New Alternative To Flat Plate Construction

A new proprietary steel system presents a cost-effective alternative for residential design

The four-story, 70,000-sq.-ft. hotel, "The Inn at Somerset Hills" in Somerset County, NJ, is one of the first completed Flex-Frame projects in the U.S.

By Peter A. Naccarato, P.E.

Ever since the 1993 revision to the BOCA Seismic Section, the block bearing wall type of construction has begun a slow demise. The revision created three distinct disadvantages:

- Lateral loads increased
- Lateral loads were equal in all directions
- Reinforcement of the masonry walls was mandatory

For more than 40 years, Costanza Contracting Company, a General Contractor, AISC-member Fisher Steel, Inc., a Structural Steel Fabricator, and O'Donnell & Naccarato Inc., a Structural Engineering Design firm, have been active in design, fabrication, and construction. Among their projects have been millions of square feet of plank and bearing wall buildings for apartment houses, hotels, condos and adult living, retirement and nursing homes—structures with bearing walls up to 10 stories in height and little or no steel wall reinforcement.

Also, since wind was the governing lateral load on these low- to mid-rise structures, the demising walls, which acted as bearing walls, functioned as shear walls to resist lateral loading at no additional cost. As a result of the BOCA revisions, the trio of forms joined to start a new company call Flex-Frame L.L.C.

