Advancing BIM for Cold-Formed Steel Structures

Adam Johnson

Roni Ramirez

Cheng Yu

Wei-Wen Yu International Specialty Conference on Cold-Formed Steel Structures
Baltimore, Maryland, U.S.A, November 9 & 10, 2016

Advancing BIM for Cold-Formed Steel Structures

Adam Johnson[1], Roni Ramirez[2], Cheng Yu[3]

Abstract

This paper presents a research project aimed at advancing BIM for cold-formed steel (CFS) structures. The creation of the CFS family for Autodesk Revit is a handy solution for the lack of CFS members and information inside the Autodesk Revit libraries. Revit is one of the industry's standard software for producing building information models. To overcome the disadvantages of not having CFS members in Revit, this research project focused on two phases to reach completion. Phase one consisted of developing a BIM library of industrial standard CFS members such as studs, tracks, and channels. Parameters were added to the members so that more information would be provided with them. These parameters include, but are not limited to, all the characteristics of CFS such as its gross, effective, and torsional properties. Phase two of the project consisted of using the developed CFS library to create light framed building models in Revit. This paper presents the results of creating and using this CFS library to produce CFS structures in combination with industry standard software.

1 Research Assistant, University of North Texas (adamjohnson2@my.unt.edu)

2 Undergraduate student, University of North Texas (roni.ramirez@unt.edu)

3 Associate Professor, University of North Texas (cheng.yu@unt.edu)

Introduction

This paper presents a research project aimed with the primary purpose of advancing building information modeling (BIM) for cold-formed steel (CFS) structures by developing a series of open BIM models that AISI committees, researchers, manufacturers, engineers, and other interested parties may use for exploration and demonstration of CFS solutions. Autodesk Revit (Autodesk I. , 2015) is one of the industry's standard software for producing building information models. Our recently completed research project is a two-phase designed practical solution that overcomes the disadvantages of not having a CFS family in Autodesk Revit. We teamed up with IKERD Consulting's two project coordinators, Eloisa Amaya and Trevor Koller in order to successfully complete the project. This research report accounts the results of creating and utilizing the CFS library and producing CFS structures in combination with industry standard software.

Building Information Modeling

BIM is the use of 3d systems to create a visual representation of a structure to assist in its construction and utilization. It is the logical development of CAD drawings, a relatively new technology that is becoming mainstream at a rapid rate (Wikipedia, 2016). The whole building is built as a three-dimensional computer model, and all the plans and other two-dimensional views are generated directly from the model so as to ensure spatial consistency. Although BIM has its roots in the mid-1980s, only recently has it risen in popularity within the Architectural, Engineering and Construction (AEC) industries. Due to this significant rise in popularity, the AEC industry has created a demand for well-trained individuals capable of implementing BIM technology in the work place. BIM is considered as a digital software system and an open standards-based collaborative business process targeting life-cycle facility management which serves as a common, centralized repository/portal for all life-cycle building related information, from its conception straight through its deconstruction (Words & Images, 2009).

Since the BIM software architecture is based on parametric modeling, the geometric consistency and integrity of the building model is maintained in spite of any changes or modifications that have been made to it. With all this being said, the true crux of the improvements of BIM over traditional methods of representation is not in the model, it is in the information held in the model. It is the access to this data that leads to the true benefits of using BIM and because of this ability to incorporate sufficient information into the models. This remained one of the main focuses on the project. Understanding the concept of these parametric objects is to understand what a building information model is and how it differs from traditional 2D design. Traditionally designed drawings had to be coordinated to assure that different building systems do not clash and can actually be constructed in the allowed space. Accordingly, most clashes are identified when the contractor receives the design drawings and everyone is on-site and working. With clashes being detected so late, delay is caused and decisions needed to be made very quickly in order to provide a solution. With the use of clash detection inside BIM, it enables potential problems to be identified early in the design phase and resolved before construction begins. A parametric object consists of a series of geometric definitions and their associated data and rules. By the same token, these geometric definitions are integrated non-redundantly and do not allow for inconsistencies between the model and its associated data set. In layman's terms, this means that any changes made directly to the model will result in an equal change to the data set associated with the model.

