



A Tale of 2 Coordinate Systems: Bridging AutoCAD Civil 3D and Revit Together

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Description

The lab will provide a hands-on approach of best practices for how to combine civil site designs in AutoCAD Civil 3D software with foundation designs in Revit software to ultimately collaborate with architects. The discussion will give guidelines for where utility modeling for building should transition from Revit MEP software above grade to AutoCAD Civil 3D software below grade, and how to use Navisworks software in this review process. A key concept to review will be the difference between local coordinate systems that building designers work in and the state plane coordinate system that civil engineers typically use. The discussion will consider civil/structure interaction and the new BIM Forum Level of Development (LOD) specification, and how it relates to setting up projects in AutoCAD Civil 3D software and Revit software. This session features Revit and AutoCAD Civil 3D. AIA Approved

Learning Objectives

At the end of this class, you will be able to:

- Discover best practices for working with teams in AutoCAD Civil 3D and Revit, and how Navisworks can be used to aid the coordination process
- Gain best practices for working with teams in AutoCAD Civil 3D and Revit, and learn how Navisworks can be used to aid the coordination process
- Learn how to use the Action recorder to document transforms in AutoCAD Civil 3D
- Understand what the BIM Forum LOD Specification is and how it can be used with AutoCAD Civil 3D and Revit for site modeling

About the Speaker

Will Ikerd—PE, CM-BIM, LEED AP—is principal at IKERD Consulting, an internationally recognized consulting group in buildings, civil, and industrial construction markets specializing in using Building Information Modeling (BIM)-enabled Virtual Design and Construction (VDC). He serves as an expert consultant in design and construction cases involving BIM and VDC processes. Currently, he is on the board of directors of the national BIM Forum, and he was past chair of the Structural Engineering Institute's national BIM Committee. He has won the Best Speaker award twice from the International Structures conference, and he was named Structural Engineering magazine's "Top 10 Leaders in Structural Engineering," Glass Magazine's "Top 30 under 40," and Building Design & Construction magazine's "Top 40 Under 40." He has served as PCI's BIM consultant in that industry's innovation initiatives.

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About This Session & Paper

This paper suggests protocols, expected levels of development, and authorized uses of Building Information Models in the civil aspects of a project.

Definitions

The following are common definitions used in this paper that have been adapted from the AIA E202 and the 301 BIM Addenda.

Building Information Model (BIM) is defined as a relational database of building objects that stores information such as geometry, material, schedule, cost and many other aspects of the objects. A Building Information Model(s) is a digital representation of the physical and functional characteristics of the Project it is created for. "Building Information Modeling" means the process and technology used to create the models.

Federated Model is defined as a relational database of building objects that store information such as geometry, material, schedule, and cost that is created from two or more separate models. An example of a federated model would be the combination of an architectural BIM, a structural BIM and a MEP BIM. **The 301 BIM Addendum defines a Federated Model as** "a Model consisting of linked but distinct component Models, drawings derived from the Models, texts, and other data sources that do not lose their identity or integrity by being so linked, so that a change to one component Model in a Federated Model does not create a change in another component Model in that Federated Model."

Level of Development (LOD) in the AIA E202 describes the level of completeness to which a Model Element is developed (Architects, American Institute of, 2008). LOD should only be used to describe individual model objects. It is an incorrect application of LOD to refer to an overall model as a particular LOD, rather a model is a collection of objects that are varying LODs.

Level of Detail (LOD) is a deprecated term that should no longer be used in describing BIM content. The level of "detail" of model object geometry is often very misleading as a measure of the quality of the information that objects represents. As an example, a steel open web joist in Revit Structure looks highly "detailed" at the fine level of display. However, the web geometry is only suggestive and not developed. The geometry detail is very precise but the information the object conveys is in-accurate and not developed. For this reason, the AIA and the AGC BIM Forum use the term Level Of Development to describe a model object.

Model Element is defined by the AIA E202 as a portion of the Building Information Model representing a component, system or assembly within a building or building site. For the purposes of this paper focused on structural content, Model Elements are represented by the Construction Specifications Institute (CSI) MasterFormat classification system with cross referencing to the Omniclass system.

Model Element Author is defined by the AIA E202 as the party responsible for developing the content of a specific Model Element to the LOD required for a particular phase of the Project. Model Element Authors should be identified at the beginning of a project in the LOD table that accompanies this document.

