Composition Analysis of Perforated Concrete Roster Raw Materials To Improve Product Compressive Strength Using Experimental Design Approach

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ABSTRACT

The compressive strength of lightweight bricks produced by CV. Sinar Jaya Maros has a veryhigh variation because there is no standard raw material composition that meets SNI standards, according to SNI 03-0349-1989 that the requirements for hollow concrete bricks for K-350 concrete quality must have a compressive strength of 350 kg/cm2. This research was conducted to design an improvement or quality improvement of hollow concrete brick products in CV. Sinar Jaya Maros. The quality improvement is in increasing the compressive strength of the concrete brick with an optimal composition. Quality improvement was carried out by using the Taguchi method experimental design to obtain the optimal combination of compositions. The orthogonal array notation used is L9(34) with material control factors in the form of cement (A), water (B), and (C), and Casting plaster (D). Data processing is carried out by calculating ANOVA on the average value and S/N Ratio with the best nominal classification. The classification was chosen because the closer to the compressive strength based on the SNI of hollow concrete bricks, the higher the quality of the concrete bricks. This ANOVA calculationis carried out to know which factors have a significant effect on the compressive strength of concrete bricks. The test conducted to determine the quality of lightweight bricks is the compressive strength test of concrete which is carried out using a compression machine. Based on the results of data processing, the ratio of the optimal composition of cement:water: sand was obtained by 2:1:3,5. Confirmation experiments prove that the compressive strength of the composition is robust.

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1. INTRODUCTION

The rapid population growth has resulted in the need for housing, facilities and infrastructure such as other supporting buildings to increase. Based on data from the Population Administration (Adminduk) as of June 2021, the total population of Indonesia is 272 million people, this shows that the rate of population growth will always be directly proportional to the need for residential land. Makassar City is one of them, Makassar City is a city located in South Sulawesi Province which has an area of 175.8 km²[1]. Based on the results of the 2020 population census, the population in South Sulawesi Province is 9.07 million people[2].

The high population causes the demand for residential housing to also increase. This also shows that the demand for building materials is also increasing[3][4].

The construction of housing will be in line with the demand for building material needs. One of the building materials that is often used in the manufacture of houses or residences is a perforated concrete roster[5][6]. According to SK SNI S – 04 – 1989 – F roster is a building material made from a mixture of portland cement (PC), fine aggregate, water and or other addictive additives (casting plaster) which are shaped in various ways and are usually mounted on walls[7][8].

One of the industries engaged in the manufacture of perforated concrete roster products is VC. Sinar Jaya Maros. CV. Sinar Jaya Maros produces perforated concrete roster manually without any assistance from a printing machine[9][10]. As a result, the manufacture of perforated concrete roster products is carried out based on estimates from workers who do not have the right composition and process. This results in a quality that is not in accordance with the standard, in this case the level of strength of the perforated concrete roster product produced still does not meet the standard (SNI)[11]. According to SNI, the roster requirements (perforated concrete brick) must have a compressive strength of around 30 MPa or the equivalent of 350 kg/cm2[12]. The unequal hardness of these products causes some products to crack easily.

Based on the results of initial observations made by researchers by taking 10 samples of concrete roster with a size of 20 x 10 x 20 cm produced by CV[13]. Sinar Jaya Maros, then carried out a compressive strength test, it was found that the average compressive strength of the roster product only reached 293.70 Kg/cm2, this indicates that the roster product is still below the SNI standard of 350 Kg/cm2[14][15]. Therefore, it is necessary to take action to test the level of strength on the quality of perforated concrete roster products which aims to provide solutions for companies[16][17]. Based on the above problems, the idea emerged to improve product quality by conducting tests related to the compressive strength of perforated concrete roster products with the Taguchi method experimental design approach[18][19].

