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Structural Feasibility Analysis of PT Phapros Building Subjected to Additional Machinery Loads

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Abstract

This study evaluates the structural feasibility of Building H at PT Phapros Tbk Semarang under existing conditions and after the planned addition of machinery loads. The assessment combined visual inspection, non-destructive testing using Rebound Hammer, Rebar Detector, Ultrasonic Pulse Velocity, carbonation testing, and structural analysis using ETABS. Structural performance was evaluated according to SNI 2847:2019, SNI 1726:2019, and SNI 1727:2020. The results show that the existing concrete condition was generally adequate, while structural deficiencies were identified in several critical components. Inter-story drift in the upper stories exceeded the allowable limit, indicating insufficient seismic performance. Beam sections generally satisfied flexural requirements, although several support regions were inadequate in shear. The columns did not satisfy the Strong Column–Weak Beam requirement and showed deficiencies in flexural, shear, and confinement performance. After the addition of machinery loads, column axial and bending demands increased considerably, while the maximum slab moment increased from 6.44 to 18.58 kN·m but remained below its reduced flexural capacity of 37.09 kN·m. Structural strengthening, particularly of the column system, is required before the additional machinery is permanently installed.

Keywords: *structural feasibility, additional machinery load, existing building, seismic performance, reinforced concrete.*

INTRODUCTION

The pharmaceutical industry operates under strict regulatory requirements because its products are directly associated with human health and safety. PT Phapros Tbk Semarang, as a pharmaceutical manufacturer in Indonesia, is required to maintain production facilities that comply with Good Manufacturing Practices (Cara Pembuatan Obat yang Baik/CPOB). CPOB requirements cover not only personnel hygiene and raw-material control but also the physical condition and reliability of production infrastructure. Production buildings must provide an environment that supports continuous manufacturing activities while reducing the potential for cross-contamination, dust accumulation, and other conditions that may affect pharmaceutical product quality.

Structural reliability constitutes an essential component of industrial building performance. A production building must retain adequate capacity to resist gravity loads, operational loads, and lateral actions generated by seismic events. Structural deficiencies may interrupt production activities, damage installed equipment, and increase occupational safety risks. These considerations are particularly relevant to pharmaceutical facilities because production continuity depends on the functional and physical integrity of the building infrastructure.

A building is a physical construction permanently associated with its location and may be situated partly or entirely above ground, below ground, or in water. Its functions may include residential, religious, commercial, social, cultural, or other specific activities. The Ministry of Public Works (2006), as cited in Sulistyono et al. (2022), identifies buildings as constructed facilities used to accommodate various forms of human activity. Industrial buildings require additional attention because the structural system must accommodate loads originating from both the building components and the operational equipment installed within the facility.

The assessment of existing buildings requires reference to technical standards that represent current structural safety requirements. In Indonesia, seismic evaluation of buildings is governed by SNI

1726:2019 concerning procedures for earthquake-resistant design of building and non-building structures. This standard provides parameters for evaluating structural response to seismic actions and the capacity of a building to resist lateral forces. Existing structures designed under earlier provisions may exhibit different levels of compliance when reassessed using the current seismic requirements (SNI 1726:2019).

Reinforced-concrete structural elements are evaluated using SNI 2847:2019 concerning structural concrete requirements for buildings. The standard regulates material properties, reinforcement ratios, reinforcement detailing, development requirements, and other parameters associated with structural strength and ductility. These provisions form the technical basis for assessing the capacity of beams, columns, and floor slabs in an existing reinforced-concrete building. Comparison between existing structural conditions and the requirements of SNI 2847:2019 provides a basis for identifying elements that satisfy or fail to satisfy current structural criteria (SNI 2847:2019).

Building H of PT Phapros Semarang was constructed in 1992 when structural design was based on standards applicable at that time. The building has remained in service as part of the pharmaceutical production facility, while current structural assessment requirements are governed by more recent technical standards. Differences between the original design provisions and current requirements create the need to reassess the existing structural system. The evaluation must consider the actual condition of the structural materials and the capacity of the structural elements under the loads currently acting on the building.

