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APPLICATION OF BIM 5D IN THE RE-DESIGN OF BUILDING 2 OF HERMINA HOSPITAL BANYUMANIK SEMARANG USING AUTODESK SOFTWARE

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Abstract

Penerapan metode Building Information Modelling (BIM) berbasis 5D dalam perencanaan ulang Gedung 2 Rumah Sakit Hermina Banyumanik dimaksudkan untuk meningkatkan efektivitas dan efisiensi proyek konstruksi. Metode yang digunakan meliputi studi literatur terkait pedoman perencanaan struktur gedung, perhitungan dimensi, penulangan, dan pembebanan struktur bawah dan atas. Selanjutnya dilakukan pemodelan 3D menggunakan Autodesk Revit 2024, analisis struktur dengan Autodesk *Robot Structural Analysis Professional* (RSAP) 2024, serta integrasi penjadwalan dan estimasi biaya melalui Autodesk Naviswork 2024 dan Microsoft Project 2021. Proses ini menghasilkan perencanaan ulang yang mencakup volume pekerjaan, durasi proyek, dan Rencana Anggaran Biaya (RAB). Hasil menunjukkan elemen struktur aman sesuai standar, durasi pelaksanaan selama 33 minggu, dan RAB sebesar Rp 40.642.964.000,00 sudah termasuk PPN 11%. Integrasi model 3D, jadwal, dan anggaran dalam BIM 5D memberikan visualisasi yang lebih baik dan membantu mengantisipasi potensi keterlambatan pelaksanaan proyek. Dengan demikian, penerapan BIM 5D mampu meningkatkan kinerja stakeholder dan efisiensi dalam pengelolaan proyek konstruksi gedung.

Kata kunci: Autodesk, *Building Information Modelling*, integrasi, perencanaan, struktur

Abstract

The application of 5D-based Building Information Modeling (BIM) method in the re-design of Building 2 of Hermina Banyumanik Semarang Hospital to intended improve the effectiveness and efficiency of construction projects. The methods used include literature studies related to building structure planning guidelines, calculation of dimensions, reinforcement, and loading of lower and upper structures. Furthermore, 3D modeling using Autodesk Revit 2024, structural analysis with Autodesk Robot Structural Analysis Professional (RSAP) 2024, and integration of scheduling and cost estimation through Autodesk Naviswork 2024 and Microsoft Project 2021 were conducted. This process resulted in a re-design that included the volume of work, project duration, and budget cost. The results show that the structural elements were safe according to standards, the project duration is 33 weeks, and the project cost is IDR 40,642,964,000.00 including 11% VAT. The integration of 3D models, schedules, and budgets in BIM 5D provides better visualization and helps anticipate potential delays in project implementation. Thus, the application of BIM 5D can improve stakeholder performance and efficiency in managing building construction projects.

Keywords: *Autodesk, Building Information Modelling, integration, planning, structure.*

I. INTRODUCTION

Construction projects encompass the entire process from planning to building maintenance. Success in terms of quality, time, and cost is highly dependent on proper and efficient resource management. Construction projects usually go through several stages, namely the planning and design stage and the construction stage [1]. During construction, various obstacles often arise, especially when using conventional methods [2]. These obstacles include environmental issues around the project site, licensing, limited funds, a shortage of skilled and experienced workers, errors in planning, and occupational safety issues. Errors in the planning stage generally occur due to a lack of coordination and integration between different disciplines, such as architecture, structure, mechanical, and electrical. This lack of synergy between disciplines can cause conflicts between building elements and errors arising from human error. One approach that can be implemented in construction projects to reduce these errors is to use the Building Information Modeling method [3].

BIM is capable of providing comprehensive digital simulations that represent a building, covering detailed information and aspects of its use [4]. With BIM, the actual construction process can be modeled, providing direct 3D visualization, detecting potential collisions between structural elements, and presenting complete data on the materials, dimensions, and thickness of each object, including project scheduling and cost estimates.

The construction project for Building 2 of Hermina Banyumanik Hospital previously relied on 2D Computer Aided Design (CAD) in the design process. This research conducted a redesign with the main objective of implementing the 5D Building Information Modeling (BIM) method through an interactive model. In addition, this redesign also aimed to review the structural dimensions to produce a more efficient and economical system. This redesign process involved the application of the Moment Frame System method and the use of Autodesk software for various stages, from 3D modeling and structural analysis to BIM integration. This was done to identify the advantages of using BIM in projects that previously still adhered to conventional methods.

II. LITERATURE REVIEW

A. Computer Aided Design (CAD)

With the advancement of digital technology, Computer Aided Design (CAD) has developed as an important tool in the design process. CAD allows designers to realize their ideas in the form of digital images, from initial sketches to complete working drawings. In addition, CAD facilitates digital design revisions without the need to redraw the entire image, thereby increasing efficiency and flexibility in the design process [5].

