Optimizing the use of Recycled Materials in Environmentally Friendly Concrete Block Production

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ABSTRACT

The construction industry significantly impacts the environment through resource consumption and carbon emissions. This study explores environmentally friendly concrete block production using recycled materials to address these challenges. By incorporating waste materials such as Styrofoam (X1), HVS paper (X2), and Onggok Aren fiber (X3), this study aimed to reduce landfill waste and lower carbon emissions. Our research shows that these materials can be effectively used in concrete block production, meeting required standards. However, high initial production costs remain a barrier. Effective cost modeling and optimization, using linear programming, showed that production costs for blocks made from Styrofoam (X1), HVS Paper (X2), and Onggok Aren Fiber (X3) could be significantly reduced. The optimized costs were Rp 1,804.26 for Styrofoam (X1), Rp 3,500 for HVS Paper (X2), and Rp 4,000 for Onggok Aren Fiber (X3) per block. By incorporating a 30% profit margin, the selling prices were set at Rp 2,345.54 for Styrofoam (X1), Rp 4,550 for HVS Paper (X2), and Rp 5,200 for Onggok Aren Fiber (X3). This approach ensures market competitiveness and sustainable profitability, promoting the use of alternative materials in construction and advancing environmental sustainability

Keywords: concrete; cost optimization; recycled materials; sustainability; environmental impact.

INTRODUCTION

The construction industry is known for its significant impact on the environment, both in terms of resource consumption and carbon emissions. One of the primary challenges in this industry is the high volume of waste generated and the limited reuse of building materials (Rayhan & Bhuiyan, 2024). To address this issue, the concept of environmentally friendly block (concrete blocks) production has emerged as an innovative solution that utilizes recycled materials and reduces dependence on natural resources (Yılmaz et al., 2023).

Environmentally friendly block are made from a mixture of recycled materials such as construction and industrial waste, processed to produce a product of comparable quality to conventional block (Junkes et al., 2024; Li et al., 2024). The use of recycled materials not only helps reduce the amount of waste ending up in landfills but also lowers the carbon emissions associated with producing new materials. Waste materials are often abundantly available and can be effectively repurposed to create innovative construction products, thereby promoting sustainability and reducing environmental impact (Hendarto et al., 2023; Sudjatmiko & Rahman, 2020). According to research, using recycled materials in block production can reduce carbon emissions by up to 30% compared to conventional brick production (Jiménez et al., 2018).

Studies have shown that the use of waste substitute materials in the production of concrete blocks can yield minimum strength, stability, durability, and specifications that meet standards. According to research, the use of construction industry waste and chemical industry waste in environmentally friendly concrete block production not only helps reduce waste sent to landfills but also improves the mechanical properties and durability of the concrete. For example, the use of quarry dust as a partial replacement for cement has been proven to enhance the compressive strength and durability of concrete while reducing the environmental impact of conventional cement production (Junkes et al., 2024; Mitikie et al., 2022). The previous research also demonstrates that incorporating up to 50% Styrofoam as a partial substitute for fine aggregate is suitable for concrete brick production, meeting the required standards (Solikin & Ikhsan, 2018).

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However, one of the main obstacles to the adoption of environmentally friendly block is the high initial production cost, which often poses a barrier for manufacturers. Effective cost modeling is crucial to ensure that these products can be produced at a reasonable cost and remain competitive in the market. A study by Puri et al. (2023) shows that by implementing efficient production technologies and good cost management, the production costs of environmentally friendly block can be significantly reduced without compromising product quality (Puri et al., 2022).

With the growing global awareness of the importance of environmentally friendly practices, more research and innovation are needed in the cost modeling of environmentally friendly brick production (Ashokan et al., 2024; Jhatial et al., 2022; Viranthy Dian Pertiwi et al., 2024). This approach not only provides a solution to environmental problems but also offers long-term economic benefits for the construction industry and the broader community.

