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BIM to FEM Model Conversion of Low-rise Residential Buildings for Debris Flow Damage Analysis

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Abstract

In Hong Kong, low-rise residential buildings, which are mostly built next to mountains and occupy half of the total residential area, are often seriously damaged by debris flow. The extent of damage to each building depends not only on the intensity of the debris flow but also on the interaction of the neighboring components of the building and their collective performance. With the application of BIM (Building Information Modeling) technology in structural analysis, data conversion and information transfer between the BIM model and the FEM (Finite Element Method) model have become the main factors limiting its efficiency and quality. Unlike the automatic conversion method for frame structure building models, the conversion method for such models is a semi-automated method that relies on manual labor at the cost of losing a large amount of BIM information due to the problems of non-standardization and confusing information. Therefore, this study proposes an automatic standardized conversion method based on OpenBIM data (IFC) for developing refined FEM models of low-rise residential buildings. It consists of three parts: 1) guaranteeing model refinement and spatial robustness through model geometry transformation and calibration; 2) standardized conversion during the conversion process through material information database establishment and matching; and 3) integration of the output information to achieve data interoperability and provide a reference for debris flow damage assessment. Conversion tests of this method and the traditional conversion method were conducted in the same BIM model, and the results show that the FEM model generated by this method is significantly better than the traditional conversion method in terms of spatial closure and mesh quality (i.e., spatial robustness and model refinement). Future research will continue refining spatial robustness detection, standardized conversion, and data interoperability.

1 Introduction

Debris flows, as one of the most frequent geohazards in mountainous areas (Zhang et al., 2018), pose a significant threat to human lives, buildings, and critical infrastructure (Tang et al., 2011). Debris flow events occurring in populated mountainous areas are catastrophic, especially in areas with high populations and building densities (Prieto et al., 2018; Zhou et al., 2019). Facilities exposed to debris flow threats include buildings, roads, railroads, mines, and reservoirs. Residential buildings are more vulnerable to debris flow damage than other facilities (Hu et al., 2012).

Low-rise residential buildings, as one of the types of residential buildings, are commonly found in small houses (Hong Kong village houses) of indigenous villagers in Hong Kong (*New Territories Exempted Houses (NTEH) - Buildings Department*, 2024). According to the statistics of the Hong Kong Housing Bureau and the Hong Kong Planning Department in 2023, village houses take up 48% of the housing land in Hong Kong (*Planning Department - Land Utilization in Hong Kong*, 2024). As more than 70% of Hong Kong's land is mountainous, debris flows are not uncommon in Hong Kong (Chau & Lo, 2004). Meanwhile, village houses in Hong Kong are often clustered at high densities, and there are instances where rooms in village houses are separated to accommodate more residents(Aijmer, 1975; Nelson, 1969). This makes debris flows catastrophic for the areas where village houses are clustered in Hong Kong. Therefore, debris flow damage assessment of low-rise residential buildings in Hong Kong would be useful for more effective risk assessment, emergency management, and housing maintenance.

Debris flow damage assessment has been extensively studied. Existing studies consist mainly of regional assessments and assessments of individual buildings.

1.1 Regional Damage Assessment

Regional damage assessment calculates the overall damage level of a house by generalizing buildings into categories (e.g., building age, building structure type, etc.) and applying predefined curves (Amirebrahimi et al., 2015; de Moel et al., 2015). While the validity of these methods has been demonstrated in large-scale assessments (Hu et al., 2012; Zhang et al., 2018), they are not applicable to damage assessments such as those for Hong Kong village houses. Hong Kong village houses are exempted from Hong Kong’s laws and regulations, which makes the information on materials, spatial relationship of building components, and building structure vary from one village house to another (*New Territories Exempted Houses (NTEH) - Buildings Department*, 2024). This is mainly because regional assessment methods have limited input data and are often based on regional information to output a quantitative rating of the overall building physical damage or a single figure for the overall building economic loss (Ciurean et al., 2017; Hu et al., 2012; Kang & Kim, 2016; Mejía-Navarro et al., 1994). As a result, regional assessments cannot provide significant feedback on differences within different buildings (e.g., spatial relationships between house components, material properties, information in component attributes such as size and shape).

