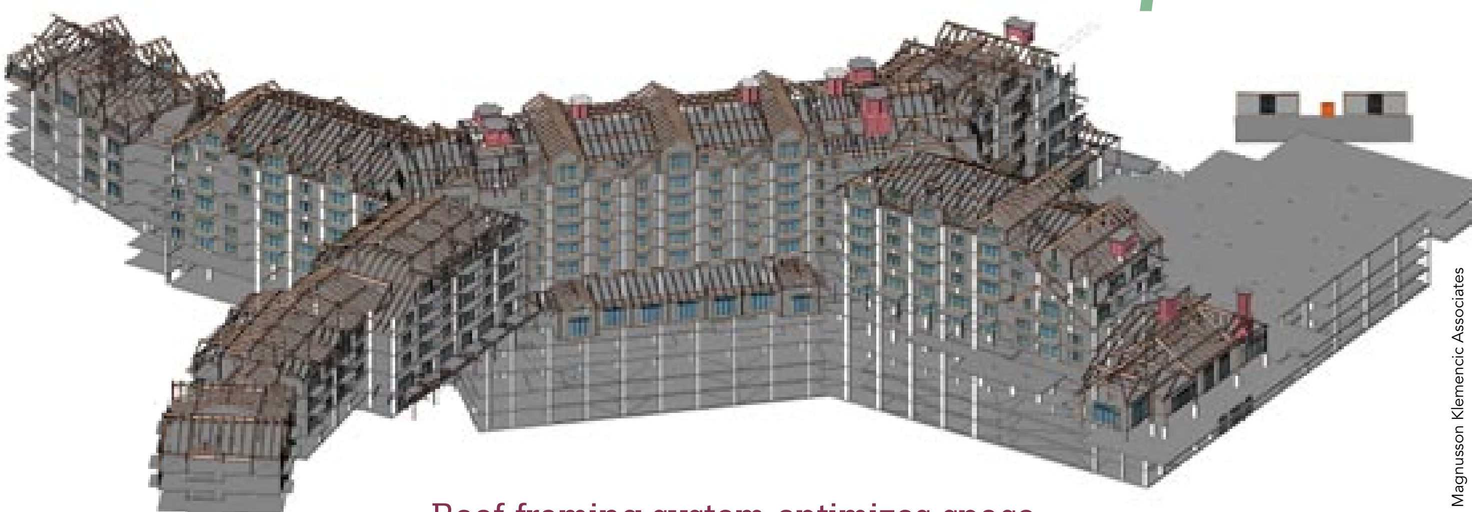
Steel on the *Slopes*

BY MICHAEL JEWSBURY, S.E., P.E., AND ADAM EVARTS, LEED AP



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Roof framing system optimizes space offering strength and speedy construction.

THE MONTAGE DEER VALLEY PROJECT near Park City, Utah, initially was conceived of by the developer as a smaller boutique ski resort but quickly grew into a large-scale resort and spa comprising more than 950,000 sq. ft and 13 levels. Located partway up the Deer Valley Resort ski mountain, the project was a significant undertaking, given the environmentally sensitive mountain site, prior mining activities in the area, high seismic hazard, and complex building geometries. Together, the ownership, design, and construction teams rose to the challenge, developing a resort that will provide 360-degree, ski-in/ski-out access to the resort and boast some of Park City's most stunning views.

Designed in a mountain craftsman style, the lodge's four wings of residential and hotel space terrace across the sloping hillside, arranged in a butterfly pattern around a central core. A three-level underground parking garage sits below the hotel and lobby-level spaces, and a ski run skirts the site's perimeter. The lodge design cuts into the hillside to minimize its scale and presence. When approached from the uphill side, the 13-level building appears as a smaller, nine-story hotel.

The site was a silver mine in the 1800s, with remnant mine shafts near the building footprint that had to be filled. During excavation, there was a brief scare when a mining-era dynamite cache was unearthed. An extensive evaluation using ground-penetrating radar ensured no similar "surprises" would be found.

