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The Effect of Lightweight Brick Walls and Sandwich Panels on the Foundation and Price of Type 45 Houses

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ABSTRACT : *The incident of residents' houses collapsing has often occurred in Banjarmasin. Buildings that collapse are due to broken house foundations and the shape of the foundation does not match the load of the house building. The selection of wall materials is important to consider because the load of the foundation structure also causes the weight of the wall load, sandwich panels are an alternative raw material in wall installation work because they are lighter than lightweight bricks. The study used two methods, namely the descriptive method and the comparative method. The descriptive method, which is to analyze the data obtained carefully. The comparative method, which is to compare the results of the loading on the building and the price of a type 45 house between lightweight brick wall materials and sandwich panels. The results obtained, sandwich panel work is cheaper than lightweight bricks. The price of wall work using sandwich panels is 28% cheaper than using lightweight bricks. The load of buildings using sandwich panel wall materials is 16.41% lighter than buildings using lightweight bricks and there are three types of pile caps that change. In the use of lightweight brick materials, the building price is IDR 485,025,565.00, while in the use of sandwich panel materials, the building price is IDR 398,270,976.67. So using sandwich panel wall material saves costs by 18% compared to buildings that use lightweight brick wall material.*

KEYWORDS *lightweight bricks, sandwich panels, house prices*

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I. INTRODUCTION

Department of Civil and Earth Engineering, Banjarmasin State Polytechnic, Indonesia. Cases of collapsed houses in Banjarmasin occur frequently, including concrete buildings. The main causes are lack of maintenance and deterioration of concrete strength due to age. Many house foundations are cracked or do not conform to building designs [3], making them unable to support excessive loads [16]. This condition renders the buildings unsafe. The primary load on foundations, aside from structural loads, is the dead load from walls. The selection of wall materials plays a significant role in determining foundation dimensions. Currently, lightweight bricks are often used due to their lower weight compared to conventional bricks. However, house collapses still occur, necessitating material innovations such as lighter sandwich panels. Such material changes require adjustments to foundation designs and budget plans to ensure buildings remain safe and economical.

II. LITERATURE REVIEW

Walls are vertical elements in a building that serve as space dividers, both between indoor and outdoor spaces and between rooms within a building. In construction, the selection of wall materials is important because technological developments continue to encourage the use of materials that are more effective in terms of cost, time, and quality. Innovations such as lightweight bricks and sandwich panels have made a positive contribution to the construction industry [4]. Based on their function, walls are classified into load-bearing walls, exterior cladding walls, and interior partition walls. Load-bearing walls serve as the primary structural elements of a building, while exterior cladding walls protect the interior from weather conditions and regulate heat, airflow, sound, humidity, and rainwater, while also providing resistance to sunlight, wind, and rain. Meanwhile, interior partition walls serve to divide spaces without bearing loads [5].

Lightweight bricks are made from a mixture of cement, sand, and lightweight materials such as fly ash or chemical foam, with a process of forming air bubbles that produces lightweight yet sturdy bricks. This material has good thermal insulation, is fire-resistant, and can reduce structural load [8]. This study uses lightweight bricks measuring 600 × 200 × 100 mm in accordance with SNI 8640:2018, weighing 56 kg/m². The advantages of lightweight bricks include precise dimensions, high compressive strength with lightweight, optimal thermal and sound insulation, ease of construction, accelerated construction, and non-toxic properties [4].

Sandwich panels are building materials consisting of three layers, namely a low-density core sandwiched between two thinner, denser, and stronger outer layers. This material is used in constructions that require structural strength combined with lightweight properties [2] In this study, sandwich panels measuring 3000 × 1000 × 100 mm were used, with a weight of 12 kg/m² [1]. Its advantages include ease of installation and dismantling, lower construction costs compared to bricks or blocks, and thermal and acoustic insulation capabilities that protect buildings from solar heat and external noise [2].

