

The Adaptation of Building Information Modelling (BIM) on Multipurpose Building in Johor Matriculation College Architectural Plan for Future Engineering Reference

Tan Wan Yi¹, Muhammad Nizam Zakaria^{1*}

¹Faculty of Civil Engineering and Built Environment,
University Tun Hussien Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author Designation

DOI: <https://doi.org/10.30880/rtcebe.2022.03.01.013>

Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Building Information Modeling (BIM) is a process involved in planning, designing, building, operation and maintenance, which is rapidly growing worldwide for improvement in the field of architecture, engineering, and construction (AEC). The development of BIM is often implemented for new buildings. Meanwhile, most of the existing structures are not preserved, renovated, or deconstructed with BIM yet. The purpose of this study is to contribute for future engineer reference by providing the information and data in the work of maintenance, renovation, and demolition on the building in future. In this study, the analysis of the existing building structure in Johor Matriculation College was conducted to obtain the 3D modeling from BIM approaches. Regarding the studies from review of literature, the BIM tools implemented in this research is Tekla Structural Designer (TSD), which is to structurally analyze and design the existing building structure in accordance to Eurocode Standard, meanwhile Autodesk Revit is to create an information-rich 3D model of the facilities. The adaptation of BIM in this model designing requires Level of Development (LOD) to reach LOD 300: Design Development. This study has also introduced shear walls in the building design and the structural behaviour in sway drift has been observed. In summary, this study has been proven that BIM tends to provide efficiency and accuracy along the project lifecycle in construction firm, according to the conceptual design, visualization, and analysis of the structure.

Keywords: Building Information Modelling, Engineering Reference, Existing Building and Autodesk Revit

1. Introduction

Building Information Modelling (BIM) is a process involved in planning, designing, building, operation and maintenance, which is rapidly growing worldwide for improvement in the field of architecture, engineering, and construction (AEC). The concept of BIM was first introduced since 1970s

*Corresponding author: mnizam@uthm.edu.my

202 UTHM Publisher. All rights reserved.

publisher.uthm.edu.my/periodicals/index.php/rtcebe

by Professor Charles M. Eastman, mainly to replace the traditional 2D drawing to the information-rich architectural 3D modeling. [1] In Malaysia, BIM was established in the BIM Standard Manual and Guideline developed by the “Jabatan Kerja Raya (JKR)” (Public Works Department, PWD) in 2007. The first construction project in Malaysia involved in the implementation of BIM was the National Cancer Institute of Malaysia (NCI) in Sepang, Selangor in the year of 2010. [2] BIM brings benefit to the architects and engineers in the planning phase to reduce the costs and time when designing a building and be able to correct design errors in a project. Since BIM is relatively new in Malaysia, the BIM implementation is still slow and less favorable among construction companies. Hence, the awareness to implement BIM in AEC field has always been promoted and encouraged by the government sectors, Construction Industry Development Board (CIDB) and PWD.

Nowadays, BIM technologies are usually developed in new projects in civil and industrial construction. However, most of the existing buildings and structures have not been transformed into BIM. Although producing BIM technology for existing buildings is complex, time consuming and pricey, yet it is still important for the need of future works, historic preservation or future projects’ references on a particular structure. Thereby, a study of BIM adaptation on Johor Matriculation College Multipurpose Building As-Built Plan is carried out for future engineering reference. Johor Matriculation College is a pre-university tertiary education college, which located in Tangkak District, Johor. The Multipurpose Building is placed at the middle of the whole campus and it is function as examination halls and large classrooms, which is named as “Bangunan Peperiksaan”. The college was established in 2002, whereby the multipurpose building was built in 2007.

This research has transferred the information of the building to a 3D digital model for BIM implementation by conventional software in accordance to Eurocode Standard. The architectural plan of Johor Matriculation College Multipurpose Building has been obtained and studied for integrated modeling, analysis and design in steel and concrete buildings by using Tekla Structural Designer (TSD) software. TSD software allows engineers to deliver safe, effective, and rationalized buildings design more quickly, efficiently and profitably. Consequently, shear wall has been introduced in the design to observe the structural behaviour of the building based on Tekla Structural Designer (TSD) software. After that, a BIM 3D modeling has been generated using Autodesk Revit, which is a BIM supported software tool to provide efficiency and accuracy along the project lifecycle in construction firm, according to the conceptual design, visualization, and analysis of the structure.

1.1 Application BIM for Existing Buildings

BIM is usually used for new buildings as BIM adaptation for new buildings is easier, where the designers can have a clean, fresh start and all the necessary information can be set out precisely. [3] However, BIM also need to be implemented in existing buildings for any addition, renovation or historic preservation. The important part which is agreed by majority of the structural engineer is probably the information and data conceal behind the existing facade or finish. Yet, most of the industries and companies still have not aware of the advantages on implementing BIM in existing buildings. The following paragraph will discuss about the examples of applying BIM in existing buildings from different researches.