Existing issues in BIM families of CFS

The purpose of this project was never to recreate something that already existed, but rather to address the weakness of any pre-existing Revit families and convert them into strengths for this project. That being said, there exists similar Revit families and libraries that are based off of light gauge steel in the software's library that have a low level of details. However, there are no official cold-formed steel families found in the Revit's library and because of this lack of a CFS family, there was a need to have one created. This newly created CFS library focused not just on the 3D modeling but also the lack of information in the pre-existing families in Revit. By comparison to the light gauge steel families in Revit, this newly created CFS family offers more parameters that encompass more information such as, but are not limited to, all the characteristics of CFS sections such as the gross, effective, and torsional properties. The family also offers more variety compared to the pre-existing light gauge steel family, meaning that every member created comes in two flavors; structural columns and beams with and without holes. Figure 1 is a direct image captured from Revit 2015 depicting the parameters from the light gauge steel family.

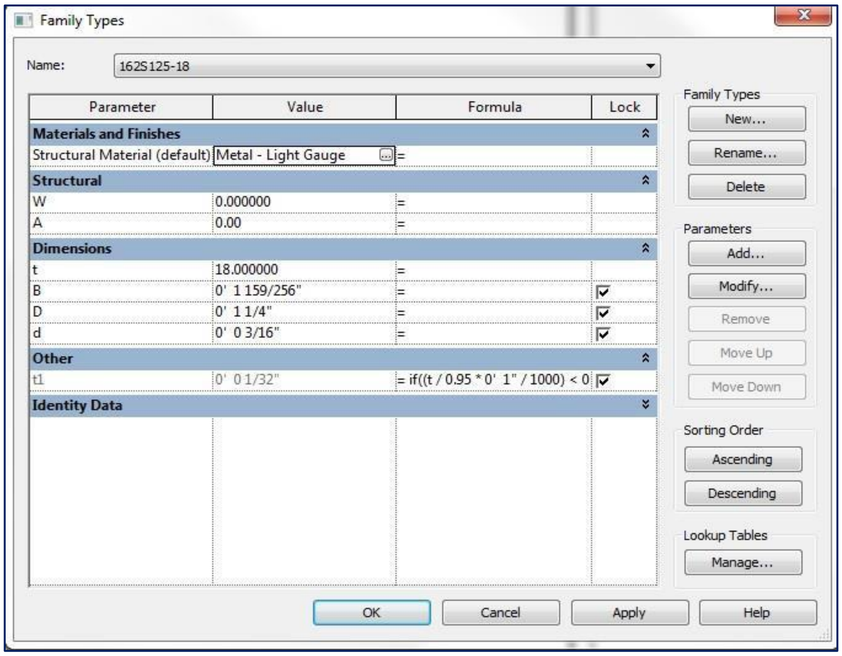


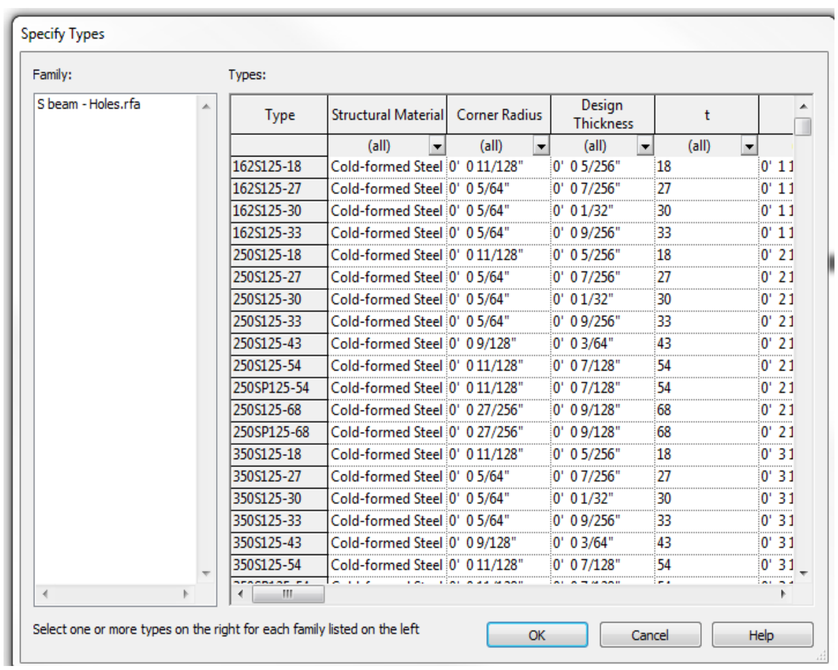
Figure 1: Light gauge family parameters

Developing CFS families in Revit

This section will walk through the necessary steps used to create the CFS library with a certain level of details. The SSMA catalog (SSMA, 2015) was used as the reference for the geometry of CFS sections in this research. The first step in creating the family began with creating and laying out the model lines for the members and these were done by using the light gauge steel family as a template based on which type of member was being created (i.e. studs, tracks, zees, channels, etc.). Parameters were created for the information we sought to input into the models. The parameters were created and assigned their proper types and disciplines. After this step was completed, the Revit family file was saved in a convenient location. The next step in mass producing hundreds of similar Revit models with different dimensions such as a 162S125-33 versus an 800S125-68, was gathering all the information we deemed necessary and putting it into a type catalog. This was done by creating a text file using the Notepad software, then inputting the first line of text in the order the information would be read (left to right). The first line would include the name of the parameters as seen in Revit followed by two pound signs (#), followed by the type of parameter, and then another set of number signs and finally the units of measurement. For example:

Design Thickness##length##inches, Corner Radius##length##inches

After listing all the parameters for the members and ensuring that only parameters that have been created in the Revit family file were listed (otherwise they would be ignored by the Revit software), on the very next line of the text file is where the name of the member and its parameters would be listed with a comma in-between each parameter value. After all the parameter values had been entered into the text file, the file was then saved with the exact same name as the Revit family file and saved in the same location. Finally, the last step was verifying the newly cataloged family would open correctly. This was done by loading a new Revit project or family file and loading the new family from the Insert tab. After navigating to the location of the file, Revit opened up a new section that encompassed all of the different sizes of that particular family such as studs or tracks, as illustrated in Figure 2.



Type	Structural Material	Corner Radius	Design Thickness	t	
	(all)	(all)	(all)	(all)	
162S125-18	Cold-formed Steel	0' 0 11/128"	0' 0 5/256"	18	0' 1 1
162S125-27	Cold-formed Steel	0' 0 5/64"	0' 0 7/256"	27	0' 1 1
162S125-30	Cold-formed Steel	0' 0 5/64"	0' 0 1/32"	30	0' 1 1
162S125-33	Cold-formed Steel	0' 0 5/64"	0' 0 9/256"	33	0' 1 1
250S125-18	Cold-formed Steel	0' 0 11/128"	0' 0 5/256"	18	0' 2 1
250S125-27	Cold-formed Steel	0' 0 5/64"	0' 0 7/256"	27	0' 2 1
250S125-30	Cold-formed Steel	0' 0 5/64"	0' 0 1/32"	30	0' 2 1
250S125-33	Cold-formed Steel	0' 0 5/64"	0' 0 9/256"	33	0' 2 1
250S125-43	Cold-formed Steel	0' 0 9/128"	0' 0 3/64"	43	0' 2 1
250S125-54	Cold-formed Steel	0' 0 11/128"	0' 0 7/128"	54	0' 2 1
250SP125-54	Cold-formed Steel	0' 0 11/128"	0' 0 7/128"	54	0' 2 1
250S125-68	Cold-formed Steel	0' 0 27/256"	0' 0 9/128"	68	0' 2 1
250SP125-68	Cold-formed Steel	0' 0 27/256"	0' 0 9/128"	68	0' 2 1
350S125-18	Cold-formed Steel	0' 0 11/128"	0' 0 5/256"	18	0' 3 1
350S125-27	Cold-formed Steel	0' 0 5/64"	0' 0 7/256"	27	0' 3 1
350S125-30	Cold-formed Steel	0' 0 5/64"	0' 0 1/32"	30	0' 3 1
350S125-33	Cold-formed Steel	0' 0 5/64"	0' 0 9/256"	33	0' 3 1
350S125-43	Cold-formed Steel	0' 0 9/128"	0' 0 3/64"	43	0' 3 1
350S125-54	Cold-formed Steel	0' 0 11/128"	0' 0 7/128"	54	0' 3 1