Pile foundations serve to transfer loads to deeper soil layers that are capable of safely bearing the working loads without causing collapse or settlement that would reduce the structural performance [14]. The construction process must be designed so as not to disturb the stability of surrounding buildings. The main design requirements for pile foundations include safety against collapse of the piles and soil, control of total and differential settlement, and protection of the stability of surrounding buildings. If the distance between piles is too close, a pile group will form, affecting bearing capacity and settlement behaviour. SNI specifies that the minimum distance between pile axes must be equal to the pile circumference, or for circular piles, at least 2.5 times the diameter. The foundation must also be designed to withstand seismic forces and movements in accordance with SNI 1726:2019.

A pile cap is a method of securing the foundation before columns are erected on top of it. The pile cap serves to resist shear forces from the loads it receives. The purpose of the pile cap is to ensure that the columns are precisely located at the centre of the foundation [10]. A pile cap is a reinforced concrete slab used to distribute the load from the columns to the piles. A pile cap is an internal foundation element that combines pile foundations, including tie beams and foundation rafts [11].

SAP2000 is an important software in civil engineering designed to accurately and comprehensively analyse building structures [9]. This program has been widely used in various countries by engineers and academics. In accordance with SNI 1847:2019, loading includes self-weight, working loads, prestressing forces, earthquakes, and restraint effects due to volume changes and settlement. SNI 1727:2020 provides detailed provisions regarding dead loads, live loads, wind loads, and earthquake loads, with the requirement that the design strength of structures, components, and foundations must be at least equal to or exceed the effects of factored loads, including loads that may not always be applied. This study analyses portal structures using SAP2000 v22 with 3D frame models. The procedure includes load cases, load application, load combination creation, analysis, review of results, and final design.

A Cost Estimate Plan is a plan for a building, both in terms of form and function, along with a calculation of the costs required for the administration and implementation of the work. Costs are calculated by multiplying the volume of work by the unit price, or Cost Estimate Plan = Σ Volume x Unit Price of Work. Calculating the cost estimate plan requires a detailed analysis of the amount of materials and labour costs. Each type of work is calculated by volume, then multiplied by the material cost and labour cost to obtain the total cost. Generally, calculations begin with earthwork such as foundation excavation and backfilling, followed by concrete work and masonry up to finishing. Structural work such as foundations and beams is calculated in cubic metres (length × width × height) [17]. Cost estimate plan consists of two main components: work volume and unit prices. Volume is obtained from calculations based on design drawings or field data, while unit prices are calculated from analyses of materials, labour, and equipment costs [6].

III. RESEARCH METHODOLOGY

The location of this final project research was conducted on Jl. Cengkeh, Kebun Bunga Village, Banjarmasin City, South Kalimantan. Coordinates: -3.333892,114.621096.

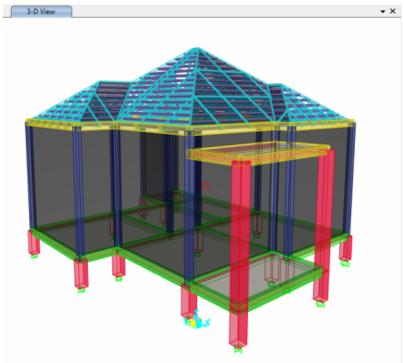
Source: Google Maps

Fig.1. Research location in Banjarmasin

This study uses a descriptive method, which involves carefully analysing the data obtained, with load data processing using SAP2000 and cost calculations using Microsoft Excel. A comparative method is used to compare the structural load results and prices of type 45 houses using lightweight brick walls and sandwich panels. The stages begin with the creation of a house plan to determine the shape and load of the materials. Foundation dimension updates were calculated using foundation engineering principles based on sondir data and initial foundation dimensions. House prices were calculated from working drawings adjusted for variations in wall materials and foundation dimensions. The obtained material volumes were then processed in a Unit Price Analysis with material and labour costs according to the year of implementation.

