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An Interoperable Analysis of Building Information Modeling for Structural Design Purposes

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The main objective of the research was to explore the ways and methods for integration of information in the context of processes based on Building Information Modeling (BIM) technologies and to investigate the main issues underlying the inadequate interoperability between applications used for Architecture, Engineering and Construction (AEC) projects with special emphasis on architectural and structural design. For identifying various interoperability issues, different parametric models were created in the chosen software. In the first part of the interoperability experiments of the research, simple self-tests were performed to verify support of software applications for IFC (Industry Foundation Classes) and interpret internal mapping mechanism of these software resulting from exporting of model in IFC format. The information exchange was analyzed using direct link through API and indirect link through open universal standard IFC as it

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severs the purpose of openBIM. After the comprehensive analysis of data sharing among most commonly used BIM authoring tools in architectural and structural domains, it was realized that interfaces for the exchange differed significantly between the software tools. The results demonstrate that interoperability issues commonly arise, such as the increasing file-size, inconsistent object types, geometric misrepresentation, different colours, loss of properties and relations. Interoperability issues such as data loss and misrepresentation do exist, when software tools import IFC models created by other software tools. The comparative study indicates that BIM workflow is not yet fully competent to fulfill the inter domain information exchange process because many drawbacks. The integration of all the project data from various disciplines enhances coordination, transparency, prevents loss of information, design conflicts, duplication of work resulting in better project management.

Keywords: OpenBIM; interoperability; IFC; architectural design; structural analysis.

1. INTRODUCTION

In the period of information technology, the Architecture, Engineering and Construction (AEC) industry is also advancing rapidly towards automation. Management of the construction projects starting from conceptualization stage, construction, maintenance and up to demolition of the project are being restructured through the use of innovative technologies [1]. Exponential increase in digital landscape of the industry can be seen as engineers are looking for new ways to enhance productivity, quality and efficiency and to reduce cost and time of delivery of the project. Construction industry is known by its unique nature because professionals collaborate temporarily for the duration of a project only, exchange information based on paper drawings [2]. Construction industry has also been reported to be slow in adoption of new technologies [3]. So to reshape the image of industry and for better organization of vital data produced due to increase in complexity of construction projects, demands the implementation of innovative techniques. A number of professionals work separately in their own domains for planning, design, construction and maintenance of a project. For a successful construction project, an uninterrupted understanding and widespread exchange of information among these stakeholders is essential. In other words, cooperation and collaboration among the different disciplines of the project is essential for successful completion of a project and to make the process more productive and qualitative. Exchange of data between those involved in a construction project is always a fundamental requirement. With the advent of IT, paper-based technical drawing exchange has been replaced by semantically rich, digital 3D models. In this era of digital transformation Building Information Modelling, commonly known as BIM, has been playing a vital role. BIM is the foundation of digital transformation in AEC industry [4]. BIM is a process of using 3D virtual representation of buildings, for collecting and managing building data from the start of the project to the operation of building through its construction. By applying the BIM technique, everything begins with a 3D digital model of the building. In this process a full digital physical appearance and functional description of the built facility, preserves and shares all information using comprehensive digital illustrations known as BIM models [5]. By reducing the manual re-entering of data to a minimum and enabling the consequent re-use of digital information, laborious and error-prone work is avoided, which in turn results in an increase in productivity and quality in construction projects.

Successful implementation of BIM is directly measured by the integration and exchange of wealth of information contained in the BIM model among different parties and different stages of the project which is technically known as interoperability [6]. Interoperability is a process of data import and export among heterogeneous software tools, in which a software tool exports its model in a standard format for sharing and exchange of data and the other one imports this model for further use. Although it offers a lot of opportunities, there are some difficulties when applying this idea in reality. The interoperability between applications is not always error-free: the main problem is data loss during the export/import processes. The main reason for the absence of interoperability is the use of unique interfaces, libraries and functions for various domain specific BIM software.

Building smart International a non-profit organisation has developed and regularly promoted the use of IFC-Industry Foundation

Classes (a common language), to solve data exchange problems. IFC, an object-oriented standardized terminology and a common data model, which aims to achieve a high level of interoperability to facilitate data exchanges between BIM tools in the building industry.

The main objective of the research was to explore the ways and methods for integration of information in the context of processes based on BIM technologies and to investigate the main issues underlying the inadequate interoperability between applications used for AEC projects with special emphasis on architectural and structural design. After comprehensive review of literature, the inefficiencies that currently exist in the exchange of information between systems and applications used in AEC projects using BIM technology have been examined. A comprehensive assessment has thereby been conducted among available information exchange methods, the focus being interoperability of data between architectural and structural analysis domains.

2. METHODOLOGY

The study was aimed at investigating the degree of interoperability between software platforms that are commonly used for architectural and structural design in construction industry. The purpose was to analyze the possible ways of data exchange between architectural design and structural analysis applications and to understand the pros and cons of current practices of sharing the information in the AEC industry. The information exchange was analyzed using direct link through API and indirect link through open universal standard IFC as it severs the purpose of openBIM. BIM authoring applications considered in the interoperability assessment were Revit Architecture from architectural domain and Robot Structural Analysis (RSA) and Staad Pro from structural analysis domain. Fig. 1 shows the information exchange scenario realized in this research. The goal was not to judge a single software application to decide if a specific one is better than another, but to provide practical

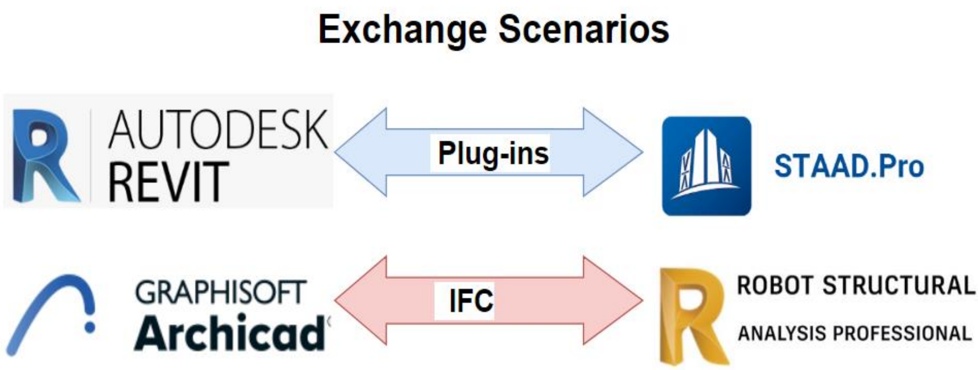


Fig. 1. Information exchange links investigated

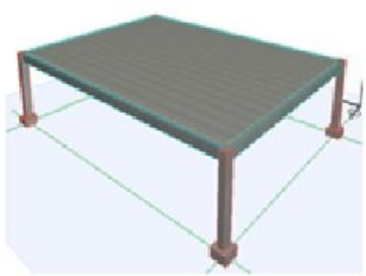
Software	ArchiCAD	Revit
Screenshots of models in Architectural software		

Fig. 2. Models in architectural software

information to users facing similar problems in the real world.

2.1 Data Analysis of IFC Export

For identifying various interoperability issues, different parametric models were created in the chosen software in this sub-section. In the first part of the interoperability experiments of the research, simple self-tests were performed to verify support of software applications for IFC and interpret internal mapping mechanism of these software resulting from exporting of model in IFC format. For this purpose, a simple concrete frame consisting of beams, columns, footings and slab with respective physical properties, was created in the architectural application. All elements were assigned concrete as material and defined as load bearing elements. For each building model, typical elements available in the library of the modeling software were selected representing the structural components. The modeling instructions, if provided by each of the modeling software, were followed while creating the models. Although these BIM tools offered the possibility to edit IFC export-related properties of a single building element, the default assigned properties were not changed. Fig. 2 shows the models created in each of chosen software for study. In this way, two IFC building data models were exported from these software for the IFC2×3 schema, intended to test the support for IFC features in the most reliable way.

The models which were exported from the selected software were analyzed using the NIST IFC File Analyzer (IFA), in order to formally check them and to compare the summary statistics of IFC files generated by these tools [7]. This tool can be downloaded for free from http://ciks.cbt.nist.gov/cgibin/ctv/ifa_request.cgi.
All the entities processed by IFA are listed in the first column of the summary sheet. The tool counts the number of entities, relationships and properties and summarizes it in CSV or excel format. IFC entities are grouped in different colours in the summary worksheet.

