Establishing Value of Ceramic Solid Waste Into Light Weight Concrete

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Abstract. Ceramic solid waste is a waste in the form of the ceramic or ceramic powder that has a defect and cannot be resold where the amount will continue to increase as the ceramic industry continues to produce. Handling waste so far is done by pilling it on vacant land so that if the waste continues to grow the more areas are also needed to stockpile. In addition, waste handling by boards can be a potential hazard to the surrounding environment such as chemical content in ceramics can be carried to the waters and the dust can be blown by the wind and disrupt breathing. This study aims to convert ceramics solid wastes into bricks that have more added value. Data collection is done with primary and secondary data. The method used is Taguchi experiment design to determine the optimum brick composition. The experiment consisted of 4 factors and 3 levels of ceramic with 4 kg, 5 kg and 6 kg, cement with level 3 kg, 4 kg and 5 kg, silica with level 3 kg, 4 kg and 5 kg, water level 500 ml, 750 ml, and 1000 ml. After that proceed with the financial analysis that is determining the selling price, Break Event Point (BEP, Internal Rate of Return (IRR), Pay Back Period (PBP), and Profitability Index. The results of this research are the optimum composition of the concrete blocks, 6 kg of ceramics, 5 kg of cement, 4 kg of silica sand and 1000 ml of water with the compressive strength of 125,677 kg/cm2 and signal to noise is 41,964 dB. In the financial analysis, the selling price of brick is Rp 7,751.75/unit and BEP 318,612 units of product, IRR level 43.174% and PBP for 1 year and 10 months

1. Introduction

Ceramic solid waste is a waste in the form of ceramic or the ceramic powder that has a defect and can not be resold where the number will continue to increase as the ceramic industry continues to produce. Handling of waste during this done by hoarding empty land so that if the wastes continue to grow increasingly also the area needed to hoard it [1]. In addition, confectionary waste in a hoard can potentially harm the surrounding environment such as chemical content in ceramics can be brought to the waters and the dust can be blown by the wind and disrupt breathing [2].

The current emerging technology is the management of industrial waste to be used as raw material for building materials. With the discovery of materials, innovations are expected to replace building materials and reduce production costs and reduce industrial waste[3]. One such innovation is to use ceramic wastes instead of sand aggregates in brick [4].

Brick is one of the building material with sand and aggregate forming material (the mixture of sand, gravel, and water) [5]. Brick is molded through a compacting process into blocks with certain

sizes and requirements and the hardening process is placed in moist areas or not exposed to direct sunlight or rain [6].

Brick includes non-structural wall building materials. Although only a nonstructural part of the building does not mean that the brick has no standard of strength and tolerance to be met because in its use a certain quality brick can be used in a load-bearing construction [7]. There are certain restrictions as a requirement on the brick so that in its use, the brick has the resilience of various influences either directly or indirectly influences such as the provisions in Indonesian National Standard (SNI 03-0349-1989) [8]. The price of the brick in the market today is Rp 7500, much different than the price of Rp 1200, but the brick has advantages over the bricks that have stronger strength, easier installation, more waterproof and can isolate the air [9].

Based on the study that has been done, the processing of solid waste (ceramic defects) in XYZ company does not have good processing yet. In research at this company before, it is known that the factory has a production capacity of 40,000 m2 and has a target disability rate of 5% that is 2000 m2 per day and actual ceramic disability of 12.43% ie 4,972 m2 per day, from the defective product there is no solution to add The sale value of the defective product. So far, the defect product has been dumped to cause the accumulation of defective products and does not generate profits and damage the environment.

Given these conditions, research needs to be done to increase the value of solid waste into more value. Therefore, researchers have thought to treat the solid waste into brick considering the basic nature of the ceramics that can be used into the product. In the research used Taguchi experimental design method to find a good composition in order to meet the existing standards and can be marketed to the market.

The purpose of this research is to get the composition of brick from ceramic solid waste so it is feasible for sale to the market, besides also to analyze the response of test result and signal to noise brick to each given treatment, know the optimum strength and optimum signal to noise by the brick from ceramic solid waste materials, knowing the influencing factors in the press test and signal to noise brick.

