COA 8833 Case Study Tao Cheng

Solaris Vail

Modified EJCDC owner-engineer with BIM language

Introduction

The Solaris is being built in the center of Vail village, Colorado, on schedule for April, 2010 opening. The luxury new condominium development with cathedral ceilings, gourmet kitchen with top-of-the-line appliances, natural stone countertops and custom woodwork throughout standing just steps from the North America's best ski resort is believed to redefine the rocky mountain lifestyle. This case study addresses issues relevant to building information modeling (BIM), involving new BIM innovations, implementations, the advantages and disadvantages encountered, how the design team and project team coordinated, and the lesson learned.

Figure 1. A rendering of the Solaris Vail

The Solaris redevelopment project will replace structures built in the 1970's with $170 million of new construction of new construction. The total budget of the project is over $220 million. The luxury property in the center of Vail Village is comprised of 77 high-tech condominiums with unsurpassed mountain view, 60,000 sq. ft. of retail/restaurant space, a new half-acre public plaza with winter ice skating and summer "pup-jet" interactive fountain, underground parking, three high-end stadium seating movie theaters and a 10-lane bowling alley/arcade/sports bar.

The construction encompasses a gross ground area of 420,000 square feet. It contains 7 stories on the south side and 9 stories on the north. Due to the elevation condition, 3 stories are below grade at rear of building and 2 stories are above at front, which consist of 3 stories of retail space and a buried parking structure. The entire project is a combination of cast-in-place concrete, precast concrete and structural steel frame with composite decks.

Owner	Peter Knobel, Solaris LLC
Architect	Barnes Coy, Davis Partnership
Structural	Structural Consultants Inc.
MEP	F&K
Contractor	Weitz Corporation

Table 1. The Project participants

Barnes Coy Architects is a 20-year-old firm which has realized over 250 projects throughout the United States, Latin America and the Caribbean mainly concentrated on mountainous building design. The firm consists of 15 people, including 12 architects divided among three offices: Bridgehampton, NY; Vail, CO; and NYC. The firm has remained relatively small, allowing the principals to stay closely involved in every facet of the design work. This is not the case with larger residential firms, where clients are routinely assigned associates to work with.

Structural Consultants Inc (SCI), established in 1977, is a is a full service structural engineering consulting firm with headquarters located in Denver, Colorado. As Building Information Modeling (BIM) has became the next evolution of the application of technology in the engineering community, SCI is striving toward fully detailed intelligent 3-D models incorporating all of the information currently shown in 2-D design documents. This level of information can be used to coordinate the multi-discipline design of a building and also allow the information to be passed downstream to the construction team to increase the interoperability of the design and construction team. SCI has adopted TEKLA Structures and other BIM modeling tools as the basis of their efforts. This advanced software was used successfully by SCI on the complex steel connection design of the Denver Art Museum (1998).

Delivery method

An integrated project delivery (IPD) method, Construction Management/General Contractor (CMGC), is utilized as the delivery method in this project. CM/GC offers opportunities for success that are not necessarily available through traditional contracting methods. Especially in this case of Solaris Vail, the owner is very actively involved and most major contracts of sub-consultants and sub-contractors are negotiated directly between the owner and them. A prominent advantage of CMGC contract in Solaris Vail project is that, a platform of facilitating the application of BIM has been created among different stakeholders especially among owner, design team and project team. The implementation of IPD method in conjunction with the use of BIM was paying big dividends in form of cost and schedule saving.

While the traditional design-bid-build contract method precludes subcontractors from detailing the design until the project was eventually bid, an integrated delivery method enables an early participation of subcontractors to the design team when the design is still under development. This allows quicker solution for design defects and significantly reduces the change order in construction phase.

Figure 2 illustrates the structure of CM/GC delivery method utilized in Solaris Vail. By joining the project team during design, the CM/GC firm can collaborate with the design team on the development of the design and preparation of the design documents. This interaction allows for improving constructability and for conducting value engineering reviews. What's more, BIM has become the optimal communication methods during the collaboration, which is described in next session.