Figure 2: S beam with holes family member list CFS family with holes

After creating the CFS family without holes, they were then edited so that the option of modeling with members that have holes would be available. These models have a higher level of details than the pre-existing light gauge steel family. The holes were added by following the steps described below. After successfully loading and opening a member in the CFS family, go to an elevation view that shows the best inside view of the member and create a void extrusion using the line and start-end-radius arc tool. The holes were created following the most common sized holes in cold-formed steel members in the industry. These dimensions happen to be 4 in. (10.16 cm) long with a radius of ¾ on. (1.905 cm) for members smaller than 3 ½ in. (8.89 cm) wide and for members larger than this, the radius is 1 ½ in. (3.81 cm). After drawing the holes but before finishing the extrusion and exiting the editing mode, parameters were created to control the hole's radius, hole length, and the distance from the top of the hole to the top of the CFS member. A formula was used to calculate the hole length {4-(2×(design thickness + hole radius))}, which gave an approximate length of 4 in. (10.16 cm) for the member. After creating these parameters, the editing mode was exited for the void extrusion and a vertical reference plane was created between the middle of the member (running the full length of the member). A parameter was created for the reference plane and a side of the CFS member {(width of member/2) + or – hole radius} (depending on which side of the member was chosen). The closest side of the hole to the reference plane was then locked onto the reference plane so that the location of the hole could be changed, or in this case centered. At this point, two horizontal reference plane was created that ran the width of the member. The first horizontal plane was locked onto the center of the original hole created and the second reference plane was locked a distance of "x" away from the first plane. This was done to allow user control of the distance from the top of the member to the center of the first hole. A similar thing was done to the preceding holes that were arrayed from the original hole. Once again, this was done to allow user control of the distances between the holes. After doing this, go to an elevation that shows the side of the member. This is where another reference plane was added that was locked onto the furthest protruding end of the void extrusion, and the other end was locked onto the side of the member. A parameter was added to the length of the locked side to the locked reference plane and was set as the thickness for the member, so that the hole's depth would not extend beyond the member's. Figures 3 and 4 were captured directly from Revit to illustrate all of the parameters that went into making and configuring/controlling the holes for this portion of the project.

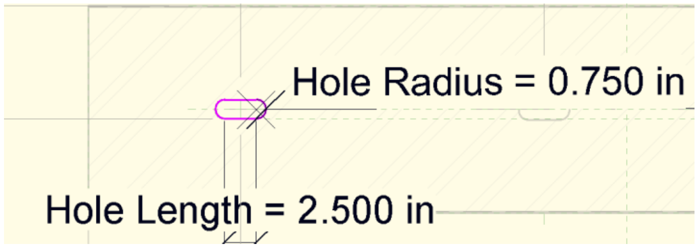


Figure 3: Foundation parameters for the holes

Hole Length	2.500 in	= 4 in - Hole Diameter	☑
Hole Radius	0.750 in	= Hole Diameter / 2	☑
Hole to Hole Spacing	24.000 in	=	☐
Member to Hole Spacing	12.000 in	=	☐
Hole Centered	8.928 in	= (D Outside / 2) + (Hole Diameter /	☑
Hole Diameter	1.500 in	=	☑
Ma1	206.9100 kip-ft	=	
Number of Holes (default)	2	= Length / 25 in	☐

Figure 4: Parameters used to relocate holes

Finally, as mentioned earlier the original hole should have been arrayed a distance ".y" (based off of the user input) to control the hole to hole spacing. After the hole was arrayed, a parameter should be created on the number of holes wanted. This parameter was set to a formula based off of the length of the member divided by the hole spacing. This allows the user to model any length of member and have a series of consistent spaced holes throughout the entirety of the member. After doing all of this, the file was then saved and then tested in Revit were multiple CFS hole members were created and had their lengths edited to verify that everything worked as hoped for. Figure 5 is an illustration of the completed family along with all the parameters that encompass them.