1.2 Individual Building Damage Assessment

Compared with regional assessments, the assessment of individual buildings can provide better feedback on the differences within different buildings. However, all existing individual building assessment methods often use simplified building models or typical building models for finite element analysis (Huan et al., 2024; P. Li et al., 2017; Liu et al., 2018; Luo et al., 2019, 2020; Milanesi et al., 2018) rather than performing finite element analysis of different buildings (e.g., different buildings do not have the same floor height, occupation shape, and spatial relationship of components inside the building). Moreover, unlike the automated model conversion for frame-structured buildings, the conversion of BIM models to FEM models for such buildings is semi-automated and based on proprietary software (e.g. Revit). This is mainly due to limited computational resources and the need for increased computational efficiency. This is especially because of the financial and time constraints that would be imposed if detailed damage assessments were used on many buildings (Jeong & Elnashai, 2007; Kwon & Elnashai, 2006). Simplified models often downscale the 3D components of a building to one-dimensional units or two-dimensional units (e.g., one-dimensional beams, one-dimensional columns, and two-dimensional walls) (Feng et al., 2019; Milanesi et al., 2018; Taucer et al., n.d.). Typical building models are based on the structural characteristics of the buildings in the study area to represent all buildings in the study area (Huan et al., 2024; Liu et al., 2018; Luo et al., 2019). However, the simplified models cannot correspond one-to-one with the structural geometry information of the buildings themselves, thus failing to identify building-specific damage components. The typical model cannot correspond with the actual buildings in the study area because it is a generalized model. As for low-rise residential buildings consisting of components with different structural information, their model conversion is often labor-intensive and not a fully automated process. Their model conversion is also difficult to apply with the above methods. Data conversion and information transfer between BIM models and FEM models have become major constraints to their efficiency and quality.

1.3 BIM-to-FEM under Damage Assessment

Individual building damage assessment of debris flows is more challenging compared to hurricanes, floods, and earthquakes. Unlike floods, where the primary considerations are immersion damage and lateral pressures on buildings, debris flows, which are similar to floods, primarily consider the response of building components under impact pressures (Ali Khan et al., 2024; Luo et al., 2020). The building damage assessment caused by debris flows often needs to consider the dynamic response analysis of the interaction between the debris flow and the building (Luo et al., 2020), i.e., the cumulative damage after the debris flow damages the building components at different moments of the debris flow from the beginning of the contact with the building to the end of the complete encirclement of the building. In contrast, the building damage assessments caused by hurricanes and earthquakes consider the mechanical analysis of the static or overall dynamic response (Charalambos et al., 2014; Nofal et al., 2022; Quinay et al., 2020). As for the flood damage assessment, its analysis of the BIM model of the building is only a cumulative analysis of static mechanical analysis with duration (Amirebrahimi et al., 2016; Aribisala et al., 2022). Other hazards require less refinement and robustness of the models converted by BIM (Charalambos et al., 2014; Nofal et al., 2022; Quinay et al., 2020). For example, the BIM model was transformed into a shell model with only the building facade in the case of the hurricane (Nofal et al., 2022). The BIM model was transformed into a simplified model with the row frame in the earthquake case (Quinay et al., 2020; Ren et al., 2019). Unlike the finite element analysis described above, the finite element analysis of the damage caused to the building by the debris flow is a coupled fluid-structure collision analysis. This requires that the model transformation has the robustness of automatically matching different material information for each component transformed and spatial relationships among the transformed components.

1.4 Research Gaps

It is observed that most of the model conversion methods, when faced with the model of Hong Kong village houses, which is not standardized and has confusing information, 1) need to rely on labor-intensive manual operations and are not able to standardize the conversion of the model automatically; 2) need to simplify the components of the model to one or two dimensions to reduce the computational usage, and are not able to reduce the model refinement level without excessively reducing the model refinement level; and 3) the loss of the BIM information in the process of the conversion causes the spatial relationship between components to be The loss of BIM information during the conversion process makes the spatial relationship between the components not touch or overlap each other, and the spatial robustness of the model in the FEM cannot be guaranteed. As a result, it can not automatically standardize the model transformation and ensure the model's high accuracy and spatial robustness, which affects the effectiveness of the debris flow damage assessment of the village houses in Hong Kong.

