

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.

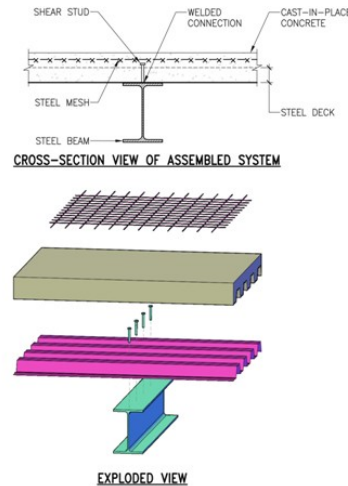


Figure 1: Conventional composite framing materials including steel mesh, steel headed stud anchors, concrete, and steel deck are not reusable; steel headed stud anchors must be removed prior to beam reuse.

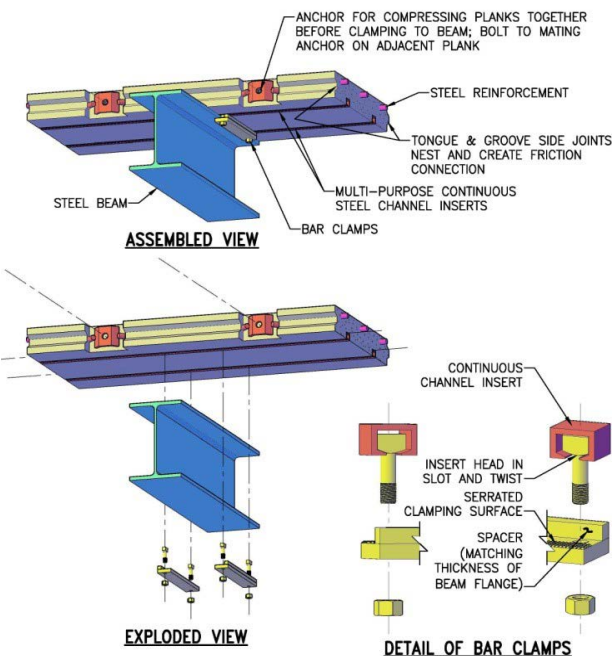


Figure 2: Proposed deconstructable floor system, consisting of precast concrete panels with steel channels embedded on the underside and tongue and groove side joints. Headed bolts, part of a bar clamp assembly, would be inserted into the channels and clamped to the steel beam top flange.

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 #3

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 floor system under gravity loading.

Figure 4 illustrates the load-deflection relationship of Specimen 3, which is a fully composite beam consisting of a W14x26 section and M20 clamps. The flexural strength of the beam is governed by the tensile strength of the steel section, rather than the shear strength of the clamps. The test was terminated after 16 in. of deflection. The initial stiffness of the beam is 36.9 kips/in., slightly larger than the AISC prediction using a lower bound moment of inertia of 34.2 kips/in. The peak strength of the beam is 59 kips, which corresponds to a bending moment of 364 ft-kips, 97% of the AISC prediction of 376 ft-kips. The maximum slip of the clamps is only 0.02 in. at the ends of the beam, since the percentage of composite action of the beam is 137.8%.

The bolt tension variation is plotted in Figure 5. After pretensioning, the tension of most bolts is above 31.6 kips, which is the minimum bolt pretension in Table J3.1M in AISC 360-10. Since the slip of the clamps is small, the shear flow the clamps resist is insignificant, and the bolts retain their pretension throughout the test.

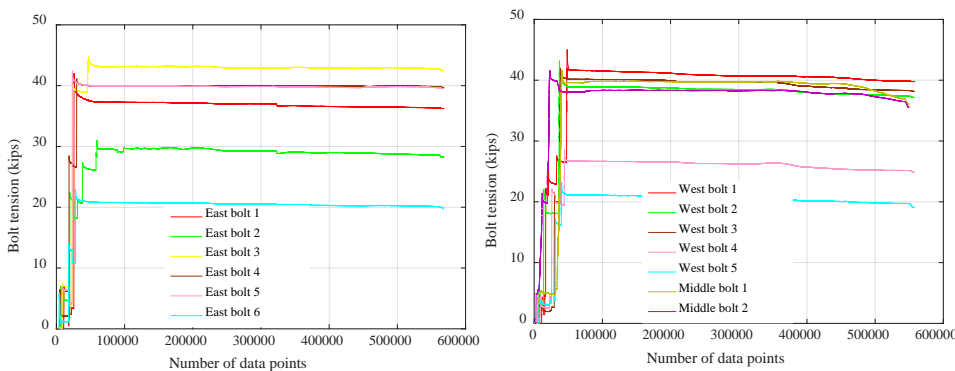
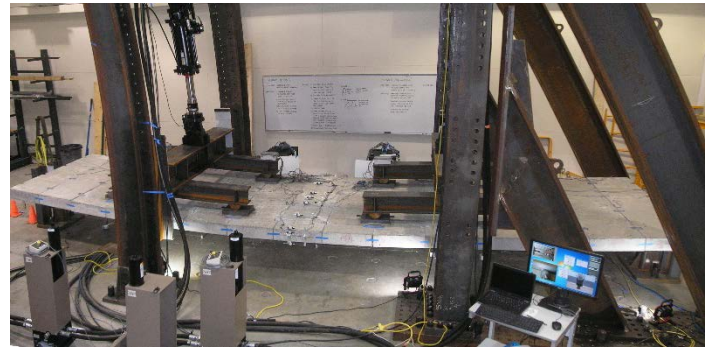


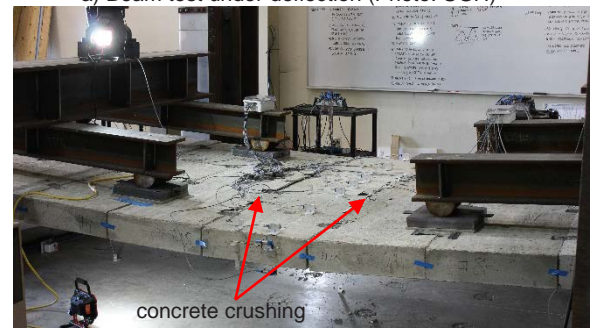
Figure 5: Bolt axial force variation

References

- [1] Renz, B. (2005). "Innovative Connections: ConXtech's systemized approach to steel construction streamlines and transforms traditional design and construction processes." *Modern Steel Construction* 45.8, 38, August.
- [2] Lawson, M., Ogden, R., Pedreschi, R., Grubb, P. J., and Popo-Ola, S. O. (2005). "Developments in Pre-fabricated Systems in Light Steel and Modular Construction," *The Structural Engineer*, 83(6), 28-35, March.
- [3] Lindapter (2011). *Steelwork Fixings Catalogue*, Lindapter, Bradford, U.K.



a) Beam test under deflection (Photo: SGH)



b) Concrete crushing at the center section



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

Figure 3: Deconstructable composite beam test

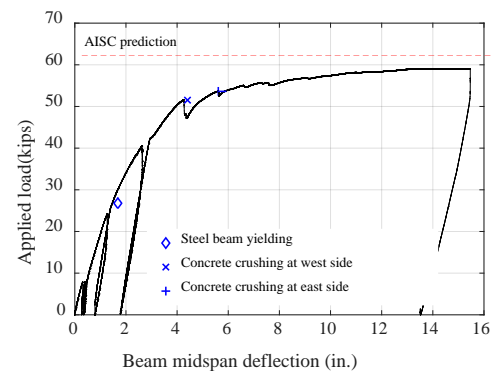


Figure 4: Load-deflection curve of Specimen 3