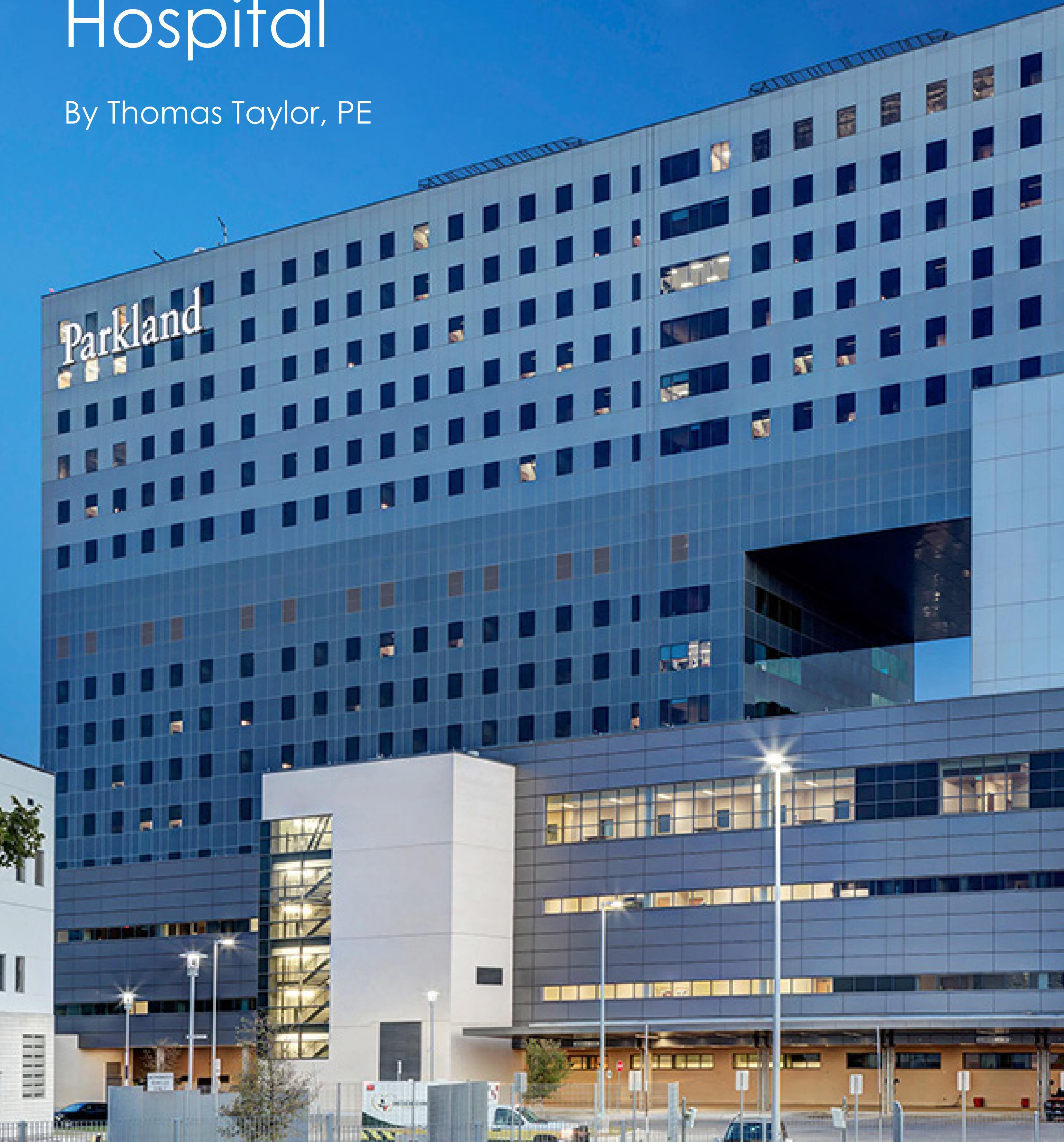
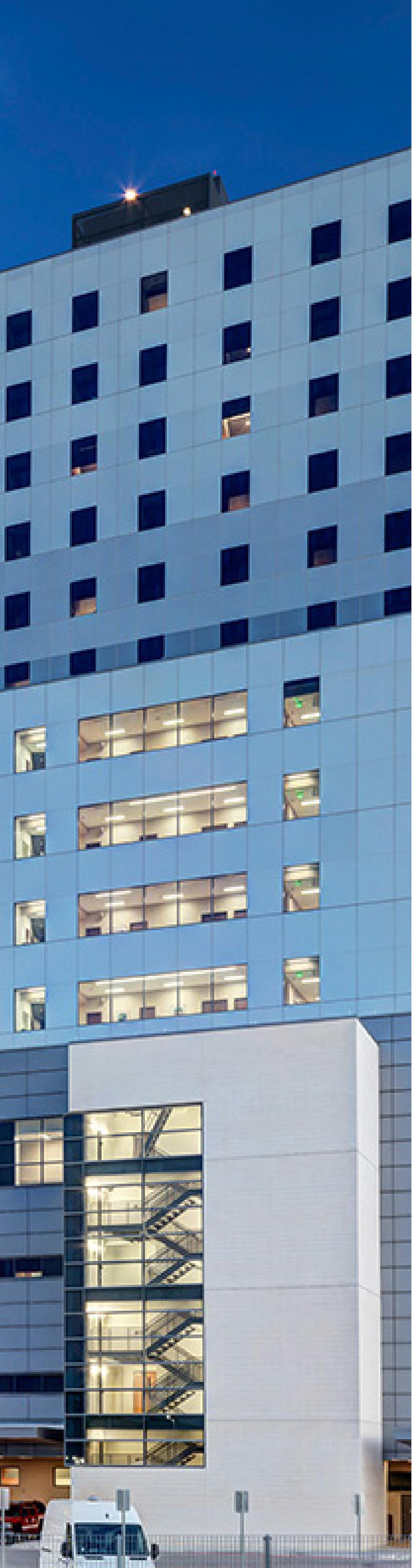
Structural Solutions Solved for Impressive Dallas Hospital

