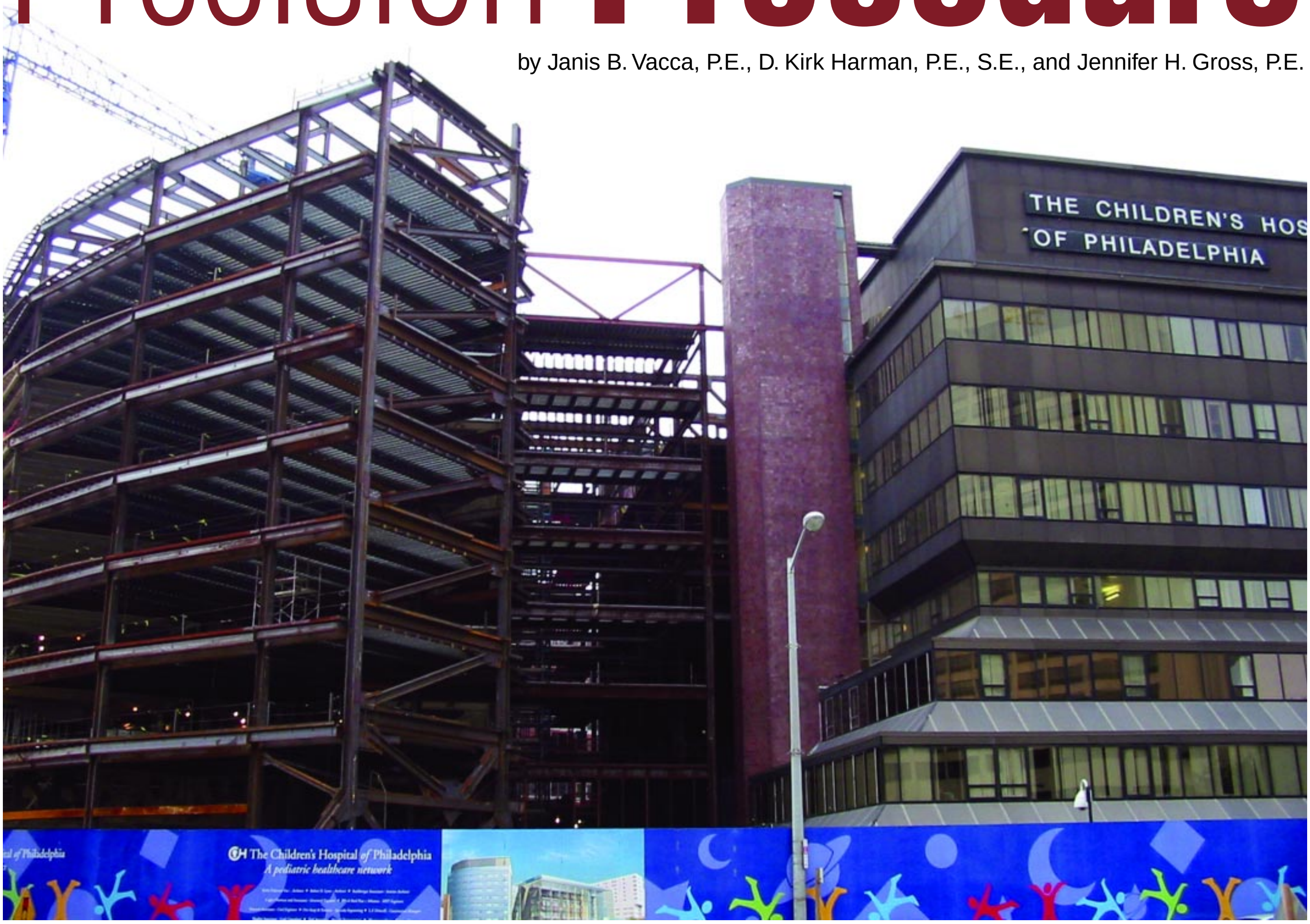
# Precision **Procedure**

by Janis B. Vacca, P.E., D. Kirk Harman, P.E., S.E., and Jennifer H. Gross, P.E.




A 10-story steel-framed tower is the first phase of a $650-million, five-year plan to grow The Children's Hospital of Philadelphia.