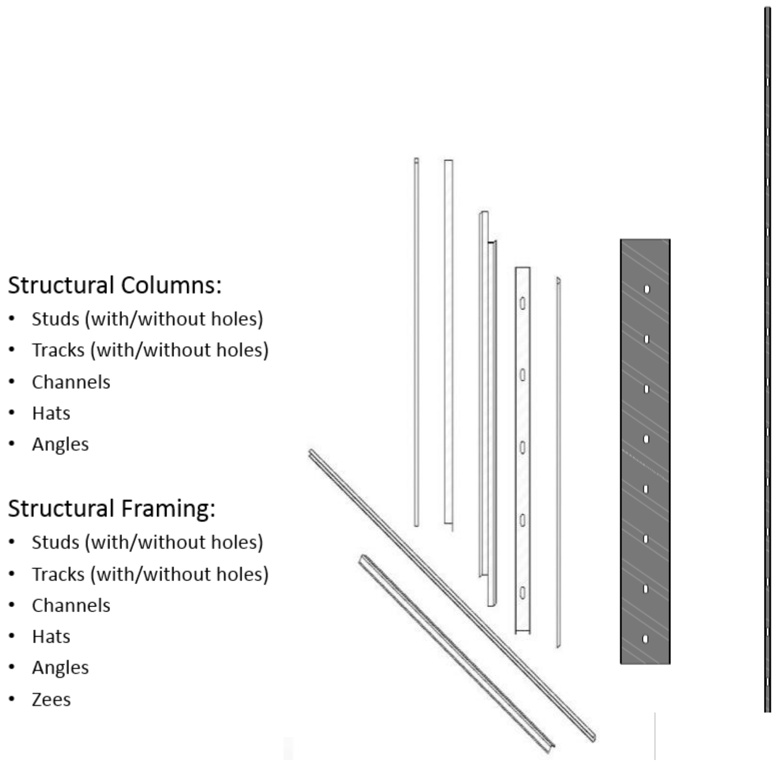
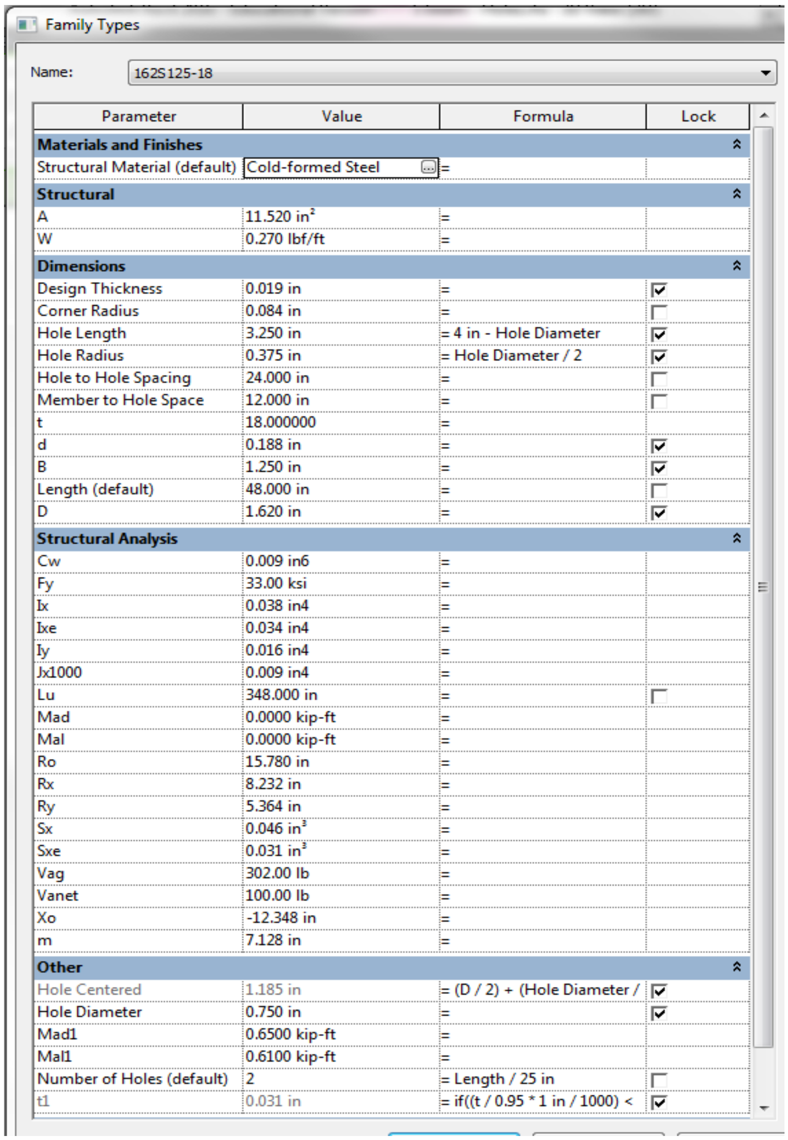


