



4-Dimensional Virtual Simulation Modeling for Structural Steel Erection Planning

Executive Summary

The National Museum of the Marine Corps has a monumental skylight system composed of a structural steel truss mast, structural steel framing, glazing, and metal cladding. As a result, the erection of the structural steel was carefully developed to determine the most efficient and safest erection sequence possible.

The structural steel erection contractor developed a 120-page document containing detailed information of the structural steel erection sequence, detailed sketches of the erection phases and information regarding the temporary falsework and lifting lugs on the structural members. The document is very complex and thorough and provides all the necessary information for the on-site erection crew to successfully erect the steel members. However, this document can be hard for an outsider to comprehend and can be difficult to communicate to other individuals not directly associated with the structural steel erection.

Therefore, the use of 4-dimensional virtual simulation modeling for structural steel erection planning has been proposed. The use of 4-dimensional modeling can assist the steel erector in the development of the structural erection plan and the erection document can also be developed based on this model. This model can be used to communicate and coordinate the structural erection phase of the project to other contractors on site (at that stage of construction). The 4-dimensional model can also be used to inform the owner (and other individuals) of the intentions of the steel erection and can allow the steel contractor to address any questions and concerns of the owner prior to commencing the steel erection on the project.

The implementation of 4-dimensional virtual modeling can be a vital tool in the development of a structural erection plan and can be used to further communicate this plan to the many individuals associated with the construction of a project.



Overview

The National Museum of the Marine Corps has a monumental skylight system composed of a structural steel truss mast, structural steel framing, glazing, and metal cladding. The design was inspired by the flag raising at Iwo Jima and the mast is angled to mimic the angle of the flag in the Iwo Jima memorial. The illustration below clearly signifies this relationship.

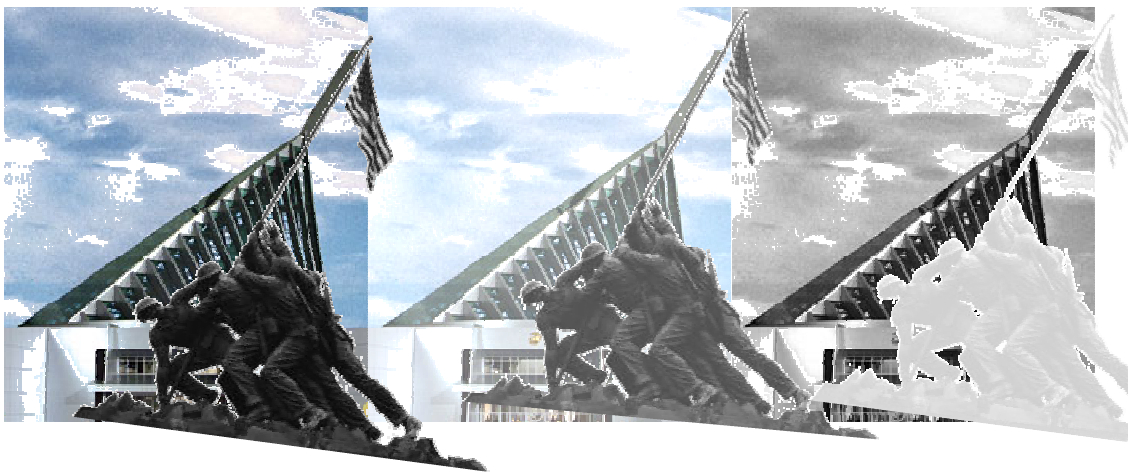


Figure 3.1 - Design Development of Skylight System

As a result of this monumental design, the structural steel component of the skylight of the museum is a very unique and complicated system. Consequently, a great deal of time and effort were required to develop the structural steel erection sequence plan. A structural steel erection sequence plan is typically a document developed by the steel erector to be used as a guide for use in the field to erect the structure correctly. A structural erection sequence plan consists of detailed erection phases with corresponding sketches to delineate which pieces of steel go where and what measures must be taken during the given phase.

