

Full Scale Experimental Test of the Girder-Slab Composite Floor System

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A full-scale test of the Girder-Slab composite steel and precast structural system was completed on April 30, 2009 at the 10,000 sq. ft. Structural Engineering Teaching and Research Laboratory at Villanova University. The objective of the research study was to observe behavior of the full-scale system under simulated field loading conditions. A variety of experimental measurements were made to evaluate load, deflections, and strains on the structural steel D-beams and surface of the hollow-core precast concrete slab. These measurements were used to evaluate strength and stiffness of the composite system. An overview of the test setup may be seen in Figure 1.



Figure 1: Overview of full-scale test setup



Figure 2: Hydraulic loading cylinders and load distribution elements

The full scale test specimen was designed to replicate two bays of the composite floor system in a low to high rise residential building, and measured 56 ft. long by 16 ft. wide. The test specimen was comprised of three 16 ft. long D-Beams (two exterior and one interior) and eight 28 ft. long precast hollow core concrete slabs (four in each bay). The system was fully grouted and reinforced per typical Girder-Slab construction procedures using #4 (1/2 in. diameter) rebar at 24 in. spacing. The entire specimen was elevated approximately four feet above the laboratory's strong floor using custom built steel stub columns outfitted with instrumentation to measure support reaction forces. The setup allowed for easy visual observation of the behavior of the test specimen under loading. Several companies assisted in the fabrication of the test specimen in the laboratory after delivery of individual components.

Load was applied to the full scale specimen using 25 ton capacity hydraulic cylinders spaced 4 ft. apart along the span of interest. The load from each hydraulic cylinder was then transformed to a uniform distributed line load using load distribution elements as shown in Figure 2. Uniform line loads were located either at midspan of the plank in either bay or over the interior D-beam. In total, nine tests were conducted on the full-scale specimen. Prior to the test to failure, the specimen was initially subjected to four initial service-level loadings corresponding to equivalent applied floor loads of 30 psf, followed by four identical tests to equivalent applied floor loads of 60 psf.

Extensive instrumentation was installed on the specimen to measure support reaction forces, D-Beam and slab deflections, steel strains, and concrete surface strains. A total of 119 measurements were recorded continuously using a high-speed data acquisition system. An example of instrumentation used to measure steel strains can be seen in Figure 3. The measurements will be used to better quantify specific section properties of the composite system for design. These critical properties include effective width, section modulus, and moment of inertia, which are used to compute elastic flexural stresses in the composite D-beam/slab system, as well as deflection of the D-beam under service-level loading.

