ASTONJADRO

pISSN 2302-4240
eISSN 2655-2086

Volume 14, Issue 2, June 2025, pp.0393-0407
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17207 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Comparison of Design and Cost of Reinforced Concrete Structures in Buildings with Brick, Brick and Light Brick Walls in front of SD No. 9 Benoa

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| Submitted: July 03, 2024 | Revised: December 30, 2024 | Accepted: February 16, 2025 |

| Published: May 12, 2025 |

ABSTRACT

In building structures, the accepted dead load is the load of the elements in the building, including reinforced concrete, rebated concrete, specs, ceramics, tiles, ceilings, MEP, walls and others. The wall load depends on what material is used on the wall. Bricks with half masonry provide a load of 250 kg/m^2. A pair of hollow brick walls weighs 120 kg/m^2 for HB 10. Light brick is concrete where air bubbles are caused by chemical reactions, AAC (Autoclaved Aerated Concrete) mixture generally consists of quartz sand, cement, lime, a little gypsum, water, and aluminum paste as a developer. Has a weight of 60 kg/m2 for the type with a thickness of 10 cm. Research is needed to compare the calculation results and structural costs of sloofs, beams, columns, ring beams and foundations in structures that use brick walls, concrete blocks and lightweight bricks. In this research, three structural models were created, namely those using brick walls, concrete blocks and lightweight bricks. Analysis was assisted using the SAP2000 Version 14.2.2 computer program. In this research, a three-story school building located in Benoa, South Kuta Badung was studied. The results of the analysis resulted in a comparison of material requirements for the structural model with brick walls: In the overall structure, it was found that the concrete requirement in the model with brick walls was 15.71% smaller, while in the model with lightweight bricks it was 16.50% smaller. And the iron requirement for the model with bricks is 5.85% smaller, while for the model with lightweight bricks it is 6.69% smaller. The comparison of structural costs to the structural model with brick walls was found to be 8.67% smaller for the model with brick walls, and 9.26% smaller for the model with lightweight brick walls.

Keywords: reinforced concrete; brick; Concrete brick; light brick; SAP2000; cost structure.

INTRODUCTION

In building structures, the accepted dead load is the load of the elements in the building, including reinforced concrete, rebated concrete, specs, ceramics, tiles, ceilings, MEP, walls and others. The wall load depends on what material is used on the wall. Some use brick walls, concrete blocks and light bricks. During the author's Field Work Practice (PKL) at the Harris Benoa Hotel Construction Project, in the project the wall material used was lightweight brick. If lightweight bricks are placed in water they will float, this is because the specific gravity of lightweight bricks is smaller than that of brick and concrete blocks.

By looking at the small specific gravity, it will affect the load received by the structure. Wall materials such as bricks, bricks and lightweight bricks will affect the dead load of a structure.

Bricks are one of the materials used to make walls. Bricks are made from clay that is burned until it is reddish in color. With a half stone pair, it provides a load of 250 kg/m^2 (PPIUG, 1983).

Next after red brick is brick, this brick wall material is generally made from a mixture of cement and coarse sand which is molded solid or pressed. With the manufacturing materials as mentioned, brick has a weakness, namely that its strength is lower than red brick, so it tends to crack in walls, especially if the empty parts are not filled with concrete mortar. Using brick material for walls also makes the building warmer and even tends to be stuffy and hot. The perforated brick wall pair weighs 120 kg/m^2 (PPIUG, 1983) for HB 10.

The compressive strength of concrete is one of its most critical mechanical properties, especially in structural applications. For lightweight concrete, this characteristic determines its suitability for various construction purposes such as slabs, walls, and structural frames. Lightweight concrete differs from normal concrete primarily due to the types of aggregates used, which are typically lightweight materials such as expanded clay, shale, pumice, or perlite. These aggregates reduce the overall density of the concrete, generally to less than 2000 kg/m^3, without drastically compromising strength (Octaviani R et.al, 2024; Listiana I.D.T et.al, 2024). In assessing the compressive strength of lightweight concrete, the testing method remains consistent with that of normal concrete, typically involving cylindrical or cubic specimens subjected to increasing compressive loads until failure occurs. This value, expressed in megapascals (MPa), reflects the concrete's ability to withstand axial loads. However, the microstructural differences between lightweight and normal-weight concrete mean that the internal stress distribution and failure modes during loading can vary significantly. Lightweight aggregates often possess higher porosity and lower stiffness compared to traditional aggregates, influencing the way stresses are transferred through the matrix and ultimately affecting the compressive strength (Astariani N.K et.al, 2023; Argoanto Y et.al, 2023).