RESEARCH METHODS

Previous research on environmentally friendly block has explored the use of various composite materials. These studies demonstrate the potential success of these materials in terms of structural strength and positive environmental impact. However, despite the experiments showing that these block meet the necessary strength standards, there has not yet been a comprehensive cost analysis conducted. This lack of a thorough cost evaluation presents a major obstacle in determining the economic feasibility of mass production of these environmentally friendly block. Therefore, to optimize cost usage and ensure economic feasibility, detailed mathematical modeling is required. This approach is expected to provide more accurate and comprehensive data, which will serve as a strong foundation for decision-making regarding the production and application of environmentally friendly block.

Materials

In this research, various materials were utilized to analyze the strength and composition of environmentally friendly concrete blocks. The materials included Styrofoam (Sudarman et al., 2023) or X1, HVS paper (Hendriyani et al., 2017) or X2, and Onggok Aren fiber (Antika et al., 2023) or X3, each mixed with specific proportions of cement, sand, and water. The strength of each mixture was measured in kilonewtons (kN). Table 1 shows the detailed compositions and results for each type of material.

Table 1. Detailed compositions of blocks

Parameters	Waste Material		
	Styrofoam (X1)	HVS Paper (X2)	Onggok Aren Fiber (X3)
Cement (kg)	0,85	1,07	0,93
Sand (kg)	0,85	2,56	2,70
Water (lt)	0,95	0,24	0,33
Waste (kg)	1,71	0,43	0,34
Strength (kN)	55.83	77.5	23.65
Class	IV	IV	IV

According to SNI 03-0349-1989, concrete blocks are classified based on compressive strength as follows: Class I (≥ 10 MPa), Class II (7.5 - 10 MPa), Class III (5 - 7.5 MPa), and Class IV (< 5 MPa) (Badan Standardisasi Nasional, 1989). To classify the strength of concrete blocks according to the above standards, the strength should be converted from kN to MPa. Assuming the cross-sectional area is 100 cm² (0.01 m² or 1000 mm²), The compressive strengths of the tested concrete blocks are as follows: X1 is 0.5583 MPa, X2 is 0.775 MPa, and X3 is 0.2365 MPa. All the strengths of these concrete blocks are below 5 MPa, so they fall into **Class IV** according to SNI 03-0349-1989. According to the classification standards of SNI 03-0349-1989, all specimen are used for constructions that do not require significant load-bearing capacity. These blocks are suitable for applications such as lightweight partition walls, infill walls in framed structures, garden fences, and temporary buildings.

Methods

This research was conducted in the Surakarta area, Central Java, in May – June 2024. First, data regarding the prices of materials and waste in the Surakarta area were collected through surveys, which were then used to establish pricing during the Forum Group Discussion (FGD) to formulate the calculation of waste material prices. The second stage involved a second round of surveys and interviews targeting SMEs/factories producing concrete blocks to document equipment and raw material prices, aiming to calculate the overall cost per unit of produced items. In the third stage, Furthermore, the full costing method helps enhance objectivity in product pricing. By taking into account all involved costs, companies can set more realistic and competitive prices in the market.

Price feasibility also needs to be formulated to achieve optimal calculations, ensuring that the selling price not only covers production costs but also provides an appropriate profit margin. The full costing method, with its comprehensive approach, enables companies to have a better understanding of their cost structure, thereby making more strategic decisions in managing production and pricing. Full costing is an approach that estimates production costs by considering all cost components, including direct labor, raw material costs, and both variable and fixed factory overhead costs (Drury, 2018; Horngren et al., 2016). Finally, in the fifth stage, price optimization was conducted using mathematical modeling with the assistance of Phyton, which helped process and analyze data, provide price scenario simulations, and offer predictive insights for better decision-making. **Figure 1** shows the flow chart of the research.