2.1.1 Round-trip testing of software applications

Other type of test criteria that have been used to make a comparison of one IFC file to another for projects that relied on re-exporting or round-tripping of an IFC file. In this test methodology, the original IFC model is compared to the re-exported model from same software [8,9]. The Original IFC model exported from software was imported back in the software itself and again re-exported as IFC model without any modification. This practice is known as round-trip of data.

2.2 Geometric Data Exchange Analysis

The main critique for using IFC as per Jeong et al. [10], as a BIM exchange format has been the data loss when sharing data from one application to another. Digital data exchange between architectural design and structural analysis, when both domains use BIM authoring software tools, is still burdened with numerous difficulties and mostly caused by semantic problems and particularly challenging problems of geometric interpretation [11]. To identify the origins of data losses, misinterpretations in data mapping and inconsistencies in data exchange between architectural design and structural analysis, more comprehensive testing of BIM application was conducted. In order to test the end-user experience and know the level of maturity of data exchange based on direct links using API and IFC standards of each of the BIM applications, distinct building models were created in these applications.

2.3 Export from Revit to Staad Pro

The export process of Revit model to Staad Pro could be performed using two procedures. Firstly the ISM- Revit Plug-in, provided by Bentley can be used. It needs to be installed on the Revit interface. The second method of export is based on the IFC standard. The direct import of IFC model from Revit to Staad Pro is not supported. The IFC model needs to be converted to an ISM file before importing it to Staad Pro. iTwin Analytical Synchronizer has been used for this conversion. Bentley, parallel to the concept of BIM has developed an open platform technology well-known as Integrated Structural Modelling (ISM) for sharing structural engineering project information among structural modelling, analysis, design, drafting and detailing applications. ISM has been introduced with main focus on the structural information to aid and deal with the major challenges of structural interoperability and modification of the load bearing components of buildings, bridges and other structures. ISM interoperability is a fundamental capability of Bentley analytical and design modelling applications such as STAAD Pro, AECOsim Building designeer, ProStructures and RAM. In

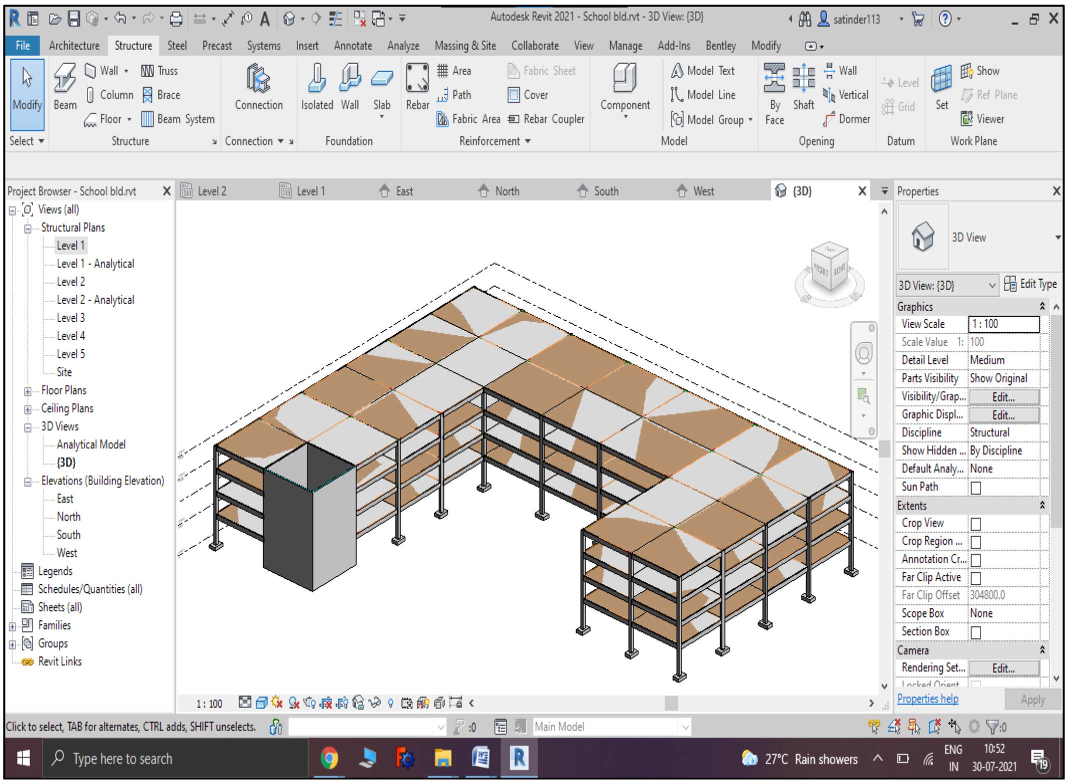


Fig. 3. Model generated in revit architecture

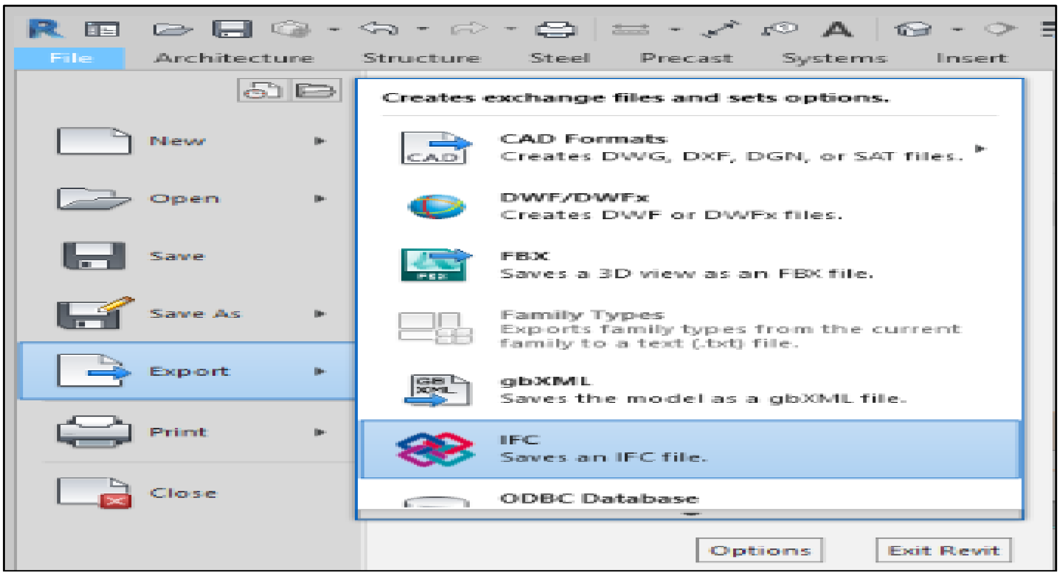


Fig. 4. User interface for IFC export in Revit

addition, plug-ins have also been developed to interoperate with non-Bentley applications such as Revit and Tekla.

The model considered for case study was the central block of a college building created in Revit 2021. The building (Fig. 3) was composed of four floors and the material adopted was reinforced concrete. The beams and columns admit rectangular section and the orientation of columns were kept perpendicular to the largest dimension. The structural walls around the elevators were also considered.

2.3.1 Export to staad pro through ISM revit plug-in

ISM Revit plug-in provided an interface to convert Revit model to ISM repository. In this process of export, the native format of Revit was recognized directly by Staad Pro. Despite the fact that, it is known as the direct connection, to utilize this choice a third program, called iTwin Synchronizer, must be utilized for transformation of Revit model to ISM file [12].

2.3.2 Export to staad pro through IFC

To analyze the support for open standards, IFC file format was used to save the model and export it to Staad Pro. The user interface for IFC export in Revit is shown in Fig. 4. The “Current selected setup” gives the user a choice between a few predefined options of IFC version and Model View Definition (MVD). The most recent “IFC 4 Design Transfer View” would be the most appropriate as it was designed to allow geometric modifications of a model after its hand-over to another design application. However currently, Staad Pro does not support importing the IFC 4 version [13], therefore “IFC 2x3 Coordination View 2.0” was the option used in this study (Fig. 5). The “IFC 2x3 Coordination View 2.0” is a default and certified version which is generally supported by various BIM authoring applications.