1.5 Research Objectives and Questions

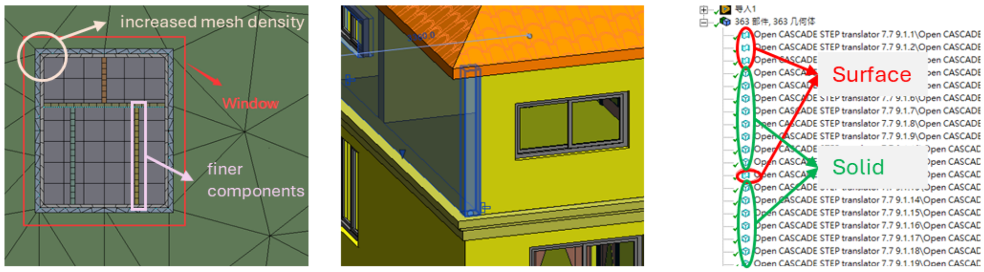
This study aims to propose a preprocessing method from OpenBIM data (IFC) to develop FEM models of low-rise residential buildings. The objectives of the study are (1) to transform a normalized transformation of the IFC model automatically, (2) to reduce the level of refinement based on the non-excessive reduction of the converted model of the IFC model, and (3) to guarantee the spatial robustness of the converted model. To achieve these objectives, the subsequent questions will be answered.

First, how to standardize the conversion of BIM models with problems such as irregular establishment and confusing information of different components? Although 'IfcMaterial' of 'IfcMaterialDefinition' and 'IfcProperties' of 'IfcPropertyDefinition' can extract model information and provide a way to standardize it. However, the 'IfcMaterial' and 'IfcProperties' of the above BIM model built at the early stage are not set, or their information sets are confusing. Moreover, the 'IfcMaterial' and 'IfcProperties' of each BIM model are set differently for each due to the model creators' different habits. These problems can lead to loss of information, confusing material information, or even garbled information in some parts of the components of the converted model.

Second, how to control the degree of simplification of the model during the conversion process? BIM contains digital parameters of a large number of building components. This large amount of information brought by BIM makes the debris flow damage assessment with numerical simulation, which will cause the problem of excessive computational volume and a long computational period. Excessive computational volume will lead to an increase in computational cost, which is why previous studies have commonly used the method of simplified modeling of typical buildings to represent all the buildings in the study area to reduce computational usage. However, those methods lose most of the building information. If the model is not simplified as in the above approach, the computational usage for analyzing the model will increase significantly. Figure 1(a) shows the model component after automatic conversion by previous methods without simplification (From Revit). The component is a window in the building, which is split into finer components under this method. These finer components lose their physical meaning as windows and cause a sudden increase in the mesh density in this area, significantly increasing computational usage.

Third, how to guarantee the spatial robustness of the converted model? Existing methods often lose more BIM information and cause the spatial relationships between components to not touch or overlap when converting the above BIM model. These errors in spatial relationships are not reported in the BIM, but they are explicitly reported in the FEM analysis and even implicitly affect the analysis results in the FEM. Figure 1(b) shows the problem of components overlapping in the converted model. The blue part is the wall and column of the model, which spatially overlap with each other making the meshing of the part collapse, and then the model cannot be analyzed by FEM. Figure 1(c) shows the properties of each component of the converted model in FEM. The model loses BIM information during the conversion process and leaves the components spatially out of contact, resulting in the inability to generate the correct lines and surfaces to form solids.

To answer these questions, an IFC-based model transformation method is proposed. The method consists of three parts: model geometry transformation and calibration, establishment and matching of the material information database, and output information integration. The paper is organized as follows: Section 2 provides a partial overview of the proposed methodology; Section 3 describes the experimental setup and demonstrates the method's current results; Section 4 shows future work; Section 5 presents the conclusions drawn from the study.