PT Phapros Semarang plans to upgrade several pieces of production equipment in Building H to increase production capacity. Installation of new machinery introduces additional loads at specific locations within the building. These loads may alter the demand on floor slabs, beams, columns, and the structural system as a whole. The capacity of the existing structure must be examined before the additional machinery is placed in service, particularly because the building was originally designed without reference to the present equipment configuration.

The structural evaluation of Building H focuses on the existing condition and the structural response after the proposed machinery loads are introduced. Material conditions are identified through visual inspection and non-destructive testing, including Rebound Hammer testing and reinforcement detection using a Rebar Detector. Structural performance is assessed using current provisions, particularly SNI 2847:2019 and SNI 1726:2019, to determine the adequacy of the structural components under existing and additional loading conditions. The assessment provides a technical basis for determining whether the existing building can accommodate the planned operational changes or whether structural strengthening is required.

RESEARCH METHODS

This study employed a structural assessment approach to evaluate Building H of PT Phapros Tbk, Semarang, Central Java. The building consists of three main floors and one roof level. Primary data were obtained through visual inspection and non-destructive testing, including the Rebound Hammer Test, Rebar Detector, Leeb Hardness Test, concrete carbonation test, Ultrasonic Pulse Velocity (UPV), and waterpass measurements. Since the as-built drawings were unavailable, the structural geometry and reinforcement configuration were reconstructed from field measurements before numerical modelling.

Table 1. Data Collection and Structural Assessment Methods

Method	Main purpose
Visual inspection	Identification of cracks, honeycombing, and structural deterioration
Rebound Hammer Test	Estimation of concrete surface strength
Rebar Detector	Identification of reinforcement position, spacing, and concrete cover
Leeb Hardness Test	Evaluation of steel hardness
Carbonation test	Assessment of concrete carbonation
Ultrasonic Pulse Velocity	Evaluation of concrete quality and internal uniformity
Waterpass	Measurement of structural level and geometric deformation

The field data were used to develop a three-dimensional structural model in ETABS V23. Structural analysis was conducted using SNI 2847:2019 for reinforced-concrete evaluation, SNI

1726:2019 for seismic performance, and SNI 1727:2020 for structural loading. The assessment included seismic response, fundamental period, base shear, inter-story drift, P–Delta effects, structural irregularities, and the capacity of beams, columns, and floor slabs. ETABS results were supplemented by manual calculations and Microsoft Excel for verification of member capacities.

Two loading conditions were evaluated: the existing structural condition and the condition after modification of the machinery loads. Existing machinery loads were incorporated according to their actual locations, while the proposed scenario accounted for both newly installed and removed machines on the third floor. The structural responses obtained from both conditions were compared to identify changes in member demand and determine the adequacy of the building under the planned operational loads.