By Thomas Taylor, PE





Dallas' Parkland Hospital, built in the 1950s was functionally inadequate for 21st century needs. Many complaints and state-issued mandates pushed the owner to reach out to consultants to develop a new architectural and engineering vision. A large structure evolved, resulting in unusual engineering challenges.

The two million sq. ft. facility includes a 17-story acute care tower, an outpatient center, a Women and Infants Specialty Hospital (WISH), an administrative center, and a central utility plant. The top 8 floors of the acute tower bridge 120 ft and cantilever 60 ft beyond the supporting 9-story WISH building below. This was accomplished with a system of 30-ft-deep, post-tensioned transfer walls and girders. These elements were designed to be stressed in 8 stages. The form consists of a 62-ft cantilever, coupled with a 120-ft span over an opening; both support seven stories above.

The owner mandated that the design concept must allow for the highest number of windows, an important criterion in terms of patient comfort and sense of well-being.

The architectural team and the owner recognized the magnitude of the concept and its cost became a prominent issue. For the concept to advance, the structural team was challenged to select the most economical method of creating the desired form. As structural engineers, we had our work cut out for us, but the team was up to the task, developing a 5-step process to bring the concept to fruition, at a cost that could meet the owner's needs.

STEP ONE

1.A: The Alternative Systems Study

The initial step for the structural engineers was to identify potential structural systems, which they could then submit to a general contractor for pricing. The first option involved a two-story structural steel transfer girder between the 10th and 12th floors; but the structural engineers' calculations determined the deflections were unacceptably high and that the steel tonnage was clearly unrealistic based on the size and structure of the building. The second option included adding steel diagonals from the 10th floor to the roof thereby creating a seven-story truss. This proved to be a more cost-effective solution.

1.B: The Vibration Factor

With any steel system, the structural engineers have an inherent concern about vibration. This is overcome by adding structural steel tonnage or a thicker composite concrete slab to increase mass. Either option would dampen vibration, however, this also leads to additional costs. Furthermore, locating the diagonals through the floors could create significant functional coordination issues between the architects and mechanical engineers. The contractor also expressed major concerns about the cost of this concept, but the structural engineers chose to provide suitable drawing details to allow the contractor to proceed in developing a proper cost estimate.

In 2009, the structural team determined that concrete was more competitively priced than steel in Dallas, Texas. Hence, a third system was priced with the top seven floors constructed as a cast-in-place concrete structure supported on a two-story post-tensioned transfer girder system, situated between the 10th and the 12th floors.

The structural engineers and the architect recognized the need for minimum window openings in the post-tensioned transfer girder due to the high stresses and congestion of reinforcing steel; so the mechanical equipment, originally planned to be located on the top floor, was relocated down to the 10th floor. The space created by the transfer system was well-suited for mechanical equipment as the units did not require windows or louvers in the girder.

This system did not come without constructability concerns. The major issue was the five-story-tall shoring required to support the dead weight of the cast-in-place concrete transfer girders during construction. The structural engineers presented a shoring concept to the contractor to address constructability issues. When the concrete system was priced, the cost came in less than the steel truss option.