(a) Finer components lose their physical meaning as windows and increase the mesh density

(b) Components overlapping will lead the model cannot be analyzed by FEM

(c) The model loses information during the conversion process and fails to form solids

Figure 1: Example diagram of previous model conversion results

2 Methodology

The steps of the method proposed in this paper are shown in Figure 2. In the first part, the Python code is used to realize the geometric entity transformation of each model component and verify each component's closure and the spatial relationship's robustness. In this, the geometric entity transformation constructs line faces by finding the maximum outer contour envelope of the corresponding component to form the entity. This allows the model to reduce the computational usage of FEM analysis without unduly reducing the level of detail. The stitching relationship of each set of line faces then verifies the closure of each component. The second part establishes the interface for importing material information, and the database is automatically generated according to the corresponding component types. The material information matching is realized by Python code on the FEM platform side. Among them, the generated database can be used to standardize the model information by external input information when the model information is lost or confused. Then the standardized conversion of the model is realized through the information matching at the FEM platform. In the third part, the FEM results are merged with the corresponding component information to generate a database and provide data visualization. In particular, the final generated database enables the analysis results to be data-interoperable in dual platforms, which can help the mudslide damage assessment of village houses in Hong Kong.

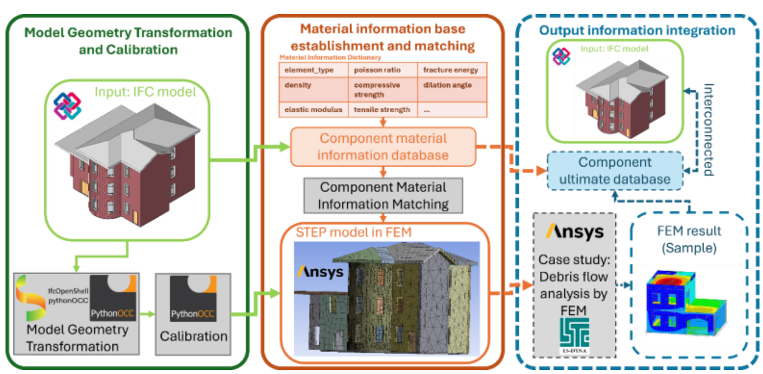


Figure 2: The overall framework of the methodology

2.1 Model Geometry Transformation and Calibration

To avoid being restricted by proprietary software, this study is consistent with the openBIM method and uses the IFC model as the input model. Some of the acquired public BIM models in RVT file format are exported to IFC files (IFC4) through the built-in IFC interpreter of Revit software (*Revit IFC Manual*, 2024). The model conversion method between IFC and FEM is implemented through Python code, and an interface is provided for importing material information.

Model transformation requires extracting components within the model, and a BIM model usually contains the structural components, wiring components, furniture components, etc. (N. Li et al., 2020). Only structural components in the model are extracted to analyze the damage caused by debris flows on buildings. Components such as furniture components, which highly occupy the computational resources of FEM but do not play a role in analyzing the debris flow impact on the building structure, are not extracted. For structural components, the following components were extracted based on Giuffre's work (Giuffré, 1993): (1) walls, (2) beams, (3) columns, (4) floor slabs, (5) roofs, (6) doors, (7) windows, and (8) foundations. The following “IfcBuildingElement” are needed to represent the different objects mentioned earlier: “IfcWall” for walls, “IfcBeam “ for primary and secondary beams, “IfcColumn” for columns, “IfcSlab” for floor slabs, “IfcRoof “ for roofs, “IfcDoor” for doors, “IfcWindow” for windows, and “IfcFooting “ for foundations. Each IFC object belongs to a specific “IfcBuildingElementType.” The component types are shown in Figure 3.

Figure 3: Schematic diagram of the types of components extracted

In this paper, if the component material is masonry, reinforced concrete, etc., the geometry of the component is modeled as an equivalent homogeneous entity without the need to geometrically model the wall bricks, mortar, reinforcement bars, etc. Similarly, when the component type is door and window, the largest contour in the component is found as the corresponding equivalent homogeneous entity without geometrically modeling the battens, glazing, frames, etc. If components such as walls, doors, windows, etc. are modeled as smaller solids such as wall tiles, retaining strips, glass, etc., these smaller solids would not be able to represent the components such as walls, doors, windows, etc., as having their physical meaning. This approach reduces the complexity of the converted model while preserving the component information and making the component still physically meaningful. For the IFC model view format imported into the conversion method, this paper selects the Design Transfer View instead of the Reference View. This is mainly because the Design Transfer View is used to share component information, such as spatial relationships and geometry of components. “The Reference View is mainly used for collision detection between components.