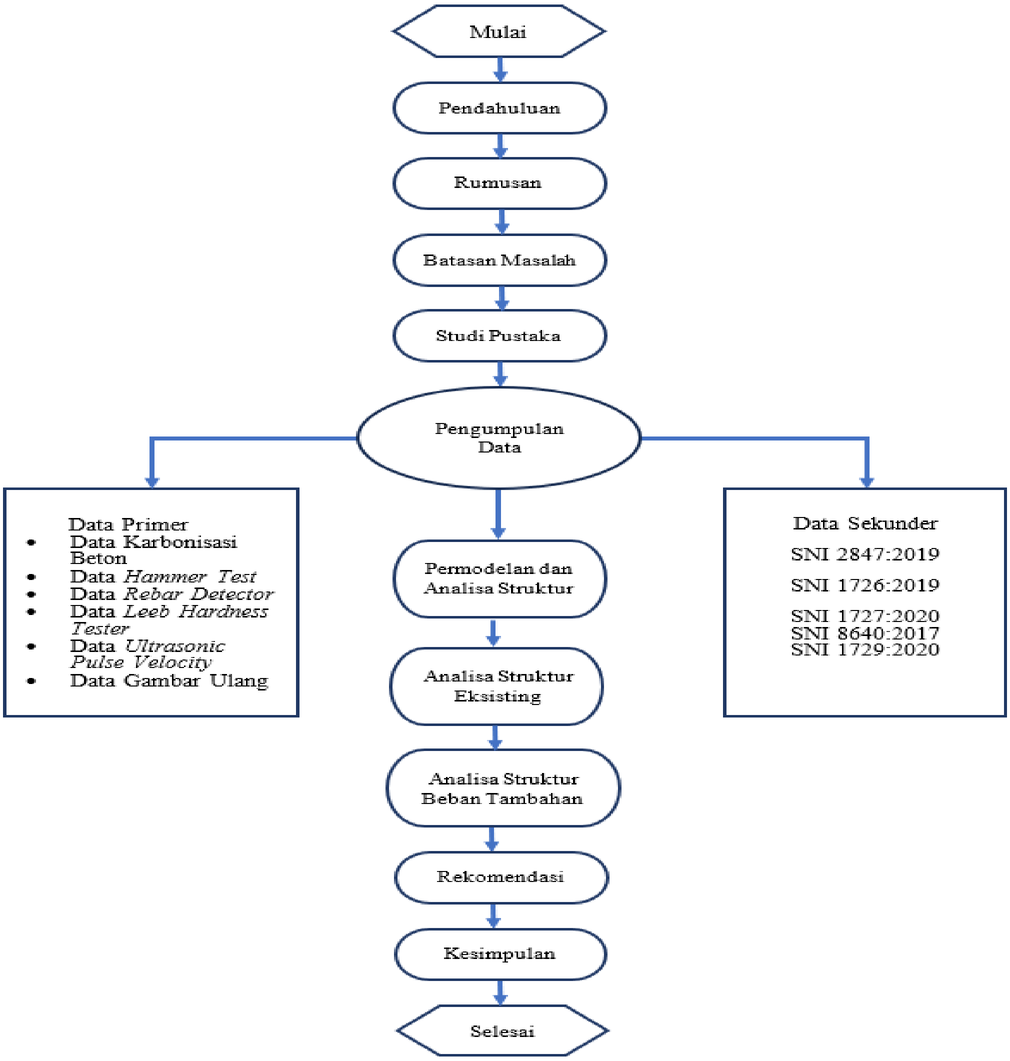

Figure 1. Research workflow

The research sequence consisted of field investigation, data collection, structural reconstruction, ETABS modelling, analysis of the existing condition, analysis of additional machinery loads, structural performance comparison, and formulation of engineering recommendations.

RESULTS AND DISCUSSION

Existing Structural Condition and Seismic Performance

Visual inspection showed that the main structural elements of Building H remained generally intact. No major cracking was observed in the columns and floor slabs, while several beams exhibited localized honeycombing. The walls also showed no severe cracking, although traces of previous fire exposure were identified in several areas. These observations suggest that the visible condition alone did not indicate severe structural deterioration, but field inspection could not be used as the sole basis for structural feasibility because the building was constructed in 1992 and is currently assessed using newer structural provisions.

Figure 1. Existing column condition during field investigation

The Rebound Hammer Test provided quantitative information on the existing concrete. The average cylinder-equivalent strength was 389 kg/cm² for columns, 390 kg/cm² for beams, and 476 kg/cm² for floor slabs. The corresponding cube-equivalent values were 469, 470, and 574 kg/cm². The coefficients of variation remained below approximately 11% for the principal structural components, indicating relatively consistent rebound values across the tested locations. The structural model subsequently adopted $f_c' = 21$MPa, reinforcing steel yield strength $f_y = 390$MPa for deformed bars, and $f_y = 240$MPa for plain reinforcement.