1.1. Taguchi Method

Taguchi method is a most powerful and popular statistical method used for the design of experiments (DOE) can be effectively employed in optimizing the process/product by using number of steps such as planning, conducting and evaluating results of orthogonal array (OA) experiments to determine the optimum levels of control parameters under very noisy environment [10]. The prime objective goal is to maintain the variance in the results very minimal even in the presence of noise inputs to make robust design process against all variations. Generally, its focus is to optimize the quality characteristic of a process economically and for determining the optimal parameter settings of a process and thereby achieving improved process performance with reduced process variability [11]. Taguchi's method involves the use of specially constructed tables called "orthogonal array" (OA) required for very less number of experimental runs in designing which are consistent and easy to apply [10]. It is successfully used in the various fields of Engineering especially in manufacturing industries. The paper deals with implementation of Taguchi's DOE methodology and technique in respect of shrinkage and optimization of process parameters [12].

2. Methodology/Experimental

The determination of variables is determined by:

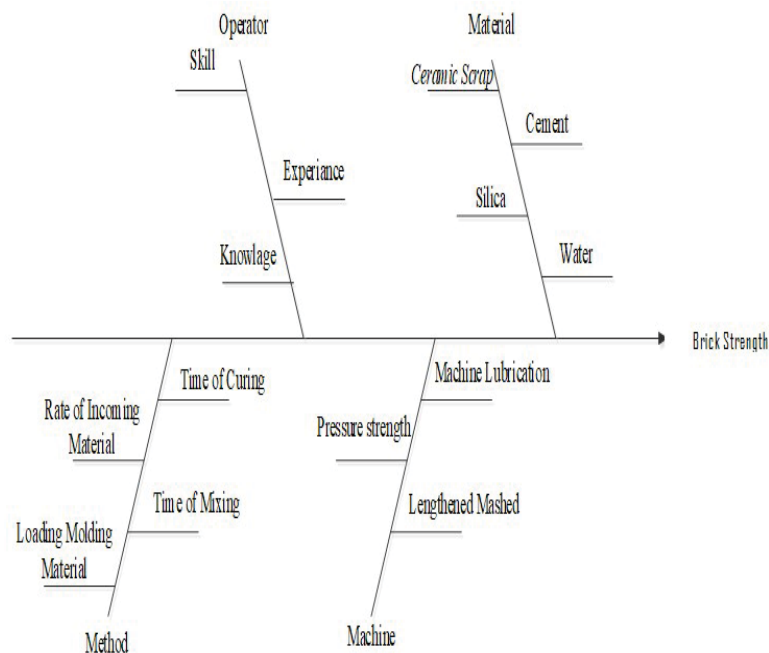- Brainstroming

  In this research, brainstorming is done by writer, colleague writer, expert staff of brick and writer**.**

- Flowchart Diagram

  Flow diagram can be seen in Figure 1.

- Cause-and-effect Diagram
  A cause-and-effect diagram is used to identify potential causes. Cause and effect diagram can be seen in Figure 2.
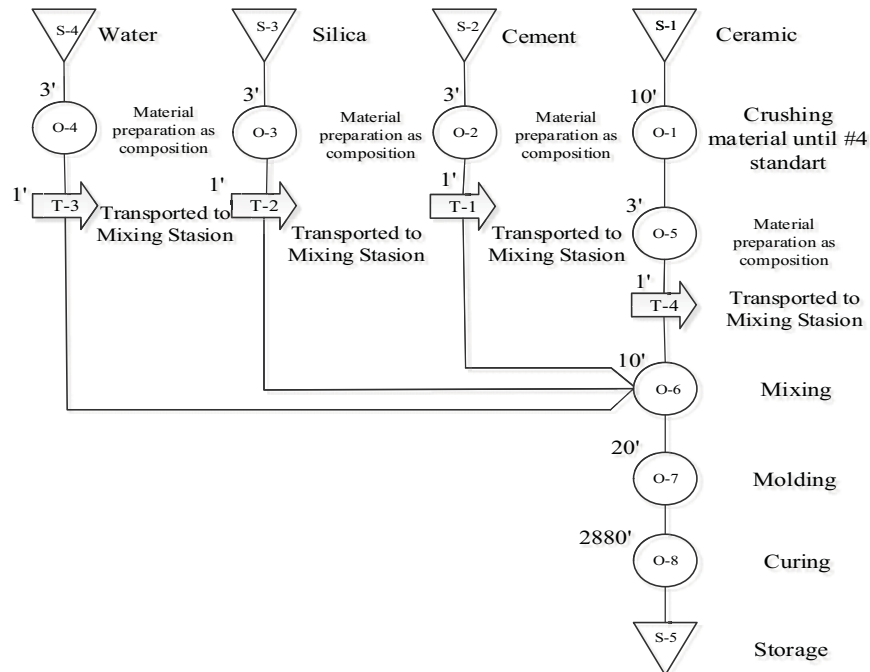
Figure 1. Flowchart Diagram

