

## **The Adaptation of Building Information Modelling (BIM) on Existing As-Built Plan for Future Engineering Reference. Case Study: Bangunan Tempat Letak Kereta, Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)**

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**Abstract:** Building Information Modeling (BIM) is a new alternative approach from construction schemes that replaces conventional methods. BIM is also a collaborative tool used by the architecture, engineering and construction (AEC) industry based on various software solutions. Currently, most of the BIM processes are being developed for new structures. Therefore, it is difficult for engineers to refer to most existing buildings in the future. The purpose of this study is to facilitate engineers in obtaining all data for maintenances and operation buildings in the future. Therefore, the analysis and design of the existing building in “Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)” was conducted to obtain detailed data on the materials used in the building such as the type of building materials, size of reinforcement and others related things. In addition, this study was also conducted to compare the design results of the building using conventional design software with an existing As-built plan. Literature review is also useful to get information on the use of BIM in existing buildings and its benefits. This study was also conducted with the tools of BIM software which are Tekla Structural Designer for analyse and design the building structure and AutoCAD REVIT for modelling the building. Therefore, the software will help to documentation in detail the design of steel and concrete in 3 dimensional concepts. Thus, the model elements are directly presentation of information from the building database for engineering reference in future.

**Keywords:** Building Information Modelling, AutoCAD REVIT.

## 1. Introduction

Building Information Modelling (BIM) was a modern technology used in the construction industry. So that BIM was a new alternative approach of construction scheme replacing the conventional method. BIM modelling introduced in the pilot project to support building design of architects and engineers. In general, BIM was started in 2002 after a paper entitled "Building Information Modelling" was released by Autodesk. The first country that implements BIM is United State America (USA) than followed by United Kingdom (UK), Hong Kong, Denmark, Norway, Australia, Finland and Singapore. Even though BIM is not widely used in Malaysia, Malaysia does not pass up the opportunity. However, the positive path has been taken as a result of the government's recognition of the capabilities and benefits of BIM in reducing construction costs and avoiding design errors during the planning phase. Furthermore, BIM is a collaborative tool used by architectural, engineering and construction (AEC) industries based on various software solutions [1].

Building and structure vary by their type of use (e.g. in residential, commercial and municipal use), as well as by age (e.g. new, existing, heritage). These differences will influence the use of BIM. Nowadays, most BIM processes are designed for new structures rather than existing structures. Therefore, the engineer will have a difficult time referring to most existing buildings in the future [2]. Thereby, this study is about the adaptation of BIM on existing As-Built Plan for future engineering references.

This study was carried out in order to perform analysis using conventional software in accordance with Eurocode. The study was conducted at "Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)". The As-Built Plan of the existing building will be obtained for integrated modelling, design, analysis and detailing of reinforced concrete structure by using Tekla Structural Designer software. Tekla Structural Designer software is specifically designed for structural engineers to provide an integrated solution in designing reinforced concrete buildings. Hence, the results of the Tekla Structural Designer software after design will be compared to the manual calculation using the Eurocode. After that, the building was modelled using AutoCAD REVIT. AutoCAD REVIT is one of the BIM tools recommended by the government for use in construction projects, allowing structural engineers to carry out structural design and analysis through building modelling.

### 1.1 Application BIM for Existing Buildings

Building Information Modeling is commonly referring to the process of creating a new building. This is because capitalizing on BIM for new buildings is simple which is start with a clean, fresh file and lay out all of the necessary information exactly where it should be. The existing building, however, still needs to be extend, renovate or historically preserve. Most of what is important to a structural engineer is possibly concealed behind an existing facade or surface. But the building industries are still not very aware of their advantages on existing buildings. Due to the valuable benefits of efficient resource management, many types of research are currently underway to solve the problems of building conditions in existing buildings and a lack of documentation.

The construction industry agrees that compelling photos can record delivers better for point cloud surveys. With a laser scanner, you could see every bit. These surveys are the basis for the creation of geometric building models. There is no question about the advantages of this kind of survey. It ensures precise in geometric information. As a result of these surveys, we can return to the point which could further discussed later. Moreover, it significantly reduces the need for site visits [3].

An existing model can be of great strategic benefit by getting information on the performance, requirement and life cycle as well as other feature of the windows, walls, door and other structures in the building. The scanner cannot record it, unfortunately. But, the stakeholder needs the implementation of BIM and research in existing buildings because of the rapid developments in BIM research [3].

