

Optimization of significant factors of cement compressive strength at PT Semen Padang

by Prima Fithri

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TIME SUBMITTED	15-JAN-2020 11:40PM (UTC+0700)	WORD COUNT	3699
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To cite this article: P Fithri *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **602** 012049

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Optimization of significant factors of cement compressive strength at PT Semen Padang

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Abstract. The quality measurement of cement production is focussed on five factors, namely: Blaine fineness (Blaine), SO₃ content (SO₃), Sieving on 45 μ m (Sieve), Loss on ignition value (LOI) and Biomass-to-liquid value (BTL). They were measured when cement was 3rd, 7th and 28th days old. This study analyzed the effect of significant influence using multiple regression analysis and the optimal value of the five factors that affect compressive strength using the Response Surface Method (RSM). The results obtained for Portland Composite Cement(PCC)significant factor for 3rd day: Blaine: 379 m²/kg; SO₃: 1.72%; Sieving on 45 μ m: 8.78%; LOI: 5.40% and BTL: 7.75%. For 7th day compressive strength: Blaine: 389 m²/kg; SO₃: 1.72%; sieving on 45 μ m: 9.47%; LOI: 4.17% and BTL: 10.98%. For 28th day compressive strength: Blaine: 388 m²/kg, SO₃: 1.78%, sieving on 45 μ m: 8.49%, LOI: 4.20% and BTL: 8.18%.

1. Introduction

The cement industry is one industry that is experiencing rapid development due to increasing infrastructure development. PT Semen Padang is the cement companies located at Padang City, West Sumatra. One of the products produced every day by the company is Portland Composite Cement (PCC). PCC is the cement that is currently widely produced because PCC uses a small amount of clinker and the addition of an objective material to increase the compressive strength of PCC. So that PCC can minimize environmental impacts and be more economical. The main thing that consumers concern is quality [1]–[4]. If the product quality is good, it can increase customer satisfied, and customers will always use the product. So that, to reach that goal, quality must concern to its product and also service [5]. Therefore, every company needs to carry out quality control to maintain the quality of products produced so that consumers do not switch to similar products produced by competing companies and can compete globally, both nationally and internationally.

The parameters of cement quality regarding consumers are based on the compressive strength produced by cement. Testing of compressive strength of cement was carried out when cement was 3rd, 7th, 28th days old. Testing the compressive strength of cement at the age of 3rd and 7th days was done to obtain the initial compressive strength of cement as the prediction of the final compressive strength produced later. While testing the compressive strength of cement at 28th days was done to obtain the final compressive strength of cement. PT Semen Padang controls the quality of the compressive strength of cement at compressive strengths 3rd, 7th and 28th days. The better the compressive strength produced by cement, the higher the ability of cement to hold a load so that the resulting infrastructure is stronger and durable. The compressive strength of cement is influenced by several



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main factors, namely the amount of SO₃, the percentage of Dissolved Parts (BTL), the percentage of Loss On Ignition (LOI), Blaine and sieve on 45 μm [6]. Blaine, sieve on 45 μm, SO₃, LOI, and BTL, can be used to determine the amount of material in cement making. In controlling cement quality, PT Semen Padang sets quality standards for each of the factors that affect cement and cement compressive strength.

PT Semen Padang's quality control system is using a trial and error system based on a range of quality standards. PT Semen Padang has not received optimal value for each of the factors that affect the compressive strength of 3rd, 7th and 28th days of PCC. PT Semen Padang also does not know among the factors that affect the compressive strength that most significantly influences the compressive strength of PCC. As a result of not getting optimal value from the factors that affect the compressive strength, the number of additional material in cement production has not been fixed and the compressive strength of 3rd, 7th and 28th days of PCC have fluctuated. Fluctuating compressive strength values will affect the product price and quality of PCC products. Based on these problems, the company needs to know the significant factors that influence the compressive strength of 3rd, 7th and 28th days of PCC products as a reference in controlling the quality and optimal value of these factors.