Direct import of the IFC model from Revit to Staad Pro is not possible [14]. It needs to be transformed to ISM file format. The iTwin Structural Synchronizer was used for this purpose. After the transformation from the IFC model to the ISM document in the Synchronizer, it would be possible to import the ISM file to STAAD.Pro. Altogether, the model will be changed over multiple times. The workflow for import of IFC model to Staad pro is shown in Fig. 6.

For conversion of this IFC file to ISM file, the file was transferred to iTwin Analytical Synchronizer. Before importing the IFC-file, the general, profile section and material settings must be defined. After conversion to ISM format, the model can be visualized in ISM viewer (Fig. 7) and log file can be checked for errors. Log file with details of errors and omissions was displayed before the creation of the ISM repository can be seen in Fig. 8.

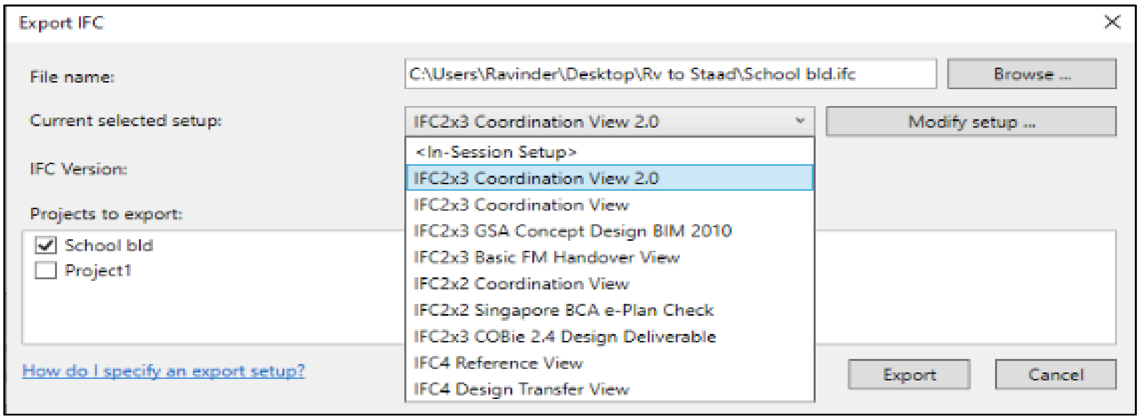


Fig. 5. IFC export options in Revit

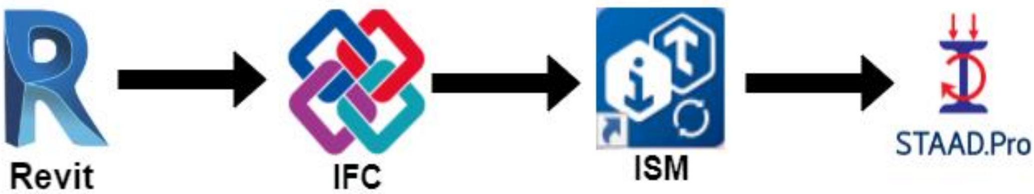


Fig. 6. Workflow for import of IFC model to Staad Pro

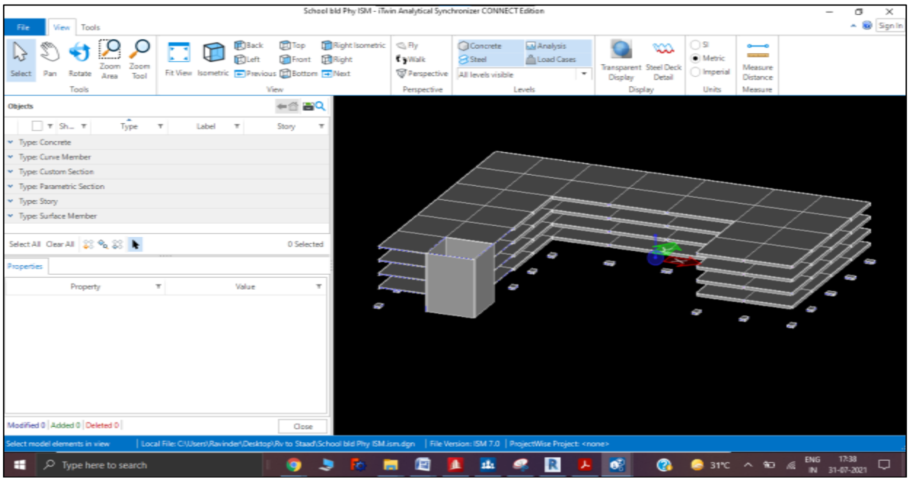


Fig. 7. IFC model in ISM viewer

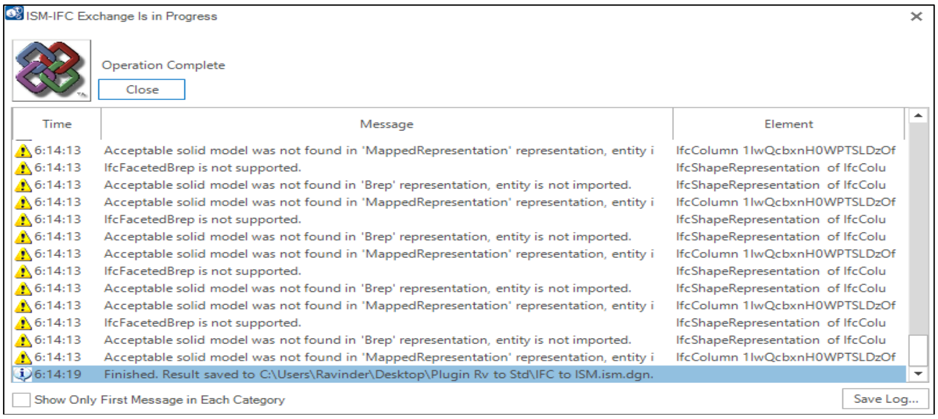


Fig. 8. Log file for IFC import to ISM repository

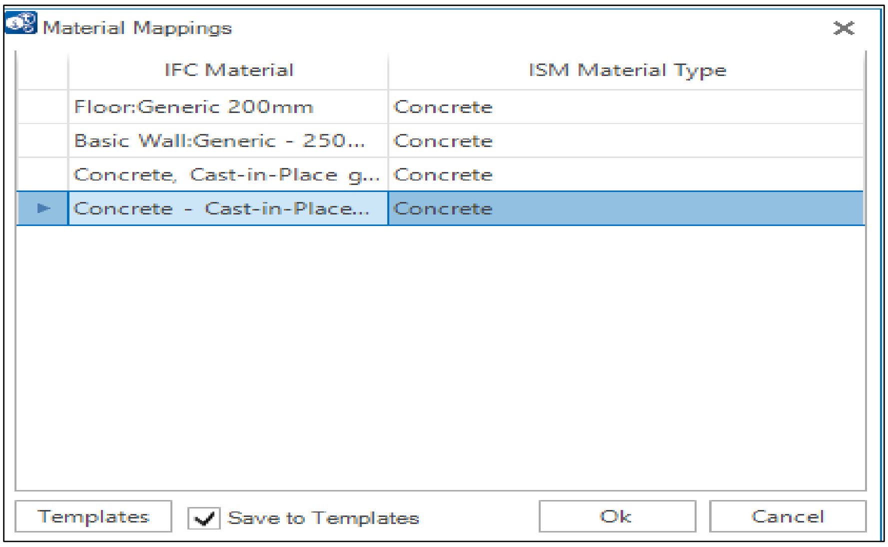


Fig. 9. Material mapping in staad pro

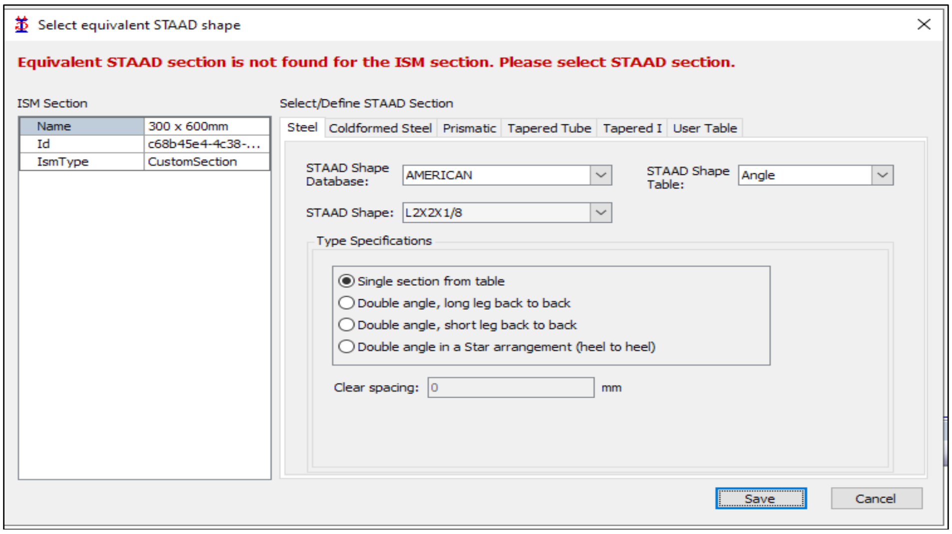


Fig. 10. Section mapping to staad section

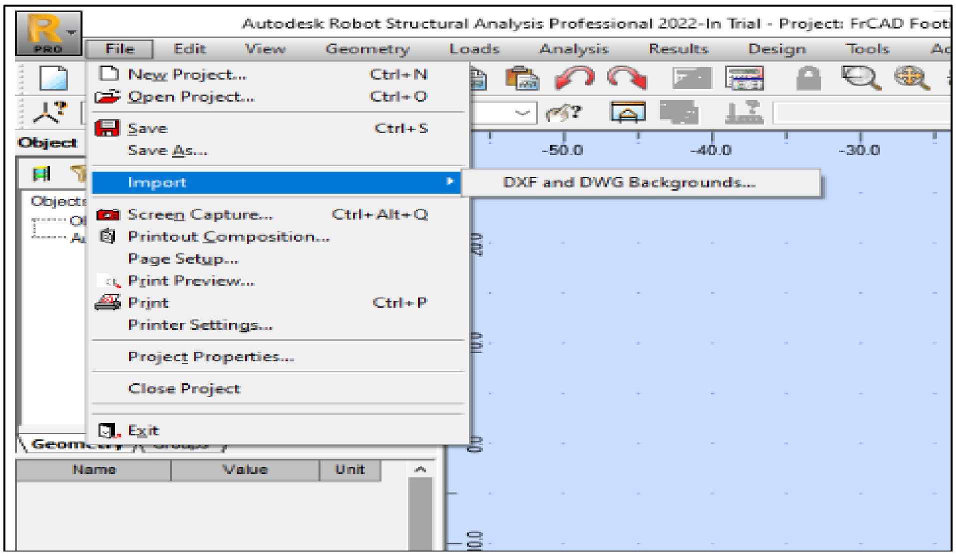


Fig. 11. Import options in RSA

2.3.3 Importing ISM file into staad pro

After the conversion of IFC-file to an ISM-file, a new file was created in STAAD Pro. Here, a new file would be created by using the tab 'new file from Repository'. The meaning of this command is to import a project which is made in different software. The repository means the entire project what the user can see on the display and also contains the relevant information for the project, which are to be exported or imported. A series of