Computer-Aided Architectural Design Optimization Based on BIM Technology

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This article addresses the problem of the non-circulation of information in each stage of architectural design. This paper explores the architectural design process based on the BIM platform and puts forward the structural design method based on the BIM platform. It carries out the seismic analysis of a high-rise building with a transfer floor structure and compares the analysis results with the structural analysis software commonly used by the current design institute. The results obtained for experimentation show that the period ratio, displacement ratio, and the first six modes calculated by the two methods in the modal analysis are consistent. The error between calculation results and PKPM calculation results is within a reasonable range. In the analysis of the mode decomposition response spectrum method, the seismic forces in X and Y directions, floor shear, overturning moment, floor average displacement, and displacement angle obtained by the two models are compared respectively. The analysis results of the two methods accord with the mechanical characteristics of the transfer floor structure, and the calculation error is within the allowable range. The structural design based on the BIM platform has the advantages of high visualization, parameter-driven component size, and high model accuracy, improving design drawing efficiency.

Povzetek: S platformo BIM so izboljšali arhitekturo snovanja na praktičnem primeru seizmične analize.

1 Introduction

In recent years, with the rapid growth of the social economy and the acceleration of urbanization, more and more complex residential buildings and transfinite high commercial complex buildings have sprung up [1-2]. The intervention of CAD has changed the design method and production mode of manual drawing with a drawing board. This not only liberates the engineering designers from the traditional design calculation and repeated manual drawing modification design mode, but also promotes the professionals involved in the project to focus more on the solution of professional problems and the optimization of the design scheme, improves the design quality and improves the modification efficiency of design drawings. However, with the continuous changes of the types of building structures and the structural forms of building components, the relatively simple two-dimensional expression has more and more limitations in the expression of architectural and structural design. BIM, as an extension of the production and application technology of the mechanical industry in the construction industry, provides a new technical idea for the information management and exchange of construction projects [3].

BIM Technology not only provides a solution to improve the quality of architectural design drawings, but also makes the building model and design information better transmitted in the process of building life cycle, and fundamentally solves the problem of non-circulation of information in each stage of design, construction, operation and maintenance [4]. It reproduces the real situation of buildings through computer simulation. It is the third technological revolution in the construction industry. The six characteristics of this technology are visualization, synergy, interoperability, simulation, relevance, and parameterization. BIM Technology has brought unprecedented changes to the traditional working mode and provided a better solution for the needs of fine design. The involvement of computer software has rapidly improved the work efficiency and design quality of the majority of design institutes. However, Auto CAD software presents its design information in the form of point, line, and surface based on the plane, which is basically consistent with the information carried by traditional manually drawn drawings, and does not have much impact on the design method. With more and more special-shaped buildings and more complex building functions, the architectural design method based on CAD software has increasingly exposed many deficiencies [5-6]. Figure 1 shows a design diagram of a computer-aided architecture based on BIM technology.

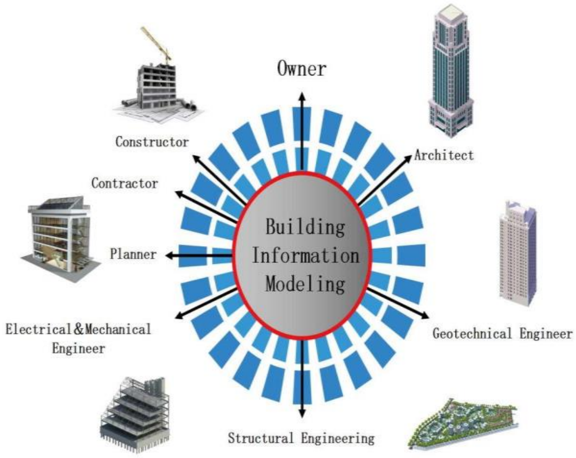


Figure 1: Optimization of computer-aided building design

The BIM software technology has become a boom these days as the design specifications are entered into the BIM software the 3D model plan is elevated along with the detailed design. The designers utilize the drawing for extracting basic design information in order to deal with the management limitations of the project.