Research has been done on the ‘Integration of BIM and Archibus for Facility Management (FM) in FKAAS, UTHM Building’ by Mohmed Solla and the team members from the Department of Construction Engineering and Architecture, Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia (UTHM) in 2020. [4] The aim of the study is to discover the integration of applying BIM tools and FM software for space management. This research has developed a 3D BIM model by using Revit Autodesk and transferred into ARCHIBUS software to manage spaces based on ‘Sistem Kod Aset Tak Alih Kerajaan (SKATA)’. The result of the research has shown that the data of the building can be used by the facility management to manage the building spaces in a more efficient way and enhance the building performance in the future. Hence, the application of BIM in existing building can be proven to bring benefits to the stakeholders regarding that particular building in the future.

University of Salford, Manchester had published a research entitled 'Towards Building Information Modeling for Existing Structures' by Arayici, Y in the year of 2008. [5] The research is intended to be applied into various structures including historical buildings that have intensive architectural details by using the point cloud data capture, processing and modelling. In the case study, 3D point cloud data was captured at the building in East Manchester with the Riegl LMS Z210 scanner RiSCANPro software to produce a 3D mesh model of the building, and then proceed to create a CAD model. The result data had been verified to be used by the facility management to manage the building spaces in a more effective way and improve the building performance in future. This research had claimed that BIM can be accomplished for existing facilities by modeling the data captured with 3D laser scanner from the real-world structures.

1.2 Level of Development (LOD) in BIM

The BIM's Level of Development (LOD) acts as a measure of the essential service level, which explains how the 3D geometry of a building model can accomplish different levels of modification. The term 'Level of Development' was revealed by American Institute of Architects (AIA) from the publishing of AIA E202-2008: Building Information Modelling Protocol Exhibit in 2008. On the other hand, UK defined the LOD as 'Level of Detail' which was introduced within BIM Protocol released by AEC (UK) in 2009 within its Model Development Methodology. [6] Anyhow, LOD is such an important degree to be applied in the adaptation of BIM projects.

LOD specification allows professionals in engineering to clarify how the geometry and related information of an element has evolved throughout the entire process, which enables all members in the team to rely on the information associated with an element. Other than that, designers tend to define the characteristics of elements in a model at different stages of development. With the help of LOD, designers and engineers as well as other professionals can communicate to each other when using the model in the future to discuss further about the usability and limitations of the model. [7] LOD specifications were intended to standardize the use of LOD framework and to be used as an efficient and collaborative communication tool.

LOD is classified as 6 different levels where each level outlines the design requirements at each stage. LOD 100 is the conceptual design stage where the model is represented with 2D symbols to indicate the existence of the elements. Parameters like area, height, volume, location and orientation are defined in this phase. LOD 200 can be called as the schematic design stage. In this phase, the elements are partially modeled with approximate quantities, sizes, shapes, locations and orientations. Non-geometric information can also be attached to the model elements. In LOD 300, the detailed design stage, accurate modeling is formed where the elements are defined with exact dimensions and precise information. Similarly, in this phase, non-geometric information can also be attached to the model elements.

LOD 350 is defined as the construction documentation stage. This phase describes the detailed information of an element precisely and outlines the interconnection of the components with graphics and written definitions. Moreover, LOD 400, the fabrication and assembly stage outline the detail of basic information about the construction of various elements. Same as the previous phases, non-geometric information can also be attached to the model elements in this stage. Lastly is the as-built stage for LOD 500. In this phase, the model starts representing the real-life functions of elements in a real building. All the elements are modeled as constructed components assembled for maintenance and operations.

2. Materials and Methods

2.1 Planning

This study focused on the existing building of Johor Matriculation College Multipurpose Building in Tangkak. The existing multipurpose building consists of 4 level and the Architectural drawing for the building is shown in Figure 1.

