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The One-Third Stress Increase:

Where is it now?

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ASCE/SEI standards no longer permit the familiar one-third stress increase in allowable stress design. In practical terms, what does this mean for designers?

The one-third stress increase has a long history of use in Allowable Stress Design (ASD). It is most commonly used to account for the improbability of two transient loads concurrently acting at their maximum lifetime values–for example, will the design earthquake really occur at the same time as the design snowstorm? Recent changes in the load standard ASCE 7 (*Minimum Design Loads for Buildings and Other Structures*) restrict the use of the one-third increase, and accordingly, the AISC *ASD Specification* has been modified for consistency in *Supplement No. 1 to the Specification for Structural Steel Buildings: Allowable Stress Design and Plastic Design*, available as a free download from www.aisc.org/freedownloads.

This article provides a summary of current provisions in the AISC *Specification*, ASCE 7 and the model building codes with respect to the one-third stress increase. The increase is often applied as a reciprocal ¾ reduction factor on the load side of the equation, so for simplicity and uniformity, this reciprocal format is used. Coverage is included of provisions from ASCE 7-93, ASCE 7-95, ASCE 7-98, SEI/ASCE 7-02, the 2000 *International Building Code* (IBC), the 2003 *IBC*, the 1999 *National Building Code* (BOCA), the 1999 *Standard Building Code*, the 1997 *Uniform Building Code* (UBC), and the 2003 *NFPA 5000*. For each source, the load combination information is located and summarized, and the limits of the application of the one-third stress increase are discussed.

Engineering judgment is necessary to determine load combinations that potentially cause unfavorable effects, as the given load combinations are not meant to be all-inclusive.

The following loads are shown in the load combinations given in this paper:

D	Dead load
L	Live load
L_r	Roof live load
S	Snow load
R	Rain load
W	Wind load
E	Earthquake load

Other loads that might need to be considered are F (fluid load), H (earth load), P (ponding load), T (self-straining force), and F_a (nominal flood load). For simplicity, these loads are shown only in the combinations when they appear in the corresponding standard or code.

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Producers of three of the model building codes (Southern Building Code Congress International, *Standard Building Code*; International Conference of Building Officials, *Uniform Building Code*; Building Officials and Code Administrators, *National Building Code*) have joined together to form the International Code Council (ICC). The ICC produces the *International Building Code*, a code intended to replace the other three model building codes.

Shortly thereafter, the National Fire Protection Association created its own building code, the *NFPA 5000*.

CONCLUSIONS

Code-specified ASD load combinations today provide for the proper amplification of loads, with one transient load at its maximum lifetime value and other transient load(s) reduced to their arbitrary point-in-time value(s). This accomplishes what the one-third stress increase used to accomplish on the material-strength side of the equation. Consequently, the one-third stress increase usually is inappropriate for use with current ASD load combinations. Engineers that "double-dip," i.e., use both the one-third stress increase on the material side and reduced ASD load combinations, are violating the code in an unconservative way.

The summary provides a look at the majority of current model building codes and how the one-third stress increase is or is not appropriately used.

As the load standard upon which most current (and all future) model building codes are based, SEI/ASCE 7-02 best summarizes the current use of ASD load combinations and the one-third stress increase. The reader is encouraged to become familiar with this document. ★

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ASCE 7-93

Applicable Sections in ASCE 7-93
2.3.1, 2.3.2, 2.3.3, and A9.10.2.1

Load Combinations in ASCE 7-93
Section 2.3.1 gives the following basic loading combinations:

1. D
2. $D + L + (L_r \text{ or } S \text{ or } R)$
3. $D + (W \text{ or } E)$
4. $D + L + (L_r \text{ or } S \text{ or } R) + (W \text{ or } E)$

Section 2.3.2 states that the effects of F, H, P, or T shall be considered in design.

Load Combination Factors in ASCE 7-93
Section 2.3.3 allows the load combinations of 2.3.1 to be reduced as follows:
$D + 0.75 \times$ below combinations
$L + (L_r \text{ or } S \text{ or } R) + (W \text{ or } E)$
$L + (L_r \text{ or } S \text{ or } R) + T$
$(W \text{ or } E) + T$
$D + 0.66 \times [L + (L_r \text{ or } S \text{ or } R) + (W \text{ or } E) + T]$

The reduction factors do not apply to F, H or P loads.

Use of One-Third Stress Increase in ASCE 7-93
The Commentary to 2.3.3 states "Specification writers should consider carefully the intent of allowing [a one third stress increase on the material side] if the combined load effects are also reduced by the appropriate load combination factor specified in 2.3.3." A9.10.2.1 states "the one-third increase in allowable stress given [in the *ASD Specification*] for use with seismic loads is permitted. The load combination adjustment factors of Sec. 2.3.3 shall not be used."