The compressive strength of lightweight concrete is influenced by multiple factors, including the type and proportion of lightweight aggregate, the water-cement ratio, the presence of admixtures, and curing conditions. Generally, lightweight concrete may exhibit compressive strengths ranging from 15 MPa for non-structural applications to over 50 MPa for structural uses, although this upper range may involve special mix designs and quality control measures. The strength development of lightweight concrete tends to be slightly slower than that of conventional concrete due to the different hydration environments created by the porous aggregates, which may retain water and prolong internal curing (Yudhistira B et.al, 2023; Bagio T.H. et.al, 2021). Despite its reduced density, lightweight concrete can be engineered to meet structural load-bearing requirements through optimized mix designs. For instance, partially replacing lightweight aggregates with finer materials or incorporating pozzolanic additives can help enhance matrix density and improve bond strength between the aggregate and cement paste. The resulting concrete may achieve satisfactory compressive strength while maintaining the benefits of reduced dead load, thermal insulation, and easier handling (Gumilang P.D et.al, 2021).

Lightweight brick is concrete where the air bubbles present are caused by a chemical reaction. AAC (Autoclaved Aerated Concrete) mixture generally consists of quartz sand, cement, lime, a little gypsum, water, and aluminum paste as a developer (chemical air filler). It has different weights offered on the market today, ± 60 kg/m^2 for a size of 10 x 20 x 60 cm.

Bricks, bricks and lightweight bricks have different specific densities which will affect the load on each structure that uses these wall materials. In this research, we will calculate the comparative cost of structures using bricks, bricks and lightweight bricks as wall materials using the SAP 2000 version computer program.

The variable is the specific gravity of the wall material. This research will examine the SD No. 9 Benoa as the research object in this research. The objectives to be achieved from this research include the following, 1) to find out the calculation results of sloofs, beams, columns, ring beams and structural foundations that use bricks, bricks and lightweight bricks as wall materials, 2) to find out the comparison of structural costs of sloofs, beams, columns, ring beams and structural foundations that use bricks, bricks and lightweight bricks as wall materials.

In research that discusses the comparison of reinforced concrete designs for structures using bricks, concrete blocks and lightweight bricks. With the following problem limitations:

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The structural parts compared are sloofs, beams, columns, ring beams and foundations.

To calculate this structure, use the SAP 2000 Version 14.2.2 computer program.

Concrete quality (f'c) = 20 Mpa = 2000000 kg/m^2

Steel quality (fy) = 390 MPa = 39000000 kg/m^2

Shear reinforcement steel quality = 240 MPa = 24000000 kg/m^2

Concrete specific gravity (Wc) = 2400 kg/m3 (SNI 2847-2013 Article 8.5.1)

Concrete modulus of elasticity (Ec) = 4700 √f'c Mpa; f'c = 20 Mpa

= 2.1x109 kg/m2 (SNI 2847-2013 Article 8.5.1)

Steel modulus of elasticity (Ey) = 200000 MPa = 2.0x1010 kg/m2

(SNI 2847-2013 Article 8.5.2)

Concrete

In construction, concrete is a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate and water, with or without additional ingredients that form a solid mass.

Concrete structures are widely used in medium to high-rise buildings. This structure is most widely used compared to other structures because this structure is more monolithic and has a fairly long design life.

Reinforced concrete

Reinforced concrete is concrete that is reinforced with an area and number of reinforcements that are not less than the minimum value required with or without prestressing, and is planned based on the assumption that the two materials work together to support the forces.

The main characteristic of reinforcing steel is that it is very strong against tensile loads, while concrete is able to withstand compressive loads. From these main properties it can be seen that each material has advantages and disadvantages, so if the two materials (concrete and reinforcing steel) are combined into one composite unit, a new material called reinforced concrete will be obtained. This reinforced concrete has properties in accordance with the properties of the materials that make it up, namely that it is very strong against tensile and compressive loads. The tensile load on reinforced concrete is supported by reinforcing steel, while the compressive load is sufficiently supported by the concrete. Concrete is also fire resistant and protects the steel so it lasts.