Multi-faceted Structure

The structural system developed had to address several complicated criteria unique to the high-mountain resort's location. The relatively high seismic risk (from the nearby Wasatch fault), steeply sloping site, heavy snow loading requirements, and intricate nature of the multi-story stepped roof all called for a creative and flexible structure.

Permanent shoring including both tieback soldier pile walls up to 50 ft tall and built-up mechanically stabilized earth walls were part of the final design for the sloping site. The parking, residential, and hotel floors are cast-in-place concrete flat plates. Two concrete cores around elevators and stairways provide lateral resistance and provide vertical circulation for the building.

Of most challenge and interest was the multi-story roof, with its articulated hips and valleys. Because penthouse residencies were being located within the sloped roofs, the structure had to maintain open and flexible space below the roof framing. Multiple options were considered for supporting these areas, including concrete, steel, and wood. Ultimately the flexibility, strength, and spanning capabilities of structural steel made it the ideal answer.

The solution was to finish the roof enclosure structure with 3-in. metal deck spanning between steel purlins, with cantilevered eave supports in many locations. Architectural finishes and roof tiles were then placed above.

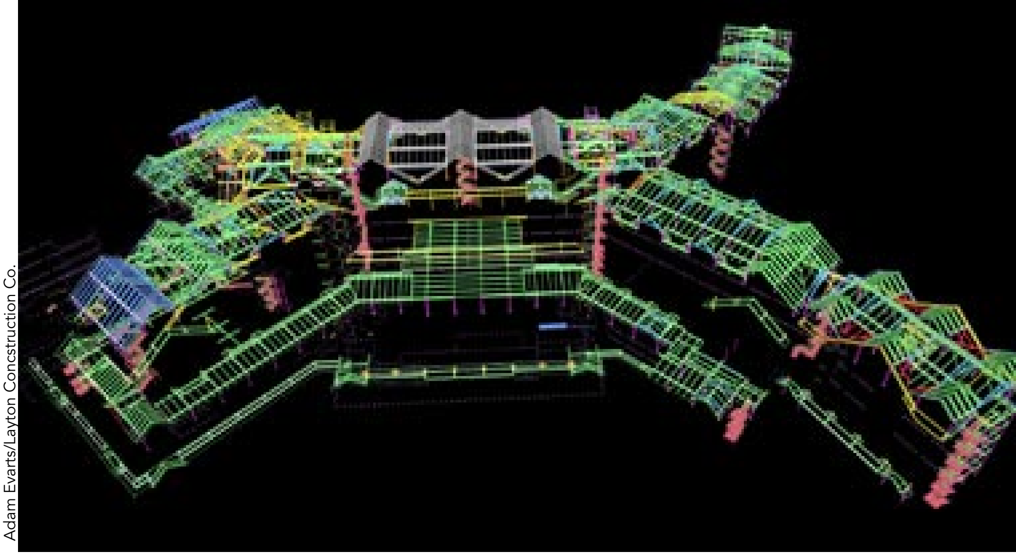
Snow, Long Spans, and Steel

Snow load requirements in excess of 230 psf increased the level of design difficulty relative to rooftop strength, seismic loading, and column transfers. Differential snow loads also held the potential to cause movement and distress to the building finishes after every heavy snow fall. Columns landing on transfer girders would be especially susceptible.

The structural engineer proposed a solution of steel trusses and bent steel frames spanning to non-transferring perimeter columns in locations where column transfers were required above the main hotel lobby and ballrooms. This eliminated the possibility for dif-

◀ Overall isometric of structural steel framing.

➤ Overall Navisworks steel framing.