## 1.2 Level of Development (LOD) in BIM

Level of development (LOD) is a BIM industry standard that describes the various stages of development of construction projects. LOD helps architects, engineers, contractors, construction firms, drafters, and design consultants to articulate component geometry and information evolution at different stages of a project. Its specification enables engineers to clarify how an element's geometry and related information have evolved throughout the process, allowing all team members to rely on the information associated with an element.

This study has achieved LOD 300 in terms of its focus as it using the AutoCAD REVIT software. AutoCAD REVIT modeling professionals create 3D BIM models that comply with industry LOD criteria due to its function such as review building plan quickly, calculate precise quantities, improve project handover and communication with subcontractors, fabricators, and others. Table 1 below shows the stages of LOD that have been covered in this study.

**Table 1: Level of Development (LOD)**

<b>LOD</b>	<b>Design Stage</b>	<b>Description</b>	<b>Building Design Elements</b>
LOD 100	Conceptual Design	Basic information regarding the building site and the shape of the building.	Site Plan
LOD 200	Schematic Design	Details layout of the building and spaces with structural details and specifications.	Preliminary Building Plan, Sections and Elevations
LOD 300	Detailed Design	Coordination review and clash detection	Complete Building Plan, Sections Elevations, Superstructure; column, beam, slab

## 1.3 As-built drawing that scan to BIM conversion approach

A revised 2D drawing in AutoCAD produced and submitted by a contractor after completion of a construction project is an as-built drawing. They provide modifications made from the original sketches during the construction process which include an exact representation of the building and property when it appears to be completed. Also, minor details, such as the materials used, should be registered to allow future reference to changes in the construction process if the details are different from those specified in the original plan [4].

As-built drawings are normally regarded as a necessity if a structure demolished for reconstruction [5]. When reconstruction is necessary, survey companies will measure a building manually and develop 2D As-built drawings in AutoCAD. This usually led to a delay and a lack of data as these measures carried out externally. Therefore, Virtual Construction Modelling led to a complete technical revolution in the AEC and construction sector [5]. It also can be one of the easiest and effective references for an engineer to reconstruction or renovation an existing building in future. It is also able to facilitate the work of contractors since they will only refer to BIM. This is because all the requirement of the existing building already recorded into the BIM system.

## 2. Materials and Methods

### 2.1 Building Selection

This study focused on the existing building of “Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)”. The existing building consists of two (2) level of basement car park floors and eight (8) levels of upper car park floors. Figure 1 and Figure 2 shows the As-Built drawing for the basement level and upper level of the building, respectively.