This article addresses the collision problem of design and construction drawings caused by delayed communication among disciplines in the design stage. The collision problem in the process of collaborative design is solved in this article through practical engineering cases and puts forward a solution based on the BIM platform. This article basically analyses the BIM design software in the design stage. This work explores the architectural design process based on the BIM platform. A solution based on the BIM tool is proposed for structural seismic analysis. Aiming at the structural design method based on the BIM platform proposed in this paper, the seismic analysis of a high-rise building with a transfer floor structure is carried out. The analysis results are compared with the analysis results of the current structural analysis software used by the design institute.

The rest of this article is systematized as literature is presented in section 2 followed by research methods in section 3. Section 4 depicts the results and the conclusion is presented in section 5.

2 Related work

In this section various state-of-the-art work in the field of optimization design based on Computer-Aided architecture is presented.

With regard to the application of computer-aided technology in architectural design, Kamel and Memari [7] uses the BIM model established by the calculation software to directly convert the two-dimensional electronic diagram and generate collision reports automatically, in batches, or according to conditions. Nan Fangying and others use the ruling principle to automatically generate multiple design ranges that comply with laws and regulations, and then select the most ideal results of energy consumption simulation to assist in decision-making building volume design. Sayary and Omar [8] and others proposed a method to transform DFS rules into a computer language recognized by Revit, so as to automatically review the design and effectively identify construction safety risks. Du *et al.* [9] and others made a preliminary exploration of the inspection method and process of BIM model quality mainly with the help of the rule inspection software solibri model checker (SMC) v8.0 of solibri company in Finland. Hattab and Hamzeh [10] and others analyzed and summarized the technical advantages of rule checking, expounded the application methods of different types of rules, and further explained the application prospect of rule checking technology from the perspective of solving practical problems and improving work efficiency.

For the application of BIM Technology, Ning *et al.* [11] and others proposed a BIM 3D solid modeling based on a CAD graphics engine based on IFC Standard, which can be transformed into the surface model to meet the application requirements of BIM geometric data for different stages of construction engineering. This method improves the reusability and universality of avoiding data. Heaton *et al.* [12] studied how to combine the BIM technical concept with the current plane representation method of structural construction drawings in China, and analyzed the feasibility of the plane representation method of structural construction drawings based on the BIM platform. A plane representation method of structural construction drawing is proposed, which realizes the correlation of parameters through sharing parameters and label family, realizes the transformation from FIC standard to Revit structural software, and is verified by an example. Lin *et al.* [13] and others analyzed the value and application process of using BIM Technology in prefabricated buildings, studied how to apply BIM Technology to prefabricated houses, and analyzed their adaptability based on actual project cases, providing a reference for the further application of BIM Technology in prefabricated buildings. Mattern and Konig [14] studied the building information model based on Revit software to extract structural information and provide reliable information data for structural analysis, and gave the model conversion method between Revit software and international general structural analysis software SAP2000.

With the growth in the worldwide economy and improvement in technology, the design schemes of domestic engineered architecture have been improving daily, thus, combining the CAD architectural designing with BIM technology [15, 16]. Further with the development in construction technology, architectural designing is also changing from hand-made drawings to CAD-based architects [17, 18]. The CAD architects are using BIM technology which promotes the architectural design to be more scientific and stabilized, thereby improving the efficiency of design in architectural construction [19]. The improvement in the construction industry is noticed with the involvement of BIM technology with the CAD architecture and has created a high value to the construction industry [20, 21]. This work is also considered for the industrial applications and contributing towards social life with the integration of the Internet of Things, AI, and robotics [22-25].

This article basically introduces the principle of BIM affecting the architectural design using CAD software and thus compared this novel strategy with the other CAD optimization approaches which apply BIM for their technological applicability.

3 Research methods

This section includes the project design process, structural seismic analysis and detailed modeling steps of proposed architecture.