Model User is defined by the AIA E202 as any individual or entity authorized to use the Model on the Project, such as for analysis, estimating or scheduling.

Construction BIM is defined by the 301 BIM Addendum as "a Model that (a) consists of those aspects of the Project that are to be modeled as specified in the BIM Execution Plan prepared pursuant to this Addendum; (b) utilizes data imported from a Design Model or, if none, from a designer's Construction Documents; and (c) contains the equivalent of shop drawings and other information useful for construction." **As a reference, the authors consider this a BIM with a LOD greater than 300 as described in this paper.**

Contribution is defined by the 301 BIM Addendum as " the expression, design, data or information that a Project Participant (a) creates or prepares, and (b) incorporates, distributes, transmits, communicates or otherwise shares with other Project Participant(s) for use in or in connection with a Model for the Project." **This is typically adding or modifying a BIM to change its LOD.**

Contributor is defined by the 301 BIM Addenda as "a Project Participant who makes a Contribution." In the structural domain these would include Owners, Architects, Construction Managers, Steel Fabricators, and Erectors.

Design Model is defined by the 301 BIM Addendum as "a Model of those aspects of the Project that (a) are to be modeled as specified in the BIM Execution Plan prepared pursuant to this Addendum and (b) have reached the stage of completion that would customarily be expressed by an Architect/Engineer in two-dimensional Construction Documents. This shall not include Models such as analytical evaluations, preliminary designs, studies, or renderings. A Model prepared by an Architect/Engineer that has not reached the stage of completion specified in this definition is referred to as a Model." **This is typically a BIM with a LOD less than or equal to 300.**

Drawings are defined by the 301 BIM Addendum as "(a) those two-dimensional plans, sketches or other drawings that are Contract Documents under the Governing Contract and are created separately from, and are not derived from, a Model and (b) those two-dimensional projections derived from a Model supplemented with independent graphics and annotations specified by the Parties to be Contract Documents."

Full Design Model is defined by the 301 BIM Addenda as "a Model consisting of coordinated structural, architectural, MEP and other Design Models designated in the BIM Execution Plan to be produced by the design team." **This is typically comprised of BIMs with LODs of 300 but may require greater LOD than 300.**

Level of Development 350, Pre-construction Coordination Model Elements is defined as that content that goes beyond what designers have information to show but is less than a manufacturing level of development. This could include construction engineered items such as light gage kicker locations, open web joist web member configuration, miscellaneous steel braces, and curtain wall systems. This content is not always available from designers due to the information being contingent on which manufactures are selected by the contractor. However, content such as these can effect 3D spatial trade coordination and is typically needed before full fabrication level of development model elements (LOD 400) can be made. Models with LOD of 350 can be a hybrid of manufacturing level information that is known along with 3D massing based on rational assumptions for that content that falls short of a LOD 400.

Ikerd's Rules Of Thumb for Design Level Structural Modeling (100-350 LOD)

The following are my opinions on eleven topics I believe are fundamental to workable model element development in the design and construction of structures. Some of them relate more to sociology than technology (9, 10, and 11). As you review them, please send your comments and feedback to me (au@lkerd.com). Below is a summary of my eleven rules of thumb followed by a more detailed definition of each:

- 1. Avoid Re-modeling, Strive for Collaboration (IFC & CIS/2)**
- 2. Clearly Define the Local X,Y,Z Origin During Design**
- 3. Model Typical 1/8" Plan Structural and Civil Content for Design (1" = 20')**
- 4. Model Structure and Civil Content as it will be Constructed**
- 5. Do Not Duplicate Model Content Between A, S & MEP**
- 6. Use Shared Model When Two Disciplines Need to Control A Given Content**
- 7. Don't Assume Construction Ways & Means During Design (Ask!)**
- 8. Match BIM Material with Project Specifications [IC1]**
- 9. Have Engineers in Responsible Charge Open & Review Their Models**
- 10. Not All Steel, Concrete and Wood Content is Structural**
- 11. Train the Team Inside & Out on Structural BIM LOD**

1. Avoid Re-modeling, Strive for Collaboration (IFC & CIS/2):

Where possible, avoid modeling content that will have little downstream value. Most 3D structural detailing applications used do not readily import Revit content beyond the basic standard member information. As an example, approximately 90% of the North American steel detailers working in 3D are using one of two nonAutodesk applications for steel detailing. To date, these common steel detailing applications do not readily read in any custom families such as connections, gusset plates, and built-up members. Strive for modeling content that will export to IFC and CIS/2 formats when possible. Critically review the value of modeling content if it cannot be used downstream in construction via model hand-off or export.

