Structural Steel "Flat Plate" Construction

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Using a system of custom-fabricated steel beams to support hollow-core plank enables quick and economical construction of low floor-to-floor height structures.

FLAT PLATE FLOOR SYSTEMS offer several advantages over other floor framing systems—the primary one being the ability to build structures with low floor-to-floor heights. Low floor-to-floor height is a standard requirement for most residential projects such as apartments, condominiums and university residence halls. Flat plates are usually associated with materials other than structural steel; however, when Girder-Slab Technologies developed the D-Beam® 10 years ago, it opened the door to using steel framing in a flat plate system.

D-Beams are shallow, structural steel beams custom-fabricated from wide-flange shapes and steel plate and configured to support precast hollow-core plank in a manner that buries them within the depth of the plank (see Figure 1). The resulting floor system is essentially a "flat plate" where few, if any, steel beams protrude below the bottom of the plank.

The D-Beam is the heart of the Girder-Slab® System, and also is the way by which Girder-Slab licenses fabrication of D-Beams to fabricators. Steel fabricators bidding Girder-Slab projects request a license fee from Girder-Slab when preparing their bids. The fee is added to the bid price and the successful bidder pays Girder-Slab Technologies the license fee, which allows them to fabricate D-Beams and to assemble the beams in a manner that achieves composite action with the hollow-core plank.

The composite action between the D-Beams and the grouted hollow-core provides an in-slab girder with flexural strength much greater than that of the steel beam acting alone. It is both the D-Beam and its composite action with the plank that have been patented by Girder-Slab Technologies.

The company has developed six different D-Beam sizes as well as a design procedure for use by designers for sizing the members. The design procedure is explained in a design guide that is available at no cost on the Girder-Slab website, **www.girder-slab.com**.

A Recent Project

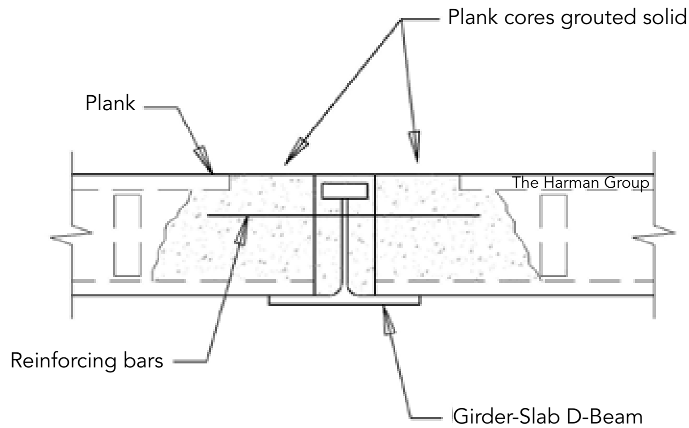
Rutgers University
Camden Housing Project Details

Tower square footage:	161,653 sq. ft
Number of floors:	12
Steel tonnage:	600 tons (7.4 psf)
Construction started:	April 2011
Steel erection started:	July 2011
Steel topped off:	September 19, 2011

One example of a project using Girder-Slab construction is on Rutgers University's Camden, N.J., campus. When the university recently was looking to build a new residence hall, several alternative structural systems were investigated. The goal was to select a framing system with the following characteristics:

- Economical
- Non-proprietary system
- Fast construction
- Low floor-to-floor height
- Accommodation of other trades to permit fit-out on lower levels while building above
- Easy accommodation of alternative facade systems
- Open space on ground
- No transfer girders
- Flexibility to permit architectural expression

A structural steel frame with Girder-Slab D-Beams supporting hollow-core plank met all of the requirements. Once the system was selected, the design team worked closely with the construction manager, the steel fabricator and Girder-Slab Technologies to optimize the design to best suit the fabricator's fabrication and erection preferences.



➤ Figure 1: Section through a Girder-Slab D-Beam.