The model geometry conversion algorithm converts the IFC file to a STEP file, which enables the FEM platform to read the model file and realize the debris flow analysis. Although IFC to STEP conversion can be achieved directly and automatically by proprietary software such as Revit, its conversion function cannot control the component fineness of the resulting model, as shown in Figure 4. In this case, the frames, glazing, and retaining strips between the glazing of the door and window were converted by this function into entities that are independent of each other. This caused the door and window, which should have been treated as a whole in the FEM platform, to lose their physical meaning. At the same time, the subcomponents located in the window and door sections are small in size, which leads to a drastic increase in mesh density when meshing in FEM, thereby increasing the computational cost.

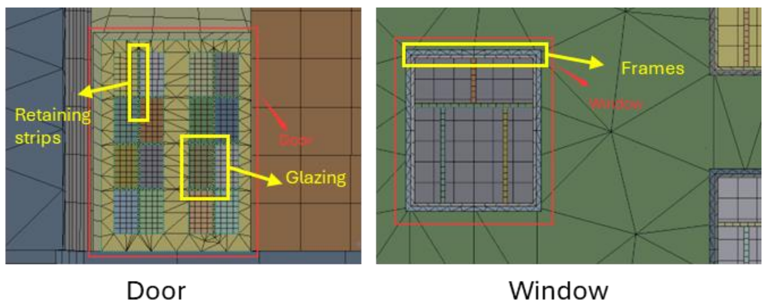


Figure 4: Drastically increasing mesh density and components that lose physical meaning

The details of the model geometry transformation algorithm are as follows:

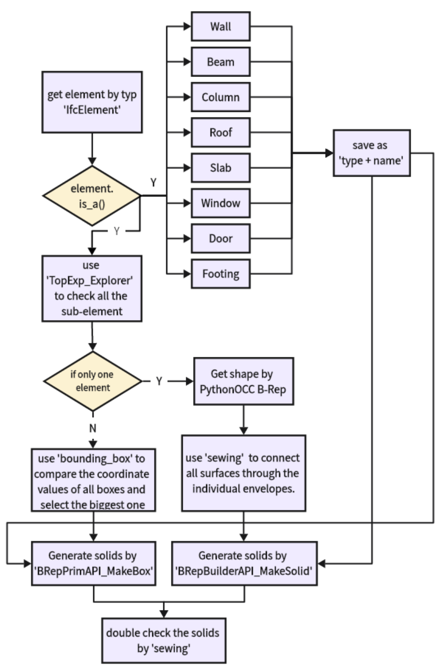


Figure 5: Flowchart of the model geometry transformation algorithm

Iterate over all the IfcElements collected in the input model and classify each component by a "for" loop relying on the "element.is_a()" function. At the same time, the "corresponding type + name" is stored as its component name in the FEM model and the primary key in the material information database. The geometry of each IFC component is extracted in B-Rep format using "PythonOCC." The surfaces are extracted from the shape composite (TopoDs composite) of the IFC component when it is converted to a STEP component. At this point, these surfaces are recognized by "PythonOCC" as sub-levels of the component. These surfaces are collaged into a true 3D solid by their envelopes using the sewing function. When encountering an IFC component that has subcomponents, the component's entity in the STEP file is created by finding the largest contour in the component and creating the smallest cube that completely wraps that contour. Finally, the sewing function is used again for each converted entity to check whether each face is properly connected according to the envelope. The flowchart of the algorithm is shown in Figure 5.

2.2 Material Information Database Establishment and Matching

In real projects, the original BIM model may have problems such as non-standardized establishment, non-harmonized standards, and the confusing information of different components. This makes it difficult to utilize the 'IfcMaterial' of the 'IfcMaterialDefinition' and the 'IfcPropertyDefinition' of the 'IfcPropertyDefinition' in the IFC architecture. 'IfcMaterial' and 'IfcProperties' will have problems when modeling the component materials, as shown in Figure 6. The material information extracted from (a) and (b) in Figure 6 comes from different IFC models, and due to the above problem, the material information in (a) is confusing, while in (b), the material information is even missing. For the IFC models that may have the above problems, it is necessary to supplement the material information from the outside world during the model conversion and correspond the material information to each component in the IFC model.