Founded in 1855 as the nation's first pediatric hospital, the Children's Hospital of Philadelphia is a driving force in the worldwide medical community. The hospital has begun implementing a $650-million, five-year expansion plan to facilitate controlled growth necessary for continuing patient care, professional training and major research initiatives. Phase I of this aggressive campaign is a new, 10-story, 332,000-sq.-ft South Tower.

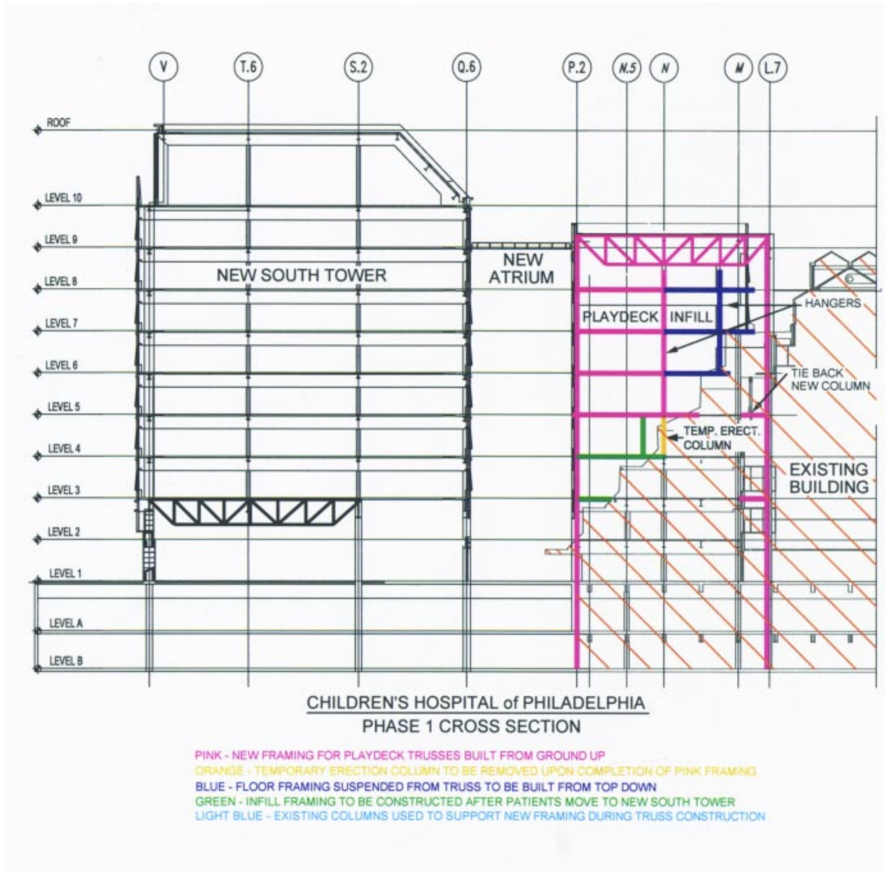
The hospital has been located on its current campus since 1972, when the existing 10-story, steel-framed structure designed by Philadelphia architectural firm H2L2 (then Harbeson, Hough, Livingston, & Larson) was completed. The existing exterior skin—a steel-framed backup for a metal panel façade resembling a tiered wedding cake—provided architectural appeal in the 1970s, but presented challenges for the expansion design team of 2000. In addition, existing floor-to-floor elevations of 13′-4″ made it difficult to fit modern ventilation and medical equipment into what is currently considered a tight floor height for hospital purposes.