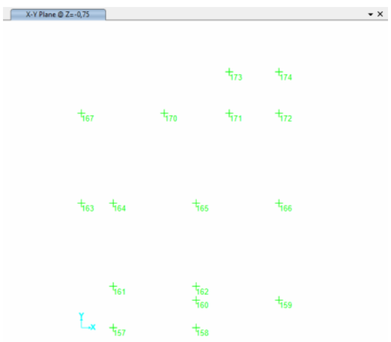
IV. RESULTS AND DISCUSSION

The structural load analysis of this residential house was conducted using SAP2000, beginning with the creation of a model based on field measurements and working drawings. The loads calculated include dead loads, live loads, and wind loads, with a combination of 1D + 1L + 0.5W. The main difference lies in the weight of the walls: lightweight walls at 90 kg/m² and sandwich panels at 12 kg/m². The Joint Reaction data at point F3 was used as a reference for the results. The total structural load with lightweight bricks was recorded at 68.57 tonnes, while with sandwich panels it decreased to 57.32 tonnes.



Source: SAP2000

Fig. 2. House Modelling in SAP2000



Source: SAP2000

Fig. 2. Sketch of Joint Reaction

Table 1. Comparison of Loads Bearing on Foundations

Joint	Burden Carried (Kgf)		Deviation
	Lightweight Brick Walls	Sandwich Panels	
157	2032,13	2034,42	0,11%
158	1721,65	1713,52	-0,47%
159	3901,57	3053,74	-21,73%
160	2406,73	2008,76	-16,54%
161	5736,41	4924,94	-14,15%
162	7744,43	6726,8	-13,14%
163	2680,04	2090,83	-21,99%
164	5803,68	4828,52	-16,80%
165	7974,74	7119,11	-10,73%
166	6464,13	5217,5	-19,29%
167	3680,7	2834,82	-22,98%
170	5559,38	4452,47	-19,91%
171	5835,2	5016,35	-14,03%
172	3782,91	2936,8	-22,35%
173	1587,77	1138,76	-28,28%
174	1654,56	1219,31	26,31%
Total	69565,03	57316,65	16,41%

Source: SAP2000 Calculation Analysis

Based on the load analysis results from SAP2000, the number of piles required per foundation point can be calculated after taking soil reinforcement into account. The soil data used was obtained from sounding results. After the cone penetration test data was obtained, calculations were performed to determine the ultimate capacity (Q Ultimate) of the pile foundation and its relationship with soil reinforcement. At a depth of 4 m, in accordance with the planned length of the pile foundation at the foundation, a Qult-single value of 1.20 tonnes was obtained.

With the calculated Q Ultimate value, the number of piles at each foundation point is then determined. The calculation uses Qult-single at a depth of 4 m, in accordance with the pile driving plan. The load acting on the foundation is also taken into account to determine the number of piles required. Table 2 shows a summary comparison of the differences in the number of piles per foundation point depending on the type of material.

Table 2. Comparison of the Number of Galam Poles

Joint	Number of Poles per Point		Difference
	Lightweight Brick Walls	Sandwich Panels	
157	16	4	12
158	16	4	12
159	16	4	12
160	16	4	12
161	25	16	9
162	64	42	22
163	16	4	12
164	25	16	9
165	64	42	22
166	64	16	48
167	16	4	12
170	25	16	9
171	25	16	9
172	16	4	12
173	16	4	12
174	16	4	12

Source: Foundation Engineering Calculations

There are three types of pilecaps used in the construction of this type 45 house, namely F1, F2, and F3. All three types of pilecaps have undergone changes. Table 3 details the dimensions of the pilecaps at each joint.

Table 3. Differences in Shape, Size, and Number of Galam on Pile Caps

Joint	Pile Caps Dimensions (m)	
	Lightweight Brick Walls	Sandwich Panels
157	1,00 x 1,00	0,50 x 0,50
158	1,00 x 1,00	0,50 x 0,50
159	1,00 x 1,00	0,50 x 0,50
160	1,00 x 1,00	0,50 x 0,50
161	1,25 x 1,25	1,00 x 1,00
162	2,00 x 2,00	1,75 x 1,50
163	1,00 x 1,00	0,50 x 0,50
164	1,25 x 1,25	1,00 x 1,00
165	2,00 x 2,00	1,75 x 1,50
166	2,00 x 2,00	1,00 x 1,00
167	1,00 x 1,00	0,50 x 0,50
170	1,25 x 1,25	1,00 x 1,00
171	1,25 x 1,25	1,00 x 1,00
172	1,00 x 1,00	0,50 x 0,50
173	1,00 x 1,00	0,50 x 0,50
174	1,00 x 1,00	0,50 x 0,50