3.1 BIM based construction project design process

When compared with the traditional architectural design method, the architectural design method based on BIM is characterized in that the professional engineers involved in the project do not need to imagine and build a three-dimensional drawing in front of a pile of simple and numerous two-dimensional plans [26]. The BIM-based construction project design process repeatedly compares and calculates the architectural design information, but arranges components and designs architectural information in the virtual three-dimensional space through computer software technology. Based on the understanding of the current BIM platform software, this paper attempts to establish the BIM building structure design process in the design stage. In the process of structural design, the main components of the structure should always be built around the building model, which does not affect the artistic effect and use of the function of the building. Based on the visualization characteristics of BIM core modeling software Revit, the CAD files of the building model and scheme design can be loaded into the new structure template by importing or linking. After completing the structural model in the BIM core modeling software, it is necessary to reasonably select the structural finite element calculation software for trial calculation [27, 28]. Based on the characteristics of BIM platform data sharing, the selection of structural finite element analysis software in the BIM platform shall be based on the following points:

i. It has a data exchange interface corresponding to BIM core modeling software. The geometric dimensions, load cases, and boundary constraints in the structural model can be directly or indirectly transformed into the structural finite element software as analysis data, which can avoid repeated modeling in the structural analysis software. This data transfer method can improve the efficiency of structural analysis in the process of structural design.

ii. The structural finite element analysis software can feed back the model after calculation, analysis, and adjustment to the corresponding BIM core modeling software, so as to update or modify the original model.

The main task in the construction drawing stage is to reflect the final model of each discipline in the preliminary design of the two-dimensional drawing. Before sorting out the construction drawings, we should integrate the needs of architecture, structure, plumbing, and electricity, and further deepen the model of architecture and structure. Rigid structures and prefabricated buildings can simulate the construction of complex hoisting links. The final outcome document of the construction drawing level is to complete the trap drawings of various disciplines of architecture, structure, and equipment that meet the requirements of equipment and material procurement, non-standard equipment manufacturing, and construction [29].

BIM core modeling software Revit architecture software and Revit structure software are modeling software based on parametric design. When the building or structural model is completed, it can be converted into a construction drawing through the plan view of each level. And when the later design changes, whether the construction drawing of the Revit project browser is modified directly or in the 3D model, the components at the corresponding positions of other views will be modified, that is, if one change occurs, the corresponding parts of other drawings will also be changed [30, 31]. Through the project browser of Revit series software, you can efficiently manage design drawings, construction drawings, design descriptions, and other drawing files.

3.2 Structural seismic analysis based on BIM

The structural analysis model based on Revit software is formed while creating the structural geometric model. While creating the geometric model, the analytical model is automatically connected to the nodes. The creation process of the geometric model is carried out in the order of floor-by-floor construction from low to high in the actual construction project. The project consists of a podium and main building [32]. Therefore, when dividing the project for modeling, it can be divided into the main building and podium according to the primary and secondary structure of the project, so as to improve the modeling efficiency. The creation of the BIM structural 3D model is to build an information model with structural component properties through different component families, classes, and elements. This project belongs to frame supported shear wall structure. BIM model is created by taking basic structural components, beams, structural columns, and structural plates as basic elements [33]. The modeling steps of the proposed architecture are depicted in Figure 2.

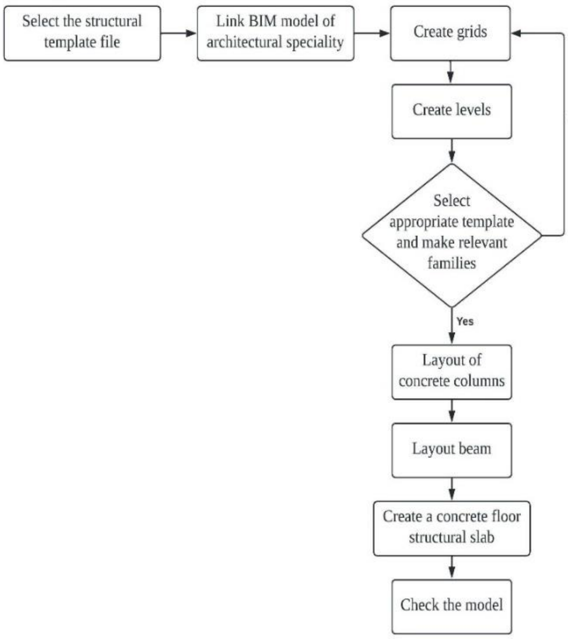


Figure 2: Modeling steps of the proposed architecture

The basic modeling steps are as follows: Select the structure template file; Link BIM model of architecture specialty; Create grids; Create levels; Select the appropriate family template file and make relevant component families; Layout of concrete columns; Layout beam; Create a concrete floor structural slab; Check the model.