B. Conventional Method VS BIM 5D

Conventional methods in construction rely on 2D drawings and manual calculations that are prone to errors and inefficient. This process affects cost and schedule inaccuracies. BIM 5D combines 3D models with time and cost information, facilitating visualization, coordination, and more accurate estimates. BIM models store information from architectural designs, work schedules, cost estimates, to post-construction maintenance. By using BIM, potential design errors can be minimized, project coordination can be more effective, and the impact of changes can be visualized in real-time [6]. In the construction of the DP3 and DISDAG buildings in Balikpapan, the application of BIM 5D can increase time efficiency by up to almost 53%. BIM 5D can reduce volume and cost calculation stages by 42% and reduce personnel and cost requirements by up to 9.5% compared to conventional methods [7]. BIM allows all stakeholders to access and update data on the same model, enabling more integrated collaboration.

C. Supporting Software (Autodesk Group)

Various Autodesk products, such as AutoCAD for 2D and 3D design, Revit for BIM modeling, and Robot Structural Analysis Professional (RSAP) for structural analysis, support a more integrated and efficient planning and design process. The use of Autodesk products in Indonesian construction projects has driven significant digital transformation, particularly in terms of accuracy and productivity [8].

D. Structural Concrete Requirements for Buildings

SNI 2847:2019 is the mandatory reference for designing reinforced concrete structures in Indonesia. This standard specifies the requirements for materials, mixtures, and concrete implementation methods to ensure the strength and reliability of buildings. Concrete and reinforcing steel materials must meet technical specifications to ensure the safety of components such as slabs, beams, columns, walls, and foundations [5].

E. Minimal Design Load for Buildings

When designing building structures, all potential loads must be carefully calculated, because heavy loads on multi-story buildings will have a significant impact on structural strength [9]. Structural stability is achieved when the structure is able to withstand all loads acting on it [10]. In planning, loads such as dead loads (weight of the structure and permanent materials), live loads (resulting from activities and occupants), and wind loads (wind pressure) are referenced based on SNI 1727:2020 concerning Minimum Design Loads for Buildings. Meanwhile, earthquake loads (ground movement) and load combinations are based on SNI 1726:2019.

F. Earthquake Resistance Planning

Seismic design requires dynamic analysis to understand the response of structures to earthquakes [10]. The main guideline for this is SNI 1726:2019. This standard classifies buildings based on earthquake risk categories and multiplies them by earthquake importance factors (Ie). In addition, site classification based on soil conditions is also crucial because it affects construction methods and structural dimensions. Based on acceleration response parameters, seismic design categories are established to ensure structures have sufficient strength, stiffness, and ductility to absorb and dissipate earthquake energy.

G. Upper Structure Planning

The upper structure consisting of columns, slabs, and beams must be designed to safely withstand working loads in accordance with SNI 2847:2019 (Structural Concrete Design Requirements) and SNI 1727:2020 (Minimum Loads). Slabs, which are flat surfaces for supporting floor and roof loads, must be designed to limit deformation and deflection. Columns serve as the main vertical supports, while beams transfer loads from the slabs to the columns. The design of the superstructure involves calculations of dimensions, materials, and reinforcement that meet safety and structural function requirements [11].

H. Structural Analysis

Structural analysis is an important process to ensure the strength, durability, and behavior of building structures under planned loads, in accordance with safety standards. Structural planning for buildings involves various scientific factors and is tailored to the purpose of use and the level of complexity of the building [12]. In this study, Autodesk Robot Structural Analysis Professional (RSAP) was used for structural analysis. RSAP is capable of performing 3D structural design and simulation analysis simultaneously, facilitating load calculations and seismic resistance analysis [13].

I. Lower Structure Planning

Substructure planning, particularly foundations, is a crucial step in producing strong, stable, and durable building foundations. This process involves soil investigation to understand soil conditions and profiles [14], determining the appropriate type of foundation, calculating bearing capacity, predicting settlement, and designing foundation reinforcement.

J. 3D Modeling

3D modeling is the first step in design visualization that enables clash detection before construction begins. Modeling with Autodesk Revit and RSAP allows for the integration of analysis and design in a single platform, accelerating the planning process and minimizing the risk of changes and errors in the field [15].

K. Budget Plan

Autodesk Revit has the ability to generate quantity takeoffs, which then become the basis for budget plan (RAB) calculations. The results of these quantity takeoffs are then processed manually and compiled in Microsoft Excel, by multiplying the volume by the relevant Unit Price Analysis (AHSP) [16].

