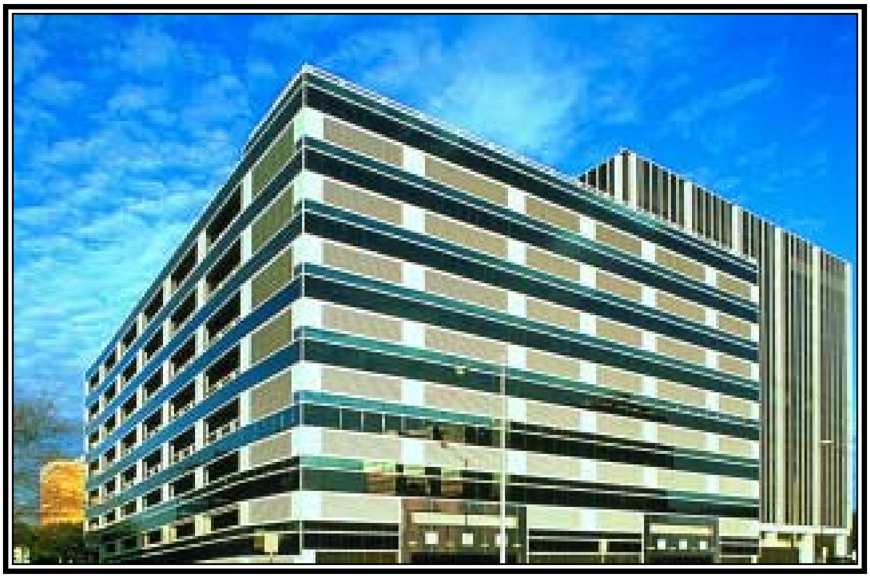


VERTICAL EXPANSION

Faced with a need for more parking spaces, a Houston-based owner had no where to go but up

By David H. Sadeghpour, P.E.

WHEN THE OWNERS OF AN OFFICE/GARAGE COMPLEX IN HOUSTON WERE FACED WITH A SHORTAGE OF PARKING SPACES, they considered a variety of options. Their goal was to at least double the available parking spaces—some of which could be used to enhance the leaseability of the attached office tower, with the remainder to be rented for additional revenues.

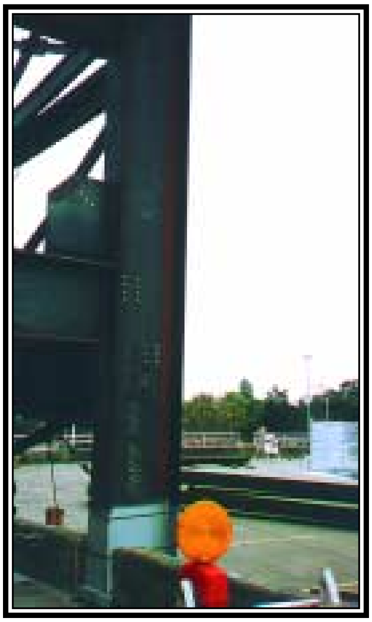
Since no more land was available in the Texas Medical Center, their first thought was to build an off-site garage and provide shuttle service. However, this was rejected because of the cost involved and because tenants didn't want a long travel time. Ultimately, after careful study, it was decided that the most time and cost effective solution would be to vertically expand the existing parking structure. This option not only eliminated the need to purchase expensive land for additional parking, but would alleviate any additional management problems or costs.

The existing four-story garage, which was built in 1962, was a cast-in-place concrete frame with single-tee flooring in a double-tear, two-way traffic configuration. The first step in designing the addition was to take a careful look at the existing structure. An early assessment of the structural condition of the garage revealed that it was much in need of repair and modernization. In addition, the structural engineers examined existing design drawings and used non-destructive testing to analyze the existing columns, footings and basement walls to determine their capacities for vertical expansion. Also, a new soil test was conducted to investigate the reserved capacity of the soil to bear new loads. Unfortunately, no construction or shop drawings were found, so the burden of discovering the as-built conditions fell solely on the site inspectors and testing laboratories. Adding to the complexity was that all of the site testing had to be performed after normal business hours in order to minimize any inconvenience to existing tenants.

During the testing and review process, it was discovered that the original design called for a small future vertical expansion, but it had never been built. At the same time, however, a few design flaws were discovered. For example, we found that a continuous strip footing that was built right on the south property line did not have adequate shear capacity. In addition, a basement wall and the columns that sit on the tip of the footing could cause excessive overturning, which could result in moving and bending the entire system outward.

The shear problem was solved by digging and placing a new concrete grade beam on top of the existing footings and connecting it to the column caps at approximately eight feet below the lowest point of the basement. The overturning problem was solved by introducing a new steel beam at street level and attaching it to the interior columns by epoxied bolts, thereby sharing the horizontal force with more structure and reducing its effect on the exterior structural system.

While successful, this solution did present some construction difficulties. The contractor had only minimal space with which to work and low floor-to-floor heights limited equipment access. A complex system of drilling and attaching to the existing structure was designed and excavation was phased in alternate bays, which left one bay intact at all times and reduced the danger of the four-story wall moving outward and collapsing during construction.



