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Evaluation of Reinforced Concrete Structural Design of the Bengkalis State Polytechnic Rectorate Building against Vertical Load Performance Based on Indonesian National Standards (SNI)

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ABSTRACT

This study evaluates the reinforced concrete (RC) structural design of the Bengkalis State Polytechnic Rectorate Building, with a particular focus on its performance under vertical loads an aspect that has been rarely addressed for educational buildings in Indonesia. Structural analysis was conducted based on Indonesian National Standards (SNI 1727:2020, SNI 2847:2019, and SNI 1726:2019). Dead and live loads were determined according to building functions, and the factored load combination (1.2DL + 1.6LL) was applied. The total design vertical load was found to be approximately 12,255 kN. Verification of structural members demonstrated that all reinforced concrete elements including beams, columns, and slabs satisfied both ultimate strength and serviceability requirements, with demand-to-capacity ratios (DCR) well below unity. Columns showed significant reserve strength, while beams and slabs met flexural and deflection criteria. These results confirm that the RC structural design of the rectorate building is safe and reliable under vertical loading conditions. The study contributes to the limited literature on vertical load assessment for Indonesian educational facilities and recommends that future research include seismic and lateral load analysis due to the country's high seismicity.

Keywords : *Reinforced Concrete, Structural Design, Vertical Load Performance, Demand-to-Capacity Ratio, Bengkalis State Polytechnic*

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INTRODUCTION

Reinforced concrete (RC) has become the backbone of modern civil engineering due to its versatility, durability, and cost efficiency. As a composite material, RC combines the high compressive strength of concrete with the excellent tensile resistance of steel reinforcement, forming a reliable structural system for multistory buildings, bridges, and critical infrastructure (Mahmood et al., 2021). Its widespread adoption is also supported by the ability to adapt design to various architectural and functional requirements. In public buildings such as universities, offices, and rectorate buildings, reinforced concrete not only ensures structural stability but also provides long-term service life, essential for supporting the continuous operation of institutional facilities (Blazy & Blazy, 2021).

The structural design of RC is generally guided by the limit state design approach, which requires verification against two critical conditions: the ultimate limit state (ULS) to prevent collapse under extreme loading, and the serviceability limit state (SLS) to maintain user comfort and durability during normal operation. Adherence to these design philosophies has proven crucial in mitigating risks of overloading and progressive failure in multistory structures (Ho, Le, & Nguyen, 2022). In Indonesia, the application of reinforced concrete design is governed by the Indonesian National Standards (SNI), which provide guidelines for loads (SNI 1727:2020), structural concrete design (SNI 2847:2019), and seismic resistance (SNI 1726:2019). These regulations are largely aligned with the ACI code provisions and ensure that structures are safe and reliable under both vertical and lateral load conditions, but verification of their actual performance remains an essential step to guarantee compliance.

The evaluation of vertical load performance is particularly significant because vertical loads comprising dead loads from structural and non-structural components, and live loads from occupants and furnishings are continuously imposed throughout the building's service life. Failure to accommodate these loads may result in long-term deflections, cracking, or even structural collapse, especially in multistory buildings where cumulative loads are substantial (Isufi et al., 2022) .Research has shown that insufficient attention to vertical load performance can compromise the structural integrity of RC buildings, making systematic evaluation and recalibration of design parameters necessary (Ebadi-Jamkhaneh et al., 2024). Furthermore, the importance of performance evaluation and strengthening as strategies to prevent premature degradation in RC buildings has been emphasized, highlighting that design verification against both service and ultimate states is a prerequisite for structural safety (Erdem & Karal, 2022).

Several recent studies have introduced advanced methodologies to evaluate RC structures. Probabilistic models, for instance, allow engineers to assess failure probabilities of structural members more accurately, incorporating uncertainties in material strength, geometry, and applied loads (Wang, Zhang, Li, & Yu, 2025) . Experimental works on innovative reinforcement strategies have demonstrated significant improvements in load resistance and energy dissipation capacity, which can be directly related to vertical load performance (Aksoylu, Özkılıç, & Arslan, 2022). Moreover, research into retrofitting strategies for existing RC buildings highlights the crucial role of floor systems in redistributing loads and enhancing sustainability during interventions (Vona et al., 2024). Despite these developments, most studies have primarily focused on seismic or lateral load evaluation, leaving a gap in the systematic assessment of vertical load performance, particularly for institutional buildings in developing regions such as Indonesia (Rajasekaran et al., 2024).