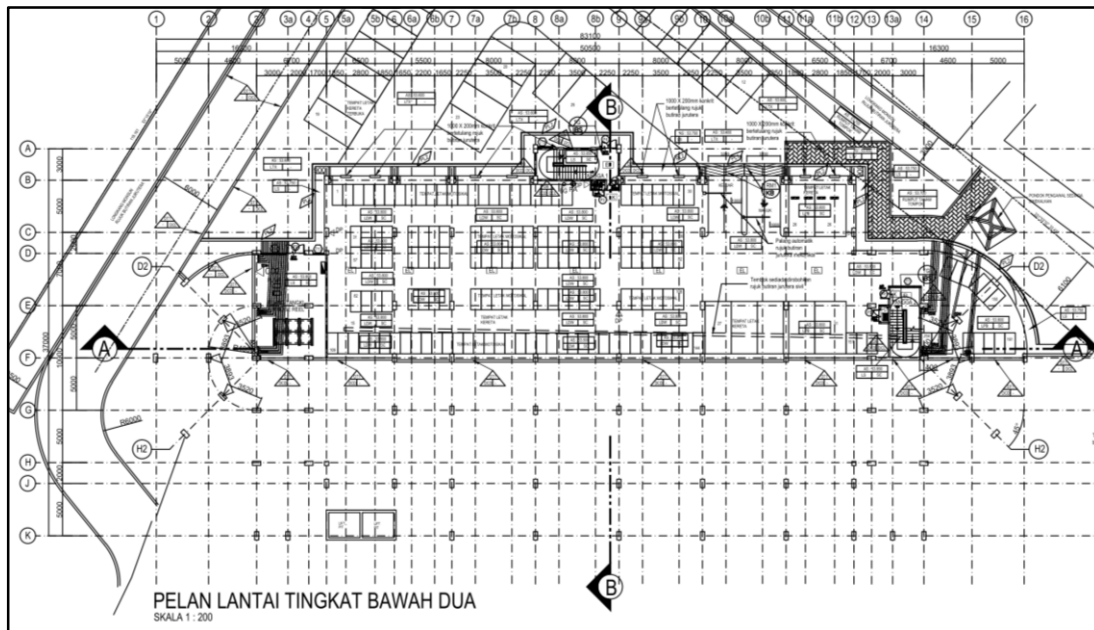


Figure 1: As-Built drawing of Basement Level

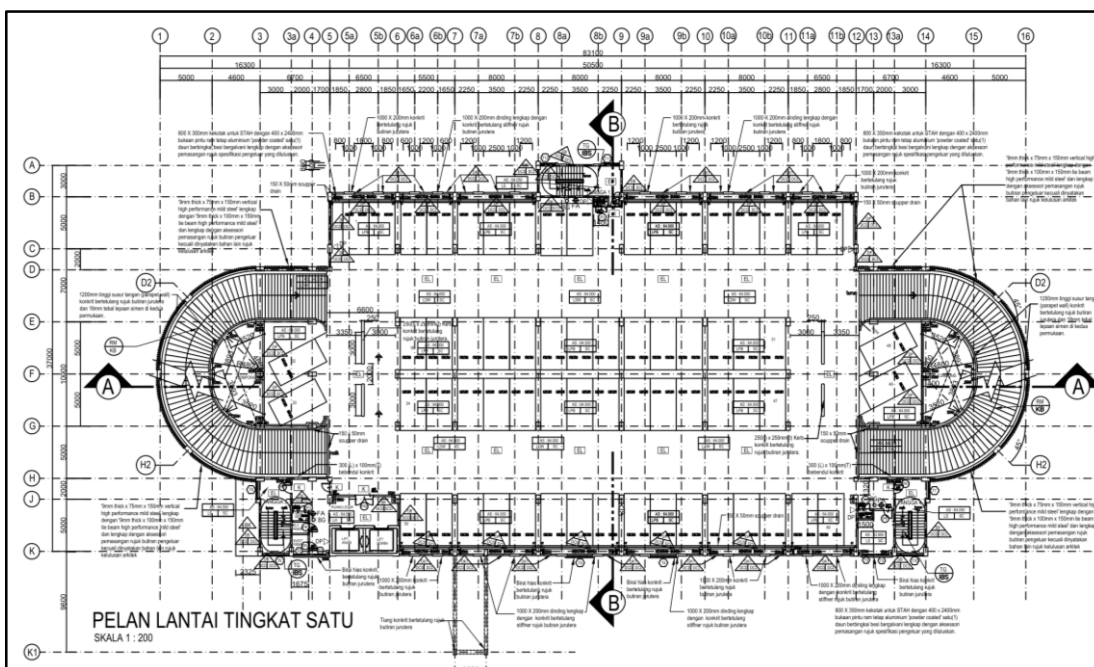


Figure 2: As-Built drawing of Upper Level

## 2.2 Material Properties

For the concrete characteristic strength,  $f_{ck}$  is 28 days' cylinder strength. The grade of concrete appropriate for used 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  $25 \text{ kN/m}^3$ . Meanwhile, the design of reinforcement used to minimize deflection and control cracking, based on the required characteristic strength or lower value if desired. For high yield steel, the strength was  $500 \text{ N/mm}^2$ .

## 2.3 Tekla Structural Designer (TSD)

Figure 3 shows the flow of the Tekla Structural Designer software used to perform the analysis and design of “Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)”

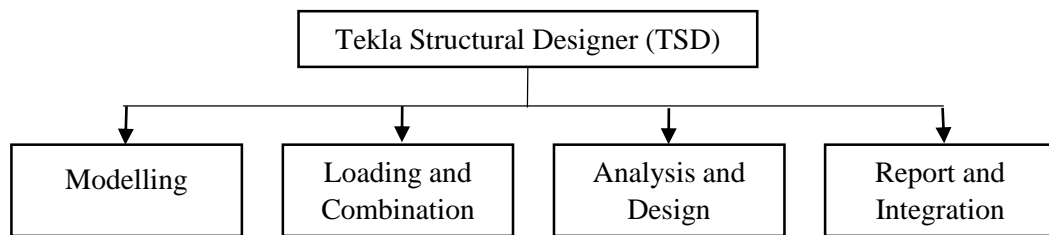


Figure 3: Flow for performed analysis and design on TSD software

For modelling step, the existing building's construction level was created by referring to the As-built drawing. Second, the building's gridline was built to indicate structural columns and bearing walls. Then, input the structural elements, such as mesh walls, columns, beams, and slabs. In Table 2 below, the loading that input for the building was shown.

