Computer-Aided Design and Applications

# Research on the Design Method of Prefabricated Concrete Structure Based on BIM

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**Abstract.** With the gradual development in industrialization, the advent of computer and information technology has evolved in the field of engineering and construction industry. BIM technology has become a valuable part of prefabricated concrete engineering with the advancement of modern technology based on 3D modeling simulation. In order to realize the industrialization and automation of prefabricated concrete structures, this paper analyzes the characteristics of fabricated concrete structure and BIM, combining the two techniques. This work applies BIM to fabricated concrete design and chooses finite element analysis and calculation software ETABS to analyze the structure model. The results show that the mass participation ratio of the model studied in this paper reaches more than 90%, the interlayer displacement angle is less than 1/550, and the modal and shell internal force analysis results meet the requirements. In this paper, modal analysis, shell internal force analysis under live load and structural dynamic analysis under response spectrum load conditions were carried out on the ETABS model converted from the Revit model and the model directly established by ETABS. The ETABS model converted from the Revit model by the data interface plug-in can be used for structural analysis.

**Keywords:** Industrialization; BIM; prefabricated concrete structure; finite element analysis; structure analysis.
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# 1 INTRODUCTION

Building information Modeling (BIM) is characterized by the conception, parameterizations, and incorporation of the building designs [1]. As part of this method, a coordinated digital description of every element of the generated asset is constructed using a set of appropriate technologies. This digital description is planned to include data-rich 3D representations as well as structured data such as product, execution, and handover information [2, 3]. As the project moves into the construction phase, the information gained may be utilized to improve the project's design and execution. Any design adjustments that are required can adhere to the agreed-upon methodology in a clear and documented way [4, 5]. The industrial platforms have widely accepted it as a finest solution for informatization of the building structures [6]. Nowadays, the prefabricated building designs are being integrated entire information in designing and construction. The dataset for prefabricated designing can be established via BIM modeling and it can be used for the construction projects.

In BIM based fabricated structural designing, unified common elements were used from the prefabricated element library for construction, analysis, optimization, and application [7]. Digital fabrication is a cutting-edge method that combines the benefits of BIM with virtual design and construction (VDC). Using BIM-based digital fabrication processes, designers, contractors, builders, and engineers may improve the efficiency of prefabricated product design, construction, and manufacturing [8, 9]. Fabrication designs may now be digitally visualized owing to BIM. BIM-based methods make it easier to integrate design, production, and construction processes. This enables more transparency, enhanced cooperation opportunities, and interoperability across stakeholders in the digital manufacturing process [10, 11]. The energy is consumed by the buildings throughout the entire life cycle.

The prefabrication strategy has been promoted as a way, to reduce the life cycle energy consumption of buildings [12, 13]. Prefabricated construction strategy offers significant benefits in terms of various sustainable perspectives like reduction in construction waste [14,15], reduction in green gas emission during the manufacturing activities [16,17], and relocation instead of disposing the waste [18-19]. Because prefab operations are carried out indoors in a factory, construction professionals do not have to worry about delays and interference from the weather, vandals, burglars, or other problematic difficulties. This is a secure, controlled environment that allows owners to expedite the construction process and decrease waste. Prefabrication costs are reduced as a result [20, 21]. While the industry confronts a talent crisis, prefab can help you accomplish a work with a smaller team. Because the main of the job is done indoors and requires less effort, fewer individuals will do more. Workers consider these locations to be safer than others [22, 23]. The buildings absorb energy during their whole life cycle.

The prefabrication method has been touted as a means of lowering building life cycle energy usage. The prefabricated system for the monitoring and reduced energy consumption has been integrated into scientific research in the building sector. For the integration of all information in planning and construction, prefabricated building designs are employed. BIM modeling may be used to create a dataset for prefabricated design, which can then be utilized in building projects. For construction, analysis, optimization, and application in BIM-based fabricated building structure, unified common elements from a prefabricated element library were employed. The various applications of BIM technology for the prefabricated building designs are listed in the Figure 1.

The construction business is clearly being transformed by 4D and 5D BIM. The addition of planning (4D) and cost/material estimate (5D) dimensions to information-rich 3D BIM models ensures improved management of change orders on project costs and schedules. The use of cloud technologies in conjunction with BIM allows participants to access data from any location and on any device. The applications include the renovation, planning, conceptualization of design, detailed designing, analysis, plotting, prefabrication, operation, and construction of 4D and 5D building designs.

At this stage, the construction industry in the country has achieved extremely rapid development, and both its quality and cost have improved. In its construction process, large-scale mechanical equipment and other electronic computer technologies are often used, which will simplify the entire construction process. The use of mechanical equipment, in addition to effectively reducing the construction period and improving efficiency, also reduces the cost of investment to the greatest extent, so the future prefabricated concrete structure will be the main trend of the development of the entire industry. Applying BIM technology to the structural design can maximize the design efficiency and quality, further optimize the model design, and maximize the value of resources. In the current construction field, if you want to solve the main problems in component processing and construction, applying BIM technology is a more feasible solution [24, 25].

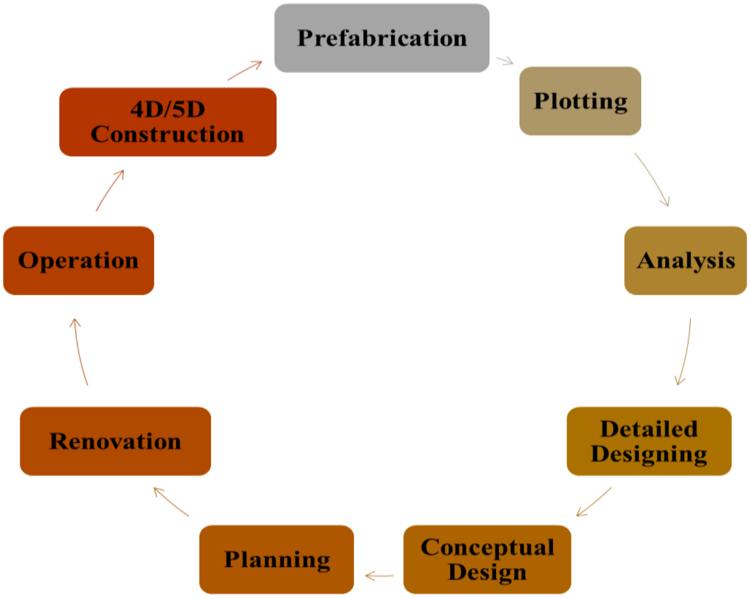


**Figure 1**: Applications of BIM technology in prefabricated building design.

Without the use of BIM technology, the structural analysis, design and detailing of building information becomes a tedious task for complex engineering structures. However, the utilization of BIM technological tool for pre-fabricated concrete structures can provide the detailed information of design and complex geometries in a short period of time. BIM technology enables the decision-making process prior to implementation, clearly specifying the requirements, management considerations, issues which can be encountered and detailed planning/execution scenario for addressing those problems. The implementation of BIM improves the productivity of engineering designs while reducing the errors, time and cost. The application of BIM technology cannot only solve the problems of component processing and building construction, but also effectively reduce the cost of waste in the development process of the construction industry. Moreover, after the completion of the parameterized construction, the BIM technology can fully optimize the related model design, which greatly promotes the improvement of the construction quality of the construction project [26, 27]. The available software for comparing the building information modeling is AutoCAD, Revit, Sketchup, Arcidcad, etc. The Revit BIM software is chosen among all these as it creates the relationship between 2D and 3D design drawings. Revit is used for this research work due to its various advantages like its parametric considerations, landscape design, energy efficient designing, etc.