2. RESEARCH METHODS

2.1 Time and Place of Research.

The time of this research was carried out for two months at CV. Sinar Jaya Maros, located at JL. Abd. Kadir Dg. Suro, Samata, Kec. Somba Opu, Kab. Gowa, South Sulawesi. The raw materials used are cement, sand, water, and casting plaster. The equipment used is a shovel, sieve (0.5 mm), bucket, and mould.

2.2 Data Collection

The data used in this study is primary data, namely data obtained directly from respondents who are the target of research[20]. The data of this research is in the form of compressive strength test data for pthe erforated concrete roster.

2.3 Data Processing

The data processing used in this study using an experimental design is a series of tests carried out sequentially by changing the input variables in a process so that they can see and identify changes that occur in the output variables. the Taguchi method is a methodology in engineering that aims to improve product and process quality while at the same time reducing costs and resources to a minimum : 1) Identify quality characteristics; 2) Identify control factors and noise factors; 3) Determine the setting level for each factor; 4) Determine the objective function Signal-to-noise (S/N) ratio;5) Control factor and factor level; 6) Selection of orthogonal array matrices; 7) Calculating analysis of variance (ANOVA); 8) Polling up 8) Confirmation experiment.

3. RESULTS AND DISCUSSION

3.1 Analysis of the Causes of the Problem

The following are the results of the analysis of the causes of problems in CV. Sinar Jaya Maros using the causal diagram shown in Figure 1. Based on Figure 1, it is known that there are five main factors that cause variations in the compressive strength of lightweight bricks. The five factors

consist of material, human, machine, environmental and method factors other factors such as the environment and humans were not chosen because they did not affect the compressive strength of lightweight bricks. The drying time factor actually also affects the

compressive strength of lightweight bricks. However, based on discussions with the head of production taking into account the research time and factory conditions, it was decided to use the drying time following the average standard in CV. Sinar Jaya Maros which is for 14 days
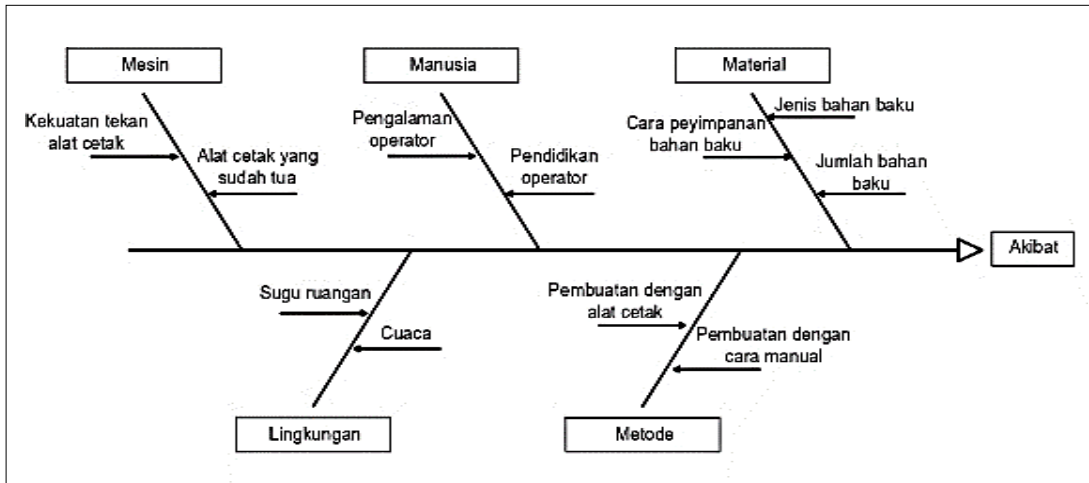

Figure 1 Cause-and-effect diagram

3.2 Determining Experimental Factors

Determination of experimental factors aims to determine what factors are used in the experiment. After identifying the factors, there are two control factors, namely material and method. These two factors are critical factors for the selected quality dimension, namely the compressive strength performance of lightweight bricks. The materials used in the manufacture of lightweight bricks, namely cement, water, sand and casting plaster, greatly affect the compressive strength of lightweight bricks. The method factor was also selected as a control factor. This is because the determination of the composition will determine the compressive strength of lightweight bricks. Meanwhile