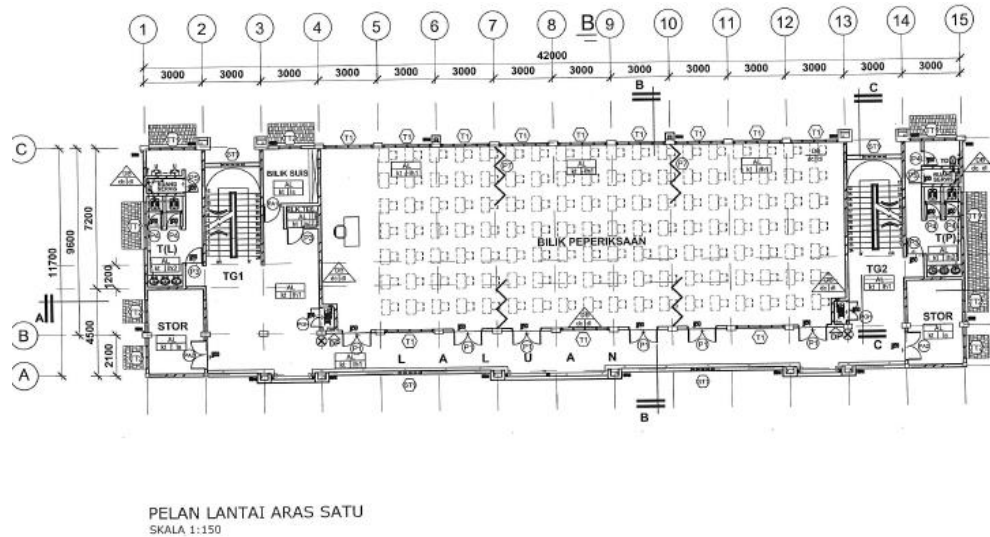


Figure 1: Architectural drawing for Multipurpose Building

2.2 Material Properties

For the concrete characteristic strength, f_{ck} is 28 days cylinder strength. The characteristic compressive strength of concrete was selected by including the factor of adequate strength for the limit state requirement, durability, concrete grade and unit weight of concrete. The concrete grade used in this study was C30/37 and the unit weight of concrete used was 25 kN/m^3 , hence the value of f_{ck} is 30 N/mm^2 . Meanwhile, the design of reinforcement used to minimize deflection and control cracking, based on the required characteristic strength or lower value is desired. For high yield steel, the strength f_{yk} used was 500 N/mm^2 .

2.3 Tekla Structural Designer (TSD)

The flow to perform analysis and design of Johor Matriculation College Multipurpose Building using Tekla Structural Designer (TSD) software has shown in Figure 2.

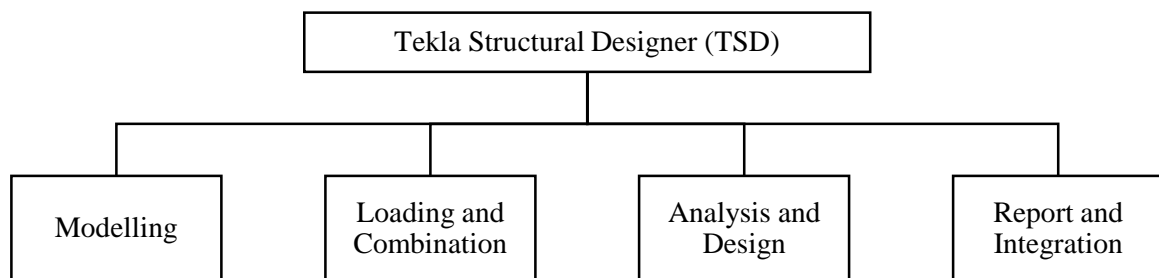


Figure 2: Flow to perform analysis and design on TSD software

For the modelling step, construction level of the existing building was created by referring the architectural drawing. Then, the gridline of the building had been created for denoting structural column and bearing wall. Then, the structural elements such as meshed walls, columns, beams and slabs were input in TSD software. The loading that input into the building has shown in Table 1.

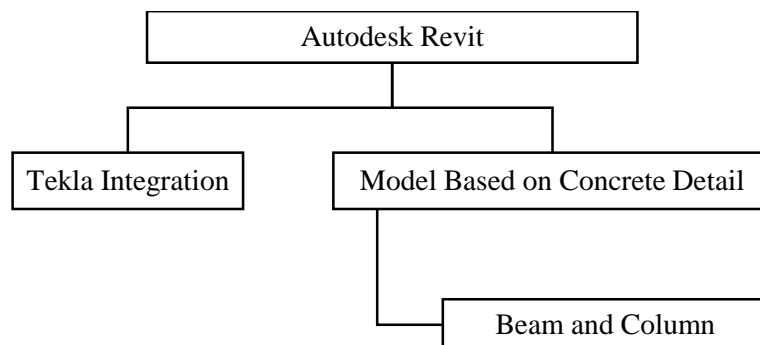
Table 1: Imposed load on each area of the building

Category	Element	q_k (kN/m ²)
A3	Toilet	2.0
C13	Examination Hall/Classroom	3.0
C31	Corridor	3.0
C32	Stairs	3.0
E11	General Store	2.0
E13	Store	2.4
F	Parking Area	2.5
H	Roof	0.6

After input all the loading, the analysis and design have been run to determine the building's ability to withstand loads as well as to design reinforcement on structure elements. Lastly, the report of the analysis and design have been generated for the building and the modelling was exported into the Autodesk Revit by using Tekla Integration.

2.4 Autodesk Revit

In this project, “JKR template” was used in Autodesk Revit software so that the format is standardized as Malaysia format. The flow to model an existing building of Johor Matriculation College Multipurpose Building by using Autodesk Revit has shown in Figure 3.