Figure 2. Cause and Effect Diagram

2.1. Pre-Experiment

In the experiments to determine the level of each factor by experimenting directly with the expert staff of the brickwork by looking at a critical point (the point where the brick is destroyed/ unreachable) from the brick and from that critical point, the range is divided into certain levels. Based on the method of identifying the problem, the researcher chose the material factors as the independent variable. These factors are as follows:

- Water composition
  In this study, there are three levels of water composition that is 500 ml, 750 ml, and 1000 ml.
- Silica sand composition
  In this research, there are three levels of silica sand composition that is 3 kg, 4 kg and 5 kg.
- The composition of cement
  In this study, there are three levels of the cement composition that is 3 kg, 4 kg, and 5 kg.
- Ceramic scarp composition
  In this study, there are three levels of ceramic scrap composition of 4 kg, 5 kg, and 6 kg.

2.2. Data collection

Material and material specifications can be seen in Table 1.

Table 1. Material Specification

No	Name	Specification	Figure
1	Ceramic Waste	Ceramic of with mesh by 4	
2	Cement	Portland Cement type I	
3	Silica Sand	Sludge level max 20% Mesh 50	
4	Water	Ground water, Ph = 7.4 Hardness $CaCO_{3} = 322$ mg/ L	

Total Inventory effort can be seen in Table 2 and total fixed cost can be seen in Table 3.

Table 2. Total Investation

No.	Investation	Price (Rp)
1	Machine	195,000,000
2	Tools	34,249,000
3	Truck	221,000,000
4	Building	500,000,000
Total		950,249,000

Table 3. Total Fixed Cost

Information	Cost Estimation (Rp)
1. Maintenance	22,512,450
2. Salary	318,600,000
3. Depression	48,449,900
4. Operational	2,396,900
Total	391,959,250

Variable costs can be seen in Table 4.

Table 4. Total Variable Cost

| Information	Cost Estimation (Rp)
1. Material Cost	6,327
2. Electricity	194.58
Total	6521.58
Total Cost 2520 products /day	16,434,370.08
Total Cost/Year	4,864,573,544

3. Data Processing

3.1.Taguchi Method
In this study there are 4 factors and 3 levels observed, it can be in Table 5.

Table 5. Taguchi Treatment

Treatment	Information	Level		
		1	2	3
A	Ceramic Waste	4 kg	5 kg	6 kg
B	Cement	3 kg	4 kg	5 kg
C	Silica Sand	3 kg	4 kg	5 kg
D	Water	500 ml	750 ml	1000 ml

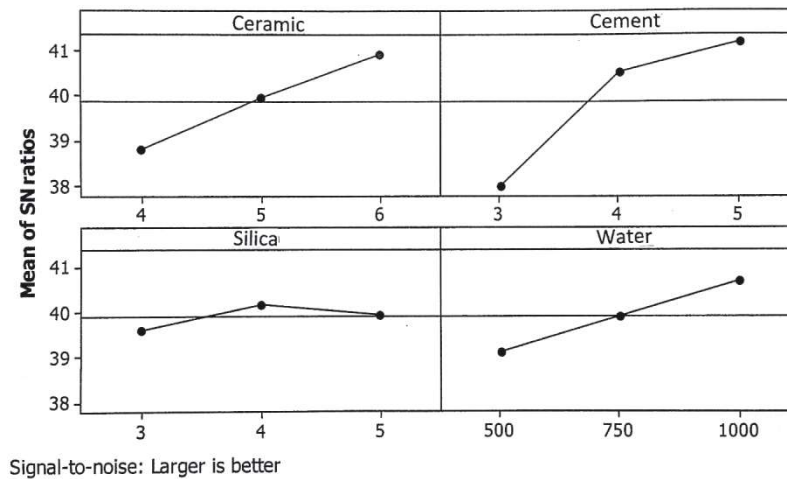The response of each factor and level treatment can be seen in Figure 3.
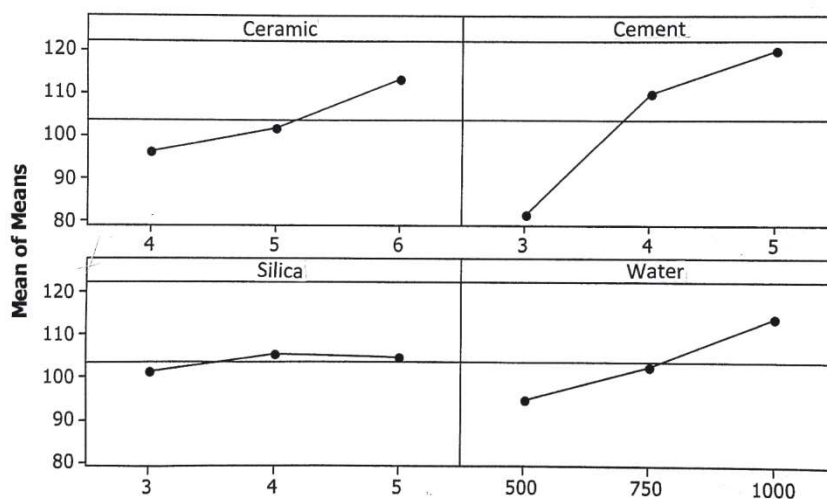
Figure 3. Treatment Response