Loading

This loading planning uses several standard references as follows:
1. Structural Concrete Requirements for Buildings (SNI 2847-2013);
2. Procedures for Earthquake Resistance Planning for Building and Non-Building Structures (SNI 1726-2012).
3. Indonesian Loading Regulations for Buildings (PPIUG-1983)

Based on the regulations above, the structure of a building must be designed for strength against the following loads:
1. Dead Load, expressed by the symbol DL;
2. Live Load, expressed by the symbol LL;
3. Earthquake Load, expressed with the symbol E;

The loads acting on this building structure are as follows:

Dead Load (DL)

The dead load calculated in the structure of a multi-storey building is the own weight of the building

structural elements which have a load-bearing structural function. The loads from the own weight of these elements include the following (PPIUG, 1983):
Reinforced Concrete = 2400 kg/m^3
Rebated Concrete = 21 kg/m^2/cm thick
Speci = 21 kg/m^2/cm thick
Ceramic = 24 kg/m^2/cm thick
Roof Tile = 50 kg/m^2
Ceiling + hanger = 18 kg/m^2
MEP = 10 kg/m^2
Brick Wall = 250 kg/m^2
Brick Wall = 120 kg/m^2
Lightweight Brick Wall = 101 kg/m^2 (Calculation below)
Bricks are one of the materials used to make walls. Bricks are made from clay that is burned until it is reddish in color. With half a stone, it provides a load of 250 kg/m^2 (PPIUG, 1983) and at a price of Rp. 91,000,- /m^2 for size 5 x 11 x 22 cm.
Next after red brick is brick, this brick wall material is generally made from a mixture of cement and coarse sand which is molded solid or pressed. With the manufacturing materials as mentioned, brick has a weakness, namely that its strength is lower than red brick, so it tends to crack in walls, especially if the empty parts are not filled with concrete mortar. Using brick material for walls also makes the building warmer and even tends to be stuffy and hot. A pair of hollow brick walls weighs 120 kg/m^2 (PPIUG, 1983) with a current price of Rp. 26,250,- /m^2 for HB 10.
For light brick masonry loads and mortar, you can get it from various brands of light bricks on the market.
Specific gravity of lightweight brick = 600 kg/m^3
1 cm Plaster Mortar = 17.5 kg/m^2
2.5 mm Cement Mortar = 3 kg/m^2 (average of various brands)
If using 10 cm thick hebel (light brick) then kg
Hebel weight t 10 cm = 600 m^3 x 0.10 m = 60 kg/m^2
So the total for the hebel wall = 60 + (2 x 17.5) + (2 x 3) kg/m^2 = 101 kg/m^2
The load must be adjusted to the volume of the structural elements to be used. Because the analysis is carried out with the SAP2000 program, the weight itself will be calculated directly by the program.

Live Load (LL)

The live load that is calculated is the live load during the period of use of the building. The live load during the construction period is not taken into account because it is estimated that the live load during the use of the building is greater than the live load during the construction period. The planned live load is as follows (PPIUG, 1983):
1. Live Load on Building Floors
2. The live load used refers to the existing standard loading guidelines, namely 250 kg/m^2 (for schools). And 300 kg/m^2 for stairs and balcony plates.

Live Load on Building Roof

1. The live load used refers to the existing standard loading guidelines, namely 100 kg/m^2.
2. The Live Load of rainwater is 20 kg/m^2.

Earthquake Load (E)

Earthquake loads are loads that arise due to accelerated ground vibrations when an earthquake occurs. To plan an earthquake-resistant building structure, it is necessary to know the acceleration that occurs in the bedrock.

Loading Combinations

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Structures and structural components must be designed so that all cross-sections have a minimum design strength equal to the required strength, which is calculated based on a combination of factored loads and forces. The structural components are quite good at the workload level.

The strength combination needed is U for several load combinations required on concrete structures such as sloofs, beams, ring beam columns and foundations, including the following (SNI 2847-2013 Article C.9.2.2):

U = 1.4 D (1)
U = 1.2 D + 1.6 L (2)
U = 1.2 D + 1 L + Ex + 0.3 Ey (3)
U = 1.2 D + 1 L + 0.3 Ex + Ey (4)
U = 0.9 D + 1.0 E (5)
Information:
U: strong is necessary
D: Dead Load
L: Live Load
E : Earthquake

SAP2000 program

One of the most popular application programs in the world of construction structure design is SAP2000. This cannot be separated from the convenience offered by this software, which includes providing a graphical mode and fully working in the Windows operating system environment.