**Figure 3: Flow to model an existing building using Autodesk Revit**

Firstly, the model has been integrated with Tekla Structural Designer and the type of structural column, framing as well as the materials used have been input into Autodesk Revit. The material was selected by using ‘JKR Template’. After that, the modelling was shown on 3D view. The elevation plan, Structural Plan and Floor plan was automatically updated in this software. Next, the reinforcement for beam and column were input by referring the design result that performed from Tekla Structural Designer software. Hence, the reinforcement bar for column and beam was formed on 3D view. Lastly, other model-based elements such as foundation, staircase and roof were created in this software as well.

3. Results and Discussion

The analysis result of the existing building of Johor Matriculation College Multipurpose Building has obtained by the performance in the Tekla Structural Designer software. From the analysis result, the maximum value of shear force diagram (SFD) and bending moment diagram (BMD) of beam and column have been obtained. The maximum deflection that occurred on beam, column and slab was also

shown in the software. Moreover, the value of wind analysis and seismic analysis were revealed. The design result Tekla Structural Designer software was performed for knowing the arrangement of the reinforcement. Additionally, the result occurred while performing Autodesk Revit was the modelling of the building in 3D view, the elevation plan, floor plan, structural plan and arrangement of reinforcement in 3D view, as well as other model-based element such as foundation, staircase and roof.

3.1 Maximum Shear Force Diagram (SFD) and Bending Moment Diagram (BMD)

The maximum SFD and BMD on beam GLB32 that located at Ground Floor Level were shown in Figure 4. The value of the maximum shear force on the beam was 217.1 kN while the maximum value for bending moment diagram was -344.6 kNm. In this case, the critical shear force and bending moment happened because of the excessive load on load combination. However, the maximum SFD and BMD on column C13 that located on Second Floor Level have shown in Figure 5. The maximum shear force of the column was 149.5 kN and the maximum bending moment on column was 141.2 kNm. This happened because of the load from beam, slab, roof panel was transmitted to column.

