structural practices

Composite Beam Design

By Steven M. Ashton, P.E.

This is the first of a series of seven articles that will appear in STRUCTURE Magazine. AISC is currently touring the country with the seminar "Steel Design after College", a presentation that teaches the intricacies of steel design not covered in the college classroom.

The course was authored by Lawrence G. (Larry) Griffis, P.E., Viral B. Patel, P.E., S.E., and the Research and Development group staff at Walter P. Moore and Associates, Inc. The seminar covers much of what is considered "standard office practice" and introduces new design methods and strategies to make structural engineering design and analysis more efficient. Though written with the less experienced structural engineer in mind, the course is beneficial even to those with substantial experience.

The seminar covers seven topics, each of which will be featured as a separate article in this and upcoming issues.

- *Design of Flexural Members*
- *Composite Beam Design*
- *Lateral Design of Steel Buildings*
- *Deck Design*
- *Diaphragms*
- *Base Plates and Anchor Rods*
- *Steel Trusses and Computer Analysis Verification*

Though most engineers understand the general theory of composite beam calculations, the execution of composite beam design in practice requires consideration of a number of issues beyond structural calculations, including fire engineering, constructability, and more. Several factors need to be considered when designing composite beams and ten of these will be discussed briefly in this article.

Typical composite beam construction

Materials Considerations

Section A3 of the AISC Specification lists all of the ASTM material specifications that are allowed. When wide-flange beams are used, ASTM A992 should always be specified. However, the AISC provisions also apply to HSS, pipes and built-up shapes.

Shear studs are commonly specified as ASTM A108, which has a tensile strength of 60 ksi. The most common size of studs used in building construction is ¾-inch diameter.

Slab reinforcing can consist of either welded wire reinforcing or reinforcing bars, and in certain situations the slab can be steel fiber reinforced per ASTM C1116.

In the slab, the minimum specified compressive strength of the concrete needs to be between 3 ksi and 10 ksi for normal-weight concrete, and between 3 ksi and 6 ksi for light-weight concrete. Higher strengths may be counted on for stiffness only. 3.5 ksi normal-weight concrete and 3 ksi light-weight concrete are usually specified to conform with typical fire rated assemblies.

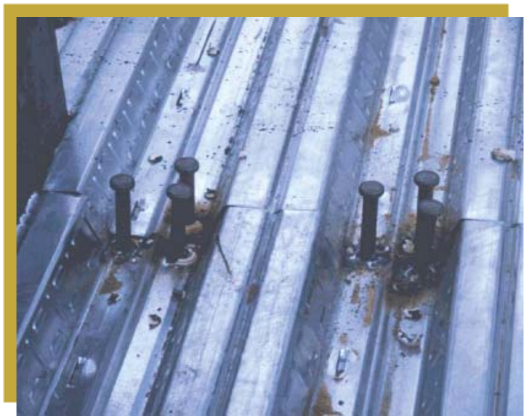
Fire Resistance Issues

Fire resistance is an important consideration when detailing a composite system. Commercial construction typically is Type I-A (Fire Rated) per IBC, which requires a 2-hour fire-rating for the floor beams and a 3-hour fire-rating for the structural frame.

Deck and slab thickness selection is usually performed by choosing an Underwriter Laboratories (UL) listed assembly that achieves the required hourly fire rating. The UL assemblies contain numerous notes that must be fully understood by the engineer in specifying the floor system.

Deck and Slab Considerations

Within reason, the deck size should be chosen to accommodate the beam spacing. The Steel Deck Institute (SDI) provides tables that show the maximum allowable span for a given deck and slab system for un-shored construction. Maximizing the span for a given deck size, for un-shored construction, generally improves economy of the steel floor system. It is recommended that you select deck assuming a 2-span un-shored condition, avoiding single span conditions whenever possible.



Stud placement in violation of AISC limits

Concrete ponding will need to be considered, as well as the method of pouring the slab. When calculating concrete quantities for slabs that need to be poured flat, you may want to assume an additional ½ inch of concrete to account for ponding. It is important to consider an appropriate value for the wet weight of light-weight concrete, as field reported wet-weight can be as much as 125 pcf.

Strength Design Topics

There are currently two different methods of composite beam design being used in the industry. The method described in the 9th Edition *Manual of Steel Construction* is more complicated than the method found in the 3rd Edition *LRFD Manual of Steel Construction*, which is not only simpler in design, but also more economical. Using ASD, the moment capacity is calculated from the superposition of elastic stresses, and using LRFD, the moment capacity is calculated from plastic stress distribution.