The average equation model of compressive strength of the resulting brick is as follows:

$$\text{Mean Prediction} = Y + (A_3 - Y) + (B_3 - Y)) \tag{1}$$
$$= 129, 401$$

$$Cl \quad = \pm \sqrt{F(0,10; (1:18)x\ Ve\ x\ \frac{1}{neff}}} \tag{2}$$
$$= \pm\ 7,796$$

$$\text{Mean Prediction} = 121,694 \le 129,401 \le 137,107$$

The S / N response to each factor and level treatment can be seen in Figure 4.

Figure 4. Treatment Response S/N

The average equation model of the signal noise of the resulting brick is as follows:

$$\text{Mean Prediction} = \quad Y + (A_3 \text{-} Y) + (B_3 \text{-} Y) \tag{3}$$
$$= 42.343$$

$$Cl \quad = \pm \sqrt{F(0,10; (1:18)x\ Ve\ x\ \frac{1}{neff}}} \tag{4}$$
$$= \pm\ 0.629$$

$$\text{Mean Prediction} = 41.714 \le 42.343 \le\ 42.973$$

Confirmation Experiment
The results of the confirmation experiment can be seen in Table 6.

Table 6. Confirmation Experiment Result

No	Result (kg/cm2)
1	114.1511
2	125.8763
3	128.4928
4	116.5586
5	119.9401
6	123.4148
7	136.6102
8	137.2174
9	139.3076
10	115.2077
Mean	125.6777

The average confidence interval for the confirmation experiment is as follows:

$$Cl = \pm \sqrt{F(0,10; 1:18) \; x \; MSe \; x \left[\frac{1}{neff} + \frac{1}{r} \right]} \tag{5}$$
$$= \pm 12.474$$

The average Trust Interval is: $113.203 \leq 125.677 \leq 138.152$

S/N confidence interval for confirmation experiment is as follows:

$$Cl = \pm \sqrt{F(0,10; 1:18) \; x \; MSe \; x \left[\frac{1}{neff} + \frac{1}{r} \right]} \tag{6}$$
$$= \pm 1.018$$

The average trust interval is:$40.944 \leq 41.963 \leq 42.982$
Comparison between experiment result and confirmation result can be seen in Table 7.

Table 7. Comparison of Experiment Results and Confirmation

		Prediction	Optimization
Taguchi Experiment	Mean	129.4011	129.4011 ± 7.706
	Variability S/N	42.343	42.343 ± 0.629
Confirmation Experiment	Mean	125.677	125.677 ± 12.474
	Variability S/N	41.963	41.963 ± 1.018

3.2. Financial Aspects
In the financial aspect will be calculated the feasibility of the brick business that will be made as
follows**:**

Production per day $= 40.000 m^2$
Height of ceramic $= 0.35$ cm $= 0.0035$ m
Production volume/day $= 40,000$ x $0.0035 m = 140$ m^3
Defect $= 140$ m^3 x $5 \% = 7$ m^3
Defect volume $= 0.4$ m x 0.25 m x 0.0035 m $= 0.00035$ m^3
Scrap/day $= 7 m^3$ x 2257.761 $kg/m^3 = 15,804.33$ kg

Lightweight concrete should produce $= 15804.33$ kg / 6 kg $= 2634.055$ unit

Production time without curing process = 56 minutes
Total cycle/day   = 7 hour x 60 minutes / 56 minutes = 7.5 = 7 cycle

