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Assessment of the Structure of Public Elementary School 28 Air Tawar Timur Padang

Prima Yane Putri[1*] and Candra[1]

[1] Department of Civil Engineering, State University of Padang
Jl. Prof. Dr. Hamka Kampus UNP Air Tawar Padang, Indonesia-25131

*Corresponding author: primayaneputri@ft.unp.ac.id
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Abstract

The State Elementary School 28 Air Tawar Timur Padang is an Inpres School which was built in 1982. The current condition of the school building is damaged, such as cracks, loose concrete (spalling), deflection and shaking floors. This study aims to provide recommendations for repair or maintenance of the school building. The assessment method used in this study is the Non Destructive Test (NDT) method. Testing the compressive strength of concrete using a Schmidt Rebound Hammer. To see the amount of reinforcing steel, diameter of reinforcing steel and dimensions of structural elements using a Rebar Locator, Caliper, and a meter. Testing the building geometry and deflection floor plates using Total Station and Laser Measurement. The building structure was analyzed using the SAP2000 program. The results of the concrete compressive strength test (fc ') are on average 20.40 MPa on the column, 22.23 MPa on the beam, and 23.43 MPa on the floor plate. The results of visual observations of the building are categorized as severely damaged with the proportion of damage above 20%. Where the proportion level of column damage is 32%, beams 20.35%, and the floor court is 65%. The results of the building structure evaluation show that all elements are categorized as unsafe except Beams 3, Beams 4, and Column 2. The maximum deflection of the floor as high as 73 mm exceeds the allowable permit, which is 18.9 mm. The recommendation for repair of the school is building renovation.

Keywords: Assessment, building, structural analysis, building repair, building maintenance

1. Introduction

The building is a physical form resulting from construction work that is integrated with its domicile, partially or wholly located above and/or in the land and/or water, which functions as a place for humans to carry out their activities, whether for housing or residence, religious activities, business activities. , social, cultural and special activities [1]. The school building is one of the buildings that serves as a place to carry out the teaching and learning process and other educational activities. State Elementary School 28 Air Tawar Timur Padang is geographically located at 0˚53'40" South Latitude and 100˚21'16" East Longitude. This school has two floors and is located on Jalan Pinangsori, Air Tawar Timur Village, North Padang District, Padang City, West Sumatra Province.

According to the Padang City Education Office, the State Elementary School 28 Air Tawar Timur Padang was included in the construction of the Inpres School in the 1980s and according to the Principal and Teachers that the school was an Inpres School which was built in 1982. Currently the school building has cracks on the floor and walls. In addition, there was also the release of concrete parts (spalling) which showed corroded reinforcing steel in columns, floor plates and stairs. The floor shook causing the principal and teachers to feel worried when carrying out activities at the 28 Air Tawar Timur State Elementary School building. To find out whether the school building is safe to use, an assessment of the structure of the building is carried out to determine the condition of the school building.

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a. b. c.

Figure 1 a. Spalling Columns, b. Broken Joint Beams, c. Floor Plate Spalling

Building structure assessment is an activity of examining and assessing the condition of existing building structures that are focused on analyzing the reliability or strength of the building structure according to the conditions at the time of inspection by considering SNI 1726 - 2019 concerning procedures for planning earthquake resistance for building and non-building structures. The purpose of the building structure assessment is to assess the existing building including the damage to the building, the quality of the concrete, the quality of the reinforcing steel and the analysis of the structure, useful for knowing the decrease in the strength of the building structure. This will affect the safety, health and security aspects of building operations.

1.1 Building Assessment

Building structure assessment is the activity of collecting, analyzing, and interpreting data or information to obtain an overview of the condition of the building structure. The main concern in building assessment activities is the safety of building occupants and maintenance of structural functions during the life of the building at a more affordable cost. Post-assessment recommendations are given to building owners in taking actions to be taken in the future [2].

In carrying out repairs and reinforcement of reinforced concrete structures in order to obtain optimal results, three stages are carried out, namely investigation, evaluation, and implementation. If the investigation stage is good, then it can carry out an evaluation correctly, as well as a correct evaluation, then the improvement and strengthening can achieve the set targets, then the implementation is good, then all the stages that have been carried out previously become meaningful [3]. In general, the inspection and assessment of reinforced concrete buildings will involve several activities: (1) Visual Survey and Damage Documentation, (2) Non-Destructive Test, and (3) Evaluation of Test Results, Analysis and Improvement Recommendations.

