Strength Analysis of Existing Upper Structure of Right Wing Building Jambi University Teaching Hospital

M. Nuklirullah[1*], Dila Oktarise Dwina[2], Ekom Ofronazel[3]
[1,2,3]Civil Engineering Study Program, Jambi University, Indonesia

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ABSTRACT

The building of the Teaching Hospital at Jambi University has stopped until now with the current development of physical development in the form of the upper structure work stage of the building. To be able to resume the physical construction of the RSP UNJA building, it is necessary to have a technical study in the form of an evaluation of the building's current structural state, to ensure that the existing structure has good strength and is feasible to continue the stages of work until it is completed according to planning. The technical standards used by the planning consultant in its 2015 planning used old standards, while the standards used have been updated with the latest technical standards. Building planning data and existing data on completed work are gathered as part of the evaluation approach employed in this study, then an analysis is carried out based on the latest standards. The analysis's findings indicate that while all floor slab structure elements at every level satisfy the requirements for moment strength and shear force, some beam elements in specific locations do not, and all column types satisfy the requirements for axial strength but some column elements in specific locations do not meet the requirements for shear force strength. From the results of the analysis and conclusions, it was obtained that some of the existing structures meet the strength requirements which means that they can withstand the load of the working service.

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Corresponding Author:

Ekom Ofronazel,
Civil Engineering Study Program,
Jambi University,
Jl. Jambi-Muara Bulian Km 15, Muaro Jambi Regency, Jambi, 36361, Indonesia.
Email: ekom.ofronazel2001@gmail.com

1. INTRODUCTION

1.1. Background

Along with the current globalization that demands change and development towards the progress of a nation, the government continues to raise educational standards in order to better prepare a generation of quality and integrity, one of which is by providing educational hospital facilities in the university environment that supports the improvement and development of educational activities, research and health services in the university environment.

The increasingly difficult availability of land makes the provision of building facilities need to be built effectively and efficiently. So that facilities built on limited land can have a capacity that meets the needs, the effective choice is a multi-story building [1]. Every building must comply with administrative and technical standards relevant to its function, as stipulated by Law No. 28 of 2002 addressing buildings. Building planning requirements and building dependability requirements are examples of building technical requirements [2].

The University of Jambi Teaching Hospital Building is located on the Pinang Masak Campus, Mendalo Darat, Muaro Jambi. The building of the Teaching Hospital at Jambi University physically started to be built in 2010 for the middle building segment and the left-wing building. The building of the Teaching Hospital at Jambi University was stopped for five years, which was then resumed again in 2015 with the addition of the construction of the right-wing building segment. However, construction has stopped again until now with the development of physical development currently in the form of the upper structure work stage of the building [3].

A building must be constructed to be used in a way that is consistent with its intended use and to last as intended. This is possible if the planning makes use of the relevant regulations' provisions[4]. The technical standards used by the planning consultant in the 2015 planning used the old standards, namely SNI 2847:2013 on Building Structural Concrete Requirements, SNI 1726:2012 on Methods for Planning for Earthquake Resistance in Buildings and Non-Building Structures, and SNI 1727:2013 on Minimum Weights for Building and Other Structure Design. The standards used have been updated with the latest technical standards, namely SNI 2847:2019, SNI 1726:2019, and SNI 1727:2020.

SNI 1726-2019 has been updated to reflect the increased value of divergence between levels; if this deviation beyond the established safe requirements, the building will fail. Additionally, SNI 2847-2019's change pertains to the standards for deflection clearance [5]. This means that buildings designed according to the previous regulations must be re-evaluated to determine whether or not they are still safe according to the new requirements[6].

1.2. Problem Formulation

The purpose of the research on Strength Analysis of Existing Upper Structure of the Right Wing Building Jambi University Teaching Hospital is to determine the strength of the reinforced concrete floor slab, beam, and column structures in the Right Wing Building of the Jambi University Teaching Hospital retrieved from SNI 2847: 2019, SNI 1726: 2019, and SNI 1727: 2020 standards.

