In the Beginning

The Origins of the One-Third Stress Increase

By Charles J. Carter, P.E., S.E.

Current ASCE 7 provisions have significantly altered the familiar "one-third stress increase" —but where did it come from in the first place?

An article by Keith Mueller and Charlie Carter in the October 2003 issue of *Modern Steel Construction* magazine titled "The One-Third Stress Increase: Where Is It Now?" has renewed interest in the history of this topic. The article focused on what is and is not permissible in ASCE 7, as well as the various current and recent major model-building codes in the U.S. It did not, however, attempt to address the history of the one-third stress increase or the rationale behind it in any great detail. Fortunately, these aspects are well covered in a paper published in the 4th Quarter 1977 AISC *Engineering Journal*. The paper, by Duane Ellifritt, entitled "The Mysterious One-Third Stress Increase," is paraphrased in abbreviated form in this article. The full paper is available at **www.aisc.org/epubs**.

What was it for?

Ellifritt wrote about the confusion that stirs over the one-third stress increase and exactly for what types of conditions it is supposed to account. Some believe it represents a low probability that maximum live load and maximum wind load would ever occur simultaneously and apply it as a four-thirds factor on the strength side. Others believe it is to account for wind load phenomena that reduce the actual load used in design and apply it as a three-quarter load reduction. Although these operations appear to accomplish the same thing, Ellifritt contends that the three-quarter factor is not the inverse of the four-thirds factor—that is—the allowable stress increase for wind is not the same as the probability factor when accounting for simultaneous application of maximum live load and maximum wind load.

The Survey Says …

Ellifritt surveyed colleagues and determined a great many of them used the one-third increase merely because AISC permitted it. Most other replies fell into one of three categories:

1. The action of wind on a structure is highly localized and of very short duration. Therefore, it is not necessary to have as high a safety factor when designing for wind loads.
2. The properties of some materials change with the rate of loading. Steel, when loaded rapidly, will show higher yield strength than when it is loaded slowly. The one-third stress increase merely reflects the increase in properties due to rapid loading and does not diminish the safety factor.
3. The one-third stress increase reflects the low probability of maximum live and wind loads occurring simultaneously. Therefore, when checking D + W only, it should not be used.

From the Literature

Many references included some coverage of this principle (see the original paper for the full bibliography of references below):

- ➜ The oldest reference, found in Theodore Cooper's 1896 *General Specifications for Steel Railroad Bridges and Viaducts*, permitted a ¼ increase but gave no reason for this measurement.
- ➜ A.J. DuBois's article entitled "The Stresses in Framed Structures" (also in 1896) recommended an allowable stress for beams of 10,000 psi and an allowable for lateral bracing of 15,000 psi. Although no statement is made regarding the reason for a higher allowable stress for bracing, it could be interpreted as a 50% increase because of wind forces.
- ➜ Milo Ketchum, in his 1903 *General Specifications for Mill Buildings*, said: "When combined direct and flexural stress due to wind is considered, add 25% to the above allowable tensile and compressive stresses." Like Cooper, he does not offer any explanation as to why this should be permitted.
- ➜ The New York City Building Code of 1904 contained this statement: "In calculations for wind bracing the working stresses set forth in this code may be increased by 50%." Again, no reason is given.
- ➜ In 1923, AISC published its first specification. In it were these words: "*Combined Stresses*—For combined stresses due to wind and other loads, the permissible working stress may be increased 33%, provided the section thus found is not less than that required by the dead and live loads alone. *Members Carrying Wind Only*—For members carrying wind stresses only, the permissible wind stresses may be increased 33%." This provision in AISC's specification remained

virtually unchanged for 51 years, except for the inclusion of seismic stresses.

Supplement No. 3 added a qualifying paragraph in 1974: "and provided that stresses are not otherwise* required to be calculated on the basis of reduction factors applied to design loads in combinations." The footnote read: "*For example, see ANSI A58.1, Section 4.2."

➜ Robins Fleming wrote a comprehensive text in 1930 on wind stresses in buildings. He put forth the first logical explanation of the mysterious increase that Ellifritt was able to find: "*Because wind loads are intermittent and seldom reach their maximum*, greater working stresses are permissible for them than for live and dead loads."

He continued, "This is recognized generally by engineers and has found a place in most building codes. In the New York City code, where at present (1929) a working stress of 16,000 psi is specified for tension in rolled steel, an excess of 50% of stresses prescribed elsewhere in the code is allowed for combined wind, dead, and live loads, provided that the sections thus found are not less than those required by the dead and live loads alone. In Chicago, where 18,000 psi is the basic unit stress for tension, an excess of 33% is allowed for combined stress, thus permitting in both New York and Chicago a working stress of 24,000-psi tension for combined loads. This same unit stress is followed in the code recommended by the National Board of Fire Underwriters. The *Recommended Building Code Requirements for Working Stresses in Building Materials*, 1926, of the U.S. Bureau of Standards, favor an increase of 25% based on 18,000 psi in tension."

After listing the requirements of several codes, Fleming recommended the use of 24,000-psi tension on the net section for "stresses due to wind loads combined with live and dead loads, or for members taking wind stress alone."