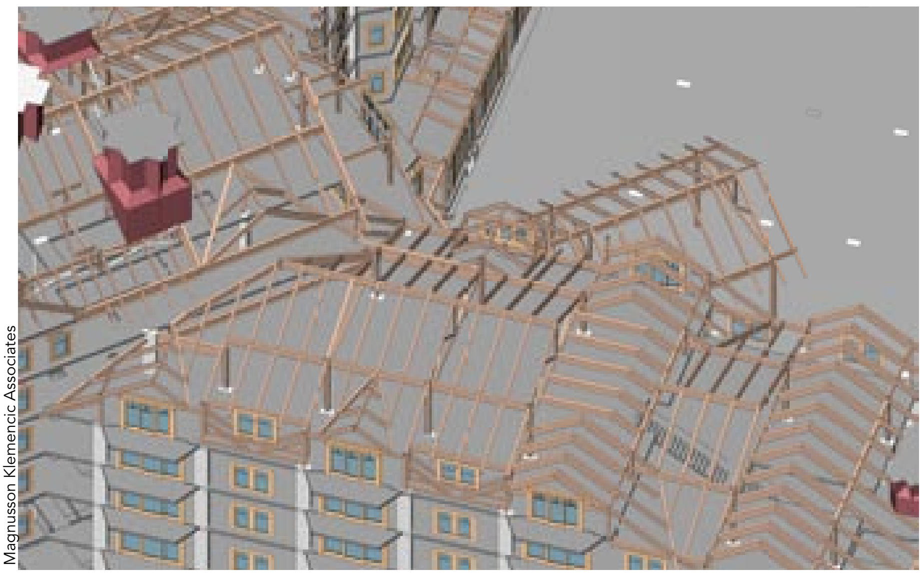
Adam Evarts/Layton Construction Co.

ferential movement due to snow from interior framing above the lobby. These trusses and bent girders also allowed for flexible, open penthouses at the upper levels of the building. The fundamental framing concept of truss and bent girders was repeated throughout the project with variations based on geometry.

Open spans also were called for lower in the central portion of the building, below the typical guest rooms, to accommodate lobby and ballroom functions. After transferring snow loads to perimeter columns via long-span trusses at the roof, the interior columns also were transferred using two-level opposite and opposing column knuckle transfers. This arrangement provided wide-open spans while maintaining the shorter-span efficiency of the typical floors above. Due to the anticipated seismic movement, the transfers were modeled in the lateral system and designed with reserve ductility to accommodate the anticipated diaphragm forces. Lateral stability to these transfers was also ensured due to the symmetrically arranged concrete core walls on either side of the transfer locations.

The lateral loads in the roof are collected in the diaphragm through in-plane braces and delivered to the various levels of the concrete structure below by braced frames. The braced frames all are designed as "special concentrically braced frames," with the gusset plates designed for ductile hinging. The plastic hinging of the brace is forced into the gusset connection so that a buckling failure in the stiffer connections and braces is prevented. Very careful detailing of the gusset plates was required to ensure this behavior. In addition to the gusset and the connecting gravity framing, the braced frames were oriented at skewed angles, also calling for careful detailing.

The complex roof slopes, transfer conditions, heavy snow loads, and substantial lateral loading initially led to the anticipation of heavy roof steel weights. However, through optimization and attention to design, the final roof steel, as constructed, is estimated to be 13.5 psf. Given all the design requirements, this is a very economical result, compared to other comparable framing metrics.



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▲ BIM truss framing with compound angles.

The Salvation of BIM

With the design direction established, the next challenge was how best to achieve detailing, fabrication and erection. The answer was found in Building Information Modeling (BIM). BIM initially was employed by the design team as part of the design process. Additional models were generated by the general contractor and the detailer. This approach proved both a salvation and a demonstration of how powerful BIM can be when used effectively by the design and construction teams.

The general contractor worked closely with the design team as well as the fabricator and erector, who were engaged during early design to best coordinate the construction process. It quickly became evident that BIM would be key to meeting the

Michael Jewsbury, S.E., P.E., is a senior associate with Magnusson Klemencic Associates. Adam Evarts, LEED AP, is a project engineer with Layton Construction Company, Inc.

Erin Conaway/AISC

As-built truss framing with compound angles.

Erin Conaway/AISC

As-built special concentrically braced frames.

Winter construction.

Shawn Newman/HKS

accelerated schedule demands and facilitating fabrication of the complex connections.

Ultimately, the team established an optimum BIM sequence. The steel detailer provided a structural steel model as .dwf files exported from Tekla Structures. At the same time, the general contractor maintained a concrete and exterior skin Revit model that was used as a baseline model. The combined BIM (Tekla and Revit) models were imported and overlaid in Autodesk Navisworks, where orientation, location, and scale were coordinated so that a common model could be reviewed in detail.