Table 1. Summary of Rebound Hammer Test results

Structural element	Average cylinder strength (kg/cm²)	Average cube strength (kg/cm²)	Coefficient of variation
Column	389	469	8.98%
Beam	390	470	10.85%
Floor slab	476	574	9.68%
Overall average	416	502	9.99%

The ETABS model was evaluated under dead, live, and seismic loads. Additional dead load on the floor consisted of 1.1 kN/m² for floor finishing, 0.2 kN/m² for ceilings, 0.5 kN/m² for MEP components, and 0.4 kN/m² for other permanent loads, giving a total additional dead load of 2.2 kN/m². Live loads varied according to room function, with the production/machinery area carrying the largest distributed live load of 6.0 kN/m². Other applied values included 4.8 kN/m² for temporary storage and mechanical-equipment rooms, 3.0 kN/m² for sterilization rooms, and 2.5 kN/m² for corridors and administrative-support areas, following SNI 1727:2020 (Badan Standardisasi Nasional, 2020).

Table 2. Principal Seismic Parameters Used in The Analysis

Parameter	Value
Risk category	III
Importance factor, I_e	1.25
Site class	SD
Seismic Design Category	D
S_s	0.916
S_1	0.392
F_a	1.134
F_v	1.907
S_{DS}	0.692
S_{D1}	0.499
Response modification coefficient, R	8

Overstrength factor, Ω_0	3
Deflection amplification factor, C_d	5.5
Maximum permitted period, T_{max}	0.746 s
ETABS period, X direction	1.322 s
ETABS period, Y direction	1.275 s

The building was classified in Seismic Design Category D with a medium-soil site classification. The ETABS fundamental periods of 1.322 s in the X direction and 1.275 s in the Y direction exceeded the calculated maximum period of 0.746 s, and the subsequent seismic calculations adopted the upper-period restriction prescribed by SNI 1726:2019. Twelve vibration modes produced 100% accumulated modal mass participation, satisfying the modal participation requirement. The structural system was evaluated as a Special Moment Resisting Frame with $R = 8$, $\Omega_0 = 3$, and $C_d = 5.5$, consistent with the ductility requirements associated with special moment frames (Athallah & Aryanata, 2023).

Inter-story drift represented the principal global seismic deficiency. In the X direction, the calculated inelastic drift reached 109.894 mm at Story 4 and 124.753 mm at Story 3, compared with a drift limit of 57.692 mm. Both levels were classified as NOT OK under SNI 1726:2019. Similar exceedance occurred in the Y direction, with values of approximately 104.161 mm and 127.816 mm at the upper stories. The P–Delta stability coefficients obtained from the detailed analysis remained below the maximum stability coefficient, with $\theta_X$and $\theta_Y$values ranging approximately from 0.024 to 0.042 against $\theta_{max} = 0.0909$. The detailed results classify the P–Delta stability check as acceptable, while the inter-story drift criterion remains unsatisfied.

Table 3. Selected Existing Structural Performance Results

Evaluation parameter	Existing result	Status
X-direction drift, Story 4	109.894 mm	NOT OK
X-direction drift, Story 3	124.753 mm	NOT OK
Drift limit	57.692 mm	—
Column nominal moment, M_{nc}	530.76 kN·m	—
Beam negative nominal moment, M_n^-	907.73 kN·m	—
Beam positive nominal moment, M_n^+	454.77 kN·m	—
Strong Column–Weak Beam requirement	Not satisfied	NOT OK
Column confinement A_{sh}/s	1.57	NOT OK
Required confinement A_{sh}/s	4.73	—
Slab reduced flexural capacity, ϕM_n	37.09 kN·m	OK
Existing slab demand, M_u	6.44 kN·m	OK
Installed slab reinforcement area	334.93 mm²	NOT OK against minimum
Minimum slab reinforcement area	1744.62 mm²	—

Member-level evaluation produced a different response among beams, columns, and floor slabs. The existing beam section was adequate in flexure at both the support and span regions, while shear capacity at the support did not satisfy the current requirement; the span region remained acceptable for both flexure and shear. The column was the critical element. The Strong Column–Weak Beam criterion was not satisfied because the nominal column flexural strength was insufficient relative to the connected beams, contrary to the capacity-design requirement of SNI 2847:2019. The installed transverse reinforcement also remained below the confinement and shear requirements outside the plastic-hinge zone. For the floor slab, $\phi M_n = 37.09$kN·m exceeded $M_u = 6.44$kN·m, although the installed reinforcement area remained lower than the minimum reinforcement prescribed by the current standard.