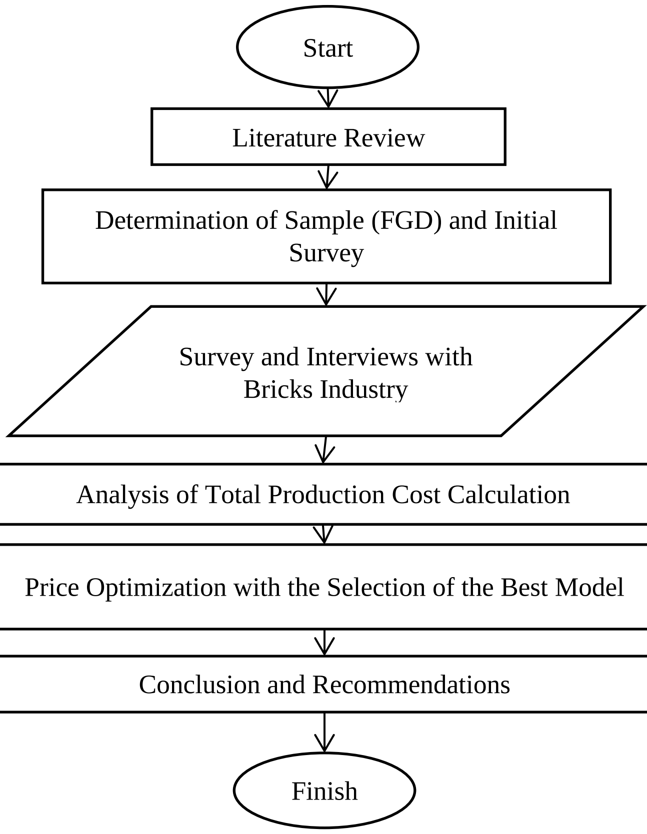

Figure 1. Flow chart

Data Analysis

The costs of block calculated include material costs, labor wages, and factory overhead, thus encompassing all expenditures necessary to produce a desired product. One method used to

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accommodate price analysis needs is the full costing method (Ratnasih & Sulbahri, 2022). This method aims to improve cost analysis accuracy by considering all real factors affecting the production of a good, including fixed and variable costs. With the full costing method, all costs, both direct and indirect, are allocated to the product, providing a more comprehensive picture of production costs (Ratnasih & Sulbahri, 2022).

In this method, the selling price per unit is determined by calculating the total cost per unit and adding a certain amount/percentage to cover the desired profit margin (equation 1).

$$\text{Selling Price} = \text{Total Cost} + (\text{Profit Percentage} \times \text{Cost}) \quad (1)$$

The production costs of the analyzed concrete blocks were then optimized using mathematical modeling with the assistance of Using the PuLP library in Python for linear programming offers significant advantages, including intuitive syntax and integration with various industry-standard solvers like GLPK and COIN-OR, making it accessible and flexible for handling diverse optimization tasks (Mitchell et al., 2011). Additionally, PuLP supports both continuous and discrete variables, accommodates a wide range of constraints, and is bolstered by strong community support and comprehensive documentation, which enhance its applicability and ease of use across different fields (Mitchell et al., 2011). This capability is crucial for complex manufacturing processes like concrete block production, where numerous factors, including material costs, labor, and overhead, need to be accounted for (Arinze & Jacks, 2024). This research method ensures that all aspects related to the production of environmentally friendly concrete blocks have been comprehensively analyzed. By using a systematic approach and Phyton, it is expected that the results of this research will provide significant contributions to cost optimization and more effective pricing strategies.

RESULT AND DISCUSSION

Concrete blocks are construction materials composed of cement, water, and sand. This mixture is known as mortar. According to the General Requirements for Building Materials in Indonesia (PUBI), the composition of concrete blocks is 75% fine aggregate, 20% cement, and 5% water. Interviews revealed that a standard-sized concrete block (35 cm x 10 cm x 15 cm) requires approximately 6.1 kg of mortar. According to Basuni & Iskandar (2021), production cost refers to the exchange value of money that has occurred or is likely to occur to obtain revenue. The cost of production includes all components such as raw materials, direct labor, and both fixed and variable factory overhead costs (Basuni & Iskandar, 2021). The formula for calculating the cost of production is as follows:

1. Raw Material Cost (A): Price of waste, cement, sand and water.
2. Direct Labor Cost (B): Employee wages.
3. Fixed Factory Overhead Cost (C): Cost of machine needs.
4. Variable Factory Overhead Cost (D): Cost of machine maintenance.