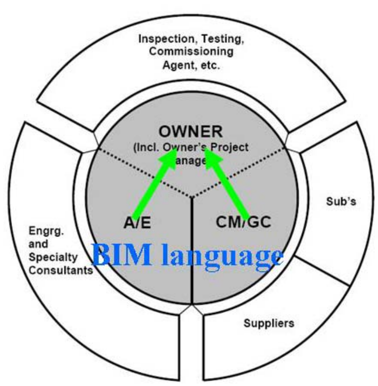

Figure 2. CM/GC in Solaris Vail

BIM in design and construction

The pertinent of BIM-related issues in this project were conceptual design, structural design, interoperability and drawing production. The complexity of the building represent that a significant payoffs of early implementation of BIM on the design, construction and fabrication has been demonstrated in this Solaris Vail project.

Figure 3 illustrates the approximate timeline of the project. A very early implementation of BIM during the schematic design stage can be found in this timeline.

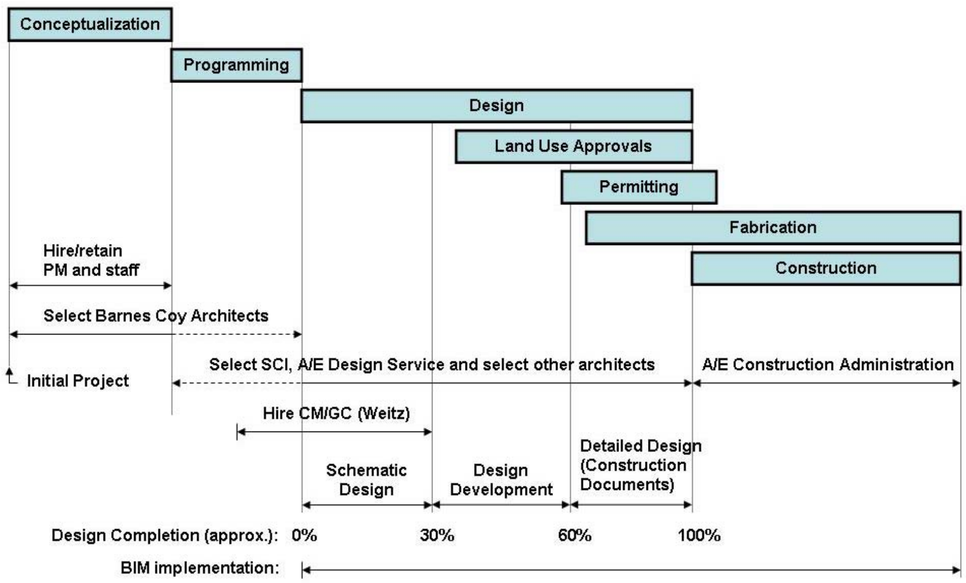

Figure 3. Project Timeline

The project timeline for design was not a linear event due to negotiations and stoppage of work twice while the project was voted on and negotiated with the City of Vail planning department. The schematic design took 3 months, which is approximately same as DD. The Composite Designs spent about 6 months on the structural design. Table 2 represents the major milestones of this project.

The structural design was issued almost one year earlier than the architectural and mechanical final CDs. It was only through careful and continued coordination in the models that the structural core and shell work was able to be completed so far ahead of the rest of the design team without major design coordination problems. In addition, with the beneficial of an early implementation of BIM, the steel fabrication began 5 months prior to issuance of the final architectural and mechanical CD's.

