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Evaluation of Floor Plates in the Bima City Regional General Hospital Building

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Abstract: *Floor slabs are the main structural elements that withstand the gravitational load of multi-storey buildings. This study aims to evaluate the deflection of the roof floor plate of the Bima City Regional General Hospital (RSUD) building to ensure the safety and adequacy of the structure based on service requirements. The analysis was performed numerically using SAP2000 v22 software with Shell-Thin elements. Structural data includes 8 m × 8 m slabs, 120 mm thick, concrete quality f'c = 25 MPa, fy steel quality = 420 MPa, and two-layer D10-150 reinforcement. Loading refers to SNI 1727:2020 and PPIUG 1983, with a total dead load of 4.16 kN/m² and a live load of 0.96 kN/m². The permissible deflection is calculated based on SNI 2847:2019 as δ_allow = L/240 = 33.33 mm. The results of the SAP2000 analysis showed a maximum deflection of 3.08 mm, which was far below the permissible limit, so that the roof floor plate of the Bima City Hospital was declared safe and met the requirements of the service limit country.*

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INTRODUCTION

Multi-storey buildings for healthcare facilities such as hospitals require stricter structural design standards compared to public buildings, given their critical functions and high-intensity use 24 hours a day (Fageer 2023). As the main horizontal element, the floor plate receives gravitational loads directly, so its deflection behavior is an important indicator in assessing structural adequacy (Study et al. 2022).

Excessive deflection of the floor plate can cause damage to non-structural elements such as ceilings and mechanical-electrical installations, as well as cause discomfort to building occupants (Indarta, Jokowi, and Ratnaningsih 2025). In the context of hospitals, this condition has the potential to interfere with the operation of medical devices that are sensitive to vibration and deformation (Mas 2021). Therefore, the evaluation of floor plate deflection is an important step in ensuring the quality of the structure of a healthcare building. (Lestari 2021)

The Bima City Hospital Building is a public health service facility located in Bima City, West Nusa Tenggara (Zengin and Usta 2021). The building consists of several floors, with the roof plate of the 4th floor as the object of research. Given the vital function of buildings as public health facilities, periodic structural evaluations are an urgent need to ensure that structural reliability continues to be met (Dewi and Mayanti 2021).

Several previous studies have evaluated floor plate deflection in various types of buildings, such as educational buildings (Lestari 2021; Dewi and Mayanti 2021) and storage buildings (Study et al. 2022). However, evaluations of floor plate deflection in hospital buildings, which have stricter operational requirements due to the sensitivity of medical equipment to vibration and deformation, are still relatively limited in publication, especially for regional health facilities outside major cities. This

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study seeks to fill this gap by evaluating the roof floor plate of the Bima City Hospital using a combination of numerical analysis of elements up to (SAP2000) and manual verification based on the Branson equation, so that the results of numerical analysis can be cross-validated with conventional analytical approaches.

The analysis in this study refers to SNI 2847:2019 (Building Structural Concrete Requirements), SNI 1727:2020 (Minimum Design Load), and PPIUG 1983 as a loading reference (Istiono and Septiarsilia 2023). Numerical analysis using SAP2000 v22 is used to obtain the distribution of moment details and deflections. (Prayogo and Harsono 2020) The permissible deflection is determined based on the provisions of SNI 2847:2019 Table 24.2.2.

The objectives of this study are: (1) to calculate the dead load and living load working on the roof floor slab of the Bima City Hospital; (2) determine the deflection that is allowed in accordance with SNI 2847:2019; (3) to obtain the actual plate deflection value through SAP2000 analysis; and (4) to evaluate whether the resulting deflection remains within the specified permissible limits so that the plate can be declared safe.

RESEARCH METHOD

Location and Object of Research

This research was conducted in the Bima City Hospital building located in Bima City, West Nusa Tenggara Province. The object of the research is the 4th floor roof slab, a bidirectional plate with span dimensions of 8 m × 8 m. Primary data collection includes structural element dimensions, material quality, and loading data obtained from original design documents and field observations.

Structural Data

The structural parameters of the plates used in the analysis are summarized in Table 1 below.