Figure 5: Developed CFS families



Family Types

Name: 162S125-18

Parameter	Value	Formula	Lock
Materials and Finishes			
Structural Material (default)	Cold-formed Steel	=	
Structural			
A	11.520 in²	=	
W	0.270 lbf/ft	=	
Dimensions			
Design Thickness	0.019 in	=	☑
Corner Radius	0.084 in	=	☐
Hole Length	3.250 in	= 4 in - Hole Diameter	☑
Hole Radius	0.375 in	= Hole Diameter / 2	☑
Hole to Hole Spacing	24.000 in	=	☐
Member to Hole Space	12.000 in	=	☐
t	18.000000	=	
d	0.188 in	=	☑
B	1.250 in	=	☑
Length (default)	48.000 in	=	☐
D	1.620 in	=	☑
Structural Analysis			
Cw	0.009 in6	=	
Fy	33.00 ksi	=	
Ix	0.038 in4	=	
Ixe	0.034 in4	=	
Iy	0.016 in4	=	
Jx1000	0.009 in4	=	
Lu	348.000 in	=	☐
Mad	0.0000 kip-ft	=	
Mal	0.0000 kip-ft	=	
Ro	15.780 in	=	
Rx	8.232 in	=	
Ry	5.364 in	=	
Sx	0.046 in³	=	
Sxe	0.031 in³	=	
Vag	302.00 lb	=	
Vanet	100.00 lb	=	
Xo	-12.348 in	=	
m	7.128 in	=	
Other			
Hole Centered	1.185 in	= (D / 2) + (Hole Diameter /	☑
Hole Diameter	0.750 in	=	☑
Mad1	0.6500 kip-ft	=	
Mal1	0.6100 kip-ft	=	
Number of Holes (default)	2	= Length / 25 in	☐
t1	0.031 in	= if((t / 0.95 * 1 in / 1000) <	☑

Figure 6: Gross, effective, torsional, and hole parameters

Application of CFS families in building BIMs

The creation of a building model using the newly created cold-formed steel family was the first step of the second phase. This was an essential step in the finishing of this project because it was necessary to verify that the new family could be used with industry standard software. It was already determined that the CFS families could be used in Revit, so that creating a building model by placing members manually by a user was possible and tested.

Essentially, a user would load in the CFS members that they wanted to use by going to the “Structure” tab and choosing the beam or column option and selecting ”Load family”, after creating a new Revit project file. From there, the user would select all member sizes that they would like to model with, then begin placing the beams and columns wherever they would like. This is just one method of modeling a building using the CFS family that was also recorded for tutorial purposes, with the final result being illustrated in Figure 7 below.

