Seismic Forces Acting on Ductwork

When subjected to an earthquake, ductwork must resist lateral and axial buckling forces, and the restraint components for these systems must resist pullout and localized structural failures.

Most duct systems are suspended from the deck above on either fixed or isolated hanger rod systems. While ducts are normally supported singly, there may occasionally be multiple ducts attached to a common trapeze. On some occasions ducts may run vertically or may be mounted to the floor.

Suspended Systems

Most codes do not require that ductwork supported on non-moment generating (swiveling) hanger rods 12 in or less in length be restrained. This length was determined based on the natural frequency of systems supported on the short hanger rods. In practice, it has been found that the vibrations generated by earthquakes do not excite these types of systems and, although the ducts may move back and forth somewhat as a result of an earthquake, they do not tend to oscillate severely and tear themselves apart.

There are also exclusions in most codes for small ducts (under 6 square ft in area), no matter what the hanger rod length. Again, this exclusion is based on the post-earthquake review of many installations. It has been found that smaller ducts are light and flexible enough that they cannot generate enough energy to do significant damage to themselves.

For cases where restraints are required, however, the forces involved can be significant. This is due to the difference between the required spacing of ductwork supports and restraints. Supports for ductwork will normally carry the weight of approximately 10 ft of duct (in the case of trapezes, this could be multiple ducts, but the length is still held to approx 10 ft). Seismic restraints, on the other hand, are normally spaced considerably further apart, with the spacing varying by restraint type, restraint capacity, duct size, and the seismic design load. It is very important to be aware of the impact of the difference in spacing, as the wider this spacing, the larger the seismic load when compared to the support load. Guidance in determining restraint spacing requirements is available in Chapter D4 of this manual.

To illustrate this difference, consider a simple example of a 54 x 60 inch duct weighing about 50 lb/ft being restrained against a 0.2g seismic force. Assume the axial restraints are located on 80 ft centers (the max permitted) and supports are located on 10 ft centers. The load that is applied to the hanger rods by the weight of the duct is 50 lb/ft x 10 ft or 250 lb each (assuming two support rods). The horizontal load that occurs at the restraint locations is the total restrained weight (50 lb/ft x 80 ft = 4000 lb) multiplied by the seismic force (0.2g) or 800 lb. Thus the seismic load is considerably larger than the vertical dead load.

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Restraints for suspended systems are normally in the form of cables or struts that run from the duct up to the deck at an angle. Because of the angle, horizontal seismic loads also generate vertical forces that must be resisted. Therefore, restraint devices must be attached at support locations so that there is a vertical force-resisting member available.

As the angle becomes steeper (the restraint member becomes more vertical), the vertical forces increase. At 45 degrees the vertical force equals the horizontal force and at 60 degrees the vertical force is 1.73 times the horizontal force.

The net result is that for cable systems or for struts loaded in tension, the uplift force at the bottom end of the restraint can be considerably higher than the downward weight load of the duct. Returning to our example, assume that we have a restraint member installed at a 60 degree angle from horizontal and that the lateral force will load it in tension. In this case, the 800 lb seismic force generates an uplift force of 1.73 x 800 lb or 1384 lb. This is 1134 lb more than the support load and, depending upon the support rod length and stiffness, can cause the support rod to buckle. Rod stiffeners are used to protect against this condition and sizing information is available in Chapter D4 of this manual.

Unlike cables, if struts are used for restraint they can also be loaded in compression. In the example above, if the strut were loaded in compression the 1384 lb load would be added to the support load (trying to pry the hanger rod out of the deck). The total support capacity required would be 1384 lb + 250 lb or 1634 lb. As a consequence, when using struts, the hanger rod must be designed to support 1634 lb instead of the 250 lb maximum generated with cables. Hanger rod sizing information is also available in Chapter D4 of this manual.

Riser Systems

Where ductwork runs through the structure vertically, except for the loads directly applied by vertical seismic load components identified in the code, there will be little variation in vertical forces from the static condition. Lateral loads are normally addressed by support brackets and the spacing between brackets is not to exceed the maximum tabulated lateral restraint spacing indicated in the design tables in Chapter D4.

Floor-Mounted Systems

The primary difference between floor- and ceiling-mounted duct systems is that the support loads in the duct support structure are in compression instead of tension (as in the hanger rods). Although a support column and diagonal cables can be used, a fixed stand made of angle or strut is generally preferred. Rules relating to restraint spacing and the sizing information for diagonal struts are the same as for hanging applications.

However, the support legs need to be designed to support the combined weight and

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vertical seismic load (for a two-legged stand and the example above, the supported weight is again 500 lb / 2. Thus the total load the supports must be designed to is 250 lb + 1384 lb or 1634 lb) in compression. The anchorage for the legs needs to be able to withstand the difference between the dead weight and the vertical seismic load (in the example above 1384 lb - 250 lb or 1134 lb).

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