1.1.1. Visual Survey and Damage Documentation

Visual examination can be done with the naked eye or with aids such as a camera. The goal is to investigate defects in buildings in the form of porous, perforated, peeling, and so on. This activity is carried out mainly on structural elements that function to carry loads, both vertical loads and horizontal loads. In addition to the description of the building, the visual inspection must be accompanied by supporting documents such as photos and videos [4]. In order to facilitate the process of conducting the audit, it is recommended that the audit format be compiled in the form of a checklist. The checklist for these inspections can be seen in the Regulation of the Minister of Public Works No. 16 of 2010 concerning Technical Guidelines for Periodic Inspections of Buildings.

1.1.2. Non-Destructive Test

The Non-Destructive Test (NDT) test method is a test on building structures that is fast and does not damage the existing building. Besides that, NDT testing can help in saving building evaluation costs and reducing core concrete drilling in buildings [4].

1.1.3. Evaluation of Test Results, Analysis and Improvement Recommendations

Structural analysis in building assessment for structural evaluation based on resume data from investigations that have been carried out. The purpose of the structural analysis is to determine the actual

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capacity based on the regulations that have been set. In the analysis of the structure of the building used tools such as computers or laptops and structural analysis programs such as SAP2000. From the results of the structural analysis, the strength control of the structural elements will be carried out.

The results of the analysis will generally be the basis for the selection of improvements. This depends on the extent of the damage, ranging from architectural repairs to repairs to building elements. Generally, decision making for repairs includes the cost and time to carry out building repairs [4].

1.2 Building Damage Level

Damage to buildings is classified into three levels of damage [5], namely: light damage, moderate damage, heavy damage. Light damage is damage mainly to non-structural components, such as roof coverings, ceilings, floor coverings, and infill walls. The percentage rate of mild damage is less than 10%. Moderate damage is damage to some non-structural components or structural components such as roofs, floors, etc. The percentage rate of mold damage is in the range of ten to twenty (10-20) percent. Heavy damage is damage to most of the building components, structural and non-structural which after repair can still function properly. The percentage rate of severe damage is greater than 20%

1.3 Improvement Recommendations

The recommended activities for building repairs are as classified in fous categories: rehabilitation, renovation and restoration. The first category is rehabilitation, is an activity to repair partially damaged buildings without changing the function of the building. In rehabilitation activities, architectural components and building structures are maintained as before, while utility components may change. Renovation is an activity to repair a building that has been heavily damaged by changing or without changing the function of the building, both architecture, structure, and building utilities. The last categoru is restoration that is an activity to repair a partially damaged building by changing or without changing the function of the building, by maintaining the architecture of the building while the structure and utility of the building can change.

1.4 Building Load

The building load can be clasified in 4 categories: (1). Dead load, (2) Live load, (3) Earthquake Load (Equivalent Static Load) and (4) Wind Load. Dead load is a load that comes from the building's weight which always works throughout the life of the building. Self-weight includes columns, beams, floors, walls, and integral parts of the building [6]. in the other hand, live load is all loads resulting from the use of the building and including floor loads [7]. The dead loads and the Live loads used are as presented in the Table.1.

Table 1. Dead Load and live load in the building

Dead Load			Live Load		
reinforced concrete	2400	kg/m^3	Class Room	1.92	kN/m^2
Steel	7850	kg/m^3	Corridor	3.83	kN/m^2
ceramic floor covering	24	kg/m^2			
red brick masonry	250	kg/m^2			
MEP	25	kg/m^2			

Equivalent static load analysis is an analysis of the building structure which assumes that the horizontal static load is obtained from the influence of the response of earthquake vibrations. Equivalent static analysis is suitable for regular shaped buildings, the calculation of the nominal earthquake load can be assumed as an equivalent static earthquake load acting on the center of mass of the floors. According to the classification of regular and irregular buildings are divided into two configurations [8], namely: (a) Horizontal irregularity and (b) Horizontal irregularity. These configuration are presented in Figure 2.