By providing a research based on the design approach of prefabricated concrete buildings utilizing BIM technology, this article has accomplished the industrialization and automation of prefabricated concrete structures. The research examines the properties of manufactured concrete structures and BIM, merging the two methodologies by using BIM to fabricated concrete design and analyzing the structural model with ETABS finite element analysis and computation software. Modal analysis, live load shell internal force analysis, and structural dynamic analysis under response spectrum load circumstances were investigated. The ETABS model was converted from the Revit model and the model directly established by ETABS. This ETABS model converted from the Revit model is used for data interfacing and plug-in can be used for structural analysis. The results show that the mass participation ratio of the model studied in this paper reaches a significant value with feasible interlayer displacement angle and shell internal force analysis. The research on the design method of prefabricated concrete structure based on BIM in this paper is of great significance.

The remainder of this paper is organized as follows: section 2 presents a literature evaluation of the current state of prefabricated concrete structure industrialization. The study methodologies are presented in part 3, and the results are analyzed in section 4. Section 5 contains a discussion of the current work's findings, and section 6 contains concluding remarks as well as future research directions for the research effort described in this article.

## 2 LITERATURE REVIEW

The country where BIM technology first emerged was the United States, and then gradually developed to the United Kingdom, Canada and other countries. BIM is a brand-new idea, the second information revolution in the construction industry, and a fast channel to accelerate the development of construction industry informatization. The following research on theoretical knowledge has promoted the sustainable development of BIM technology. The domestic BIM wave has gradually started, and it has been recognized by more and more people in the industry. The second information revolution after CAD has started, and it has spread and developed rapidly in the construction industry.

Hu, Y. et al. proposed a fully prefabricated concrete-filled double-steel steel tube/flexural frame with a steel plate shear wall system that only connects beams. A round-robin test was performed on three samples of 1/2 ratio. The damage observation, damage mechanism and hysteresis behavior of the samples are studied and compared. The results showed that the steel plate shear wall (BSW) with only connecting beams enhanced the lateral resistance, initial stiffness and ductility of the precast concrete-filled double-layer steel tube/flexural frame. The specimens with BSW can withstand a story drift rate of more than 5%, which is larger than the value of the bare frame, which increases with the number of BSWs, and the increment between each specimen is approximately equal. Similar findings were observed in terms of initial stiffness, lateral resistance and ductility ratio [28].

Buildings have long been chastised for their low productivity, lengthy building times, poor safety and reliability [29], as well as their high energy use and pollution [30]. Because of the low durability and poor building quality in underdeveloped nations, consumption is higher. Buildings that use sophisticated modular prefabrication have gotten a lot of attention in the architectural, engineering, and construction (AEC) sector in recent years. These new structures are seen as a creative way to address the limitations of traditional structures [31, 32]. Modular prefabrication is a revolutionary construction method in which building components are prefabricated in a controlled environment, then transported, positioned, and assembled on the job site [33]. Modular prefabrication improves building sustainability and has environmental advantages [34].

The air suspension platform uses air pressure to realize the suspension function during the suspension process, which has the disadvantages of high air pressure and low suspension force. Gao, S. et al. used a bionic design to construct an air suspension platform to reduce the required air pressure and increase the suspension force. According to the physiological structure characteristics of the albatross wings, a suspension structure mapping model was established. A bionic model was established using theoretical calculation formulas and structural size parameters of structural design. 3D printers are used to manufacture physical prototypes of suspended work pieces. On this basis, a suspension test bench was built. Six sets of comparative experiments were designed. The experimental results of the suspension test bench are compared with the theoretical calculation results. The results show that for the same air pressure as other work pieces, the buoyancy of a suspended work piece with a V-shaped surface with an angle of attack of 15°is the best. The surface structure of the suspended work piece is applied to the air static pressure rail. By comparing the experimental data, the air pressure of the original air suspension rail was reduced by 37%, which verified the correctness of the theory and design method [35]. Introduction of the first series of test results of precast reinforced concrete columns by Imek, O. et al. Pillars that simulate the wall part are formed in the prefabricated walls of residential buildings after carving openings. There are many ways to strengthen the pillars: from simple reinforcement with wire mesh to reinforcement with standard steel bars. According to the type of steel bar and the type of load, the deformation and tension of each pillar are studied. All pillars were damaged due to local compression of concrete, and transverse tensile failure occurred in all cases [36].

Prefabrication is considered as the most effective way for sustainable construction, and it utilizes the productive safer and good quality construction process which has very less effect on the environment [37]. A method utilized by Liu et al. [38] evaluates the carbon emission during the process of prefabricated manufacturing and energy evaluation. Modular prefabrication enhances building efficiency and has environmental advantages. Furthermore, most researchers have focussed on the overall life cycle performance of buildings, with just a few focusing on specific sustainability development in stages such as design, construction, operation, and maintenance. Sustainable performance in response to stakeholders' concerns influences their decisions and active engagement in selecting modular prefabrication in today's increasingly fragmented construction sector. Tumminia, et al. [39] studied the prefabricated building for reduction in carbon emission, energy saving, protection of environment for green prefabricated buildings. Atmaca presented a construction model highlighting the operation phase for energy estimation [40]. Faludi et al. [41] provided a comprehensive sustainability assessment tool for the application of prefabricated buildings. Monahan and Powell [42] provided a comparative study for analysis of carbon emission and energy assessment. An IOT based technology has been proposed by Tao et al. [43] for real time monitoring of carbon emission as well as energy consumption while manufacturing the prefabricated components. A software-based architecture has been proposed by Kang and Hong for the integration of BIM technology for facility management and analyze the energy consumption during the entire life cycle of construction management. Ajayi et al. [44] assessed the scope of building management for assessing the environmental performance of BIM technology. The prediction of energy consumption was done by Torregrosa-Jaime et al. [45] for optimization of building envelop and balancing of heat during the operation. The assets and limitations of BIM tools are analyzed by Reeves et al. [46] during the energy consumption stage. During the entire life cycle of the construction projects, there are certain difficulties which are faced by the industrial chain like economic problems, energy consumption and environmental impacts. Life cycle assessment (LCA) is one of the methods for achieving sustainable construction practices, and it is well acknowledged for its relevance in acquiring environmental-related product information. Using LCA in the construction industry has established a distinct field of LCA practise. This is related not just to the complexity of buildings, but also to the following aspects, which when combined, distinguish this industry from other complicated goods.