Considering these gaps, this study aims to evaluate the reinforced concrete structural design of the Bengkalis State Polytechnic Rectorate Building, with a particular focus on its vertical load performance. The building, designed as a three-story RC structure, serves as the administrative center of the institution, making its safety and reliability a top priority. Using SNI standards as the primary benchmark, this study examines whether the reinforced concrete elements beams, columns, slabs, and foundations meet both ultimate and serviceability requirements under vertical load conditions. By integrating data from the project's structural design with contemporary evaluation methods, the study contributes to a more comprehensive understanding of RC building performance in the Indonesian context. Furthermore, it offers practical insights for engineers and policymakers in ensuring the safety, resilience, and sustainability of future educational infrastructure.

METHODS

1. Research Design

This study adopts a quantitative engineering evaluation approach, focusing on the verification of the reinforced concrete (RC) structural design of the Bengkalis State Polytechnic Rectorate Building under vertical load conditions. The research relies on secondary data obtained from project documentation, including architectural drawings, structural drawings, technical specifications, and material test results. The design evaluation was conducted in accordance with the Indonesian National Standards (SNI), specifically SNI 1727:2020 for minimum load requirements, SNI 2847:2019 for reinforced concrete structures, and SNI 1726:2019 for seismic design considerations. The methodological framework consists of three main stages: (1) data collection and identification of structural elements, (2) load calculation and load combination, and (3) structural analysis and verification against design criteria.

2. Data Source

The primary source of data is the official design documentation of the Rectorate Building of Bengkalis State Polytechnic, which includes technical details of the building's structure. According to the project data, the building is a three-story reinforced concrete structure with a total area of approximately 1,763 m^2 and a building height of ±12 meters. The structural system consists of bore pile foundations, tie beams, reinforced concrete columns, beams, slabs, and a reinforced concrete roof (dak beton). The compressive strength of concrete ($f'c$) specified for structural elements, such as columns, beams, and slabs, is 22.83 MPa, while the reinforcement includes plain bars (Ø) and deformed bars (D13, D16, D19). These parameters serve as the baseline for the structural evaluation.

3. Load Calculation

The loads considered in this study follow the classification of SNI 1727:2020, which distinguishes between dead load (*Dead load*) and live load (L*ive load*).

a. **Dead Load (DL):**
Dead load consists of the self-weight of structural elements, including beams, columns, slabs, and foundations, as well as non-structural components such as walls, finishes, and roofing. Unit weights of concrete (24 kN/m^3), masonry, and other materials are taken from SNI provisions and adjusted according to project specifications.

b. **Live Load (LL):**
Live load is applied based on the function of the building. As an administrative office (rectorate building), the live load is taken as 3.0 kN/m^2 for office areas and corridors, as specified by SNI 1727:2020. Additional concentrated loads from furniture and equipment are considered where relevant.

c. **Load Combinations:**

Load combinations are determined in accordance with SNI 2847:2019, which uses a strength design method (ultimate load). This approach accounts for worst-case loading scenarios. The standard prescribes several combinations, including:

1) $1.2D + 1.6L$ (1)
2) $1.2D + 1.6L + 0.5\,(Lr\ or\ S\ or\ R)$ (2)

Here, D represents dead load, L is live load, and the term in parentheses represents roof live load (Lr), snow load (S), or rain load (R). These factors are applied to ensure that the structure's design strength is greater than the required strength for the expected loads.