2. Clearly Define the Local X,Y,Z Origin

The project general notes and specification should clearly define the local relative X, Y, Z coordinates that other trades will use in construction that are coordinated with the structural model. I typically prefer defining the X,Y coordinates of the origin (0,0) at the southwest most column grid intersection with a south and west offset of 10, 100 or 1000 feet depending on the project size. The southwest column intersection is chosen so that the structure is in a positive X-Y coordinate system. The offsets of 10, 100 or 1000 feet south and west of the origin are so that any portions of the building that extend south or west of the project origin grid intersections will also be within a positive X-Y coordinate system. The Z elevation should be defined as 0, 100' or absolute elevation depending on firm preference. I typically use a relative 100' elevation. We also establish plan north as being in the positive Y direction.

These rules above form the basis of the project's "local" relative building coordinate system. This process aids linking the structural model to 3rd party applications that are based on traditional CAD coordinate systems. A benefit of defining the local relative origin early and stating it in the project's general notes is so other models that are developed for shop drawings from the construction documents have a point of reference to follow when they are submitted for review. This local relative building coordinate system is also tied back to the civil engineers' state plane coordinate system. The civil state plane absolute coordinate system will then have a set relationship with the structural local relative coordinate system of an X, Y, and Z offset and a Z-axis rotation. Using this set relationship between the civil absolute and structural relative coordinate system, all federated project models can be easily converted to absolute or relative systems depending on the owner's preference in their facility management models (LOD 500).

3. Model Typical 1/8" Plan Structural and Civil Content for Design (LOD ~300)

For design documents (LOD ~300) model those elements that would traditionally appear on a 1/8" scale structural plan.

4. Model Structure and Civil Content as it will be Constructed:

Model as it is built at LOD 300 and higher. Material strengths and other similar items should be modeled as they are specified in the construction documents.

5. Do Not Duplicate Model Content Across Disciplines (A, S, & MEP)

Do not duplicate model content in different design team models. Rather create a shared model with that shared content that is linked into the structural and architectural model for example.

6. Use Shared Model When Two Disciplines Need to Control the Content:

Use a shared model when two or more designers need to control model elements. Structural content that is a candidate for a shared model would be structural slabs with architectural recesses, load bearing tilt-panels with architectural reveals, miscellaneous support steel and lenth shelf angles, and interior masonry walls.

7. Don't Assume Construction Ways & Means During Design

Structural design (LOD <350) BIM should not **assume** ways & means of construction by modeling content that requires decisions and direction from the construction team. **If** (1) the structural team's contract includes higher levels of modeling and (2) they have received direction from the construction team, there is definitive value in the additional modeling. However, if these two conditions are not met, **the structural model is more accurate without assumptions modeled into it.** The following are a couple of examples of structural items that should not be modeled during design unless their construction sequence has a material effect on the structure's performance and the two conditions listed above are met:

- a. Concrete pour breaks and construction joints in continuous concrete sections.
- b. Tilt-wall panel numbers for erecting sequences.

8. Match 3D Civil with Project Specifications (LOD 300_[a2]^[i3])

The material names, strengths and other properties used in Civil 3D shall be correlated with the project specifications and general notes. Structural model materials should match those that will be used in the design. My preference is for firms to develop a consistent color template for their structural materials that will aid in checking model content. Projects with existing structures for example that have A36 steel wide flange members with new construction with A992 steel should be modeled with the proper materials for each. Concrete should similarly have a separate BIM concrete material property for each distinct concrete mix design shown in the project's general notes and specifications. This may mean there will be a 3000 psi mix with air-entrainment for exposed concrete members and a second 3000 psi mix without air-entrainment for interior conditions.