mapping dialogs open to set the mapping of the material (Fig. 9), framing shapes before finishing the import. During mapping if the section mapping to the ISM sections is not available, a mapping table would be opened to map the ISM section with available Staad section (Fig. 10). Staad Pro offered the sections of its own choice to select as the section previously defined in Revit was not available in the design software library. According to Dravai et al. [12] for the import of Revit analytical model in Staad Pro, the material properties were set to zero and section properties were changed as beam with hollow square section was transferred as rectangular beam.

2.4 Import to Robot Structural Analysis

Models generated in Revit can be directly imported in Robot Structural analysis (RSA). This type of internal interoperability of software applications was excluded from the scope of the research as it will not serve the idea of OpenBIM workflows. There was no provision for any model generated in any BIM software to be directly imported in RSA as it imports files only in DXF or DWG formats (Fig. 11). There is no provision to receive models in IFC format.

Although no arrangements of direct IFC model import were there in RSA [14] open file manager showed the option to select .ifc files (Fig. 12). After selection of IFC model from system, when open button was clicked, instead of any import of model, a message box appears on window with warning that ifc contains an incorrect schema (Fig. 13).

Literature was explored to find the ways and issues related to RSA import. Search revealed that IFC model needs to be exported in Revit architecture first [14]. So in this study, all the models developed in other architectural software were imported to Revit architecture to check the support of design tool.

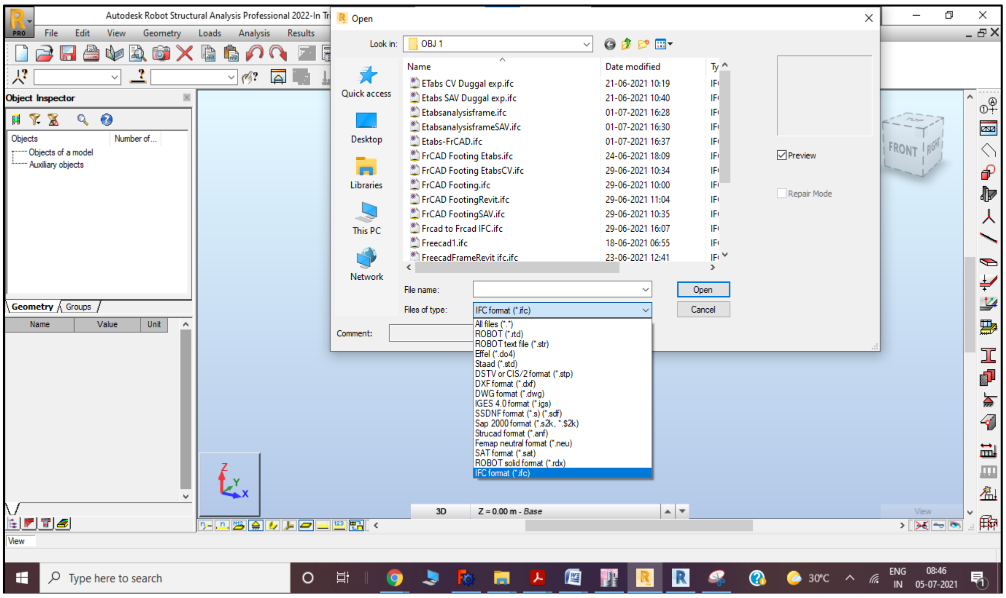


Fig. 12. Open file manager in RSA

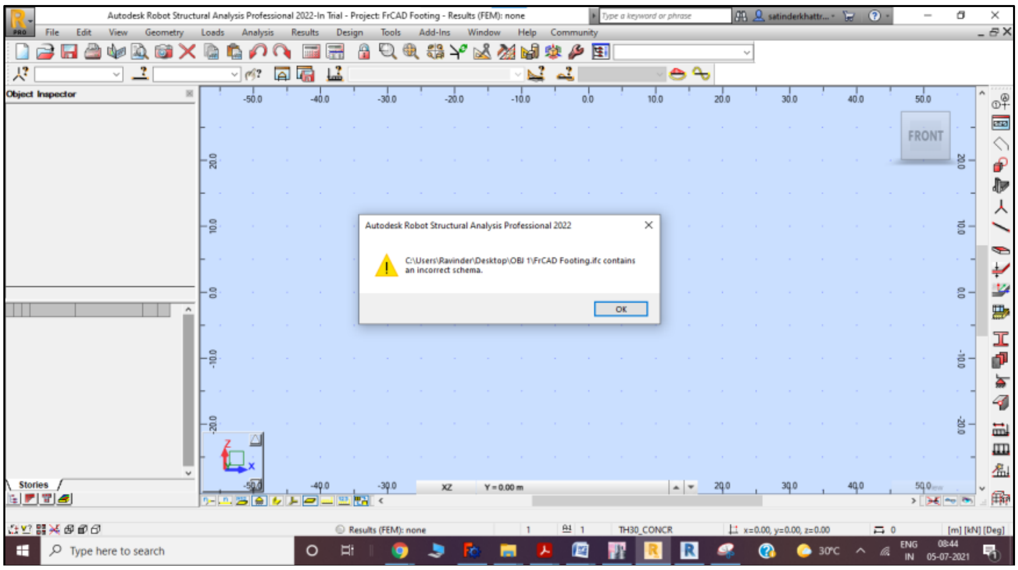
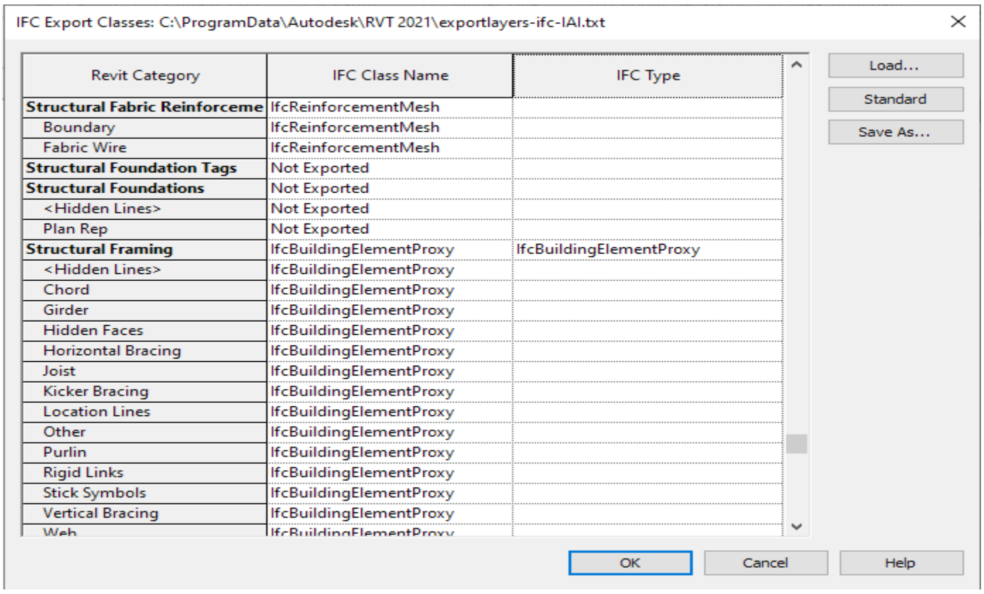