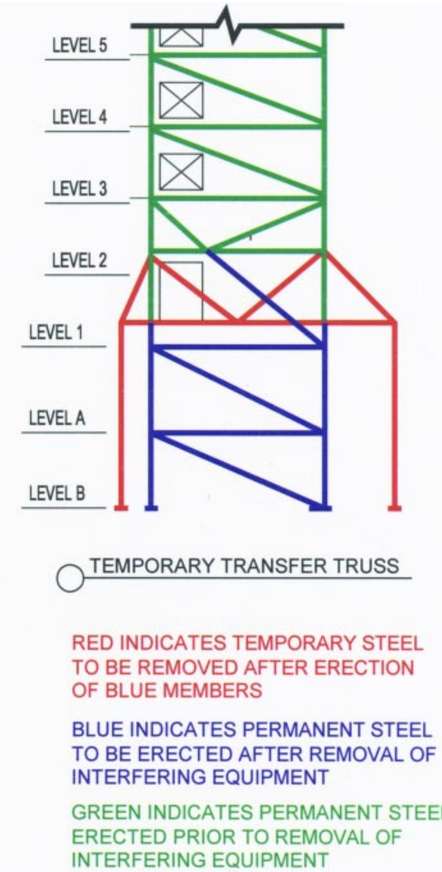
## Room to Grow

The state-of-the-art South Tower expands Children's Hospital to the south with a curved blue-green expanse of curtain wall designed by New York-based architect Kohn Pedersen Fox. The Tower's 13′-4″ floor-to-floor dimension was accommodated with 18″ maximum-depth steel-composite beam framing.

Columns in the new building were transferred out at the third level to accommodate a new ambulance entrance beneath the Tower. Steel transfer trusses were depth-restricted to 9′-0″ to provide adequate clearance for the ambulances. To meet schedule demands, fit-out of the third floor was required to begin as the building erection continued above. These construction sequencing and fit-out issues required stringent deflection limitations. The trusses weighed approximately 35 tons each and were required to be field-assembled because of site restrictions.

Expansion directly adjacent to the hospital, referred to as the Playdeck Infill, filled-in the tiered steps of the existing hospital. Early analysis proved the existing columns and transfer girders at the parking level were inadequate to




*Above:* The new south tower connects to the existing hospital via a new atrium and infill framing over the hospital's original stair-stepped configuration.

*Right:* A transfer truss and temporary columns allowed the the 10-story building to be constructed prior to the relocation of critical telephone equipment. In this photo, the equipment has been removed. The final framing members will be inserted, and the truss members will be removed.

support the infill framing. This resulted in a design scheme of new floor framing supported by hangers from roof-level trusses. Each truss was supported on two columns: one column outside the existing hospital façade, and the other an interior column threading through the existing interior atrium, emergency department and critical care units like the Neonatal Intensive Care Unit (NICU). A temporary erection column allowed portions of the infill framing to be built from the ground up, supported by the existing hospital. To limit loads on the existing framing, concrete slabs initially were not placed. After the roof-level truss was field-assembled, the temporary erection column was removed, and then the infill framing was hung from the truss. At this time, additional

The Playdeck Infill Truss, located at roof level, supports the infill floor framing with a tension member suspended from the center of the truss (lower left in photo).

infill framing was added from the top down, and concrete floors were placed hanging from the roof-level truss. Through it all, the hospital remained fully operational.

## Avoiding Construction Headaches

As hospital needs fluctuated, construction sequence demands numbered in the hundreds and changed daily.

New construction within the existing hospital could not be welded due to concerns regarding welding gases and smoke exhaust. Columns threading through the existing interior atrium, emergency department and NICU could be constructed only during limited hours, typically between 2 a.m. and 4 a.m. To minimize impact to hospital operations, columns passing through the existing atrium were increased in size, after design, to reduce the number of tie- back bracing locations. Exposed in portions of the atrium but clad in drywall, the new columns blend with the existing building.

Construction within the hospital was scheduled during months statistically proven to have the lightest demand. Construction was required to stop and start instantaneously when activity within the hospital changed.

Scheduling demands required construction to focus on building the floors at levels 3, 4 and 5–critical patient floors that required occupancy by summer 2003. Fast-track construction meant temporarily skipping areas to minimize disruptive and time-consuming construction. Areas adjacent to the existing hospital were constructed bay-by-bay, since patient rooms in the existing hospital were relocated to allow for the selective demolition necessary to join the new construction with the existing structure. Columns were braced temporarily or increased in size for stability when portions of the lower floor construction were not in place. Lateral and gravity analyses were completed multiple times to coordinate with the construction phases.