Andriamamonjy et al. [47] studied various essential components for energy performance simulation in order to overcome all these limitations. The energy consumption optimization is carried out for building construction by Zhang and Chen [48] and the user comfort is increased using the lighting, heating, proper ventilation and air conditioning methods during the energy management phase.

The previous literature of prefabricated building deals with the energy performance evaluation of primary energy sources which check the emission of greenhouse gases and provide a quantitative measure for the building life cycle. But there are very few studies which are specifically dedicated to the utilization of BIM technology for the assessment of energy consumption providing saving opportunities for prefabricated manufacturing. The integration of building information has become complicated due to the increasing volume of prefabricated knowledge. Thus, literature review suggests that the BIM technology is significant for improving the sustainability for the prefabricated manufacturing. The innovation of this paper is that according to the characteristics and process of traditional prefabricated concrete structure design, a BIM-based prefabricated concrete structure design process is proposed. Revit structure model is established for actual engineering project and converted into ETABS model using data interface plug-in. Modal analysis of the ETABS model converted from the Revit model and the model directly established by ETABS are performed respectively, and the shell internal force analysis and response under live load The dynamic analysis of the structure under spectral load conditions and comparisons draw conclusions.

## 3 RESEARCH METHODS

### 3.1 Design Process of Fabricated Concrete Structure Based on BIM

Although the traditional prefabricated concrete structure will consider the structural system and make corresponding adjustments before deepening the design, the depth of consideration cannot be guaranteed, and the status quo of many types of components and low mold repetition rate cannot be changed. The design of prefabricated concrete structures based on BIM, starting from a single prefabricated component, combining, and then designing the structure, can fundamentally change this status quo. The design stage can also be divided into five stages: planning stage, scheme design stage, BIM model establishment stage, analysis calculation and optimization stage, and construction drawing and prefabricated component detail design stage. The design process is shown in Figure 2.

### 3.2 Model Conversion Analysis

#### *3.2.1 Model conversion method selection*

The core of BIM technology is to manage all the attributes of the building's life cycle through the data technology of the computer platform, so the popularization and application of BIM technology cannot be separated from the support of software technology. Although there is software that is applicable to various stages in the world, there are still problems with the interfaces of these software, and the model cannot be converted well. The central idea of "one model with multiple uses" can only become a slogan. In addition, international software citations will not fit the current situation in China very well due to the restrictions of norms and standards, and most domestic software is not mature enough, and there is still a big gap between being directly applied to the construction of projects.

Revit is the core software of BIM modeling, but its ability to perform structural calculations is insufficient, and other software is needed for structural calculations. Autodesk's Robot Structural Analysis can perform structural analysis and can perform effective data conversion, but the software does not support the latest domestic norms and standards. The existence of the conversion problem is the main reason why the promotion and application of domestic BIM technology in structural majors is far less than other majors. Combining with the current situation of domestic structure majors, the most suitable way of model conversion is to use data interface plug-in through secondary development conversion. During the secondary development conversion, a data interface plug-in is developed by using two dedicated software to realize the two-way link. This transmission method can ensure the accuracy of information, but it needs to be customized and developed, and its versatility is poor.

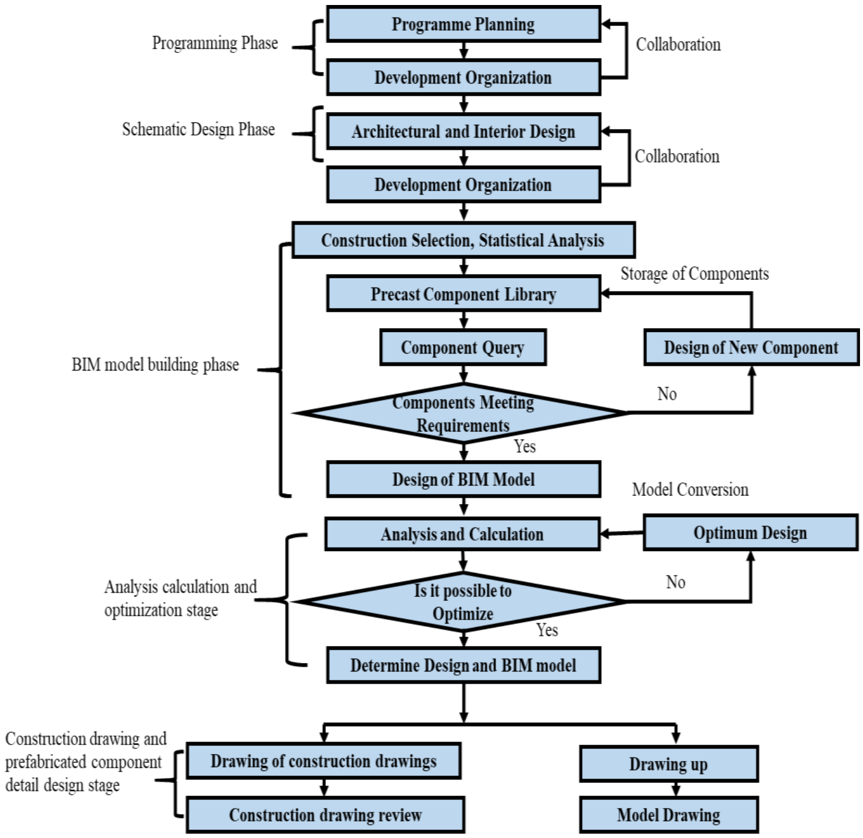


**Figure 2**: Design flow chart of prefabricated concrete structure based on BIM.

### *3.2.2 Selection of structural analysis software*

There are various software packages available for the analysis of structural design and its calculations like ETABS, ABAQUS, ANASYS FLUENT, OpenSees, and many more. All these software is suitable for different applications. ABAQUS software is good for the estimation of model structures; however, ANASYS FLUENT is useful tool for modeling the matters dealing with fluid flow. OpenSees software is a useful tool for the examination of structures including pushover as well as time history investigation. In this article, the application deals with the prefabricated and concrete structures, thus, ETABS software is suitable for design structuring. The literature also suggests that ETABS software is best suitable for the analysis of design structures.

Taking into account the conversion with Revit and the calculation of the fabricated part, and the need for a built-in open data interaction interface for secondary development and other operations, ETABS was selected for structural analysis and calculation. ETABS is finite element software that integrates structural analysis and design. As an international structural analysis and design software, it includes multi-national standards, and its Chinese version includes Chinese standards. The software integrates all calculations and analysis such as load calculation, static and dynamic analysis, linear and nonlinear calculations. The rich section cell library can adapt to more section design methods. At the same time, the software also has built-in open data interaction interface, which can realize the mutual conversion of structural information with other software by means of two-dimensional development and other methods.