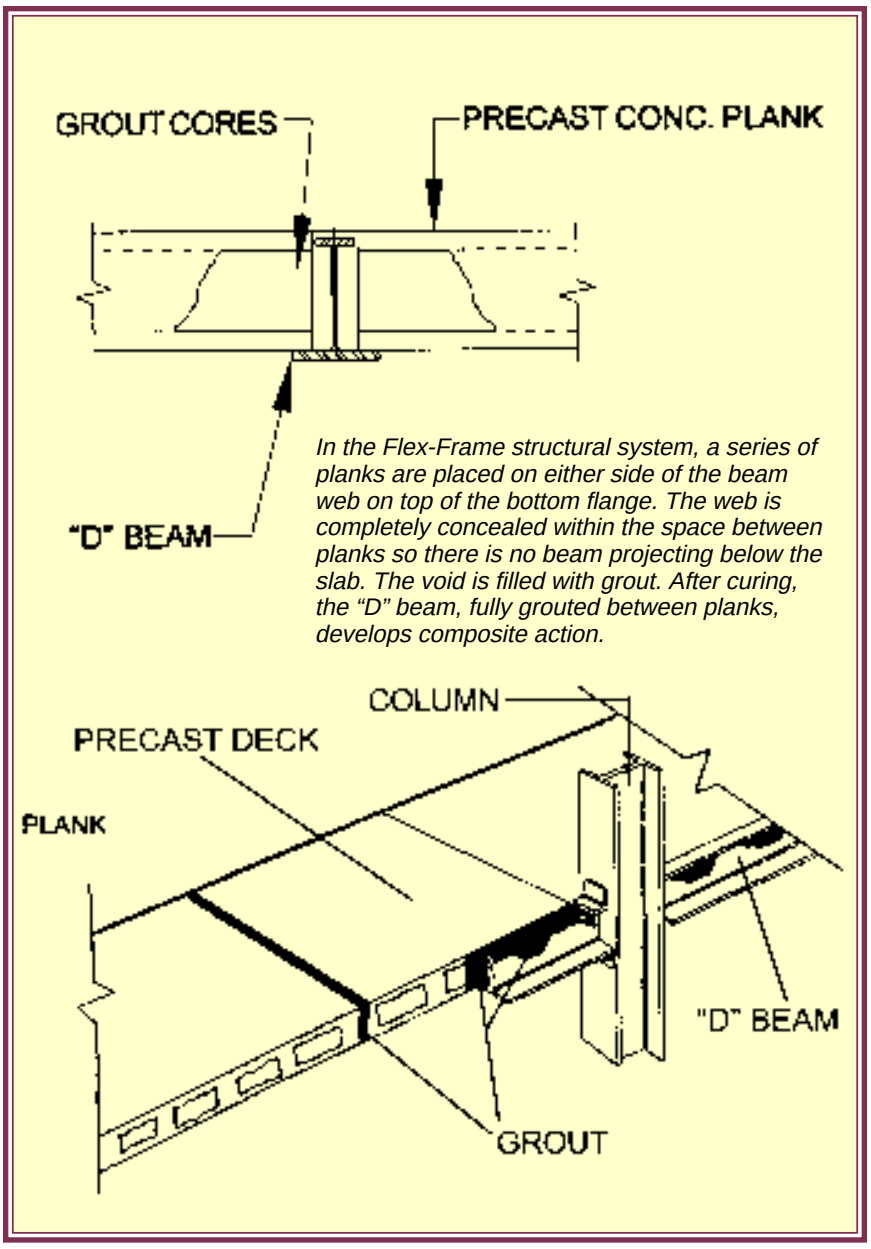
A New Design

Flex-Frame's sole purpose was to set about perfecting a steel

and plank design—a design that could take the place of the plank and bearing wall system. Knowing that the primary alternative to plank and bearing wall would be cast-in-place flat plate construction (the most expensive structural system in the Philadelphia area), the new company designed and built several residential buildings with the use of conventional structural steel and prestressed precast plank. Unfortunately, this system had both pros and cons. The advantage was its low cost when compared to cast-in-place flat plate construction; the disadvantage was that the rolled steel shapes beneath the floor slab necessitated an increase in the floor-to-floor height, resulting in an increased height of 2'-0" per floor. Also, ceilings and soffits were needed to conceal the steel beams, and holes had to be cut through the beam webs to accommodate pipes and ducts.

In order to solve the floor-to-floor and interference problems, the company implemented a research and development program. It wanted a system where the interior structural steel girder could be placed within the plane of the precast plank, thereby producing a flat plate system with a floor to ceiling height of 8'-0". The key to the system would be the development of a unique steel section, which could provide the plank support with only an 8" depth while spanning a respectable distance. If the system could be designed and fabricated to provide interlocking,

the appropriate steel shape could develop composite action with the precast plank and cast-in-place grout.



In the Flex-Frame structural system, a series of planks are placed on either side of the beam web on top of the bottom flange. The web is completely concealed within the space between planks so there is no beam projecting below the slab. The void is filled with grout. After curing, the "D" beam, fully grouted between planks, develops composite action.

Testing Begins

After a significant collaboration between O'Donnell & Naccarato, Inc. and Fisher Steel, a steel section was fabricated for testing purposes. The beam, which resembled a large rail section, was a combination of two split tees. The lower tee was cut from a W8 x 40 and the upper tee from an S3 x 7.5. The result was a dissymetric beam 8" deep. It provided a bearing ledge for the plank, which could be installed from above in a level position. The beam and plank were interlocked by cement grout. This system was tested at Fisher's plant and it was positively determined that composite action was developed between the steel section, the grout, and the precast plank. Based on this revelation, Flex-Frame L.L.C. agreed to fund professional testing.

The Structural Engineering Department at Philadelphia's Drexel University was selected to provide the testing. A Professor of the Structural Engineering Department, Mohamed Elgaaly, Sc.D., P.E., headed up the project for Drexel University. Prior to beginning the testing program, calculations were performed to predict the load carrying capacity of various sections. During that time, it was decided that the steel section would be changed in order to guarantee a homogenous and uniform bond between the structural steel and the precast concrete. The beam was now formed by castellating a W10 x 49, so as

to provide two equal tees with "half castellations" in each tee. A 1" x 3" continuous flat bar was welded to the high points of the web sections. The resulting dissymetric beam measured 10" across the bottom and 3" along the top, leaving 3 ½" for plank bearing on either side of the beam. The "half castellations" permitted the free flow of grout through the beam. The testing program proved that composite action was created in all of the test specimens. It was then decided that a full-scale test should be performed in order to uncover any problems that might arise during construction of the actual system.