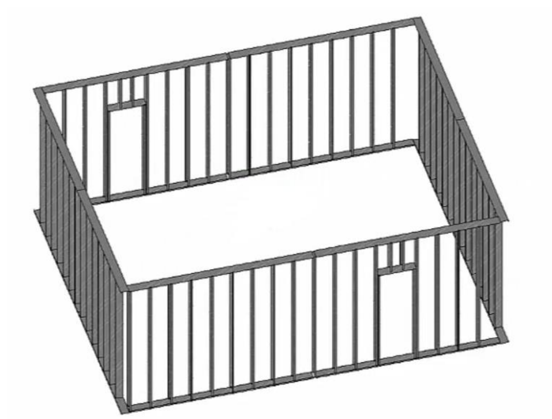


Figure 7: Simple single-story CFS structure modeled manually

Another method used with this project that was also recorded for tutorial purposes, features a Revit add-in known as Metal Wood Framer (MWF) (Solutions, 2015). This add-in is considered to be among the industry top software and a standard. This is why it was imperative to verify that the CFS members would be compatible with the software. After following a few of the tutorial videos provided by StrucSoft, it was determined that the CFS members were indeed compatible with the add-in and were able to produce building models with the members in a very short time span. Figure 7 illustrates a building that was modeled with the use of the CFS family and MWF.

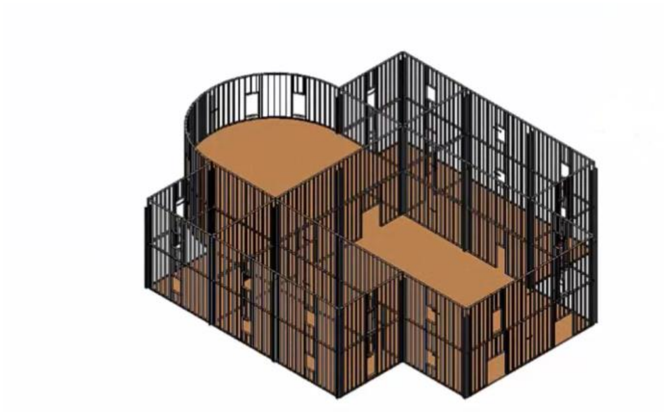


Figure 8: Two floor CFS structure modeled with MWF

Discussion

Advancing building information modeling for cold-formed steel epitomizes the primary goal for this project. There are several questions that have already been answered in this paper such as, what is BIM, was there a need for this project, and even what steps were taken to complete the phases of the project. However, even with these set of questions answered, there is still a lot more work and thought that went into this project for example, the level of development for modeling the cold-formed steel members, contacting industry leaders, and creating tutorial videos on how to use the CFS members with and without any add-ins.

The Level of Development and Level of Detail (LOD) specification is a reference that allows specialists in the architecture, engineering, and construction industry to specify and articulate with a very high degree of clarity on content and reliability of BIMs at various stages in the design and construction process (BIMForum, 2015). Level of Detail is essentially how much detail is included in the model whereas Level of Development is the degree to which an element's geometry and attached information has been thought through. Currently, there are no detailed standards for the design phases. Many companies and architects have created in-house standards, but as you can imagine, they differ from one company to the next. With that being said, LOD is essentially on its way to being the standard for describing the level of detail design phase in the industry. This then creates a basis for which other companies and firms can communicate on the design process without misunderstandings and lack of consistency. This project incorporates some of the principles of LOD 200, LOD 300, and even LOD 350, which may actually even be considered LOD 400 under certain circumstances.

The CFS families range from just standard solid members such as studs, tracks, and channels, to these members having as much detail in them such as their torsional and gross properties, not to mention the variation of members with and without holes. Below is an excerpt from the LOD Specification guide to give a clear idea of how LOD works.