January 2007	Design began
November 2007	Structural CD’s issued
March 2008	Steel fabrication started
August 2008	Architectural and Mechanical CD’s issued
September 2008	Foundations Completed
October 2009	Precast erection completed
March 2009	Steel erection scheduled completion

Table 2. Major Milestones

Conceptual design

During the stage of conceptual design, a general appearance of the building as well as basic building plan is generated, and how the project will realize the basic building program is defined. With traditional 2D drawing based processes, analysis must be done independently of the building design information, often requiring duplicate, tedious and error-prone data entry. However, BIM can have a prominent impact in enhance the quality of decision made by the owner in this phase. The scope of the project has been defined in this phase, and a 3-D sketch of space planning has been developed, based on which, the ownership team were able to respond to vail city’s requirement and tenant needs.

In addition, Peter Knobel, the owner of this project, has great challenge and support to seek out the latest technology for any aspect of the project and to improve the work flow. Therefore, the design architectural team (Barnes Coy) was selected by the Owner based on his desires that a parametric modeling of the building were developed in schematic design.

BIM for design and analysis

The design process and modeling techniques of this project were selected from the start to facilitate the use of the model not only by the design team but also for “downstream” use by the construction team.

As design proceeds past the conceptual stage, system requires detailed specification, for instance, the structural systems must be engineered. Because of its experience with the integrated delivery systems with proven benefits to the project quality and schedule, Structural Consultant Inc. (SCI) has been selected as engineering specialists of design team.

The project design began and it became readily apparent that traditional 2-D design methods would be inadequate to accurately capture and coordinate the design complexities. A recommendation was made to the project owner that a 3-D BIM model would be the best design approach for the building design. SCI also suggested that the BIM design should be structurally based on parametric model that could be directly transferred to "downstream" use of the contractor and steel detailer without the data loss that has be prevalent in modeling translation.

SCI selected Tekla as the BIM software for the project, because the main purpose of the BIM modeling for this project was to ensure that the 3-D design was able to flow seamlessly into the fabrication and construction processes, and Tekla has export capabilities to CNC fabrication equipment and to fabrication plant automation software, such as Fabtrol (steel) and Eliplan (precast), While the architectural team used Revit as their parametric modeling tools. SCI coordinated the 3-D design with the architectural team via IFC interface exchanges. Figure 4 shows the modeling translation between two parametric modeling tools.

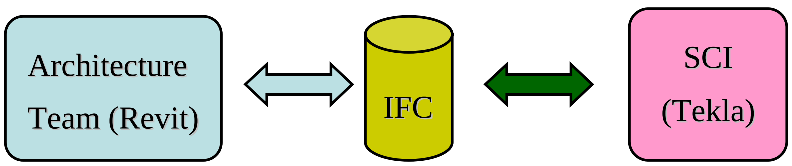

Figure 4. Modeling translation

One of the most important aspects of BIM is the facilitation of information exchange, which becomes the kernel of the communication and collaboration between design and construction team. However, interoperability has been and will continue to be one of the hindrances with model sharing. Since the industry is still not advanced to overcome interoperability issue, interchange between the design team was more challenging during design or construction phase.

By using the IFC product data model, the design team did not encounter major geometrical and topological issues. The physical data such as location of objects and their geometry data were able to share back and forth without loss of information.

Because EXPRESS supports applications with multiple redundant types of attributes and geometry, Revit and Tekla have different export and import for describing the same object. In the design phase of this project, some of the "intelligence" data embedded in the model disappeared during the model translation. For example, in the origin model adequate attributes of a beam such as the size, grade, piece mark for the shop, if it is primed, etc. were available, but much of these data can be lost with translation and only the physical object itself was proceeded along. The design coordination meetings therefore became extremely important in the design phase, although this often was not a severe issue because the interdisciplinary sharing of information is to confirm the geometric coordination of the structure to the architecture and vise-versa that can still be accomplished with less “intelligent” objects transfers.

Coordination between design and construction team

The major subcontractors were selected at the Design Development phase. The General Constructor issued Design Development package as part of RFP to select steel team and precast concrete team, and all the subcontractors were required to interchange the design using 3-D parametric model. Afterward, the design coordination meetings were hold weekly based on a 3-D fly through of overlaid architectural and structural models.

