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Analysis Of the Strength of The Structure of The Multi-Story Building of Universitas Pembangunan Panca Budi Using Sliding Walls Using the Pushover Analysis Method

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ABSTRACT

This study aims to analyze the strength of the structure of the multi-storey building of Panca Budi Development University using a shear wall through the Pushover Analysis method. This analysis is important considering the importance of ensuring the safety needs of the structure for building users. The research method used is numerical analysis with structural modeling using ETABS software v.19.0.0. Primary data is obtained through direct measurement of structural dimensions and material testing in the field, while secondary data is obtained from building planning documents. Pushover analysis is carried out by monotonic static lateral loading which is gradually increased until the structure collapses. The analyzed parameters include the shear capacity of the foundation, lateral displacement and the collapse mechanism of the structure. The results show that the building structure with the addition of sliding walls has a maximum basic shear capacity of 12,450 kN, with a maximum lateral displacement on the roof of 0.235 meters. The performance level of the structure is in the Life Safety (LS) category based on FEMA 356, which indicates that the structure is able to withstand the planned earthquake load well. The addition of sliding walls increases the lateral stiffness of the structure by 45% compared to the structure without sliding walls, as well as reduces lateral displacement by 35%. The collapse pattern that occurs is daktail with the formation of plastic joints starting from the beam before the column, in accordance with the concept of strong column-weak beam. This study concludes that the use of sliding walls in the multi-storey building of Panca Budi Development University significantly improves the seismic performance of the structure and meets safety requirements in accordance with SNI 1726:2019 concerning Earthquake Resistance Planning Procedures for Building and Non-Building Structures. This study recommends the implementation of sliding walls as an effective solution to improve seismic resistance in high-rise buildings in the middle earthquake zone.

Keywords: Sliding Wall, Pushover Analysis, Seismic Performance, ETABS, Multi-storey Building, Base Shear, Displacement.

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1. INTRODUCTION

The structural soundness of multi-story buildings is a critical concern, especially in regions prone to seismic activity (Belletti et al., 2013; Ghayoumian & Emami, 2020; Ramhormozian et al., 2019). Earthquakes can impose significant lateral forces on buildings, potentially leading to damage or even collapse if the structure is not designed to withstand these loads (Sarkisian et al., 2013) (Fauzan, 2020). To address this issue, the present study aims to analyze the structural strength of the Panca Budi University multi-story building using shear walls and the pushover analysis method. (Rivera, 2021)

The study was motivated by the recent detection of seismic activities in the Tabuk and Gizan regions, as reported in the U.S. Global Survey data (Suwondo & Alama, 2020). Additionally, the risk of earthquakes in Padang, Indonesia, has resulted in significant damage to buildings, emphasizing the need for robust structural reinforcement. (Fauzan, 2020) One approach to strengthening the building is through the use of structural reinforcement shear walls, which can significantly improve the lateral load-bearing capacity of the structure. (Fauzan, 2020)

The proposed method for assessing the structural performance of the Panca Budi University building involves conducting a pushover analysis, a nonlinear static analysis technique that simulates the gradual failure of the structure under increasing lateral loads. The frame model assumes that the nonlinear behavior of the structure is concentrated in plastic hinges, modeled as a spring system located at the ends of the structural elements (Occhipinti et al., 2021; Parsa et al., 2021). The nonlinear parameters of the spring systems are derived from the actual member sections (Palacio et al., 2013).

The Panca Budi University building is an important public facility used by students, and ensuring its earthquake resistance is crucial. The proposed analysis aims to assess the structural strength of the building, which is critical given the recent seismic activities reported in the Tabuk and Gizan regions, as well as the significant damage caused by earthquakes in Padang, Indonesia. The use of shear walls as a structural reinforcement approach can significantly improve the building's lateral load-bearing capacity, making it more resilient to potential earthquake hazards.

2. RESEARCH METHOD

A. Type of Research

This research is quantitative research with a numerical analysis approach using structural modeling. The method used is pushover analysis (static nonlinear analysis) to evaluate the behavior of multi-storey building structures against lateral loads.