The structural steel erection sequence plan for the National Museum of the Marine Corps project is approximately 120 pages. The development of the erection sequence plan can be a very time-consuming task and requires a lot of attention. The steel erection sequence plan was developed by an engineer based on the construction drawings. Safety measures have been carefully considered and the erection sequence



determined in the safest manner possible. The information contained in this document is very useful to the on-site erection crew; however, it can be cumbersome and difficult to understand by other individuals on the project.

Therefore, the use of virtual simulation modeling as a tool to assist in the development of the erection sequence plan, to communicate the plan to other contractors on-site for coordination purposes and to present to the owner for information purposes would be beneficial on a given construction project.

2D Structural Steel Erection Planning

The structural steel skylight for the National Museum of the Marine Corps is a very unique and complex system. As a result, a vast amount of planning had to be undertaken in order to properly erect the steel components in the fastest and safest manner possible.

The steel erector developed a “Roof Erection Procedure” document that details step-by-step how each component is to be erected in sequence. Also included are the details on temporary falsework, stabilizing guys, and important information regarding the stability of members and when additional components must be installed before a member is stable. Another portion of the “Roof Erection Procedure” document are the details of the lifting lug locations of the steel members.

When all is said and done, the document is composed of approximately 120 pages. These pages vary from a detailed written erection sequence to hand drafted 2-dimensional sketches of the erection sequence. The following images depict the 2-dimensional sketches for the steel erection procedure for the Marine Corps project.

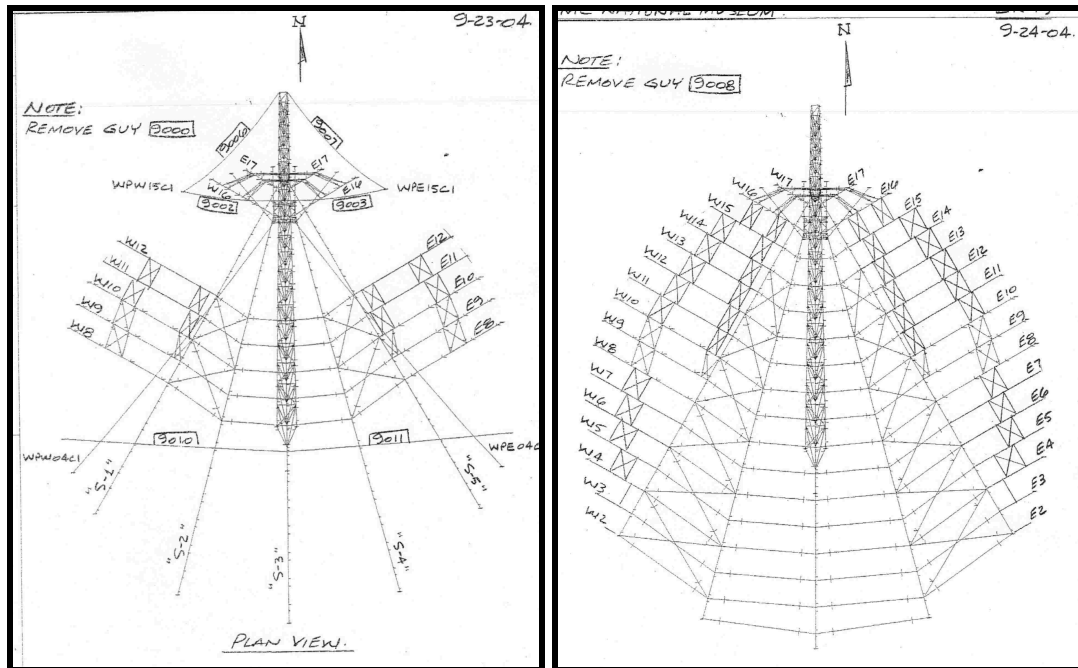


Figure 3.2 - 2-dimensional sketches from “Roof Erection Procedure”

The development of the steel erection sequence plan for the National Museum of the Marine Corps took one engineer approximately six months to complete.

3D/4D Virtual Simulation Structural Steel Erection Planning

In an attempt to improve the structural steel erection planning procedure, the use of 3-dimensional and 4-dimension virtual simulation modeling has been investigated for the National Museum of the Marine Corps project.