4. Structural Modeling and Analysis

The structural analysis was carried out based on the official design documentation and relevant provisions of the Indonesian National Standards (SNI) to evaluate load distribution and assess performance under vertical loading. Beams and columns were considered as frame elements to capture axial forces, shear forces, and bending moments, while slabs were treated as two-way systems for load distribution. Boundary conditions were defined according to the bore pile foundation system to simulate load transfer from the superstructure to the soil realistically. The structural evaluation focused on four main components: (a) beams, which were verified for flexural capacity (Mn) and shear capacity (Vn) against applied factored loads; (b) columns, which were evaluated for axial load capacity (Pn) with consideration of slenderness effects; (c) slabs, which were checked for adequacy of thickness, deflection control, and reinforcement requirements.

5. Verification Against Standards

The verification process compared the calculated capacities of structural members with factored applied loads using the safety criteria established in SNI 2847:2019. For each structural element, the demand-to-capacity ratio (DCR) was calculated, where a DCR ≤ 1.0 indicates adequacy under vertical load conditions. In addition, serviceability checks for deflection and crack width were conducted to confirm that the structure meets user comfort and long-term durability requirements.

6. Limitations of the Study

The scope of this study is limited to the evaluation of vertical load performance. Lateral loads such as wind and seismic forces, although highly relevant in the Indonesian context, are not addressed in detail. The primary focus of this paper is to examine the adequacy of reinforced concrete structural design under vertical load conditions, ensuring compliance with the applicable SNI standards.

RESULTS

1. Dead Load (DL) Estimation

Dead loads were calculated based on the self-weight of reinforced concrete and non-structural components. The unit weight of reinforced concrete was assumed to be 24 kN/m^3, in accordance with SNI 1727:2020. Table 1 summarizes the estimated dead loads for primary structural elements.

Table 1. Dead Load Estimation of Main Structural Components

Structural Element	Dimensions (example)	Volume (m^3)	Unit Weight (kN/m^3)	Dead Load (kN)
Slab (thickness 120 mm, area 475.9 m^2 per floor)	0.12 × 475.9	57.11	24	1,370.6
Beam B1 (30×60 cm, L=6 m, 20 pcs)	0.18 × 6 × 20	21.6	24	518.4
Column K1 (50×50 cm, H=4 m, 16 pcs)	0.25 × 4 × 16	16.0	24	384.0
Stairs (3.06 m^3 total)	–	3.06	24	73.4
Roof slab (thickness 120 mm, area 475.9 m^2)	0.12 × 475.9	57.11	24	1,370.6
Total Dead Load	**–**	**–**	**–**	**3,716.9 kN**

(Source: dimensions derived from project drawings, RAB tables, and structural data in the Bengkalis Rectorate Project Report).

2. Live Load (LL) Estimation

Live loads were determined based on SNI 1727:2020 for office buildings, where 3.0 kN/m^2 is specified for working areas. Table 2 presents the calculation results.

Table 2. Live Load Estimation

Floor	Floor Area (m^2)	Live Load (kN/m^2)	Total Load (kN)
First floor	475.9	3.0	1,427.7
Second floor	475.9	3.0	1,427.7
Third floor	475.9	3.0	1,427.7
Roof	475.9	1.5	713.9
Total Live Load	**1,903.6**	**–**	**4,997.0 kN**

3. Load Combination

Following SNI 2847:2019, the critical load combination for vertical loads is:

$$U = 1.2\,DL + 1.6\,LL \tag{3}$$

Applying this:

$$U = 1.2 \times 3{,}716.9 + 1.6 \times 4{,}997.0$$
$$U = 4{,}460.3 + 7{,}995.2$$
$$U \approx 12{,}455.5\ kN$$

Thus, the design factored vertical load demand on the building is approximately 12,455.5 kN.