After the BIM pattern is adjusted, the BIM pattern will be displayed.

Modal analysis is to analyze the properties of the structure itself. It is the most commonly used and effective analysis method in the seismic response analysis of uncoupled linear structures or decoupled linear structures [34, 35]. At the same time, structural modal analysis is also the analysis basis of response spectrum analysis and time history analysis.

According to D'Alembert's principle, the dynamic balance equation of structural system under earthquake action:

$$F_I(t) + F_D(t) + F_S(t) = F(t) \quad (1)$$

Where: $F_I(t)$ is inertial force vector acting on node mass; $F_D(t)$ is viscous damping force vector or energy dispersive force vector; $F_S(t)$ is internal force vector borne by structure; $F(t)$ is the load vector imposed on the structure by the outside world.

For seismic action, when the external load F(t) in Equation (1) is equal to zero and the structure is undamped, it can be expressed as a second-order differential equation (2).

$$\mathrm{MX''(t) + KX(t) = 0} \quad (2)$$

Where M and K are the mass matrix and stiffness matrix of the structural system respectively; X"(t) and X(t) are structural acceleration and displacement vector.

Assuming that each particle vibrates with the same frequency ω, the same phase angle $\omega t + \varphi$ and different amplitude X:

$$\mathrm{X(t) = \{X\}\sin(\omega t + \varphi)} \quad (3)$$

Substitute (3) into the natural vibration equation (4)

$$[\mathrm{K}]\{\mathrm{X}\}\sin(\omega t + \varphi) - \omega^2[\mathrm{M}]\{\mathrm{X}\}\sin(\omega t + \varphi) = 0 \quad (4)$$

The above formula holds for any time, so there is a characteristic equation

$$([\mathrm{K}] - \omega^2[\mathrm{M}])\{\mathrm{X}\} = 0 \quad (5)$$

It is impossible to obtain {X} by the vibration coefficient of each node in the determinant, so Equation (5) must be equal to zero

$$|[K] - \omega^2[\mathrm{M}]| = 0 \quad (6)$$

Through the finite element software SATWE and YJK, the two structural models are calculated respectively, and the 18th order vibration mode is selected for analysis. Read the first 6 vibration modes from the calculation result file, and the structural natural vibration period of each vibration mode is shown in Table 1. In structural design, in order to make the structure have good torsional resistance, the overall torsional deformation resistance of the structure is usually indirectly reflected by the period ratio, that is, the ratio of the first natural vibration period Tt with torsion to the first natural vibration period T1 dominated by translation.

Vibration mode	**SATWE**		**YJK**	
	Cycle	**Torsion coefficient**	**Cycle**	**Torsion coefficient**
1	3.0524	0.00	3.0058	0.00
2	2.9234	0.09	2.9043	0.07
3	2.5312	0.91	2.3595	0.93
4	0.9639	0.02	0.8981	0.03
5	0.7879	0.00	0.7505	0.00
6	0.6676	0.98	0.6101	0.96

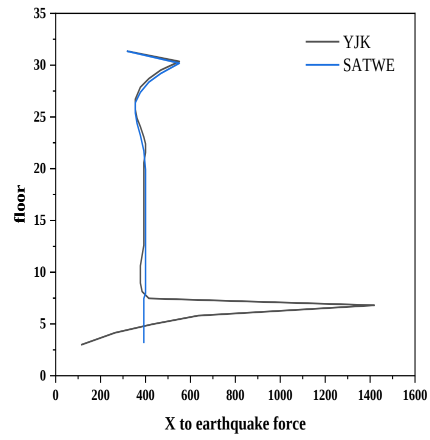
Table 1: Natural vibration period and vibration mode characteristics of structure

The number of vibration modes calculated by yingjianke software is also 18, and the effective mass coefficient in X direction is 92.12%, and the effective mass coefficient in Y direction is 94.32%, both of which are greater than 90%, which also meet the specification requirements. It shows that the calculation results of BIM structure model imported into YJK software are basically consistent with those of conventional calculation methods [36].