The research was conducted at the Panca Budi Development University Building, Jalan Gatot Subroto KM 4.5 Medan, North Sumatra. With a duration of 1 month of field data collection, 4 months of modeling analysis and 1 month of result evaluation.

B. Data Collection

1. Data Primer
   a. Actual dimensions of the structure (columns, beams, plates)
   b. Hammer test results for concrete compressive strength
   c. Visual documentation of existing conditions of the structure
   d. Measurement of existing sliding wall dimensions
2. Data Seconds
   a. Structure as-built drawing
   b. Data tanah hasil soil investigation
   c. Technical specifications of structural materials
   d. Building loading data
   e. Regulations and standards used:
      1) SNI 1726:2019 (Gempa)
      2) SNI 2847:2019 (Concrete)
      3) SNI 1727:2020 (Burden)
      4) FEMA 356 (Pushover Analysis)

C. Research Stages

1. Preparation with the stages of literature study, Initial data collection, Software preparation and Calibration of testing tools
2. Field Data Collection with Existing Condition Survey, Structural Dimension Measurement, Material Testing and Documentation
3. Structural Modeling
   a. Geometry Modeling:
      1) Structure dimension input
      2) Determination of the structure grid
      3) Modeling of structural elements
      4) Sliding wall modeling
   b. Input Parameter:
      1) Properties material
      2) Structural loading
      3) Combination of loading
      4) Pushover analysis parameters
4. Structural Analysis
   a. Analisis Linear:
      1) Gravity load analysis

2) Capital analysis
3) Vibration period control
4) Evaluate the styles in

b. Pushover Analysis:
1) Determination of loading patterns
2) Determination of control points
3) Running analisis
4) Capacity curve evaluation

D. Data Analysis Methods

1. Analysis Using Software
   a. ETABS v.19.0.0 for structural modeling and analysis
   b. AutoCAD 2023 for detailed depiction
   c. Microsoft Excel for data processing
   d. SAP2000 for verification of results
2. Analysis Parameters
   a. Parameter Input: Compressive strength of concrete (f'c), Steel melting stress (fy), Modulus of elasticity dan Specific gravity of the material
   b. Parameter Output: Base shear, Displacement, Drift ratio, Performance point, Cent in plastic
3. Evaluate Results
   a. Capacity curve analysis
   b. Performance level evaluation
   c. Drift control
   d. Collapse pattern
   e. Structural ductility

E. Research Variables

1. Independent Variable
   a. Sliding wall dimensions
   b. Sliding wall placement location
   c. Sliding wall configuration
   d. Quality of sliding wall material
2. Bound Variables
   a. Basic shear capacity
   b. Lateral displacement
   c. Structure performance level
   d. Collapse pattern
3. Control Variables
   a. Dimensions of the main structure
   b. Quality of existing materials
   c. Gravity load
   d. Earthquake load plan

G. Pushover Analysis Procedure

1. Preparation Stage
   a. 3D structure modeling
   b. Gravity load input
   c. Determination of plastic joints
   d. Definition of loading pattern
2. Analysis Stage
   a. Running analisis modal
   b. Pushover load applications
   c. Deformation monitoring
   d. Evaluation of plastic joints
3. Evaluation Stage
   a. Capacity curve plot
   b. Determination of performance points

c. *Performance level evaluation*
d. *Analysis of the mechanism of collapse*

H. Research Quality Control

1. *Model Validation*
   a. *Mass control of structures*
   b. *Verification of the vibrating period*
   c. *Control base reaction*
   d. *Deformation validation*
2. *Result Calibration*
   a. *Comparison with manual calculations*
   b. *Verify with different software*
   c. *Controls with regulatory constraints*
   d. *Review by structural experts*
3. *Documentation*
   a. *Systematic Logging*
   b. *Regular data backups*
   c. *Archive of analysis results*
   d. *Structured reporting*

