A California healthcare complex takes structural engineering collaborative design and integrated project delivery to new heights.

Special Delivery

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Sutter Health, Devenney Group, Ltd., Christopher Skow Photography

THERE'S INTEGRATED PROJECT delivery (IPD), and then there's extreme integrated project delivery.

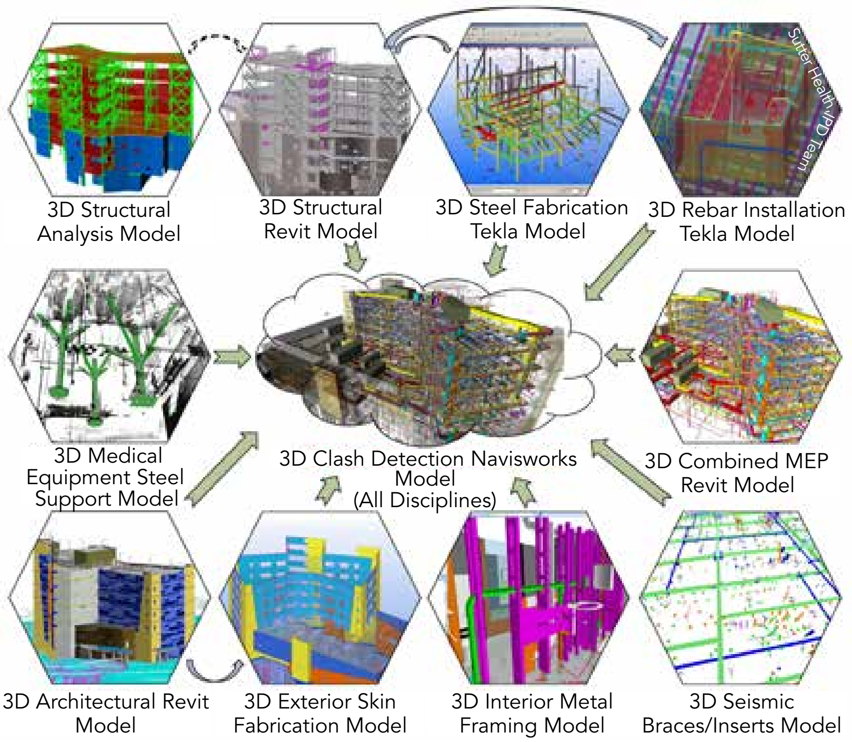
The process that brought together the recently completed Sutter Health Eden Medical Center (SHEMC) in Castro Valley, Calif., is an example of the latter.

The state-of-the-art, 230,000-sq.-ft, seven-story hospital complex, with a total staff of nearly 1,300, takes over for an adjacent 55-year-old hospital building. The $230 million project brought the owner, architect, structural engineer, general contractor and selected trade subcontractors together to form a first-of-its-kind 11-party IPD team to complete a building with a schedule 30% faster than comparable hospital projects in California. An integrated form of agreement (IFOA) contract required the team to fully use 3D BIM technology and implement lean practices in a shared risk and reward environment. To accomplish these goals, the IPD team used several strategies including: pull planning to map the workflow in various details; allocating sufficient time and resources early in the project to plan priorities before the start of design; carrying biweekly meetings (dubbed "big room meetings"); engaging in extensive BIM and clash-detection efforts; and providing live, web-based access of information and models to team members throughout the course of the project.

◄ One of the building's signature canopies.

▲ SHEMC (left building) will take over for an adjacent, 55-year-old hospital.

▼ A chart of the multi-disciplinary 3D BIM-based design and fabrication delivery.



