The 2010 AISC Specification: Composing in Steel and Concrete

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Enlarged and reorganized, the new Chapter I provides direction for many more ways of designing for composite action.

THE 2010 AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-10) contains significantly fewer changes than was the case when the 2005 AISC *Specification* was released; however, some very important improvements have been included in the new *Specification* to reflect advances in the state of the art in both practice and research over the past five years. For instance, the Direct Analysis Method is now the primary method of designing for stability in Chapter C, while a brand new Chapter N on Quality Control and Assurance has been provided.

Another area of expansion in the 2010 *Specification* involves Chapter I and the design of composite members. Whereas composite floor design and construction is popular in the U.S., use of composite members for other gravity and lateral load resisting elements is still uncommon. Some high-rise building designers have seen the benefits of using composite columns to achieve both strength and stiffness, but in general, other exceptionally beneficial uses of composite construction have yet to be exploited.

The AISC Committee on Specifications, Task Committee 5 on Composite Design, has thus worked to expand the scope of Chapter I to encourage the use of a wider array of composite systems. Chapter I in the 2010 *Specification* includes new provisions that are based on research in three different areas. The first addresses the design of large built-up filled members with noncompact steel sections. This essentially ends the old limitation in the *Specification* that all filled members had to be compact. Chapter I also includes expanded provisions on load transfer at composite connections. Finally, a new section on the nominal strengths of anchors, in applications other than composite floors, has been added. In general, the commentary to Chapter I also has been expanded significantly to explain the new provisions as well as reintroduce equations for composite beam design that were included in previous AISC LRFD specifications but not in the 2005 AISC *Specification*.

The use of the term *anchors* reflects a change in nomenclature between the 2005 and 2010 specifications. In an effort to harmonize terminologies across various standards in construction, the terms *shear stud* and *shear connector* have been dropped in favor of *steel headed stud anchor*. The new term recognizes that stud anchors can be used both in shear and tension and that their use need not be limited to composite floor systems where they are most commonly used today.

Noncompact Filled Sections

The behavior of filled composite members differs from the behavior of hollow steel members. The concrete infill has a significant influence on the stiffness, strength, and ductility of composite members. As the steel area (reinforcement ratio) decreases, the concrete contribution becomes more significant. For this reason, only compact steel sections were previously permitted. The compact section limits were provided in the 2005 *Specification*, and their numerical values remain the same. The noncompact limit and a maximum slender, and the associated elastic buckling stress equations, are new to the 2010 *Specification* and are provided in Section I1.

The elastic buckling stress (F_{cr}) of slender elements for both cases of uniform compression and flexure in a section are the same. However the slenderness limits for elements that are subjected to a stress gradient due to flexure have been relaxed.

Section I2 provides the nominal section strength (P_{no}) in compression which depends on the slenderness classification (compact, noncompact, or slender) of the filled composite section. The compressive strength of the composite section need not be less than that of the bare steel section alone. The behavior of the section within these slenderness limits can be summarized as follows:

Compact sections have sufficient wall thickness to develop yielding of the HSS in longitudinal compression, and to provide confinement to the concrete infill to develop its compressive strength ($0.85 f'_c$ for rectangular and $0.95 f'_c$ for round).

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Noncompact sections have sufficient wall thickness to develop yielding of the HSS in the longitudinal direction, but cannot adequately confine the concrete infill after it reaches $0.70 f'_c$ compressive stress and starts undergoing significant inelasticity and volumetric dilation (pushing against the HSS).

Slender sections can neither develop yielding of the HSS in the longitudinal direction, nor confine the concrete after it reaches $0.70 f'_c$ compressive stress and starts undergoing inelastic strains and significant volumetric dilation pushing against the HSS.

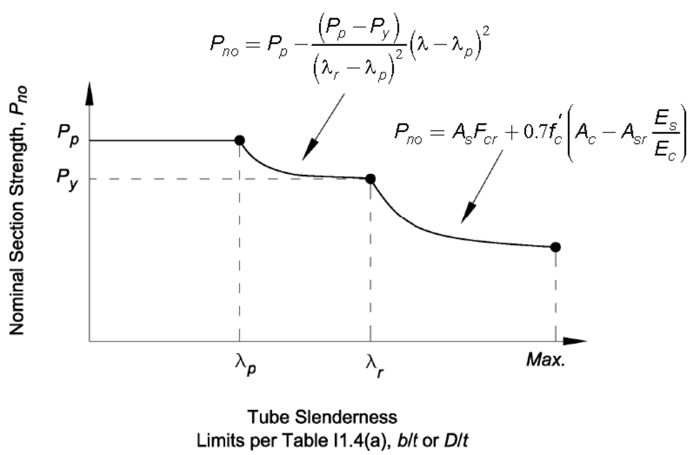

Fig. 1: Nominal Axial Strength of Filled Composite Members

The nominal flexural strength (M_n) for filled sections is provided in Section I3. Again the section is classified as compact, noncompact, or slender, but this time the flange and web are addressed separately. This approach allows for the relaxation of slenderness limits in the webs of rectangular HSS and the walls of round HSS due to the presence of stress gradients in flexure. Moreover the webs of rectangular HSS and the walls of round HSS are not permitted to be slender.