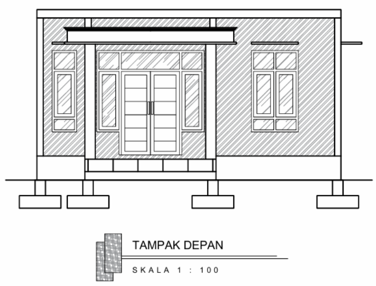
Source : Foundation Engineering Calculations

The volume calculation for each job is adjusted according to the working drawings that have been made. For each type of work, the method of calculating the volume differs depending on its shape. The following is the volume calculation and elevation drawing of a type 45 house with lightweight brick walls.

Table 4. Lightweight Brick Wall Volume

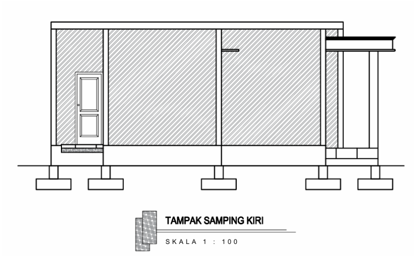
No	Job Description	Unit	Volume
1	Length	m	43,70
2	Height	m	3,30
3	Framework	m2	19,22
	- P1	m2	3,75
	- P2	m2	4,92
	- P3	m2	1,23
	- J1	m2	2,34
	- J2	m2	4,37
	- J3	m2	2,34
	- BV	m2	0,28
4	Pair of bricks	m2	124,99
5	Wall plastering 1SP : 2PP	m2	40,55
6	Wall plastering 1SP : 4PP	m2	209,42
7	Wall rendering	m2	249,97

Source : Calculation Results



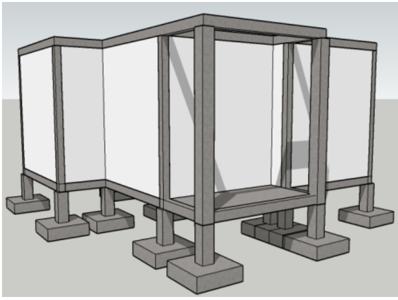
Source : AutoCAD 2017

Fig 4. Front View of Lightweight Brick Wall Installation



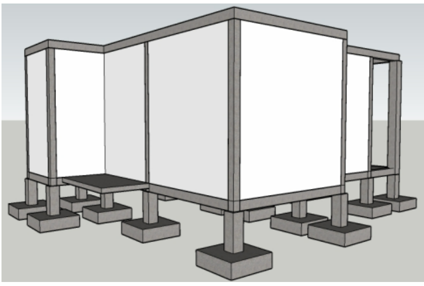
Source : AutoCAD 2017

Fig 5. Left Side View of Lightweight Brick Wall Installation



Source : SketchUp 2019

Fig 6. Front and Left Side 3D Module of Lightweight Brick Wall



Source : SketchUp 2019

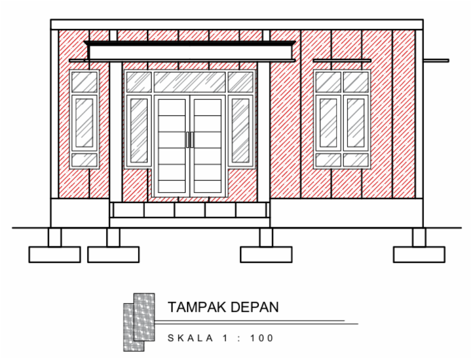
Fig 7. 3D Module of Rear and Left Side of Lightweight Brick Wall

The following are the volume calculations and images of a type 45 house with sandwich panel walls.

