Composite Column Design

The 2005 AISC specification for axially loaded composite columns uses a model that closely resembles that of traditional steel columns.

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Composite columns, either encased or filled, can be an economical solution for cases where additional load capacity is desired over that available with steel columns alone. The new 2005 AISC *Specification for Structural Steel Buildings* provides simple and practical methods to determine their capacity. This article covers the design provisions for both encased composite columns (steel shapes embedded in concrete) and filled composite columns (hollow structural sections (HSS) filled with concrete) covered in Chapter I of the 2005 *Specification*.

Overview– 2005 AISC Specification

The 2005 AISC *Specification for Structural Steel Buildings* permits design of composite columns by either ASD (Allowable Stress Design) or LRFD (Load and Resistance Factor Design). There is no preference for one approach over the other. The resulting designs are safe, economical, and practical. Provisions for composite columns have been available in all previous LRFD specifications, but this edition is the first to make them available to designers using ASD.

Uses for Composite Columns

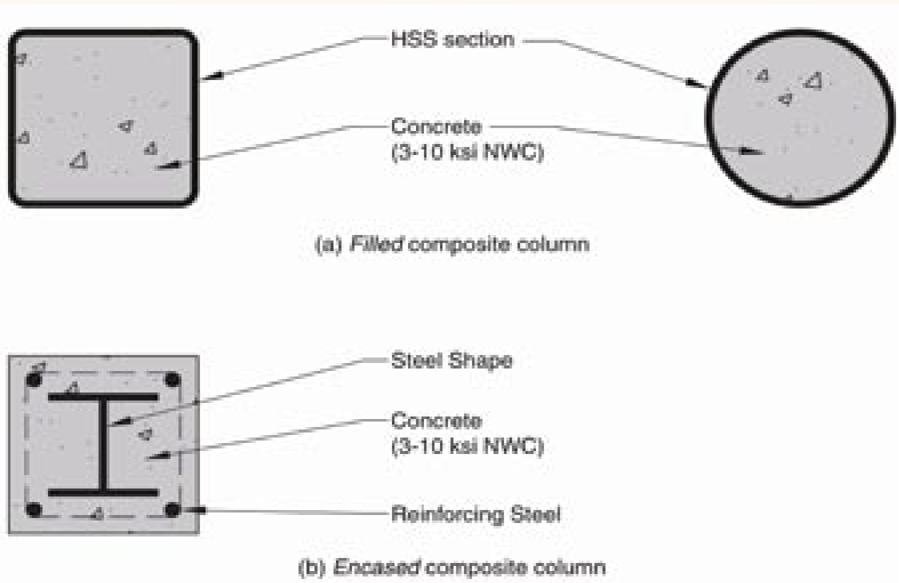
Composite columns can provide an effective solution to many of the problems found in practical design. In applications where a column is exposed, many architects like the use of concrete in fire and corrosion protection, as well as for the final exposed surface. In these situations, the engineer may take advantage of the additional load-carrying capacity for both vertical and lateral loads, as well as the additional stiffness that is available. In situations where heavy column loads are being supported, concrete can be added to carry additional loads without requiring an increase in the size of the steel section. In medium-rise and high-rise construction, composite columns are often used to permit the phasing of construction. Erection of the bare steel frame can proceed ahead with the concrete work following behind. Composite columns are also excellent for lower levels of multistory buildings to carry the vertical loads at the high floor-to-floor heights often used at these levels. Composite columns have additional toughness that makes them an excellent choice for situations where blast loading is a design consideration.

Strength of Composite Columns

Encased Composite Columns—An encased composite column is a column composed of a steel shape core encased in concrete with additional longitudinal reinforcing steel and lateral ties. In order to qualify under the 2005 *Specification* as an encased composite column, the following criteria must be met:

1. The cross-sectional area of the steel core must comprise at least 1% of the total composite cross section.
2. The concrete encasement of the steel core must be reinforced with continuous longitudinal bars and lateral ties or spirals. The minimum lateral reinforcement must be at least 0.009 sq. in. per inch of tie spacing.
3. The minimum reinforcement ratio for continuous longitudinal reinforcing is 0.4% of the gross column area.

For this specification, composite columns may now be designed with a minimum of 1% steel ratio, down from the 4% required in previous LRFD specifications. This removes the previous discontinuities in design that occurred as the steel



Chapter I of the 2005 Specification covers the design of concrete filled HSS columns and encased composite columns.

ratio decreased below 4% and the designer was required to use the provisions of ACI 318, *Building Code Requirements for Structural Concrete and Commentary*. All concrete and reinforcing steel detailing requirements for encased composite columns must conform to the applicable building code, which normally references ACI 318.

Filled Composite Columns—A filled composite column is a column composed of a rectangular or round HSS or pipe section. In order to qualify under the 2005 *Specification* as a filled composite column, the following criteria must be met:

1. The cross-sectional area of the steel HSS must comprise at least 1% of the total composite cross section.
2. The b/t ratio for the walls of a rectangular HSS to be used in a composite column must be less than or equal to 2.26 $(E/F_y)^{0.5}$, although higher ratios are permitted if justified by testing or analysis.
3. The D/t ratio for the walls of a round HSS to be used as a composite column must be less than or equal to 0.15 E/F_y although higher ratios are permitted if justified by testing or analysis.

As with encased columns, filled composite columns may now be designed with a minimum steel ratio of 1%. In addition, the minimum wall slenderness has been liberalized from previous editions of the LRFD specification. Those editions did not differentiate between buckling of filled and unfilled HSS. The new provisions take into account the restraining effect of the concrete on the local buckling of the section wall.

The compressive strength of composite column cross sections is given as the sum of the strengths of its components. The beneficial confining effect of a round HSS can be taken into account by increasing the strength of the concrete from $0.85f'_c$ for encased columns and filled rectangular HSS to $0.95f'_c$ for round HSS.

The compressive strength for axially loaded encased and filled composite columns, considering length effects, is determined for the limit state of flexural buckling based on column slenderness provisions that closely parallel those for steel columns. Rather than expressing the column stiffness as a function of a modified modulus of elasticity, E_m, as in previous specifications, the new provisions use an effective stiffness, EI_{eff}, for determining the buckling strength.

Additionally, provisions have been added for tensile strength as well as shear strength of composite columns. Tensile strength has been addressed for situations where uplift is a concern and for computations related to beam-column interaction. For shear strength, the new provisions require the use of the steel section alone plus the contribution from any transverse reinforcement present in the form of ties; or the shear strength based on the reinforced concrete portion of the cross section alone.

The general principals for designing composite beam-columns are set by the *Specification*, and several different approaches are outlined in its Commentary section. The guiding principals are:

1. The required strength of the member, as for any steel beam column, must be based on a second order analysis as defined in Chapter C. This may be a rigorous or approximate second order analysis.
2. The nominal strength of the section is determined using the plastic stress distribution method or the more general strain compatibility method. These methods are similar to those used in reinforced concrete column design.
3. Slenderness effects are accounted for the same as in axially loaded steel columns.

One simple approach to design of doubly symmetric composite beam-columns is to use the straight line interaction equations defined in Chapter H. This approach parallels that used for design of wide-flange or HSS steel columns but yields a significantly more conservative estimate of the beam-column capacity for composite columns than it does for steel beam columns. ★

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