SAP2000 is really capable of taking on structural analysis tasks because if you have input the data correctly, the analysis process will immediately be taken over by SAP2000 and the process is also very fast (depending on the specifications of the computer used).

Under these conditions, the constructor's task should be the design task and not the analysis calculation process. With SAP2000 the analytical task of the constructor shifts from calculating to analyzing the output results.

The facilities provided by SAP2000 include the ability to design structural models from simple ones (roll joints) to complex ones such as 3D frames, 3D shells, moving loads, dynamic analysis, and so on.

One of the advantages of this program is that it doesn't just stop at structural analysis (to find out the internal forces that arise), but you can also proceed to the structural check/design section to find out the amount of reinforcement (concrete) or the stresses that arise in the profile (steel).

Considering that the Sap2000 program was created in America, in order to comply with existing regulations in Indonesia, there is an option to slightly replace it with the SNI regulations that apply in Indonesia.

Beam Reinforcement Calculation

A beam can be defined as one of the portal structural elements with a horizontal span. The loads acting on the beam are usually in the form of bending loads, shear loads or torsion (torsion moment), so reinforcing steel is needed to withstand these loads. This reinforcement is in the form of longitudinal reinforcement or longitudinal reinforcement (which resists bending loads) as well as shear/begel reinforcement (which resists shear and torsion loads).

The sequence in analyzing beams:
Maximum beam design transverse force
U = 1,2 D + 1,6 L (6)
Information:

U = factored shear force at the cross section
D = factored dead load per unit area
L = factored live load per unit
Maximum beam design moment
$Mu = 1,2\ M_{DL} + 1,6\ M_{LL}$ (7)
Information:
Mu = factored moment at the cross section
MDL = moment due to dead load
MLL = moment due to live load
Flexural and shear reinforcement
If the dimensions are specified and a single flexible reinforcement is used.
Flexural reinforcement of fields and supports
Calculate the strength of the plan moment

$$R_{umax} = \phi\, \rho_{max}\, f_y \left(1 - \frac{\rho_{max} f_y}{1,7\, f'c}\right) \quad (8)$$

$$\phi M_{nmax} = R_{umax}\, bd \quad (9)$$

Reinforcement calculations

$$\frac{\phi f'c \quad bd^2}{fy} \quad (10)$$

$$\rho = f'c\,(0,85 - \sqrt{0,85^2 - Q}) \quad (11)$$

As = ρbd (12)
Shear reinforcement plan
Ø Vc = Ø 0,17 λ √(f'c) b d (13)
If:
Vu < 1 $\emptyset Vc$; no shear reinforcement required
$\emptyset Vc$ < Vu < øVc ; minimum shear reinforcement
Vu > øVc ; Shear reinforcement is required

Inspection Vs against Vc2
$V_{c1} = 0,33\sqrt{f'c}\ b\ d$ (14)
$V_{c2} = 0,66\sqrt{f'c}\ b\ d$ (15)

$$V_s = \frac{Vu - \emptyset Vc}{\emptyset} \quad (16)$$

If Vs < Vc2, then the cross section is enlarged
Calculation of Reinforcement Distance S1 = Av fy d/ Vs
S2 = d/2; if Vs ≤ Vc1
S2 = d/4; if Vc1 < Vs ≤ Vc2 S3 = Av fy /0.35 b

Calculation of Column Reinforcement

pISSN 2302-4240
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Columns are building structural components whose main task is to support vertical compressive axial loads with the highest unsupported part being at least three times the smallest lateral dimension.
The sequences in analyzing columns:
Reinforcement for columns is made from symmetrical reinforcement based on a combination of Pu and Mu. For one bar column and two load combinations, namely at the top and bottom ends of each freebody, the reinforcement for each is calculated and the largest is taken.

Maximum column design load

U = 1.2D + 1.6L (17)
Information:
U = factored load on the cross section
D = axial load strength due to dead load L = axial load strength due to live load

Dimensional Calculation

Calculation for columns against axial loads and by determining the longitudinal reinforcement ratio first
$Ast = \rho_g\ Ag$ (18)
$Pu \leq \o Pn$ (19)
$\emptyset Pn = \emptyset 0{,}8\ (0{,}85\ f'c\ Ag + Ast\ (fy - 0{,}85 f'c))$ (20)
then Ag is obtained
$b = h = \sqrt{Ag}$
Longitudinal Reinforcement Calculation
$\emptyset Pn = \emptyset 0{,}8\ (0{,}85\ f'c\ Ag + Ast\ (fy - 0{,}85 f'c))$ (21)
then obtained Ast
Shear Reinforcement Calculation Used the smallest value of
48 stirrup diameters
16 times the longitudinal reinforcement diameter
value b or h.