Steel's should have separate material and color at a minimum for the following types :

- a. A500 (HSS sections)
- b. A36 (angle and plate material)
- c. A992 (wide flange members)
- d. F1557 (anchor rod material)
- e. A53 (pipe material)

9. Have Senior Engineers in Responsible Charge Open & Review their Models

Many states that I am aware of have some requirements to the effect of having the structural engineer who will be sealing the design of a building to have continuous and direct supervision and oversight of the work product used to create the design. This is often part of a state's definition of Responsible Charge. As such, it seems reasonable that the structural engineer of record should be opening the models and reviewing the work done in them by their EIT's, junior engineers and technicians. Engineers who have not learned the BIM tools in their office enough to open the models and walk through them cannot make informed decisions about BIM LOD. It is hard to understand how senior engineers who cannot open and review models can manage BIM projects to a LOD and write proposals that define that LOD using a process that they cannot access. I am not suggesting that firm owners and senior engineers model their own projects. However, they should consider having a very basic day to day level of knowledge that will allow them to open the models, walk through them and review the content without having to ask a junior engineer to come help them spin the model around. The level of competency to be able to navigate a model typically only takes one or two hours of effort to learn and allows the engineer in responsible charge to be an active part of their design in BIM. More importantly, it gives them a powerful way to mentor and train the next generation of engineers by having them review their junior engineers work in a graphically rich 3D environment.

10. Not All Steel, Concrete, Masonry and Wood Content is Structural

Not all model content that is steel, concrete, masonry and wood is structural nor should it be in the structural engineer's model beyond typical 2D details. Examples of such content would be steel lintels supporting brick over architectural openings, non-load bearing masonry and wood framing architectural partition walls, concrete site paving, concrete recesses in floors and concrete mechanical equipment pads. All such content should be modeled by the discipline that has the greatest control over the design and /or coordination of the element.

11. Train the team Inside & Out

All of the discussion of structural BIM LOD is academic unless everyone who works on the project understands what the goal for the project LOD are. This means that PM and engineers in the firm need to learn how to master the BIM tools. These engineers must then work with their architects and mechanical engineers to form a rational approach to the LOD across the project.

About the E202 OBJECT CLASSIFICATION UniFormat & MasterFormat

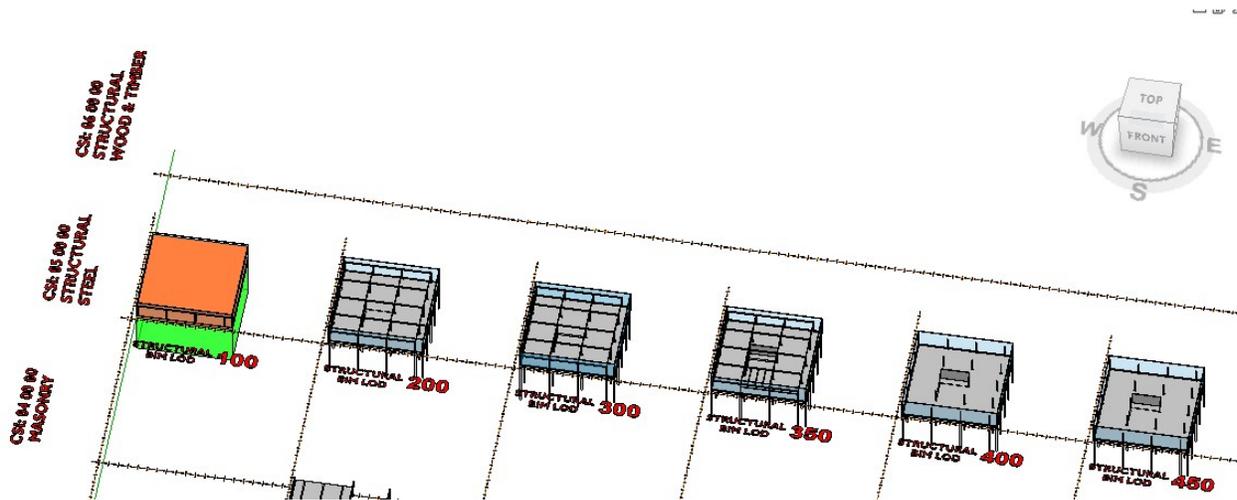
The AIA E202 document utilizes the Construction Specification Institute's (CSI) UniFormat in its table for defining the 'Level of Definition' of the models (AIA E202 § 1.2.3 Model Element). CSI's website states that "UniFormat's approach to organizing data is also important to the continued development of building information modeling (BIM) software, as its system organization allows objects to be placed before their properties have been further defined. When revision is complete, this version of UniFormat will be used as the basis for Table 21 – Elements of OmniClass. OmniClass, MasterFormat and UniFormat are three of the foundation classification systems available to structure the construction data attached to a model."