(a) Confusing material information (b) Missing material information

Figure 6: Example diagram of material information in the IFC model

The details of the model material information conversion algorithm are as follows:

Iterate over all the IfcElements collected in the input model and classify each component by a "for" loop relying on the "element.is_a()" function. At the same time, the "corresponding type + name" is stored as its component name in the FEM model and the primary key in the material information database.

Iterate over all the IfcElements collected in the input model, and through a "for" loop, rely on the 'element.is_a()' function to categorize each component and store the "corresponding type + name" as its primary key in the material information database. Then, through a "for" loop, the 'RelatingMaterial' function is used to extract the related material name. At the same time, read the externally defined material information, match the traversed components with the material names in the material information, and add the corresponding material information to the material information database after successful matching. If the match is unsuccessful, the default material information of the component type is added to the material information database and printed to correspond to the primary key value. Similarly, create a "for" loop of the same level as the "for" loop that relies on the 'RelatingMaterial' function. This loop relies on the 'RelatingType' function to perform the same operations as its sibling "for" loop. Finally, a CSV file is generated so that the material information of each component can be automatically added to the model utilizing the APDL command flow in the FEM platform. The flowchart of the algorithm is shown in Figure 7.

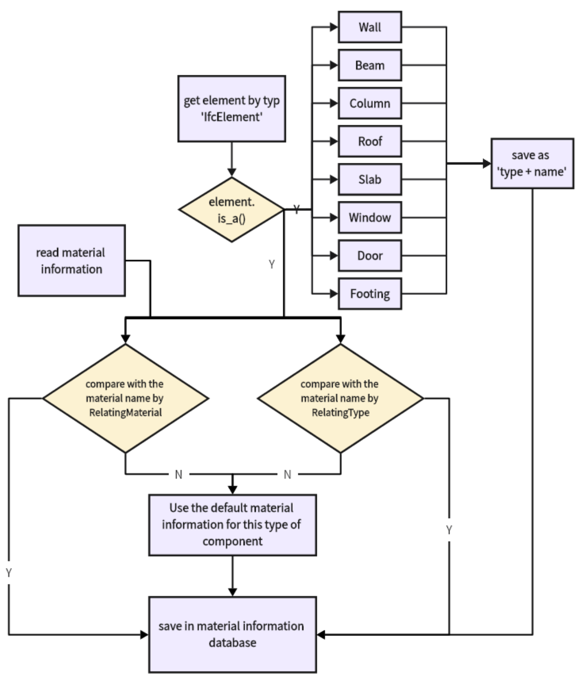


Figure 7: Flowchart of material information database establishment and matching algorithm

3 Experiment and Result

3.1 Experimental Setup

To verify the feasibility and reliability of the proposed methodology and to fit the actual situation of Hong Kong village houses, the experiments were conducted using public BIM models downloaded from online sources. Most of the downloaded models face problems such as the version being too old (component information is lost in the version upgrade) and the component confusing information. In this experiment, randomly selected one model from the downloaded BIM models is used for preliminary validation. Among them, the model base information is shown in Table 1, the model overview diagram in Figure 8, and the material information in Table 2.

	Model
Revit version	2011
Number of stories	3
Housing structure	brick hybrid structure
Material information completeness	incompleteness