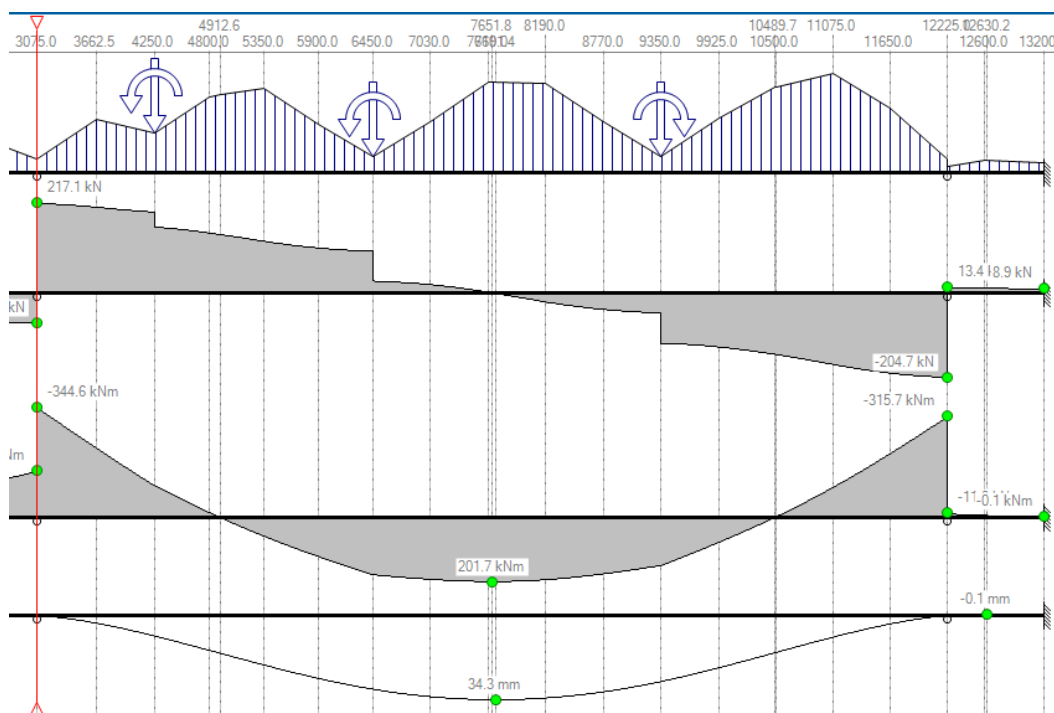


Figure 4: Maximum SFD and BMD on beam

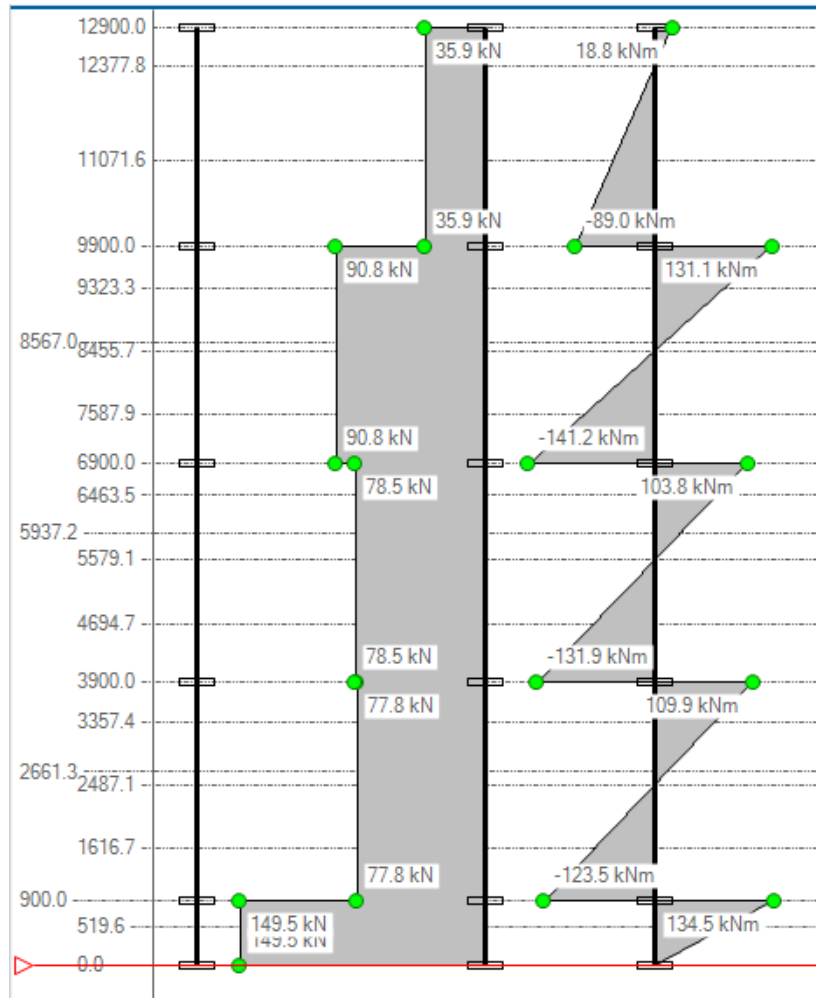


Figure 5: Maximum SFD and BMD on column

3.2 Maximum Deflection on Beam, Column and Slab

The difference types of loads also caused deflection, hence the maximum deflection on beam has shown in Figure 6. The value of deflection occurred on the beam was 43.1 mm while the critical value of deflection on column was 10.8 mm which has shown in Figure 7. Meanwhile, the slab deflection on the building shown in Figure 8 was occurred on the middle part of the building. The maximum deflection value of the slab was 37.9 mm.

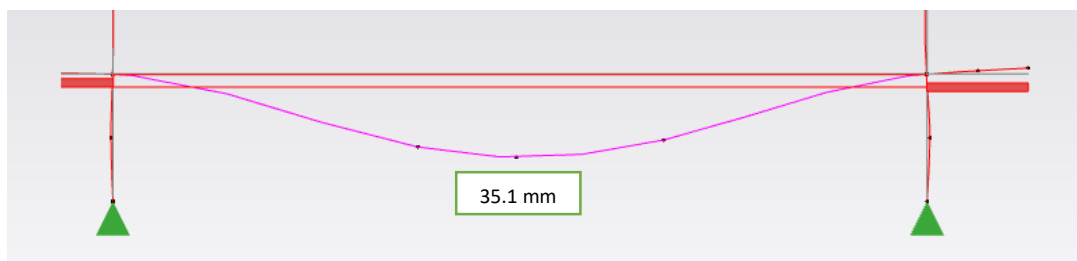


Figure 6: Maximum deflection on beam

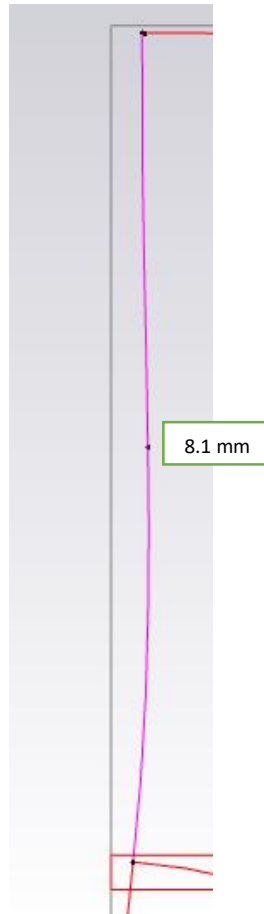


Figure 7: Maximum deflection on column

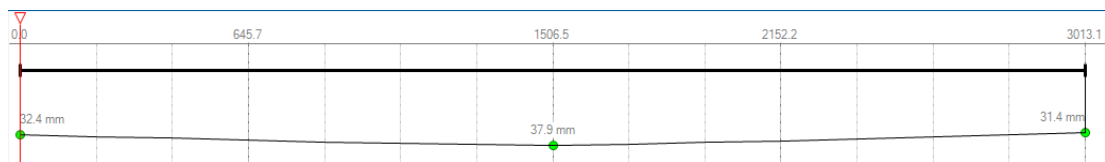


Figure 8: Maximum deflection on slab

3.3 Wind Analysis

Simple wind load has been applied to the building in four directions which are the front, back and both sides of the building. Wind load that applied was listed on Table 2.