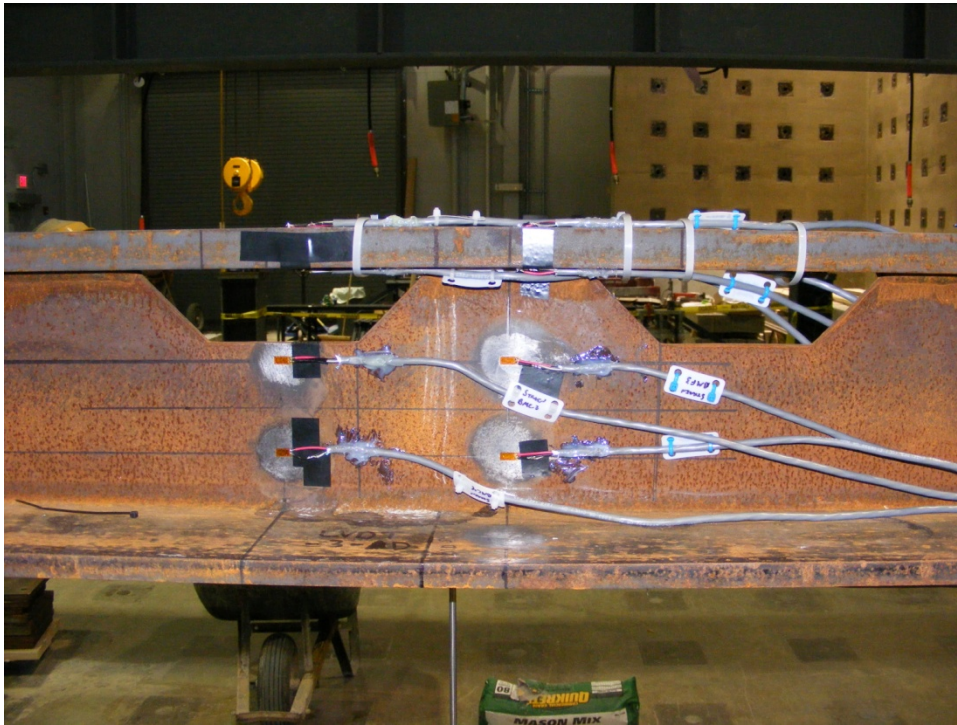


Figure 3: Instrumentation of the steel D-beam for strain measurement

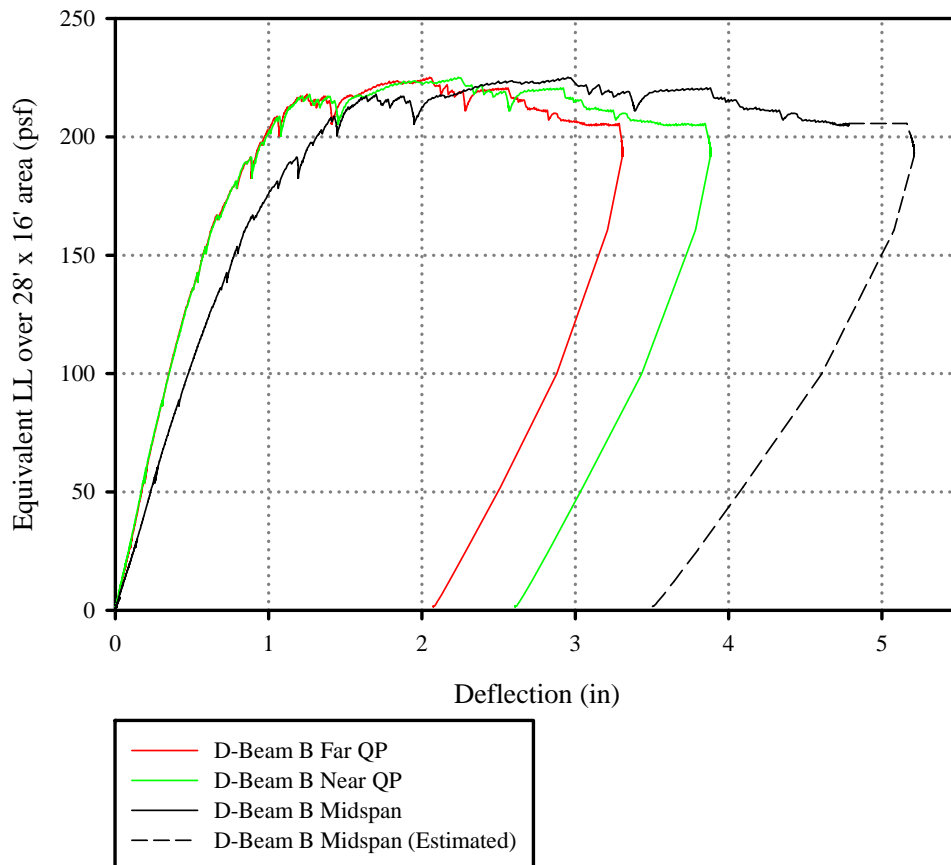


Figure 4: Equivalent floor load vs. interior D-beam deflection (test to failure)

A plot of equivalent applied floor load vs. interior D-beam deflection may be seen in Figure 4. The full-scale specimen performed extremely well during the full-scale test, and resisted an equivalent applied floor load of 225 psf prior to failure. This equivalent load is roughly four times a typical service live load plus partition load of 60 psf, and is in addition to the approximately 60 psf corresponding to the self-weight of the system. The specimen proved to be extremely ductile, as noted by the large deflections at failure shown in Figure 4.

Failure was defined by shear cracking of slab on either side of the interior D-Beam after significant yielding of the D-Beam. Shear cracking was first observed at an equivalent applied load of 191 psf, and continued to propagate under further loading. It is noteworthy that a true collapse condition was never achieved; rather the specimen was unloaded after the slab shear cracking caused severe distortion of the specimen, as shown in Figures 5 and 6.

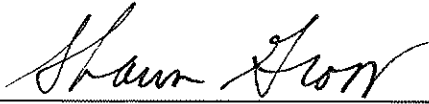


Figure 5: Failure of test specimen was defined by shear cracking of slab

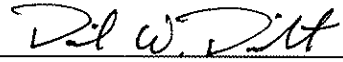


Figure 6: Test was stopped after severe distortion of slab due to shear cracking

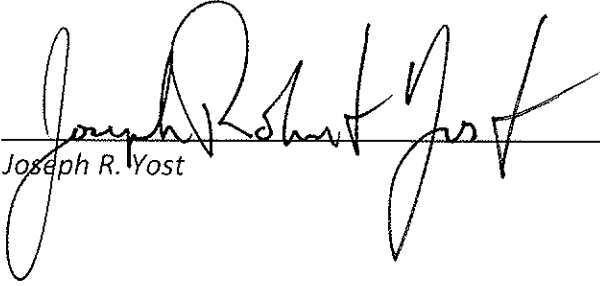
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