3-dimensional modeling of the National Museum of the Marine Corps was developed through the use of AutoCAD software. The steel erection model was developed from the original 3-dimensional Marine Corps model developed by Jason Reece of Centex Construction. The model was developed to show the entire construction site including the locations of the following:

- Temporary construction facilities
- Access Roads
- Steel Staging Areas
- Crane Locations
- Site boundaries



The 3D model of the steel erection for the Marine Corps museum is shown in Figure 3.3.

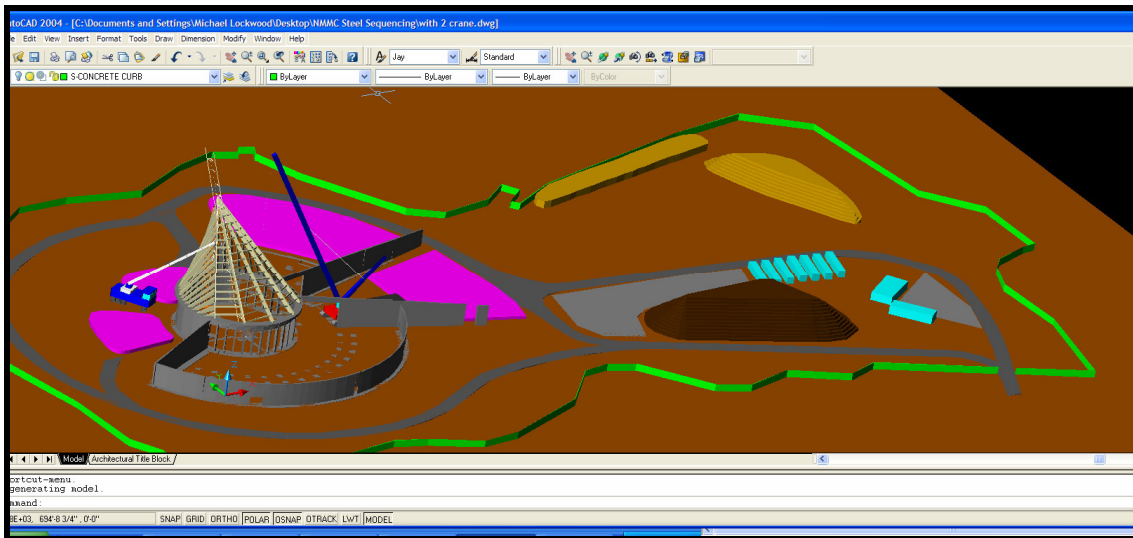


Figure 3.3 - 3-dimensional model of entire Marine Corps construction site

The model illustrated above is fully interactive and can be easily navigated for different positions and viewpoints throughout the model. Figure 3.4 shows a close up view of the skylight steel and crane locations for the erection.