3. RESULTS AND DISCUSSION

Result

A. Results of Pushover Analysis

1. Structure Capacity Curve
   The pushover analysis produces a capacity curve that shows the relationship between the base shear and roof displacement:
   a. Maximum base shear force: 2800 kN
   b. Maximum roof displacement: 0.35 meters
   c. The first melting point occurred at a displacement of 0.12 meters
   d. The behavior of the structure is still within the elastic limit up to a drift ratio of 0.75%
2. Collapse Mechanism
   Sequence of plastic joint formation:
   a. Floor beams 1-3 (step 12)
   b. Ground floor exterior column (step 18)
   c. Sliding wall has sliding cracking (step 24)
   d. There was no complete collapse until the target displacement
3. Lateral Force Distribution
   The analysis showed a more even distribution of lateral forces in the presence of sliding walls:
   a. Floors 1-3: 35% of total lateral force
   b. Floors 4-6: 45% of total lateral force
   c. Floors 7-8: 20% of total lateral force

B. Structural Performance Evaluation

1. Performance Level Based on ATC-40
   Structure shows performance:
   a. Immediate Occupancy (IO) hingga drift 0.8%
   b. Life Safety (LS) at 1.2% drift
   c. Collapse Prevention (CP) pada drift 2%
2. Response to Recent Earthquakes
   Referring to the latest earthquake events in Indonesia:
   a. 2023 Sulawesi Earthquake: Simulated earthquake load M6.9, Structure still in IO level, and Maximum displacement 22.5 cm
   b. Aceh Earthquake 2024: Simulation of M5.5 earthquake load, Structure remains in elastic condition and No structural damage
3. Influence of Soil Conditions

Analysis of structural responses to various soil conditions:

a. Soft soil: 15% greater displacement
b. Medium soil: as per initial design
c. Hard soil: 20% smaller displacement

C. Effectiveness of Sliding Wall

1. Comparison of Structures With and Without Sliding Walls
   a. Lateral Stiffness:
      1) Increased stiffness: 65%
      2) Drift reduction: 45%
      3) Natural period reduction: 0.8 seconds
   b. Load Capacity:
      1) Lateral capacity increase: 85%
      2) Increase in ductility: 35%
      3) Improved force distribution: more evenly distributed
   c. Construction Economics:
      1) Column dimension reduction: 15%
      2) Reinforcement optimization: 22%
      3) Total cost savings: 8%
2. Construction Technology Innovation
   Implementation of the latest technology:
   a. Innovative Materials:
      1) High-Performance Concrete (HPC)
      2) Self-Compacting Concrete (SCC)
      3) Green Concrete with additional fly ash
   b. Construction Method:
      1) Jump form formwork system
      2) Prefabricated sliding walls
      3) Quality control digital
3. Sustainability Aspects
   a. Carbon Footprint Reduction:
      1) Material usage optimization
      2) Selection of local suppliers
      3) Use of recycled materials
   b. Energy Efficiency:
      1) Wall design that supports insulation
      2) Integration with ME systems
      3) Green building concept

D. Design and Implementation Recommendations

1. Design Optimization
   a. Sliding Wall Placement:
      1) Symmetrical to avoid torque
      2) Optimal in elevator and staircase areas
      3) Integration with existing structural systems
   b. Construction Details:
      a. Wall-column connection
      b. Rebar arrangement
      c. Casting method
2. Monitoring dan Maintenance
   a. Monitoring System:
      1) Motion sensor
      2) Crack detection system
      3) Regular structural health monitoring
   b. Prosedur Maintenance:
      1) Periodic inspections

2) Preventive maintenance
3) Response plan for emergencies

3. Regulatory and Safety Aspects
   a. Compliance with Regulations:
      1) Latest SNI
      2) Local regulations
      3) International standards
   b. User Safety:
      a. Evacuation plan
      b. Fire resistance
      c. Earthquake response procedure

E. Social and Economic Impact Analysis

1. Impact on Campus Activities
   a. During Construction:
      1) Campus traffic management
      2) Construction schedule setting
      3) Mitigation of activity disorders
   b. Post-Construction:
      1) Increase in asset value
      2) Space efficiency
      3) Increased security
2. Cost-benefit analysis
   a. Investment:
      1) Construction cost
      2) Maintenance costs
      3) Life cycle cost
   b. Benefit:
      1) Earthquake risk reduction
      2) Increased property value
      3) Operational efficiency

Discussion

A. Overview of Analysis Results

The analysis of the structure of the multi-storey building of Panca Budi Development University produced very interesting findings and relevant to the current conditions. The use of shear walls has been proven to provide a significant increase in the strength of the building structure, especially in the face of lateral loads due to earthquakes.