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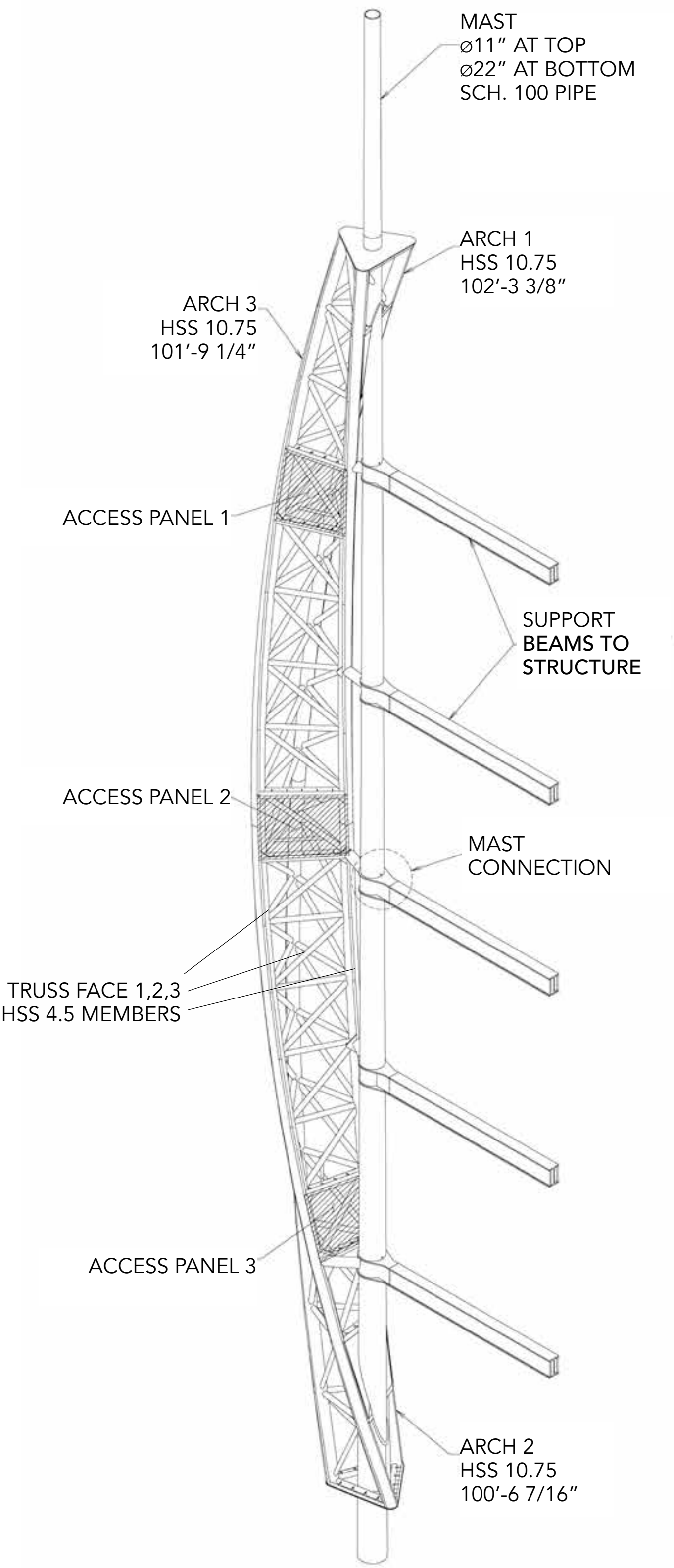


◄ ▲ Diagrammatic view and installation of the signature 125-ft-tall spire element.

Site Conditions and Structural System

The project site itself was very challenging, with sloped grades and limited space for use during construction—plus the nearby existing hospital had to remain fully operational during construction of the new facility. On top of that, the site is also within a half-mile of the active Hayward Fault, which necessitated stringent inter-story drift limitations for the highly irregularly shaped floor plan. As such, the hospital is designated an essential facility with an occupancy category of IV (per Table 1-1 of ASCE 7) and a seismic importance factor of I = 1.5 under California Office of Statewide Health Planning and Development (OSHPD) jurisdiction.

Several structural lateral systems were initially studied, including a shear wall system, a steel moment frame system, a steel braced frame system (with various bracing configurations), a base isolation system and energy-passive systems such as dampers. A hybrid system combining special reinforced concrete shear walls for the podium and steel special concentric braced frames (SCBFs) was selected as the optimal lateral system for the tower. At the request of the architectural team, the steel braces are distributed mostly along the perimeter of the building and around the elevator cores in the forms of single-story or double-story "X" assemblies. This design provides a very robust and balanced distribution of the seismic-resisting elements to control the torsional and lateral movements.

The braces, which range from W12×96 to W14×176, are supported on concrete shear walls in the podium level; their columns, ranging from W14×193 to W14×398, continue to the foundation for axial force transfer mechanism. Additional shear walls at the perimeter of the podium provide lateral stability for the larger podium area. The gravity load-resisting system includes lightweight concrete over metal deck supported on steel purlins, beams, girders and columns.

Much of the MEP equipment, including five large air-handling units with weights ranging from 17.2 tons to 30 tons, is located on tower and podium roofs on top of con-

Sutter Health, DPR

Construction after main steel erection.

crete platforms, which are supported by secondary steel members that connect to the building's main steel framing system. Due to very congested interior space of the building, any small change in the size or location of any structural elements had to be fully reviewed and coordinated with the other disciplines. To this end, 3D review meetings were conducted regularly, either in person or via the Internet, and any effects of the changes were carefully discussed and considered.