1.3. Problem Limitation

For the discussion to be more focused and able to achieve the desired goals and benefits, The problems in this study have the following limitations:

a. This research only analyzes the reinforced concrete construction of the Upper Structure of the Right-Wing Building of the Jambi University Teaching Hospital following SNI 2847: 2019[7], Steel Deck Institute 2011[8], PPPURG 1987[9] and SNI 1727: 2020[10].
b. This research analyzes earthquake resistance using a variety of response spectrum analyses following SNI 1726: 2019 regarding the processes for preparing buildings and non-building structures to withstand earthquakes [11].
c. The upper structure of the Right-Wing Building of the Jambi University Teaching Hospital consists of 4 floors with the main function as a hospital building.
d. Analysis of the building structure using the help of a computer program.
e. Loading for building structure analysis calculates dead load, additional dead load (construction materials' weight), live load, earthquake load, and wind load.
f. The structural system used to withstand gravity loads and lateral loads is a frame system, namely The Bearing Frame System for Special Moments (SRPMK) consisting of plate, beam, and column elements[12].

g. The strength requirements of the reinforced concrete structure under review are moment strength (M), shear strength (V), and compressive axial strength (P).

1.4. Literature Rivew

Based on SNI 2847: 2019 Article 9.5 regarding plan strength, it explains that buildings and structural components must have a plan strength along the component or design strength must be greater than or equal to the necessary strength obtained from the factored load and force in the loading combination ($\phi S_n \geq U$), which includes[7]:

$$\phi M_n \geq M_u \quad (1)$$

$$\phi V_n \geq V_u \quad (2)$$

$$\phi P_n \geq P_u \quad (3)$$

Based on SNI 1727: 2020 explains that loads are forces or other actions due to the weight of the building material itself, users and goods that load it, environmental impacts, the difference in movement that occurs in the structure. Service load is the load acting on the structure due to the structure's weight, additional dead load, live load, environmental load during the expected service life as well as self-strain forces and effects[10].

The loading combination is the necessary strength required for a structural component to withstand the factored load acting with various combinations of load effects, the essential strength (U) is required. The strength of a cross section or structural element needed to support the calculated load is known as the necessary strength [13]. When loads is applied, it is also evident from the structural analysis that certain structural members are overstressed. Several suggestions for reinforcing the structure can be offered if any structural components are overstressed[14].

The loading combination is determined in compliance with the rules of SNI 1726:2019 Article 4.2.2.1 and Article 4.2.2.3, which details the basic loading combination and the combination of loading with the influence of earthquake loads, as follows[11]:

$$U = 1{,}4D \quad (4)$$

$$U = 1{,}2D + 1{,}6L + 0{,}5(L_r \text{ or } R) \quad (5)$$

$$U = 1{,}2D + 1{,}6(L_r \text{ or } R) + (L_r \text{ or } 0{,}5W) \quad (6)$$

$$U = 1{,}2D + 1{,}0W + \mathrm{L} + 0{,}5(L_r \text{ or } R) \quad (7)$$

$$U = 0{,}9D + 1{,}0W \quad (8)$$

$$U = 1{,}2D + E_v + E_h + L \quad (9)$$

$$U = 0{,}9D - E_v + E_h \quad (10)$$

The values of Ev and Eh are described in sections 7.4.2.1. and 7.4.2.2, respectively, as follows:

$$E_h = \rho\ (Q_{E-x} + Q_{E-y}) \quad (11)$$

$$E_v = 0{,}2S_{DS}D \quad (12)$$

Because Indonesia is one of the nations with the highest risk of earthquakes, planners must think about safe, earthquake-resistant building designs[15]. Structural elements of a building generally function to endure gravitational loads, both live and dead. However, due to the phenomenon of lateral loads, namely wind loads and earthquake loads, building structural elements must be able to withstand the combined load between gravity loads and lateral loads, especially earthquake loads which often cause major damage to buildings and cause casualties[16].