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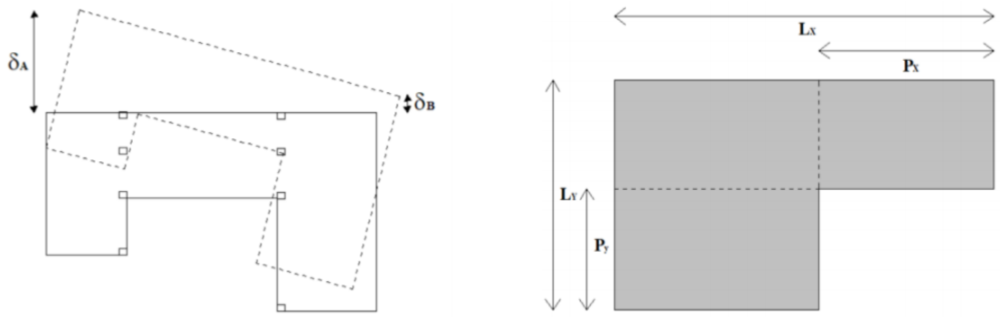
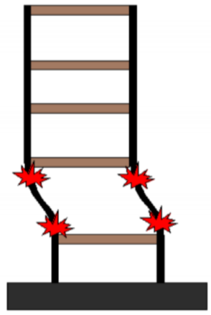


a. Horizontal Irregularity



b. Vertical Irregularity

Figure 2 The different configurations of building irregularity

The analysis of equivalent static earthquake loads according to SNI 1726-2019 for buildings is presented by Eq. 1 and Eq. 2

$$Fx = Cvx.V \quad \text{Eq. 1}$$

$$Cvx = \frac{w_{x.}\, h_x^k}{\sum_{i=1}^{n} w_i\, h_i^k} \quad \text{Eq. 2}$$

Where *Cvx* is vertical distribution factor, *V* is Total design lateral force or shear at the base of the structure (kN). The value of V can be calculated by the equation 3. Where *Cs* is Seismic response coefficient and *W* is Effective seismic weight. The last type of load is wind load. Wind load is all loads acting on a building or part of a building caused by differences in air pressure [7]. The minimum design wind load is 0.38 kN/m2 for the roof of the building

$$V = Cs.W \quad \text{Eq. 3}$$

In analyzing the safety factor of building structures, there are several combinations load can be analyzed by several equations presented in the Table 2.

Table 2. Loading Combination

No	Load Combination	Load
1	U = 1.4 DL	Dead (DL)
2	U = 1.2DL + 1.6 LL + 0.5 (L_r or R)	Live (LL)
3	U = 1.2DL + 1.6 (L_r or R) + (1.0 L or 0.5 W)	Rain (L_r atau R)
4	U = 1.2DL + 1.0 W + 1.0 L + 0.5 (L_r or R)	Wind (W)
5	U = 1.2DL +1.0 E + 1.0 L	Earthquake (E)
6	U = 0.9 DL + 1.0 W	Wind (W)
7	U = 0.9 DL + 1.0 E	Earthquake (E)

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2. Method

To research the structural assessment of the 28 Air Tawar Timur Elementary School in Padang, several stages of activities were carried out as follows: visual check, Collection of Drawing Data and Planning Data, Geometric, Testing the Quality of Materials and Materials Using the Non-Destructive Test Method and Building Structure Analysis. Visual observation can be done using the naked eye or with the help of tools such as cameras. This activity is useful for checking structural elements that are damaged such as cracks, peeling, corrosion, holes, and others. Collection of Drawing Data and Planning Data is useful for collecting data needed in the modeling and analysis of structures in buildings. In this study, there is no image data and planning data, so field data (conditions) are used as input in the analysis of building structures.

Regarding the absence of drawing data and planning data, to obtain information related to the existing condition of the building, direct measurements were carried out in the field using Total Station, Laser Distance Meter, meter, and other tools. The results obtained from this activity are building plans, beam dimensions, column dimensions, floor slab thickness, and floor plate deflection values. In this study, the quality of building concrete was obtained using the Schmidt Rebound Hammer. For the number and diameter of the installed reinforcement using the Rebar Locator and Calipers.

Analysis of the structure of the building is carried out with the help of a computer equipped with structural analysis software, namely the SAP2000 V16 Program. The model of the building structure uses data from the results of research in the field. The results of the analysis of the structure of the building will be checked for the strength of the column, beam, and slab elements using the special Moment Bearing Frame System method. An then the shear strength can be calcu;ated by Eq 5 until Eq 7. The values of nominal axial then calculated by expression 8.

$$\emptyset Mn = \emptyset . As . fy(d - \frac{a}{2}) \quad \text{Eq. 4}$$

$$\mathrm{Vn} = \mathrm{Vc} + \mathrm{Vs} \quad \text{Eq. 5}$$

$$Vc = \frac{1}{6}\sqrt{fc'} . bw . d \quad \text{Eq. 6}$$

$$\mathrm{Vs} = (\mathrm{Av.fy.d})/s \quad \text{Eq. 7}$$

$$\emptyset\,\mathrm{Pn} = 0{,}8.\ \emptyset.[\,0{,}85.\ \mathrm{Fc}\,(\mathrm{Ag} - \mathrm{Ast}) + \mathrm{fy}\ \mathrm{x}\ \mathrm{Ast}] \quad \text{Eq. 8}$$