Table 5. Sandwich Panel Wall Volume

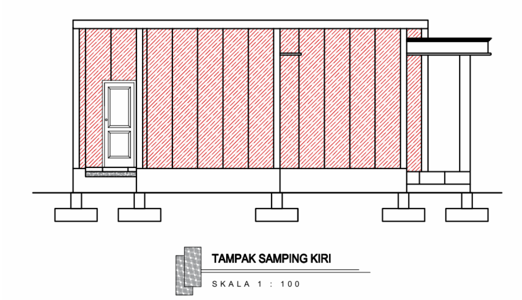
No	Job Description	Unit	Volume
1	Length	m	43,70
2	Height	m	3,30
3	Framework	m2	19,22
	- P1	m2	3,75
	- P2	m2	4,92
	- P3	m2	1,23
	- J1	m2	2,34
	- J2	m2	4,37
	- J3	m2	2,34
	- BV	m2	0,28
4	Pair of bricks	m2	124,99
5	Wall plastering 1SP : 2PP	m2	-
6	Wall plastering 1SP : 4PP	m2	-
7	Wall rendering	m2	249,97

Source: Calculation Results



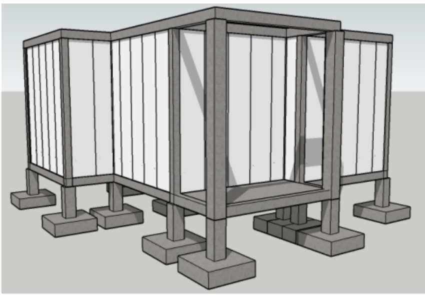
Source : AutoCAD 2017

Fig 8. Front View of Sandwich Panel Wall Installation



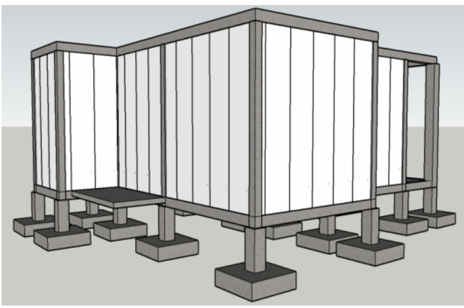
Source : AutoCAD 2017

Fig 9. Left Side View of Sandwich Panel Wall Installation



Source : SketchUp 2019

Fig 10. Front and Left Side 3D Module of Sandwich Panel Wall



Source : SketchUp 2019

Fig 11. 3D Module Rear and Left Side Sandwich Panel Wall

In calculating the cost estimate plan, an analysis of the unit price of the work is required so that the price obtained is more precise and accurate. According to (PUPR 2023), in this study, the analysis of the work to be compared is as follows:

Table 6. Unit Price Analysis for Installing Lightweight Brick Walls

No	Description	Kode	Unit	Coefficient	Unit Price (Rp)	Number Price (Rp)
A	LABORERS					
	Workers	L.01	OH	0,168	Rp.100.000,00	Rp. 16.770,00
	Craftsmen	L.02	OH	0,083	Rp. 110.000,00	Rp. 9.163,00
	Foremen	L.03	OH	0,008	Rp. 175.000,00	Rp. 1452,50
	Supervisors	L.04	OH	0,003	Rp. 178.800,00	Rp. 500,64
			TOTAL LABOR COSTS			Rp. 27.886,14
B	MATERIALS					
	10 cm thick lightweight brick		unit	8,750	Rp. 16.000,00	Rp. 140.000,00
	Lightweight Brick Adhesive Mortar		kg	3,429	Rp. 2.5625,00	Rp. 9.001,13
			TOTAL MATERIAL COST			Rp. 149.001,13
C	EQUIPMENT					
			TOTAL PRICE OF EQUIPMENT			
D	TOTAL LABOR, MATERIALS, AND EQUIPMENT COSTS (A+B+C)					Rp. 176.887,27
E	GENERAL EXPENSES AND PROFITS (10% - 15%) x D					Rp. 17.668,73
F	UNIT PRICE OF WORK (D+E)					Rp. 194.575,99