Fig. 13. IFC import error in RSA

3. RESULTS AND DISCUSSION

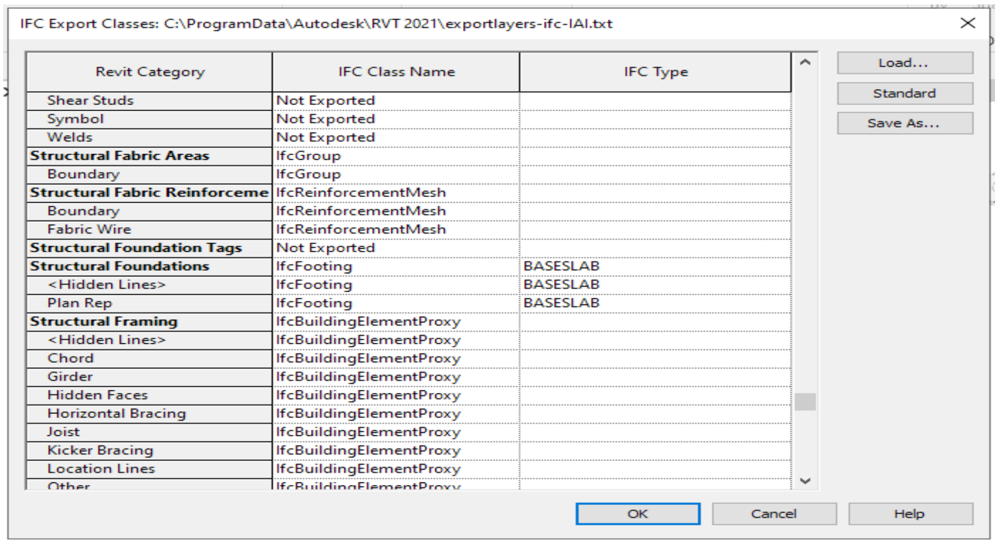
3.1 Mapping to IFC Classes When Exporting Revit Models

When the model developed in Revit was exported to IFC format by using default setting of export, the footing designed in Revit was exported as IfcSlab. The process of converting the objects of one schema to data sets to the equivalent classes in another is known as mapping. To assign the software parameters to the standardized parameters in the IFC data model, software vendors have developed mapping tables and templates to automate this process. To correctly export the objects as defined in IFC schema, parameter mapping table allows the overwriting or extended assignment of certain parameters that are already defined in the IFC schema. A mapping table (Fig. 14) is provided to assign the Revit categories to the IFC classes. It can be accessed through the path File > Export > Options > IFC Options in Revit menu. For instance to map the foundation created in Revit category, the structural foundation in Revit was mapped to IfcFooting by changing the IFC class name in second column of the mapping table (Fig. 15).



Revit Category	IFC Class Name	IFC Type
Structural Fabric Reinforceme	IfcReinforcementMesh	
Boundary	IfcReinforcementMesh	
Fabric Wire	IfcReinforcementMesh	
Structural Foundation Tags	Not Exported	
Structural Foundations	Not Exported	
<Hidden Lines>	Not Exported	
Plan Rep	Not Exported	
Structural Framing	IfcBuildingElementProxy	IfcBuildingElementProxy
<Hidden Lines>	IfcBuildingElementProxy	
Chord	IfcBuildingElementProxy	
Girder	IfcBuildingElementProxy	
Hidden Faces	IfcBuildingElementProxy	
Horizontal Bracing	IfcBuildingElementProxy	
Joist	IfcBuildingElementProxy	
Kicker Bracing	IfcBuildingElementProxy	
Location Lines	IfcBuildingElementProxy	
Other	IfcBuildingElementProxy	
Purlin	IfcBuildingElementProxy	
Rigid Links	IfcBuildingElementProxy	
Stick Symbols	IfcBuildingElementProxy	
Vertical Bracing	IfcBuildingElementProxy	
Web	IfcBuildingElementProxy	

Fig. 14. Default mapping table in Revit



Revit Category	IFC Class Name	IFC Type
Shear Studs	Not Exported	
Symbol	Not Exported	
Welds	Not Exported	
Structural Fabric Areas	IfcGroup	
Boundary	IfcGroup	
Structural Fabric Reinforceme	IfcReinforcementMesh	
Boundary	IfcReinforcementMesh	
Fabric Wire	IfcReinforcementMesh	
Structural Foundation Tags	Not Exported	
Structural Foundations	IfcFooting	BASESLAB
<Hidden Lines>	IfcFooting	BASESLAB
Plan Rep	IfcFooting	BASESLAB
Structural Framing	IfcBuildingElementProxy	
<Hidden Lines>	IfcBuildingElementProxy	
Chord	IfcBuildingElementProxy	
Girder	IfcBuildingElementProxy	
Hidden Faces	IfcBuildingElementProxy	
Horizontal Bracing	IfcBuildingElementProxy	
Joist	IfcBuildingElementProxy	
Kicker Bracing	IfcBuildingElementProxy	
Location Lines	IfcBuildingElementProxy	
Other	IfcBuildingElementProxy	

