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steel interchange

Reinforcing with Differing Grades of Steel

An existing singly symmetric, built-up I-section requires reinforcing. The yield strength of the section is 50 ksi, and the web is non-compact. AISC *Specification* Section F4 requires four criteria to be checked: yielding, lateral-torsional buckling, flange local buckling and tension flange yielding. If A36 angles and plates are used as reinforcing, what yield strength should be assumed in the limit state calculations?

You should not assume 50 ksi for the entire section, as that would be unconservative.

The simplest approach is to assume 36 ksi for everything. However, it must be noted that this approach is conservative and results in a reduction in the assumed design strength of the original section, and may require you to add more reinforcing than is strictly necessary. However, that is not always the primary concern. Oftentimes, the costs associated with reinforcing an existing member are largely influenced by the labor involved, and the material costs are minor in comparison. In such cases, being conservative and adding a little extra material, in order to simplify the design process, may not really burden the project. Judgment must be exercised to ensure an economical outcome.

The most efficient design would assume a combination of both the 36- and 50-ksi material strengths in the calculations, depending on the limit state being reviewed. First, I would recommend checking each of the limit states using the existing beam section (unreinforced) and 50-ksi material with the new loads, and only for those limit states that fail would I consider the reinforced section with the 50/36-ksi steel mix. Any of the four limit states that "work" before reinforcing the beam should not be negatively impacted by the addition of the beam reinforcing and need not be rechecked.

Next, you would need to determine the plastic neutral axis location—M_p, S_{xc} and S_{xt}—for the built-up shape. In order to maintain equilibrium, you would need $\Sigma F_{yc}A_c = \Sigma F_{yt}A_t$ where the "c" and "t" subscripts represent compression and tension, respectively. You will need to perform an analysis using the plastic force distribution method, distinguishing between the 50-ksi sections and the 36-ksi sections, in order to locate your plastic neutral axis and determine what portion of the built-up member contributes to S_{xc} or S_{xt}. When you calculate M_p for this member, you would need to perform a plastic moment capacity analysis that accounts for the portion of the section that is 36 ksi and not simply use the equation given for the definition of M_p in Equation F4-9.

In Sections F4.1 and F4.4 - Compression Flange Yielding or Tension Flange Yielding: For this limit state, you could use the F_y of each component, as applicable. You would simply use $M_{yc} = \Sigma F_y S_{xc}$ or $M_{yt} = \Sigma F_y S_{xt}$ and use M_p as calculated above.

In Section F4.2 - Lateral-Torsional Buckling: Assuming your member is unbraced for a length greater than L_p and you have to consider this limit state, I recommend using 36 ksi in these calculations since the entire cross section is considered in the limit state check and the various material components cannot be segregated within the equations.

In Section F4.3 - Compression Flange Local Buckling: If the entire area in compression is within the 50-ksi material, you could use 50 ksi for this check. Otherwise, I would use 36 ksi for the check.

Susan Burmeister, P.E.

Curved Members

We are designing a lifting beam at a power plant. The design uses a W21×201 bent about the weak axis to form a ring beam with a radius of approximately 20 ft. What is the strength reduction after bending, and are there publications that we can use as a guide?

The answer to this question is more involved than the effects of bending on strength, and the strength concern is slightly different than what you are picturing.

Torsional effects usually govern a design like this. Lateral-torsional buckling is usually not the controlling limit state. For torsional stresses, AISC Design Guide 9 is a good reference.

Concerning the effect of the rolling process on the material properties, there are two things to consider: residual stresses induced by the rolling process and the potential reduction in ductility due to cold working.

Generally, residual stresses have no effect on the ultimate strength of a member but can affect stability. For a wide-flange member rolled the easy way, the tension residual stress at the inner edge of the flange will be about 50% of the yield stress. The compression residual stress at the outer edge of the flange will also be about 50% of the yield stress. This is comparable to straight wide-flange members, which have a compression residual at the flange edges that can vary from about 20% to 80% of the yield stress, depending on the flange thickness. Therefore, compared to straight members, the effect of residual stresses due to the rolling process should be insignificant because the effect is already included at these levels in the design equations in the AISC *Specification*.

According to Riviezzi (1984), "The reduction in notch ductility as a result of cold working alone becomes significant only when the amount of cold working produces a strain in the outermost fibers exceeding about 5%." Because the strain in your ring due to cold rolling is only about 2.6%, the ductility should be adequate unless it is subjected to extreme combinations of low temperature and severe impact/fatigue loading.

Riviezzi also recommended that "galvanizing after cold bending is not advisable."

Below is a reference list for horizontally curved members. The most designer-friendly reference is *Design of Curved Steel* published by the Steel Construction Institute. The publications provide equations for lateral-torsional buckling of curved members, though again, lateral-torsional buckling is usually not the controlling limit state.

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Bo Dowswell, P.E., Ph.D.

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Susan Burmeister and Bo Dowswell are consultants to AISC.

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1 E Wacker Dr., Ste. 700, Chicago, IL 60601
tel: 866.ASK.AISC • fax: 312.803.4709
solutions@aisc.org

Steel SolutionsCenter