Extreme Torsional Irregularity

By Jerod G. Johnson, Ph.D., S.E.

Extreme torsional irregularity is something that can greatly limit and restrict flexibility in choosing seismic force-resisting systems and configurations.

Among categorizations of seismic behavior that have been adopted in modern codes is *extreme torsional irregularity*. Torsional irregularity is not an unfamiliar concept, having been expressed in codes in various forms for decades. It is an issue that engineers have learned to deal with, particularly in seismically active areas. Extreme torsional irregularity, however, is a somewhat newer concept and subset within the larger issue of torsional behavior. It is something that can greatly limit and restrict flexibility in choosing seismic force-resisting systems and configurations.

Recent codes have defined torsional irregularity as the condition where the maximum story drift, including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure. A little pencil work will show this means that if one end of a rectangular structure drifts more than 1.5 times the other end, torsional irregularity is said to exist. For the newer category of extreme torsional irregularity, the calculation steps are fundamentally the same, but this designation is assigned to structures where the maximum story drift, including accidental torsion, at one end of the structure transverse to an axis is more than 1.4 times the average of the story drifts at the two ends of the structure. Again, in simple terms, this means that if one end of a rectangular structure drifts in excess of 2.33 times the other end, extreme torsional irregularity is said to exist.

What difference does this make in design? Today's sophisticated analysis software is capable of handling any degree of torsion. As far as basic analysis goes, there is fundamentally no difference between "regular" torsional irregularity and extreme torsional irregularity. The major difference is found in structures assigned to Seismic Design Category (SDC) E or F. To put it simply, section 12.3.3 of ASCE 7-10 states that structures assigned to SDC E or F having horizontal irregularity Type 1b of Table 12.3-1 (extreme torsional irregularity) "shall not be permitted". In other words, any structure assigned to SDC E or F *is not allowed* to have extreme torsional irregularity, and thus the design must be changed accordingly. Assignment of SDC E or F occurs for structures with long-period spectral accelerations (S_1) of 0.75g or greater. This pertains to a great many sites in heavily populated regions of moderate to high seismicity. Under the current code, designers of projects within these areas must be aware of the extreme torsional irregularity issue and design buildings accordingly.

Recent changes to long-period spectral accelerations resulted in diminished values for many regions across the country. This made a tremendous impact on seismic design in regions of moderate to high seismicity, which were plagued with a 0.75g "trigger boundary" for S_1. For a time, this code provision meant limitations on permissible behaviors regarding the torsional issue as mentioned previously. Engineers had less latitude and were forced to help clients understand the limitations of geometries that were once compliant, but had become problematic because of issues such as torsion.

In the ever-evolving field of seismic design, only time will tell what direction future spectral acceleration maps will go. Those designing structures in regions where the long-period spectral acceleration response is near 0.75g should maintain a keen awareness of changes to these criteria, as this issue holds major implications, including the assignment of the SDC and associated limitations regarding certain irregularities.

An issue of discussion that many engineers have raised regarding the classification of torsional irregularity is the fact that the methodology does not address the magnitude of relative story drifts. Using values derived from the fundamental rectangular model mentioned previously, if one end of a rectangular structure drifts 0.8 inches and the other end drifts 1.2 inches, the average drift is 1.0 inch, and since the maximum drift is at least 1.2 times the average drift, the structure is said to have torsional irregularity. For the same model, if one end of the structure drifts 0.6 inches and the other end drifts 1.4 inches, the average again is 1.0 inch, but the structure is now said to have extreme torsional irregularity since the maximum drift is at least 1.4 times the average.

Next, consider a similar structure with a lateral force-resisting system consisting of concrete shear walls. Perhaps the drifts are 0.08 inches at one end and 0.12 inches at the other end, for an average of 0.10 inches. Although the deflections are miniscule, the structure is nonetheless classified has having torsional irregularity. Likewise, for drifts of 0.06 inches at one end and 0.14 inches at the other, the maximum drift divided by the average is 1.4 and the structure has an extreme torsional irregularity, forbidden for SDC E or F. Thus story drifts may be almost immeasurably small, yet the irregularities are still said to exist.

Granted, torsional irregularity is meant to reflect a broad behavioral issue encompassing not only drift, but distribution of forces. In this case, magnitudes of forces and baseline strengths of systems may be the controlling design concern, relegating drifts to the "non-governing" category. However, magnitudes of drifts play a major role in the serviceability of nonstructural systems, and stability assessment of both structural and nonstructural systems. Clearly, smaller drifts carry reduced consequences, and larger drifts carry increased consequences.▪

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