"Understanding Wind Loading and Serviceability"

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Architects and owners typically prefer moment frame systems as they provide more "openness" and flexibility than a braced frame or shear wall system. Although vertical bracing may be accommodated in an initial floor layout, the owner is now "locked-in" with these wall locations and limited in future programming options. So why aren't moment frames used more frequently? One of the main reasons I hear from engineers is that it's "too difficult to control the drift", and the structural steel becomes heavier and more expensive. It is true that, rather than being governed by strength design, most moment frame buildings are governed by limits on either overall building drift (top story vs. ground) or differential interstory drifts. But where do these drift limits come from? For seismic loading, ASCE 7 specifies *inelastic* drift limits based on the building occupancy and lateral system used, but there are no specific code provisions for drift limits under wind loads. This is a serviceability issue rather than a strength design issue and will depend on the type of interior and exterior finishes. We often hear "H/400", but where does that come from and what does it mean?

It is important to understand that the code provisions were developed using statistics and risk over different return intervals, rather than specifying a building be designed to withstand certain wind speeds. The following is generally relevant to non-hurricane wind levels.

ASCE 7-05

- Wind loads (W) in Chapter 2 load combinations have a 1.0 factor for Allowable Stress and a 1.6 factor for Strength Design.
- Wind speed maps in Chapter 6 are based on "design-level" forces with a 50-year **mean recurrence interval (MRI)**, so the annual probability of exceedance=0.02.
- Importance factors (I) are used to extend the MRI on certain buildings (i.e., using I=1.15 adjusts the design-level wind velocity to be a MRI of 100 years, rather than the typical 50 years). The thinking is that these facilities should have additional capacity for the higher winds that could be anticipated when considering an extended time interval.
- Note that, because Importance Factors extend the MRI, it is overly conservative to include them in serviceability checks, which are more frequent, short-term loading events.
- Commentary C6.5.5 Importance Factor (p. 286) discusses this further, and Table C6-7 (p. 318) gives conversion factors for different MRIs.
- Part of the industry confusion on this may be related to the fact that the Commentary for "Appendix C, Serviceability Considerations" was not included in the original printed version of ASCE 7-05 (the "Errata" page can be found here: http://www.asce.org/uploadedFiles/Codes_and_Standards_-_New/erratasheet7-05.pdf). Section CC.1.2 discusses drift due to wind effects and states "*Use of the factored wind load in checking serviceability is excessively conservative.*" For wind serviceability checks, which again are short-term loadings, the Commentary recommends a load combination of D + 0.5L + 0.7W, and this has an annual probability of exceedance of 0.05. (Interestingly, this would be a 20-year MRI and doesn't seem to match the conversion factors in Table C6-7, but the point is that this is a judgment call.)

Example: the 90 mph wind covering most of the country (which is a 50-year "design-level" wind) has a corresponding 10-year wind of 76 mph (=90 mph * 0.84 factor in Table C6-7). Because velocity pressure is a function of wind speed squared (Eq. 6-15), the 10-year velocity pressure is 0.7 times the 50-year velocity pressure (76^2/90^2=0.713). When using software like RAM Structural System and checking H/400 (0.0025) interstory drift at a 10-year MRI, the design-level wind speeds (50-yr) can be used for analysis and design, but the allowable drift could be checked to meet H/280 (=H/(400*0.7)). This allows you to check *design* at the 50-year winds and *serviceability* at the 10-year winds without having to add more Load Cases.