The capacity of each cyle production is 270 kg raw material, so total mold brick each cyle is :
Total mold brick each cycle   = 270 / 15   = 18 mold
Total brick each cyle   =18 mold x 5 unit/ mold   = 90 unit
Total brick 1 shift 1 machine   = 7 cycle x 90 unit   = 630 unit
Total brick 2 shift 2 machine   = 2 machine x 2 shift x 630 unit = 2520 unit

The steps taken to determine the Break Even Point (BEP) are:
- Define product price
  If the profit define as 10 %, so the calculation be :
  Profit   = TR-TC
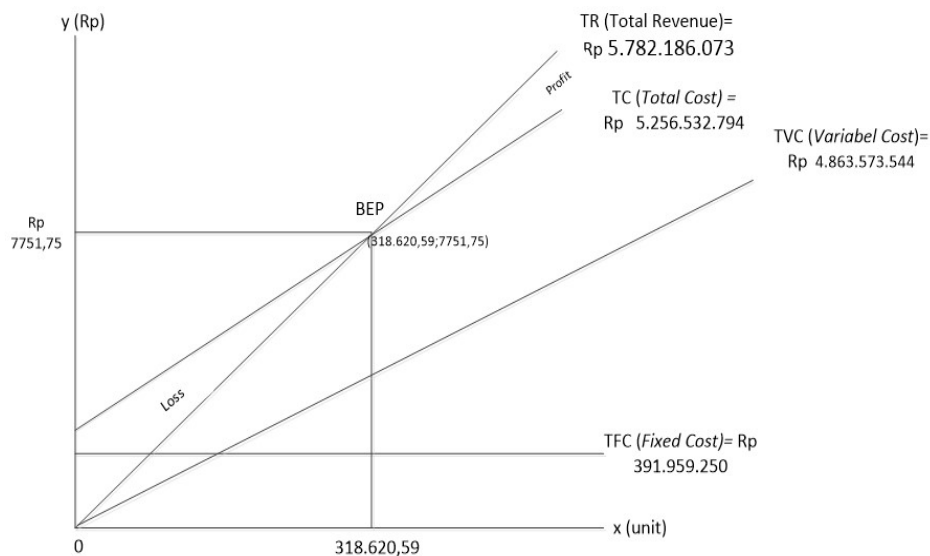 10%.TC   = TR -TC
  TC(10% + 1)   = TR
  P (Price)   = Rp 7751,750

- Define Break Even Point
  From the above data. Then BEP per year can be calculated that is:

$$N_{BEP} = \frac{TFC}{P - VC} \tag{7}$$
$$= 318{,}620.59 \approx 318{,}621 \text{ unit/year}$$

The figure of Break Even Point can be seen in Figure 5.

Figure 5. BEP Point

IRR calculation
For I   = 40 %
ΣNPV =Rp420,869,696 (P/A.40%.10) – Rp950,249,000=Rp65,730,445
For i   = 45%
Σ NPV = Rp420,869,696 (P/A.45%.10) – Rp   950,249,000= - Rp 37,803,500

IRR is the value of discount rate i which makes the NPV of the project equal to zero. From the calculation can be seen IRR is between i = 40% and i = 45%. Then with interpolation obtained:

IRR :

$$= 40\% + \frac{-37.803,500}{-37.803,500 - .730.445} (45\% - 40\%) = 43.1743\%$$

Payback period calculation can be seen in Table 8.

Table 8. Payback Period (PBP) Calculation

Year	Net Cash Flow	Outcash Flow	Cash
0		-950,249,000	-950,249,000
1	367,957,296		-582,291,704
2	735,914,591		153,622,887
3	1,103,871,887		1,257,494,773
4	1,471,829,182		2,729,323,956
5	1,839,786,478		4,569,110,433
6	2,207,743,773		6,776,854,207
7	2,575,701,069		9,352,555,276
8	2,943,658,364		12,296,213,640
9	3,311,615,660		15,607,829,300
10	3,724,197,956		19,332,027,256

PBP = 1,7912year or 1 year 10 month.
Profitability Index calculation for brick business plan can be seen as:

Profitability Index (PI)$= \frac{\text{Rp}4.208.696.956}{\text{Rp } 950.249.000} = 4,4290 > 1$

so the plan is feasible.