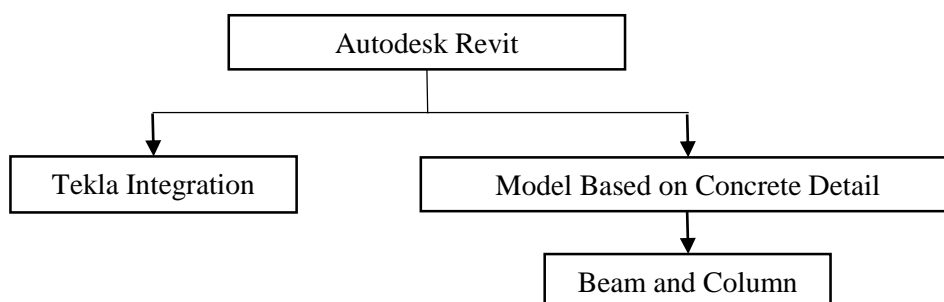
Table 2: Imposed load on each area of the building

Categories of loaded areas	$q_k \text{ (kN/m}^2\text{)}$
Toilet	$2.0 \text{ kN/m}^2$
Stairs	$3.0 \text{ kN/m}^2$
Roof	$0.75 \text{ kN/m}^2$

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

## 2.4 Autodesk Revit

Figure 4 showed the flow for model an existing building of “Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)” by using AutoCAD REVIT.



#### Figure 4: Flow for model an existing building using Autodesk Revit

First, integrate the model with Tekla Structural Designer and input the type of structural column and framing as well as the materials used. 'JKR Template' was used to select the material. After that, the modelling was showed on 3D view. The elevation plan, Structural Plan and Floor plan was automatically updated on this software. Next, input the reinforcement for beam and column 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 the foundation, staircase, and roof was created also by using this software.

### 3. Result and Discussion

The analysis result of the existing building of “Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)” obtained by performed the Tekla Structural Designer software. As a result of the analysis, the maximum value of the shear force diagram (SFD) and bending moment diagram (BMD) of the beam and column were obtained. The software also displayed the maximum deflection on the beam, column, and slab. The Tekla Structural Designer software design result was used to determine the placement of the reinforcement. Furthermore, the modelling of the building in 3D view, the elevation plan, floor plan, structural plan, and reinforcement arrangement in 3D view, as well as other model-based elements such as foundation, staircase, and roof, occurred while performing AutoCAD REVIT.

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

The maximum SFD and BMD on beam 11B257 that located at Eight Floor Level were shown in Figure 5. The value of the maximum shear force on the beam was 152.5kN while the maximum value for bending moment diagram was 201.7kNm. In this case, the critical shear force and bending moment happened because of the excessive load on load combination. Then, the maximum SFD and BMD on column C132 that located on Second Floor Level were shown in Figure 6. The maximum sheer force of the column was -60.9kN and the maximum value of the bending moment on column was 81.4kNm. This happened due to the load from beam, slab, roof panel that was transmitted to column.

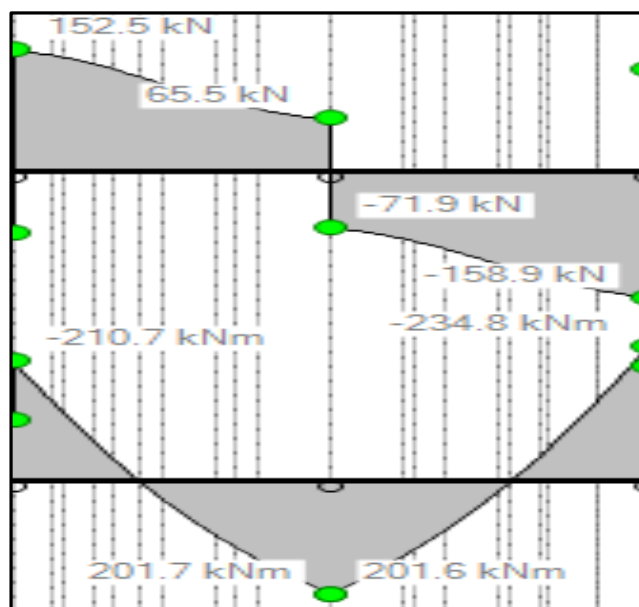
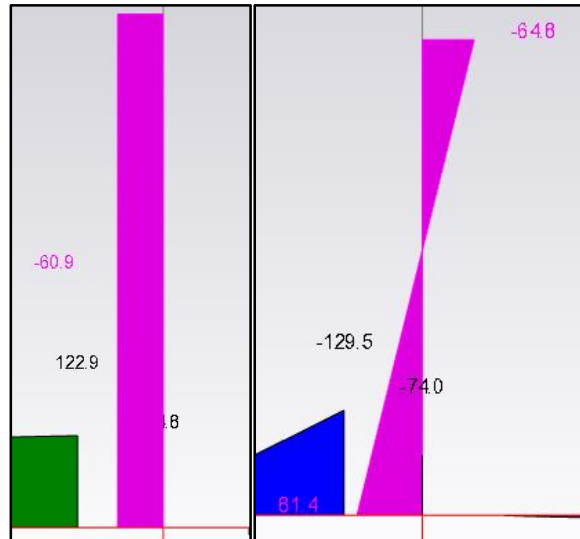