Table 1: Basic information about the selected BIM model

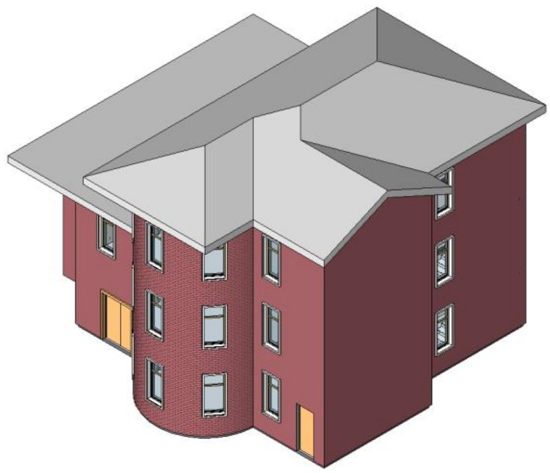


Figure 8: Overview diagram of the selected BIM model

element type	Material in IFC	density (kg/m3)	elastic modulus (MPa)	Poisson ratio	compressive strength (MPa)	tensile strength (MPa)	fracture energy (KJ/m2)	dilation angle (degree)
IfcWall	default	1800	3000	0.2	3	1.7	0.055	20
IfcWall	StructuralMasonry6	2200	3000	0.2	3	1.7	0.055	20
IfcWall	reinforced concrete	2400	25000	0.2	30	3	0.1	35
IfcRoof	default	1800	3000	0.2	3	0.03	0.055	20
IfcSlab	default	2400	25000	0.2	30	3	0.1	35
IfcFooting	default	2400	25000	0.2	30	3	0.1	35
IfcWindow	default	2500	70000	0.2	120	35	0.015	10
IfcDoor	default	700	11000	0.3	40	60	0.035	15
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 2: Material information source
(Kržan et al., 2015), (P. Li et al., 2017), (Milanesi et al., 2018), (Luo et al., 2020)

The above building was modeled in Autodesk Revit and exported to IFC4 Design Transfer View via Revit's built-in IFC interpreter. The structural model was subsequently loaded into the code folder. After running the code, the corresponding STEP file and the corresponding material information database were automatically generated, and the STEP file was imported into the Ansys FEM platform used in this experiment. Finally, the quality of the model transformation at the current stage is compared using Ansys meshing.

3.2 Result

The feasibility and reliability of the proposed method can be initially assessed by visualizing the generated STEP file and viewing the component properties in Ansys. In the proprietary software approach, the above BIM model was directly exported as a STEP file through Revit. In the method of this paper, the above BIM model is exported to an IFC file through Revit and converted to a STEP file through the proposed method. Then, the models are imported into Ansys and meshed using the built-in mesh generator with the same default configuration. Finally, the model quality is assessed by preliminary comparison and comparison of mesh quality criteria.

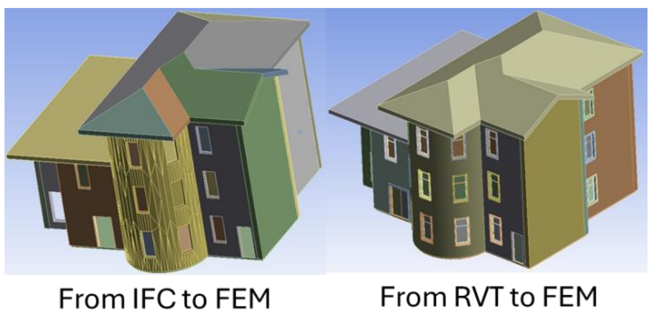


Figure 9: Overview comparison of converted models

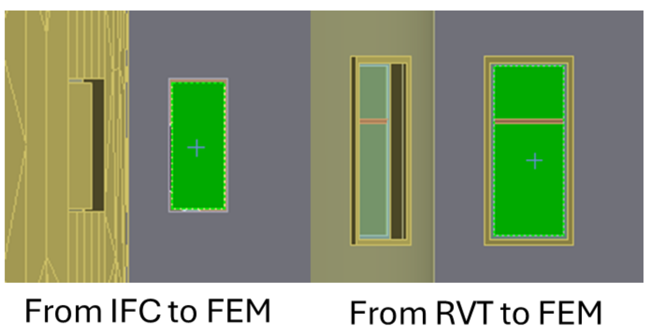


Figure 10: Detailed comparison of the converted components

	From IFC to FEM	From RVT to FEM
Total	119	444
Solid	119	331
Surface	0	113

Table 3: Conversion model component statistics

A preliminary comparison reveals that the proposed method can transform the component as a whole without continuing to split it when targeting components with sub-levels, such as doors and windows, as shown in Figure 10. This keeps the component from losing its physical meaning. Table 3 illustrates that the proposed method ensures that the converted components are closed and also reflects that the method reduces the number of split components. Therefore, it is tentatively concluded that the proposed method is more advantageous than the conversion function of the proprietary software.

