STEEL BRACING STABILIZES CONCRETE BUILDING

By Zareh B. Gregorian, P.E.

The conversion of a parking structure to a high-tech manufacturing facility required removal of part of the existing floor slab and the addition of lateral bracing

WHEN FRAUNHOFFER, ONE OF THE WORLD'S LEADING MANUFACTURING/ ENGINEERING RESEARCH ORGANIZATIONS agreed to a joint venture program with Boston University, the first step was to find a facility to house the program. Since one of the purposes of the program was to enable graduate students to work on and solve real-world business problems, it was clear that an on-campus site was most desirable.

After careful examination, it was decided that the most practical solution was to convert an on-campus concrete parking garage dating from the 1920s into the needed state-of-the-art manufacturing facility—complete with high-tech machinery and cutting-edge video conferencing and communication capabilities.

The project called for 28'x122' of research space with a concrete slab to carry a live load of 2,000 psf and a 10-ton capacity overhead crane. Cannon, the project's architect, determined that the nearly rectangular footprint of the two-story garage could meet the project's needs with the addition of a high-bay area in the center of the building to accommodate the overhead crane. The perimeter of the building would then be used to house a variety of machines, including stereolithography and laser machining tools, for use in the manufacturing engineering process.

An 18"-thick heavy duty slab was constructed in the high-bay area to accommodate the 2,000 psf live load. In addition, this area was isolated from the rest of the building where moderate and highly sensitive equipment is used.

The existing reinforced concrete building included a partial basement, a first floor and a mezzanine floor. The lower story was formed of four rows of concrete columns carrying a longitudinal girder supporting T-beam slabs spanning between longitudinal girders. The roof was covered with steel trusses span-

As part of the conversion, the central portion of the building was removed and replaced with a high-bay area and a slab capable of carrying a live load of 2,000 psf..

ning between end walls and resting on concrete columns extending from the lower floor and creating a column-free space at the upper floor.

Due to a lack of structural drawings, a complete survey of the building was done to identify the sizes of the various members and other building elements. Destructive and nondestructive tests were then performed to identify the existing condition and strength of the structural components. Likewise, sizes of footings and subsoil conditions were investigated by the soil engineers.

The tests and investigations were performed in accordance with the requirements of the project structural engineers and with the aid of ACI437-R-91 “Strength Evaluation of Existing Concrete Buildings.”

STABILIZING THE STRUCTURE

Creation of the high-bay area required cutting and removing a large portion—one bay out of five total bays in the building—of the first floor slab in order to provide the necessary ceiling height. Removing this large section of slab, however, created a stability problem. Various bracing schemes, including X-bracing or shear walls on the inside were considered but eliminated due to architectural or open-space requirements. Also, buttresses could not be used on the outside of the building since the structure abutted the Massachusetts Turnpike.

The solution was to use steel beams to tie the columns of the adjacent bays to the first floor ceiling elevation.

As a first step to designing the bracing, an arbitrary force P was applied to a typical frame and the corresponding deflection was calculated. The calculations were then repeated with the slab removed for the crane opening but with steel reinforcing applied. W16 steel beams were chosen for the reinforcement on the basis that the same amount of deflection was achieved with that size bracing and the slab removed as existed with the slab in place.

Cutting of the slab was performed by light weight equipment to avoid transfer of excessive force and vibration on the structure.

Once the moment in the connection of the steel beam to the column was calculated and the in-situ design load capacity of the anchors was determined, the connection was designed accordingly. Steel beams were installed at the first floor ceiling elevation to tie the exterior and interior columns. Connection of the steel beams to the concrete columns was accomplished with a pair of 8”x8”x½” steel angles on the top and bottom of the beam, anchored to the column with ¾”-diameter epoxy anchors. The epoxy were tested to have 5 kips of design load pull-out strength each.

Crane Structure Design

The opening created for the crane provided a limited space of 12” on each side for the installation of the crane columns. This increased the weight of the crane columns but was necessary due to the tight space. The height from the ground floor slab to the bottom chord of the steel roof trusses was hardly enough for operation of the crane trolley, leaving no space to tie the top of the crane columns in the transverse direction.

As a result, in order to tie the top of the crane columns, the top 8’ of the columns had to be converted to a fork extending to the sides and barely touching the existing trusses. The two columns forming the fork were then tied with beams at an elevation higher than the bottom chord of the roof trusses. The tie beams were then connected with horizontal members passing through the openings of the roof truss.

This “fork” design was discussed with the architects at Cannon, including Paul McGowan, senior vice president, and Drake Jacobs, project manager. Their input helped develop the details for stabiliyt of the crane using steel knee braced frames in the long direction, which followed the same shape and angle of inclination as the existing haunched concrete beams of the second floor, thus creating a consistent visual image between the existing and new structural materials despite the differences in material.

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The close cooperation between the architect and structural engineer also helped in fine tuning and developing the exposed steel details. The project was built on a tight timetable and was successfully completed in part due to the quick decision making of the owner's team, which included Gus Stathis, Director of Project Management, and Ed Shamons, Assistant Director of Project Management at Boston University's Department of Physical Plant.

The Manufacturing Engineering Resource Center will serve to produce the latest in manufacturing machinery and to facilitate the rapid prototyping and tooling that can speed new products to market. According to Professor Peter Z. Bulkeley, who heads the laboratory and was the driving force behind the project, "...the whole building will be 'wired' for video cameras so class participants can see what faculty and researchers are talking about." In addition, the center plans to offer short courses on the latest manufacturing technology and processes to engineers and others at manufacturing firms.

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