Strong column weak beam, which is part of the SRPMK method series, is one of the ideas of earthquake-resistant building planning. Structural capacity is a feature of earthquake-resistant building designs that enables the building to withstand seismic activity, hence improving building occupant safety[17]. This system is appropriate for usage in locations or structures with a high risk of earthquakes due to its high degree of ductility. It has specific details and can withstand shearing[18].

The floor plate structure is part of the building structure that is directly related to the loads acting on the building[19]. One structural component of the floor slab is used to distribute dead and live loads to other main structures, such as beams and columns[20]. Floor slabs are treated as shells when analyzed with ETABS software, meaning that both vertical and horizontal forces are considered to be applied to the slabs. [21].

One of the primary components of building constructions that are positioned laterally or horizontally are beams. Beams are linked with columns to form a stable frame structural system to withstand the working load. Beams have the main function as an element that transmits the gravity load from the floor plate to the column element, in the form of forces and moments[22].

The primary structural components that support the combined weight of compressive axial and bending forces are columns[23]. Additionally, columns are crucial for supporting lateral loads, especially earthquake loads. In general, columns in buildings are planned as sway-lance columns. This type of planning considers relatively more limping dimensions and considers the earthquake loads carried by the structure[24].

Methods that are often used to determine the strength of concrete construction installed in a building are divided into two types, namely[25]:

a. Non-Destructive Test (NDT), which is a method of testing construction materials by not damaging structural elements in taking test samples or testing directly in the field.
b. Destructive Test (DT), which is a method of testing construction materials by damaging structural elements in testing or taking test samples.

One way to determine the quality value of existing concrete with non-destructive test is to use a hammer test. In order to perform this test, an impact load is applied to the concrete's surface using a mass that is activated by a specific quantity of energy. The standard number provided by the hammer manufacturer is compared with the bounce value that was achieved[26]. Regarding the destructive test method, you can find the concrete's true compressive strength by conducting a core drilled test[27]. A concrete drilling machine was used to remove the concrete core. After that, the collected concrete core samples are brought to the lab to undergo compressive testing using a concrete compressive strength testing apparatus[28].

2. METHODS

The research object in this research, The Jambi University Teaching Hospital's Right-Wing Building (RSP UNJA), located at the Jambi University Pinang Masak Campus, Jl. Jambi-Muara Bulian Km 15, Muaro Jambi Regency, Jambi Province. The location and layout of RSP UNJA can be observed in Figures 1 and 2.

Figure 1. The Location of UNJA Teaching Hospital Building

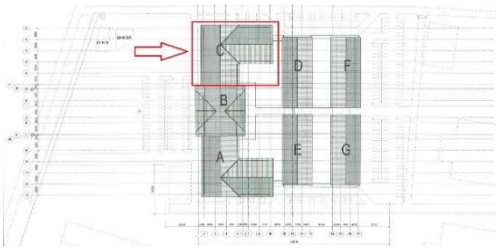


Figure 2. Right Wing Building Layout of Jambi University Teaching Hospital

The assessment approach employed in this study is completed by gathering pre-existing data on work carried out and building planning data, then analyzing based on the latest standards related to reinforced concrete, loading and earthquake-resistant structural systems. Figure 3 illustrates that this research is divided into multiple phases.