Recommendations
If you are bound by ASCE 7-93, you are permitted to use the load combinations given in 2.3.1 and, where applicable, take advantage of the load reduction factors given in 2.3.3. A one-third increase on the material side should not be used when using these load combinations.

ASCE 7-95

Applicable Sections in ASCE 7-95
Sections 2.4.1, 2.4.2, 2.4.3, and A9.5.1.2

Changes from ASCE 7-93
The loading combinations between ASCE 7-93 and 7-95 are similar, but not the same. A key difference is the removal of the 0.66 reduction factor on the load side in ASCE 7-95. There are no significant changes with respect to the one-third stress increase on the material side of the equation.

Load Combinations in ASCE 7-95
Section 2.4.1 gives the following basic loading combinations:

1. D
2. $D + L + F + H + T + (L_r \text{ or } S \text{ or } R)$
3. $D + (W \text{ or } E)$
4. $D + L + (L_r \text{ or } S \text{ or } R) + (W \text{ or } E)$

Section 2.4.2 states that the effects of F_a shall be considered in design.

Load Combination Factors in ASCE 7-95
Section 2.4.3 discusses a 0.75 reduction factor for these load cases. When the "structural effects due to two or more loads in combination with dead load, but excluding earthquake load, are investigated in load combinations of Sections 2.4.1 and 2.4.2, the combined effects shall comply with both of the following requirements: (a) The combined effects due to two or more loads multiplied by 0.75 plus effects due to dead loads shall not be less than the effects from the load combination of the dead load plus the load producing the largest effects; and (b) the allowable stress shall not be increased to account for these combinations."

Use of One-Third Stress Increase in ASCE 7-95
Section 2.4.3 is clear that the 0.75 reduction factor should not be used at the same time as any increases in allowable stress. The Commentary to 2.4.3 further clarifies, stating "This is not to be confused with allowable stress increases that are based upon duration of load or loading rate effects, which are independent concepts and could be combined with the reduction factor for combining multiple transient loads." Similar to ASCE 7-93, A9.5.1.2 states "the one-third increase in allowable stress given [in the *ASD Specification*] for use with seismic loads is permitted. The load combination adjustment factors of Sec. 2.4.3 shall not be used."

Recommendations
The same recommendations given for ASCE 7-93 apply here. That is, you can use the load combinations given in 2.4.1 and, where applicable, take advantage of the load reduction factors given in 2.4.3. A one-third increase on the material side should not be used when using these load combinations.

ASCE 7-98

Applicable Sections in ASCE 7-98
Sections 2.4.1, 2.4.2, 2.4.3, and A9.8.1.2

Changes from ASCE 7-95
Loading factors of 0.6 on *D* and 0.7 on *E* were introduced in ASCE 7-98.

Load Combinations in ASCE 7-98
Section 2.4.1 gives the following basic loading combinations:

1. D
2. $D + L + F + H + T + (L_r \text{ or } S \text{ or } R)$
3. $D + (W \text{ or } 0.7E) + L + (L_r \text{ or } S \text{ or } R)$
4. $0.6D + W + H$
5. $0.6D + 0.7E + H$

Section 2.4.2 covers load combinations for structures in a flood zone and also states that the effects of *F*, *H*, *P*, or *T* shall be considered in design.

Note that *E* is a strengh level force. The 0.7 factor brings this down to ASD and is not a reduction as a result of a combination of multiple transient loads.

Load Combination Factors in ASCE 7-98
Section 2.4.3 discusses a 0.75 reduction factor for these load cases. When the "structural effects due to two or more loads in combination with dead load, but excluding earthquake load, are investigated in load combinations of Sections 2.4.1 and 2.4.2, the combined effects due to the two or more loads multiplied by 0.75 plus effects due to dead loads shall not be less than the effects from the load combination of the dead load plus the load producing the largest effects." Note that the exclusion on earthquake loads was eliminated in an ASCE 7-98 Errata dated April 19, 2001. This means the loading combinations (ignoring *F*, *H*, *T*, and *P* loads for simplicity) that need to be checked are:

1. D
2a. $D + L$
2b. $D + (L_r \text{ or } S \text{ or } R)$
2c. $D + 0.75[L + (L_r \text{ or } S \text{ or } R)]$
3a. $D + (W \text{ or } 0.7E)$
3b. $D + 0.75[(W \text{ or } 0.7E) + L + (L_r \text{ or } S \text{ or } R)]$
4. $0.6D + W$
5. $0.6D + 0.7E$

The above loading combinations are similar to those listed directly in Section 2.4.1 of SEI/ASCE 7-02. Note that the 0.75 reduction factor never applies to the dead load.