Planning on Foundations

Permissible Soil Carrying Capacity
The allowable bearing capacity / allowable stress at the base of the foundation is,

$$q_a = \frac{q_{ult}}{SF} \quad (22)$$

Qult is the ultimate stress that occurs

SF is the safety factor which generally ranges between 2.5 – 3.

Soil Pressure Under the Foundation

If the foundation receives an axial load and also a lateral load which causes a moment to occur at the base of the foundation, the distribution of soil pressure at the base of the foundation, the soil pressure under the foundation as in the picture can be written in the equation below.

$$q = \frac{P}{A} \quad \frac{My}{I} \quad (23)$$

Where:

P: vertical load, positive in compressive conditions
A: surface contact area between the soil and the footing M: moment about the central axis
X: moment of inertia of the contact area of the soil and foundation
Y: distance from the center axis to the point where the stress is calculated.

RESEARCH METHODS
Project location

The project location that will be used as a case study is in Benoa, South Kuta District. It is SD No. 9 Benoa. Because the author only calculates the structure of sloofs, beams, rings, columns, the author can do the calculations using the SAP2000 computer program application.

Primary data

Understanding primary data is a source of research data obtained directly from the original source in the form of interviews, opinion polls from individuals or groups (people) or the results of observations of an object, event or test result (object). In other words, researchers need to collect data by answering research questions (survey method) or research objects (observation method). In this research there is no primary data, only secondary data.

Secondary Data

Understanding secondary data is a source of research data obtained through intermediary media or indirectly in the form of books, notes, existing evidence, or archives, whether published or not published generally. In other words, researchers need to collect data by visiting libraries, study centers, archive centers or reading lots of books related to their research.

The data sources used include the following.

Project Drawings

Material Price List

Land Data (Sondir)

Wall Material Weight

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eISSN 2655-2086
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Variable

The variable in this research is the specific gravity of the wall material, which has a different specific gravity. Because the specific gravity is different, the load transmitted to the structure will be different. This will affect the dimensions of the structure and the amount of reinforcement required. So you can see the difference between the sloof, beam, column, ring beam and foundation.

Table 1. Specific gravity of bricks, concrete blocks and lightweight bricks

	Bricks	Batako	Lightweight Bricks
Specific gravity	250 kg/m^2	120 kg/m^2	101 kg/m^2

(Sumber. PPIUG 1983)

Structural Analysis Using SAP2000

Based on the research discussed, it is a school building with a 3D frame structure model that receives static (fixed) loads. So in general, the planning of the frame structure model with SAP2000 will go through 7 stages, namely:

Determine the geometry of the structural model.

The geometry of the planned structural model is made using a 3-dimensional model.

Defining data.

The data defined include, among other things, the type and strength of materials, cross-sectional dimensions of structural elements, types/types of loads, and combinations of loads.

Placing (assigning) data that has been defined to the structure model.

The data placed in the structural model are cross-sectional data and load data

Checking data input.

Check all data that has been entered.

Engineering mechanics analysis.

At this stage, we carry out engineering mechanics analysis on the planned model.

Design steel/concrete structures in accordance with existing regulations. The structural design is modeled based on SNI 2847 2013 regulations.

Structural modification / Redesign

Modify the structure if there is a cross-section that does not meet the requirements by increasing **the dimensions of the cross-section.**

RESULTS AND DISCUSSION

Structural Model Description

In this research, we will plan a structure with three different treatments, namely using brick walls, brick walls and light brick walls. The structure is modeled in 3 dimensions (space portal) as an open portal with the help of SAP 2000.

Structural Geometry Data

Data on the geometric characteristics of the building are as follows:

3 story school building

The height of the ground floor and second floor is 4.2 meters and the height of the third floor is 3.9 meters

The main structure is planned with an open portal system, the columns and beams use a reinforced concrete structure, the floor slab uses a reinforced concrete plate with a thickness of 120 mm.

Preliminary Structural Design

The structural components contained in this building include beams, columns, ring beams and foundations. The initial dimensions of the building's structural components will be planned first (Pre-Planning).