Since the structural engineer had priced both structural steel and concrete systems, it did not take much additional structural analysis to investigate a hybrid system to possibly combine the benefits of both materials. The system consisted of a concrete structure below the transfer girder, and a steel frame above. This system was evaluated, but the cost of construction was adversely affected by coordination between two subcontractors working in the same area. After evaluation of the four structural systems, post-tensioned girders with a concrete structure were ultimately chosen.

The post-tensioned transfer girders were the most practical, and by far the best solution for deflection control. Extensive structural calculations were prepared by the structural team whose absolute accuracy was critical. Post-tensioning allowed the use of staged stressing to control the elevation and deflection of the floors as each floor was constructed. The structural engineers worked very closely with the general contractor and post-tensioning supplier to aid in this effort.

STEP TWO

2.A: Primary Role of the Structural Engineer

The primary role of the structural engineer is to prepare construction documents for the structure, including plans and specifications. The contractor uses these to obtain bids from the sub-contractors and to build the structure. To prepare such documents for the hospital, the structural engineers prepared all of the structural calculations to establish the strength and size of the concrete members, the size and the spacing of the reinforcing steel and the foundations to support the building. These calculations must be extremely precise and include calculations of stress due to dead load, wind loads and live load, creep of the concrete, and deflection of the structural elements. Once the technical analysis is complete, the engineers supervise the preparation of the documents which have to accurately describe for the contractor how to construct the structural elements. Accuracy of both the technical engineering analysis and the production of the documents is the most critical aspect of the process on a project of this complexity.

2.B: Design Criteria for Constructability

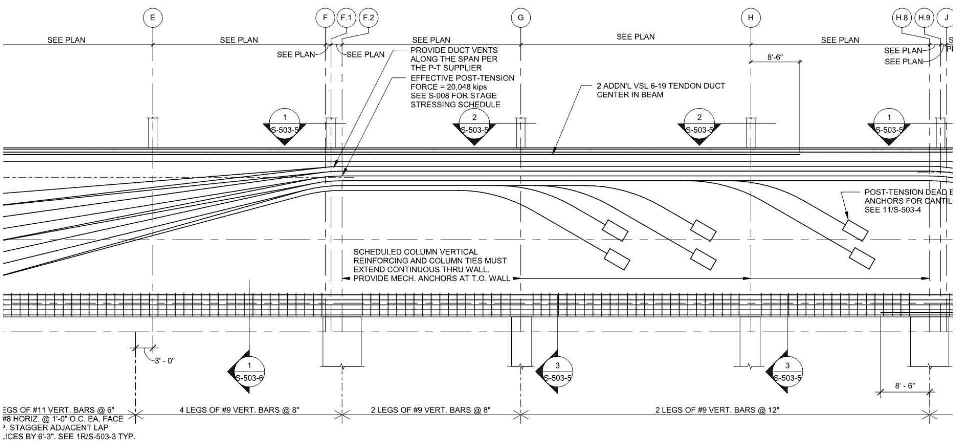
The next step was to investigate the final details of the transfer girder and the stage stressing associated with the post-tensioned solution. Since the transfer girder is considered to be a deep beam by the American Concrete Institute, Craig Rios of Datum Engineers prepared in-depth “strut-and-tie” calculations. These had to be developed before the design could be completed. For a girder of this size and importance, the structural engineers specified bonded post-tensioning cables. In this approach, the post-tensioning tendons are installed inside of the conduits and then grouted after the tendons are stressed.

The structural engineers reduced the drape of the tendons to fit in the concrete wall above the 10th-floor pour, and below the 12th-floor pour. This required additional tendons, but significantly improved the sequence and accuracy of placing the concrete and installing the tendons. The design also required a tremendous amount of reinforcing steel in addition to the post-tensioning conduits due to the high stresses on the 62 ft cantilever and 120 ft span that supports the top seven stories of the concrete building.

Concrete manufacturers were able to supply up to 14,000 psi concrete in Dallas, but the more the structural engineers debated the options, the clearer it became to proceed with a 6,000 psi concrete mix instead of using the higher strength alternative. Better quality control could be attained with this mix in Dallas because the heat of hydration could become a difficult problem. The higher strength mixes easily generate a higher heat than the selected 6,000 psi mix. A further benefit of the lower psi mix was that it allowed the use of 3/8-inch pea gravel concrete aggregate instead of 1-inch or 1- 1/2-inch aggregate. This small, course aggregate allowed for better flow around all of the inserts and the anchor plates which resulted in better consolidation.

Another benefit of using high-strength concrete was that it reduced the amount of concrete by reducing the thickness of the walls. But, as it turned out, the project needed the full 4-foot-thick concrete wall in order to prevent unacceptable steel congestion that could make pouring and vibrating the concrete difficult.