The image shows a table from the AIA Document E202-2008 Building Information Modeling Protocol Exhibit. The table is titled "Table 21 - Elements of OmniClass" and lists various object classes and their corresponding levels of definition. The table has several columns, including "Object Class", "Level of Definition", and "Level of Definition Description". The table is organized into sections for different object classes, such as "1.0000 - Structural", "2.0000 - Mechanical", "3.0000 - Electrical", and "4.0000 - Plumbing". The table is partially obscured by a watermark.

Hierarchical Structural LOD Model, version 2010.11

The following Hierarchical Structural LOD model, developed by the author, is a tool that is being developed to aid in graphically defining structural model content for project teams. The descriptions are only our opinions and the definitions will need to be adjusted depending on the

project that they are applied to. My intent in creating this content and the sample models provided is to identify the specific content requirements and associated authorized uses for each Model Element at seven different levels of completeness that are typically at progressively higher-levels of model element development. The general concept is that each subsequent LOD typically builds on the previous level and includes all the characteristics of previous levels. However, in structures and building enclosures this is not always the case. Current practice for many engineered items such as structural steel connections, unitized curtain wall systems, or steel open webbed joists is for the model content to be remodeled in the construction model. The design models (LOD 300 or less) of these elements are rarely being used to electronically automate the creation of the construction models (350+) due to lack of software interoperability.



Model Management

The level of model element development is not complete if it does not define who is responsible for managing model content for each defined phase of the project. This paper suggests that the structural model information at LOD of 100 is typically addressed with the aid of structural design narratives as this is all that is typically required early on in a project. When a structural LOD of 200 is required, the structural consultant should be responsible for the content until it is handed off to the preconstruction phase which in the US is typically at a LOD of 300 to 350 on most commercial building projects.

File Formats

The level of model element development is not complete if it does not include a definition of the applications that are used.

As an example, the team's BIM Execution plan should state "Models shall be delivered in the following format(s) as appropriate to their use for example:" The following examples would be for the level of model element development for design intent which is typically shown as 300 to 350 as suggested in this paper.

| Use of Model | Application | Required File Format(s) |
|-----------------------------|-------------------------|---|
| Architectural Design Intent | Revit Architecture 2011 | Source *.RVT Exported *.NWC (Navisworks) Exported *.DWG (for non-Revit team members) Exported *.IFC (for non-Revit team members) |
| Mechanical Design Intent | Revit MEP 2011 | Source *.RVT Exported *.NWC (Navisworks) Exported *.DWG (for non-Revit team members) Exported *.IFC (for non-Revit team members) |
| Structural Design Intent | Revit Structure 2011 | Source *.RVT Exported *.NWC (Navisworks) Exported *.DWG (for non-Revit team members) Exported *.IFC (for non-Revit team members) |

The following examples are LOD summary sheets that teams should develop at the beginning of a project. They are:

- LOD 100
- LOD 200
- LOD 300
- LOD 350
- LOD 400*
- LOD 500*

*For the structural design aspects of the LOD topic of this session, we will mainly focus on LOD 100 through 350. Few owners are currently requiring content that would be defined at LOD 400. Future updates to the structural LOD model will include level 400 topics.

Level Of Development (LOD) and the BIM Forum

Latest Version

The BIMForum has released the 2016 version of the LOD Specification.

Updates to the 2016 version include:

- New sections:
 - Railroad Bridge Steel
 - Railroad Bridge Precast
- The Attribute Tables in Part II have been expanded and reformatted for clarity
- Omniclass and Masterformat references have been added to Part I
- All definitions in Part I were reviewed and edited for consistency



Background

The *Level of Development (LOD) Specification* is a reference that enables practitioners in the AEC Industry to specify and articulate with a high level of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process. The *LOD Specification* utilizes the basic LOD definitions developed by the AIA for the *AIA G202-2013 Building Information Modeling Protocol Form*^[1] and is organized by CSI Unifomat 2010^[2]. It defines and illustrates characteristics of model elements of different building systems at different Levels of Development. This clear articulation allows model authors to define what their models can be relied on for, and allows downstream users to clearly understand the usability and the limitations of models they are receiving. The intent of this Specification is to help explain the LOD framework and standardize its use so that it becomes more useful as a communication tool. It does not prescribe what Levels of Development are to be reached at what point in a project but leaves the specification of the model progression to the user of this document. To accomplish the document's intent, its primary objectives are:

- To help teams, including owners, to specify BIM deliverables and to get a clear picture of what will be included in a BIM deliverable
- To help design managers explain to their teams the information and detail that needs to be provided at various points in the design process
- To provide a standard that can be referenced by contracts and BIM execution plans.