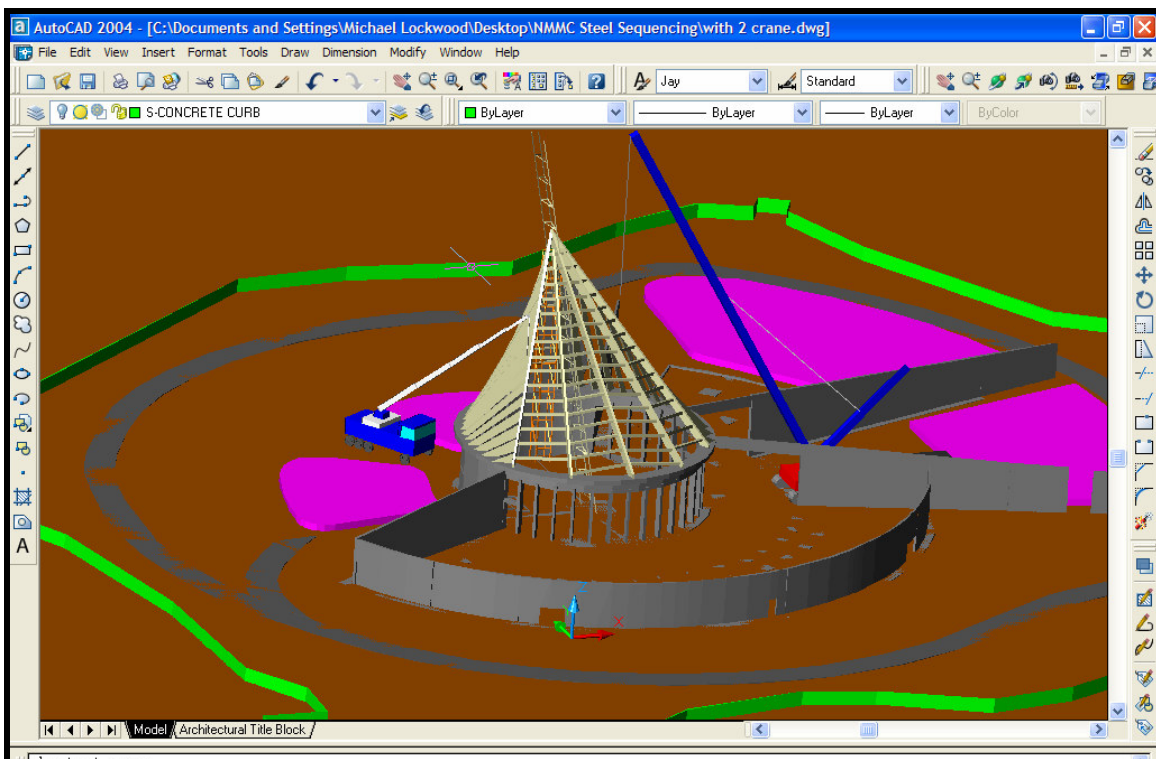


Figure 3.4 - 3-dimensional model of steel erection for Marine Corps project



The members were grouped together based on the erection procedure developed by the contractor. However, this model could have been developed prior to the erection sequence and grouped together as the plan was developed to aid in this process.

Once the 3-dimensional model was completed, the use of 4-dimensional virtual simulation modeling was executed. Common Point Project 4D was used to combine the 3-dimensional model developed in AutoCAD and an erection schedule (schedule located in the appendix) developed in Microsoft Project. The software allows users to link components of the 3D AutoCAD model and the schedule together.

Once the components are linked, the software can simulate the erection of the steel. The capabilities of this software continue to grow. The following are some of the features of the Common Point software: displays percent complete, activity name, highlighted construction activities, interactive viewpoints, and custom animation. The 4D simulation allows users to control the view and the time scale during the construction activity. Users can move to any point (in time) during the process and visually see what activities are under construction, completed, conflicting, etc.

The use of Common Point for the skylight steel erection for the National Museum of the Marine Corps can be seen in Figure 3.5. When looking at these still images, one cannot fully experience the 4-dimensional features of this project. The images in Figure 3.5 illustrate the erection sequence.

