of the **FMS** product line.

ROOF MOUNTED EQUIPMENT APPLICATIONS

D3.7.1 – Introduction:

Mounting equipment to the roofs of buildings and other structures and properly restraining it against the design seismic and wind forces has always required special attention. The roof structure of most buildings contains the lightest and weakest structural components of the building. This is because it is at the top of the building and does not carry the dead weight loads that the lower levels of the structure do. Also, the roof structure may be designed to carry the dead weight load of the roof top equipment, but it is designed to carry it as a distributed load rather than line loads or point loads.

D3.7.2 – Point Loads from Isolator/Restraints:

Many times for isolated equipment, the dead weight loads are transferred to the roof structure as point loads. Almost always, the seismic restraint loads are transferred to the roof structure as point loads. This creates a problem for the design professional charged with designing the restraint for a piece of roof top equipment because the roof structure may not be sufficient to handle the point loads generated by the restraints.

Restraints can produce concentrated loads of several types.

1. **Horizontal Loads:** The horizontal loads produce localized shear of the roof structure, and concentrated loads at anchor and bolt holes.

2. **Vertical Loads:** The vertical loads can be either downward or upward. Downward reactions from the restrains would add to the dead weight load if combination isolator restraints were used. The vertical loads tend to put the structural members in bending.

3. **Moment Loads:** Due to the fact that the restraints have some structure to them, the horizontal seismic and wind loads are not applied to the surface of the structure. They are applied at some distance above the surface of the structure. This means that there will be a moment that must be resisted at the interface between the restraint and the structure. Depending on the type of structural elements that are used, this moment will be either a bending moment or a torsional moment.

It is critical, especially in lightweight and/or long span structures, that the structural engineer of record takes these expected point loads from the restraints and isolators into account when designing the building structure. Lack of proper coordination can lead to a building structure that is inadequate to resist the design seismic and wind loads prescribed by the code. This will leave the contractor and the design professional responsible for the restraint design holding the bag at the time the building is to be commissioned.

D3.7.3 – Main Structural Elements:

For large pieces of roof top equipment such as cooling towers, air handlers, and packaged roof top units, the main structural elements of the roof need to be placed beneath the equipment to give it proper support, and to transfer the restraint reactions due to the design seismic and wind loads. Failure to do so can leave a significant portion of the equipment load cantilevered out over unsupported roof deck; which can lead to failure of the deck and a loss of roof integrity.

When the large piece of equipment is to be isolated, it important for the supporting roof structure to be stiff enough to not only support the equipment, but also to allow the equipment isolation to properly adjusted. In cases where the roof structure is not stiff enough, the when the adjusting screws of the isolators are turned down to increase the load on the springs and lift the equipment, the isolators will push the roof structure down rather than lifting the equipment. Here the isolation has been rendered useless. Also, this situation can lean to a failure of the roof deck and a loss of roof integrity. This is most often a problem when the roof structure is of lightweight and/or long span construction.

D3.7.4 – Concrete Roof Decks, Housekeeping Pads, Curbs, & Piers:

Due to the nature of roof structures there is an increasing desire to use lightweight concrete poured over a metal deck for the roof. This presents several serious problems.

1. Not all concrete anchors that have been prequalified per ACI 355.2 are rated for use in lightweight concrete.
2. The design strength of lightweight concrete is significantly less than normal-weight concrete of the same compressive strength.
3. Typically the concrete thickness is insufficient to generate the full rated strength of the anchors that are to be used.
4. The lightweight concrete deck is for all intents and purposes un-reinforced and not necessarily well bonded to the metal decking that supports it. Therefore, the probability of breaking pieces out of the roof deck during a severe seismic or wind event is very real.

The anchorage of large pieces of roof top equipment can not be an afterthought. If the roof deck is to be concrete, either concrete of the proper type, strength, and thickness must be provided to resist the design seismic and wind forces, or a steel structure penetrating the concrete and attaching directly to the structural steel of the building must be provided. Both of these options involve the efforts of the structural engineer of record in conjunction with the engineer of record for the piece of equipment that is to be attached to the roof.

If however, the concrete deck is not adequate to carry the required seismic and wind loads through the use of post installed anchors, the only viable option may be through bolting the isolator/restraints to the roof deck. This involves drilling through the concrete deck then using bolts, nuts, and large washer plates on the underside of the deck to distribute the load.

Large penetrations in a concrete roof deck must be treated with special care. There must be enough distance from the inner most anchors of the roof curbs or the base plates of the isolator/restraints to the edge of the penetration to allow the full rated capacity of the specified anchors to be developed. As much as is practical, should be kept away from the interior edge of the roof curbs or the base plates of the isolator/ restraints by at least 12 inches.

Occasionally, concrete housekeeping pads are used for roof top equipment. These concrete housekeeping pads on the roof must be;

1. Doweled to the roof structure or a continuous pour with the roof structure.
2. Normal-weight concrete of minimum 3,000 psi compressive strength.
3. Steel reinforced to resist the design seismic and wind reaction loads applied to it.
4. Thick enough to accept the embedment for the required anchors.

Concrete curbs and piers pose special issues all their own. Normally the curbs and piers have already been poured before the isolator/restraints have been selected. This means that there is a strong probability that the tops of the curbs and piers do not match the width of the isolator/restraint base plate, nor will they allow enough edge distance for the concrete anchors to generate their full rated capacity rendering the restraint system to be inadequate. In such cases special steel “caps” will need to be provided that extend far enough over the sides of the curb or pier to allow proper anchorage to be developed. The isolator/restraints are then welded to the steel “caps”. Alternately, the structural engineer of record can design the anchorage of the isolator/restraints to the curb or pier.

D3.7.5 – Metal Roof Decking:

Attaching restraint bearing roof curbs and isolator/restraints directly to metal roof decking is not generally a good idea. The only exceptions would be if the equipment along with the design seismic and wind forces were small. Then, the proper number of fasteners would be required to attach the curbs or isolator/restraints to the metal deck so that failure of an individual fastener is not likely. Also, the structural engineer of record will need to make sure that the sheets of metal decking are properly attached to the building structural steel and to each other to resist the additional seismic and wind loads that would be imposed by the equipment through the curb or isolator/restraints.

For larger pieces of equipment and/or higher design seismic and wind loads the curb and isolator/restraint connection should be made directly to the building structural steel supporting the metal roof decking. This will alleviate the problems associated with the metal deck not being stiff enough to carry the seismic and wind loads to the building structure.

D3.7.6 – Isolated Roof Top Equipment & Isolation Performance:

The restraints in most roof curbs and other isolator/restraint devices have a certain amount of built in clearance that allows for placement errors and free vertical movement of the spring support equipment. The only isolator/restraint devices that do not have this built in clearance are the Model KSR, KSCR, Kinetics Curb, and KRMS. In roof top applications, the isolator/restraints with built in clearance have the problem of having partially shorted out isolation when the wind blows. The wind will cause the equipment to move sideways and engage the horizontal restraints. Even a relatively light wind can bring the restraints into engagement. So, a periodic loss of isolation efficiency for isolated roof top equipment must be expected.

Roof top equipment that is exposed in any fashion to the wind will require restraint. Even equipment that is surrounded barrier walls will need restraint because the enclosure is open at the top and exposed to the effects of the wind. This is a code driven requirement that is explained in Section D2.2.2 of this manual. This means that all isolated roof top equipment will suffer some deterioration in isolation efficiency when the wind blows.