Table 7. Unit Price Analysis for Sandwich Panel Wall Installation Work

No	Description	Kode	Unit	Coefficient	Unit Price (Rp)	Number Price (Rp)
A	LABORERS					
	Workers	L.01	OH	0,200	Rp.100.000,00	Rp. 20.000,00
	Craftsmen	L.02	OH	0,100	Rp. 110.000,00	Rp. 11.000,00
	Foremen	L.03	OH	0,010	Rp. 175.000,00	Rp. 1.750,00
	Supervisors	L.04	OH	0,003	Rp. 178.800,00	Rp. 500,64
			TOTAL LABOR COSTS			Rp. 33.250,64
B	MATERIALS					
	EPS Sandwich Panel Wall		unit	0,333	Rp. 430.000,00	Rp. 143.333,33
			TOTAL MATERIAL COST			Rp. 143.333,33
C	EQUIPMENT					
			TOTAL PRICE OF EQUIPMENT			
D	TOTAL LABOR, MATERIALS, AND EQUIPMENT COSTS (A+B+C)					Rp. 176.583,97
E	GENERAL EXPENSES AND PROFITS (10% - 15%) x D					Rp. 17.658,40
F	UNIT PRICE OF WORK (D+E)					Rp. 194.242,37

The calculation of the Cost Estimate Plan for a type 45 house shows a price difference between the use of lightweight bricks and sandwich panels. With lightweight bricks, the total cost amounts to Rp. 485,025,565.00, while with sandwich panels it is Rp. 398,279,976.67. The price difference obtained is Rp. 86,754,588.32. A detailed comparison of the prices of the two materials is presented in Table 8.

Table 8. Comparison of Work Cost Estimates

COMPARISON OF COST RECAPITULATION				
NO.	JOB DESCRIPTION	TOTAL PRICE		DEVIATION
		LIGHTWEIGHT BRICK WALLS	SANDWICH PANELS	
1	Preparatory Work	Rp. 7.795.957,49	Rp. 7.795.957,49	0%
2	Land Work	Rp.105.435.756,19	Rp. 48.365.025,78	-54%
3	Reinforced Concrete Work	Rp. 121.863.649,35	Rp. 105.924.327,73	-13%
4	Wall Work	Rp. 48.709.081,93	Rp. 34.964.545,64	-28%
5	Flooring Work	Rp. 21.731.440,99	Rp. 21.731.440,99	0%
6	Ceiling Work	Rp. 28.182.217,07	Rp. 28.182.217,07	0%
7	Roof Covering Work	Rp. 96.686.361,92	Rp. 96.686.361,92	0%
8	Frame, Door, and Window Work	Rp. 12.056.977,86	Rp. 12.056.977,86	0%
9	Key and Hinge Work	Rp. 1.071.832,92	Rp. 1.071.832,92	0%
10	Electrical Installation Work	Rp. 6.931.257,16	Rp. 6.931.257,16	0%
11	Water Sanitation Work	Rp. 10.443.052,52	Rp. 10.443.052,52	0%
12	Painting work	Rp. 14.207.122,16	Rp. 14,207.122,16	0%
13	Septic Tank Work	Rp. 7.322.443,04	Rp. 7.322.443,04	0%
14	Cleaning Work	Rp. 2.588.414,40	Rp. 2.588.414,40	0%
TOTAL		**Rp. 485.025.565,00**	**Rp. 398.270.976,67**	**-18%**

Sumber : Calculation Results

The use of sandwich panels offers cost advantages over lightweight bricks. The cost of wall construction is reduced by up to 28%, as the lighter weight of the panels minimises the volume of reinforced concrete required. Changes in the dimensions of the pilecaps also reduce the volume of earthworks and concrete, which in turn reduces costs. Earthworks with sandwich panels are 54% cheaper, while reinforced concrete works are 13% cheaper than with lightweight bricks.

V. CONCLUSION

Based on analysis and calculations, the total weight of the structural elements of the building using lightweight brick material is 68.57 tonnes, while the total weight of the structural elements of the building using sandwich panel material is 57.32 tonnes. The building load using sandwich panel wall material is 16.41% lighter than the building using lightweight brick wall material. The use of lightweight bricks and sandwich panels affects the cost of a 45-type house. When using lightweight brick material, the building cost is Rp 485,025,565.00, while when using sandwich panel material, the building cost is Rp 398,270,976.67. The building using sandwich panel wall material saves 18% in costs compared to the building using lightweight brick wall material.

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