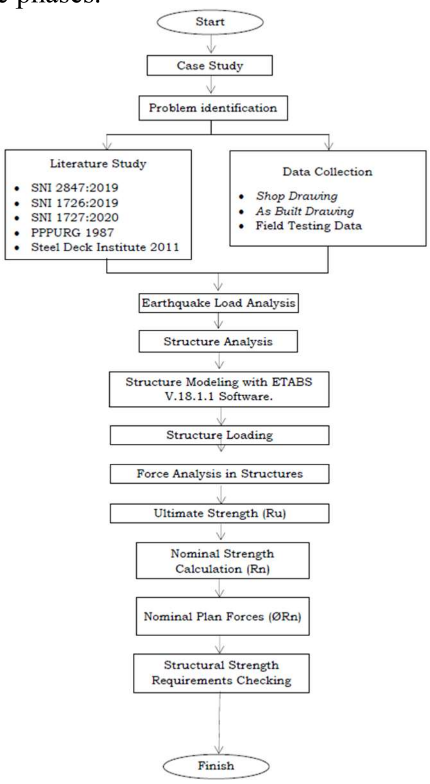


Figure 3. Research Flowchart

3. RESULTS AND DISCUSSION

The Jambi University Teaching Hospital building under review is the right-wing building that has been carried out since 2015. The technical data of the right wing building of the Jambi University Teaching Hospital is detailed as follows:

Building name	: Right Wing Building of Jambi University Teaching Hospital
Building location	: Jambi University Pinang Masak Campus, Jl. Jambi-Muara Bulian Km 15, Muaro Jambi Regency, Jambi Province.
Coordinates	: -1.609937, 103.521788
Building function	: Hospital
Number of floors	: 4 floors
Type of structure	: Reinforced concrete frame
Structural system	: Special Moment Bearing Frame Structure

Data on the number and function of floors can be detailed in Table 1

Table 1. Floor elevation and function

Floor	Height of floor (m)	Floor elevation (m)	Floor function
4th floor	3,00	+ 15,00	Concrete slab roof
3rd floor	5,20	+ 9,80	Office
2nd floor	4,90	+ 4,90	Hospital
1st floor	4,90	± 0,00	Hospital
Basement floor	4,00	- 4,00	Parking and utilities

The floor slab structure of the right wing building of Jambi University Teaching Hospital uses M8 wire mesh material and steel deck as reinforcement and floor slab formwork, with a floor slab construction thickness of 120 mm. The following Tables 2 and 3 provide specifics on the beams' size and cross-sectional characteristics.

Table 2. Beam cross section dimensions

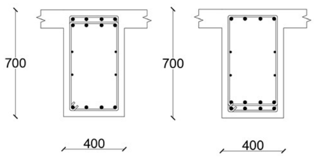
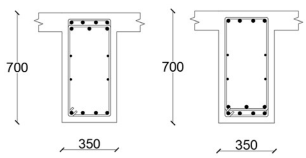
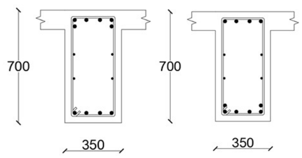
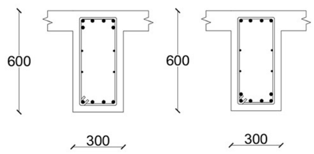
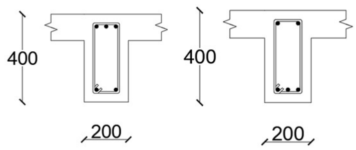
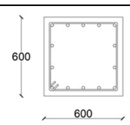
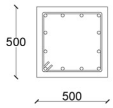
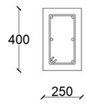
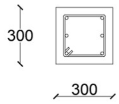
Name of beam	Rebar position	Support rebar	Field rebar	Cross-sectional drawing
B1 (400 × 700)	Top	8 D 22	4 D 22	
	Middle	4 D 13	4 D 13	
	Bottom	4 D 22	8 D 22	
	Shear Reinforcement	Ø 10 - 100	Ø 10 - 150	
B2.A (350 × 700)	Top	7 D 22	4 D 22	
	Middle	4 D 13	4 D 13	
	Bottom	4 D 22	7 D 22	
	Shear Reinforcement	Ø 10 - 100	Ø 10 - 150	
B2.B (350 × 700)	Top	6 D 22	4 D 22	
	Middle	4 D 13	4 D 13	
	Bottom	4 D 22	6 D 22	
	Shear Reinforcement	Ø 10 – 100	Ø 10 - 150	
B3 (300 × 600)	Top	6 D 19	4 D 19	
	Middle	4 Ø 10	4 Ø 10	
	Bottom	4 D 19	6 D 19	
	Shear Reinforcement	Ø 10 - 125	Ø 10 - 150	
B4 (200 × 400)	Top	3 D 16	2 D 16	
	Middle	-	-	
	Bottom	2 D 16	3 D 16	
	Shear Reinforcement	Ø 8 – 125	Ø 8 – 150	