Where *Mn* is nominal moment, *Ø* is reduction factor, *As* is Area of reinforcing steel, *Vn* is nominal shear strength, *Vc* is Shear strength of concrete section, *Vs* is Shear strength of stirrups, *fy* is yield stress of reinforcing steel, *Av* is Area of reinforcing steel ties, *d* Effective height, *s* is stirrup distance, *Pn* is nominal axial, *Ag* is Gross cross-sectional area of the column and the *Ast* is area of reinforcing steel.

3. Result and Discussion

3.1. Visual Observation

Based on visual inspection (visual check) it can be seen that certain structural elements have been damaged, such as dampness, cracks, and spalling which shows that the reinforcement has been corroded and broken stirrups are found. The percentage of damage that occurred in the column is 32 %, where the column is included in the category of heavily damaged which is greater than 20% [5].

a.

b.

Figure 3. a. Spalling on Columns, b. Broken stirrup

From the results of visual observations on beam components, it is known that some beams were damaged due to fine cracks, light spalling, joint damage, and corrosion. Based on observations, the percentage of beam damage is 20.35% where the beam is included in the heavily damaged category, which is greater than 20% [5].

a.

b.

Figure 4. a. Spalling On Beams, b. Cracks in Beams

The results of visual observations on the slab components, show that the condition of the slab looks bad. In almost every room in the school, the slabs were heavily spalled and exposed the reinforcing steel to corrosion. In addition, the school floor vibrates when carrying out activities. The percentage of damage that occurs to the slabs is 65%, where the slabs are categorized as heavily damaged, which is greater than 20% [5].

a.

b.

Figure 5. a-b. Spalling On Plate

3.2. Concrete Compressive Strength Test and earthquake analysis

The investigation esults of the hammer test data processing for the quality of the characteristic concrete are taken 80% based on PBI-1971 show that the estimated quality of the concrete is presented in the Table 3.

Table 3. Compressive strength

Section	Compressive strength	Unit
Column	20,60	MPa
Beam	22,23	MPa
Slab	23,43	MPa

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The type of earthquake load used in the analysis of building structures is static equivalent. The calculation is carried out based on the conditions that have been determined by SNI 1726-2019 so that the following results are obtained:

Table 4. Seismic Force Vertical Distribution

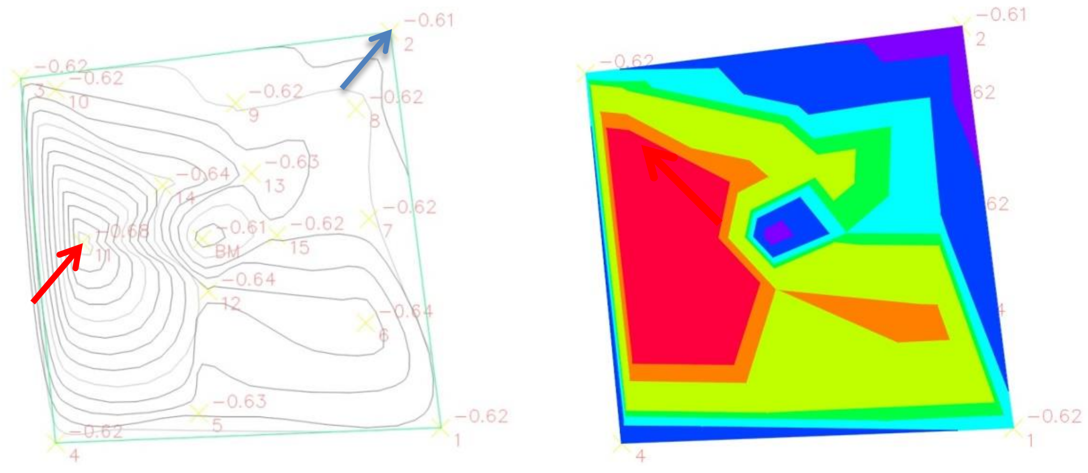
Floor	Height floor hi (m)	hi^k (m)	Weight Wi (kN)	Force $wi.hi^k$ (kN-m)	Lateral Fi x-y (kN)
2	6,8	6,800	663,3555	4510,817	206,1357
1	3,5	3,500	3223,989	10469,29	478,4267

3.3. Structure analysis and Slab Deflection

Based on the results obtained from the Total Station tool, the deflection of the slab is presented in Table 5. The maximum deflection occurs in Class V with a deflection value of 73 mm, which can be seen in Fig 6 and Figure 7. Analysis of the structure of the 28 Air Tawar Timur Padang Elementary School building assumes that the structure applied is a Special Moment Bearing Frame System using a gravity load model on beam elements and uniform load on floor slabs. The earthquake loading model on the building structure uses equivalent static analysis. The results of the structural analysis (output) are in the form of internal forces (axial force, shear force, and moment).