3.3 Creating Factor Levels

The determination of the factor level is carried out based on the results of the identification of the factors that affect the compressive strength of the perforated concrete roster product which only focuses on the composition of the roster raw materials, the units in the composition are Kg and water in liters. The levels given for several control factors are as described in Table 1 5.9 7.2

Tabel 1. Level Factor

Factor	Code	Level		
		1	2	3
Cemen	A	1,5	2	2,5
Water	B	0,8	1	1,2
Sand	C	3,5	4	4,5
Casting	D	0,1	0,2	0,3

3.4 Choosing an Orthogonal Array

The selection of the orthogonal array matrix begins with setting the factors and levels. This determination has been carried out in the previous stage where this research consists of four factors and three levels. After the factors and levels are set, the degrees of freedom can be calculated to get 8 degrees of freedom. After getting the results of the calculation of degrees of freedom, the next step is to choose an orthogonal array matrix that matches the appropriate orthogonal array notation is L9(34) where this shows that the minimum experiment to be carried out is nine times.

3.5 Execution of Experiments

Implementation of Experiments In accordance with the notation that has been determined, the number of experiments carried out in this study were nine experiments and replicated three times. Table 2 shows a combination of nine experiments in making hollow concrete roster at CV. Sinar Jaya Maros.

Table 2. Experimental combination $L_9(3^4)$

Eksperimen	Faktor			
	Semen	Air	Pasir	Casting plaster
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The data that has been obtained from the experimental results are then processed to obtain the average value and signal to noise ratio (SNR) with nominal-the-best classification. The two values will later be calculated ANOVA to get which factors have a significant influence on the strength of the perforated concrete roster. The experimental results can be seen in table 3.

Table 3 Experimental Results

Eksp.	Faktor				Kuat tekan (kg/cm²)			
	Semen (Kg)	Air (L)	Pasir (Kg)	Casting plaster (Kg)	1	2	3	Jumlah
1	1,5	0,8	3,5	0,1	213,19	210,20	202,06	625,45
2	1,5	1	4	0,2	320,38	311,23	315,15	946,76
3	1,5	1,2	4,5	0,3	246,38	265,35	250,30	762,03
4	2	0,8	4	0,3	399,82	389,33	320,42	1109,57
5	2	1	4,5	0,1	301,04	312,94	319,86	933,84
6	2	1,2	3,5	0,2	350,32	352,44	354,56	1057,32
7	2,5	0,8	4,5	0,2	309,80	310,22	334,86	954,88
8	2,5	1	3,5	0,3	412,67	404,23	415,67	1232,57
9	2,5	1,2	4	0,1	231,76	245,05	236,70	713,51

3.6 Calculation of the Average (Mean) and Signal to Noise Ratio (S/NR)

In this section, the average value (mean) and Signal to Noise Ratio (SNR) will be calculated using the average value formula and the nominal-the-best formula. Table 3 shows the calculated mean and S/N Ratio data for each experiment.

3.7 Calculation of ANOVA for Average Score

In this section, the ANOVA calculation for the average value is carried out. Calculations will be carried out starting from calculating the average value of all experiments to calculating the percentage contribution of each experiment.

Table 4 ANOVA for the mean value of

Sumber	S_s	V	M_S	F_{hit}	SSi	$\rho\%$	Pooled
A	35182,66	2	17591,33	29,50	33990,36	31,53	Y
B	20021,98	2	10010,99	16,79	20021,68	17,46	Y
C	3957,98	2	1978,99	3,31	2765,68	2,56	1
D	43870,37	2	21935,19	36,79	42678,07	39,58	Y
e	4769,27	8	596,15	1,00	9538,47	8,84	Y
St	107802,26	16	4,53		107802,26	100	
Mean	2573483,74	1					
ST	2681286	17					

To find the F table of a factor, it can be done by looking for guidelines from the degrees of freedom of a factor with degrees of error free with a specified level of accuracy. From the ANOVA above, it is obtained F table (F0.05, 2, 8) = 4.46. so it can be said that factor A, factor B, and factor D are significant while factor C is not significant because the calculated F value is smaller than F table. Then to find out the factors that make a large contribution to the average number of compressive strength results for the perforated concrete roster, an insignificant factor is combined into the error.