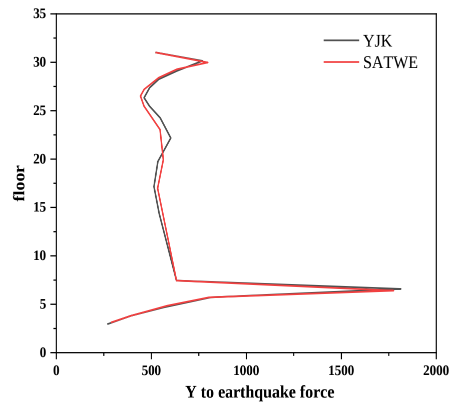
4 Results and Analysis

This section illustrates the analysis of results obtained by comparing the seismic forces calculated by two programs and finally presents its discussion and summary.

In Figure 3 (a, b), the horizontal seismic forces of each layer under X-direction seismic action and Y-direction seismic action of the two computer calculation methods are compared respectively. The calculation results of the two methods show that the overall variation trend of the horizontal seismic force along the structural height of the two calculation models is basically the same, whether in the X direction or in the Y direction. The seismic force of the fifth floor (i.e., the fourth floor of the building ground) of the two models in the figure is significantly greater than its adjacent upper and lower floors. This is because there are transfer beams with large section and transfer floor slab with thick section in the transfer floor, which makes the transfer floor have large mass and stiffness and will produce large inertial force under the action of earthquake. At the same time, due to the existence of transfer floor, the vertical stiffness of the structure changes suddenly at this floor, resulting in the rapid increase of horizontal seismic force at this floor. In addition, the podium floor at the lower part of the transfer floor has large structural stiffness, resulting in the increase of horizontal seismic forces on it compared with the upper layer. The results show that the high-rise building structure with transfer floor needs to strengthen the seismic design at the transfer floor. The figure shows that the seismic force on the structure in the Y direction is greater than that in the X direction, which also shows that the structural stiffness in the Y direction of the calculation model is greater than that in the X direction. The horizontal seismic force of several floors on the top of the structure has an obvious increasing trend, which shows that the top of the structure is vulnerable to the influence of high-order vibration modes.



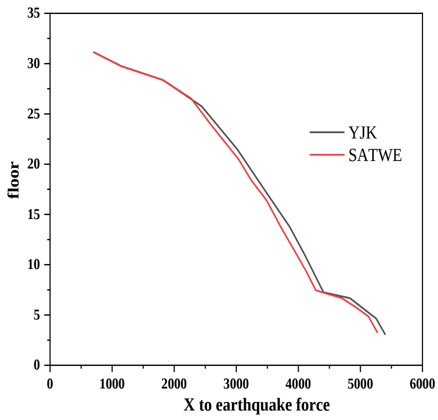
(a)



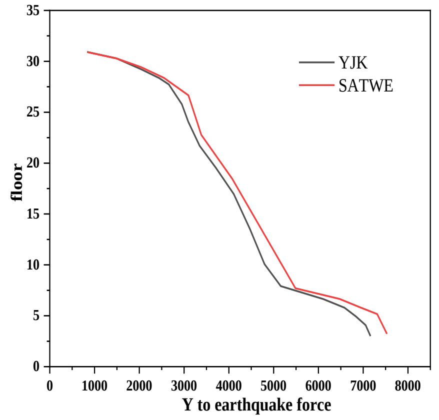
(b)

Figure 3 (a, b): Comparison of seismic forces calculated by two programs

The floor shear force calculated by the two programs under the action of x-direction and Y-direction earthquake is compared in Figure 3. It can be seen from the figure that the floor shear of the two models gradually increases from the top of the structure to the bottom of the structure. The increasing trend of model shear force calculated by YJK (Yingianke software) is basically consistent with that calculated by SATWE. The base shear in Y direction of the two calculation results is larger than that in Y direction. This also validates the analysis results of the above Fig. In the transfer floor and the lower floors of the transfer floor, the increasing trend of floor shear is more obvious than that of the floors above the transfer floor. The reason is analyzed: the transfer floor and the podium floor below have large overall stiffness and bear more seismic shear under horizontal earthquake.