Table 5. Slab Deflection

No	Section	Slab Actual Deflection	Unit
1	Class III	38	mm
2	Class IV	35	mm
3	Class V	73	mm



a. b.

Figure 6. a-b. Floor Plate Maximum Deflection

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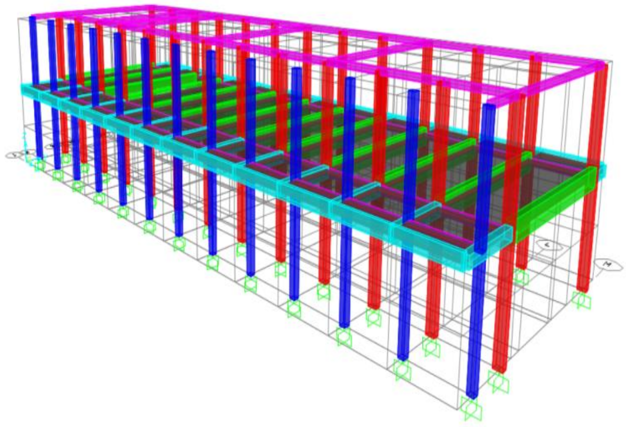

Figure 7 Building Structure Modeling

3.4. Evaluation of Structural Elements

Evaluation of structural strength is carried out to review the safety of the structure against the loads acting on the structure. Calculations include bending moment, shear force and axial force. Evaluation is carried out on the following components columns, beams and slab. The characteristics of components are presented in the Table 6 until Table 11.

Table 6. Column Axial Capacity

Type	Dimensions (mm)			Pu (kN)	Pn (kN)	Information
	b	h	d			
K1	250	350	300	254,053	889,7051	OK
K2	250	250	200	110,938	662,0751	OK

From the results of the calculation of the axial capacity of the column that has been analyzed. All columns are still within safe limits against loads acting on the building (Pn > Pu). From the calculation results, the actual deflection of the slab is greater than the allowable deflection of the slab, so the slab is in the category of unsafe against deflection. Based on the results of observations, field testing, and evaluation of the structure at the State Elementary School 28 Air Tawar Timur Padang which has been discussed previously. For safety, health, and comfort in the use of the school building, the recommendation for repair or maintenance of the selected building for this school building is the overall renovation of the building. Because the building has seen severe damage, the reinforcing steel found is plain and corroded. Currently, reinforced concrete requirements for buildings, especially in areas prone to earthquakes, already use deformed steel. For this reason, the overall renovation can be taken as a reference in the repair or maintenance of the 28 Air Tawar Timur Padang Elementary School building. Building renovation is an activity to repair a building that has been heavily damaged by changing or without changing the function of the building. The things that are taken into consideration in making recommendations for the repair or maintenance of the school building are as follows: Building Age. The age of the State Elementary School 28 Air Tawar Timur Padang is 39 (thirty-nine) years old. So that the age of the school building is almost close to the building period, which is 50 (fifty) years [9].

Table 7. Column Shear Capacity

Type	Dimensions (mm)			Vu (kN)	Vs (kN)	Information
	b	h	d			
K1	250	350	300	17,086	15,26	NOT OK
K2	250	250	200	5,918	10,17	OK

From the results of the calculation of the shear capacity of the column that has been analyzed. Column 1 (K1) is categorized as unsafe (Vs < Vu).

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Table 8. Bending Moment Capacity

Type	Dimensions (mm)			Mu (kNm)	Mn (kNm)	Information
	b	h	d			
B1	250	600	536	70,2372	131,621	OKE
B2	200	200	138	7,1011	12,0757	OKE
B3	250	350	286	18,1797	46,1125	OKE
B4	150	450	286	4,117	36,0249	OKE
Bring	150	200	138	28,1882	11,6083	NOT OK

Almost all beam components are categorized as safe against bending moments (Mn > Mu) except Ring Beams (BR). Depreciation referred to in this decision is the value of the decline in the building which is calculated equally every year during the life of the building and is calculated as a percentage. For permanent buildings, annual depreciation is 2% (two percent). Thus the depreciation that occurred in the building of the 28 Air Tawar Timur Elementary School in Padang was 88% (eighty-eight percent). So that the depreciation on the building is almost close to 100% (one hundred percent) [9].