Table 1. Structural Parameters of Roof Floor Plates of Bima City Hospital

Parameters	Value	Units
Range dimensions	8 × 8	m
Plate thickness (h)	120	mm
Concrete quality (f'c)	25	MPa
Steel quality (fy)	420	MPa
Key reinforcement	D10-150	—
Number of layers	2 (top-down)	—
Concrete cover	20	mm

Loading

Loading is calculated based on SNI 1727:2020 and PPIUG 1983. Die loads include self-weight of plates, mortar coatings, sand filling, ceilings and hangers, as well as mechanical-electrical installations. (Science 2019) The living load is taken according to the function of the space as the roof area of the hospital. Loading details are presented in Table 2.

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Table 2. Roofing Floor Plate Loading Recapitulation

Load Components	Load (kN/m²)	Description
Self-heavy plates	2.88	0.12 m × 24 kN/m³
Layer of mortar (t = 3 cm)	0.42	0.03 m × 14 kN/m³
Sand content (t = 3 cm)	0.48	0.03 m × 16 kN/m³
Ceiling & hangings	0.18	PPIUG 1983
Electrical Mechanic	0.20	—
Total Dead Load (qD)	4.16	—
Direct Load (qL)	0.96	SNI 1727:2020
Total Service Load (qD + qL)	5.12	For deflection analysis
Load Factor (1.2D+1.6L)	6.53	For strength analysis

Stages of Analysis

The analysis was carried out in three main stages: (1) calculation of permissible deflection based on SNI 2847:2019 using the formula δ_allow = L/240; (2) modeling of elements up from bidirectional plates using SAP2000 v22 with Shell-Thin elements and mesh size of 0.5 m × 0.5 m to obtain actual deflection; and (3) evaluation comparing actual deflection with permissible deflection to determine the structural adequacy of the plate. (Hernandi et al. 2020) The load combination used refers to SNI 1727:2020, which is a combination of service load (1.0D + 1.0L) for deflection analysis and a factored load combination (1.2D + 1.6L) for force analysis. The mesh size of 0.5 m × 0.5 m was chosen to achieve a balance between yield accuracy and computational efficiency, given that this size has been commonly used in the study of elements up to the same for bidirectional plates with similar span ranges.

RESULTS AND DISCUSSION

Theoretical basis of plate deflection

Deflection on reinforced concrete slabs is divided into direct deflection, which occurs immediately after loading, and long-term deflection, which increases due to creep and shrinkage of concrete (Subagio, Putra 2021). The study focuses on direct deflection, which is a key reference in service boundary status checks. (Nabiilah, Azizi, and Wibowo 2025)

SNI 2847:2019 Article 24.2 regulates the permissible deflection limits for reinforced concrete slab elements (Arthquakes, Aya, and Alimantan 2021). For elements that do not support, or are not connected to, partitions that are susceptible to damage due to excessive deflection, the allowable deflection limit is set as:

$$\delta_allow = L / 240$$

where L is the clear span of the plate (mm). This provision is based on considerations of the comfort of building occupants and the prevention of damage to non-structural elements due to excessive deformation (Science 2019).

Deflection on bidirectional slabs is affected by several key factors, including: workload intensity, slab span dimensions and ratios, slab thickness, concrete elastic modulus, and buffer conditions on all four sides of slabs (Amando and Alo 2024). The greater the bending stiffness of the plate (Ec and h functions), the smaller the deflection produced (Lestari 2021).

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Permissible deflection calculation

The permissible deflection is calculated based on SNI 2847:2019 Table 24.2.2, using the clear span of the plate as a reference. The plate span data used is L = 8 m = 8,000 mm.

Table 3. Calculation of Permissible Deflection Based on SNI 2847:2019

No.	Description	Results
1	Plate Range (L)	L = 8.000 mm
2	SNI 2847:2019 Provisions Article 24.2	δ_allow = L / 240
3	Allowable deflection calculation	δ_allow = 8.000 / 240
4	Maximum deflection allowed	δ_allow = 33.33 mm

Based on the calculations above, the maximum deflection allowed for the roof plate of the 4th floor of the Bima City Hospital with a span of 8 m is 33.33 mm. This value is the upper limit that must not be exceeded by the actual plate deflection in order for the structure to be declared safe from the point of view of serviceability (Kalib and Shewalul 2021).

SAP2000 modeling

Up element models are created using SAP2000 v22 with the following specifications: (a) Shell-Thin elements are used to represent bidirectional plate behavior; (b) a mesh size of 0.5 m × 0.5 m produces 256 elements in one panel of plates; (c) the support condition on all four sides of the plate is assumed to be simply supported, in accordance with the configuration of the support beams in the original structure design document; (d) the load is applied as a uniform load across the entire plate surface with a service load value qD + qL = 5.12 kN/m². (Beam, Physical, and Analysis 2022).