L. **Project Scheduling**

Project scheduling is an important component to ensure that projects run according to the planned schedule. Microsoft Project software is used to compile schedules and monitor work progress, while Autodesk Naviswork is used to integrate schedules and cost estimates into BIM models, enabling 4D and 5D simulations that help identify potential delays and make real-time schedule adjustments [6].

III. PLANNING METHOD

A. Data Collection and Literature Review

Initial data collection is a prerequisite before starting the redesign. This data includes general project information, land data, and shop drawings. This planning process refers to a literature study covering:

- Minimum building load planning in accordance with the latest standards (SNI 1727:2020)
- The building structure design must meet strict earthquake resistance criteria to ensure safety (SNI 1726:2019)
- In determining the dimensions and types of reinforcement, refer to the concrete planning specifications (SNI 2847:2019)

B. Tahapan Perencanaan

The following planning stages can be seen in Figure 1.

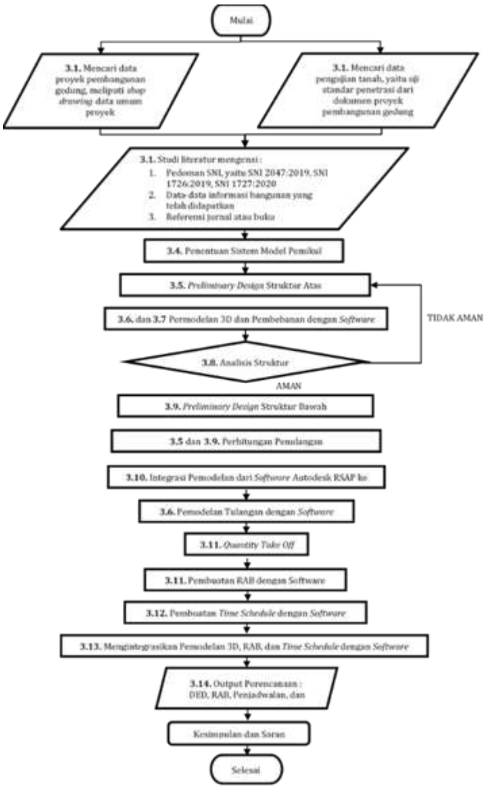

Figure 1. Planning Flowchart

C. Determination of the Load-Bearing Model System

The structural support system was determined in accordance with SNI 1726:2019 guidelines, with the collection of building data and soil classification based on test results. Next, the building risk category and earthquake priority factors were determined according to the building's function. Earthquake parameters such as Ss, S1, Fa, and Fv were taken from earthquake response information according to the region.

D. Preliminary Design of Upper Structure

1) Preliminary Slab Design

The determination of the minimum thickness of both single-direction and double-direction plates is based on several crucial factors. These include the type of plate used, the presence or absence of drop panels, the yield strength of the reinforcing steel (fy), and the existing support conditions. Specific requirements regarding this can be found in SNI 2847:2019 section 7.3.1.1 and section 8.3.1.1.

This determination is based on a comparison between the longest span (Ly) and the shortest span (Lx). In SNI 2847:2019 section 8.3.1.1, a slab is said to be unidirectional if Ly/Lx>2, where most of the load is transferred to one direction of the main support. Meanwhile, a bidirectional slab must meet the requirement of Ly/Lx≤2, which means that the load is distributed to two directions of the main support.

2) Preliminary Beam Design

The preliminary design of the beam dimensions is carried out in accordance with SNI 2847:2019. For the main beam, the height (h) is planned to be L/12 and the width (b) is planned to be h/2. Meanwhile, the secondary beam is planned to have a height (h) of L/16 and a width (b) of h/2, with the provision that the width of the beam must not be less than the minimum width required.

After the beam dimensions are determined, it is important to check the effective height and width based on SNI 2847:2019 Article 18.6.2.1. This requirement states that the clear span of the beam (Ln) must be greater than (4d), and the beam body width (bw) must be at least 250 mm.

3) Preliminary Coloumn Design

In the preliminary column design stage, the column cross-sectional area is determined based on the load to be supported and the concrete quality. This determination considers the strength reduction factor (ϕ) in accordance with SNI 2847:2019 Article 21.2.2.1 and the minimum dimension requirements of Article 18.7.2.1, and the calculation follows the following equation:

$$A = Pu/(\theta \; x \; f^{\wedge\prime} \; c) \qquad (1)$$

E. Structural Load Calculation

The load calculation is performed in accordance with applicable guidelines. The planned loads include dead loads (the weight of the structure and additional components such as stairs) and live loads adjusted to the function of the building, both of which are calculated based on SNI 1727:2020. In addition, wind loads are also calculated in accordance with SNI 1727:2020, with a minimum wind pressure of 25 kg/m², and 40 kg/m² specifically for locations in Semarang that are within 5 km of the coast. Finally, earthquake loads are determined using spectrum response analysis according to SNI 1726:2019.