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It should be noted that this Specification does not replace a project BIM Execution Plan (BIMXP), but rather is intended to be used in conjunction with such a plan, providing a means of defining models for specific information exchanges, milestones in a design work plan, and deliverables for specific functions.

In 2011 the BIMForum initiated the development of this LOD Specification and formed a working group comprising contributors from both the design and construction sides of the major disciplines. The working group first interpreted the AIA's basic LOD definitions for each building system, and then compiled examples to illustrate the interpretations. Because BIM is being put to an ever increasing number of uses, the group decided that it was beyond the initial scope to address all of them. Instead, the definitions were developed to address model element geometry, with three of the most common uses in mind – quantity take-off, 3D coordination and 3D control and planning. The group felt that in taking this approach the interpretations would be complete enough to support other uses.

LOD 200

BIMFORUM
LOD SPEC. 2016



The Model Element is graphically represented within the Model as a generic system, object, or assembly with **approximate** quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

BIMFORUM
LOD SPEC. 2016

BIMForum Interpretation: At this LOD **elements are generic placeholders**. They may be recognizable as the components they represent, or they may be volumes for space reservation. Any information derived from LOD 200 elements must be considered approximate.



LOD 300

BIMFORUM
LOD SPEC. 2016



The Model Element is graphically represented within the Model as a **specific system**, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

BIMFORUM
LOD SPEC. 2016

BIMForum Interpretation: The quantity, size, shape, location, and orientation of the element as designed can be **measured directly from the model without referring to non-modeled information** such as notes or dimension call-outs.



LOD 350

BIMFORUM
LOD SPEC. 2016

BIM FORUM
ONLY

The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location, orientation, **and interfaces with other building systems**. Non-graphic information may also be attached to the Model Element.

BIMFORUM
LOD SPEC. 2016

BIMForum Interpretation: **Parts necessary for coordination** of the element with nearby or attached elements are modeled. These parts will include **such items as supports and connections**. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.