Material

The material used in planning and constructing this building structure is reinforced concrete. Material definition will be carried out in the SAP 2000 Ver.14.22 program. The reinforced concrete material used in this building structure has a quality of f'c 20 MPa (concrete), fy 390 MPa (longitudinal reinforcement), fy 240 MPa (transverse reinforcement/stirrups).

Beam and Column

The structural components of the beams and columns are connected with rigid connections so that the place where plastic hinges occur is at both ends of the beam and at the bottom end of the ground floor column. Beams and columns are made of reinforced concrete. With dimensions that will be adjusted to withstand the load given to this building.

Foundation

Foundation modeling is carried out by assuming that the foundation provides sufficient translational and rotational restraint in all directions of the building axis. Based on the assumptions used, the foundation is modeled as a pin placement at the base of the foundation.

Structural Loading

Loading planning is defining the loads acting on a structure in accordance with the Indonesian Loading Regulations for Buildings (PPIUG, 1983). All loads that have been defined will work on this building structure model. The loads acting on this building structure include:

Roof Load

In this analysis, it is assumed that the loads acting on the roof are roof tiles, wind, human live loads and light steel trusses. And the ceiling is hung on light steel trusses on the 3rd floor.
By using the following loads:

Roof tiles	= 50 kg/m^2
Ceiling and hangers	= 18 kg/m^2
Light steel (assumption)	= 10 kg/m^2
Wind load	= 25 kg/m^2
Live load	= 100 kg.

To determine the roof load that will be received by the ring beam, the largest value of the positioning reaction of the light steel trusses is required. The load combination is 1.4DL; 1.2DL + 1.6LL; and 1.2 DL +0.5LL + 0.8W. by modeling using SAP2000, the largest laying force was obtained, namely 995.65 kg at a load combination of 1.2DL + 1.6LL. So the total load received by the ring beam is 995.65 kg per placement of light steel trusses.

Dead Load

The dead load carried by the plate structure is (PPIUG, 1983):

Rebated concrete + specs: 2.5 cm x 21 kg/m2/cm thickness	= 52.5 kg/m^2
Ceramic: 0.5 cm x 24 kg/m^2/cm thick	= 12 kg/m^2
Ceiling and hanging	= 18 kg/m^2
ME : 10% x (52.5+12+18) kg/m^2	= 8.25 kg/m^2
Total	= 90.75 kg/m^2

The dead load of the wall is assumed to be directly carried by the beam so that the wall load is placed directly on the beam (from PPIUG, 1983).

Brick masonry (half stone)	= 250 kg/m^2
10 cm thick brick (HB10) with holes	= 120 kg/m^2

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Fit. Hebel + plaster + mortar (12.5 cm) = 101 kg/m^2

Living Burden

The planned and calculated live load is 250 kg/m^2 for the floor plate load. And for stairs and landings, the load is 300 kg/m^2. This load is adjusted to its use as a school building. For roofs, the live load is 100 kg/m^2.

Earthquake Load

Earthquake loads use dynamic earthquake analysis using spectrum response graphs based on SNI 1726-2012. You will get a graph like in Figure 1 below

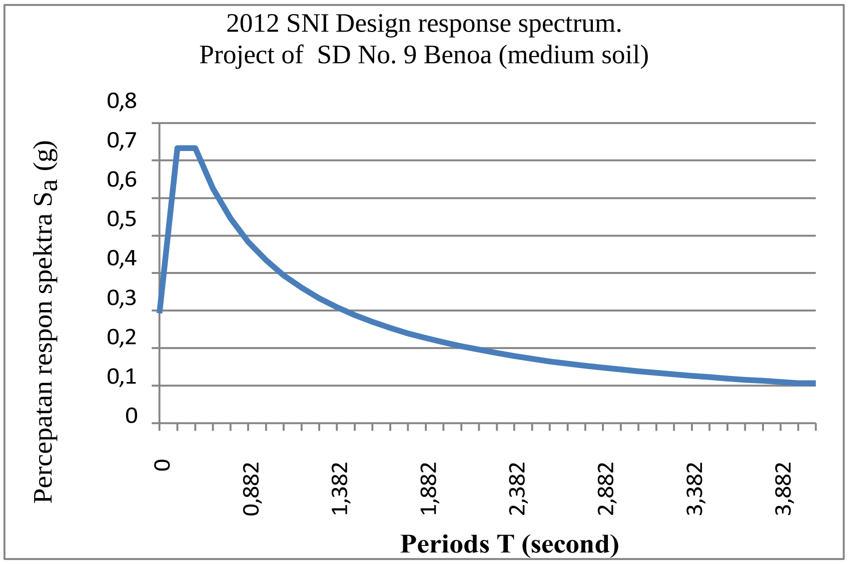

Figure 1. Calculation results of the design response spectrum for the SD No. 9 Benoa