Simple but critical issues included omitting column stiffeners, designing and documenting all connection details on the contract documents, eliminating perimeter spandrel framing parallel to the plank span and coordinating between the structural system and mechanical systems to eliminate issues between the two that often arise during construction. Coordination and attention to detail by the design team permitted construction to progress at a rate of 16,000 sq. ft per week (see Figure 2).

As with any framing system, the key to economical design is familiarity with details and constraints. The structural engineer, the Harman Group, was familiar with the Girder-Slab System, having previously designed five Girder-Slab projects. The steel fabricator, Berlin Steel Construction Company, also was experienced in using this system. The Rutgers-Camden project was its 13th Girder-Slab building. Additionally, Dan Fisher, Sr., the managing partner of Girder-Slab, provided excellent support throughout the project. A steel fabricator for more than 30 years prior to starting Girder-Slab Technologies in 2002, Fisher's expertise in steel fabrication and erection was an invaluable resource to the team during design.

The Rutgers Camden project was delivered on budget and ahead of schedule. The versatile combination of structural steel framing with Girder-Slab D-Beams provided Rutgers University the perfect answer to its need for more student housing.

More About the System Efficiency

Girder-Slab-framed floors are extremely economical. The basic weight of the D-Beams on the typical floors in the Rutgers project was about 1.5 lb per sq. ft. That allowed flexibility in the project budget for some remarkable architectural expression, such as a cantilevered corner in the northeast quadrant of the building.

Erection with this system is quick. All-bolted construction permits the steel to go up fast. After the floor framing is in place the hollow-core plank is placed, reinforcing steel is installed through the D-Beams into the ends of the plank and the plank ends are grouted (Figure 1).

▲ Figure 2: The fully erected and planked structure in mid-September 2011.

▼ Figure 3: By the first week of January, 2012, the structure was almost fully enclosed.

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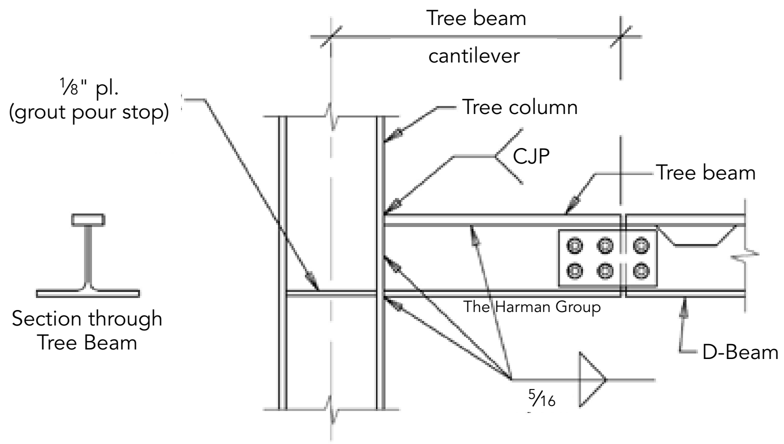

Figure 4: Tree columns are used to increase column spacing.

Figure 5: Tree columns in place.

Efficiently Configuring D-Beam-Framed Floors

The practical span limitation is about 18 ft for 8-in.-deep D-Beams supporting 8-in. hollow-core plank spanning up to 30 ft. Column spacing can be increased by shop welding cantilevered beams to the columns, commonly referred to as "tree columns" (see Figures 4 and 5). The cantilevered "tree beams" on the tree columns have the same configuration as the D-Beams, but are non-composite members resisting the negative bending moment. When tree columns are used, column spacing can be increased to about 23 ft, although span limits vary depending on member sizes, plank span and loads. D-Beams are used only where required. Conventional W-shape framing should be used where possible, such as at spandrels, on braced frames and at other locations where the use of W-shapes can be accommodated.