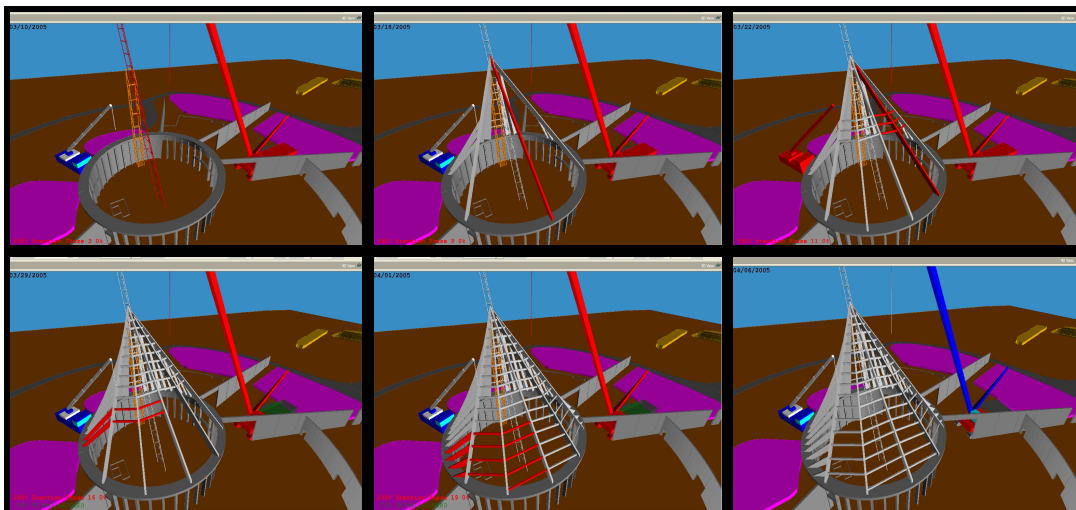


Figure 3.5 - 4-dimension virtual simulation modeling of steel erection



The steel members and cranes highlighted in red are activities that are under construction at this point in time. Once a member has been erected, the color changes to the gray color. In an instance when both cranes are red (as in the picture in the upper right corner), both cranes were required to be used because a member was not laterally stable until bracing was installed.

One of the key features of virtual simulation modeling is that users can manipulate the viewpoints. Figure 3.6 below illustrates alternate viewpoints.

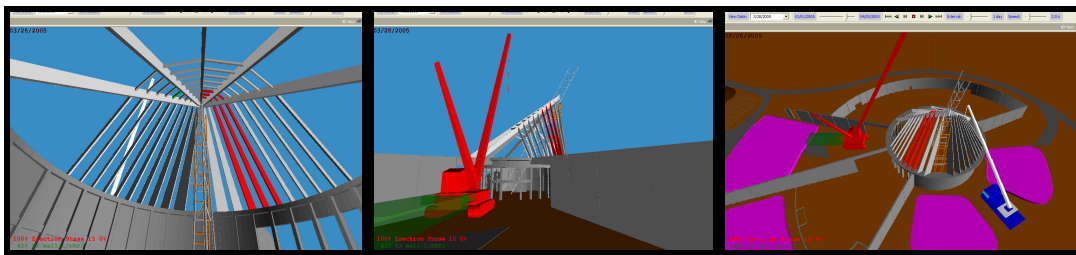


Figure 3.6 - Examples of alternative viewpoints in Common Point software

Since the 3-dimensional model of the Marine Corps museum was already developed by the contractor for alternative reasons for this project, the time and cost associated with the use of 4-dimensional modeling was very minimal. The time required developing the 3D model, the erection schedule, and the 4D model was approximately 20 hours in total by one individual. This included the creation of the crane models which took approximately 3 hours. Once the 3D model has been created, the linking of schedule components to the model is relatively easy and alternative sequences can be simulated in virtually no time.

2D vs. 4D Structural Steel Erection Planning

The steel erection contractor's erection procedure document presents all of the information needed by the on-site erection crew and the steel can be easily erected from this procedure. However, the disadvantage of this type of erection planning is the time required to develop this plan and the inability to clearly communicate the information within the document to other individuals involved in the project.

The use of 4-dimensional planning has been proposed as a tool to assist in the development of the erection procedure. The 4-dimensional virtual modeling clearly



communicates the erection procedure and allows the erection contractor to compare and contrast multiple erection scenarios.

The following images in Figure 3.7 are a direct comparison of the contractor's 2-dimensional erection sketches and the 4-dimensional virtual modeling snapshots. Clearly, the snapshot of the 4D model provides a better representation of the steel pieces being erected at this stage with viewpoints possible from all angles. The 4-dimensional model, when used interactively can be even more beneficial in reviewing any conflicts or safety hazards associated with the erection.