Fig. 15. Structural foundation mapped to IfcFooting

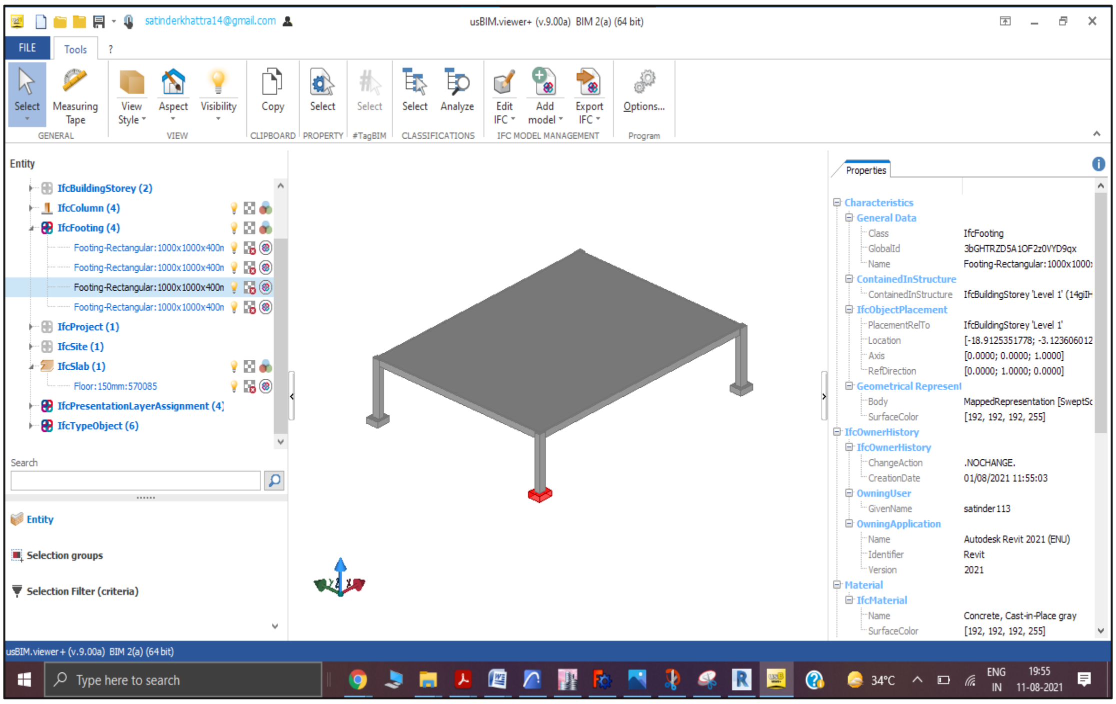


Fig. 16. Mapping of revit foundations to IFC footing

Figs. 15 and 16 shows the mapping table for Revit parameters before and after the mapping. Before assigning the IfcFooting as base slab, it was exported as *IfcBuildingElementProxy*. A building element is assigned a more general entity namely *Ifc Building ElementProxy* when it is not recognized in IFC export [15]. After this manual mapping, structural foundation in Revit category was exported as IfcFooting (Fig. 16).

3.2 Results of Re-Export from Revit to Revit

Round trip testing where single IFC compatible application has been used is characterized as pure round trip testing procedure [16]. Since information distortion or/and information loss have been expected, it is natural to begin evaluation with such tests. The Original IFC model exported from Revit was imported in Revit itself and again re-exported as IFC model without any modification. This practice is known as round-trip of data.

The potentially heterogeneous IFC binding assignments of the Revit to the original and re-exported IFC files were reported in this testing. As per the summary worksheet generated from NIST File analyzer, the number of entities increased from 728 to 935 in re-exported file as compared to original exported IFC file and file size changed from 46 KB to 60 KB. Table 1 gives a summary worksheet of entities and relations exported and re-exported in to IFC2x3 from Revit.

For the beam object entity built in the Revit Architecture, its attributes and relations were redefined by the heterogeneous IFC mapping process for original and re-exported files as can be seen from Fig. 17.

It is noticeable from figure how Revit has reported inconsistencies with respect to the original exported data, although being that the IFC file was imported to the same software from it was exported. The Revit interface, in the re-export process replaced *IfcBeam* with *IfcBuildingElementProxy* in the round-trip testing. Within architectural design applications such replacements may not be relevant, but may cause difficulties when mapping the model into other design applications. So the promise of interoperability is still a little way down the road.

3.3 Results of Export from Revit to Staad Pro

The export process of Revit model to STAAD Pro could be performed using two procedures. Firstly the ISM- Revit Plug-in, provided by Bentley can be used. It needs to be installed on the Revit interface. The second method of export is based on the IFC standard. The direct import of model from Revit to STAAD Pro was not supported. The model needs to be converted to an ISM file before importing it to STAAD Pro.

Table 1. Comparison of IFC files of Revit round-trip

IFC Directory	C:\Users\Ravinder\Desktop\Rv to Rv			
	Re-export	Export		
	60 KB	46 KB		
Entity	935	728	Total Entities	Total Files
IfcBeam		4	4	1
IfcBeamType		1	1	1
IfcBuildingElementProxy	4		4	1
IfcBuildingElementProxyType	4		4	1
IfcColumn	4	4	8	2
IfcColumnType	4	4	8	2
IfcFooting	4	4	8	2
IfcSlab	1	1	2	2
IfcSlabType	1	1	2	2
IfcArbitraryClosedProfileDef	4	4	8	2
IfcExtrudedAreaSolid	9	6	15	2
IfcRectangleProfileDef	5	2	7	2
IfcMaterial	1	1	2	2
IfcMaterialLayer	1	1	2	2
IfcMaterialLayerSet	1	1	2	2
IfcMaterialLayerSetUsage	1	1	2	2
IfcRelAssociatesMaterial	3	3	6	2
IfcPropertySet	95	87	182	2
IfcPropertySingleValue	76	69	145	2
IfcRelDefinesByProperties	62	62	124	2

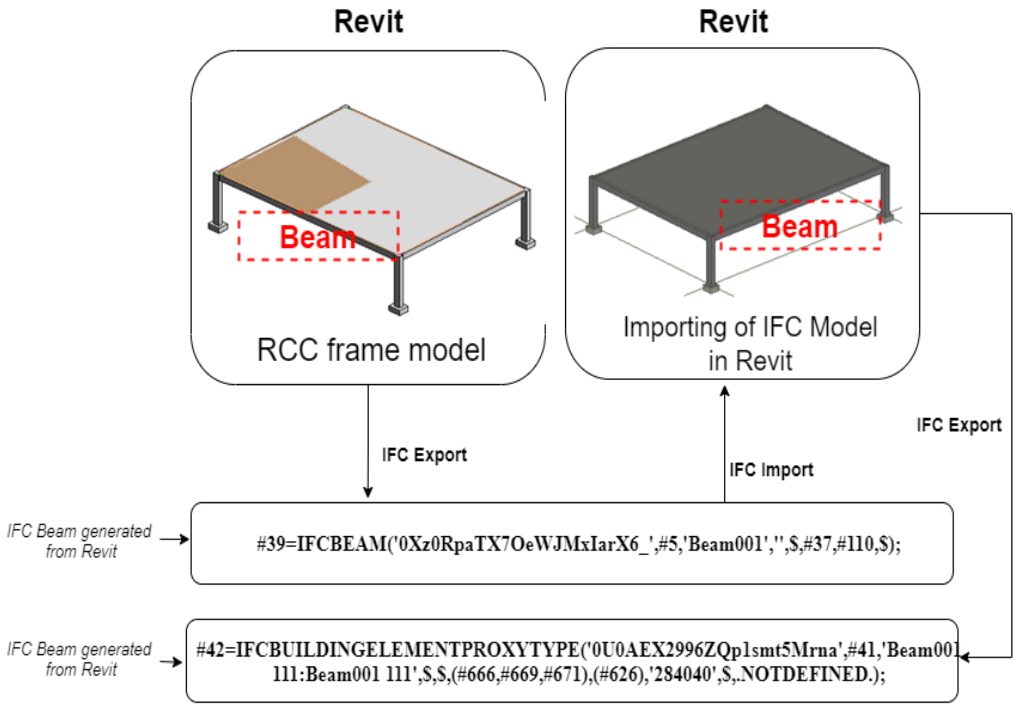


Fig. 17. Potential heterogeneous IFC binding assignments of the Revit model

3.3.1 Through ISM revit plug-in

Before importing to ISM repository, a number of mappings were required to match materials, sections and surface members created from Revit libraries to the ISM repository. Mapping of the materials was completed automatically. However mapping of the columns and beams did not work properly as the same parametric type was not found in ISM repository (ISM Mapping). So the elements have to be matched to an external family (Fig. 18) and that shapes have to be imported before it can be used in the model. After defining the shapes, columns and beams were imported to ISM repository as verified by greens ticks in the column and beam rows (Fig. 19).

Slabs and structural walls could not be imported by default settings. These were added manually to the repository. So the overall conversion of the Revit model to ISM repository through ISM Revit plug-in was not fully automatic. Time consuming manual mappings were completed before importing the model. After the file was converted to an ISM file, all the properties could be seen in the iTwin Analytical Synchronizer (Fig. 20). Little changes to the geometry of the profiles and the properties of the elements can be made in this software. Accurate ISM repository of Revit model was created as can be seen in ISM viewer.

This ISM file was imported in STAAD.Pro by using the 'New from Repository' command. Geometry, material and section properties of columns and beams were imported (Fig. 21). Although properly imported in ISM repository, STAAD Pro was not capable of transferring slabs, structural walls and support conditions [17,12].