Tabel 5 pooling up

Sumber	S_s	V	M_S	F_{hit}	SSi	$\rho\%$	Pooled
A	35182,66	2	17591,33	29,50	33990,36	31,53	
B	20021,98	2	10010,99	16,79	20021,68	17,46	
C							Y
D	43870,37	2	21935,19	36,79	42678,07	39,58	
e							
Pooled	8727,25	10	2575,14		12304,15	11,4	
St	107802,26	16	4,53		107802,26	100	
Mean	2573483,74	1					
ST	2681286	17					

The process of combining factors follows Taguchi's pooling-up rules, starting with the insignificant factor having the smallest sum of squares combined into the pooled error, then the other factors are F-tested against the pooled error. If later from the test results there are factors that are not statistically significant, then the factors are combined again. This is done continuously until statistically significant factors are obtained and the pooled error degrees of freedom are close to or equal to half of the total degrees of freedom. With a confidence level of 95% (α 0.05) and by

combining the factor combination procedure as above, the ANOVA results are obtained as listed in the table below.

In interpreting the results of the ANOVA calculation, a hypothesis test will be carried out. The following is the hypothesis test used in decision making in this study:

1. $H_0: \alpha_1 = \alpha_2$ (there is no effect of factor A on the compressive strength of perforated concrete roster)

   $H_1: \alpha_1 \neq \alpha_2$ (there is an effect of factor A on the compressive strength of hollow concrete roster)

   Conclusion: F Count = 29.50 > F table ($F_{0,05, 2, 8}$) = 4.46; then Ho is rejected, meaning that there is an influence of factor A on the compressive strength of the perforated concrete roster.

2. $H_0: \gamma_1 = \gamma_2$ (there is no effect of factor B on the compressive strength of perforated concrete roster)

   $H_1: \gamma_1 \neq \gamma_2$ (there is an effect of factor B on the compressive strength of the perforated concrete roster),

   Conclusion: F Count = 16.79 > F table ($F_{0,05, 2, 8}$) = 4.46; then Ho is rejected, meaning that there is an influence of factor B on the compressive strength of the hollow concrete roster.

3. $H_0: \varphi_1 = \varphi_2$ (there is no effect of factor D on the compressive strength of perforated concrete roster)

   $H_1: \varphi_1 \neq \varphi_2$ (there is an effect of factor D on the compressive strength of hollow concrete roster)

   Conclusion: F Count = 36.79 > F table ($F_{0,05, 2, 8}$) = 4.46; then Ho is rejected, meaning that there is an influence of factor D on the compressive strength of the perforated concrete roster.

In addition, it can also be seen that the percentage of the pooled error contribution is 11.04%, which means that all factors that are said to have a significant effect on the average value are sufficient to be involved in the experiment (the requirement for the percentage of pooled error contribution in the Taguchi method is not > 50%).
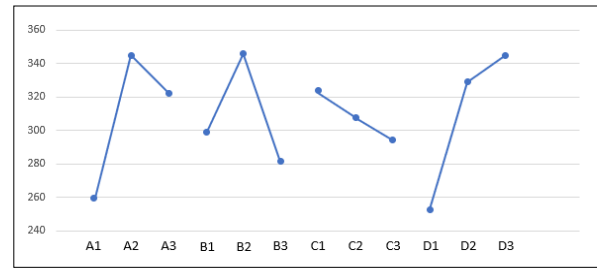
Graph 1 Average value response

Based on the results of the hypothesis test above, it was concluded that the three factors used in the experiment, namely cement, water and casting plaster had a significant effect on the compressive strength of the perforated concrete roster. Based on Table 5, it is found that factors A, B and D do have a significant influence or contribution to the compressive strength of lightweight bricks. Meanwhile, factor C is not significant.