F. Structural Analysis with 3D Modeling

Structural analysis was performed using three-dimensional modeling with Autodesk RSAP. This model includes dead, live, wind, and earthquake loads in accordance with SNI 1727:2020 and SNI 1726:2019. The response spectrum method was applied to calculate dynamic earthquake forces, ensuring that the structure meets safety and seismic performance requirements. In addition, the analysis results were used as the basis for optimizing the dimensions of structural elements to support planning efficiency.

G. Preliminary Design of Lower Structure

The lower structure is planned to use bored pile foundations supported by pile caps for load distribution. The diameter and depth of the bored piles are adjusted to the soil conditions and structural loads, while the pile cap is designed to distribute the load from the columns to the bored piles evenly. The dimensions and reinforcement are determined manually to ensure that the foundation has adequate bearing capacity and stability.

H. 3D Modeling Integration

Autodesk RSAP is used for structural analysis and optimization of elements under various loads. The analysis results and design details from RSAP, including reinforcement requirements, are then transferred to Revit. Autodesk Revit is used to model the structure and reinforcement, starting from the borepile foundation and pile cap as the lower structure, to the columns, beams, and floor slabs as the upper structure.

I. Preparation of Budget Plan (RAB)

The budget plan is prepared using Microsoft Excel based on the results of the Quantity Take Off (QTO), which is the volume calculation from Autodesk Revit. The data is then processed in Microsoft Excel, and calculations are performed using AHSP according to the region to produce the RAB.

J. Scheduling

This planning involves scheduling using Microsoft Project software. The schedule can be set based on the project start date, operating hours, and a list of work items along with the duration for each task. The results of this scheduling will be integrated into Autodesk Naviswork for 4D visualization.

K. Interactive 5D BIM Integration

This planning integrates BIM using Autodesk Navisworks by importing 3D models from Revit, RAB data, and schedules from Microsoft Project. This integration produces a 4D simulation that combines model visualization, schedules, and costs interactively, facilitating effective progress monitoring and project coordination before construction begins [4].

L. Planning Output

The output of the redesign of Building 2 of Hermina Banyumanik Hospital includes Detailed Engineering Design (DED), Budget Plan (RAB), project scheduling, and simulation of the gradual construction process through BIM 5D integration.

IV. RESULT AND DISCUSSION

A. Results of the Analysis of the Determination of the Moment-Resisting Frame System Method

Based on Table 4 in SNI 1726:2019 regarding earthquake priority factors, Building 2 of Hermina Banyumanik Hospital is classified into risk category IV with an earthquake priority factor (Ie) value of 1.50 as shown in Table 1. This category indicates that the building has a high priority in planning for earthquake resistance in accordance with applicable standards.

Table 1. Earthquake Priority Factor

Risk Category	Earthquake Priority Factor, Ie
I or II	1,0
III	1,25
IV	1,50

Based on the SPT test results at three points, the average N value for the location was 11.256, which falls into the SE (Soft Soil) site class category. From the design response spectrum website by the Ministry of Public Works and Public Housing in Figure 2, the Semarang area with an SE site class obtained spectral acceleration parameters SDS 0.71 and SD1 0.63 g.

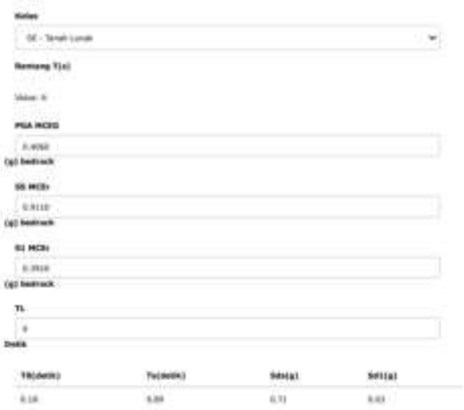

Figure 2. Result of the design response

Based on Tables 8 and 9 of SNI 1726:2019, this project falls under seismic design category (KDS D). Therefore, the system planned for this building is the Special Moment Resisting Frame System (SRPMK), in accordance with the relationship between KDS and the required planning method.

B. Preliminary Design Results

Before the design is created, a preliminary design stage is carried out to obtain efficient dimensions.

1) Preliminary Slab Design

Determine the type of slab based on the span lengths Ly and Lx.

$$Ly/Lx = 5{,}5/5{,}375 = 1{,}023 \leq 2 \quad (2)$$

Based on the above calculations, slab S1 is categorized as a two-way slab. The next step is to determine the dimensions, resulting in a planned slab thickness of 17 cm.

$$Lx/33 = 5{,}375/33 = 16{,}288 \text{ cm} \quad (3)$$

The calculation yields a value of hmin1 of 12.287 cm and hmin2 of 9 cm. Referring to Table 8.3.1.2 of SNI 2847:2019, since αfm > 2.0, the minimum plate thickness (hmin) is taken from the largest value, which is 12.287 cm. Thus, the planned plate thickness of 17 cm (hrencana) is greater than hmin, i.e., 17 cm > 12.287 cm, so the minimum plate thickness requirement is met. The results of the preliminary design calculation recapitulation can be seen in Table 2.