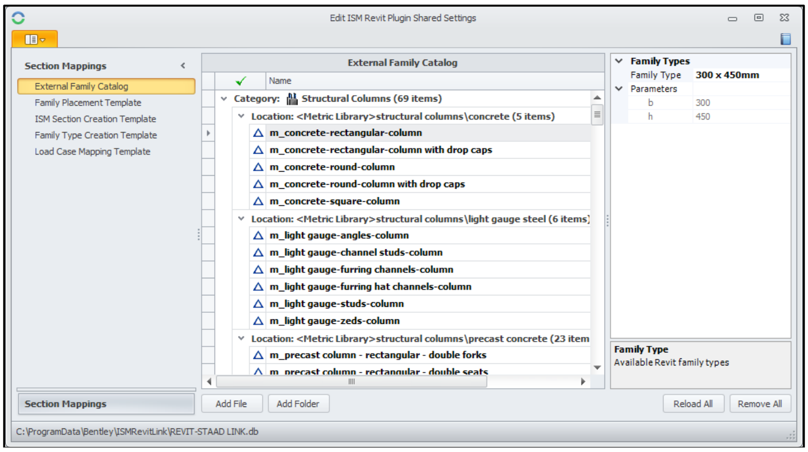


Fig. 18. External family import settings

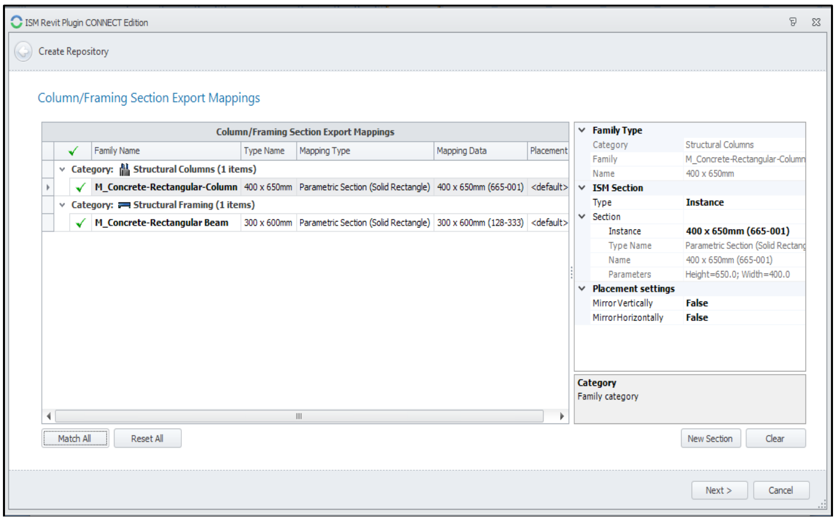


Fig. 19. Framing section export mappings

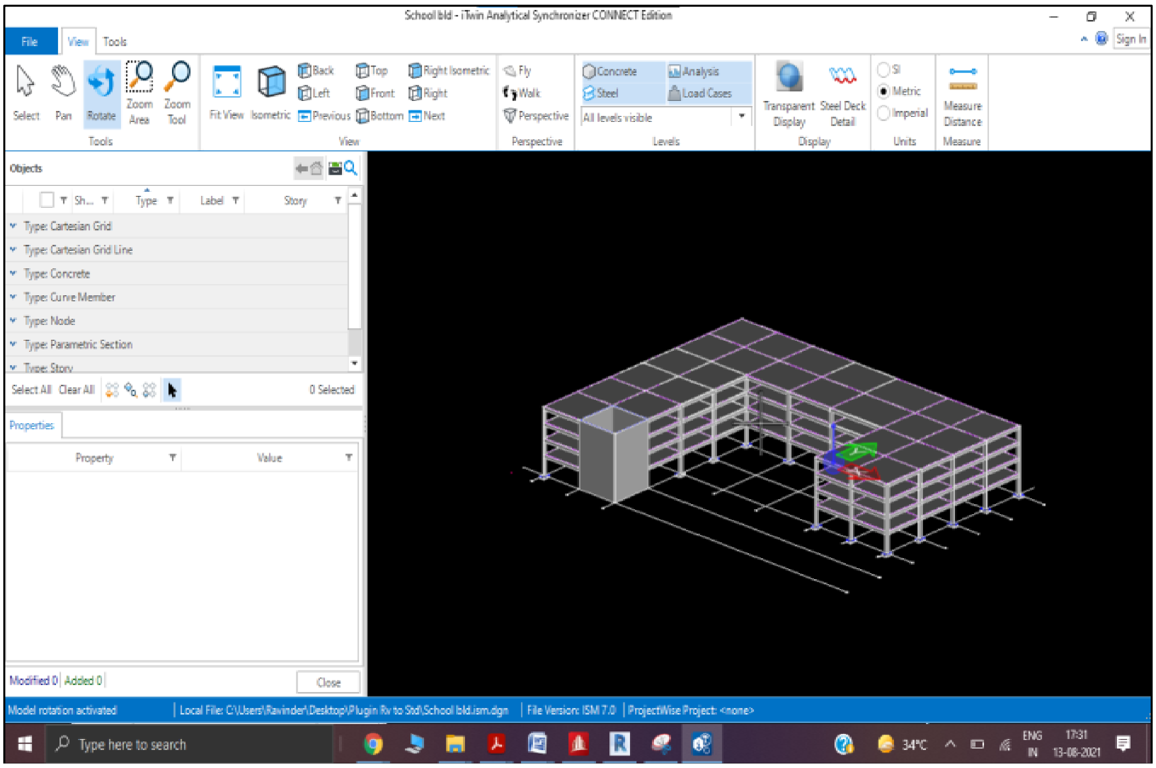


Fig. 20. Revit model viewed in the analytical synchronizer

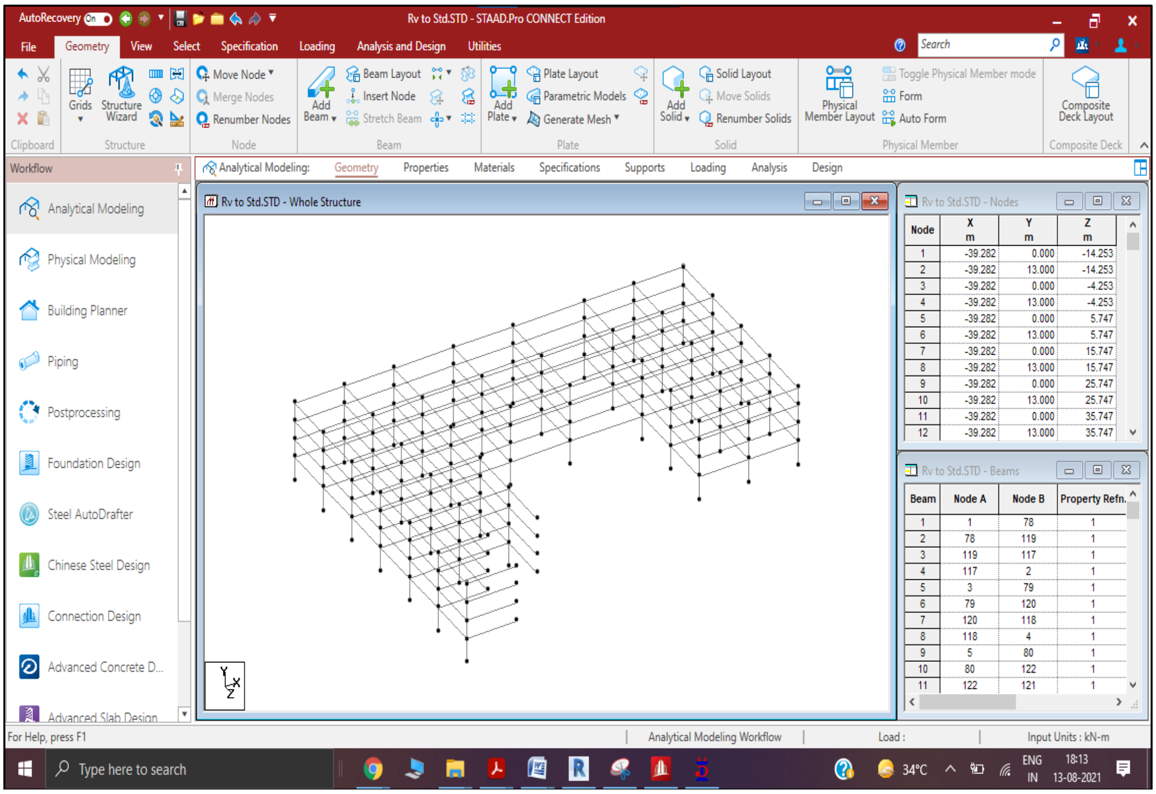


Fig. 21. Revit model imported in STAAD Pro

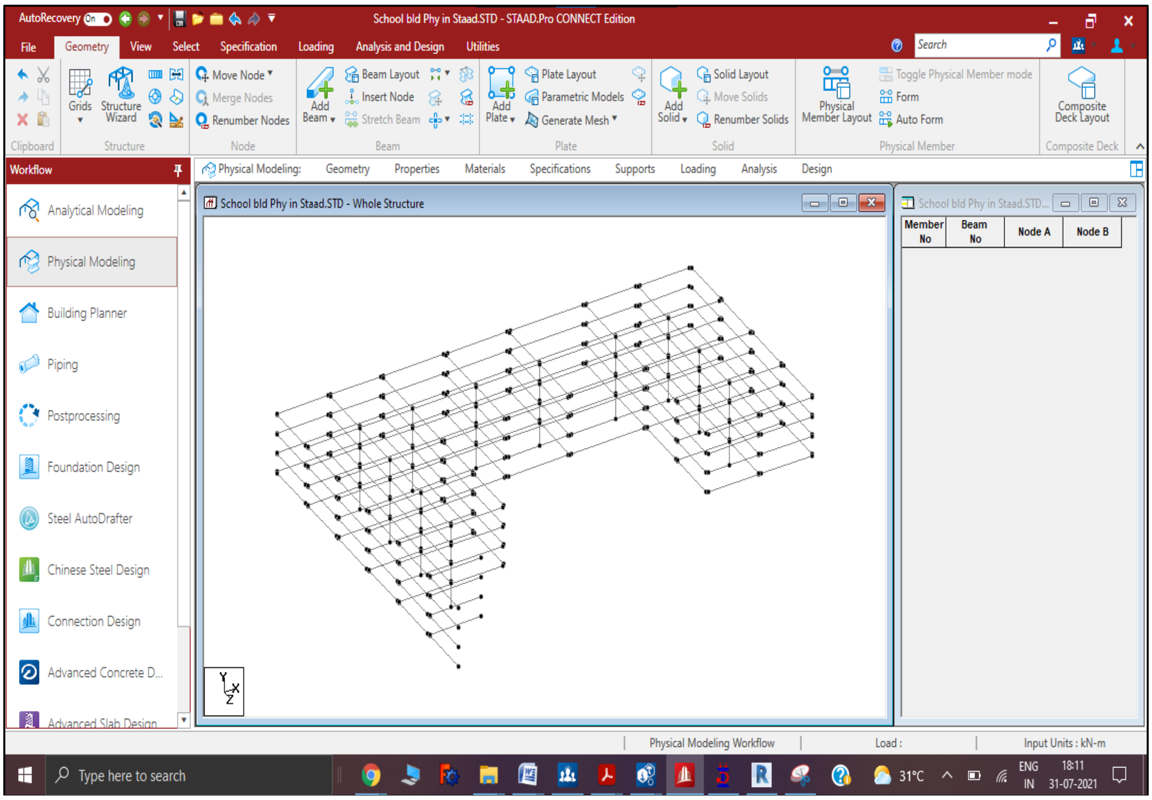


Fig. 22. Revit IFC model imported in STAAD Pro

4.3.2 Through IFC format

For the conversion of IFC-file to an ISM-file, a series of mapping were required to set the mapping of the material and framing shapes before finishing the import. During mapping if the section mapping to the ISM sections is not available, a mapping table would be opened to map the ISM section with available STAAD section. That means the sections of the building elements created in Revit model were not mapped to the sections available in STAAD. Pro. STAAD Pro offered the sections of its own choice to select as the section previously defined in Revit.

Using an IFC data format to import in STAAD.Pro, after converting it to ISM, was clearly not ideal. It was a cumbersome method and a lot of data got lost during the process (Fig. 22). So information exchange through IFC is not much supported by STAAD Pro.

In order to run structural analysis in STAAD. Pro after importing the model from Revit, the design engineer needs to redefine the properties of structural elements. To complete the structural model, building elements such as slab, footing should be added, connection at the building joints need to be established, to define the various types of loads and load combinations and to modify the sectional properties of various building components. All these adjustments and changes are time consuming and onerous.

5. CONCLUSION

After the comprehensive analysis of data sharing among most commonly used BIM authoring tools in architectural and structural domains, it was realized that interfaces for the exchange differed significantly between the software tools. The results demonstrate that interoperability issues commonly arise, such as the increasing file-size, inconsistent object types, geometric misrepresentation, different colours, loss of properties and relations. Interoperability issues such as data loss and misrepresentation do exist, when software tools import IFC models created by other software tools.

IFC interfaces are available in various IFC certified applications to exchange information through open standards. These interfaces translate the internal proprietary classes of their data models to IFC complaint objects. The main reason behind poor interoperability is the incomplete mapping between software native models and IFC models.

The comparative study indicates that BIM workflow is not yet fully competent to fulfill the inter domain information exchange process because many drawbacks, as given below, were observed. Software tools that are certified to be IFC compliant did not provide the means of performing the data exchange satisfactorily.

According to a process of software certification started by BuildingSMART, more than 150 BIM authoring software have got the certification for supporting the information exchange using IFC format.