3.8 Calculation of ANOVA for S/N Ratio Value

In this section, the ANOVA calculation for the average value is carried out. Calculations will be carried out starting from the calculation of the S/N ratio of all experiments to the calculation of the percent contribution of each experiment.

Table 6 ANOVA S/N Ratio

Sumber	S_s	V	M_s	F_{hit}	SSi	ρ%	Pooled
A	1,13	2	0,56	2,27	0,65	0,15	1
B	160,94	2	80,47	323,49	160,46	37,85	Y
C	157,02	2	78,51	315,61	156,54	36,92	Y
D	102,81	2	51,40	206,65	102,33	24,14	Y
e	1,99	8	0,24	1,00	3,91	0,46	Y
St	423,89	16	63,62		423,89	100	
Mean	9994	1	-				
ST	10415,9	17	-				

To find the F table of a factor, it can be done by looking for guidelines from the degrees of freedom of a factor with degrees of error free with a specified level of accuracy. From the ANOVA above, it is obtained F table (F0.05, 2, 8) = 4.46. so it can be said that factor A is not significant, while for factor B, factor C, and factor D are significant. Then to find out the factors that make a large contribution to the average number of compressive strengths of the perforated concrete roster, an insignificant factor is combined into the error.

The process of combining factors follows Taguchi's pooling-up rules, starting with the insignificant factor having the smallest sum of squares combined into the pooled error, then the other factors are F-tested against the pooled error.

If later from the test results there are factors that are not statistically significant, then the factors are combined again. This is done continuously until statistically significant factors are obtained and the pooled error degrees of freedom are close to or equal to half of the total degrees of freedom.

With a confidence level of 95% (α 0.05) and by combining The factor combination procedure as described above, obtained ANOVA results as listed in the table below.

Table 7 pooling up

Sumber	S_s	V	M_S	F_{hit}	SSi	$\rho\%$	Pooled
A							Y
B	160,94	2	80,47	323,49	160,46	37,85	
C	157,02	2	78,51	315,61	156,54	36,92	
D	102,81	2	51,40	206,65	102,33	24,14	
e							
pooled	3,12	10	0,8		4,56	0,61	
St	423,89	16	63,62		423,89	100	
Mean	9994	1	-				
ST	10415,9	17	-				

In interpreting the results of the ANOVA calculation, a hypothesis test will be carried out. The following is the hypothesis test used in decision making in this study:

1. H_0: $\alpha_1 = \alpha_2$ (there is no effect of factor B on the compressive strength of perforated concrete roster)
   H_1: $\alpha_1 \neq \alpha_2$ (there is an effect of factor B on the compressive strength of the perforated concrete roster)
   Conclusion: F Count = 323.49 > F table ($F_{0.05, 1, 5}$) = 4.46; then Ho is rejected, meaning that there is an influence of factor B on the compressive strength of the perforated concrete roster.

2. H_0: $\gamma_1 = \gamma_2$ (there is no effect of factor C on the compressive strength of perforated concrete roster)
   H_1: $\gamma_1 \neq \gamma_2$ (there is an effect of factor C on the compressive strength of perforated concrete roster)
   Conclusion: F Count = 315.61 > F table ($F_{0.05, 1, 5}$) = 4.46; then Ho is rejected, meaning that there is an influence of factor C on the compressive strength of the perforated concrete roster.

3. H_0: $\varphi_1 = \varphi_2$ (there is no effect of factor D on the compressive strength of perforated concrete roster)
 H_1: $\varphi_1 \neq \varphi_2$ (there is an effect of factor D on the compressive strength of the perforated

concrete roster) Conclusion: F Count = 102.33 > F table ($F_{0.05, 1, 5}$) = 4.46; then Ho is rejected, meaning that there is an influence of factor D on the compressive strength of the perforated concrete roster.