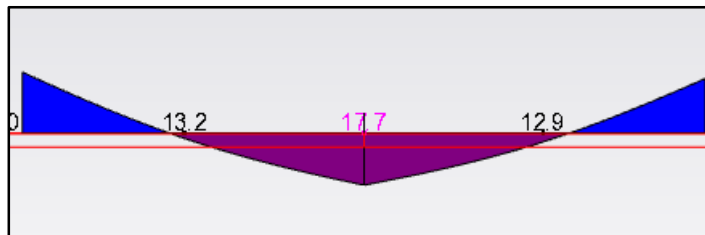
Figure 5: Max SFD and BMD on Beam



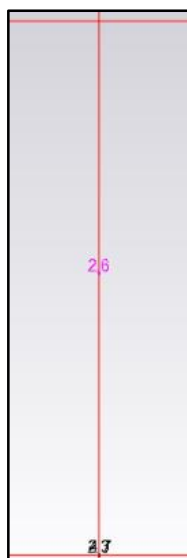
**Figure 6: Max SFD and BMD on Column**

### 3.2 Maximum Deflection on Beam and Column

The difference types of load also caused deflection. The deflection occurred on beam 11B257, which is located on the Eight Floor Level was shown in Figure 7. The value of the deflection on the beam was 17.3mm. For column member, the deflection occurred on column C132, that located on the First Floor Level is shown in Figure 8. The deflection's value on the column was 2.6mm.



**Figure 7: Maximum Deflection on Beam**



**Figure 8: Maximum Deflection on Column**

### 3.3 Design Result on Beam, Column, Wall and Slab

The maximum size of reinforcement on beam and column was showed on Table 3 that is 2H25 occurred on beam size 250x400mm, while for column was 12H12 occurred on column size 400x800mm. Based on Table 4, showed the maximum size of reinforcement on wall that is 132H10 on vertical bar and H16 on horizontal bar. For the slab, the maximum size of reinforcement occurred on slab that thickness was 200mm. The reinforcement size was H8 on bottom- X and bottom-Y while, H10 on top-X and top-Y.

**Table 3: Maximum size of reinforcement on beam**

<b>Beam size (mm)</b>	<b>Reinforcement size</b>
250x400	H25
<b>Column size (mm)</b>	<b>Reinforcement size</b>
400x800	12H12

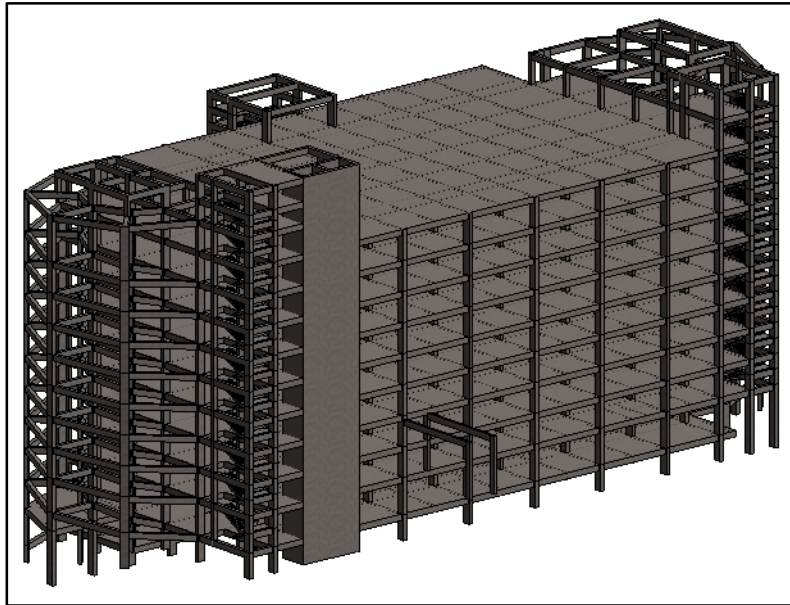
**Table 4: Maximum size of reinforcement on wall**