Table 3. Column cross section dimensions

Name of column	Rebar	Reinforcement dimensions	Cross-sectional drawing
K1 (600 × 600)	Longitudinal Rebar	14 D 22	
	Support Shear Rebar	Ø 10 - 100	
	Field Shear Rebar	Ø 10 - 150	

K2 (500 × 500)	Longitudinal Rebar	12 D 22	
	Support Shear Rebar	Ø 10 - 100	
	Field Shear Rebar	Ø 10 - 150	
K3 (250 × 400)	Longitudinal Rebar	6 D 16	
	Support Shear Rebar	Ø 8 - 100	
	Field Shear Rebar	Ø 8 - 150	
K4 (300 × 300)	Longitudinal Rebar	6 D 16	
	Support Shear Rebar	Ø 8 - 100	
	Field Shear Rebar	Ø 8 - 150	

The concrete quality used in analyzing the building structure, the lowest concrete quality obtained from the hammer test results is used, namely with a concrete quality of 30.90 MPa. Based on Table 6 of SNI 2052: 2017 concerning concrete reinforcement bars, the tensile strength's quality value of the reinforcing steel used according to the outcomes of the steel tensile test is displayed in Table 4.

Table 4. Quality of reinforcement bars used

Reinforcement bars grade	Yield strength (f_u) MPa	Tensile strength (f_y) MPa
BjTS 520	Min. 520, Max. 645	Min. 650
BjTP 280	Min. 280, Max. 405	Min. 350

The thickness of the concrete blanket used is by the provisions of SNI 2847: 2019 Article 20.6.1.3, namely the thickness of the concrete blanket on the structural components under review is 20 mm for floor slabs and 40 mm for beams and columns. The modulus of elasticity of concrete used is $4.700\sqrt{30{,}90}$ MPa or 26,126.25 MPa, while the modulus of elasticity of steel used according to SNI 2847: 2019 is 200,000 MPa.

The following are details of the loading used in the calculation of this building structure, namely:

a. Dead Load (DL)
The specific gravity of concrete material is 24,00 kN/m^3 and the specific gravity of steel material is 78,50 kN/m^3 [29].

b. Super Impose Dead Load (SIDL)

Table 5. Super impose dead load on floor slab

Area load	Load (kN/m^2)
On roof deck plate	0,28
On floor slab above ground floor	0,94
On basement/ground floor slab	0,66

Table 6. Super impose dead load on beam

Floor level	Load (kN/m)
4th floor	7,50
3rd floor	13,00
2nd floor	12,25
1st floor	12,25
Basement floor	10,00

c. Live Load (LL)

Table 7. Live load on the building

Space function	Load (kN/m^2)
Balcony and deck	2,88
Flat, pitched, and curved roofs	0,96

Office	2,40
Corridor above first floor	3,83
Corridor of the first floor	4,79
Laboratory and operating room	2,87
Patient room	1,92
Stairs and escape routes	4,79
Light storage warehouse	6,00
Passenger car garage/parking	1,92

d. Earthquake Load (EL)
Based on SNI 1726:2019, the seismic load is calculated, with the results for each parameter as follows:
1) Risk category IV
2) Earthquake primacy factor used 1.50
3) Site classification obtained SE (soft soil)
4) The seismic design category obtained risk category D
5) The structural framework that was employed is the bearing frame system for special moments, with the design parameter values used, namely:
Coefficient of response modification, R : 8,0
Overpower factor of the system, Ω_0 : 3,0
Factor of deflection magnification, C_d : 5,5
6) The permitted analysis procedure with a building height above ground level of 18 m < 48.8 m and no irregularities, the type of analysis procedure can be performed by a variational response spectrum analysis.