BIM adoption is rapidly growing with the realization of benefits it offers. BIM technology is pushing the construction industry towards digitalization across the life cycle of the project. Successful implementation of BIM depends on shifting the file based exchange of information to information rich digital models.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hao Q, Shen W, Neelamkavil J, Thomas R. Change management in construction projects. Inthe proceedings of international conference on information technology in construction CIBW78. 2008; 15-17.
2. Dave B, Koskela L. Collaborative knowledge management—A construction case study. Automation in construction. 2009;18(7):894-902.
3. Ahuja V, Yang J, Shankar R. Study of ICT adoption for building project management in the Indian construction industry. Automation in construction. 2009;18(4): 415-23.
4. Azhar S. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering. 2011;11(3):241-52.
5. Oraee M, Hosseini MR, Papadonikolaki E, Palliyaguru R, Arashpour M. Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review. International Journal of Project Management. 2017;35(7):1288-301.
6. Sacks R, Eastman C, Lee G, Teicholz P. BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers, John Wiley & Sons; 2018.
7. Lipman R. IFC file analyzer software. Journal of Research of the National Institute of Standards and Technology, 2017;122(15):1-2.
8. Amor RW, Ma H. Preservation of meaning in mapped IFCs. IneWork and eBusiness in Architecture, Engineering and Construction. ECPPM CRC Press. 2006; (2020):233-236).
9. Ma H, Ha KM, Chung CK, Amor R. Testing semantic interoperability. In Proceedings of joint international conference on computing and decision making in civil and building engineering, montreal, Canada. 2006;14:16.
10. Jeong YS, Eastman CM, Sacks R, Kaner I. Benchmark tests for BIM data exchanges of precast concrete. Automation in Construction. 2009;18(4): 469-84.
11. Sibenik G. Building information modelling based interdisciplinary data exchange: A case study. In the 1st international UK BIM Academic Forum Conference. 2016;13-15.
12. Drávai T, Khalyar H, Nagy G. The effect of interoperability between BIM and FEM tools on structural modeling and analysis. project library, Aalborg University, Aalborg University, Aalborg, Denmark; 2016.
13. Trzeciak M, Borrmann A. Design-to-design exchange of bridge models using IFC: A case study with Revit and Allplan. Ine Work and eBusiness in Architecture, Engineering and Construction CRC Press. 2018;231-239.
14. Beirnaert F, Lippens A. Analysis of the interoperability from BIM to FEM, Master's

thesis, Tampere University of Applied Sciences; 2018.

15. Gerbino S, Cieri L, Rainieri C, Fabbrocino G. On bim interoperability via the ifc standard: An assessment from the structural engineering and design viewpoint. Applied Sciences. 2021;11(23): 11430.
16. Pazlar T, Turk Ž. Interoperability in practice: Geometric data exchance using the IFC standard. Journal of Information Technology in Construction (ITcon). 2008; 13(24):362-80.
17. Shoieb K, Serror MH, Marzouk M. Web-based tool for interoperability among structural analysis applications. Journal of Construction Engineering and Mana gement. 2020;146(6) :04020058.

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