Economical design is often achieved with less than full composite action in the beam. In many cases, one can bump-up the beam one or two sizes and greatly reduce the number of studs required to achieve the design moment. Composite beam design is almost always performed with a computer program, or with design aids like in the AISC Manual.

Camber

Though there are a variety of methods to achieve level steel-framed floors, the method of choice in the U.S. is by cambering of beams. Proper cambering of beams is an art whose purposes are often misunderstood by practicing engineers. Beam camber is only a part of an overall floor levelness strategy that must include consideration of the slab pour method, building occupancy, and steel fabrication and erection practice.

The primary goal in cambering beams is to correctly predict the actual deflection of the beam under the weight of the concrete. Due to connection restraint and fabrication tolerances, correct camber is best achieved at 75-80% of the calculated dead load deflection. Over-cambering of beams should always be avoided. In addition, there are many types of beams for which cambering is inappropriate, including brace beams and very short beams.

Serviceability Considerations

Serviceability considerations for composite floors include long-term deflections due to superimposed dead load, short-term deflections due to live load, vibration control, and performance of the slab system. Proper evaluation of deflections must consider partial composite action, creep deflections under superimposed dead load, and acceptance criteria appropriate to the intended floor use.

Design and Detailing of Studs

Proper design and detailing of studs is addressed in Section I5.6 of the 1999 AISC Specification. Minimum stud spacing is 6 times the stud diameter in the longitudinal direction and 4 times the stud diameter in the transverse direction.

In the 2005 Specification, two new factors–the stud geometry and the stud position within the deck ribs - will need to be considered.

Reactions and Connections

The suggestions for showing reactions on design drawings for fabricator-selected connections of composite beams are not necessarily specific to composite beams. A common approach is for the engineer to show end reactions on the drawings, and allow the fabricator to select the connections by referring to tables in the AISC Manual of Steel Construction. If there is a chance of future load increases due to occupancy changes, it may be appropriate to increase the specified end reactions. However, any increase should be limited to a practical value so that standard connection details may be selected by the fabricator.

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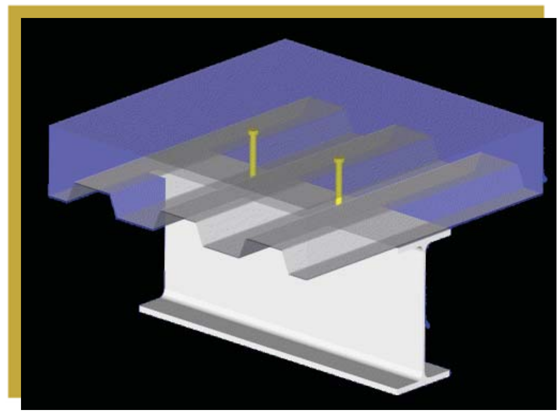

Components of a composite beam

Composite Beams in Lateral Load Systems

For ease of design, the standard practice is for the engineer to ignore the benefits of composite action when designing the lateral load resisting system. However, taking composite action into account can be extremely beneficial, especially in moment frames where the member sizes are usually dictated by drift criteria rather than strength requirements. The stiffness of the composite beams that are part of the lateral load resisting system is based on an equivalent moment of inertia determined from the stiffness contribution of the slab in the positive moment region.

Strengthening of Existing Beams

If a floor system in an existing structure needs to be strengthened as a result of higher floor loads due to a change in occupancy, one potential solution is to strengthen the existing beams. Non-composite beams can be strengthened by making them composite. The procedure for each new stud location is to core out the existing slab, install the new stud, and replace the cored out slab with non-shrink grout.

Theoretically, you could increase the strength of a partially-composite beam by adding more studs. But, in practice, it is difficult to work around the existing studs when coring out the slab over the beam. Composite beams are typically strengthened by field welding reinforcement (typically plate or a WT section) to the bottom flange. Connections must also be evaluated when strengthening a floor system.▪

This article contained ten practical topics in design of composite beams covered in AISC's Steel *Design After College* seminar. While this article briefly touched on the considerations, the full day seminar will go into much greater detail with a one-hour session on composite beam design, and will include sessions on the many other topics listed at the beginning of this article. A major benefit of attending this "live" seminar is that you will have the opportunity to ask the experts about your unique situations. For more information on seminar content, and when the seminar is coming to your area, visit **www.aisc.org/seminars.**

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