Due to the close spacing of the steel stirrups, the structural engineers created openings in the reinforcing steel to allow the concrete hoses to be inserted through the steel to the bottom of the form.
This was an important detail to improve constructability.



2.C: Safety First

An important safety factor built into the system design was the addition of four extra conduits installed in the concrete for possible emergencies. If one of the conduits was pinched and the tendons could not thread through the conduit, or if other kinds of accidents or emergencies occurred, a potential major problem could be avoided by planning ahead. Although the four conduits were ultimately not needed, they provided insurance and assurance that construction would proceed smoothly and on schedule.

STEP THREE

3.A: Concrete Shoring Concept

Design of steel shoring to support the wet weight of the concrete is a major engineering consideration. Datum Engineers created the forming concept for the concrete contractor to assure all construction issues were properly addressed from a structural point of view.

The structural design of the building and practical constructability were very closely coordinated with the five-story-tall shoring system supported on the 5th floor. The 5th floor had to be designed to support the concrete weight of the transfer girder and the 10th and 12th floors. Since the design of the roof at the 5th floor had to support the load, the engineers needed a clear understanding of how the contractor was going to shore all this dead weight at the 5th floor. This would allow engineers to design the beams and the columns at the 5th floor to safely and adequately support that load. The structural team coordinated with the contractor to locate the beams and columns of the shoring system and determine the locations that would be the most cost-effective to strengthen the roof at the 5th floor. Pre-planning this process provided a major contribution to the success of the project.

3.2: Stage Stressing the Post-Tensioning Tendons

The post-tensioning solution included stage stressing and grouting of the tendons. The tendons were installed and stressed as each floor was poured. The appropriate amount of stress was applied to support the weight of the addition of each floor, and after stressing, the tendons were grouted. Each floor was cast level and then the contractor would cast the next floor. When construction of each area began, the weight of the transfer girder on the 10th floor required the post-tensioning

CONSTRUCTION FACTS

- 3,200 cubic yards of concrete was poured--enough to fill an Olympic-sized swimming pool
- The transfer girders were poured in four 800-yard concrete pours
- 900,000 lbs. of reinforcing steel was used in the construction
- 140,000 lbs. of post-tensioning cables were installed
- 35 miles of post-tensioning tendons were needed within the conduits
- 20 million lbs. of post-tensioning force was applied to the main girders

of six conduits. There are 31 tendons in each conduit. After pouring the transfer girder and tensioning the six conduits, the next floor was poured. This step-and-repeat process continued until the roof was poured and completed. A stressing jack was used to stress the tendons in the conduit at the end of the transfer girder.

STEP FOUR

4.A: Quality Control Process

Quality control was another extremely important part of the success of this complex project. In addition to a highly successful structural engineering design, contractor team coordination, testing laboratory inspections, concrete testing, and all of the pre-planning that goes into a project, the contractor also proposed building a mock-up of the highly congested corner condition.

This benefited the project in many ways. First, the post-tensioning anchors were larger than expected. The manufacturer had ceased making the anchors that were in the catalog and the ones they delivered were much larger than the ones that were originally specified, therefore, they required additional space. The spiral steel that surrounded the end anchors was also larger than expected. Congestion factors were studied in the mock-up and responses to each were defined. As a result, the thickness of the wall at the anchors was flared to create more room at the end of the wall to reduce congestion. It is always extremely important to monitor and test a mass concrete pour during construction. Mass concrete testing simulations were performed in large concrete pier caps in advance of casting the transfer girder. There were 88 maturity meters installed in the forms. With these meters on the inside of the walls and on the forms of the walls, the heat of the concrete and the differential of the heat of the concrete in the middle of the wall and at the formed edges of the wall could be measured. This focus helped prevent internal cracking in the concrete.

As a continuation of the quality control process, the structural engineer that designed the transfer girders, Craig Rios, was designated as the inspector on the job. His knowledge allowed him to best determine if something was amiss in the field.

One additional challenge was that a large amount of superplasticizer produced a 10-inch slump. A mix of 3/8-inch pea gravel was used to flow around and under the congested areas. This represents another example of quality pre-planning.

At the beginning of the project, the contractor had scheduled the walls to be poured in cool weather months to help reduce the potential heat of hydration problems. This being the case, the team concurred that the forms would provide sufficient curing with just blankets on top. All of the steps—from selecting the system, designing the system, teamwork between the design professionals and the contractor, all of the close attention to details, constructability and quality control—were key ingredients that led to an extremely successful project.

The new Parkland opened on Aug. 20, 2015.