Raw material cost

The raw material cost (A) includes the expenses associated with the essential components required for manufacturing the concrete blocks. These components are cement, sand, water, and waste materials such as styrofoam, HVS paper, or onggok aren fiber. Cement, a critical component in concrete block production, costs Rp 1,500 per kg (Gresik brand), calculated from Rp 60,000 per 40 kg/ bag. Water, essential for mixing, is priced at Rp 7 per kg or liter, given its price of Rp 7,000 per cubic meter. Sand, specifically Pasir Pasang Cilegon, costs Rp 118.75 per kg, with a price of Rp 1,900,000 per 10 cubic meters. Waste materials used as additives include Styrofoam at Rp 123,000 per kg, HVS paper at Rp 10,500 per kg, and Onggok Aren fiber at Rp 15,120 per kg. The prices for the raw materials were obtained from a survey conducted at several building supply stores, while the prices for the waste materials were sourced from collectors whose identities are not disclosed here. **Table 2** summarizes the prices per kilogram for essential raw materials used in concrete block production.

Table 1. Price of raw materials

Material	Price per kg (Rp)

Cement	1,500
Water	7 (liter)
Sand	118.75
Styrofoam	123,000
HVS Paper	10,500
Onggok Aren Fiber	15,120

These prices form the basis for calculating the total raw material costs in the manufacturing process, ensuring accurate budgeting and cost management.

Direct labor cost

The direct labor cost for the production of concrete blocks includes the wages for workers operating the machinery and those involved in transporting and drying the blocks. Based on the production process, the operation requires 1-2 workers per machine and an additional 1-2 workers for transportation and drying, totaling 2-4 workers to produce 1,000 blocks per day (Neupane et al., 2024). Based on observations and interviews, it was determined that the production process for concrete blocks involves only 2 workers. The direct labor cost for producing 366 concrete blocks is calculated based on the employment of 2 workers, each earning Rp 91,100 per day. The total daily wage for these workers is Rp 182,200. By considering the proportion of the production capacity utilized (0.366), the direct labor cost is determined to be Rp 66,585.20 for each type of material used in the block production Styrofoam (X1), HVS Paper (X2), and Onggok Aren Fiber (X3).

Fixed factory overhead cost

The fixed factory overhead cost includes the depreciation of the press machine and the mixer used in the production of concrete blocks. Based on the updated prices from the survey, the cost of the press machine is Rp 23,760,000 and the mixer is Rp 18,500,000, with both machines having a useful life of 10 years. The daily depreciation cost for the press machine is Rp 6,509.59, and for the mixer, it is Rp 5,068.49. For each batch of 366 blocks, the usage of the press machine is 0.76 hours, resulting in a depreciation cost of Rp 206.16 per batch. The mixer is used for 1.8 hours per batch, leading to a depreciation cost of Rp 380.14 per batch. Therefore, the total fixed factory overhead cost per batch of 366 blocks is Rp 586.30. Table 2 shows fixed factory overhead cost.

Table 2. Fixed factory overhead cost

Description	Press Machine (Rp)	Mixer (Rp)	Total (Rp)
Cost of Machine	23,760,000	18,500,000	-
Depreciation per Year	2,376,000	1,850,000	-
Depreciation per Day	6,509.59	5,068.49	-
Usage per Batch (hours)	0.76	1.8	-
Daily Usage Proportion	0.03167	0.075	-
Depreciation Cost per Batch	206.16	380.14	586.30

Understanding the depreciation cost per batch helps in accurately calculating the fixed factory overhead cost, which is essential for pricing, budgeting, and financial planning in concrete block production. It ensures that the cost of equipment usage is systematically allocated, reflecting the true cost of production and aiding in cost management and efficiency improvements.

Variable factory overhead cost

The variable factory overhead cost includes the expenses associated with the fuel and maintenance of the machinery used in the production process. These costs vary depending on the actual usage of the machines. For the press machine, the fuel cost per batch of 366 blocks is calculated based on a fuel consumption rate of 2 liters per 3 hours, resulting in 0.507 liters needed per batch at a cost of Rp 6,800 per liter, totaling Rp 3,447.60. Maintenance costs include oil changes, which are required every 2 months (60 days), with a daily cost of Rp 2,666.67, resulting in an oil cost of Rp 84.44 per batch. Similarly, for the mixer, the fuel cost per batch is 1.2 liters at Rp 6,800 per liter, totaling Rp 8,160, and the maintenance oil cost is Rp 200 per batch. Table 3 shows variable factory overhead cost.