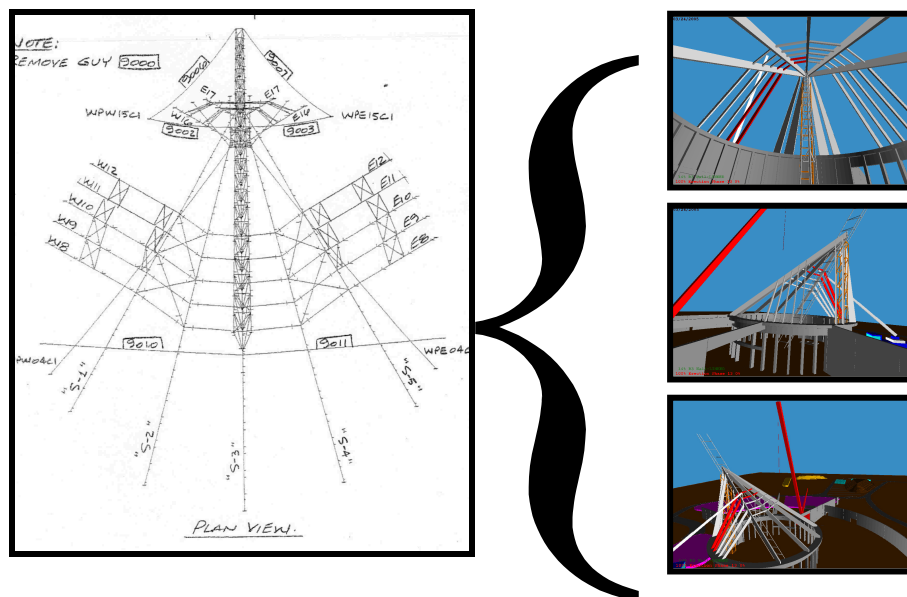


Figure 3.7 - Comparison of 2D vs. 4D of Erection Phase 13

The use of 4-dimensional virtual modeling can be an essential tool for a steel erection contractor to assist in the development of the structural erection procedure for a given project. The proposed use of 4-dimensional modeling does not mean the elimination of the erection procedure document used in the field. The proposed use of virtual modeling is to assist in the development of that document by reducing the time required to develop the sequence, to help communicate the erection procedure to other contractors working on the site, and to present the sequence to the owner and other individuals associated with the project.



Application of 4-dimensional Virtual Simulation

The use of virtual simulation for structural steel erection planning can be used in three specific areas: (1) assistance in developing erection procedure, (2) coordination between other trades on construction site, and (3) communication to all individuals associated with a construction project.

Tool for Developing Erection Procedure

The use of 4-dimensional virtual simulation modeling can be utilized by a steel erection contractor as a critical tool for developing the structural erection sequence for a project. The 4-dimensional model allows users to visualize a given erection sequence and compare and contrast different sequences. The erection contractor can use the 4-dimensional model in a trial and error scenario for the development of the erection sequence.

The ability to visualize and change the sequence prior to beginning the actual erection can be very beneficial and cost saving to the erection contractor. The virtual model can help the contractor identify potential conflicts and hazards associated with the erection sequence. Therefore, these conflicts can be addressed prior to facing them in the field during actual erection.

Trade Coordination

Once the erection sequence has been finalized, the 4-dimensional model can then be used for trade coordination purposes on the project. The virtual model can be presented to the other contractors working on the site during the erection phase of a project. The model could be used to educate the other contractors of the potential hazards associated with the steel erection procedures, clearly identify the crane locations and swing radius of the crane, the steel lay down areas and the different areas of a building that will be erected at a given time.



Project Communication

On any project, the owner is very interested and curious as to the means and methods the contractors are implementing for constructing their project. In most cases, a preparatory meeting is conducted before the major activities of a project begin. The meeting generally involves the contractor directly associated with the activity, the general contractor, the construction manager and the owner's representative.

Therefore, the use of the 4-dimensional steel erection simulation can be utilized as a presentation tool to inform this owner and the other individuals as to the contractor's plans. This will allow the contractor to address any questions or concerns of the owner prior to beginning the erection of the project that could potentially impact the erection procedure if they become apparent during the actual erection of the steel.