LOD 400

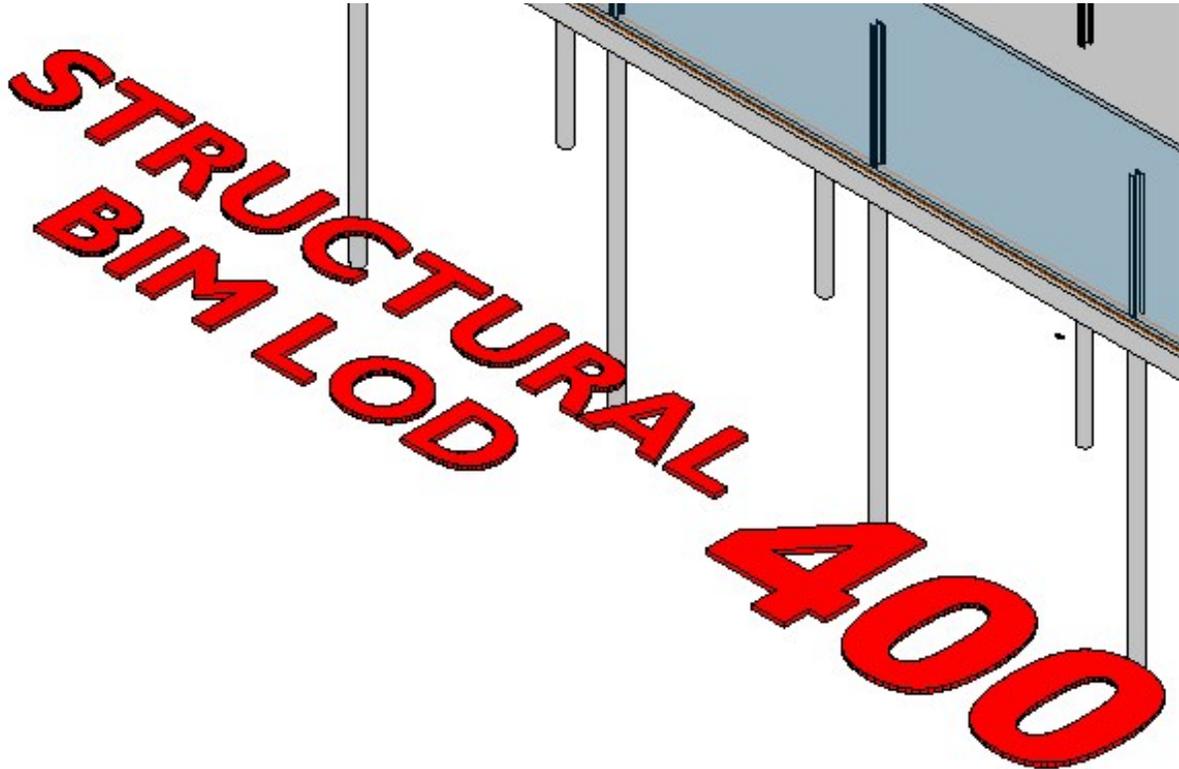
BIMFORUM
LOD SPEC. 2016



The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation **with detailing, fabrication, assembly, and installation information**. Non-graphic information may also be attached to the Model Element.

BIMFORUM
LOD SPEC. 2016

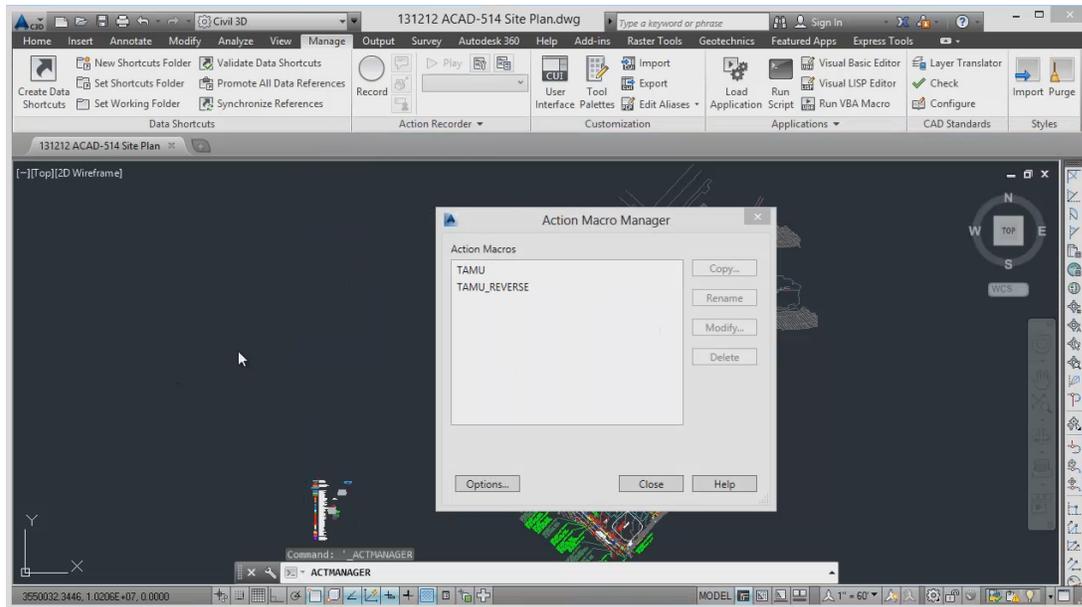
BIMForum Interpretation: An LOD 400 element is modeled at sufficient detail and accuracy for fabrication of the represented component. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.