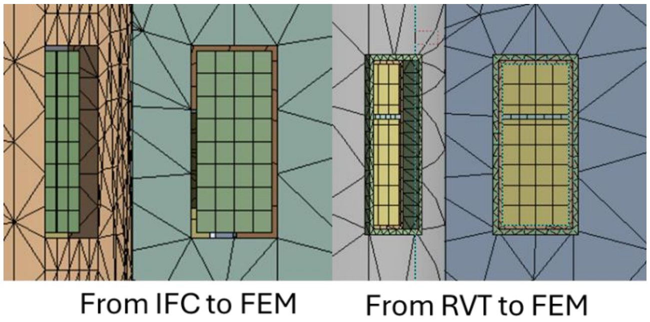


Figure 11: Mesh comparison of converted models

	From IFC to FEM	From RVT to FEM
Element Quality (Avg.)	0.71	0.43
Aspect Ratio (Avg.)	4.92	7.07
Jacobian Ratio (Avg.)	0.986	0.875

Table 4: Statistical table of grid quality standards

For the above two models generated by different conversion methods, the meshing is done with default control cells, and the cell size, resolution, and other parameters are consistent. For FEM, components such as doors and windows should not occupy a large amount of computational resources in the structural analysis. Therefore, the number of meshes in this region should be minimized, and the mesh density should be reduced when meshing. Figure 11 illustrates that the method significantly reduces the mesh density in this region. In terms of data, the mesh quality standard can well reflect the mesh quality of the whole model (Sorgente et al., 2023). As shown in Table 4, Element Quality (Avg.) is a generalized mesh checking criterion, and the larger the value, the better. Moreover, Element Quality (Avg.) should be greater than 0.7; otherwise, the error is significant. The Aspect Ratio (Avg.) should be less than 7 as much as possible to obtain a better displacement solution. The Jacobian Ratio (Avg.) is in the range of 0-1, and the value of 1 indicates a perfect mesh. The lower value indicates a poor mesh. Negative values indicate the presence of a negative volume mesh, which cannot be accepted by the solver. In the default configuration without human intervention, the quality of the models generated by this method after automatic meshing meets the mesh quality criteria. The quality of the model generated by the dedicated software did not meet the mesh quality criteria. The model generated by this method is more advantageous in terms of closure and mesh quality compared to the conversion methods of specialized software.

4 Future Works

In terms of spatial relationships of components, the spatial relationships between the transformed components do not touch or overlap each other, making them lack robustness. The finite element analysis is needed to eliminate this adverse effect. Therefore, future work may extract more component information to solve this problem. This is because more component information will help determine whether the spatial relationships between components are contained or overlapping conflicts, and more coordinate information will be recorded to help recover from coordinate misalignment after transformation. Regarding material matching, only the creation of a material information database has been completed. Adding material information to each component to match it in the FEM platform has not yet been completed. Future work will be done to interoperate the data by writing APDL command flow scripts. For the third component, future work may be done to interoperate the data by creating a database that is accessible to both BIM and FEM.

5 Conclusions

The establishment of a BIM to FEM low-rise residential building model conversion method for debris flow analysis is helpful for debris flow damage assessment of village houses in Hong Kong. Then, it is difficult to automatically convert BIM models into FEM models and achieve model robustness due to the non-standardization and confusing information of each BIM model. The aim of this study is to convert the non-standardized BIM models into FEM models for debris flow FEM analysis and to achieve model robustness. For this purpose, a preprocessing method for automatic conversion of BIM models to FEM models was developed. The method has the following innovations compared to previous studies.

The goal of the Model Geometry Conversion and Calibration section is to automate the conversion of BIM models into FEM models. Previous studies have used simplified and typical models to represent the target model or generated FEM models through labor-intensive manual conversion. That is because the existing BIM models are unstandardized and have confusing component information. As a result, the robustness of the converted models and the accuracy of component information are susceptible to conflicting spatial relationships, confusing material information, and difficulty in closing components into solids. In contrast, the first part is based on 'IfcOpenShell' and 'pythonOCC' to design the closure detection algorithm and component splitting degree detection algorithm. The experimental results show that the method exceeds the conversion effect of proprietary software in terms of closure and model quality.

The material information database creation and matching section is designed to extract the component information from the BIM and add the missing or confusing information through the matching process. Previous studies have used 'IfcMaterial' and 'IfcProperties' from IFC to match the material information, but this method fails when faced with non-standardized and confusing BIM models. In contrast, Part II not only supplements the missing or confusing information but also supports the data integration in Part III.

Finally, future goals of this work include (1) detection and repair of spatial relationships between components, (2) matching and assignment of material information, and (3) design of dual-platform data interoperability after data integration.

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