Benefit of 4-dimensional Virtual Simulation Modeling

The erection for the skylight steel on the Marine Corps project requires two cranes: a Liebherr 1400 series crane and a smaller truck crane. The Liebherr crane was to be located near the main entrance to the museum between the two concrete walls that converge on the main entrance. Prior to the crane arrival on-site, the contractors realized that the counterweight required on the crane to make the critical steel lifts was to extend approximately 75 feet beyond the end of the crane. As a result of this additional space needed by the crane and the addition of another phase of the project, the concrete contractor was forced to re-sequence the concrete activities and leave the R3 wall and a portion of the C4 wall out until the skylight steel was erected in order to allow enough space for the crane.

In a situation such as this, the use of 4-dimensional virtual simulation modeling could have been very beneficial. As the steel erector began to plan out the erection procedure, the key elements could be in place and scaled to the appropriate dimensions (i.e. the crane, staging areas, etc.). If 4-dimensional modeling had been used for this project, the conflict between the crane and the concrete wall could have been identified earlier in the project and the sequence adjusted accordingly with minimal impact to all parties.



Figure 3.8 from the 4D model below clearly shows the conflict between the crane and the concrete wall when the crane is positioned in a manner to pick up another piece of steel from the staging area.

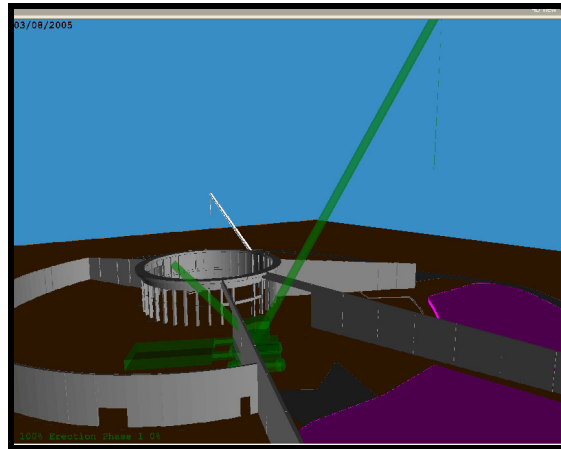


Figure 3.8 - 4D conflict with R3 wall

Figure 3.9 is a snapshot of the 4D model once the conflict was identified and the concrete work was re-sequenced to allow the crane adequate space to maneuver and make the required picks from the staging areas.

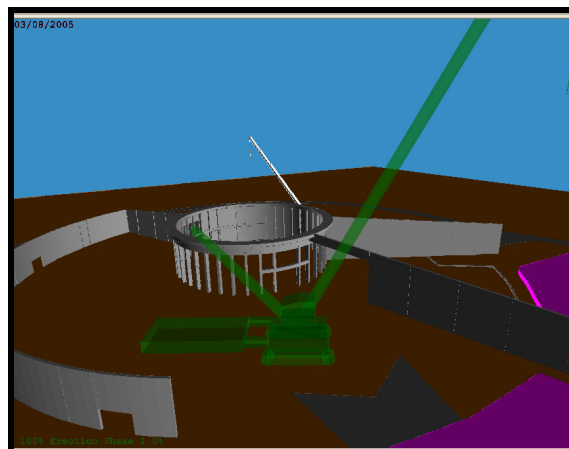


Figure 3.9 - 4D new sequence of concrete work

This was just one example of a situation that arose on the Marine Corps project (to date) that may have been prevented and/or identified earlier on had 4-dimensional virtual simulation modeling been utilized thus reducing the severity of the impact to the project as a whole.



Conclusion

Typically, a structural steel erection plan is developed by an engineer along with other individuals of a steel erection contractor. The process takes a great deal of time and is not able to be “tested” prior to the actual steel erection of the project based on the developed plan. The use of 4-dimensional virtual simulation modeling during the development process of the steel erection plan can allow the erection contractor to determine the best erection sequence by allowing them to test and compare different sequences and scenarios.

The 4-dimensional model can also be used to communicate the potential hazards and conflicts associated with the steel erection to other contractors on the site. The model can also be presented to the owner in an informative manner to address any questions or concerns of the owner prior to beginning the steel erection.

In the instance of the Marine Corps project, and other phased construction projects, 4-dimensional modeling could be an essential tool to identify conflicts and concerns with additional phases of a project being added during construction.