The Spire and Canopies

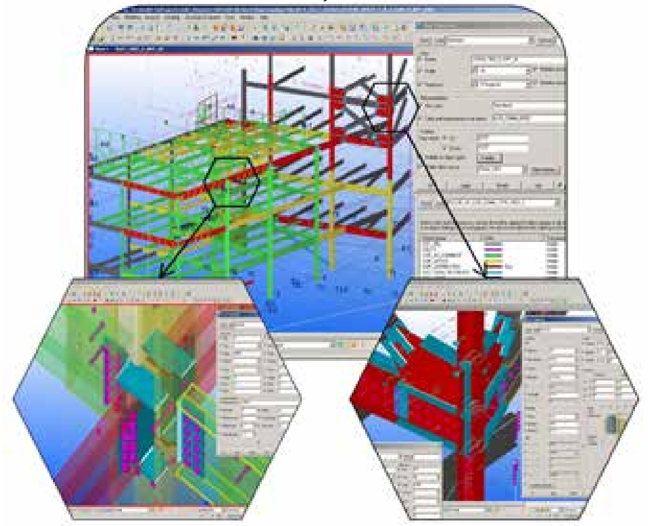
A signature 125-ft-tall spire element, using HSS members ranging from 4 in. to 22 in., is connected to the main structure by five 16-ft-long steel cantilevered beams using double-ended plate-bolted connections (these five beams were put in place first). Due to the expected settlements of the steel beam tips and standard tolerances in their construction, the design and fabrication of the spire had to take into account the exact as-built locations and orientations of the support beams. The whole spire element was fabricated in pieces and transported to the job site, then interconnected together before connecting to the main structure's support beams. Two cranes were used simultaneously to lift and align the spire at its five support locations and allow bolt tightening.

The project also features two geometrically complicated and irregular canopies. These are formed with cantilevered girders ranging from 18 ft up to 36 ft using W36×135 and W36×194 sections with free ends (tips) tapered down to 12 in., each sitting on a single column. The columns (W24×229) provide the lateral resisting system for the canopy as a cantilevered column system. The cantilevered girders have been detailed with a slight additional upward slope to allow relatively uniform vertical deflections at girder tips. This was required to eliminate potential cracking and stress concentrations on a skylight platform built with glass and aluminum and sitting on steel girders. Since the tip of each girder will deflect differently due to cantilever size and member sizes, the structural engineer, TMAD Taylor and Gaines (TTG), had to accurately calculate the deflection values and specify a different upward slope for each girder.

Laser Scanning

Laser scanning was used as an added quality-control element in order to verify that field construction matched the coordinated 3D models. This allowed early detection and fixing of field layout errors and mismatching. Any deviation found in the scanning process was reflected back in the 3D models for potential impact and resolution. In addition, a relatively accurate reading of deflections and settlements of structural steel beams was monitored and checked to make sure these elements were within the acceptable and expected code limits for construction and partial service loads. The scanning process also confirmed the as-built location of five cantilevered steel beams supporting the spire element outside the building perimeter. The results were used to complete the design and fabrication of the spire structure based on the exact as-built location and rotation of each beam.

Sutter Health, TMAD Taylor and Gaines, Herrick



▲ Installation of shear wall coupling beam reinforcing with steel columns embedded in the concrete wall.

➤ 3D review of the Tekla structural steel fabrication model through customized menus to streamline and accelerate review process.

3D Review

SHEMC is one of the first projects where the engineering team reviewed the structural steel in a 3D environment without shop drawings. The 3D structural Revit model was used as a base model for creating the steel fabrication models, which were made with Tekla Structures. The fabricator and erector, Herrick, divided the steel erection into 22 different segments and exchanged them with TTG in the order of scheduled construction sequence. After modeling the main structural steel and their connections, most of the elements in the building skin system that connected to the structural steel were also modeled. At any point in time, TTG's team was reviewing the new segments while back-checking the revised models based on prior reviews, and Herrick's team was developing new segments while revising the previous segments based on the comments.

TTG worked closely with Herrick to further enhance their customized Tekla Structures toolkit for streamlining and accelerating the review process. The toolkit included various types of report generation, drawings templates, API interface for RFI creation and management and visualization tools. There was no 2D printing or review. The design team was able to make direct comments on steel elements—such as beam sizes, connection weld types/sizes, base plates and bolts and brace gusset plate connections—within Tekla, then these comments were transferred online to Herrick for corrections. (The color-coding tool allowed faster and easier identification of both the status of each element to be approved for Herrick's release and the need for further revisions.)

As the 3D review process eliminated the need to print and mail thousands of hard copies of shop drawings, there were significant savings in cost and schedule. The 3D approach also made field connection issues visible in the design phase and greatly reduced potential conflicts in the field during construction. Based on the team's close collaboration and the use of a customized 3D review process, Herrick delivered the entire structural steel package six months ahead of time and more than $1 million under budget. The structural design and steel fabrication 3D models were entirely coordinated and constructible, which contributed to a very low number of structural construction changes and RFIs—just under 15% of estimates for comparable hospital projects in California. MSC

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General Contractor
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Steel Team

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