New Construction

After careful analysis of the existing structure, it was determined that by strengthening the existing concrete columns and some footings, enough capacity could be acquired to support a six-story steel structure on top of

the existing garage. The six-story addition would add 155,000 sq. ft. and increase the available parking from 302 spaces to 672.

In addition to the obvious problems of meeting wind loading, life safety, fire safety and handicapped access requirements, the project was complicated both by the need to keep the existing garage open during construction and by the tight parameters imposed by the site. For example, because of tight garage clearances, no new columns were allowed to continue down into the existing structure. Also, the existing footings were located up to 18-ft. below the lowest basement level, which would have made the excavation and conStructability of new footings very difficult and extremely expensive. Therefore, it was decided that the new structure had to closely follow the existing grid. In addition, the owner required that the height of the new structure be as low as possible so as to only minimally affect the views of the attached office tower.

As a result of all of the conditions imposed on the new construction, light-weight concrete and metal deck floors were chosen in conjunction with composite steel beams with headed studs. This design limited the dead load of the new structure, which allowed for more vertical expansion and both eased and speeded construction.

Minimizing Columns

The parking structure is rectangular and measures approximately 196-ft.-by-129-ft. To minimize columns, W30 girders as long as 64-ft. were designed. However, these girders proved to be difficult to erect so they were cut in half and moment spliced at the job site. Typical beams were W14s.

In the middle of the garage, where two sloping ramps frame into one column, heavy beam sections were used for columns due to dimensional limitations. This eliminated the problems associated with placing two new steel columns, side-by-side, on a small steel base plate—the size of which was dictated by the concrete columns on the existing levels. In addition, this unorthodox design allowed for connection of two separate ramp beams into the web of one column, which was easier to detail and erect. The other benefit was in the stiffness of the beam/column section for lateral wind bracing.

The existing perimeter and side concrete columns were enlarged to withstand the new loads. However, these columns could only be enlarged on two sides since the other sides were either protruding into parking spaces or to the exterior skin. The enlargement was accomplished by drilling and epoxing dowels into the sides of the columns and then forming new concrete columns adjacent to the existing columns. The process was very time-consuming and was made even more-so by the requirement that the work be done at night to avoid inconveniencing tenants. Load transfer analysis was performed to determine the workability of the design and to reduce the size of the new column additions as much as possible since the bigger columns reduced the amount of open space required for natural ventilation and reduced visibility.

The next challenge involved attaching the new steel superstructure to the top of the existing columns and to the side of the last existing ramp. The existing column sizes dictated the dimensions of the new base plates, which resulted in unusually thick (some up to 4-in. thick) high-strength base plates. All of the base wind shear had to be transferred into the existing structure with anchor bolts drilled and set in epoxy atop the existing columns. Drilling operation was very slow because of the congestion of rebar in the column-base joints and since no longitudinal beam rebar could be cut during this operation. Often, the holes had to be drilled at irregular plan dimensions and the results of a successful bolt hole were conveyed to the engineer and steel fabricator, who then reconfigured the plate's bolt holes. In addition, the existing sloping structure made the column heights variable. As a result, the detailing of the steel was extremely difficult. Fabricator on the project was AISC-member Ennis Steel.

The slope in the parking garage also meant that the first new floor couldn't be attached to the new columns. Instead, it had to be attached to the existing concrete beams. This was accomplished by drilling horizontal holes and setting the bolts in epoxy. As a result, the designer needed to check and verify the shear capacity of the existing beams and place the new girders at places where the effect of the new loads would be minimized and the existing concrete beams could take the additional imposed shear load.

X-Bracing

The wind bracing system chosen for the addition is a combination of double angle offset K braces at the interior columns and X brace frames at the ends of the building. This eliminated the need for a moment connected frame, which would have been costly and not very efficient due to the interruptions at the interior bays by new elevators and stairs. Because spans are longer in parking structures than in many other building types, the combined gravity and wind moments are very high at a moment connected joint. At the same time, because of sloped floors, many girders do not connect at the same elevation on each side of the column. The combination would have increased the column sizes, which were limited by the size of the base plates. A cost study showed a savings of $500,000 by using a braced frame instead of a moment frame.

Four new elevator banks and

two new stair shafts were required by the owner and the current building codes to extend all the way to ground level. The space available for these new penetrations was very tight and the openings were created by cutting the flange of existing single tees and placing the new structure inside of them. Inches were important and a survey was performed to make sure that the webs of these tees lined up. An analysis of the existing tees revealed that the flanges could be cut and the surfaces epoxied.

Several traffic flow studies were performed to maximize the number of available parking spaces and to provide for ease of traffic movement during peak hours in the tall, slender garage. The existing parking structure had only one two-way entrance/exit, which was insufficient for the greater traffic volume expected with the addition. The parking structure was configured into a threaded continuous helix and two new exits and one new entrance was added.

Architect on the project was Prozign Architects, Inc., Houston, contractor was Turner Construction Co., Houston, and traffic engineering was performed by Carl Walker Engineers, Dallas.

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