To complete the final stage of testing, a full-scale two bay system was constructed. A structural steel dissymetric beam spanned 16' between supports, holding up planks spanning 28' on either side of the dissymetric beam. The tested area measured 16'-0 x 56'-0. The system was loaded with a series of solid concrete "dead men" weighing 2,400 lbs. The system was loaded to 140-lbs. psf, which was almost four times the design live load. At that point, one of the planks developed a shear failure, thereby ending the test. The dissymetric beam did not fail.

The testing concluded that this system has five major advantages:

- Low cost
- Low floor to floor height
- Fast erection
- Materials prefabricated under controlled conditions
- Can be constructed during most weather conditions

Marketing the System

The Flex-Frame system is now being marketed as an alternative to flat plate construction. Its primary effectiveness is in the residential market, where regularly spaced partitions can be used to conceal the columns and cross bracing. The lateral bracing system for the building consists of cross bracing in the short direction and moment frames in the long direction. The spandrel beams, columns, and other miscellaneous items consist of conventional steel shapes designed, fabricated, and erected in accordance with AISC requirements.

The interior girders are the dissymetric beam and span the short direction of the building and are fastened to the columns with end plate connections. Only foundation considerations and the ability to introduce lateral load restraining systems limit the total height of the building. Flex-Frame L.L.C. is communicating with a national steel supplier interested in providing the dissymetric beam who have expressed an interest in becoming an approved source of the beam. In addition, fabricators would have the option of manufacturing the beam in-house or ordering it through a service center.

This structural system will make it possible for the steel industry to compete with the cast-in-place concrete industry for a larger share of the multi-family residential market. The steel industry's share will continue to grow as the industry responds to seismic and other restrictive code practices. The structural steel industry will now share in a market, which was heretofore primarily cemen-

titious. Flex-Frame L.L.C. is the exclusive licensee for the patent in the United States, with international patents pending. A licensing fee must be paid to Flex-Frame L.L.C. in order to use it. However, none of the individual materials are proprietary. This approach allows the general contractor/owner to procure the plank, steel, and grout through his normal purchasing procedures.

Putting Flex-Frame to Use

At the present time, one project has been completed, two projects are under construction, and two projects are in design utilizing the Flex-Frame system. The completed project is a four-story, 70,000 square foot hotel, "The Inn at Somerset Hills" in Somerset County New Jersey. Steel, plank, and grout were installed in 18 working days. A senior housing project and a residential housing project are in progress.

The Flex-Frame system brought flexibility to the hotel project. The more common plank and bearing wall system could not be utilized because the bearing walls would interfere with ground floor functions. In the case of a senior housing project, the building is to be constructed in an area with a building height limit. Zoning would not permit a floor-to-floor height greater than 9' –0".

Costs have been completed for the Inn at Somerset Hills and cost estimates have been completed on the residential housing project. In the case of the hotel, actual estimates of $16.00 per square foot are confirming the predicted savings. In the case of the senior housing building, projected savings are much higher than predicted because of the increased cost of cast-in-place flat plate concrete ($16.00 vs. $22.00 per sq. ft.).

AISC-member Fisher Steel, Inc. of Bellmawr, NJ has fabricated all of the dissymetric beams. They have employed a structural service center to provide the castellated tee. Fisher is attaching the top flange flat bar with his own certified welders. The automated cutting procedure utilized by the service center produced a castellated tee for about the same cost as a split tee. These savings will pass through to the building owner.

The formal introduction of this system to the industry occurred during the AISC Convention in Toronto. Flex-Frame staffed a booth depicting the components of the system and discussed the system from engineering through fabrication and erection, and the ramifications to the general contractor/ construction manager.

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