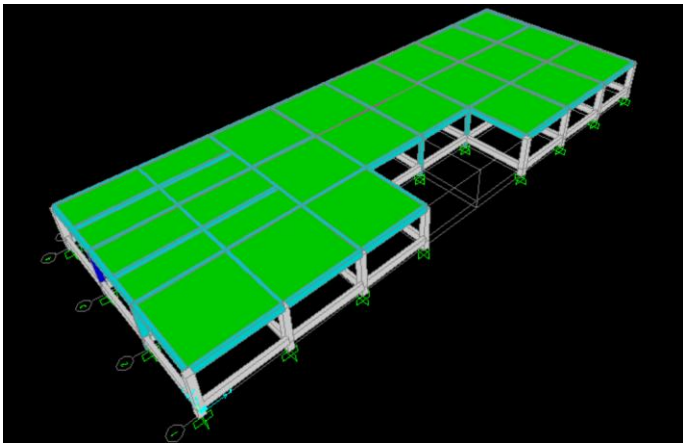

Figure 1. 3D view of floor slab model in SAP2000

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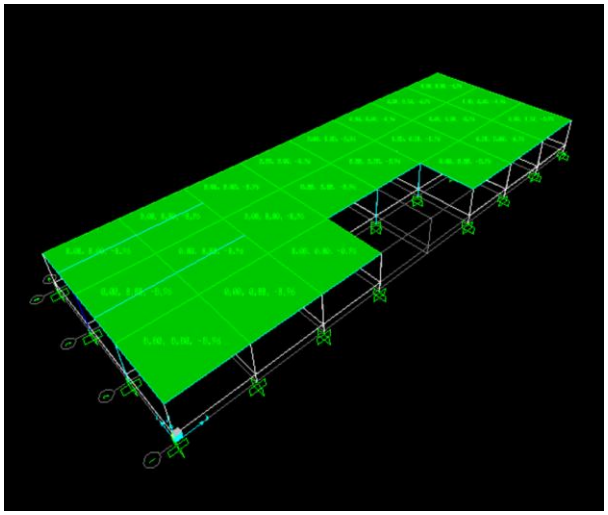
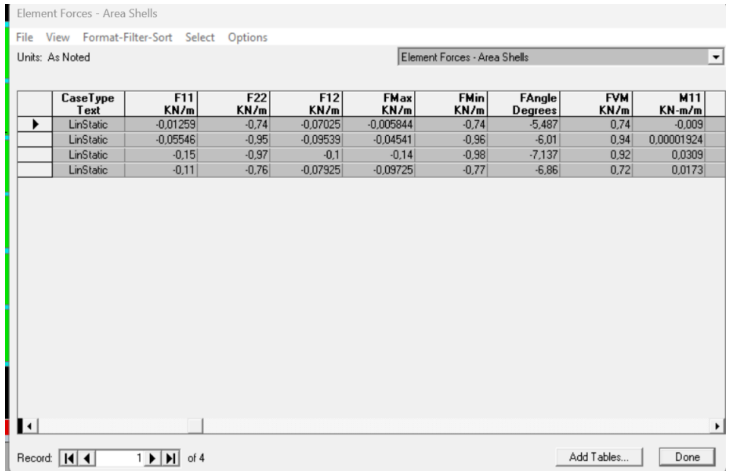


Figure 2. Application of uniform loads in SAP2000 models

SAP2000 Analysis Results

After running the model, the output is obtained in the form of moment distribution, shear force, and vertical deflection for all plate elements. The main result used in the evaluation was the maximum deflection value at the midpoint of the plate (Pratama 2025).

a) M11 Moment Distribution



CaseType Text	F11 KN/m	F22 KN/m	F12 KN/m	FMax KN/m	FMin KN/m	FAngle Degrees	FVM KN/m	M11 KN-m/m
LinStatic	-0,01259	-0,74	-0,07025	-0,005844	-0,74	-5,487	0,74	-0,009
LinStatic	-0,05546	-0,95	-0,09539	-0,04541	-0,96	-6,01	0,94	0,00001924
LinStatic	-0,15	-0,97	-0,1	-0,14	-0,98	-7,137	0,92	0,0309
LinStatic	-0,11	-0,76	-0,07925	-0,09725	-0,77	-6,86	0,72	0,0173

Figure 3. M11 Moment Contour Obtained from SAP2000 Analysis

The contour of the M11 moment (bending moment in the direction of X) shows the value of the maximum moment that occurs at the mid-range and gradually decreases towards the buffer. This pattern is consistent with the theoretical behavior of the two-way plate supported on all four sides.