Lateral Load Resisting System and Floor Diaphragm

Lateral loads in steel-framed structures with hollow-core plank floors typically are resisted with braced frames and/or moment frames. Braced frames and moment frames must be configured to work within the span limitations of untopped hollow-core plank diaphragms. Typically, this requires placing braced frames in every second or third bay perpendicular to the plank span. This arrangement limits diaphragm spans to manageable dimensions and better mobilizes the dead load of the structure in resisting the overturning moments from lateral loads. The greater the number of braced frames used, the smaller the net tension forces will be in the columns and foundations. Single strut 4-in.-wide HSS diagonal braces should be used when possible because these narrow members fit well within standard walls.

On the Rutgers-Camden project a single braced frame was configured parallel to the long direction of the building. A continuous drag strut was installed parallel and adjacent to the corridor to tie the building together and to collect lateral loads along the length of the building to transfer them to the braced frame. An alternative to the single longitudinal braced frame would have been to provide W12 spandrel beams and moment frames along the exterior column lines.

The use of a 2-in. structural topping slab can greatly increase the spanning capability and strength of the floor diaphragm. Topping slabs are required on projects where seismic forces are of a magnitude that precludes the use of untopped plank diaphragms. The disadvantage of a structural topping slab, however, is that it adds several dollars per sq. ft to the project cost and may introduce issues related to pouring the topping slab during the winter months. When a topping slab is not used, a ¾-in.-thick self-leveling material should be specified in order to achieve a level floor finish. Significant camber can occur in hollow-core plank and the leveling material will serve to provide a more level floor. The self-leveling material can be installed after the building is enclosed.

Spandrel Beams

Spandrel beams spanning parallel to the span of the hollow-core plank may be eliminated when the plank is designed to support the facade, or when the facade is panelized and designed to span column to column. Eliminating the spandrel beams will reduce steel tonnage, however attention must be paid in providing continuous chord reinforcing steel within the plank floor diaphragm that would have otherwise been provided by the spandrels.

On the Rutgers-Camden project the spandrels were eliminated. The plank was designed to support the facade and continuous chord reinforcing steel was provided in the edges of the plank.

Conclusion

Steel-framed structures using Girder-Slab D-Beams to support hollow-core plank floors often provide the most economical solution for mid-rise residential construction. The system's low weight, compared to cast-in-place concrete construction or masonry bearing walls, results in lower foundation costs. As a structural system, it offers low floor-to-floor heights and fast, year-round construction. The hollow-core planks provide good sound attenuation and a flat soffit that eliminates conflicts with mechanical systems above ceilings. Because the system is patented but not proprietary, fabricators pay a project-specific license fee to fabricate D-Beams in an arrangement that benefits owners by allowing all steel fabricators to bid on Girder-Slab projects. MSC

Developer
Michaels Development Company dba Camden Student Housing, LLC, for ownership by Camden County (N.J.) Improvement Authority

Architect
Erdy McHenry Architecture, Philadelphia

Structural Engineer
The Harman Group, Inc., King of Prussia, Pa.

General Contractor and Construction Manager
Joseph Jingoli and Son, Inc., Lawrenceville, N.J.

Steel Fabricator
The Berlin Steel Construction Company, Malvern, Pa. (AISC Member)

Steel Erector
JL Erectors, Inc., Blackwood, N.J. (IMPACT Member)

The Matter of Cost

Comparing the cost of one project with the cost of another is difficult. Differences in location, economic conditions and the specific geometry of projects make dollar comparisons misleading. For example, some additional steel cost on the Rutgers-Camden project went into the cantilevered corner at one end of the building. However, had this been a plank and masonry bearing wall project we would not have been able to cantilever the corner as we did on this project. Likewise a masonry bearing wall building would have required costly transfer girders below the second floor to provide the required open space on the first floor.

Structural engineers often are judged by the "pounds per square foot" of steel on the project. Averaging 1.5 psf for basic floor framing on this project is extremely low, as is 7.4 psf overall. But even with such good structural efficiency, structural steel would not even have been considered were it not for the low floor-to-floor heights achievable with the Girder-Slab system.