In order to ensure the quality after the model conversion, the conversion of the Revit model to the ETABS model adopts the conversion form of the data interface plug-in. The developers of

CSixRevit and ETABS are both CSi companies, which can better ensure the stability of the plug-in and the conversion effect, which can meet the requirements of Revit.

## 3.3 Establishment of Structural Model

### *3.3.1 Project Overview*

The project is located in an industrial area in Pudong New District, Shanghai. The structural form is an assembled monolithic frame structure, the structural safety level is Class II, the structural design service life is 50 years, the seismic intensity is 7 degrees, 4 floors above ground, and the total structure height is 18.850. The prefabricated components include prefabricated columns, prefabricated beams, prefabricated laminated panels, prefabricated double panels, prefabricated cantilever panels, prefabricated stairs and prefabricated parapets, with a prefabrication rate of 40.97%. During model establishment and analysis and calculation, precast concrete columns (precast columns for short), precast concrete composite beams (precast beams for short), precast truss reinforced soil composite slabs (precast composite slabs for short) and precast prestressed concrete double T slabs (for short) Prefabricated double T board) is the main research object. See Table 1 for the concrete strength grades of precast components.

| Serial number | Prefabricated parts | Precast component concrete strength grade | Strength grade of post-cast concrete laminated layer |
|---|---|---|---|
| 1 | Precast pre-stressed concrete double T slab | C35 | C35 |
| 2 | Precast concrete composite beam | C35 | C35 |
| 3 | Prefabricated truss reinforced concrete composite slab bottom plate | C35 | C35 |
| 4 | Precast concrete column | C40 | C40 |

**Table 1**: Concrete strength grades of precast components.

(Note: The concrete strength grade of frame beam and column joint area is the same as that of column concrete)

### *3.3.2 Establishment of Revit model*

This article uses Revit to build the BIM model. The establishment of the structural model can be modified on the basis of the architectural model, but the model in this article is to directly establish the structural model, taking into account the main research objects: prefabricated beams, prefabricated columns, prefabricated laminated slabs and prefabricated double slabs, so in the model. In the process of establishing, focus on these components, and the components that are not considered will be appropriately deleted. Revit comes with a certain material library from which you can choose commonly used components. However, when the form of the component is more complex, the designer needs to establish the family according to the needs of the project, and the established family can also enrich the prefabricated Component library, in the future use process, to avoid duplication of work.

### *3.3.3 Conversion of ETABS model*

The conversion from Revit model to ETABS model requires the installation of a data interface plug-in, which uses the form of secondary development to ensure the stability of the interaction between Revit and ETABS. The process of converting a Revit model to an ETABS model is as follows:

1. Select the Revit software, select "External Tools" in the "Add-on Modules" in the menu bar, click the "Eport to Create New ETABS Model" option, and check the grid, frame and floor in the pop-up option box, After confirming, save the exported file as a file in .exr format;
2. Open ETABS, click on the import "Revit Structure.exr file" in the file, enter the "Revit Data Overlay/Control" editor, edit and adjust the warning part, and also adjust all imported frame section types Make adjustments. If necessary, adjust the Revit model and re-convert.
3. After checking all the imported structure data, click OK to exchange data. The ETABS structure model obtained after conversion is shown in Figure 3. The converted model only does not match the original model at the non-rectangular section beams. The inverted T-shaped beam with double T-plates becomes a T-shaped beam after conversion and needs to be modified separately.

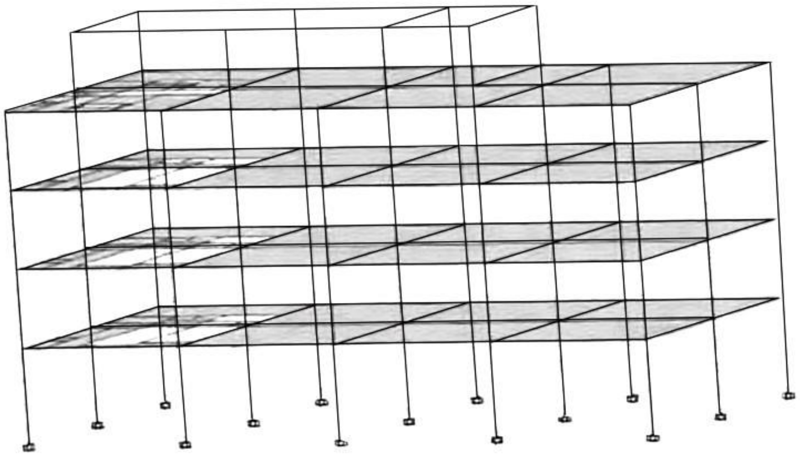

**Figure 3**: ETABS structure model after conversion.

## 4 RESULT ANALYSIS

### 4.1 Definition of Load

The ETABS model converted from Revit is recorded as model A; the structural model established by ETABS directly is recorded as model B, and the two models are compared and analyzed to study the stability and information effectiveness of structural analysis from the converted structural model from Revit Sex. According to the functional zoning of the building and the layout of the structure, the definition of structural load is shown in Table 2.

| Layers | Floor dead load $KN/m^2$ | Floor live load $KN/m^2$ | Side beam line load $KN/m$ |
|---|---|---|---|
| 2 layers | 1.50 | 4.00 | 11 |
| 3 layers | 1.50 | 4.00 | 11 |
| 4th floor | 1.50 | 4.00 | 11 |
| Oya side | 4.00 (partial 8.00) | 3.00 | 11 |
| Hut side | 1.50 | 4.00 | 8 |

**Table 2**: Definition of load.

The graphical representation of the functional zoning of building depicting the layout of the structure is shown in Figure 4.