Table 9. Shear Capacity

Type	Dimensions (mm)			Vu (kN)	Vs (kN)	Information
	b	h	d			
B1	250	600	536	60,34	36,35	NOT OK
B2	200	200	138	15,91	9,36	NOT OK
B3	250	350	286	16,06	19,40	OK
B4	150	450	286	8,4	26,32	OK
Bring	150	200	138	23,88	9,36	NOT OK

Almost all beam components are categorized as unsafe against shear forces (Vs < Vu) except for Beam 3 (B3) and Beam 4 (B4).

Table 10. Bending Moment Capacity

Slab	Dimensions (mm)		Mu (kN-m)	Mn (kN-m)	Information
	Lx	Ly			
X	2500	7150	6,8145	5,50	NOT OK
Y	2500	7150	17,267	5,50	NOT OK

The slab is included in the category of unsafe against bending moment (Mn < Mu).

Table 11. Permission deflection

Section	Dimensions (mm)		Actual deflection (mm)	Permission deflection (mm)	Information
	Lx	Ly			
Class III	2500	7150	38		NOT OK
Class IV	2500	7150	35	18,9	NOT OK
Class V	2500	7150	73		NOT OK

The building of State Elementary School 28 Air Tawar Timur Padang is included in the heavy category of damage, where all structural and non-structural elements that are reviewed are included in the heavy category, which is greater than 20%. From the results of the evaluation of the analysis of building structures that have been carried out, almost all structural elements are not included in the safe category against bending moments, shear forces, and axial forces except for Beams 3, 4, and Columns 2. In addition, the actual deflection value of the floor slab is in classes III, IV, and V are 38 mm, 35 mm, and 73 mm, greater than the allowable deflection of 18.9 mm.

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4. Conclusion

Based on the research and data analysis that has been carried out, it can be concluded that the State Elementary School 28 Air Tawar Timur Padang from visual observations is included in the category of heavy damaged, which is greater than 20%. From the results of the structural evaluation, almost all structural components are categorized as unsafe except for Beams 3, Beams 4, and Columns 2. The actual deflection of the slabs exceeds the allowable deflection of the floor slabs. So the recommendation for building repair or maintenance is the overall renovation of the building.

References

[1] P. Indonesia, “Bangunan Gedung,” *Undang. Republik Indonesia. Nomor 28 Tahun 2002 tentang Bangunan Gedung*, no. 1, pp. 1–5, 2002

[2] H. Erndahl. *Repair and maintenance of concrete structures. Decisions and requirements for repair - a review. no. April 2004*, 2014.

[3] M. D. Astawa. *STRUKTUR BETON FIBER (Bagian Materi Sruktur Beton I)*. Surabaya, 2016.

[4] E. Juliafad. *Investigasi Kerusakan Pada Bangunan Beton Bertulang*. Depok: *PT Raja Grafindo Persada*, 2020.

[5] M. P. Umum. *Peraturan Menteri Pekerjaan Umum Nomor 16 Tahun 2010 Tentang Pedoman Teknis Pemeriksaan Berkala Bangunan Gedung*. 2010.

[6] Departemen Pekerjaan Umum. *Pedoman Perencanaan Pembebanan Untuk Rumah dan Gedung*. Jakarta, 1987.

[7] Badan Standardisasi Nasional. *Beban desain minimum dan kriteria terkait untuk bangunan gedung dan struktur lain (SNI 1727:2020)*. Jakarta: *BSN*, 2020.

[8] Badan Standardisasi Nasional. *Tata Cara Perencanaan Ketahanan Gempa Untuk Bangunan Gedung dan Nongedung (SNI 1726:2019).* Jakarta: *BSN*, 2019.

[9] P. Indonesia. *Peraturan Pemerintah Republik Indonesia Nomor 16 Tahun 2021 Tentang Peraturan Pelaksanaan Undang-Undang No 28 Tahun 2002 Tentang Bangunan Gedung.* 2021.

[10] P. Y. Putri. *Analisis Struktur Dan Perencanaan Kontruksi Menggunakan SAP2000 Tentang Bangunan Gedung. Padang*: *UNP Press*, 2018.