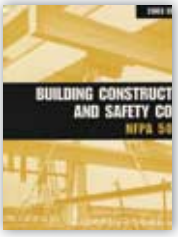
Use of One-Third Stress Increase in ASCE 7-98
The Commentary to 2.4.3 states "…simultaneous use of both the one-third stress increase in allowable stress and the 25% reduction in combined loads is unsafe and is not permitted." As was the case in ASCE 7-93 and ASCE 7-95, A9.8.1.2 states "the one-third increase in allowable stress given [in the *ASD Specification*]…for use with seismic loads is permitted. The load combination adjustment factors of Section 2.4.3 shall not be used." Unlike previous versions of ASCE 7, ASCE 7-98 also states in A9.8.1.2, "The increase in allowable stress given in [the 1997 AISC *Seismic Provisions for Structural Steel Buildings* including *Supplement No. 1*]…shall not be used in conjunction with the load combinations of Section 2.4.1." Section 2.4.3 states, "Increases in allowable stress shall not be used with these loads or load combinations unless it can be demonstrated that such an increase is justified by structural behavior caused by rate or duration of load."

Recommendations
As with ASCE 7-93 and ASCE 7-95, the one-third stress increase is not applicable when the ASD load combinations given in ASCE 7-98 are used.

BOCA 1999
(*National Building Code*)

Section 1613.1 of this code references ASCE 7-93 for all loading combinations. For Allowable Stress Design, the 1989 *ASD Specification* (without *Supplement No. 1*) is referenced. See the section in this paper for ASCE 7-93.

NFPA 5000
2003 Edition



Section 35.15.1 of the 2003 *Building Construction and Safety Code* (NFPA 5000) references Section 2 of SEI/ASCE 7-02 for all loading combinations. For Allowable Stress Design, the 1989 *ASD Specification* (including *Supplement No. 1*) is referenced. See the section on SEI/ASCE 7-02 in this paper.

SEI/ASCE 7-02

Applicable Sections in SEI/ASCE 7-02
Sections 2.4.1, 2.4.2, 2.4.3

Changes from ASCE 7-98
The first notable change is that SEI was added to the title of the standard, recognizing that ASCE is rebranding its structural standard as belonging to its Structural Engineering Institute (SEI). Regarding load combinations, this version now directly lists applicable loading combinations, instead of simply describing how the loading combinations were affected by the 0.75 reduction factor.

Load Combinations in SEI/ASCE 7-02
Section 2.4.1 gives the following basic loading combinations:

1. $D + F$
2. $D + H + F + L + T$
3. $D + H + F + (L_r \text{ or } S \text{ or } R)$
4. $D + H + F + 0.75(L + T) + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + H + F + (W \text{ or } 0.7E)$
6. $D + H + F + 0.75(W \text{ or } 0.7E) + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
7. $0.6D + W + H$
8. $0.6D + 0.7E + H$

Sections 2.4.2 and 2.4.3 cover flood-zone loads and atmospheric ice loads, respectively.

Load Combination Factors in SEI/ASCE 7-02
The load combination factors have been incorporated directly into the load combinations in Section 2.4.1.

Use of One-Third Stress Increase in SEI/ASCE 7-02
Section 2.4.1 states, "Increases in allowable stress shall not be used with these loads or load combinations unless it can be demonstrated that such an increase is justified by structural behavior caused by rate or duration of load."

Recommendations
More of the same. When using the load combinations in SEI/ASCE 7-02, the one-third stress increase on the material side does not apply.

UBC 1997

Applicable Sections in UBC 1997
Sections 1612.3.1, 1612.3.2, 1612.3.3, 1612.4, 2209

Load Combinations in UBC 1997
Section 1612.3.1 lists the following basic ASD loading combinations:

1. D
2. $D + L + (L_r \text{ or S})$
3. $D + (W \text{ or } E/1.4)$
4. $0.9D \pm E/1.4$
5. $0.6D + W$
6. $D + 0.75[L + (L_r \text{ or } S) + (W \text{ or } E/1.4)]$

Alternate basic load combinations
Section 1612.3.2 gives the following alternate load combinations:

1. $D + L + (L_r \text{ or } S)$
2. $D + L + (W \text{ or } E/1.4)$
3. $D + L + W + S/2$
4. $D + L + S + W/2$
5. $D + L + S + E/1.4$
6. $0.9D \pm E/1.4$

When F, H, P, or T loads are to be considered in design, they should be added to each of either set load cases per Section 1612.3.3.

Load Combination Factors in UBC 1997
The load combination factors are worked directly into the basic load combinations from Section 1612.3.1.

Use of One-Third Stress Increase in UBC 1997
A one-third stress increase is allowed for all combinations involving W or E when the alternate load combinations of Section 1612.3.2 are used (see Section 1612.3.3). Section 2209 amends the provisions of the *ASD Specification* to disallow any stress increase when the load combinations of Section 1612.3.1 are used.

Recommendations
You are permitted to use the loading combinations from 1612.3.1. These loading combinations do not allow the use of the one-third stress increase factor.