(a)



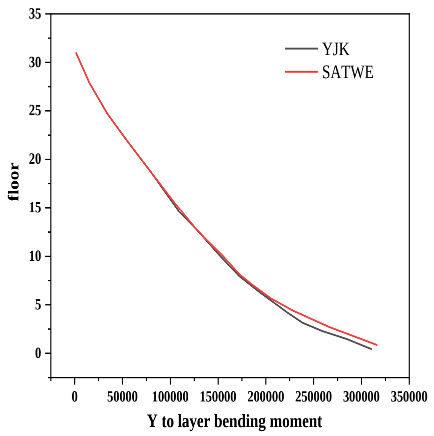
(b)

Figure 4 (a, b): Calculation of floor shear force by two programs

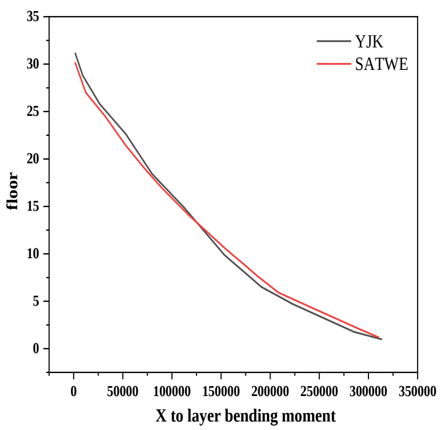
The overturning bending moments in X direction and Y direction of the calculation model are compared through Figure 4 (a, b). It can be seen from the figure that the values of floor overturning bending moment calculated by the two programs are similar and the change trend is similar, which gradually decreases from the top to the bottom of the structure.

	X-direction seismic action			**Y-direction earthquake action**		
Seismic direction	Top floor displacement Δ/mm	Total displacement angle Δ/H	Maximum interlayer displacemen δ/h	Top floor displacement Δ/mm	Total displacement angle Δ/H	Maximum interlayer displacement δ/h
SATWE	57.82	1/1695	1/1036	62.39	1/1571	1/1195
YJK	55.32	1/1772	1/1173	65.75	1/1190	1/1095

Table 2: Top floor displacement and inter floor displacement angle of structural model



(a)



(b)

Figure 5 (a, b): Calculation of overturning moment by two programs

The bottom overturning moment calculated by YJK program is slightly smaller than that calculated by SATWE. The bottom overturning moment in Y direction is greater than that in X direction, which is consistent with the analysis results in the previous two figures, indicating that the structural stiffness in Y direction is greater than that in X direction. In the transfer floor and its lower floors, the seismic overturning moment of the floor increases significantly compared with that above the transfer floor, which also verifies the analysis results in Figure 5 (a, b). The outcomes indicate that the overall stiffness of the transfer floor and its lower floors is larger than that of the upper floors of the transfer floor and absorbs more energy from seismic action. According to the theoretical knowledge of seismic design, the floor seismic shear force and floor overturning moment are essentially determined by the magnitude of seismic action. From the above analysis, it can be seen that the transfer floor and its lower floors with large floor stiffness are also subject to large horizontal seismic action. Through the comparison of the above three figures, it can be seen that the calculated values of the two methods are basically similar, and the three data in each method can also be mutually verified.