Primary school classroom project No. 9 Benoa is a type of use as a school building and educational facility with risk category IV and priority factor (Ie) = 1.5.
The seismic design category based on acceleration response parameters in short periods (SDS) is KDS D. The seismic design category based on acceleration response parameters in 1 second period (SD1) is KDS D. So the seismic design category based on SDS, SD1 values and risk categories are included in KDS D. The material chosen is reinforced concrete and the permitted seismic force-resisting system is a special moment resisting frame system (SRPMK) with a response modification coefficient (R) = 8.0

Structure Analysis in SAP2000

Based on the research discussed, it is a school building with a 3D frame structure model that receives static (fixed) loads. So the planning of the frame structure model with SAP2000 will go through several stages, namely Draw, Define, Assign, Run Analysis, Design.

Results of Structural Analysis with SAP2000

The results of engineering mechanics analysis for moment diagrams, latitude forces, normal forces, and for drift or displacement with a combination of loads on each structure, namely bricks, bricks and lightweight bricks, are as follows.

Inspection of Inter-Floor Deviations (Story Drift)

The performance limit of a building's serviceability is determined by the deviation between levels due to the effects of a Design Earthquake, namely to limit the occurrence of excessive melting of steel (or cracking in concrete buildings), in addition to preventing non-structural damage and occupant discomfort. The deviation between levels must be calculated from the deviation of the building structure due to the influence of the Nominal Earthquake which has been divided by the Scale Factor.
Inspection of deviations between floors is based on the following data. Deflection Enlargement Factor; Cd = 5.5
Earthquake Priority Factor: Ie = 1.5
Deviations between floors permitted for buildings with risk criteria IV:
$\Delta a= 0.015.H$
The redundancy factor for buildings with KDS D is: $\rho = 1.3$ Increased deviation: $\Delta a = (\delta b - \delta a).Cd/Ie$

Table 2. Maximum Y direction deviation table

Floor	h floor	Permissible inter-floor deviation (0.015h)	Bricks		Bricks		Lightweight Bricks	
			deviation	Inter-floor deviation is increased	deviation	Inter-floor deviation is increased	deviation	Inter-floor deviation is increased
					(cm)			
4	390	5,85	4,21	4,36	4,88	5,13	4,85	5,10
3	420	6,3	3,02	5,35	3,48	6,12	3,46	6,09
2	420	6,3	1,56	5,10	1,81	5,94	1,8	5,90
1	155	2,325	0,17	0,62	0,19	0,70	0,19	0,70

(Source: Analysis Results)

From table 2 you can see the results of the maximum deviation between floors for each model. Of the three models, the maximum deviation occurs on the 3rd floor, and the largest deviation between floors occurs in the structural model with brick walls of 6.12 cm.

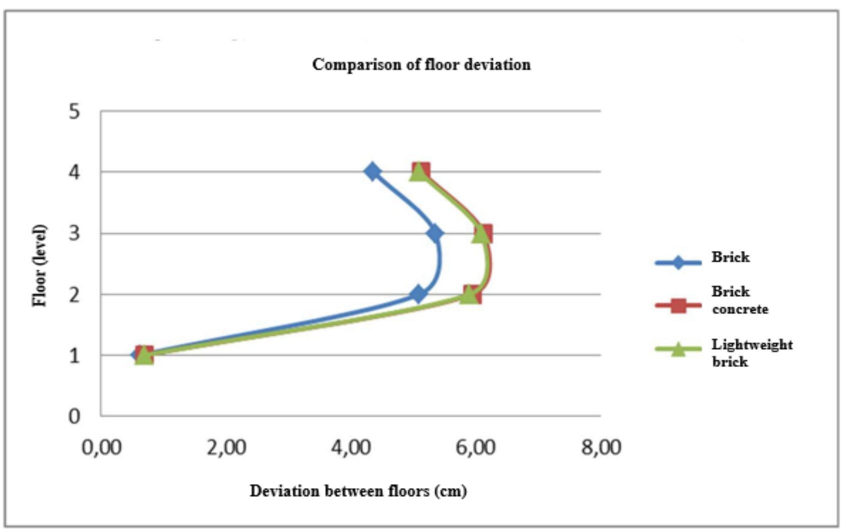

Figure 2. Graph of maximum Y direction inter-storey deviation

Based on the allowable deviation values between floors, the deviation values for each floor for each model of brick, brick and lightweight brick structures meet the requirements.
Comparison of Design and Cost of Structures

ASTONJADRO

pISSN 2302-4240
eISSN 2655-2086

Volume 14, Issue 2, June 2025, pp.0393-0407
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17207 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

By calculating material requirements based on the design of sloofs, beams, ring beams and foundations for the three structural models, a comparison of material requirements and structure costs is obtained.