IBC 2000 & IBC 2003

(ICC)

Since IBC 2000 and IBC 2003 have essentially the same loading provisions, they will both be presented in this section. Any differences will be pointed out.

Applicable Sections in IBC 2000 and IBC 2003

Sections 1605.3.1, 1605.3.1.1, 1605.3.1.2, 1605.3.2

Load Combinations in IBC 2000 and IBC 2003

Section 1605.3.1 gives the following basic loading combinations:

1. D
2. $D + L$
3. $D + L + (L_r \text{ or } S \text{ or } R)$
4. $D + (W \text{ or } 0.7E) + L + (L_r \text{ or } S \text{ or } R)$
5. $0.6D + W$
6. $0.6D + 0.7E$

Load Combination Factors in IBC 2000 and IBC 2003

Similar to ASCE 7-98 and SEI/ASCE 7-02, Section 1605.3.1.1 permits the effect of two or more transient loads to be multiplied by 0.75 when added to the effect of dead load. The combined loading using the 0.75 reduction factor cannot be less than the effects of dead load and any one of the transient loads. One difference from ASCE 7 in both IBC 2000 and IBC 2003 is that the 0.7 factor on E cannot be combined with the 0.75 factor.

In accordance with Section 1605.3.1.2, the loading combinations given in Sections 2.4.1 and 2.4.2 of ASCE 7-98 (for IBC 2000) or SEI/ASCE 7-02 (for IBC 2003) shall be used when F, H, P, T, or F_a are considerations in design.

Alternate basic load combinations

When the following loading combinations (from Section 1605.3.2) are used, allowable stresses are permitted to be increased (or load combinations reduced) for the load cases involving wind or seismic loads, when permitted by the material code of IBC 2000 and IBC 2003 or referenced standard:

1. $D + L + (L_r \text{ or } S \text{ or } R)$
2. $D + L + (\omega W)$
3. $D + L + (\omega W) + S/2$
4. $D + L + S + \omega W/2$
5. $D + L + S + E/1.4$
6. $0.9D + E/1.4$

If the wind loads are calculated in accordance with IBC 2000 (or IBC 2003) Section 1609.6 or ASCE 7-98 (or ASCE 7-02), ω is taken as 1.3. Otherwise, ω is 1.0. When F, H, P, or T, are considerations in the above alternate basic load combinations, load factors of 1.0 should be used, per Section 1605.3.2.1. Both IBC 2000 and IBC 2003 reference the 1989 ASD Specification. Since IBC 2000 does not currently reference *ASD Supplement No. 1*, the one-third stress increase is permitted as long as the loading combinations of 1605.3.2 are used. Note, however, that IBC 2003 does reference *ASD Supplement No. 1*, suggesting that these alternative load combinations should not be used in combination with a one-third stress increase.

Use of One-Third Stress Increase in IBC 2000 and IBC 2003

Section 1605.3.1.1 states, "Increases in allowable stress specified in the appropriate materials section of this code or referenced standard shall not be used with the load combinations of Section 1605.3.1 except that a duration of load increase shall be permitted in accordance with Chapter 23."

A one-third stress increase is allowed for all combinations involving W or E when the alternate load combinations of Section 1605.3.2 are used. Since IBC 2003 references *ASD Supplement No. 1*, the one-third stress increase on the material side cannot be taken advantage of.

Recommendations

Whether you are using IBC 2000 or IBC 2003, the loading combinations of Section 1605.3.1 are used in combination with the load reduction factor discussed in 1605.3.2. These loading combinations cannot be combined with the one-third stress increase. Although IBC 2000 does currently allow the use of the one-third stress increase found in the *ASD Specification* (only because *Supplement No. 1* is not referenced specifically), this stress increase is allowed only when the alternate loading combinations of 1605.3.2 are used.

1999 Standard Building Code

Applicable Section in SBC 1999
Sections 1609.1, 1609.1.1

Load Combinations in SBC 1999
Section 1609.1 lists the following ASD loading combinations:

1. $D + L + (L_r \text{ or } S)$
2. $D + L + (W \text{ or } E/1.4)$
3. $D + L + W + S/2$
4. $D + L + W/2 + S$
5. $D + L + S + E/1.4$

Load Combination Factors in SBC 1999
Load combination factors (that can be used in lieu of the one-third stress increase) are not used in the *Standard Building Code*.

Use of One-Third Stress Increase in SBC 1999
This building code references the *ASD Specification*, but does not reference *Supplement No. 1*. Thus, a one-third stress increase is allowed as specified in Section 1609.1.1: "Allowable stresses specified in the appropriate material standard for allowable stress design are permitted to be increased in accordance with the material design standard when stresses are produced by wind or seismic loading, acting alone or in combination with other loads."

Recommendations
This is the only building code considered in this summary that does not provide load combination factors that can be used instead of the one-third stress increase.