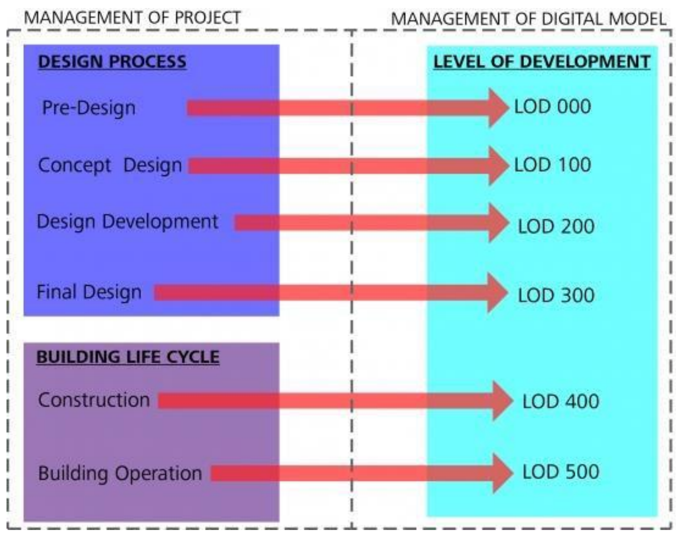


Figure 7: Fundamentals behind LOD (Autodesk, 2015)

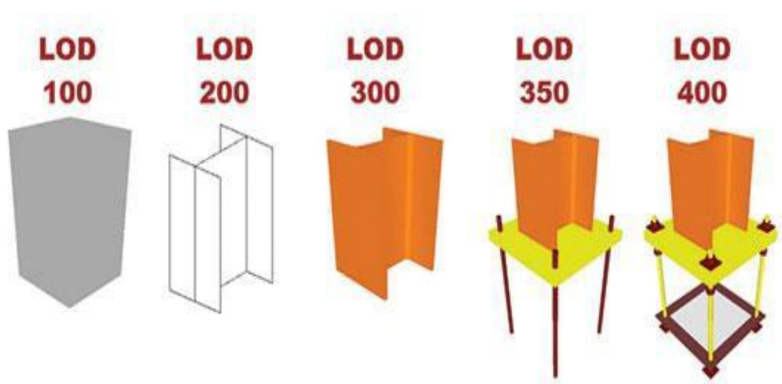


Figure 8: LOD examples (BimForum, 2015)

Conclusion

All things considered, this is a great step forward towards advancing BIM in cold-formed steel. This project produced many positive results that range from creating a working cold-formed steel family library to reaching out and communicating with some of the industry's leading software hands to verify that the families are compatible. By the same token, just because we believe this project to be a success does not mean that the project cannot be furthered and made better. There is always more work that can be done, for instance reaching out to other industry hands and trying to make the family more fluid and potentially compatible with future software is just one possibility. Also, just because the family works doesn't necessarily mean that it cannot be adjusted so it works better with other industry standards. As mentioned in the discussion, there was a certain level of development that went into this project, which means that there was a certain level of thought that was implemented into the CFS families. I say this to point out that research may never truly be finished and that more thoughts and detail can be conceived and implemented into the families to better them.

Acknowledgements

This paper was prepared as part of the 2015 AISI Small Project Fellowship award: Advancing Building Information Modeling for Cold-Formed Steel Structures. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the AISI. The authors would also like to recognize the technical advises provided from the team at Ikerd Consulting LLC, Will Ikerd, Eloisa Amaya, and Trevor Koller. UNT undergraduate students Maxine Tao and Xun Li also participated in this project as research assistants. More research details can be found at http://engineering.unt.edu/technology/public/cyu.

References:

Autodesk (2015). "A Sustainability Workshop," San Rafael, CA. Retrieved from: http://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development.

Autodesk Inc. (2015). San Rafael, CA. Retrieved from https://knowledge.autodesk.com/.

BIMForum (2015). "Level of Development Specifications Version 2015," BIM Forum, Arlington, VA.

Wikipedia. (2016). "Building Information Modeling," Retrieved from https://en.wikipedia.org/wiki/Building_information_modeling.

Words & Images, (July 2009). "BIM: Understanding and Operating in a New

Paradigm," The Foundation of Wall and Ceiling Industry, Falls Church, VA.

SSMA. (2015). "Product Technical Guide," Steel Stud Manfacturers Associatoin, Chicago, IL.

StrucSoft Solutions (2015). "Getting started with Metal Wood Framer," Quebec, Canada, Retrieved from http://strucsoftsolutions.com/.