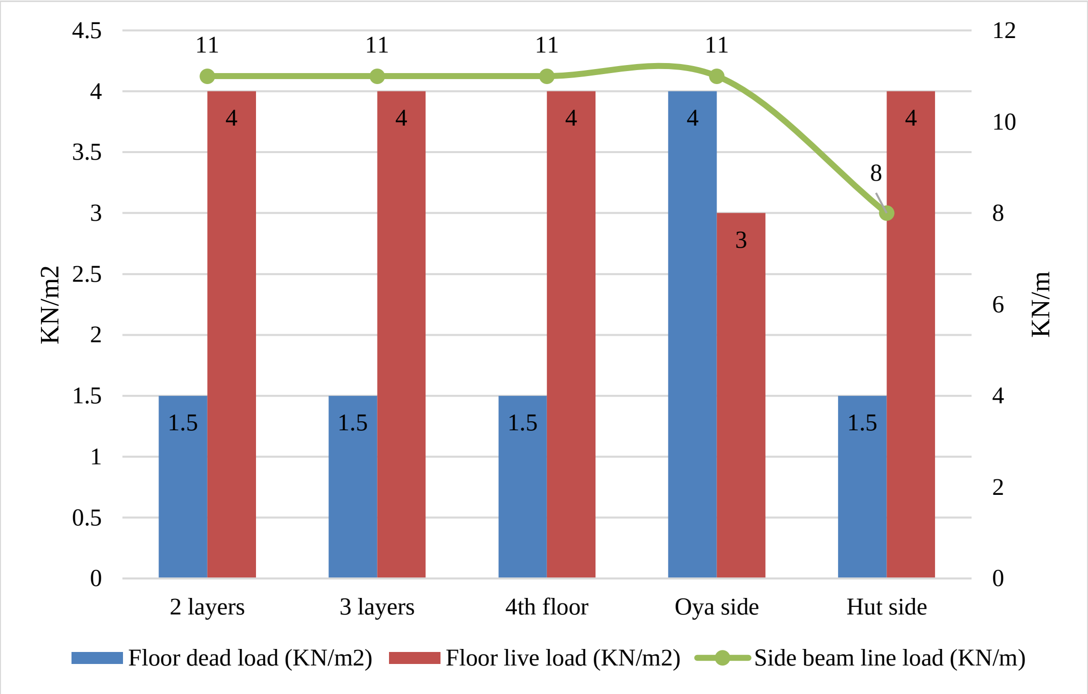


**Figure 4**: Graphical representation of definition of load.

It is depicted from the tabular and graphical representation that the floor deal load value ranges from 1.5 $KN/m^2$ to 4 $KN/m^2$while keeping the range of floor live load in the range of 3 $KN/m^2$to 4 $KN/m^2$. The average value of side beam line load ranges from 11 $KN/m$to 8 $KN/m$. The Oya side shows the floor deal load value is 4 $KN/m^2$while the floor live load value is 3 $KN/m^2$. As compared to others (2-layer, 3-layer, 4th floor and Hut side) the the Oya side shows the heigest floor dead load (4 $KN/m^2$).

## 5 DISCUSSION

### 5.1 Comparison of Modal Analysis

Self-vibration frequency and cycle are important mechanical features inherent in the structure, as well as important parameters of structural design, and the modal analysis using ETABS can obtain the self-vibration frequency of the various vibration types of the structure, thus reflecting the dynamic performance of the structure under the condition of free vibration. In this paper, ETABS is used to analyze the structure modally, extract the first 6th-order vibration type of the structure, and get the self-vibration frequency and period of the structure.

#### *5.1.1 Period and frequency analysis comparison:*

Based on the established structural model, the first 6-order modal analysis is performed using ETABS software. The period and natural frequency calculated by model A and model B are shown in Table 3.

| Working conditions/ Modes | | Model A | | Model B | |
|---|---|---|---|---|---|
| Working condition | Modes | Period sec | Frequency cyc/sec | Period sec | Frequency cyc/sec |
| Capital | 1 | 1.037 | 0.964 | 1.031 | 0.97 |
| Capital | 2 | 0.934 | 1.071 | 1.026 | 0.975 |
| Capital | 3 | 0.768 | 1.303 | 0.891 | 1.123 |
| Capital | 4 | 0.174 | 5.761 | 0.327 | 3.06 |
| Capital | 5 | 0.165 | 6.065 | 0.322 | 3.103 |
| Capital | 6 | 0.15 | 6.65 | 0.286 | 3.501 |

**Table 3**: Comparative analysis of period and frequency for Model A and Model B.

It is observed for Model A that the natural frequency of the model after the third order is obviously smaller than the first three orders. It is also observed that, higher the modal order, smaller the period of the structure and the larger the natural frequency. This is in line with the basic theory of modal analysis. According to experience, it is consistent with the first-order period of 1.037.
The first-order period difference is only 0.006 for model B, but with the increase of the order, the reduction rate of the model A period is larger, and the reduction rate of the model B period is smaller. From the perspective of the first 6-stage period, the gap is within the allowable range. The graphical comparison of the model A and Model B in terms of period and frequency is done in Figure 5.

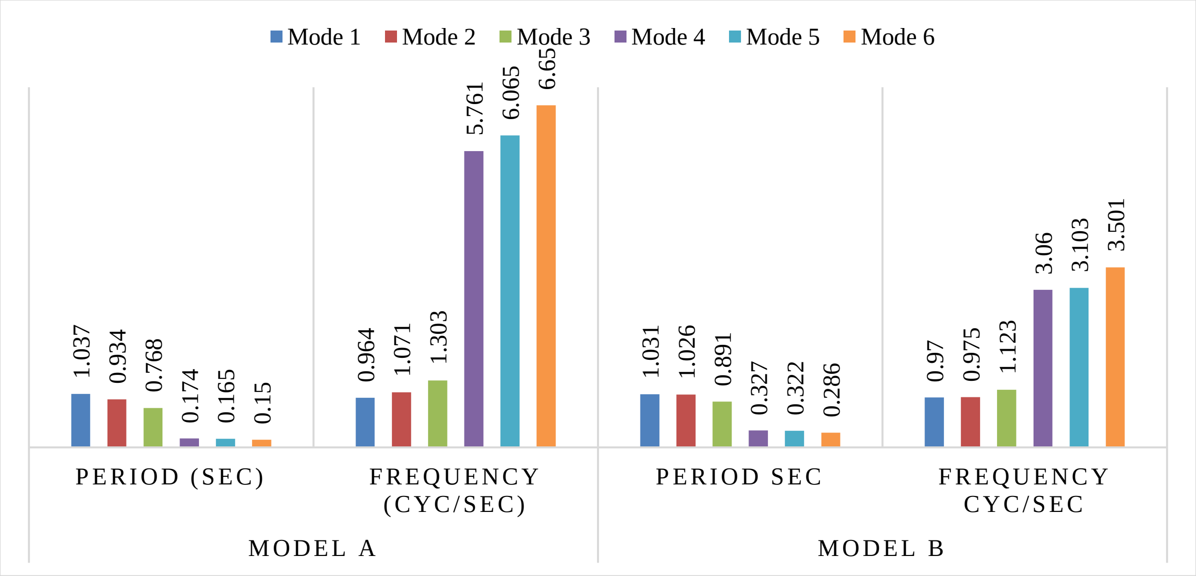


**Figure 5**: Graphical Comparison of Model A and Model B in terms of period and frequency.

Therefore, from the comparison of period and frequency analysis, it is feasible to convert from Revit model to ETABS model for structural analysis.