Table 2. Recapitulation of Preliminary Slab Design

Slab Type	Location	Ly (cm)	Lx (cm)	h (cm)
S1	1st floor	550	537,5	17
S2	2nd floor - roof	550	350	12,5

2) Preliminary Beam Design

The following is an example of a main beam calculation.
Beam type = B5
Beam span = 1000 cm
Therefore, the B5 dimensions are planned as follows.

$$h = L/12 = 1000/12 = 83{,}33 \approx 90 \text{ cm} \quad (4)$$

$$b = h/2 = 83{,}333/2 = 41{,}67 \approx 45 \text{ cm} \quad (5)$$

The following is an example of a beam calculation.
Beam type = ba3
Beam span = 1000 cm
Therefore, the dimensions of ba3 are planned as follows.

$$h = L/16 = 1000/16 = 62{,}5 \approx 70 \text{ cm} \quad (6)$$

$$h/2 = 62{,}5/2 = 31{,}25 \approx 40 \text{ cm} \quad (7)$$

After obtaining the dimensions of B5, which are 450x900 mm, and ba3, which are 400x700 mm, a check was carried out on the effective height and width in accordance with SNI 2847:2019 article 18.6.2.1, with the results showing that the dimensions of B5 and ba3 meet the requirements. The results of the preliminary design calculations for the main beam and secondary beams are shown in Table 3 and Table 4.

Table 3. Recapitulation of Pre. Main Beam Design

Beam Type	Span (cm)	Actual Height (cm)	Actual Width (cm)
B1	650	70	30
B2	800	70	40
B3	1350	120	60
B4	340	30	25
B5	1000	90	45
B6	157,7	30	30
B7	1250	105	55

Table 4. Recapitulation of Preliminary Beam Design

Beam Type	Span (cm)	Actual Height (cm)	Actual Width (cm)
Ba1	800	70	30
Ba2	800	50	25
Ba3	1000	70	40
Ba4	157,5	30	30

3) Preliminary Coloumn Design

Before determining the column dimension calculations, a load analysis was first performed on the column. In the load combination, the Pu value (due to DL structure) was 269,472 kg and the Pu value (due to SDL structure) was 245,915.6 kg. Thus, the Pu (total axial load) was 515,387.6 kg for the K2 column dimension calculation.

$$A = \frac{Pu}{\theta \, x \, f'c} = \frac{515387{,}6}{0{,}3 \, x \, 350} = 4908{,}45 \, cm \quad (8)$$

$$b \, min = \sqrt{A} = \sqrt{4908{,}45} = 70{,}06 \, cm \quad (9)$$

Table 5. Recapitulation of Preliminary Coloumn Design

Coloumn Type	Pu (kg)	A (cm^2)	b used (cm)
K1	1078528	10271,7	105
K2	515387,6	4908,45	75
K3	71544,24	681,37	55
K4	67289,14	640,85	30

From the following results, a value of 75 cm is obtained for b, so the planned dimensions for K2 are 75x75 cm. The results of the preliminary design calculations for the columns can be seen in Table 5.

C. Structural Analysis Results

Structural analysis involves creating a digital model of a structure using predetermined dimensions, then applying various loads to the model. This process generally follows certain stages.

1) Analysis of Mass Variation and Participation

Based on Figure 3, the analyzed capital participation reached 257 varieties, with a percentage of 94.05% for the X direction and 96.34% for the Y direction. These results indicate that the capital participation analysis has met the minimum requirements, which is 90% for each direction (both X and Y).

2) Analysis of Story Drif

According to SNI 1726:2019 article 7.12.1, the designed inter-floor drift value (Δ) must not exceed the allowable inter-floor drift limit (Δa). The calculation results show that the maximum allowable inter-floor drift value is 57 mm.

With the displacement values, we can calculate the floor deflection in the X direction and the floor deflection in the Y direction. The floor deflection in the X direction (Δx1) is 2.05 mm and in the Y direction (Δy1) is 2.46 mm on the first floor. Table 6 shows the results of the analysis of variance and mass partition.

Table 6. Result of Analysis of Total Variation and Mass Partition

Case	Rel.mas. UX	Rel.mas. UY	Cur.mas. UX	Cur.mas. UY
9/253	87,32	96,34	2,51	0,00
9/254	87,32	96,34	0,00	0,00
9/255	87,32	96,34	0,00	0,00
9/256	87,33	96,34	0,00	0,00
9/257	94,05	96,34	6,72	0,00

These values meet the requirements of SNI 1726:2019 section 7.12.1.