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b) Vertical Deflection Distribution

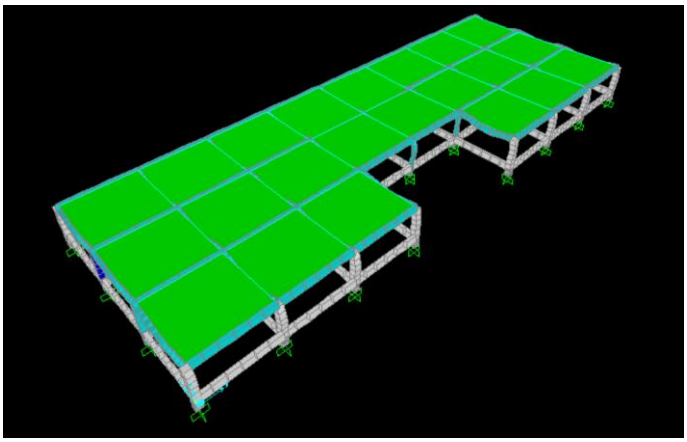

Figure 4. Vertical Deflection Contours Obtained from SAP2000 Analysis

The contour of vertical deflection shows the maximum deflection that occurs at the midpoint of the plate and decreases symmetrically towards the supports on all four sides. This deflection distribution is consistent with the moment distribution formed in the model.

Table 4. Recapitulation of SAP2000 Analysis Results

Results Parameters	Value	Units	Description
M11 maximum moment	36.80	kN · m/m	Mid-range
Maximum moment M22	36.80	kN · m/m	Mid-range
V13 maximum shear force	19.52	kN/m	On support
Maximum deflection	3.08	mm	Plate midpoint

Evaluation of Deflection Against the Permissible Limit of SNI 2847:2019

The evaluation was carried out by comparing the actual deflection of the SAP2000 results with the deflection that is allowed to be calculated based on SNI 2847:2019. (Ariyanto 2020) The results of the comparison are presented in Table 5.

Table 5. Evaluation of plate deflection against the limits allowed by SNI 2847:2019

Parameters	Value (mm)	Permissible Limit (mm)	Description
Deflection allowed (δ_allow)	33.33	—	SNI 2847:2019 L/240
SAP2000 deflection (δ_actual)	3.08	33.33	SAFE
δ_actual / δ_allow ratio	0.092	≤ 1.000	9.24% of the permissible limit

Based on Table 5, the maximum deflection from the analysis of SAP2000 3.08 mm only reached 9.24% of the permissible deflection of 33.33 mm. This very large margin (30.25 mm) shows that the roof floor plate of the Bima City Hospital has a very adequate stiffness reserve (Ravasini et al. 2023).

Manual Verification of Deflection Calculation

As an additional verification of the results of the numerical analysis, the deflection of the plate was also calculated manually using the effective moment of inertia approach based on the Branson equation, as adopted in SNI 2847:2019:

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$$I_e = (M_{cr}/M_a)^3 I_g + [1 - (M_{cr}/M_a)^3] I_{cr}$$

with a moment of cracking M_cr = 7.44 kNm and a factored moment in the middle of the span M_a = 36.80 kNm (value M11 of the results of the SAP2000 in Table 4), so that:

$$M_{cr}/M_a = 7.44 / 36.80 = 0.202$$

$$(M_{cr}/M_a)^3 = (0.202)^3 = 0.00824$$

The gross moment of inertia of the cross-sectional (I_g) is calculated using the effective width b = 1,000 mm and the thickness of the plate h = 120 mm:

$$I_g = b \cdot h^3 / 12 = 1{,}000(120)^3 / 12 = 144{,}000{,}000 \text{ mm}^4$$

Meanwhile, the moment of cross-sectional fracture inertia (I_cr) was obtained as I_cr = 23,203,632 mm^4. By substituting these values for the Branson equation, effective inertia is obtained:

$$I_e = (0.00824)(144{,}000{,}000) + (1 - 0.00824)(23{,}203{,}632)$$

$$I_e = 1{,}186{,}560 + 22{,}017{,}072 = 23{,}203{,}632 \text{ mm}^4$$

The I_e value is then used to calculate plate deflection with a simple elastic plate theory approach:

$$\delta = (5/384) \times qL^4 / (E_c I_e)$$

with a load factored q = 6.53 kN/m^2 = 6.53 N/mm, plate span L = 8 m = 8,000 mm, the modulus of elasticity of concrete E_c = 23,500 MPa, and I_e = 23,203,632 mm^4, so that:

$$\delta = (5/384) \times [6.53(8.000)^4 / (23.500 \times 23.203.632)] \approx 6.37 \text{ mm}$$