Due to the conjunction of integrated project delivery method and BIM, it allowed the early selection of the project precast concrete supplier and the project steel fabricator. The continuous coordination of architectural, structural and mechanical disciplines facilitates the integration of the model from steel and precast teams with design teams. By weekly design meeting, the erection sequence of precast and steel was optimized. Moreover, both entities were therefore able to review on-going work and provide input to the design that allowed customization for their shops and reduced the constructability issues of the overall coordinated design. Moreover, with the early involvement in the design team, specific fabrication and erection standards and constraints have been accommodated in the design of connections.

The parametric model was also used during the 2D-3D detailing and shop drawing review process. The workflow in review process of the project except roof structure utilized 3D model as an enhanced visualization tool, which still requires 2D shop drawings as the final, commented, and approved submittal to the fabricator, as the approval of the 3D construction model in lieu of 2D drawings. During review of parametric model, the design team can then verify that the specified design code is valid at each connection location, or even viewed in conjunction with the provided submitted calculation sheets by the connection engineer.

Lean construction

Lean construction is concerned with process improvement, which focuses on workflow stability. A common cause of prolonged construction duration is the long float time introduced by subcontractors, materials are not delivered in time, or design information is inadequate.

BIM impetuses leaner construction process in this project in the following four ways:

- SCI developed accurate 3-D model for structural steel, cast-in-place, and precast detailer and fabricator, which drove great degree of prefabrication and pre assembly. Therefore, the duration of onsite construction had been prominently reduced. Especially the steel fabricator began 5 months in prior to the architectural and mechanical CD's
- Due to the tight site situation and restrictions for access by the Town of Vail, off-site storage yard of materials were used. The materials were then delivered in a JIT (just in time) schedule for the very limited access and lay down area on the site.
- Due to the conjunction of IPD and BIM, the collaboration between design team and construction team began at very beginning of the project design. The objective of the entire team member were well aligned, hence the teamwork had been enhanced during the design phase. When the construction is performed by better aligned teams, fewer and shorter time buffers are needed.
- 4-D BIM modeling enables the optimization of construction sequences and priori identification of spatial, logical and organizational conflict before the construction startup. In another word, BIM improves workflow stability.

Challenging in design

3-D review on roof structure

During the design of the building the roof structure represented one of the most challenging issues. The roof structure was a complex system representing a geometric layout and design challenge for both gravity forces and lateral stability. Figure 5 shows the complex 3-D model of the entire roof structure developed in Tekla. While Figure 6 shows the real roof structure.