The existing entrance to the underground parking facility below the existing building was located underneath the eastern portion of the new South Tower, and the hospital's telephone switch was located in a room within the existing parking structure's helical ramp. Construction of the eastern portion of the building could not begin until the switch was moved and a new ramp to the parking facility could be constructed on the western portion of the South Tower. This required construction of temporary transfer trusses over the switch to stabilize the building until the eastern portion of the structure was constructed.

The tower crane and steel erection had to stop when emergency helicopters landed. The crane operator had direct communications with the helicopter operators.

Framing to fill in the tiered floors of the existing hospital served both to support final loads and to protect the occupied floors below from potential falling debris during construction.

Portions of the construction conflicted with main sewer and power lines feeding the entire hospital. Some of these services only were discovered after excavation, requiring temporary suspension of the lines during construction. In some instances, additional steel transfer girders were designed and constructed on the spot to eliminate the cost and disruption of a utility relocation.

## Trusses, Trusses and More Trusses

There were many steel trusses for the project, both temporary and permanent, and each carried a name of its own—for example, the NICU truss, Temporary Transfer truss, Playdeck Infill truss, or Level 3 truss. All had specific erection sequences, construction load limits, and stringent deflection and camber limits. Structural engineer Cagley, Harman & Associates designed and fully documented all of the connections, including approximately 250 connections for trusses alone. All of the trusses were field-assembled due to the lifting constraints and construction restrictions of the tight urban site.

One of the most difficult trusses to design and construct was the Temporary Transfer truss at the eastern end of the building. Upon design completion, it was determined that the telephone switch, located in the center of a helical parking ramp scheduled for demolition, could not be moved in a timely fashion. This forced a three-phased construction of temporary columns and trusses to support the 10-story building above. After removal of the interfering switch, permanent columns were wedged into place beneath the truss and the truss members were removed. This entire process occurred 40′-0″ in the air.

Named for its interference with the Neonatal Intensive Care Unit, the NICU truss was designed prior to construction when it was determined that a new column could not be needled through this critically sensitive area. A cantilevered truss was configured above the roof level, with a hanger threading down from the tip of the cantilever to support the framing above the NICU area. This truss, a creative solution to a troublesome problem, became an exposed architectural feature and can be seen from the eastern elevation of the Hospital.

## Seismic Prescription

Seismic design was not required by code in Philadelphia when the existing building was constructed in 1972. The *City of Philadelphia Construction Code*, 1997 incorporates the 1996 edition of the *BOCA Basic Building Code* and its seismic design requirements. The stringent design requirements in 1996 *BOCA* for emergency facilities resulted in seismic design controlling the lateral system for the new addition. Due to geometry and other considerations, expansion joints were provided wherever practical between the existing hospital and the Phase 1 addition. Cagley Harman designed a lateral system combining a series of steel braced frames and moment frames to support the South Tower.

## Steel: The Right Choice

The South Tower project incorporated 3000 tons of structural steel. The use of structural steel permitted the design team to incorporate multiple transfers and trusses. The strength, light weight, and easy assembly and dismantling of steel trusses proved critical to meet transfer requirements, both permanent and temporary. The strength of the steel trusses provided the necessary stiffness to limit deflection. The material choice also expedited the tight construction schedule and met the complicated demands of construction sequencing. A nearly impossible project was completed through group effort, and the strength and flexibility of structural steel. ★

*D. Kirk Harman, P.E., S.E., is president and managing principal of Cagley, Harman & Associates, Inc., Structural Engineers and Parking Consultants. Janis B. Vacca, P.E., is an associate and structural project manager for Phases I and II of hospital expansion. Jennifer H. Gross, P.E., is a project engineer, working on Phases I and II of the expansion project.*

**Owner/Developer**
Children's Hospital of Philadelphia, Philadelphia

**Architect**
Kohn Pedersen Fox, New York City

**Associate Architect**
Phase I, Karlsberger, Inc., Columbus, OH

**Master Plan Architect**
Robert D. Lynn Associates, Philadelphia

**Structural Engineer**
Cagley, Harman & Associates, Inc., King of Prussia, PA

**Engineering Software**
RAM Structural System, SAP 2000

**Construction Manager**
L.F. Driscoll, Bala Cynwyd, PA

**Steel Fabricator/Erector/Detailer**
Samuel Grossi & Sons, Bensalem, PA (AISC member)