Table 2: Wind load applied

X1 Dir, kN/m ²	X2 Dir, kN/m ²	Y1 Dir, kN/m ²	Y2 Dir, kN/m ²
1.052	1.052	1.150	1.150
0.990	0.990	1.088	1.088
0.916	0.916	1.012	1.012
0.872	0.872	0.967	0.967

3.4 Seismic Analysis

Seismic load has been applied to the building in seismic wizard. The analysis procedure was used is ‘Code Spectra using 2017 NA’ and ‘Modal Response Spectrum Analysis’. The analysis result of the affected member was shown in Table 3.

Table 3: Seismic analysis result

Level	Ref.	Stack	CombinationDir 1	Drift Dir 1 [mm]	$\theta_{Dir 1}$	CombinationDir 2	Drift Dir 2 [mm]	$\theta_{Dir 2}$	Status
St. 4 (Roof)	C59	5	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	0.8	0.005	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	0.7	0.005	✓ Pass
St. 4 (Roof)	C8	5	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	2.2	0.004	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	3.1	0.007	✓ Pass
St. 3 (3)	C49	6	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	1.6	0.008	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	0.8	0.004	✓ Pass
St. 2 (2)	C56	3	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	3.9	0.011	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	1.3	0.004	✓ Pass
St. 2 (2)	C11	3	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	3.6	0.010	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	1.6	0.005	✓ Pass
St. 1 (1)	C48	3	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	1.7	0.012	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	0.5	0.004	✓ Pass
St. 1 (1)	C65	3	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	1.7	0.012	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	0.7	0.005	✓ Pass
St. GL (Ground Floor)	C56	1	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	0.8	0.007	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	0.2	0.002	✓ Pass
St. GL (Ground Floor)	C11	1	16 (Final)SEIS _{1,1} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir1+}	0.7	0.007	18 (Final)SEIS _{1,2} -G+ $\psi_2 Q + \psi_2 RQ \pm A_{22}$ +EHF _{Dir2+}	0.3	0.003	✓ Pass

3.4 Design Result on Beam, Column and Wall

The maximum size of reinforcement on beam was shown in Table 4 that is 3H20 occurred on beam size 300x600 mm. While the maximum size of reinforcement on column shown in Table 5 that is 8H16 occurred on column size 450x450 mm. Furthermore, the maximum size of vertical reinforcement on shear wall shown in Table 6 which is H8-75 occurred on wall thickness of 300 mm.