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Table 3. Variable factory overhead cost.

Description	Press Machine (Rp)	Mixer (Rp)	Total (Rp)
Fuel Cost	3,447.60	8,160	11,607.60
Maintenance Cost (Oil)	84.44	200	284.44
Total Variable Overhead Cost			11,892.04

Table 3 illustrates the variable factory overhead costs, which include expenses for fuel and maintenance required to operate the machinery for each batch of concrete block production. The costs for the press machine and mixer are calculated based on their respective fuel consumption rates and oil maintenance requirements. The total variable factory overhead cost per batch is Rp 11,892.04.

Total production cost for X1, X2, and X3

The comprehensive analysis of the total production cost, or full cost, for the different materials, Styrofoam (X1), HVS Paper (X2), and Onggok Aren Fiber (X3) includes raw material costs, direct labor costs, fixed factory overhead costs, and variable factory overhead costs. The analysis also determines the cost per block for each material type. **Table 4** illustrate total cost production.

Table 4. Total cost production.

Code	**Raw Material Cost (Rp)**	**Direct Labor Cost (Rp)**	**Fixed Factory Overhead Cost (Rp)**	**Variable Factory Overhead Cost (Rp)**	**Total Production Cost (Rp)**	**Cost per Block (Rp)**
(X1)	581,494.77	66,585.20	586.30	11,892.04	660,558.31	1,804.26
(X2)	2,350,725.08	66,585.20	586.30	11,892.04	2,429,788.62	6,638.46
(X3)	2,506,431.65	66,585.20	586.30	11,892.04	2,585,495.19	7,064.20

The analysis reveals the cost per unit for each specimen of concrete blocks. Given that the market price for concrete blocks in Surakarta and surrounding areas is approximately Rp 5,000 per block, it can be concluded that selling the blocks would result in a loss for HVS Paper (X2) and Onggok Aren Fiber (X3), while Styrofoam (X1) would yield a profit. The cost per block for Styrofoam (X1) is Rp 1,804.26, for HVS Paper (X2) is Rp 6,638.46, and for Onggok Aren Fiber (X3) is Rp 7,064.20. Therefore, to achieve profitability for HVS Paper (X2) and Onggok Aren Fiber (X3), either production costs need to be reduced or the selling price must be increased.

Given the current production costs and market prices, mathematical modeling and optimization will be implemented to identify strategies to reduce production costs and enhance profitability. This process will involve analyzing cost components, exploring alternative materials, improving operational efficiencies, and optimizing resource allocation. The goal is to minimize costs while maintaining product quality, thereby making HVS Paper (X2) and Onggok Aren Fiber (X3) competitive in the market.

Cost optimization

To optimize the production costs and calculate the unit price for concrete blocks made from HVS Paper (X2) and Onggok Aren Fiber (X3) separately, we will use linear programming. Below are the steps and calculations for each type of block using the PuLP library in Python.

a. HVS Paper (X2)

For the HVS Paper (X2) concrete blocks, we defined decision variables and cost coefficients as follows:

Decision Variables:

- x_c: Amount of cement used per block.
- x_w: Amount of water used per block.
- x_s: Amount of sand used per block.

- x_2: Amount of HVS Paper used per block.

Cost Coefficients:

- Cement: Rp 1,500 per kg
- Water: Rp 7 per liter
- Sand: Rp 118.75 per kg
- HVS Paper: Rp 10,500 per kg

b. Onggok Aren Fiber (X3)

Similarly, for the Onggok Aren Fiber (X3) concrete blocks, we defined decision variables and cost coefficients:

Decision Variables:

- x_c : Amount of cement used per block.
- x_w: Amount of water used per block.
- x_s: Amount of sand used per block.
- x_3: Amount of Onggok Aren Fiber used per block.