*5.1.2 Vibration shape analysis and comparison:*

The translation coefficient and torsion coefficient of the first 3 modes of model A and model B are shown in Table 4.

| Working condition | Modes | Model A | Model B |
|---|---|---|---|

| | | Period (sec) | UX | Uruguay | TO | Period (sec) | UX | Uruguay | TO |
|---|---|---|---|---|---|---|---|---|---|
| Capital | 1 | 1.037 | 0 | 0.999 | 0.001 | 1.031 | 0 | 0.999 | 0.001 |
| Capital | 2 | 0.934 | 0.988 | 0.001 | 0.011 | 1.026 | 1 | 0 | 0 |
| Capital | 3 | 0.768 | 0.022 | 0.092 | 0.886 | 0.891 | 0.006 | 0.097 | 0.897 |

**Table 4**: Translation coefficient and torsion coefficient in first three modes of Model A and Model B.

From the tabular comparison, it can be seen that the first mode shape moves in the Y direction as a whole, and the Y direction is the structure. The vibration control direction of the second mode is the overall translation along the X direction, and the X direction is the vibration control direction of the structure; the third mode is torsion around the z axis. The first two modes of the structural system are not dominated by torsion, which conforms to the relevant codes of building structure design. Tabular depiction of Model B reveals that the lower translation coefficient and torsion coefficient in the first three modes of model B. The difference between the translational coefficient and the torsion coefficient under the first three modes is very small, so from the comparison of mode analysis, it is feasible to convert the Revit model to the ETABS model for structural analysis.

### 5.2 Comparison of Modal Analysis

ETABS will automatically mesh the floor during calculation. The sheer force of model A is mainly distributed between -5 and 20 under live load, and the bending moment is mainly distributed between -5 and 10 under live load. The sheer force of model B is mainly distributed between -5 and 20 under live load. The bending moment is mainly distributed between -5 and 10 under the action of live load. The comparative analysis of the A and B models shows that there is no significant difference in the distribution of shear and bending moments and the magnitude of the force. Therefore, from the comparison of shell internal force analysis, it is feasible to convert Revit model to ETABS model for structural analysis.

### 5.3 Structural Dynamic Analysis under Response Spectrum Load Conditions

In this paper, response spectrum method is used for structural dynamic analysis. The relevant parameters of the response spectrum function are defined according to the relevant regulations in the building anti-seismic design code. The specific setting parameters are as follows: the maximum value of the seismic influence coefficient (AlphaMax) is 0.08, the seismic intensity (SI) is 7 degrees 0.01, and the characteristic period (Tg) is 0.9, the period reduction factor (PTDF) is 0.6, and the function damping ratio is 0.05. The function period of the response spectrum and its corresponding acceleration are shown in Table 5.

| | | | | | | |
|---|---|---|---|---|---|---|
| Cycle | 0 | 0.1 | 0.9 | 1.35 | 1.8 | 2.25 |
| Acceleration | 0.036 | 0.08 | 0.08 | 0.0555 | 0.0429 | 0.0351 |
| Cycle | 2.7 | 3.15 | 3.6 | 4.05 | 4.5 | 6 |
| Acceleration | 0.0298 | 0.0259 | 0.023 | 0.0207 | 0.0188 | 0.0164 |

**Table 5**: Period and corresponding acceleration.

The calculation models all define 6 mode conditions, and the mass participation ratios of model A and model B is shown in Table 6. From the comparison, we can see that the quality participation ratio can reach more than 90%. Therefore, from the comparison of quality participation ratio analysis, it is feasible to convert Revit model to ETABS model for structural analysis.

| Mod | Model A | Model B |
|---|---|---|

| e | Period sec | UX | Uruguay | Cumulative UX | Cumulative UY | Period sec | UX | Uruguay | Cumulative UX | Cumulative UY |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.037 | 0.0001 | 0.7242 | 0.0001 | 0.7242 | 1.031 | 2.09E-05 | 0.8557 | 2.09E-05 | 0.8557 |
| 2 | 0.934 | 0.7335 | 0.0001 | 0.7336 | 0.7243 | 1.026 | 0.8301 | 2.68E-05 | 0.8301 | 0.8558 |
| 3 | 0.768 | 0.0077 | 0.0001 | 0.7413 | 0.7244 | 0.891 | 0.0003 | 0.0012 | 0.8304 | 0.857 |
| 4 | 0.174 | 1.7E-05 | 0.1934 | 0.7413 | 0.9177 | 0.327 | 0.0003 | 0.1082 | 0.8306 | 0.9651 |
| 5 | 0.165 | 0.1854 | 1.11E-06 | 0.9267 | 0.9177 | 0.322 | 0.1304 | 0.0003 | 0.961 | 0.9654 |
| 6 | 0.15 | 0.0008 | 0.0071 | 0.9275 | 0.9249 | 0.286 | 0.0005 | 0.0003 | 0.9615 | 0.9657 |

**Table 6**: Comparison on the basis of Quality ratio of model A and model B.

The response spectrum loads are applied in the X and Y directions respectively. The inter-story displacement angles of Model A and Model B are shown in Table 7.

| Floor | Load Condition/Combination | Direction | Model A Displacement Angle | Model B Displacement Angle |
|---|---|---|---|---|
| Hut side | EX Max | X | 1/1963 | 1/2616 |
| Hut side | EY Max | Y | 1/1867 | 1/2055 |
| Oya side | EX Max | X | 1/1134 | 1/1161 |
| Oya side | EY Max | Y | 1/1084 | 1/1115 |
| 4F | EX Max | X | 1/675 | 1/744 |
| 4F | EY Max | Y | 1/632 | 1/747 |
| 3F | EX Max | X | 1/611 | 1/650 |
| 3F | EY Max | Y | 1/570 | 1/623 |
| 2F | EX Max | X | 1/762 | 1/807 |
| 2F | EY Max | Y | 1/655 | 1/705 |

**Table 7**: Displacement angle between model A and model B.

The inter-story displacement angles are not much different, and both are less than the maximum limit of 1/550 required by the specification. Therefore, from the comparison analysis of the displacement angle between floors, it is feasible to convert the Revit model to the ETABS model for structural analysis.

## 6 CONCLUSION

This paper studies the prefabricated concrete structure project through reading the literature and actual participation, combined with BIM technology, believes that the introduction of BIM into the prefabricated concrete structure design stage can solve the current design problems and overcome the difficulties of the design process. To promote the industrialization and automated production of prefabricated concrete structures, the research results of this paper are as follows:

1. According to the characteristics and process of traditional prefabricated concrete structure design, a BIM-based prefabricated concrete structure design process is proposed, and the new and old processes are compared and analyzed from different perspectives, showing the connection and difference between the two.
2. According to the comparative analysis of model conversion methods, choose the data interface plug-in with the strongest stability. Through the comparison of structural analysis software, the more open finite element analysis software ETABS is determined. Establish the Revit structural model of the actual engineering project and use the data interface plug-in to convert it into an ETABS model. The ETABS model converted from the Revit model and the model directly established by ETABS are respectively subjected to modal analysis, shell internal force analysis and response spectrum under live load The dynamic analysis of the structure under load conditions and comparisons are made. Each result shows that the ETABS model converted from the Revit model through the data interface plug-in can be used for structural analysis.