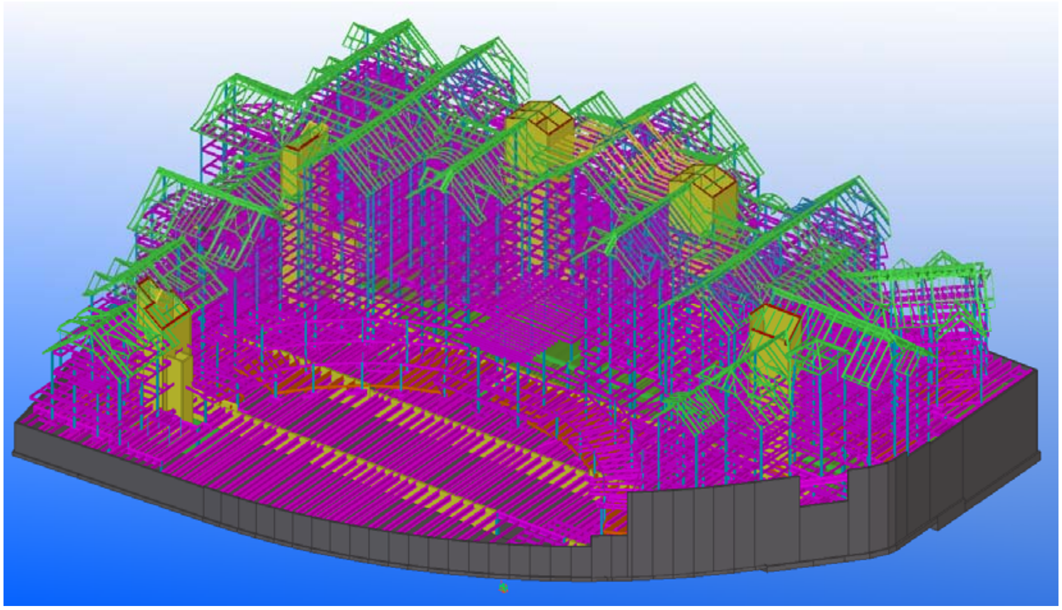

Figure 5. Roof Structure

Figure 6. Roof structure

It was determined that once the roof framing had been fully incorporated into the BIM model it would be a very inefficient process to extract 2-D documents out of the model just to have the steel detailer put the information back into the 3-D model. The design team therefore decided that the roof structure would be released for construction through the 3-D model and not be controlled by the 2-D documents. This process was discussed with the local jurisdiction and once they view the model and the design process, including

SCI's details for connection included with the permit documents, town of the Vail were comfortable with the approach and agreed to review structural model as part of the building permit review process. 2-D drawings of the roof structure were only issued for the components that were not included in 3-D model, such as the section cuts for detailing, the special SC connections.

The use of integrated project delivery (IPD) methods, in conjunction with the use of BIM, is bringing forth new workflows in 3D-reviewing and approving structural steel shop drawings. In a 3D Review approach, the engineer coordinates and reviews the model using similar procedures to that of the 2D-3D Review approach. However, how the engineer approves and communicates their approval is different than using 2D drawing submittals. Instead of using paper drawings, the engineer provides the steel fabricator the submittal comments and approval status in electronic form as a file exported from the model. This file is then submitted to the steel fabricator's detailer who imports and views the approval status and comments into his own construction model. Since the SCI developed accurate model in Tekla, and the steel detailer, fabricator and erector are requested to build their own model in Tekla as well, there is no interoperability issue in 3D-review approach.

Note that the engineer does not have to submit an actual model, but only submits comments to the fabricator's detailer. That way there is no concern with changing the fabricator's model during the review process. What can be used as a record-set of the approved submittal is the approval file of each assembly reviewed, as well as the construction model archived in a neutral file format (IFC) that maintains all the construction information per submittal, and which can be retrieved easily and with accuracy at a later date.

The benefits of the 3D Review approach are that it does not require 2D shop drawings to be produced. The engineer can still recognize the same benefits as in the 2D-3D Review process, with the exception of needing to stamp 2D electronic drawings as the submitted deliverable, which is eliminated in this process.

Moreover, BIM becomes the control point of information for the roof construction. Not only does it facilitate the pre-fabrication of the steel but also its 4-D scheduling model helps the erector optimize the installation sequence.

Beam penetration

A condominium structural grid of 20 feet was placed on center over a loading dock area, which in turn was placed over a theatre area that had parking below. All of these features had their own clear bay requirements that were not readily compatible with the others.

In addition, due to mountainous elevation, project schedule and the constraints of materials, a large scale of steel frame is required to be used for the super-structure framing. However, because of the restriction between adjacent floors, flowing below the structure member did not accommodate the mechanical system of the super structure. A system of penetrations was therefore designed in the steel frame in order to mechanically fit the system. The final design came up with an extremely sophisticated super-structure which has approximately 18,000 penetrations, 5,000 of them are reinforced.

Figure 7 shows a typical beam penetration. BIM plays a crucial role to ensure the success of the mechanical and structural coordination. Each pipe, conduit, duct, etc, was modeled and routed through the system. It was a difficult design for the mechanical sub-contractor, but the design was complete and coordinated before fabrication began which eliminated a substantial amount of potential field issues and problems with fit-up. Moreover, since the steel fabrication started 5 months prior to issuance of the final architectural and mechanical CD's, the complex super-structure system does not extend the erection scheduling.