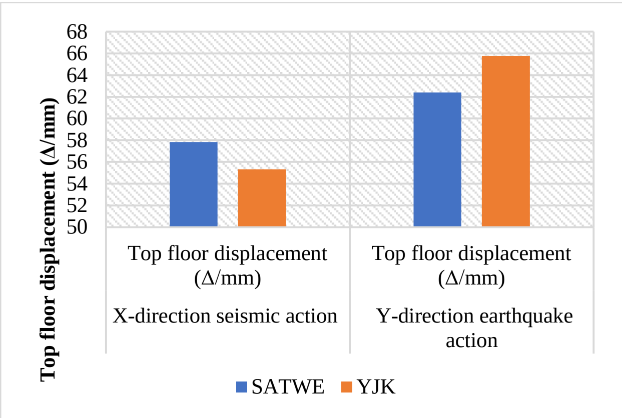


Figure 6: Structural model displacement length

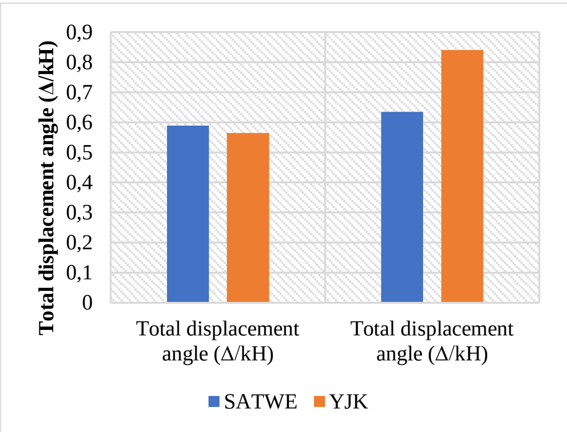


Figure 7: Structural model displacement angle

Table 2 lists the top floor displacement, maximum displacement angle and total displacement angle of displacement angle of the two calculation models under the earthquake action in X direction and Y direction. The graphical representation of structural model displacement length, angle and interlayer displacement is depicted in Figure 6, Figure 7 and Figure 8.

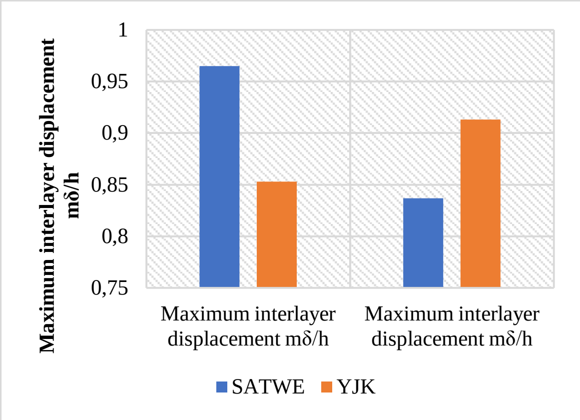


Figure 8: Structural model interlayer displacement

It can be seen from the table that the calculated value of top floor displacement of SATWE is slightly larger than that of YJK. The top displacement of the structure under X-direction seismic action calculated by SATWE is 57.82mm; The displacement of the top floor under Y-direction earthquake is 62.39mm. It is found that the difference range of inter story displacement angles corresponding to the corresponding floors of the two calculation models is within 5%, which meets the allowable error range.

5 Conclusions

The proposed WADO based retinal image transmission technology and structured numerical report in DICOM-SR can better solve the invulnerability problem of retinal image in different systems. The analysis done in this work for the investigation of invulnerable retinal imaging information can be used for quantitative analysis of morphological change of retinal vascular network. This work is mainly focused on the medical digital image transmission protocol Digital Imaging and Communications in Medicine (DICOM) version 3.0 and the retinal image Picture Archiving and Communication System (PACS) was constructed in the laboratory. The retinal image PACS system constructed in B/S mode can effectively store and transmit DICOM images when combined with the application program. This project will integrate quantitative features of retina in future research, providing more meaningful research data for data mining based on chronic disease management system. In addition, a study will be conducted on the conversion of retinal images and reports based on DICOM 3.0 standard and HL7 CDA documents. Therefore, in order to provide a technical basis for the integration of retinal images and existing resident health records with HL7 interfaces. The quantitative analysis of retinal morphology data and the original database system text information mining association rules can find more meaningful clinical information. The feasibility of the recognition rate and other evaluation parameters is justified by obtaining the 98.51% accuracy rate with comparatively better values of sensitivity, specificity and precision.

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