This article only conducts research from certain levels, and the areas that need to be further deepened and improved are:

1. The data interface plug-in used in the model conversion in this paper is provided by ETABS Development Company. For the reasons for the deviation of the higher-order modes of the structure, further research is needed.
2. For model conversion, the conversion of non-rectangular section beams has the problem of rotation. The conversion tool needs to be improved which will be the future research perspective of this work. At the same time, the effect of the tool needs to be verified by more complex and different structural types of projects in the future studies.

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## REFERENCES

[1] Aram, S.; Eastman, C.; Sacks, R.: Requirements for BIM platforms in the concrete reinforcement supply chain, Automation in construction, 35, 2013, 1-17. https://doi.org/10.1016/j.autcon.2013.01.013
[2] Ullah, N.; Asjad, M.; Ur Rehman, H.; Akgül, A.: Construction of optical solitons of Radhakrishnan–Kundu–Lakshmanan equation in birefringent fibers, Nonlinear Engineering, 11(1), 2022, 80-91. https://doi.org/10.1515/nleng-2022-0010
[3] Ren, X.; Li, C.; Ma, X.; Chen, F.; Wang, H.; Sharma, A.; Gaba, G.S.; Masud, M.: Design of multi-information fusion based intelligent electrical fire detection system for green buildings. Sustainability, 13(6), 2021, 3405. https://doi.org/10.3390/su13063405
[4] Sharma, A.; Podoplelova, E.; Shapovalov, G.; Tselykh, A.; Tselykh, A.: Sustainable smart cities: convergence of artificial intelligence and blockchain, Sustainability, 13(23), 2021, 13076. https://doi.org/10.3390/su132313076
[5] Hu, Y.; Sharma, A.; Dhiman, G.; Shabaz, M.: The Identification Nano particle Sensor Using Back Propagation Neural Network Optimized by Genetic Algorithm, Journal of Sensors, 2021, 1–12. https://doi.org/10.1155/2021/7548329

[6] Sharma, A.; Kumar, R.: Service level agreement and energy cooperative cyber physical system for quickest healthcare services, Journal of Intelligent & Fuzzy Systems, 36(5), 2019, 4077-4089. https://doi.org/10.3233/JIFS-169968

[7] Sharma, A.; Kumar, R.; Talib, M.W.A.; Srivastava, S.; Iqbal, R.: Network Modelling and Computation of Quickest Path for Service Level Agreements Using Bi-Objective Optimization, International Journal of Distributed Sensor Networks, 15(10), 2019, 1550147719881116. https://doi.org/10.1177/1550147719881116

[8] Raslan, K.; Ali, K.; Al-Jeaid, H.: N-dimensional quintic B-spline functions for solving n-dimensional partial differential equations, Nonlinear Engineering, 11(1), 2022, 123-134. https://doi.org/10.1515/nleng-2022-0016

[9] Poongodi, M.; Sharma, A.; Vijayakumar, V.; Bhardwaj, V.; Sharma, A.P.; Iqbal, R.; Kumar, R.: Prediction of the price of Ethereum blockchain cryptocurrency in an industrial finance system, Computers & Electrical Engineering, 81, 2020, 106527. https://doi.org/10.1016/j.compeleceng.2019.106527

[10] Zhou, Y.; Sharma, A.; Shabaz, M.: Feature recognition of state signal of electromechanical integration railway turnout over health parameters using CMOS area array technology, The Journal of Engineering, 2022. https://doi.org/10.1049/tje2.12154

[11] Guo, W.; Rubaiee, S.; Ahmed, A.; Othman, A.; Khosla, A.: Study on modal parameter identification of engineering structures based on nonlinear characteristics, Nonlinear Engineering, 11(1), 2022, 92-99. https://doi.org/10.1515/nleng-2022-0011

[12] Teng, Y.; Li, K.; Pan, W.; Ng, T.: Reducing building life cycle carbon emissions through prefabrication: Evidence from and gaps in empirical studies, Building and Environment, 132, 2018, 125-136. https://doi.org/10.1016/j.buildenv.2018.01.026

[13] Chang, Y.; Li, X.; Masanet, E.; Zhang, L.; Huang, Z.; Ries, R.: Unlocking the green opportunity for prefabricated buildings and construction in China, Resources, Conservation and Recycling, 139, 2018, 259-261. https://doi.org/10.1016/j.resconrec.2018.08.025

[14] Xu, Z.; Wang, S.; Wang, E.: Integration of BIM and energy consumption modelling for manufacturing prefabricated components: a case study in China, Advances in Civil Engineering, 2019. https://doi.org/10.1155/2019/1609523

[15] Hao, J.; Yuan, H.; Liu, J.; Chin, C. S.; Lu, W.: A model for assessing the economic performance of construction waste reduction, Journal of Cleaner Production, 232, 2019, 427-440. https://doi.org/10.1016/j.jclepro.2019.05.348

[16] Xie, L.; Chen, Y.; Xia, B.; Hua, C.: Importance-performance analysis of prefabricated building sustainability: a case study of Guangzhou, Advances in Civil Engineering, 2020. https://doi.org/10.1155/2020/8839118

[17] Pons, O.; Wadel, G.: Environmental impacts of prefabricated school buildings in Catalonia, Habitat International, 35(4), 2011, 553-563. https://doi.org/10.1016/j.habitatint.2011.03.005

[18] Wang, M.; Wang, C. C.; Sepasgozar, S.; Zlatanova, S.: A Systematic Review of Digital Technology Adoption in Off-Site Construction: Current Status and Future Direction towards Industry 4.0, Buildings, 10(11), 2020, 204. https://doi.org/10.3390/buildings10110204

[19] Dogra, J.; Jain, S.; Sharma, A.; Kumar, R.; Sood, M.: Brain tumor detection from MR images employing fuzzy graph cut technique, Recent Advances in Computer Science and Communications (Formerly: Recent Patents on Computer Science), 13(3), 2020, 362-369. https://doi.org/10.2174/2213275912666181207152633

[20] Zhang, X.; Rane, K. P.; Kakaravada, I.; Shabaz, M.: Research on vibration monitoring and fault diagnosis of rotating machinery based on internet of things technology, In Nonlinear Engineering, 10(1), 2021, 245–254. https://doi.org/10.1515/nleng-2021-0019

[21] Yuvaraj, N.; Srihari, K.; Dhiman, G.; Somasundaram, K., Ashutosh Sharma, Rajeskannan, S., Soni, M., Gaba, G.S., AlZain, M.A. and Masud, M., 2021. Nature-inspired-based approach for automated cyber bullying classification on multimedia social networking. Mathematical Problems in Engineering, 2021. https://doi.org/10.1155/2021/6644652