Structural Response to Additional Machinery Loads

The proposed production modification involved the installation of six machines on the third floor and the removal or replacement of four existing machines. The largest new concentrated load was generated by the Steriline washing and depyrogenation machine at 78 kN, followed by the 1,500–2,000 L autoclave at 65 kN and the powder injection filling and capping machine at 41 kN. The listed additional machinery produced a total concentrated load of 198.1 kN, while the removed equipment represented 25.3 kN. Based on these listed values, the net increase in concentrated machinery load was 172.8 kN.

Table 4. Machinery-Load Modification on the Third Floor

Machinery	Weight (kg)	Concentrated load (kN)	Condition
Autoclave 1,500–2,000 L	6,500	65.0	Added
Powder injection filling + capping machine	4,100	41.0	Added
Steriline washing + depyrogenation machine	7,800	78.0	Added
CIP-SIP Premix Tank 100 kg	250	2.5	Added
CIP-SIP Mixing Tank 300 kg	580	5.8	Added
CIP-SIP Holding Tank 300 kg	580	5.8	Added
Ampoule filling & closing machine Shun Yi/AFS 5	390	3.9	Removed
Ampoule filling & closing machine Shun Yi/AFS 5	390	3.9	Removed
Automatic ampule washing Ming Pen 2	150	1.5	Removed
Vial filling & closing Macofar MT-8	1,600	16.0	Removed

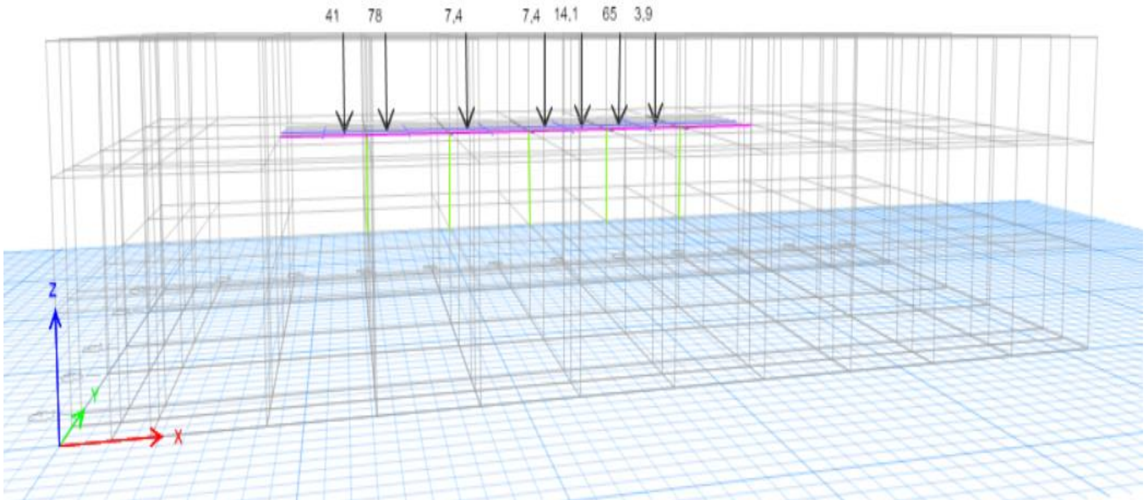

Figure 2. Additional Machinery Loads Applied in the ETABS Model

The additional machinery altered the internal forces in the columns more significantly than in the slab. For the design column, the maximum axial force changed from −305.59 kN to −528.41 kN, while the minimum axial force increased in magnitude from −1058.81 kN to −1847.01 kN. The maximum M3 moment increased from 247.27 to 345.13 kN·m, and the minimum M3 moment changed from −243.26 to −340.11 kN·m. The upper column experienced a larger relative increase, particularly for the minimum axial force, which changed from −177.69 to −1061.55 kN. These changes show that the machinery modification primarily increased axial-flexural demand on the supporting columns.