Enhanced Review and Resolution

BIM allowed for real-time conflict review/resolution and streamlined responses. The erector used 2D erection drawings in the field, taken from the original Tekla model. These drawings included the scope of the project, but there were areas that were hard to comprehend on the erection drawings due to the various angles of the hips and valleys. The erector therefore frequently reviewed the combined 3D model in the general contractor's office to obtain clarity from the all-inclusive, bird's-eye view and examine the pieces and connections from various angles. This yielded a complete picture of the erection and enhanced safety of the construction process.

BIM also allowed the general contractor to readily review the steel-to-concrete embed connections. By overlaying the multiple models, conflict areas were identified and resolutions found prior to fabrication of the embeds and structural steel. Where conflicts occurred in the field, such as misplaced embeds, the model was used to electronically convey the issue to the engineer, and a response was often available the same day.

The initial submission of shop drawings generated many redlined documents, requiring quick answers to complicated questions. The use of web conferencing in conjunction with BIM proved to be an exceptional platform for expedited resolutions to the fabrication and erection issues, particularly given the differing geographical locations of each team member. When the steel schedule was accelerated, shop drawing review time was reduced to only a few days turnaround.

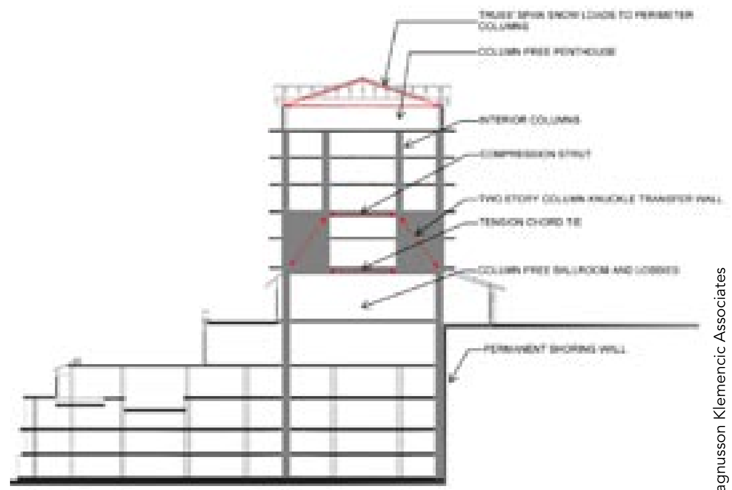
BIM also simplified understanding of the complex roof configuration. The truss framing was conventional, but each truss had a custom geometry due to roof slopes and incoming beams. In addition to the compound angles, eave locations required careful coordination. The Revit model facilitated coordination by revealing areas of reduced overhead clearance due to the compound slopes.

The lateral system was integral to the life safety of the building and required a much more detailed shop drawing review. Using the available BIM along with the 2D shop drawings accelerated this process and gave the team a higher level of confidence that the system was accurately conveyed and ultimately built from the shop drawings.

The Montage Deer Valley resort and spa will be open for the 2010-2011 ski season. The fast track project was a challenging design and construction effort, requiring a high level of coordination to procure, fabricate, and erect the steel roof. The roof design highlights the dramatic appearance of the chalet-style resort. The roof also creates

Shawn Newman/HKS

Roof construction.



Magnusson Klemencic Associates

Building cross section of column transfer.

an intimate slope experience that belies the vast size of the overall project. Steel framing was the best choice for the roof, and the BIM process enhanced the quality control in the fabrication and review process. BIM and electronic review also made the accelerated schedule possible. MSC

Developer
The Athens Group, Phoenix

Architect
HKS/Hill Glazier Studio, Palo Alto, Calif. and Salt Lake City

Structural Engineer
Magnusson Klemencic Associates, Seattle (AISC Member)

Steel Fabricator
Sanpete Steel Corporation, Moroni, Utah (AISC Member)

Steel Detailer
Phoenix Drafting Services, Inc., Abbotsford, British Columbia (AISC Member)

General Contractor
Layton Construction Company, Inc., Sandy, Utah

Geotechnical Engineer
Golder Associates Ltd., Redmond, Wash.