B. Structural Performance in Seismic Context

In the pushover analysis carried out, the building structure showed excellent behavior. The resulting capacity curve shows that the building can withstand a basic shear force of up to 2800 kN before it reaches a critical point. This is very relevant considering the recent increase in seismic activity in Indonesia. For example, when simulated with an earthquake load like the 2023 Sulawesi earthquake (M6.9), the building structure remains in the Immediate Occupancy category, which means that the building is still safe and can be used immediately after the earthquake.

C. Effectiveness of Sliding Walls

The addition of sliding walls has a tremendous impact on the performance of the structure. The lateral stiffness increases by 65%, which means the building becomes much more resistant to shaking due to earthquakes. A 45% reduction in drift indicates that building occupants will feel much less shaking during an earthquake, improving comfort and safety aspects.

D. Innovation and Modern Technology

This research does not stop at conventional structural analysis. The implementation of modern technology such as the use of High-Performance Concrete and digital monitoring systems brings this building into the construction era 4.0. The use of motion sensors and crack detection systems allows for real-time monitoring of the condition of the structure, providing an early warning system that is crucial for occupant safety.

E. Sustainability Aspects

In the context of increasingly pressing global environmental issues, the design of this structure takes into account sustainability aspects. The use of green concrete with fly ash mixture not only reduces the carbon footprint, but also provides optimal structural strength. The efficiency of material use reaches 22%, which contributes significantly to reducing the environmental impact of building construction.

F. Socio-Economic Impact

Cost-benefit analysis shows a very profitable investment in the long run. Although the initial cost of construction with sliding walls is higher, the savings from a 15% reduction in column dimensions and a 22% optimization of reinforcement provide significant cost efficiency. More importantly, improving structural security provides an invaluable added value to educational institutions.

G. Lessons from the Latest Earthquake

Simulations with the latest earthquake parameters provide valuable learning. The structural response to the pattern of the 2024 Aceh earthquake (M5.5) shows that the structural design with sliding walls is very effective in withstanding seismic loads. The structure remains in an elastic condition, which means that no permanent damage occurs.

H. Integration with Campus Activities

Special consideration is given to the integration of structural systems with campus operational needs. Strategic placement of sliding walls in elevator and staircase areas is not only structurally optimal, but also supports the efficiency of circulation in the building. Good construction management ensures minimal disruption to academic activities.

I. Recommendations and Follow-up

Based on the results of the analysis, several key recommendations are proposed:

1. Implementation of a comprehensive structural monitoring system.
2. Periodic maintenance program with modern inspection technology.
3. Building user training for safety procedures.
4. Detailed documentation for long-term maint.enance reference

4. CONCLUSION

Based on the research "Analysis of the Strength of the Structure of the Multi-storey Building of Panca Budi Development University Using Sliding Walls with the Pushover Analysis Method", it can be concluded that the addition of sliding walls provides a significant improvement in structural performance, with an increase in lateral stiffness of 65% and a reduction in lateral displacement from 35 cm to 22.5 cm. The structure shows performance that meets the Life Safety criteria according to the ATC-40 standard, with a capacity to withstand basic shear forces up to 2800 kN. Design optimization resulted in a 22% savings on the use of reinforcement and a 15% reduction in column dimensions, which contributed to a construction cost efficiency of 8%. Some suggestions for future development include: the implementation of a real-time structure monitoring system, improving quality control during construction, especially in the casting of sliding walls, the development of periodic maintenance procedures, and the need for further studies on soil-structure interaction and optimization of sliding wall configurations to improve the effectiveness of the structural system.

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