3) Structural Ratio Analysis

The ratio value in the column structure can use the following equation calculation.

$$R = \frac{\text{Pu}}{\phi \times Pn} \quad (10)$$

$$Pn = (0{,}80) \times [0{,}85 \times f'c \times Ag \times As \times (fy - 0{,}85 \times f'c)] \quad (10)$$

$$Ast = \rho \times Ag \quad (11)$$

$$\rho = 2{,}50\% \quad (12)$$

The ratio value in the column structure can be obtained using the following equation.

$$R = \text{Mu}/(\phi \times Mn) \quad (13)$$

$$Pn = As \times fy \times \left(d - \frac{As \times fy}{1{,}7 \times fc \times b}\right) \quad (14)$$

$$Ast = \rho \times Ag \quad (15)$$

$$\rho = 2{,}50\% \quad (16)$$

Based on Tables 6 and 7, the beam and column structures in this redesign meet the ratio criterion of less than 1, meaning that the structures have sufficient capacity to withstand the given loads.

Table 7. Results of Coloumn Structure Ratio Analysis

Node/Case	Type	Pn (N)	R	R<1
37/12/17	K1	34844512,5	0,25	OK
5/15/61	K2	17777812,5	0,16	OK
3098/120/45	K3	9560512,5	0,3	OK
71/247/26	K4	2844450	0,09	OK

Table 8. Results of Beam Structure Ratio Analysis

Node/Case	Type	Pn (N)	R	R<1
532/569/13	B1	1073964,71	0,78	OK
487/545/13	B2	1431952,94	0,59	OK
1311/170/15	B3	6528282,35	0,22	OK
1300/236/18	B4	146382,35	0,26	OK
155/28/16	B5	2711594,12	0,53	OK
2707/946/16	B6	175658,82	0,29	OK
1247/200/15	B7	4551379,41	0,41	OK
165/140/16	Ba1	1073964,71	0,20	OK
336/402/12	Ba2	441617,65	0,36	OK
1353/1328/22	Ba3	1431952,94	0,24	OK
457/492/16	Ba4	175658,82	0,19	OK

4) Structural Analysis Output

The following are the results of structural analysis using Autodesk Robot Structural Analyst Professional software. This output generates internal forces as the basis for structural reinforcement calculations. Figure 3 shows the axial force output results obtained after structural analysis.

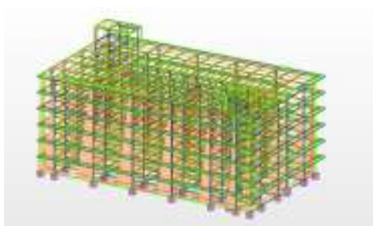

Figure 3. Axial Force Output

Figure 4 shows the shear force output obtained after the structural analysis process using.

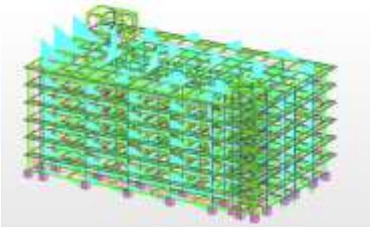

Figure 4. Shear Force Output

Figure 5 shows the moment output obtained after the structural analysis process.

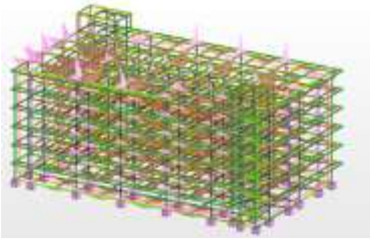

Figure 5. Moment Output

D. Structural Reinforcement Calculation

1) Slab Reinforcement Calculation

To plan slab reinforcement, the moment values (Mu) at the supports and in the X and Y directions are required. This data is obtained from the Autodesk RSAP software output. The results of the reinforcement calculation summary can be seen in Table 9.

Table 9. Recapitulation of Slab Reinforcement

Type	Direction	Area	Reinforcement Used
S1 (1st floor, t=17cm)	X	Support	D13-150
		Field	D13-150
	Y	Support	D13-125
		Field	D.13-125
S2 (2nd floor - roof, t=12,5 cm)	X	Support	D10-200
		Field	D10-200
	Y	Support	D10-200
		Field	D10-200

2) Beam Reinforcement Calculation

The data from the Autodesk RSAP software analysis plays an important role. The bending moments identified at the support and field positions are used to determine the flexural reinforcement requirements for the beams. Meanwhile, the shear forces at the support and field locations form the basis for calculating the shear reinforcement for the beams. All of these values are obtained directly from the structural analysis output performed in Autodesk RSAP. The summary of the beam reinforcement calculations can be seen in Table 10.