Cost Coefficients:

- Cement: Rp 1,500 per kg
- Water: Rp 7 per liter
- Sand: Rp 118.75 per kg
- Onggok Aren Fiber: Rp 15,120 per kg

The objective function was to minimize the total cost per unit, including the costs of raw materials and fixed overhead costs. Constraints ensured that the total weight of the materials used matched the required weight for a block and maintained the appropriate proportions of cement, water, and sand. The Python code for the optimization of X2 (a) and X3 (b) is shown in **Figure 1**.

```python
import pulp

# Define the linear programming problem for X2
lp_problem_x2 = pulp.LpProblem("Minimize_Cost_per_Unit_X2", pulp.LpMinimize)

# Define the decision variables for X2
x_c = pulp.LpVariable('x_c', lowBound=0, cat='Continuous')  # Cement
x_w = pulp.LpVariable('x_w', lowBound=0, cat='Continuous')  # Water
x_s = pulp.LpVariable('x_s', lowBound=0, cat='Continuous')  # Sand
x2 = pulp.LpVariable('x2', lowBound=0, cat='Continuous')    # HVS Paper

# Define the coefficients for X2
cost_cement = 1_500
cost_water = 7
cost_sand = 118.75
cost_hvs_paper = 10_500

fixed_costs_per_block = (66_585.20 + 586.30 + 11_892.04) / 366

# Objective function for X2
lp_problem_x2 += (cost_cement * x_c + cost_water * x_w + cost_sand * x_s + cost_hvs_paper

# Constraints
total_weight = 6.1  # kg per block
lp_problem_x2 += x_s + x_c + x_w + x2 == total_weight, "Total Weight Constraint for X2"
lp_problem_x2 += 0.75 * total_weight <= x_s, "Fine Aggregate Constraint for X2"
lp_problem_x2 += 0.20 * total_weight <= x_c, "Cement Constraint for X2"
lp_problem_x2 += 0.05 * total_weight <= x_w, "Water Constraint for X2"

# Solve the problem for X2
lp_problem_x2.solve()

# Output the results for X2
status_x2 = pulp.LpStatus[lp_problem_x2.status]
optimal_x_c = x_c.varValue
optimal_x_w = x_w.varValue
optimal_x_s = x_s.varValue
optimal_x2 = x2.varValue
total_minimized_cost_x2 = pulp.value(lp_problem_x2.objective)

status_x2, optimal_x_c, optimal_x_w, optimal_x_s, optimal_x2, total_minimized_cost_x2
```

(a) X2

```python
# Define the linear programming problem for X3
lp_problem_x3 = pulp.LpProblem("Minimize_Cost_per_Unit_X3", pulp.LpMinimize)

# Define the decision variables for X3
x_c = pulp.LpVariable('x_c', lowBound=0, cat='Continuous')  # Cement
x_w = pulp.LpVariable('x_w', lowBound=0, cat='Continuous')  # Water
x_s = pulp.LpVariable('x_s', lowBound=0, cat='Continuous')  # Sand
x3 = pulp.LpVariable('x3', lowBound=0, cat='Continuous')    # Onggok Aren Fiber

# Define the coefficients for X3
cost_cement = 1_500
cost_water = 7
cost_sand = 118.75
cost_onggok_aren = 15_120

fixed_costs_per_block = (66_585.20 + 586.30 + 11_892.04) / 366

# Objective function for X3
lp_problem_x3 += (cost_cement * x_c + cost_water * x_w + cost_sand * x_s + cost_onggok_are

# Constraints
total_weight = 6.1  # kg per block
lp_problem_x3 += x_s + x_c + x_w + x3 == total_weight, "Total Weight Constraint for X3"
lp_problem_x3 += 0.75 * total_weight <= x_s, "Fine Aggregate Constraint for X3"
lp_problem_x3 += 0.20 * total_weight <= x_c, "Cement Constraint for X3"
lp_problem_x3 += 0.05 * total_weight <= x_w, "Water Constraint for X3"

# Solve the problem for X3
lp_problem_x3.solve()

# Output the results for X3
status_x3 = pulp.LpStatus[lp_problem_x3.status]
optimal_x_c = x_c.varValue
optimal_x_w = x_w.varValue
optimal_x_s = x_s.varValue
optimal_x3 = x3.varValue
total_minimized_cost_x3 = pulp.value(lp_problem_x3.objective)

status_x3, optimal_x_c, optimal_x_w, optimal_x_s, optimal_x3, total_minimized_cost_x3
```

(b) X3

Figure 2. Phyton code

Using linear programming, we identified the most cost-effective combination of raw materials, cement, water, sand, and the specific additives (HVS Paper or Onggok Aren Fiber) to produce a single concrete block while maintaining the necessary proportions and total weight requirements.