Table 5. Comparison of Design-Column Internal Forces

Internal force	Existing	Additional machinery
P_{max}(kN)	−305.59	−528.41
P_{min}(kN)	−1058.81	−1847.01

$M2_{max}$(kN·m)	327.02	306.28
$M2_{min}$(kN·m)	−326.86	−408.24
$M3_{max}$(kN·m)	247.27	345.13
$M3_{min}$(kN·m)	−243.26	−340.11

The beam remained adequate against flexural demand after the machinery load was introduced. The reinforcement configuration evaluated in the loaded region consisted of 9D25 top reinforcement at the support, 4D25 bottom reinforcement at the support, 3D25 top reinforcement at midspan, and 6D25 bottom reinforcement at midspan. The additional-load assessment still identified inadequate shear resistance at the critical support region, while torsion did not govern the design. This result is consistent with the existing-condition assessment, where flexural capacity was less critical than shear performance.

The column remained the governing structural deficiency after the machinery loads were applied. The geometric and axial-force requirements were classified as acceptable, but flexural and shear capacities were classified as NOT OK. The evaluated column contained 12D25 longitudinal reinforcement and 2D10-100 transverse reinforcement in both principal directions. The Strong Column–Weak Beam check remained unsatisfied, with M_{nc}decreasing from 530.76 kN·m in the existing evaluation to 150.60 kN·m under the additional-load condition, while the beam nominal moments remained 907.73 and 454.77 kN·m. SNI 2847:2019 requires the column-to-beam strength hierarchy to prevent a column-dominated collapse mechanism, making this deficiency critical for the current structural system (Badan Standardisasi Nasional, 2019).

Table 6. Structural Comparison Before and After Machinery Addition

Structural parameter	Existing	Additional machinery	Assessment
Column M_{nc}(kN·m)	530.76	150.60	NOT OK
Beam M_n^-(kN·m)	907.73	907.73	—
Beam M_n^+(kN·m)	454.77	454.77	—
SCWB requirement	NOT OK	NOT OK	Critical
Column confinement A_{sh}/s	1.57	1.57	NOT OK
Minimum confinement A_{sh}/s	4.73	4.73	—
Slab ϕM_n(kN·m)	37.09	37.09	OK
Slab M_u(kN·m)	6.44	18.58	OK
Installed slab steel area (mm²)	334.93	334.93	Below minimum
Minimum slab steel area (mm²)	1744.62	1744.62	—

The floor slab showed a clear increase in demand but retained sufficient calculated flexural capacity. The maximum slab moment increased from 6.44 kN·m in the existing configuration to 18.58 kN·m after machinery installation, equivalent to almost three times the previous demand. The reduced flexural capacity remained 37.09 kN·m, leaving the slab within the calculated flexural resistance. The installed reinforcement area of 334.93 mm² remained below the current minimum requirement of 1744.62 mm² in both loading conditions. The distinction between strength capacity and minimum reinforcement compliance is relevant: the analyzed slab resisted the calculated machinery-induced moment, but its reinforcement detailing did not fully satisfy the minimum provisions of SNI 2847:2019.

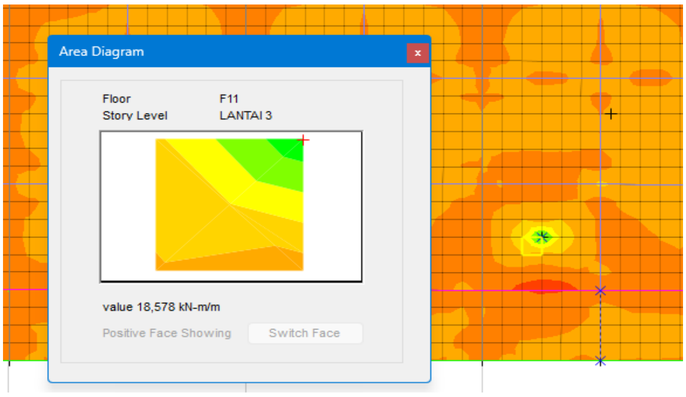

Figure 3. Maximum third-floor slab moment after the addition of machinery

The combined results identify the columns as the controlling element in the structural feasibility assessment. Additional machinery increases axial and bending demands, while the pre-existing deficiencies in column flexural hierarchy, transverse reinforcement, and shear resistance remain unresolved. Beams retain adequate flexural capacity but contain critical shear limitations, and floor slabs retain sufficient calculated flexural strength under the additional machinery loading. The proposed machinery installation cannot be assessed solely from the local slab response because the load path transfers the added demand into supporting beams and columns. Structural strengthening is required primarily at the column system before the modified machinery configuration can be treated as structurally reliable under the current SNI requirements.