Table 10. Recapitulation of Beam Reinforcement

Type	Area	Location	Flexural Reinforcement	Shear Reinforcement
B1	Support	Top	8D19	2D10 – 150
		Bottom	3D19	
	Field	Top	4D19	2D10 – 300
		Bottom	5D19	
B2	Support	Top	12D19	2D10 – 75
		Bottom	6D19	
	Field	Top	3 D19	2D10 – 150
		Bottom	6 D19	
B3	Support	Top	7D25	2D13 – 150
		Bottom	6D25	
	Field	Top	5D25	2D13 – 300
		Bottom	9D25	
B4	Support	Top	2D19	2D10 – 100
		Bottom	2D19	
	Field	Top	2D19	2D10 – 100
		Bottom	2D19	
B5	Support	Top	10D25	2D13 – 150
		Bottom	4D25	
	Field	Top	3D25	2D13 – 300
		Bottom	5D25	
B6	Support	Top	2D19	2D10 – 100
		Bottom	2D19	
	Field	Top	2D19	2D10 – 100
		Bottom	2D19	
B7	Support	Top	11D25	2D13 – 150
		Bottom	5D25	
	Field	Top	4D25	2D13 – 300
		Bottom	7D25	
BP	Support	Top	2D19	2D10 – 300
		Bottom	2D19	
	Field	Top	2D19	2D10 – 300
		Bottom	2D19	
Ba1	Support	Top	3D19	2D10 – 150
		Bottom	3D19	
	Field	Top	3D19	2D10 – 300
		Bottom	3D19	
Ba2	Support	Top	3D19	2D10 – 150
		Bottom	3D19	
	Field	Top	3D19	2D10 – 150
		Bottom	3D19	
Ba3	Support	Top	4D19	2D10 – 150
		Bottom	4D19	
	Field	Top	4D19	2D10 – 350
		Bottom	4D19	
Ba4	Support	Top	2D19	2D10 – 150
		Bottom	2D19	
	Field	Top	2D19	2D10 – 150
		Bottom	2D19	

3) Coloumn Reinforcement Calculation

Axial force values and reinforcement area are used in the calculation of flexural reinforcement for columns, while shear force is required to determine the shear reinforcement for columns. The data is obtained from the output of the RSAP software. The results of the column reinforcement calculation summary can be seen in Table 11.

Table 11. Recapitulation of Coloumn Reinforcement

Type	Flexural Reinforcement	Shear Reinforcement
K1	16D32	4D13 – 200
K2	12D25	2D13 – 200
K3	8D25	2D10 – 150
K4	4D19	2D10 – 150

4) Bore Pile Reinforcement Calculation

The lateral load and moment values transmitted by each column to the foundation are crucial. This data is obtained directly from the structural analysis output performed using RSAP software. The results of the bore pile reinforcement calculation recapitulation can be seen in Table 12.

Table 12. Recapitulation of Bore Pile Reinforcement

Diameter	Mu (kNm)	Reinforcement
Ø700	186,89	12D19
Ø850	210,15	15D19

5) Pile Cao Reinforcement Calculation

The axial force values and pile cap dimensions themselves. Obtained from the analysis results using RSAP software. The recapitulation of the pile cap reinforcement calculation results can be seen in Table 13.

Table 13. Recapitulation of Pile Cap Reinforcement

Type	Dimensi (cm)		Reinforcement		
PC1a	P	170	X	Top	D13 – 150
	L	170		Bottom	D25 – 150
	T	100	Y	Top	D13 – 150
				Bottom	D13 – 150
PC1b	P	140	X	Top	D13 – 150
	L	140		Bottom	D25 – 150
	T	100	Y	Top	D13 – 150
				Bottom	D25 – 150
PC2a	P	170	X	Top	D13 – 75
	L	382,5		Bottom	D25 – 75
	T	150	Y	Top	D13 – 100
				Bottom	D25 – 100
PC2b	P	140	X	Top	D13 – 75
	L	290		Bottom	D25 – 75
	T	120	Y	Top	D13 – 125
				Bottom	D25 – 125
PC4	P	391	X	Top	D13 – 100
	L	391		Bottom	D25 – 100
	T	100	Y	Top	D13 – 100
				Bottom	D25 – 100
PC6a	P	595	X	Top	D13 – 125
	L	382,5		Bottom	D25 – 125
	T	120	Y	Top	D13 – 100
				Bottom	D25 – 100
PC6b	P	504	X	Top	D13 – 150
	L	322		Bottom	D25 – 150
	T	100	Y	Top	D13 – 100
				Bottom	D25 – 100

E. 3D Structural Modeling

The following are the results of 3D building modeling performed in Autodesk Revit, with the upper structure modeling shown in Figure 7 and the lower structure modeling shown in Figure 6.