Table 4: Maximum size of reinforcement on beam

Beam size	Reinforcement size
350x600	H20

Table 5: Maximum size of reinforcement on column

Column size	Reinforcement size
450x450	H16

Table 6: Maximum size of reinforcement on wall

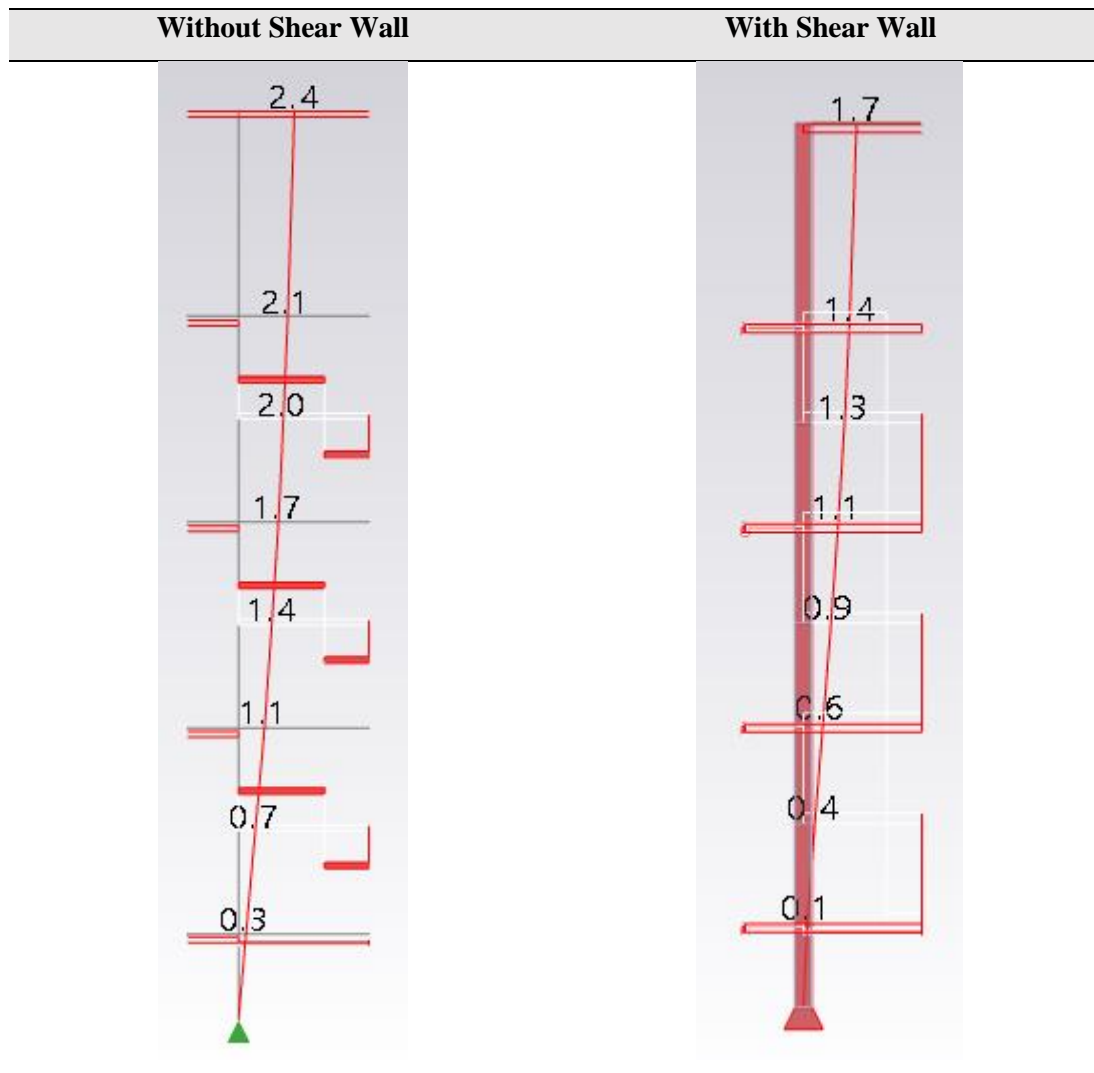
Wall thickness	Reinforcement size
300	H8-75

3.5 Structural Behaviour Due to Shear Wall

From the architectural plan obtained from JKR, there was no shear wall in the drawing. However, four shear walls with thickness of 200 mm and 300 mm were added for the analysis and design of the building. The purpose of introducing the shear walls is to resist the lateral forces from wind load and cantilever action. This is because shear wall has strong strength and stiffness to withstand the load.

The structural behaviour of the existing building is different in the sway drift with and without shear wall which has shown in Table 7. The maximum drift due to lateral loads without applying shear wall is 2.4 mm. After introducing shear wall to the design, the sway drift has decreased to 1.7 mm. In other words, the sway drift of shear wall has decreased in 29% which means that the shear wall has resisted some of the lateral loads exerted to the column.

Table 7: Sway drift with and without shear wall



3.6 Modelling an Existing Building

The modelling of an existing Johor Matriculation College Multipurpose Building by using Autodesk Revit has shown in Figure 9. This modelling was imported from Tekla Structural Designer. Then, after creating the reinforcement bar on all beams and columns, generating other elements like foundation, staircase and roof, all information and data for element structure and reinforcement bar was viewed on 3D concept.