Structural Feasibility and Engineering Implications

Structural feasibility assessment of an existing building cannot be based solely on the absence of visible damage. Aging structures require evaluation of material condition, member capacity, serviceability, and changes in operational loading because structural performance may decrease during the service period even when major surface deterioration is not apparent (Masdar et al., 2024). Technical assessment is also required to determine whether an existing building remains reliable for its current function and whether structural components retain sufficient capacity for continued operation (Sulistyono et al., 2022). The distinction between ultimate, serviceability, and abnormal-load limit states provides an appropriate basis for interpreting the condition of an existing reinforced-concrete structure (Antonius, 2021). The results obtained for Building H support this assessment approach because visual inspection indicated generally acceptable physical conditions, while structural calculations identified deficiencies that were not directly observable in the field.

Changes in building operation modify the magnitude and distribution of structural loads. The magnitude of live load is associated with the function and use of individual spaces, making changes in industrial equipment relevant to the reassessment of an existing structure (Yahya et al., 2022). SNI 1727:2020 requires structural loading to represent the actual function and occupancy of the building, including permanent and operational actions that contribute to member demand (Badan Standardisasi Nasional, 2020). Structural actions may also be influenced by building geometry and environmental exposure, while lateral pressures depend on the interaction between external actions and the structural configuration (Daniel, 1991). The structural response of a building is affected by variations in loading, geometry, and structural arrangement, which must be represented consistently during reassessment (Manoppo et al., 2023). The machinery modification in Building H is relevant at the system level because the additional load is transferred from the slab to the supporting beams and subsequently to the columns.

Seismic response forms another critical component of feasibility evaluation. Earthquake loading originates from ground motion and induces lateral and vertical structural actions whose effects depend on the dynamic characteristics of the building (Ariadi, 2016). Earthquake-resistant performance is controlled by the interaction of earthquake characteristics, soil conditions, structural strength, stiffness, and ductility (Imran & Hendrik, 2014). Adequate distribution of strength and stiffness is required to limit unfavorable dynamic response and excessive deformation under cyclic lateral loading (Tuwanakota & Banten, 2021). Static-equivalent analysis can provide a direct representation of seismic effects for relatively simple structures, while dynamic response-spectrum analysis becomes relevant when structural characteristics require more detailed modal representation (Alakbar et al., 2024). These concepts support the use of seismic response, modal properties, inter-story drift, and stability parameters in evaluating Building H.

The seismic assessment of Building H identified excessive inter-story drift at the upper levels, indicating insufficient lateral performance relative to the current seismic provisions. SNI 1726:2019 specifies allowable deformation and seismic-response criteria intended to prevent unacceptable structural and nonstructural damage under design earthquake actions (Badan Standardisasi Nasional, 2019b). Special Moment Resisting Frames rely on substantial ductility and energy dissipation, requiring the structural system to sustain inelastic deformation without premature loss of resistance (Athallah & Aryanata, 2023). Reinforcement detailing has a direct role in preventing brittle shear mechanisms in moment-resisting structural systems (Dapas & Pandaleke, 2018). Secondary components and floor systems also contribute to load transfer and overall structural response even when they are not designated as primary seismic-force-resisting elements (Sari Anggreini & Priantoro Machmoed, 2023). The drift deficiency observed in Building H indicates that satisfactory strength of individual floor components does not automatically establish satisfactory seismic performance of the complete structure.