Figure 6. 3D Modeling of Lower Structure

Figure 7. 3D Modeling of Upper Structure

F. Budget Plan Results

After obtaining the QTO data from the Autodesk Revit software, it was processed to compile the RAB. The compilation of the RAB was based on the AHSP of Semarang City and added 11% VAT with the help of Microsoft Excel software with the results of the RAB recapitulation in Table 14.

Tabel 14. Recapitulation of Budget Plan Results

No	Description of Work	Total Cost (Rp)
1	Preparation Work	299.350.002,52
2	Site Work	103.219.492,62
3	Lower Structure Work	8.773.920.201,29
4	1^{st} floor structure work	4.328.392.817,05
5	2^{nd} floor structure work	4.659.212.809,91
6	3^{rd} floor structure work	4.035.442.430.88
7	4^{th} floor structure work	4.049.694.957,51
8	5^{th} floor structure work	3.927.133.556,21
9	6^{th} floor structure work	3.634.294.036,50
10	Roof floor structure work	2.683.980.622,07
11	Roof floor structure work +26.6	120.642.776,61
Total		36.615.283.703,16
VAT 11%		4.027.681.207,35
Total After VAT		40.642.964.910,51
Arounded		40.642.964.000,00
In words: Forty billion six hundred forty-two million nine hundred sixty-four thousand rupiah		

G. Scheduling Results

The construction redesign is scheduled to take 33 weeks, with 21 days each for preparation and groundwork, 56 days for foundations, and 175 days for the superstructure. Figure 8 shows the project scheduling Gantt chart, while Figure 9 shows the S curve of project progress.

Figure 8. Gantt Chart from Microsoft Project

Figure 9. S-Curve from Microsoft Project

H. BIM 5D Integration Results

BIM 5D integration displays a visual simulation of construction from preparation to completion. Figure 10 shows the use of Autodesk Navisworks, which combines 3D models from Revit, schedules from Microsoft Project, and cost estimates from Excel.

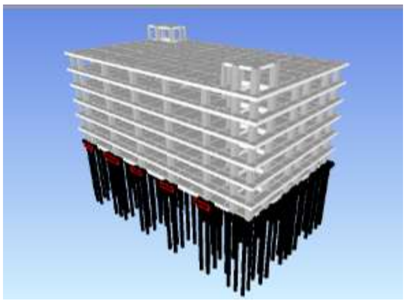

Figure 10. BIM 5D Integration Results

V. CONCLUSION

A. Conclusion

The following are the conclusions from the redesign of Building 2 of Hermina Hospital using Autodesk Group Banyumanik software:

1) The redesign of structural elements through the initial design stage has ensured the safety of the structure against loads in accordance with SNI standards using Autodesk Robot Structural Analysis Professional (RSAP). Collaboration with Autodesk Revit has produced a more detailed and precise 3D model, including foundations, beams, slabs, and columns. The integration between these two software programs has accelerated and simplified the modeling process, grid , and elevation, thereby supporting better visualization and more effective project coordination.
2) The use of Autodesk Revit's 3D model produced the following material and work quantity data: for the substructure, such as bore piles and pile caps, the concrete volume was 2,600.86 m³, the formwork area was 796.09 m², and the reinforcement weight was 223,022.29 kg. Meanwhile, for the upper structures, including beams, slabs, and columns, the concrete volume reached 3,916.03 m³, the formwork area was 26,222.68 m², and the weight of reinforcement was 719,619.56 kg. Based on the quantity takeoff and manual volume calculations, the Cost Estimate (RAB) including 11% VAT is Rp 40,642,964,000.00.
3) The construction process in this plan is scheduled to take place from July 8, 2025, to February 23, 2026, with a duration of 231 days or 33 weeks.

4) The 3D model, schedule, and RAB that have been compiled are then integrated into BIM 5D using Autodesk Navisworks software to produce a visualization of the construction process simulation according to the revised plan. Through this BIM integration, the resulting visualization helps to anticipate potential schedule delays and rework that may occur due to the lack of prior simulation.

B. Recommendations

The following are recommendations from the redesign of Building 2 of Hermina Hospital using Autodesk Group Banyumanik software:

1) Accuracy in structural analysis and reinforcement requirement calculations is crucial. Conducting experiments with variations in structural element dimensions is necessary to achieve a design that is both strong and economical.
2) 3D modeling must be carried out carefully so that the quantity takeoff data obtained is accurate and reliable.
3) The use of additional plugins in BIM software is recommended to simplify and accelerate the planning and design process.
4) Advancing to a higher level of BIM (g), such as BIM 7D, by incorporating MEP and architectural elements is recommended so that energy analysis, collision detection, and project management can be carried out more comprehensively and optimally.

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