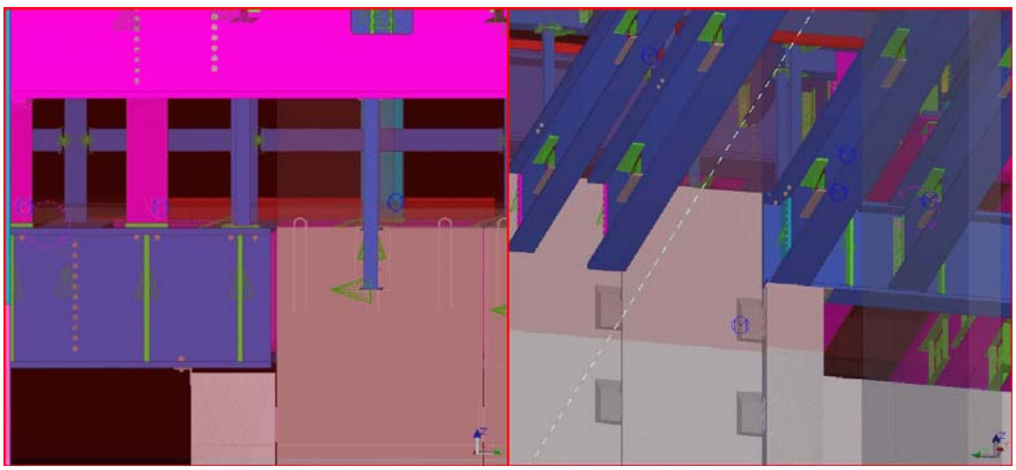

Figure 7. Beam penetrations

Lessons learned and conclusion

Several experiences in the application of BIM technology can be concluded from the Solaris Vail project.

The roof structure is one of the most challenging systems representing a complex geometry. A new approach to shop drawing review is utilized on this steel structure that 3D model is used as the controlling construction document, while 2D plans were only used as a basis to cut detail sections. This is one of the innovations involved in this project. In order to incorporate the 3D review workflows on structural steel project, an early and continuous coordination with project team is necessary. One way to facilitate this approach is by hosting a pre-coordination meeting held between the owner's representative, steel contractor, structural engineer and general contractor involved in shop drawing submittal process to determine what type of model-based review process can be realistically achieved.

Building and construction industry is being experienced with significant changes on two trends: BIM application and IPD methods. This case study demonstrated that the impact of the convergence could offer big benefits toward project productivity, while the 3D model-based review workflow discussed above is one innovation of these trends. First, BIM can not only visualize the design intention of the architecture and engineer, but also represent the interpretation of the construction team to the design during the coordination. On the other hand, project delivery method integrate and capitalize the expertise of architecture and structural contractors, will further more enable the use of BIM modeling during the early design phase.

Leaner construction becomes more practical with the application of BIM. A better design coordination and communication enable a high degree of prefabrication, which reduce the duration of onsite construction. Furthermore, if BIM can help fabricator reduce their lead time, the inventory cost will significantly decrease by just in time production.

Interoperability will be a potential hindrance of BIM application in design phase, since the most fabrication has move to parametric modeling. Although in this project, the design team did not encounter with geometry issue during the modeling exchange, some information were still lost, hence the design team had to partly recreate the model.

Other benefits of BIM implementation are summarized as follow:

- Improved design approach for a complex building geometry
- Project scheduling improvement from sharing data between design team and construction team, approximately 1100 hours were saved by the steel detailing team by using 3D-review approach
- Improved 3D coordination of mechanical system through a complex system of beam penetration
- The use of models by both the steel detailer and precast supplier results in a substantial reduction of RFIs and filed coordination issues for fit up and embed connection coordination.