<b>Wall thickness (mm)</b>	<b>Reinforcement size</b>	
400	H10 (Vertical bar)	H16 (Horizontal bar)
<b>Slab thickness (mm)</b>	<b>Reinforcement size</b>	<b>Slab thickness (mm)</b>
150	H8 (Bottom-X)	H8 (Bottom-Y)
	H10 (Top-X)	H10 (Top-Y)

### 3.4 Modelling an existing building

Figure 10 showed the modelling of an existing “Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)” by using Autodesk Revit. This modelling was imported from Tekla Structural Designer. All information and data for element structure and reinforcement bar was viewed on 3D concept.





**Figure 10: Modelling of Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)**

### 3.5 Discussion

The analysis of shear force and bending moment is essential to recognize how structural elements affect reinforcement. Shear force and bending moment were undoubtedly affected by the arrangement of reinforcement bars in the beam in this case. Shear force and bending moment diagram also was the represented of shear force and moments acting at the beam. So, reinforcement was provided to resist these acting forces and their arrangement is based on the magnitude and direction of the diagrams. Therefore, the portion of beam where shear force was higher, the shear reinforcement or stirrups was provided closely. While the longitudinal reinforcement was provided in the maximum amount in the area where the bending moment was highest. Similar to some longitudinal reinforcement, it was reduced when the bending moment was reduced, bending stresses changed direction, or stresses on the web reinforcement increased.

In this case, the comparison between design result using design software with existing as-built structural drawing is not impossible because the structural drawing was not provided. The existing As-Built plan was in architectural plan. This study has limitation since the information from the as-built plan was not provided completely. Hence, there is not enough data about the building structural elements such as the quantity and types of beam element, column element and other related structure. Besides, this study has differences with the existing building in term of the construction method used. It is because, physically, the building of “Bangunan Tempat Letak Kereta, Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)” was developed by using the Industrial Building System (IBS) method while in this study was using conventional method. This is due to the information about the existing building was limited to find from internet sources since the project has been completed recently.

## 4. Conclusion

Based on the result of this study, the first objective was achieved for structurally analyzed and designed of an existing “Bangunan Tempat Letak Kereta di Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)” using Tekla Structural Designer. The element structures of the building were successfully being analyzed and design using software Tekla Structural Designer. All the analysis and design result was clearly explained in result part in Chapter 4. The maximum value of shear force and bending moment diagram of the beam 11B257 stated as 152.5kN and 201.7kNm. For the column C132

was -60.9kN and 81.4kNm. This happened because of the excessive load of load combination was applied on it. So, in order to avoid failures in a beam and column structure, a load factor is used in the case of combination of loads acting on a building. The value of maximum deflection on beam and column was 17.3mm and 2.6mm. This happened also due to the loading that applied on it. So, if the beam 11B257 and column C132 was in maximum bending moment, the deflection of beam 11B257 and column C132 also must be in maximum value compared to other structural members.

For the second objective, the modelling of the building that performed by using AutoCAD REVIT was achieved. By performed this modelling, design result from Tekla Structure Designer was important in order to performed 3D version of reinforcement in AutoCAD REVIT. In addition, the floor plan, elevations, sections and 3D view were updated automatically. For Level of Development (LOD) of this study was accomplished which is achieved the LOD 300.

Hence, by performed this study, the main objective as references to engineering in future was successfully. The engineers will easy to refer all the information and data about the element structure such as size of elements structure, the size and the numbers of reinforcement bars used. This is because, the building was model in 3D concept including the reinforcement bars. So, it's easy for engineer to refer in future.

In a nutshell, the existing structure of the “Bangunan Tempat Letak Kereta, Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)” was successfully impement BIM technology. The software used in this study which are Tekla Structural Designer (TSD) and AutoCAD REVIT are both useful in generating Building Information Modeling (BIM). Besides, this software is very helpful in the implementation of BIM for existing buildings in UTHM to enable engineers to get instant information wherever they are. Thus, this study can be used as a reference for future engineers and will benefit future development for the “Bangunan Tempat Letak Kereta, Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)”.

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