Based on the results of the hypothesis test above, it was concluded that the three factors used in the experiment, namely cement, water and casting plaster had a significant effect on the compressive strength of the perforated concrete roster.

Based on Table 7, it is found that factors B, C and D do have a significant influence or contribution to the compressive strength of lightweight bricks. Meanwhile, factor A is not significant.

In addition, it can also be seen that the percentage of the pooled error contribution is 0.61%, which means that all the factors that are said to have a significant effect on the average value are sufficient to be involved in the experiment (the requirement for the percentage of pooled error contribution in the Taguchi method is not > 50%).
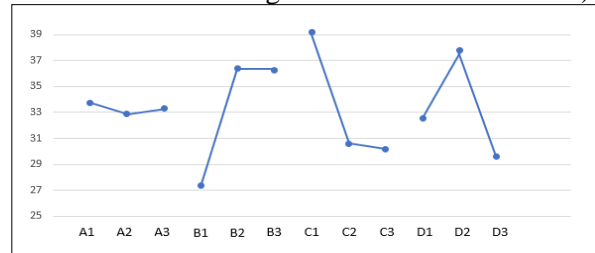
Graph 2 Response value of S/N Ratio

3.9 Determining the optimal state setting level

Determination of optimal level settings to improve product quality. Table 8 describes the determination of the optimal level setting in accordance with the calculations that have been carried out. Based on Table 8, it can be seen that the optimal combination of levels obtained are A2, B3, C1 and D3. Determination of the optimal level setting on perforated concrete roster products is not listed in the experimental composition design table. Therefore, it is necessary to carry out a confirmation experiment to obtain an optimal lightweight brick product.
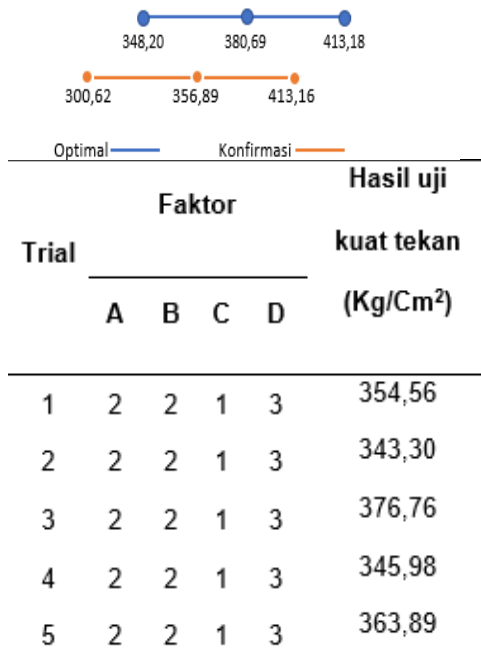
Table 8 optimal level settings

Factor	Code	Level	Perbandingan
Cemen	A	2	2 kg
Water	B	2	1 L
Sand	C	1	3,5 kg
Casting	D	3	0,3 kg

Table 9 Confirmation experimental results

Respon	Kondisi Awal	Kondisi Optimal Eksperimen	Peningkatan	Penurunan
Hasil uji kuat tekan roster beton berlubang	Rata-rata = 293,70	Rata-rata = 380,69	86,99	-
	SD = 65,48	SD = 30,45	-	35,03
	Rasio S/N = 24,14	Rasio S/N = 42,27	18,13	-

Perbandingan selang kepercayaan untuk nilai rata-rata

| | | 348,20 | | 380,69 | | 413,18 |
| | 300,62 | | 356,89 | | 413,16 | |

Optimal —— Konfirmasi ——

Trial	Faktor				Hasil uji kuat tekan (Kg/Cm²)
	A	B	C	D	
1	2	2	1	3	354,56
2	2	2	1	3	343,30
3	2	2	1	3	376,76
4	2	2	1	3	345,98
5	2	2	1	3	363,89