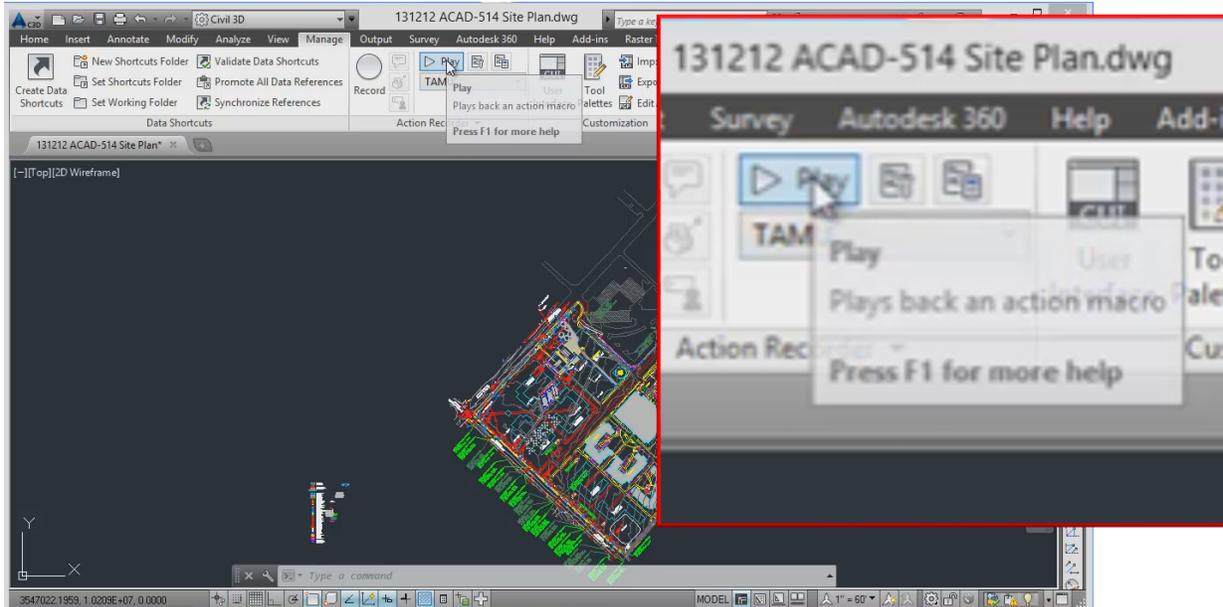
Using Action Macros in AutoCAD Civil 3D

The origin can be set to 0, 0 by using action macros in AutoCAD Civil 3D. Below are the steps that are taken with Action Recorder.

1. To set the file location, select a saved action macros in Action Recorder File Location of the Action Macro Manager.

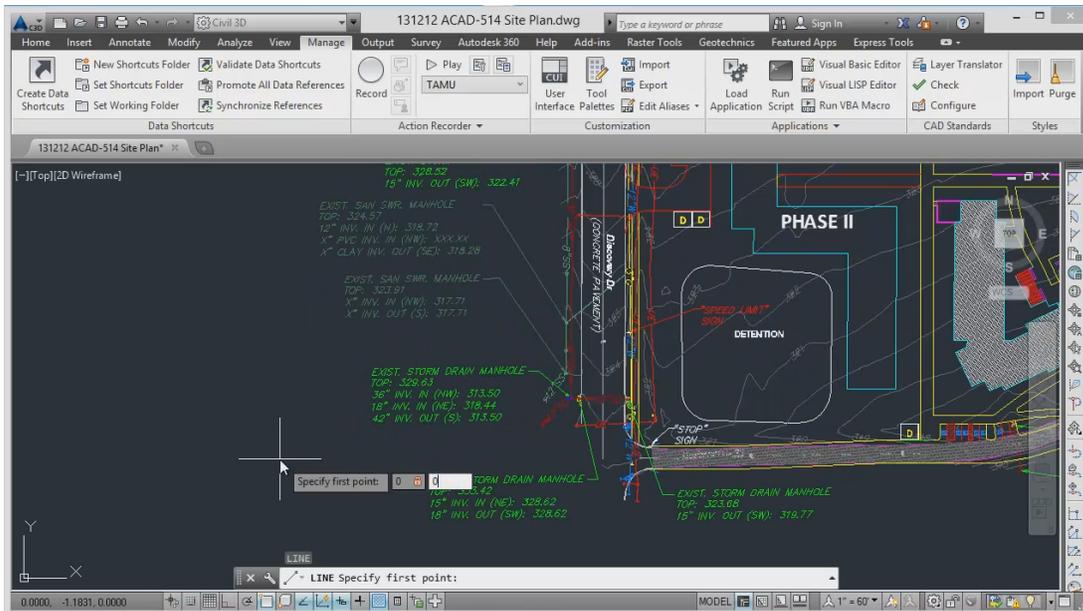


2. To execute the action macro click Play in the Action Recorder section of the Manage ribbon tab.



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- The action macro can be tested by creating a line at 0, 0.



- If the Macro executed correctly, the starting point of the line will be at the origin point 0, 0.