Value added of ceramic scrap
Brick from ceramic waste   = Rp 7751.75
Brick conventional   = Rp 7500
Stone Price / m^3 = Rp 200,000
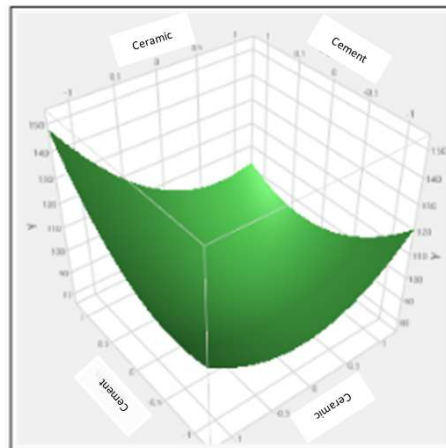Weight of 1 m^3 split stopne   = 180 kg
Split stone price per kg   = Rp 1111.11
Stone need for brick conventional   = 3 kg
%profit   = 10%
Value added ceramic waste $= \frac{(7751,75 - 75\ ) + (1111,11\ x\ 3)}{6}$ x 90%   = Rp 537.79

4. Troubleshooting Analysis

The response of each treatment to the compression means with the greater the better of each level is shown in Figure 6.

Figure 6. Surface Test Chart Press Light Weight Concrete

In the graph, the best response is ceramic at level 3 (6kg), Cement level (5kg), Silica level 2 (4) and water level 3 (1000 ml) with power 129,401. Based on this it can be concluded that 6 kg of ceramics, 5 kg of cement, 4 kg of silica and 1000 ml of water is the optimum composition to obtain the best compression test.

In Anava analysis, mean factor that has the significant difference is treatment B (cement), with F arithmetic 11,22> 2,42 F table, so known cement is a factor which has significant influence to the compressive strength of brick. Contribution to the compressive strength can be stated as 40.845%.
The response of each treatment to the Signal to Noise test press with the goal the greater the better of each level is shown Figure 7.
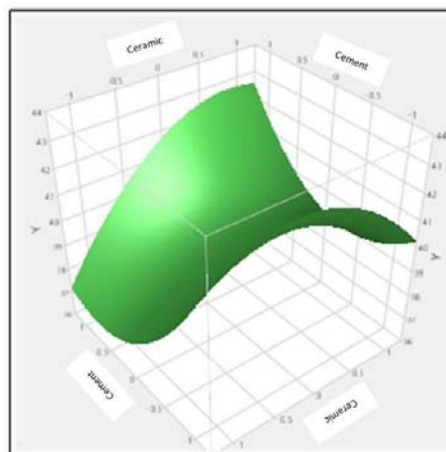
Figure 7. Surface S / N Chart of Light Weight Concrete

On the surface graph, the best response is ceramic at level 3 (6kg), cement level (5kg), silica level 2 (4) and water level 3 (1000 ml). Based on this it can be concluded that 6 kg of ceramics, 5 kg of cement, 4 kg of silica and 1000 ml of water is a solid composition in the removal of variation.

In the analysis of Anava S/N factors that have significant difference is treatment A (ceramic scrap), with F count 3.467> 2.62 with contribution of 8.427% and treatment B (cement), with F arithmetic 13.469> 2.62 F table, So that cement is known to have a significant effect on the elimination of the variation of the response. The contribution of cement to the removal of variations from the brick can be expressed by 42.590%.

IRR analysis is to compare the level of bank MARR with interest generated by doing this business. In this effort, the level of IRR is 43.174%> 6.25%, so it can be said this business is feasible

to do. In this business, payback time occurs in 1 year 10 months. The rapid return of this capital occurs because of the number of products produced, on the other hand, the need for brick in the development and market is broadly given the lack of production of bricks produced by other business actors. The PI value of this brick business is 4.429> 1 so it can be said that this brick business is feasible. The addition of ceramic value after made brick is Rp 537,79/kg. The results obtained from the removal of the value of brick from gravel with ceramic scrap and the difference in selling price of each product.

5. Conclusions

Based on experiments that have been done and financial analysis that has been done in research at XYZ company, it is concluded that the optimum composition in the brick making experiment with the ceramic solid waste material is 6 kg ceramic, 5 kg cement, 4 kg silica, and 1000 ml water, the optimum compressive strength of the ceramic wastewater bricks in this research is 125,677 kg/cm2. The optimum signal to noise of ceramic wastewater bricks in this research is 41,963 dB, the most influential factor in average of compressive test and signal to noise making of brick is ceramic scrap, cement, silica sand, and water. The price of ceramic scrap bricks can be sold at Rp 7751.75 per unit, the breakeven point is 318,621 unit of products, Internal Rate Of Return (IRR) 43.174% and Pay Back Period (PBP) for 1 year 10 months.

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