ASCE 7-10

- Wind loads (W) in Chapter 2 load combinations now have a 0.6 factor for Allowable Stress and a 1.0 factor for Strength Design (vs. 1.0 and 1.6, respectively, in ASCE 7-05).
- Occupancy Category is now called "Risk Category".
- Wind speed maps are now "ultimate" and were revised to more closely align with MRIs on seismic maps for consistency in load combinations, etc. Wind speed maps are now provided for different Risk Categories, with Category II buildings now at a 700-year MRI and Category III and IV buildings at a 1,700-year MRI. The importance factor (I) has been eliminated because the maps themselves now consider the extended MRI for higher Risk Categories (as discussed above).
- Having a longer return period means the wind speeds are higher and the initial calculated wind forces are larger, but the reduced load factors in Chapter 2 bring the design forces back down to closely match the ASCE 7-05 results in most cases (hurricane areas can be an exception).
- Commentary CC.1.2 says that the 700-year or 1,700-year MRI winds are "*excessively conservative*" for serviceability considerations, and it recommends a serviceability load combination of D + 0.5L + W_a. W_a is defined as the "*wind load based on serviceability wind speed in Figs. CC-1 through CC-4.*" The Commentary then provides a different set of wind speed maps for serviceability checks. For the majority of the country, Figure CC-1 shows the 10-year MRI wind speed as 76 mph, Figure CC-3 shows the 50-year MRI wind speed as 90 mph…both of which are the same as ASCE 7-05 noted above.
- Similar to the above ASCE 7-05 Example, when using RAM Structural System a conversion factor can be determined for scaling the drifts calculated at ultimate wind speeds (for design) to a wind speed for serviceability. To check H/400 (0.0025) interstory drift ratio for 10-yr serviceability (76 mph wind), the 700-yr ultimate (115 mph wind) drifts could be taken up to H/175 or 0.0057 (H/(400 x $76^2/115^2$)). Or you may find it easier to simply create a new wind Load Case with the 10-year wind speed specified.

AISC Design Guide 3

AISC Design Guide 3 "Serviceability Design Considerations for Steel Buildings" provides further justification for the approach of using shorter MRIs for serviceability:

Chapter 4, p. 15 (Cladding): "*For the evaluation of frame drift, ten-year recurrence interval winds are recommended due to the non-catastrophic nature of serviceability issues and because of the need to provide a standard consistent with day-to-day behavior and average perceptions. The 50-year recurrence interval winds that strength design wind loads are based upon are special events. In lieu of using the precision of a map with ten-year wind speed isobars, the authors recommend using 75 percent of 50-year wind pressure as a reasonable (plus or minus 5 percent) approximation of the ten-year wind pressures. The Commentary to Appendix B of ASCE 7-02 recommends 70 percent.*"

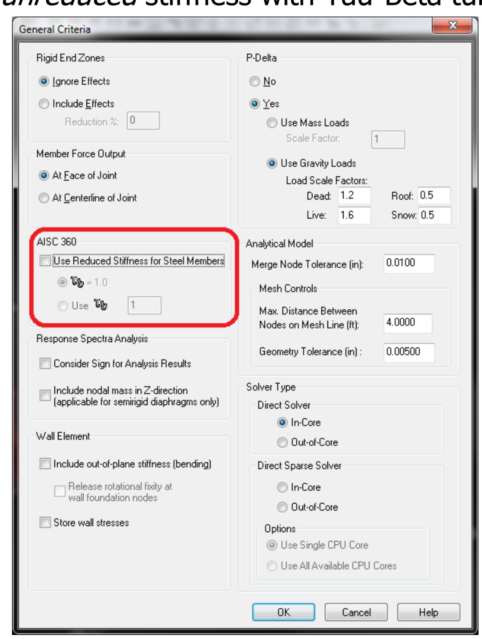
Chapter 5, p. 24 (Interiors): "*There is also a concern for partition racking induced by interstory drift. One published source gives drift indices (deflection divided by height) of 0.0025 (1/400) for "first distress" and 0.006 (1/167) for ultimate behavior for drywall on studs…*"

General guidelines: "*For lateral load: Story height (H) divided by 500 for loads associated with a ten-year wind for interstory drift using the bare frame stiffness*".

<u>SUMMARY</u>: When checking drift/serviceability, the use of design-level or ultimate-level wind loads at 50-year, 700-year, or 1700-year MRIs is typically excessively conservative and almost always unnecessary. The lower wind speeds at 10-year or 25-year MRIs are reasonable for nearly all cases and recommended by the AISC guidelines, as well as in ASCE 7.

MISCELLANEOUS:

- AISC 360-05 introduced some new checks on stability, including a Tau-Beta factor which reduces column stiffness to account for mill tolerances and residual stresses. Drifts are typically checked using the *unreduced* stiffness with Tau-Beta turned off. From RAM Frame:



Only member strength checks are to be done with Tau-Beta turned on.

- The wind Load Case by itself can typically be used when doing drift checks, rather than the Load Combination that also considers dead and live loads. The reason is that the vertical loads don't often have much effect on the drift anyway, so it's easier to check with just a single Load Case. If desired, this can be verified in RAM Frame by selecting "Load Combinations" from the drop-down and comparing the results to a "Load Cases" analysis.