[22] Rathee, G.; Sharma, A.; Saini, H.; Kumar, R.; Iqbal, R.: A hybrid framework for multimedia data processing in IoT-healthcare using blockchain technology, Multimedia Tools and Applications, 79(15), 2020, 9711-9733. https://doi.org/10.1007/s11042-019-07835-3
[23] Hillier, C.; Balyan, V.: Error Detection and Correction On-Board Nanosatellites Using Hamming Codes, Journal of Electrical and Computer Engineering, 2019(6), 2019, 1-15. https://doi.org/10.1155/2019/3905094
[24] Balyan, V.: New OZCZ Using OVSF Codes for CDMA-VLC Systems, Advances in Intelligent Systems and Computing, 1235,2022, 363-374. https://doi.org/10.1007/978-981-16-4641-6_30
[25] Yang, J.: The Structural Design Method of Prefabricated Buildings based on BIM Technology, IOP Conference Series: Earth and Environmental Science, 598(1), 2020, 012029). https://doi.org/10.1088/1755-1315/598/1/012029
[26] Yan Cangli.: Research on the design process of prefabricated structure based on BIM technology, Hans Journal of Civil Engineering, 09(10), 2020, 1099-1109. https://doi.org/10.12677/HJCE.2020.910114
[27] Ma, C.; Wang, Y.; Xu, H.: Research on prefabricated structure design method based on BIM technology, IOP Conference Series Materials Science and Engineering, 750, 2020, 012195. https://doi.org/10.1088/1757-899X/750/1/012195
[28] Hu, Y.; Zhao, J.; Zhang, D.; Zhang, H.: Cyclic tests of fully prefabricated concrete-filled double-skin steel tube/moment-resisting frames with beam-only-connected steel plate shear walls, Thin-Walled Structures, 146(1), 2020, 502-515. https://doi.org/10.1016/j.tws.2019.106272
[29] Chen, Y.; Okudan, G.E.; Riley, D.R.: Sustainable performance criteria for construction method selection in concrete buildings, Autom. Constr., 19, 2010, 235–244. https://doi.org/10.1016/j.autcon.2009.10.004
[30] Ahmed, A.; Qayoum, A.; Mir, F. Q.: Investigation of the thermal behavior of the natural insulation materials for low temperature regions, Journal of Building Engineering, 26, 2019, 100849. https://doi.org/10.1016/j.jobe.2019.100849
[31] Jaillon, L.; Poon, C.S.; Chiang, Y.H.: Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong, Waste Manag., 29, 2009, 309–320. https://doi.org/10.1016/j.wasman.2008.02.015
[32] Zhang, W.; Lee, M.W.; Jaillon, L.; Poon, C.-S.: The hindrance to using prefabrication in Hong Kong's building industry, J. Clean. Prod., 204, 2018, 70–81. https://doi.org/10.1016/j.jclepro.2018.08.190
[33] Zhang, X.; Skitmore, M.; Peng, Y.: Exploring the challenges to industrialized residential building in China, Habitat Int. 2014, 41, 176–184. https://doi.org/10.1016/j.habitatint.2013.08.005
[34] Yunus, R.; Yang, J.: Legislative challenge to sustainable application of industrialized building system (IBS), J. Teknol, 63, 2015, 1171–1183. https://doi.org/10.11113/jt.v78.8236
[35] Gao, S.; Zhang, B.; Sun, J.: Research on the design method of a bionic suspension workpiece based on the wing structure of an albatross, Applied Bionics and Biomechanics, 2019, 2019, 1-11. https://doi.org/10.1155/2019/1736763
[36] Imek, O.; Zich, M.; Janda, M.; Petr Daněk,; Neas, R.: Testing of the prefabricated reinforced concrete pillars, Solid State Phenomena, 309, 2020, 234-239. https://doi.org/10.4028/www.scientific.net/SSP.309.234
[37] Xu, Z.; Wang, S.; Wang, E.: Integration of BIM and energy consumption modelling for manufacturing prefabricated components: a case study in China, Advances in Civil Engineering, 2019. https://doi.org/10.1155/2019/1609523
[38] Liu, G.; Gu, T.; Xu, P.; Hong, J.; Shrestha, A.; Martek, I.: A production line-based carbon emission assessment model for prefabricated components in China, Journal of cleaner production, 209, 2019, 30-39. https://doi.org/10.1016/j.jclepro.2018.10.172
[39] Tumminia, G.; Guarino, F.; Longo, S.; Ferraro, M.; Cellura, M.; Antonucci, V.: Life cycle energy performances and environmental impacts of a prefabricated building module,

Renewable and Sustainable Energy Reviews, 92, 2018, 272-283. https://doi.org/10.1016/j.rser.2018.04.059
[40] Atmaca, N.: Life-cycle assessment of post-disaster temporary housing, Building Research & Information, 45(5), 2017, 524-538. https://doi.org/10.1080/09613218.2015.1127116
[41] Faludi, J.; Lepech, M. D.; Loisos, G.: Using life cycle assessment methods to guide architectural decision-making for sustainable prefabricated modular buildings, Journal of green building, 7(3), 2012, 151-170. https://doi.org/10.3992/jgb.7.3.151
[42] Monahan, J.; Powell, J. C.: An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework, Energy and buildings, 43(1), 2011, 179-188. https://doi.org/10.1016/j.enbuild.2010.09.005
[43] Tao, X.; Mao, C.; Xie, F.; Liu, G; Xu, P.: Greenhouse gas emission monitoring system for manufacturing prefabricated components, Automation in Construction, 93, 2018, 361-374. https://doi.org/10.1016/j.autcon.2018.05.015
[44] Ajayi, S. O.; Oyedele, L. O.; Ceranic, B.; Gallanagh, M.; Kadiri, K. O.: Life cycle environmental performance of material specification: a BIM-enhanced comparative assessment, International Journal of Sustainable Building Technology and Urban Development, 6(1), 2015, 14-24. https://doi.org/10.1080/2093761X.2015.1006708
[45] Balyan, V.: Cooperative relay to relay communication using NOMA for energy efficient wireless communication, Telecommunication systems, 76(2), 2021, 271-281. https://doi.org/10.1007/s11235-021-00756-3
[46] Balyan, V.: Channel Allocation with MIMO in Cognitive Radio Network, Wireless Personal Communication, 116, 2021, 45–60. https://doi.org/10.1007/s11277-020-07704-5
[47] Andriamamonjy, A.; Saelens, D.; Klein, R.: An automated IFC-based workflow for building energy performance simulation with Modelica, Automation in Construction, 91, 2018, 166-181. https://doi.org/10.1016/j.autcon.2018.03.019