The general behavior of the section in flexure within the slenderness limits is as follows:

Compact sections can develop their full plastic strength M_p.

The nominal flexural strength (M_n) of noncompact sections can be determined using a linear interpolation between the plastic strength (M_p) and the yield strength (M_y) with respect to the HSS slenderness. The yield strength (M_y) corresponds to yielding of the tension flange and first yield of the compression flange, while the concrete block is limited to linear elastic behavior with maximum compressive stress equal to $0.70 f'_c$.

Slender sections are limited to developing the first yield moment (M_{cr}) of the composite section where the tension flange reaches first yielding, while the compression flange is limited to the critical buckling stress (F_{cr}), and the concrete is limited to linear elastic behavior with maximum compressive stress equal to $0.70 f'_c$.

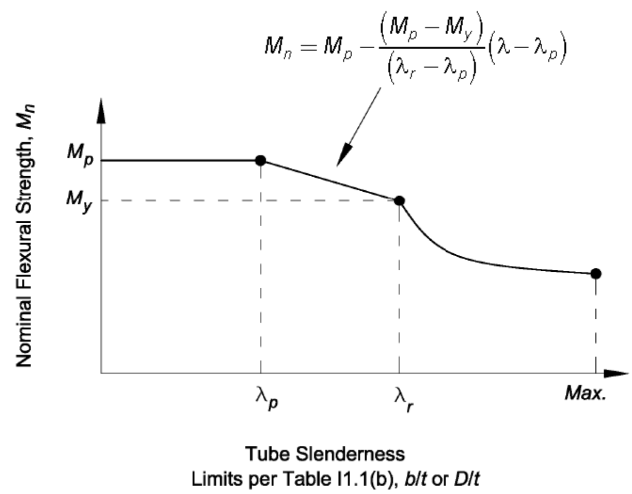

Fig. 2: Nominal Flexural Strength of Filled Composite Members

For combined loading, the interaction of the axial force and bending moment for compact filled composite members can be evaluated in the same way as before by using one of three methods. These are the equations provided in Section H1.1, strain compatibility methods, or by assuming a plastic stress distribution over the cross-section. However, for combined loading in noncompact and slender filled composite sections only the equations of Section H1.1 are permitted.

Load Transfer in Composite Connections

The 2005 *Specification* addressed the topic of load transfer but only briefly. The 2010 *Specification* now provides a much more explicit approach. The new Section I6 on load transfer includes provisions on force introduction, force allocation and force transfer.

The provision on force introduction focuses on how the force is applied to the composite section, whether it is transferred directly to the steel components, the concrete components, or both concurrently.

The force allocation requirement provides that the applied external force should be distributed within the composite section based on the ratio of the steel cross section strength to the composite cross section strength, as represented by the plastic stress distribution method. Equations are provided to calculate the shear force transfer required to achieve this force allocation when the applied force is transferred directly to the steel components only, directly to the concrete components, or to both.

The force transfer mechanisms permitted for filled composite sections are direct bearing, steel headed stud anchors, or bond between the steel and concrete components. The force transfer mechanisms permitted for encased steel shapes are direct bearing or steel headed stud anchors. Equations are provided for calculating the force transfer strength for direct bearing and bond.

Finally, the section includes detailing requirements for steel anchors in load introduction zones with a commentary discussion to illustrate the provisions.

Composite Diaphragms and Collector Beams

Section I7 on composite diaphragms and collector beams has been added to provide commentary space for design guidelines in an area that was previously left unattended. (See "Under Foot," December 2008 SteelWise article, at **www.modernsteel.com/backissues**.)

Steel Anchors

Section I8.3 of the 2010 *Specification* represents a significant addition. For the first time, the AISC *Specification* provides provisions for the design of steel anchors in composite components other than beams. It has provisions for steel anchors in shear, tension, and where shear and tension are combined. When adding this section, the intent of the AISC Committee on Specifications was to allow a wider array of composite elements and their connections to be designed without having to resort to other standards.

When operating outside the limitations provided within this section the designer will still need to refer to other relevant standards. For instance the shear strength of steel headed anchors with installed height to diameter ratio greater than 5, and for which concrete breakout strength is not an applicable limit state, can be calculated using the contribution of the steel shank alone. A new resistance factor of 0.65 is provided for this strength calculation. If concrete breakout is a relevant limit state, Appendix D of ACI 318 can be used to determine the strength of the connection.

Steel headed stud anchor strength provisions also are provided for lightweight concrete within composite construction.

Conclusion

The most visible change to Chapter I in the 2010 AISC *Specification* is the reorganization of the sections to make them more consistent with the rest of the *Specification*. The new organization also unifies related concepts so that the designer need only refer to one easily identified section when dealing with items such as shear or steel anchor strengths.

Through the application of Chapter I of the 2010 *Specification*, it is anticipated that owners, designers and contractors can now use the expansion in the *Specification* to design and construct innovative new composite systems that are structurally and architecturally superior and efficient. It is important here to recognize the origin of this vision. The Committee on Specifications and its Task Committee on Composite Design provided leadership in developing Chapter I. The committee looks forward to feedback from *MSC* readers on the new *Specification*. MSC