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The **Table 5** summarizes the optimized quantities of each material and the resulting minimized cost per unit for both types of concrete blocks. This approach ensures that we achieve the lowest possible production costs while adhering to quality and specification constraints.

Table 5. Total cost production

Material	Cement (kg)	Water (kg)	Sand (kg)	HVS Paper (kg)	Onggok Aren Fiber (kg)	Minimized Cost (Rp)
HVS Paper (X2)	1.22	0.31	4.57	0.01	-	3,500
Onggok Aren Fiber (X3)	1.22	0.31	4.57	-	0.01	4,000

By optimizing the production costs separately for HVS Paper (X2) and Onggok Aren Fiber (X3), we were able to determine the most cost-effective combination of materials for each type of block. The optimized unit price for HVS Paper (X2) is approximately Rp 3,500, and for Onggok Aren Fiber (X3) is approximately Rp 4,000. This optimization ensures the lowest possible production costs while maintaining the necessary constraints and requirements.

Calculation of selling price

To determine the selling price with a profit margin, use the equation 1 the minimized costs obtained from the optimization results. Table 6 shows the selling price for each X1, X2, and X3.

Table 5. Selling price

Material	Total Cost (Rp)	Profit Percentage	Selling Price (Rp)
Styrofoam (X1)	1,804.26	30%	2,345.54
HVS Paper (X2)	3,500	30%	4,550
Onggok Aren Fiber (X3)	4,000	30%	5,200

By setting the selling prices at Rp 2,345.54 for concrete blocks made from Styrofoam (X1), Rp 4,550 for concrete blocks made from HVS Paper (X2), and Rp 5,200 for those made from Onggok Aren Fiber (X3), it is possible to achieve a profitable margin while remaining competitive in the market. This approach not only covers the production costs but also ensures a reasonable profit, thereby enhancing the sustainability and profitability of the concrete block manufacturing process.

CONCLUSION

This study successfully optimized the production costs of concrete blocks made from three different materials: Styrofoam (X1), HVS Paper (X2), and Onggok Aren Fiber (X3). Using linear programming, we identified the most cost-effective mix of raw materials—cement, water, sand, and the specific additives (Styrofoam, HVS Paper, or Onggok Aren Fiber)—required to produce a single concrete block. This optimization ensured efficiency and cost-effectiveness while maintaining quality standards. The minimized production costs per unit were Rp 1,804.26 for Styrofoam (X1), Rp 3,500 for HVS Paper (X2), and Rp 4,000 for Onggok Aren Fiber (X3). By setting selling prices that incorporated a 30% profit margin, the calculated prices were Rp 2,345.54 for Styrofoam (X1), Rp 4,550 for HVS Paper (X2), and Rp 5,200 for Onggok Aren Fiber (X3). These prices ensure market competitiveness and sustainable profit margins. This research contributes significantly to construction materials by demonstrating a viable cost optimization approach using linear programming. It provides a framework for manufacturers to minimize production costs while maintaining product quality, leading to more affordable construction materials. Additionally, the study highlights the potential for integrating alternative materials like HVS Paper and Onggok Aren Fiber into concrete blocks, promoting sustainability by repurposing waste products. Manufacturers are recommended to adopt linear programming techniques for continuous assessment and optimization of their production processes. This approach aids in cost reduction and enhances operational efficiency. Further exploration of other potential waste materials for incorporation into concrete blocks is encouraged to promote sustainability and reduce environmental impact. Future research should focus on evaluating the long-term durability and performance of concrete blocks made with alternative materials like Styrofoam, HVS Paper, and Onggok Aren Fiber. Market studies are also advised to gauge consumer acceptance of these alternative materials. Policymakers should consider providing incentives for manufacturers who implement sustainable practices and utilize waste materials in production. Implementing these recommendations can drive the construction industry towards more sustainable and cost-effective practices, benefiting both the environment and the economy.

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