4. Structural Capacity Check

Structural capacities of beams, columns, and slabs were verified based on cross-sectional properties, reinforcement details, and material strengths in accordance with SNI 2847:2019 (equivalent to ACI 318-19). Strength reduction factors (ϕ) were applied to nominal capacities as follows: $\phi = 0.90$ for flexure (beams and slabs), $\phi = 0.75$ for shear, and $\phi = 0.65$ for axial compression in tied columns.

a. Columns (50×50 cm, f'c = 22.83 MPa, 8D16 reinforcement):

The reinforced concrete columns, measuring 50 × 50 cm with a concrete compressive strength of 22.83 MPa and 8D16 longitudinal reinforcement, were analyzed for axial capacity. Based on Equation (4), the nominal axial load capacity $P_n = 0.85 f_c' (A_g - A_s) + f_y A_s$ (4)

Produced a value of 5,463.56 kN. After applying the strength reduction factor (ϕ = 0.65) for tied columns, the design axial strength was 3,551.31 kN. When compared with the factored axial load $P_u = 450 kN$, the ratio $\frac{\phi P_n}{P_u} = 7.89$ indicated a high level of safety and sufficient column capacity to resist the applied loads.

b. Beams (30×60 cm, span 6 m, *f'c* = 22.83 MPa, 4D19 reinforcement):

For the beams with dimensions of 30 × 60 cm, a span length of 6 m, concrete strength of 22.83 MPa, and 4D19 tensile reinforcement, the flexural capacity was determined using Equations (5)–(6). The effective depth (d) was 550 mm, and the equivalent stress block parameter $a$was calculated as 77.92 mm.

The resulting nominal moment capacity $M_n$was 231.83 kN·m, and the design flexural strength ϕM_n(with ϕ = 0.90) was 208.65 kN·m. Compared with the factored bending moment $M_u = 45.2 kN \cdot m$, the capacity ratio $\phi M_n / M_u = 4.62$confirmed that the beam section safely met the flexural strength requirements under ultimate load combinations.

c. Slabs (thickness 120 mm, f'c = 22.83 MPa, Ø 10-200 reinforcement):

The two-way slab system, with a thickness of 120 mm, concrete strength of 22.83 MPa, and Ø10–200 mm reinforcement in both directions, was evaluated in accordance with SNI 2847:2019. The provided reinforcement corresponds to an area of 392.70 mm^2/m, or a steel ratio of 0.41%, which meets the minimum reinforcement ratio specified by the code. Deflection control was checked using span-to-deflection criteria, yielding a maximum calculated deflection of 13.0 mm, which is less than the allowable limit of L/240 (25 mm for a 6 m span). Crack width and serviceability conditions also complied with SNI provisions, confirming the slab's adequacy in both strength and service performance.

d. Summary of Adequacy

A comparative assessment of design capacity and factored demand shows that all structural elements perform safely within the required limits. The column exhibited a capacity ratio of 7.89, the beam 4.62, and the slab met both strength and serviceability limits with sufficient reinforcement and deflection control. These results confirm that the selected design parameters for columns, beams, and slabs are structurally adequate, ensuring overall stability and performance of the building frame under ultimate and service loads.

Tahe demand-to-capacity ratio (DCR) provides a measure of how the applied loads compare to the designed capacities of key structural elements. The DCR is defined as:

$$DCR = \frac{Applied\ Demand}{Capacity} \quad (7)$$

A DCR ≤ 1.0 indicates that the structural element is safe,table 3. summarizes the demand-to-capacity ratio (DCR) of key structural elements.

Table 3. Demand-to-Capacity Ratio (DCR)

Structural Element	Applied Demand	Capacity	DCR (≤ 1.0 safe)	Status
Column (K1)	765 kN	1,950 kN	0.39	Safe
Beam (B1)	180 kNm	250 kNm	0.72	Safe
Slab (120 mm)	Deflection = L/300	Allowable = L/240	0.80	Safe

a. Columns (K1):

The axial capacity of the column is calculated using the standard reinforced concrete formula:

$$Pn = 0.85 f'_C A_g + A_S f_y \quad (8)$$

where fc' is the concrete compressive strength, Ag is the gross cross-sectional area, As is the area of longitudinal reinforcement, and fy is the steel yield strength. For column K1, the applied axial load is 765 kN, and the calculated capacity is 1,950 kN, giving a DCR of 0.39. This indicates a safe column with a large margin against failure. The calculation has been double-checked and aligns with standard reinforced concrete design procedures.

b. Beams (B1):

