Correspondence

Dear Editor:

I enjoyed the article, "Failure Analysis of a Column k-Area Fracture" written by John M. Barsom and J. V. Pellegrino, Jr., which appeared in the September 2000 issue of *Modern Steel Construction.* It was interesting to learn that the cause of the fracture in the test specimen was not influenced by a material defect or by the fracture toughness of the material in the k-area but rather that it was related to simply exceeding the tensile strength of the steel.

The article raises a good question. Why didn't this full-scale moment connection test provide the same robust performance exhibited in the numerous full-scale reduced beam section (RBS) tests performed by SAC and other independent researchers? To date well over 75 successful full-scale RBS tests have been performed by researchers throughout the world. Even though this RBS test provided a performance level that substantially exceeded the estimated moment connection rotational demands experienced during the Northridge earthquake, this particular test didn't perform as well as the numerous RBS connections previously tested.

In my opinion, the answer to this question can be found in the report "Cyclic Response of RBS Moment Connections: Weak-Axis Configuration and Deep Column Effects" written by Chia-Ming Uang, Chad Gilton and Brandon Chi. This report summarizes the research they conducted on deep column effects for the SAC Joint Venture Phase 2. The specimen discussed in the Barsom and Pellegrino article was tested as part of this research. This report states that torsion, primarily warping torsion, in the deep column was a cause of the high tensile stresses which helped initiate the column fracture.

It needs to be noted that there was no diaphragm or beam flange bracing at the hinge location of the test assembly. Previous full scale RBS connections tests using W14 columns exceeded SAC's performance criteria without aid of these additional brace elements. It is recognized that the RBS beam will tend to twist slightly due to lateral torsional buckling (LTB) as is shown in Figure 1. However when using heavy W14 or columns with similar torsional characteristics, LTB does not significantly reduce the overall performance of the connection.

Prior to LTB there is essentially no torsion applied to the column since the flange force is transmitted directly through the shear center as shown in Figure 2. When beam LTB occurs, a torque is produced about the column as is shown in Figure 3. Since E_{cc-x} is much larger in deep column sections than in the shallow W14 sections the torque produced in the deep column sections by LTB will be larger. Also the torsional stiffness of the deeper column sections, which are typically selected in moment frames based on strong-axis stiffness, are less than an equivalent (and heavier) W14 section with respect to strong-axis stiffness. This obviously will result in a more critical torsional effect.

How do we, as structural engineers, typically handle torsion? First, we try to eliminate the torsion without compromising the economy and efficiency of the system. Or at least we should! One example of this as shown in Figure 4 is to provide a brace to eliminate or significantly reduce any torsion in the system. Even though additional cost is added to the structural frame by adding the brace, this cost is much less than the savings provided by using the deep column section. Typically, moment frame columns utilizing deep column sections are 40% to 50% lighter than frames using shallow column sections.

Another option is to design the structural sections so that they are strong and stiff enough to resist the torsion. In the aforementioned report, Uang et. al. suggest providing a column with a lower h/t_{bf}^3 value for the deep column section than that provided by the column used in a successful full-scale test. In this formula, h is the depth of the column minus t_{bf} and t_{bf} is the column flange thickness. However, it should be noted that providing deep column sections with a lower h/t_{bf}^3 value than that provided in a full scale test using W14 sections results in about the same column weight thus taking away one of the main benefits of using deep column sections.

A final alternative is to conduct the required test of the desired prototype design to demonstrate its ductility in accordance with AISC and SAC recommendations.

In summary, the key issue in this single isolated test among so many others was the torsional effect in deep columns, not any metallurgical or material concern. The use of deep columns is expected to be a focus of further discussions and/or studies by AISC and others.

Lanny J. Flynn, P.E., S.E.
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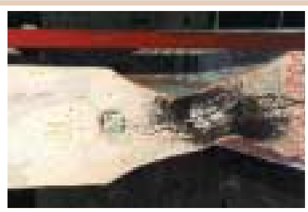

Figure No. 1
UCSD Test Specimen LS-1 at 4% Drift--Bottom Flange View

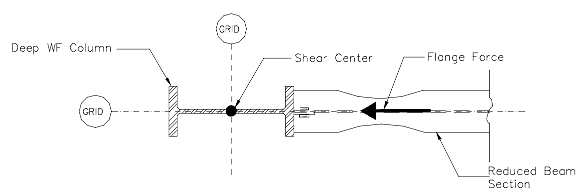

Figure No. 2
RBS Configuration Prior to LTB
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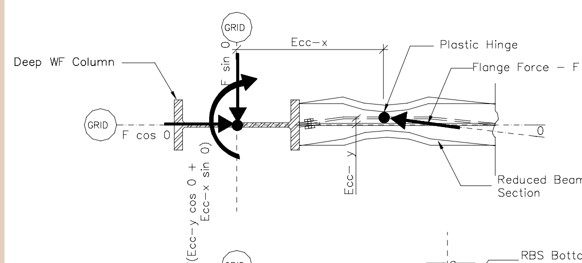

Figure No. 3
RBS Configuration After LTB
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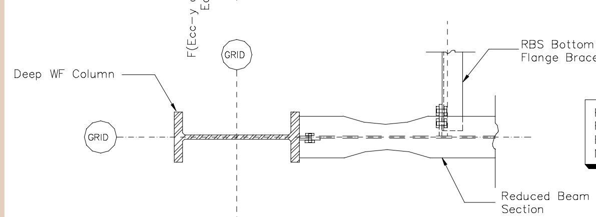

Figure No. 4
RBS Configuration Utilizing Bottom Flange Brace
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