Permit deflection based on SNI 2847:2019 Article 24.2 is calculated as:

$$\delta_{izin} = L / 240 = 8{,}000 / 240 = 33.33 \text{ mm}$$

Since δ_aktual = 6.37 mm is smaller than δ_izin = 33.33 mm (6.37 mm smaller than 33.33 mm), the results of this manual calculation also confirm that the roof floor plate meets the deflection requirements and is declared safe. This value is slightly larger than the results of the SAP2000 numerical analysis (3.08 mm), with a ratio of about 2.07 times. This difference is technically reasonable, given that manual calculations use a simpler one-way plate approach and have not fully taken into account the effects of two-way stiffness as captured by the Shell-Thin element in SAP2000. Nevertheless, both the manual result (6.37 mm) and the numerical result (3.08 mm) remained well below the permissible deflection limit of 33.33 mm, so the conclusion that the roof floor plate was declared safe remained unchanged.

Compared to the results of Amando and Alo (2024), which reported a difference of 3.44% between the deflection value of the manual calculation based on SNI 2847:2019 and the results of numerical modeling using Abaqus CAE on floor plates without child beams, the difference of 2.07 times between the manual results and the results of the SAP2000 in this study was relatively larger. This difference is likely due to the manual approach in this study that simplifies the behavior of the plate as a one-way, while the Abaqus CAE in the comparative study also models the bidirectional

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behavior more closely to the actual condition. These findings are in line with the notes of Ravasini et al. (2023), who emphasize that conventional analytical approaches tend to provide more conservative deflection estimates than elemental models due to limitations in capturing moment redistribution on bidirectional plates.

The small actual deflection value can be explained by several technical factors: (1) the ratio of range to plate thickness L/h = 8000/120 = 66.7, which results in high bending stiffness; (2) the two-layer D10-150 reinforcement configuration, which provides an adequate moment of inertia of the part; and (3) concrete quality f'c = 25 MPa, which results in the modulus of elasticity Ec = 4700√25 = 23,500 MPa.

The results of this evaluation confirm that the initial design of the floor plate of the Bima City Hospital was planned conservatively and met structural safety requirements. This condition is particularly suitable for healthcare facility buildings, which demand high reliability and operational continuity without disruption free from structural deformation (Kumar et al. 2021).

CONCLUSION

Based on the analysis and evaluation carried out, it can be concluded that the total dead load working on the roof plate on the fourth floor of the Bima City Hospital is 4.16 kN/m², which consists of the weight plate itself, screed mortar, sand filling, ceiling and hanger, and mechanical-electrical installation. In addition, the live load based on SNI 1727:2020 is 0.96 kN/m², so the total service load is 5.12 kN/m². Based on SNI 2847:2019, the maximum deflection allowed for a plate span of 8 m is 33.33 mm. Analysis of SAP2000 v22 shows that the maximum deflection of the plate is 3.08 mm, occurring in the middle of the plate span. This value is significantly lower than the permissible limit, representing only 9.24% of the permissible deflection. Therefore, the roof floor plate of the Bima City Hospital meets the service requirements specified in SNI 2847:2019 and can be considered structurally safe under the conditions of applied loading. Periodic structural evaluations are recommended, especially when there is a change in the function of the building or additional loads due to the installation of medical equipment, to ensure the safety and continued performance of the structure.

The results of this study provide practical implications that the initial design of the roof floor plate of the Bima City Hospital has a considerable stiffness reserve, so that it has the potential to accommodate the limited additional load of medical equipment in the future without the need for additional structural reinforcement. However, the study has some limitations: the evaluation is focused only on immediate deflection without taking into account the long-term effects of deflection due to concrete crawling and shrinkage, and the validation of the numerical analysis results has not been supported by direct field load testing (in-situ load test). Further research covering both aspects is recommended to strengthen the reliability of the results of this evaluation.

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