The column results provide the strongest indication of structural inadequacy. Earthquake-resistant reinforced-concrete design requires the expected failure mechanism to favor ductile beam behavior rather than premature column failure, which forms the basis of the Strong Column–Weak Beam concept (Purwono, 2005). Reinforcing steel is a major determinant of the inelastic behavior and energy-dissipation capacity of reinforced-concrete structures subjected to earthquake loading (Iswandi et al., 2009). SNI 2847:2019 establishes specific requirements for column geometry, longitudinal reinforcement, transverse reinforcement, shear resistance, confinement, beam-column joints, and the relative flexural strengths of beams and columns in special moment frames (Badan Standardisasi Nasional, 2019a). The failure of the SCWB check in both the existing and additional-machinery conditions indicates that the current column system does not provide the intended capacity hierarchy required for a ductile seismic mechanism.

The different responses of the beams, columns, and slabs also reflect their distinct structural functions. Reinforced-concrete slabs primarily distribute transverse loading to their supports and may act as structural diaphragms within the building system (Asroni, 2010). The investigated third-floor slab retained adequate calculated flexural resistance after the machinery load was increased, although the installed reinforcement area was below the minimum value specified by the current standard. Numerical structural analysis provides the internal forces and deformation response required to compare member demand with available resistance, while the reliability of the assessment remains dependent on appropriate representation of geometry, restraints, material properties, loading, and structural connectivity (Computers and Structures, Inc., 2023). The slab result should be interpreted as adequate calculated flexural strength under the analyzed load combination rather than full compliance with all detailing provisions.

Material durability remains relevant to the long-term interpretation of structural feasibility. Carbonation progressively reduces concrete alkalinity and may eventually remove the passive environment that protects embedded reinforcing steel from corrosion (Wibowo et al., 2020). Carbonation depth and progression are affected by concrete quality, moisture conditions, cover thickness, environmental exposure, and material characteristics, while prolonged carbonation can reduce durability and service life (Ashraf, 2016). The use of non-destructive material investigation in Building H provides information that complements numerical capacity assessment. Structural adequacy is not controlled only by current load resistance; deterioration mechanisms may alter reinforcement condition and member capacity during subsequent service.

The machinery-load scenario demonstrates the importance of evaluating the complete load path before changing the operation of an existing industrial building. The floor slab remained below its calculated flexural capacity, while the supporting columns showed substantially higher axial and bending demands and retained deficiencies in flexural hierarchy, confinement, and shear resistance. Structural safety under additional equipment loading must be established at the level of the entire structural system rather than from the local capacity of the supporting floor alone. The lower structural system and foundation are required to transmit vertical and lateral actions safely without becoming the premature source of structural failure (Pamungkas & Harianti, 2013). For Building H, strengthening priority should be directed toward the deficient column system and its associated seismic load-transfer mechanism before the proposed machinery configuration is placed into permanent operation.

CONCLUSION

The structural assessment of Building H at PT Phapros Semarang indicates that the existing building does not fully satisfy current structural requirements. Visual inspection and non-destructive testing showed generally acceptable material conditions, while numerical analysis identified deficiencies in the structural system, particularly in the columns. The beam sections were generally adequate in flexure, although several support regions did not satisfy shear requirements. The floor slab remained capable of resisting the calculated flexural demand, with a reduced flexural capacity of 37.09 kN·m compared with an existing ultimate moment of 6.44 kN·m. The column system did not satisfy the Strong Column–Weak Beam requirement and showed inadequate transverse reinforcement for confinement and shear resistance. Seismic evaluation also identified inter-story drift values exceeding the allowable limit specified by SNI 1726:2019.

The proposed machinery modification increased structural demand, particularly on the supporting columns. The minimum axial force in the design column increased in magnitude from −1058.81 kN to −1847.01 kN, while the maximum third-floor slab moment increased from 6.44 kN·m to 18.58 kN·m. The slab and beam elements retained sufficient flexural capacity under the additional machinery loads, but the existing column deficiencies remained critical and the column flexural and shear capacities were classified as inadequate. Structural strengthening of the column system is required before the proposed machinery configuration is implemented, accompanied by periodic structural assessment when additional equipment loads or building-function changes are introduced.

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