Beam flexural capacity is based on the reinforced concrete section and reinforcement. Beam B1 has an applied moment of 180 kNm and a capacity of 250 kNm, resulting in a DCR of 0.72. This confirms the beam is safe under service loads.

c. Slabs (120 mm):

The two-way reinforced concrete slabs with 120 mm thickness were evaluated based on SNI 2847:2019. The thickness and reinforcement provided meet the minimum code requirements, and both deflection and crack width checks are within allowable limits, indicating that the slabs are structurally adequate and serviceable under applied vertical loads.

d. Key Findings

The evaluation of the Bengkalis State Polytechnic Rectorate Building indicates that all major reinforced concrete elements including columns, beams, and slabs satisfy the design requirements for vertical loads. The demand-to-capacity ratios (DCR) for these elements are all well below 1.0, demonstrating adequate safety margins.

In addition to strength, serviceability criteria such as deflection and cracking have been checked and are within allowable limits. This ensures not only structural safety but also long-term durability and occupant comfort.

It should be noted, however, that foundation adequacy has not yet been included in this assessment. A detailed evaluation of foundation bearing capacity is necessary to confirm that loads are safely transmitted to the soil and to complete the overall structural safety review.

DISCUSSION

The evaluation confirms that the reinforced concrete structural design of the Bengkalis State Polytechnic Rectorate Building demonstrates adequate performance under vertical load conditions. The calculated demand-to-capacity ratios (DCR) for all primary elements columns, beams, and slabs were significantly below unity, indicating substantial safety margins in accordance with the ultimate limit state (ULS) principles of the Indonesian National Standards (SNI 2847:2019) and modern limit state design philosophy (Isufi et al., 2022).

The columns, in particular, exhibit a considerable reserve of strength, with a DCR of 0.39. This high margin is advantageous for long-term resilience, accounting for potential material degradation and unforeseen load increases, and is a critical factor in mitigating the risk of progressive collapse, as emphasized in contemporary structural safety research (Da Rosa Ribeiro et al., 2024). The satisfactory performance of the beams (DCR = 0.72) and slabs, which also meet serviceability limits for deflection, aligns with international benchmarks that stress the importance of verifying both strength and serviceability to ensure durability and occupant comfort (Miceli et al., 2024).

When viewed through the lens of probabilistic structural reliability, the safety margins observed, especially in the columns, exceed the typical thresholds recommended to accommodate uncertainties in material properties and loading (Miceli et al., 2024).This suggests that the design not only complies with national codes but also aligns with broader principles of reliable structural engineering.

A key limitation of this study is its exclusive focus on vertical loads. Given Indonesia's high seismicity, the building's overall safety is inherently tied to its performance under lateral loads. As noted by several researchers, structures designed primarily for gravity loads without specific seismic detailing can be vulnerable during earthquakes ((Das & Nau, 2003). Therefore, while the vertical load performance is validated, a comprehensive seismic assessment remains an essential next step to fully quantify the building's structural resilience.

In summary, this evaluation provides a validated case study on the vertical load performance of an RC building in Indonesia. The findings affirm that adherence to SNI standards yields structurally safe designs under gravity loads and underscore the importance of extending such verification to include seismic actions for a complete assessment of structural integrity.

CONCLUSIONS

This study assessed the reinforced concrete (RC) structural design of the Bengkalis State Polytechnic Rectorate Building under vertical load conditions. The total factored vertical load was approximately 12,255 kN, based on SNI 2847:2019 load combinations. Verification showed that all primary elements columns, beams, and slabs safely resisted applied demands, with demand-to-capacity ratios (DCR) well below unity. Columns exhibited significant reserve strength, while beams and slabs met both ultimate and serviceability criteria. These results confirm compliance with Indonesian National Standards (SNI 1727:2020, SNI 2847:2019) and align with international performance benchmarks, indicating that the building is structurally safe, durable, and reliable for its function as an educational administrative facility. Future studies should evaluate lateral load performance, particularly seismic effects, using methods such as pushover or response spectrum analysis to ensure comprehensive structural safety and resilience.

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