The following is a picture of 3D structural modeling of the upper structure of the right wing of the Jambi University Teaching Hospital.

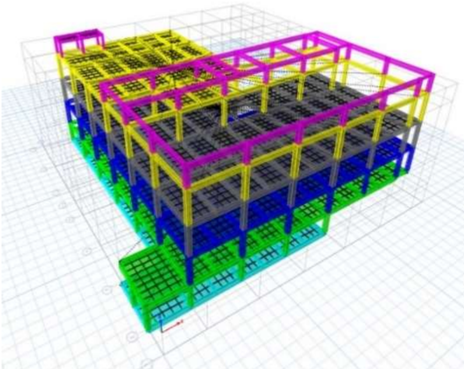


Figure 4. 3D Structure Model

The calculation data used in the floor slab analysis is as follows:
a. The floor slab's thickness is 120 mm.
b. The positive reinforcement uses a 0.7 mm thick smartdeck floordeck (fy = 550 MPa) with an effective width of 960 mm.
c. The negative reinforcement uses wire mesh M8 with a quality of U50 (fy = 500 MPa) with dimensions of 2,1 m x 5,4 m.
d. The reinforcement diameter is 8 mm with a spacing of 150 mm.

The floor slab structure that has been modeled using ETABS software produces the ultimate strength value, which as shown in Table 8.

Table 8. Ultimate strength worth of floor slab structure

Floor plate ultimate force	Mu max (kN.m)	Mu min (kN.m)	Vu max (kN)
4th floor	9,531	-22,105	19,477
3rd floor	9,438	-26,481	35,623
2nd floor	10,308	-28,979	39,064
1st floor	10,617	-23,611	25,237

Then calculate the nominal strength value of the floor slab based on the 2011 Steel Deck Institute standard and obtain the nominal strength value of the floor slab, namely:

ϕM_n = 31,153 kNm

ϕV_n = 52,808 kN

After obtaining the ultimate strength and nominal strength values, the strength requirements of the floor slab are checked as shown in Table 9.

Table 9. Comparison of ultimate strength and nominal strength values

Floor level	Mu (kN.m)	Check	Vu (kN)	Check
4th floor	9,531	OK	19,477	OK
3rd floor	9,438	OK	35,623	OK
2nd floor	10,308	OK	39,064	OK
1st floor	10,617	OK	25,237	OK
Max Value	10,617	OK	39,064	OK

The outcomes of the nominal strength computation of the floor slab show that the floor slab can withstand the maximum ultimate load acting, so the floor slab can be concluded to be safe. The beam structure that has been modeled is analyzed and produces the ultimate strength value, which as shown in Table 10.

Table 10. Ultimate strength value of beam structure

Ultimate beam force	Mu max (kN.m)	Mu min (kN.m)	Vu max (kN)
B1	1.409,157	-1.317,108	766,795
B2.A	1.512,322	-1.738,194	685,517
B2.B	1.280,083	-1.474,846	544,190
B3	176,765	-235,524	130,587
B4	340,586	-396,688	330,944

Then calculate the value of the nominal strength of each type and position of the beam based on the SNI 2847: 2019 standard and obtain the maximum nominal strength value of the beam which as shown in Table 11.