Confirmation experiments are experiments carried out with the aim of validating the conclusions obtained from previous calculations. Experiments are carried out using a design or a combination of the optimal level settings that have been obtained, namely, A2, B3, C1 and D3. Table 9 displays the test results on five samples of the hollow concrete roster from the confirmation experiment. The drying process for lightweight brick products in the confirmation experiment was only carried out for 7 days, this was due to time constraints. After getting the data from the lightweight brick test, standard deviation and variation, the mean and SNR values with nominal-the-best classification will be calculated.

Furthermore, a comparison is made between the compressive strength of the prefixed lightweight brick with the proposal to find out whether there is an increase in quality. Table 18 compares the compressive strength between the initial lightweight brick and the proposed lightweight brick.

After getting the compressive strength of the perforated concrete roster, the standard deviation and variation are also calculated. Based on the calculation of the compressive strength of the hollow concrete roser, the experimental results obtained that the average compressive strength increased significantly from 293.70 kg/cm2 to 390.69 kg/cm2 while the standard deviation also decreased significantly from 65.48 to 30.45. From the above comparison, it can be seen that under the optimal experimental conditions, it was found that the average compressive strength of the hollow concrete roster has increased.

3.10 Comparison of confidence intervals under optimal and confirmed conditions

The overlapping of the intervals above can be concluded that at the 95% confidence level the combination of factors and levels is appropriate, accurate and can be applied on an industrial scale, which means that the process of making perforated concrete roster can be applied by the company, so as to obtain conditions that are in accordance with the predetermined quality characteristics.

Perbandingan selang kepercayaan untuk nilai S/N Rasio

| 41,70 | 42,27 | 42,84 | | | |
| | | | 336,47 | 337,55 | 338,63 |

Optimal —— Konfirmasi ——
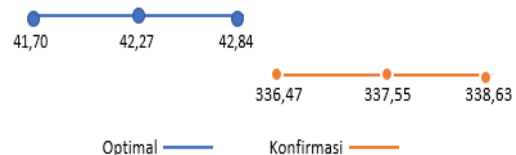
From the interval above we can see that the two lines between the prediction interval and the confirmation interval do not intersect, therefore we can conclude that at the 95% confidence level the combination of factors and levels is precise and accurate but can only be applied on a laboratory scale and cannot be applied to industrial scale.

4. CONCLUSIONS

1. Based on the results of initial testing of hollow concrete roster products with a size of 20 x 10 x 20 cm produced by CV. Sinar Jaya Maros by testing 10 samples, it was found that the average compressive strength of the roster only reached 293.70 Kg/cm2. And after conducting

experiments from this research, it was found that under optimal conditions the level of strength to withstand the load of perforated roster products can reach 337-356 Kg/cm2.

2. The factors that influence the increase in the compressive strength of the perforated concrete roster are as follows. 31.53%) and water (17.46%). The factors that have a significant effect on The value of the S/N ratio of the results of the compressive strength test of the perforated concrete roster is water (37.85%), sand (36.92%) and casting plaster (24.14%).

3. Factors and levels of factors that can provide optimal compressive strength are as follows. The combination of factors and levels that provide optimal conditions for the average response value of the compressive strength test results for perforated concrete roster is a combination of the level of the plaster casting factor at the level (0.3 kg), cement at the level (2.5 kg), water at the level (1 L), and sand at level (3.5 kg). With the average compressive strength is 356.89 Kg/cm2. while the combination of factors and levels that provide optimal conditions for the value of the S/N ratio of the compressive strength test results of the perforated concrete roster is a combination of the level of the plaster casting factor at the level (0.2 kg), water at the level (1 L), and sand at the level (3.5 kg), as well as cement at the level (1.5 kg). With the average compressive strength is 337.55 Kg/cm2.

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