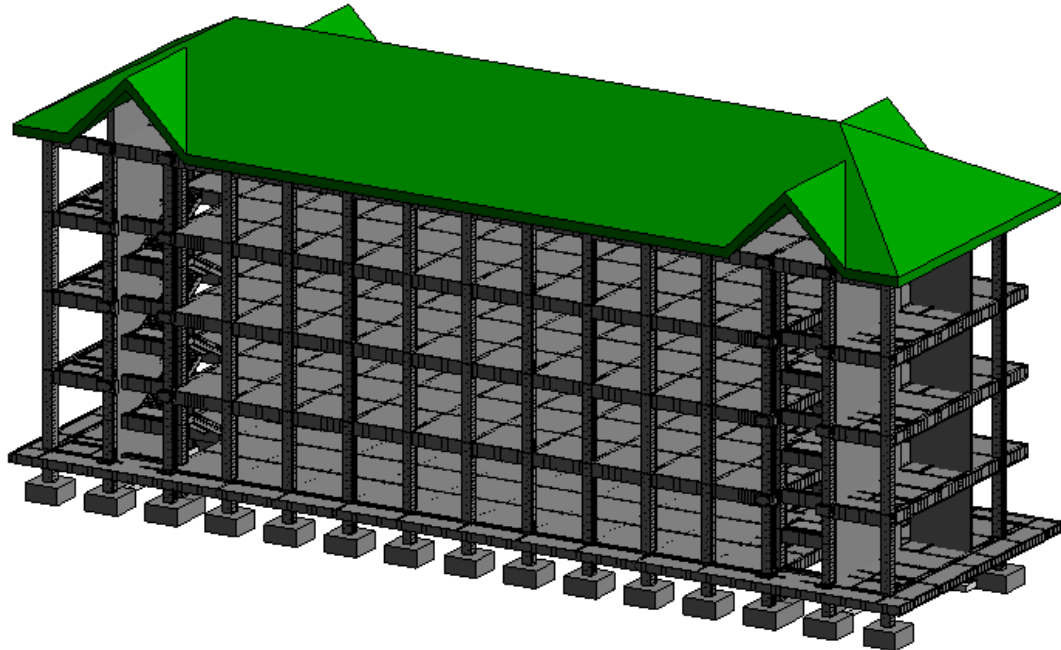


Figure 9: Modelling of Johor Matriculation College Multipurpose Building

4. Conclusion

Based on the result of this study, the main objective had been achieved for structurally analyzed and designed of the existing Johor Matriculation College Multipurpose Building. The elements of the building were successfully being analyzed and design using Tekla Structural Designer (TSD) software. All the analysis and design results were explained in Chapter 4 of this study. The maximum value of shear force and bending moment diagram of the beam GLB32 was stated as 217.1 kN and -344.6 kNm respectively. For the column C13, the SFD and BMD were 149.5kN and 141.2kNm correspondingly. Furthermore, the value of maximum deflection on beam and column was 35.1 mm and 8.1 mm respectively, and for slab was 37.9 mm.

This study has introduced shear walls in the building design and the structural behaviour has been observed. Four shear walls with thickness of 200 mm and 300 mm have been created, analyzed and designed in TSD software. The application of shear wall has decreased 29% of sway drift in the building, which is 1.7 mm of sway drift compared to 2.4 mm without shear wall. This can be concluded that the shear wall has resisted some of the lateral loads exerted to the column.

After integrating the design result from TSD software, the 3D modelling was performed by Autodesk Revit. According to the reinforcement detailing generated by TSD and exported into AutoCAD, the rebar of each element was created in the software. In addition, the structural floor plan, elevation view and 3D view were updated automatically in Autodesk Revit. The elements of foundation, staircase and roof has also been created in this software. Hence, this research has achieved all the objectives successfully and it can be use as reference in future project development. The engineers can refer all the information and data about the element structure easily in this BIM-implemented building.

In a nutshell, the existing structure of Johor Matriculation College Multipurpose Building had successfully been implemented in BIM technology. The software used in this project which are Tekla Structural Designer (TSD) and Autodesk Revit are both useful in generating Building Information Modelling (BIM). Architects and engineers are enabled to get instant information from the model produced in the software. Thus, this study can be contributed to the future engineer references and will also bring advantages to the future development in Johor Matriculation College Multipurpose Building.

5. Recommendations

The recommendation for this study was proposed to the future improvement of the quality of this research as well as for future references and investigation:

- (i) Structural drawing can be referred instead of architectural drawing so that more information of the structure can be obtained such as sizes of element in the building to perform the comparison of design results with the existing building.
- (ii) Autodesk Revit Structure software can be introduced for modelling the existing building in UTHM to facilitate the engineer by referring the information and data of the building.
- (iii) The structure modelling from Autodesk Revit can be combined with others element such as mechanical, electrical, piping system etc., so that more information of the structure can be gathered for more references usage.

Acknowledgement

The authors would also like to thank you to the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn for its support on this study.

References

- [1] Latiffi, A. A., Mohd, S., Kasim, N., & Fathi, M. S. (2013). Building Information Modeling (BIM) Application in Malaysian Construction Industry. 2, 1–6. <https://doi.org/10.5923/s.ijcem.201309.01>
- [2] Construction Research Institute of Malaysia, (CREAM). (2012). A Case Study of BIM Implementation in Malaysia. Retrieved from <http://www.myconstructionresearch.com/index.php/publication/integrateddesign-delivery-solution/file/12-bim-implementation-in-malaysia>.
- [3] Autodesk. (2013). BIM Benefits: What are The Benefits Of BIM? Available: <https://www.autodesk.com/solutions/bim/benefits-of-bim>
- [4] M Solla, A S M Shaarani, Mustaffa A A, and L H Ismail (2019). Integration of BIM and Archibus for Facility Management (FM) in FKAAS, UTHM Building. IOP Conference Series Earth and Environmental Science.
- [5] Arayici, Y (2008). Towards building information modelling for existing structures. School of Built Environment, The University of Salford, UK.
- [6] SrinSoft. BIM Level of Development (LOD) 100, 200, 300, 400 & 500. Retrieved from <https://www.srinsofttech.com/bim-level-of-development-lod-300-400-500.html>
- [7] BIM Forum LOD Specification 2017 Guide. BIM Level of Development | LOD 100, 200, 300, 350, 400, 500.