Table 11. Factorized nominal strength value of beam structure

Nominal beam force	ϕMn max (kN.m)	ϕVn max (kN)
B1	797,446	740,313
B2.A	703,476	722,420
B2.B	612,769	536,639
B3	382,400	369,613
B4	88,680	156,703

The nominal strength of the factored beam calculated for each type and position of the beam element is then compared with the ultimate strength according to the structural strength requirement $\phi R_n \geq R_u$ [30]. The results obtained show that there is a factored nominal strength (plan strength) that is smaller than the ultimate load acting on the structure, indicating the presence of a structure that cannot support the working load.

Table 12. Ultimate strength value of column structure

Ultimate column force	Pu max (kN)	Vu max (kN.m)
K1	-3.987,329	769,256
K2	-2.361,580	642,093
K3	-1.665,493	217,044
K4	-96,295	95,563

Table 13. Factorized nominal strength value of column structure

Nominal column force	ϕPn max (kN)	ϕVn max (kN.m)
K1	6.283,152	523,940
K2	4.585,602	369,339
K3	1.675,506	191,708
K4	1.538,928	105,597

Table 12 and Table 13 show the results that there is a nominal strength of the factored shear (plan strength) that is smaller than the ultimate shear force acting on the structure, meaning that there are columns that are unable to withstand the working shear force. To pinpoint the precise location of the column that cannot support the building's service load, a comparison of the amount of ultimate load to the nominal strength of the factorized (plan strength) at each column position is carried out ($\phi R_n \geq R_u$).

Based on the summary of the analytical findings comparing the factored nominal strength (plan strength), it can be seen that there are beam and column elements that are strong in resisting the working load and there are also beam and column elements that are not strong in resisting the working load.

The existence of existing beam and column elements in The Jambi University Teaching Hospital's Right-Wing Building which are unable to endure the operational service load, is a result of multiple modifications to the existing standards and is also a result of the beam and column elements' strength. The strength of the components of the beams and columns is influenced by the dimensions of the structure, the quality of the material, and the plan load.

In terms of structural dimensions, it can be seen from the plan drawings and realization drawings, that the dimensions of the implemented structure are following the plan. In terms of the quality of materials used for analysis in this study, the hammer test results are used to determine the concrete quality value, and by considering the safety factor and the accuracy of the calculation, the smallest value of the hammer test results is used.

In terms of plan load, based on SNI 2847: 2019, there are changes, namely in the β_1 factor (compressive stress block height connecting factor), strength reduction factor, and changes in the V_n equation on beams and columns. Based on SNI 1726:2019, changes were obtained regarding the determination of the response spectrum and changes in the Indonesian earthquake risk map with calculations based on longitude and latitude, so that the increase in earthquake risk affects the combination of loading on the structure, which causes differences in the earthquake load used during planning in 2015 with the load from earthquakes according to SNI 1726:2019 used during the analysis in this study.

Several conclusions can be made from the analysis and computations that have been done, including the following:

a. The floor slab elements used do not meet the minimum thickness standards based on SNI 2847: 2019, but in terms of structural strength, the slab elements on each floor meet the strength values of the moment and shear force according to the 2011 Steel Deck Institute calculation standard so that the floor slab can withstand building service loads.
b. From the calculation results, there are beam elements B1, B2.A, B2.B, and B4 at several positions of the beam element that do not meet the requirements for moment strength or shear force. While beam B3 in all positions meets the requirements for moment strength and shear force.
c. From the calculation results, all types of columns meet the requirements for compressive axial strength, but in some positions of columns K1, K2, and K3 some columns do not meet the requirements for shear force strength, while column K4 meets the requirements for moment strength and shear force.
d. Floor slab, beam and column elements that meet structural strength requirements indicate that they can withstand the service loads placed on the structure.

4. CONCLUSION

Considering the findings of the computations and analysis that have been completed, it is possible to determine that there are several beam and column positions that do not meet the strength requirements, so it is necessary to follow up on weak structural elements, so that The Jambi University Teaching Hospital Building's construction can be continued and this building can function according to its designation as the Jambi University Teaching Hospital Building.

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