In 1940, an ASCE subcommittee produced a report entitled *Wind Bracing in Steel Buildings*. The report created the first departure from the all-inclusiveness of the one-third stress increase and possible support for answer no. 3 (previous page).

"For members or details subject to wind stress only, except rivets and bolts, the permissible stress should be the same as that allowed for dead load or for dead and live load. For members subjected to stresses arising from the combined similar action of wind and other loads, and for rivets and bolts subject to wind stress, the wind stress up to 33% of the other stresses may be neglected, the excess wind stress being considered as equivalent to an added live load stress, provision being made for it at the basic working stress for dead load and live load only." Note that rivets and bolts were permitted a stress increase for wind only.

➜ In 1947, the American Iron and Steel Institute published the first edition of the *Light Gage Cold-Formed Steel Design Manual*. The pertinent provisions followed the AISC specifications in permitting a one-third increase for combined stresses and for "wind or earthquake only."

➜ A quartet of British authors stated that a 25% increase is allowed and made a good argument for answer no. 1 (previous page): "By Clause 25, the normal permissible stresses in the members may be increased by 25% in cases where such increases are due solely to the stresses induced by wind.

This higher working stress is allowed because of the transient nature of the load and also because the structure is of a sufficiently elastic nature, which allows it to absorb such transient loads without permanent defects."

➜ In a more recent publication, this insight was offered by Angus McDonald in *Wind Loading on Buildings* (1975): "It should be noted that a very high wind load is a comparatively rare occurrence and that the design wind speeds specified in most codes of practice may never actually occur in the life of a structure. For this reason, most structural codes allow a 25% (sometimes as much as 33%) increase in permissible stress for wind loadings."

➜ More evidence for answer no. 1 (the "transient nature" of wind) is found in the *Building Construction Handbook*, chapter six, by H. Stetina (1975): "For wind or earthquake forces, acting alone or in combination with the design live and dead loads, allowable stresses may be increased one-third. The increase is allowed because wind and seismic forces are of short duration."

➜ This position was also supported by Jack C. McCormac's *Structural Steel Design* (1971): "The maximum wind and earthquake pressures for which design is made occur at large intervals of time and then last for only relatively short periods of time. It, therefore, seems reasonable to use higher allowable stresses, such as the one-third AISC increase, for lateral forces than for the relatively long-term gravity live loads."

➜ A dissenting opinion is was offered in a 1972 excerpt from *Structural Engineering*,Vol. 1, by R.N. White, P. Gergely and R.G. Sexsmith: "In recognition of the highly unlikely occurrence of maximum wind or earthquake loads simultaneously with the full value of other live loads, codes generally allow a 33% increase in allowable stresses under these load combinations."

Conclusions

Ellifritt wrote that the preponderance of literature on the subject supports answer no. 1—the one-third stress increase is allowed because of the "transient nature" of wind; because wind loads "are intermittent and seldom reach their maximum;" because a very high wind load is "a comparatively rare occurrence" and "may never actually occur;" and because wind forces are of "short duration." There was no support for answer no. 2 (rate of loading), and only two references to support answer no. 3 (simultaneous occurrence). [Author's note: It is interesting to find that ASCE 7-02 Commentary Section C2.4.1 statements about the 0.75 load factor indicate that it is essentially the same concept as the one-third stress increase and that it is primarily intended to address simultaneous occurrence.]

Ellifritt continued that the one-third stress increase is rooted deeply in our engineering tradition, during a time when wind loads were not so well understood; that modern methods of applying wind loads account for some of the factors used to rationalize the stress increase, such as "short duration" and "rare occurrence." Modern wind codes are based on better meteorological information and wind tunnels, which accurately model the boundary layer. A "rare occurrence" in wind velocity is now programmed into the design pressure selection process in the form of a Mean Recurrence Interval Map. The "short duration" aspect is now accounted for by gust factors.

Is the one-third stress increase appropriate for design today?

Ellifritt said yes, with the following reasoning: The gust factor as defined in ANSI A58.1 (the precursor to ASCE 7 and current load standard at the time of Ellifritt's writing) represents anywhere from a 30% to a 120% increase in the basic pressure. The increase, of course, depends on the exposure type. If wind loads are increased by 30% and the stress increase disallowed, the net effect is a load that is increased by 70%.

Modern wind codes may have higher loads than previously used on some parts of a structure (such as corners, eaves, and ridges), but they may also have lower loads on other parts. The resultant should be about the same total load as we have always used. However, it should be distributed differently and more properly suited to location. On this basis, Ellifritt wrote that there is no valid reason why modern wind standards with gust factors, mean recurrence intervals, and peak coefficients should not continue to permit the designer to use the one-third stress increase.

The reasoning in Ellifritt's 1977 paper seems to contend that the one-third stress increase should remain valid today, even with the latest refinements to ASCE 7. However, as outlined in the *MSC* article by Keith Mueller and Charlie Carter, changes in ASCE 7 itself, as well as in the model building codes, have significantly limited the traditional applications of the one-third stress increase. ★

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