Design Comparison

Based on the design results of the sloof, beam, ring beam and foundation, the material requirements for the three structural models were obtained. Concrete requirements are based on cross-sectional size, and iron requirements are based on reinforcement design. Comparing the required volume of concrete and the required weight of iron is the same as comparing the cross-sectional design and overall or average reinforcement design.
A comparison of the material requirements of each structure for the structural model with brick walls can be seen in table 3 below.

Table 3. Comparison of material requirements

No	Type	Material Comparison Against Model With Brick			
		Brick Wall		Lightweight Brick Wall	
		Concrete Comparison (%)	Iron Comparison (%)	Concrete Comparison (%)	Iron Comparison (%)
Comparison of Materials of Each Element					
1	Sloof	0,00	29,06	0,00	29,06
2	Beam	-6,73	-3,14	-6,73	-3,47
3	Ring Beam	0,00	2,03	0,00	2,03
4	Column	-24,36	-13,53	-24,36	-15,26
5	Foundation	-29,34	-20,45	-33,82	-20,45
Material Comparison For Overall Structure					
1	Total	-15,71	-5,85	-16,50	-6,69

(Source: Calculation Results)

Cost Structure Comparison

Based on the results of structural cost calculations for the three models, the percentage efficiency of each structural model compared to the brick structure model was obtained. The cost efficiency of the structure can be seen in table 4 below.

Table 4. Comparison of cost structures

Structure costs					
Bricks wal		**Bricks wall**		**Light Brick Wall**	
Costs (Rp)	Comparison Against Bricks (%)	Costs (Rp)	Comparison Against Bricks (%)	Costs (Rp)	Comparison Against Bricks (%)
873.733.117,57	0	797.950.794,88	-8,67	792.796.459,53	-9,26

(Source: Calculation Results)

Based on table 4.14. It can be seen that the comparison of the cost of the structure to the structure model with brick walls was found to be 8.67% smaller for the model with brick walls, and for the model with lightweight brick walls it was 9.26% smaller.

CONCLUSION

Based on the results of analysis and comparison studies on building designs using brick, brick and lightweight brick walls, they are: 1) Comparison of material requirements for structural models with brick walls is as follows: a) for the sloof element, it is found that the concrete requirements in the three models have the same amount. And for the iron requirement in the model with bricks and lightweight bricks, it is 29.06% greater, b) in the beam elements, it is found that the concrete requirement in the model with bricks and lightweight bricks is 6.73% smaller. And the iron requirement in the model with bricks is 3.14% smaller, while in the model with lightweight bricks it is 3.47% smaller, c) for the ring beam element, it is found that the concrete requirement in the three models is the same. 2) and for the iron requirement in the model with brick and lightweight brick, it is 2.03% greater, a) for column elements, it is found that the concrete requirement in the model with brick and lightweight brick is 24.36% smaller. And for the iron requirement in the brick model it is 13.53% smaller while in the model with lightweight brick it is 15.26% smaller, b) in the foundation elements, it is found that the concrete requirement in the model with brick is 29.34% smaller while in the model with brick light weight is 33.82% smaller. And for the iron requirement in the brick and lightweight brick model, it is 20.45% smaller, c) in the overall structure, it is found that the concrete requirement in the brick and lightweight brick model is 15.71% smaller, while in the lightweight brick model it is 16.50% smaller. And the iron requirement for the model with bricks is 5.85% smaller, while for the model with lightweight bricks it is 6.69% smaller. 3) The comparison of structural costs to the structural model with brick walls was found for the model with brick walls to be 8.67% smaller, and for the model with lightweight brick walls to be 9.26% smaller.

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pISSN 2302-4240
eISSN 2655-2086

Volume 14, Issue 2, June 2025, pp.0393-0407
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17207 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

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