Design for Deconstruction

Deconstructable Systems for Sustainable Design of Steel and Composite Structures

Challenge

According to the U.S. Department of Energy, construction and use of commercial and residential buildings accounted for nearly 45% of U.S. energy consumption in 2009. A new design approach known as Design for Deconstruction (DfD) has emerged to facilitate future reuse of materials.

Structural steel framing systems are particularly conducive to deconstruction at the end of a structure's service life. However, the primary challenge of deconstructing steel buildings is addressing the monolithic construction of composite steel/concrete floor systems (Figure 1, at right). While these floor system components may be recycled, currently they cannot be easily refabricated and reused.

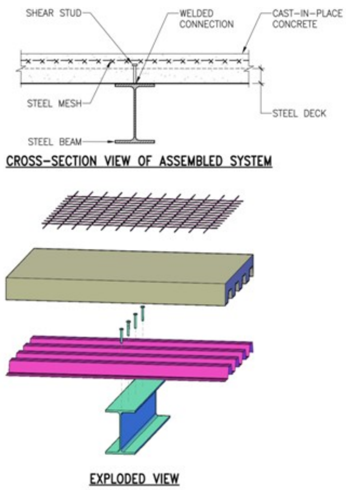

Figure 1: Conventional composite framing materials including steel mesh, steel headed stud anchors, concrete, and steel deck are not reusable; steel headed stud anchors must be removed prior to beam reuse.

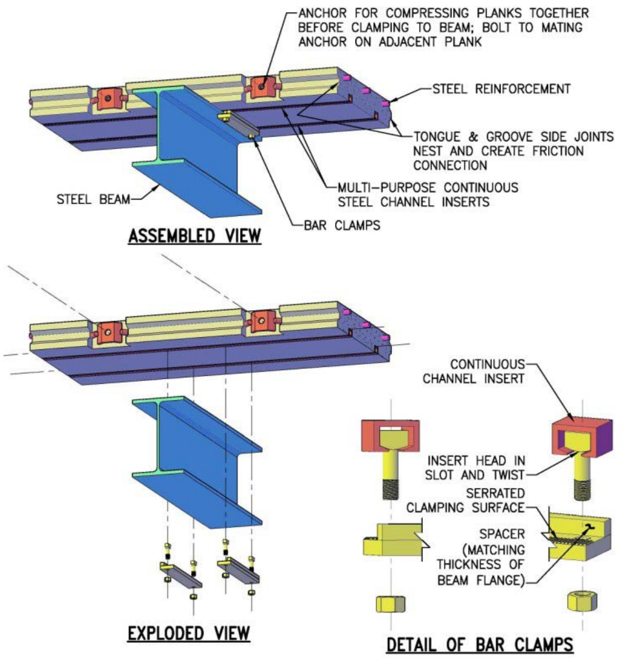

Figure 2: Proposed deconstructable floor system, consisting of precast concrete panels with steel channels embedded on the underside and tongue and groove side joints. Headed bolts, part of a bar clamp assembly, would be inserted into the channels and clamped to the steel beam top flange.

Solution

The proposed system (Figure 2, at left) maintains the efficiency benefits offered by composite action and steel construction, including reduced steel beam sizes, flexible floor framing patterns, and use of recycled materials, while directly addressing the need to reduce waste in the construction industry.

The research includes quantification of deconstructable composite connection behavior through full-scale testing of clamping connections and conducting full-scale tests and corroborating analyses of the proposed deconstructable floor system to validate its integrity.

Objectives:

Develop new structural system concepts and establish comprehensive life-cycle assessment strategies for deconstructable steel and composite steel/concrete construction to facilitate DfD coupled with the use of recycled materials in sustainably optimized construction.

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Composite Beam Test #2

A series of full-scale composite beams were designed to validate the load-slip curves obtained from the pushout tests and investigate the behavior of the deconstructable composite system under gravity loading.

Figure 4 illustrates the load-deflection relationship of Specimen 2, which is a partially composite beam consisting of a W14x38 section and M24 clamps. The test was terminated after 13 in. of deflection. The initial stiffness of the beam is 46.4 kips/in., slightly larger than the AISC prediction using a lower bound moment of inertia of 43.1 kips/in. The peak strength of the beam is 80 kips, which corresponds to a bending moment of 459 ft-kips, 91% of the AISC prediction of 502 ft-kips. The maximum slip is 0.32 in. at the ends of the beam, while the maximum slip is 0.25 in. in the corresponding fully composite beam. The service load in Figure 4 consists of a dead load of 92.5 psf and a live load of 80 psf.

The bolt tension variation is plotted in Figure 5. After pretensioning, the bolt forces are above 46.1 kips, which is the minimum bolt pretension in Table J3.1M in AISC 360-10. Under service loads, the variation of the bolt tension was insignificant. As the beam deflected and the clamps started to slip, the shear force acting on the bolts increased, especially for those bolts at the ends of the beam, and thus the bolt tension declined gradually.

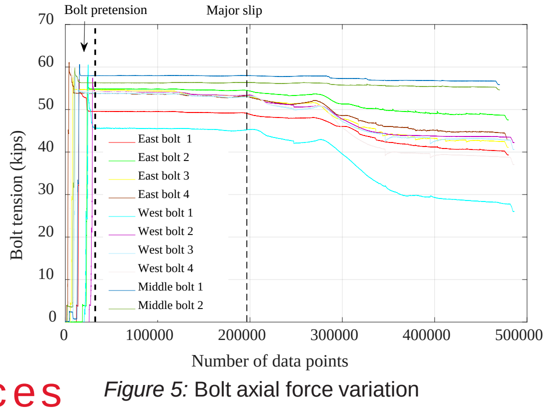
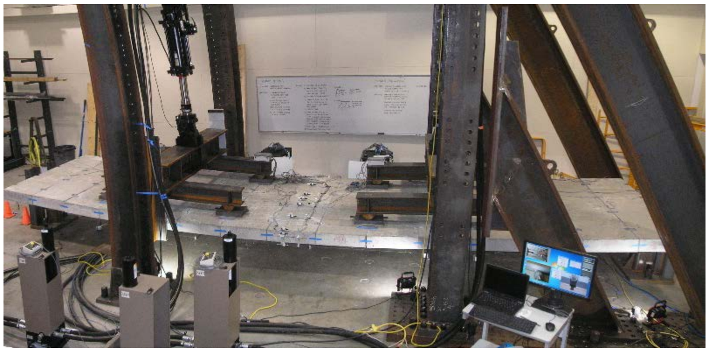


Figure 5: Bolt axial force variation



a) Beam test under deflection (Photo: SGH)

b) Concrete crushing at west interior loading point (plastic hinge region)

c) Longitudinal concrete cracks (parallel to the steel beam)

Figure 3: Deconstructable composite beam test

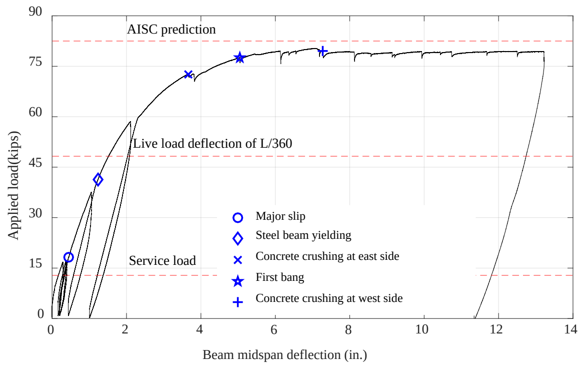


Figure 4: Load-deflection curve of Specimen 2

References

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