2. Method

Data processing in this study is grouped based on the objectives to be achieved; there are knowing the significant factors that affect the compressive strength of 3rd, 7th and 28th days of PCC products and measuring affects the compressive strength of 3rd, 7th and 28th days of PCC products to produce strong optimal press. The first goal was achieved by using multiple regression analysis methods. The initial step taken was the determination of the independent and dependent variables, the independent variables used are Blaine, SO₃, sieving on 45 μm, LOI and BTL and the dependent variables used are compressive strength 3rd, 7th and 28th days. After that, designed the compressive strength model, the selection of the model based on the value of the largest R-Square and a signature model with the tools used are Design Expert 7. The selected model was tested for classical assumptions as validation of the model. If the model fulfilled the classical assumption test, the model is estimated with the output in the form of model coefficients, model coefficient tests and significant factors that affect compressive strength.

The compressive strength model in regression analysis was used as a model in obtaining optimal values. To get the optimal value, the factors that influence the strength of the measurement results are based on the results of PT Semen Padang. Determine optimal conditions for each independent variable by using Expert Design software 7. Selection of optimal values based on maximum desirability values (close to 1).

3. Result and Discussion

3.1. Analysis of Factors Affecting Compressive Strength 3rd, 7th and 28th days PCC Products

Analyses of factors affecting compressive strength use multiple regression method.

3.1.1. Design a PCC Cement Press Strength Model. Selection of the best model is obtained based on The recommendation of Design Expert 7. Software recommendations focus on the highest value of Adjusted R-Square and Predicted R-Square and the lowest PRESS (Prediction Error of Square) values of several models available in Fit Summary. The PCC cement compressive strength 3rd is obtained in the equation below.

$$\begin{aligned}
 Y = & 359.14233 - 1.19690 X_1 - 55.65896 X_2 + 8.97836 X_3 + 44.70652 X_4 - 38.29970 X_5 + 0.59474 X_1 X_2 \\
 & + 0.027746 X_1 X_3 - 0.15254 X_1 X_4 + 0.13773 X_1 X_5 - 12.580 X_2 X_3 + 8.07579 X_2 X_4 - 9.23518 X_2 X_5 \\
 & + 0.29102 X_3 X_4 + 0.42686 X_3 X_5 - 0.85982 X_4 X_5
 \end{aligned} \tag{1}$$

Information:

Y: compressive strength

X₁: Blaine

X₂: SO₃

X₃: sieving on 45 μm

X₄: LOI

X₅: BTL

The PCC cement compressive strength 7th is obtained in the equation below.

$$Y = 71.72916 + 0.46940 X_1 + 11.14397 X_2 + 2.07820 X_3 - 4.41102 X_4 - 2.72922 X_5 \quad (2)$$

The PCC cement compressive strength 28th is obtained in the equation below.

$$Y = 160.24986 + 0.49244 X_1 + 17.99002 X_2 + 1.76364 X_3 - 10.55869 X_4 - 1.15262 X_5 \quad (3)$$

3.1.2. *Classic Assumption Test.* Classic assumption test was done as a validation of the regression model. Classic assumption test was based on the type of model produced. If the model is linear, the classic assumption test is normality, linearity, multicollinearity, heteroscedasticity, and autocorrelation. While the nonlinear model, the classic assumption test is normality, heteroscedasticity, and autocorrelation. In this study, a linear model is found at compressive strength 7th and 28th days. A nonlinear model was found at 3rd days compressive strength. The following is a classic assumption test performed on the 7th day compressive strength of PCC products:

a. Normality Test

This test was carried out by making decisions based on the assumed probability distribution on the empirical distribution, with the hypothesis used as follows [7].

H₀: distribution residue has a normal distribution

H₁: spread residue does not have a normal distribution

Accept H₀ if the significance value > α (0.05)

Table 1. Normality Test for PCC Product 7-Day Strength Press Model.

Kolmogorov-Smirnov			Shapiro-Wilk		
Statistic	Df	Sig.	Statistic	df	Sig.
.077	101	.143	.986	101	.368

Based on the results of the normality test, the value of Sig = 0.143 is obtained. Because of the value of Sig > α, the decision taken is to accept H₀, which means the distribution ε has a normal distribution.

b. Linearity Test

Linearity test was carried out for each of the influencing factors (Blaine, SO₃, sieving on 45 μm, LOI and BTL) on the 7th and 28th days compressive strength of PCC products. The significance level used is 0.05 with a hypothesis [8]:

H₀: the independent variable has a linear relationship with the dependent variable.

H₁: the independent variable does not have a linear relationship with the dependent variable.

Accept H₀ if the significance value > α (0.05). **Table 2** shows the results of the Linearity Test in Blaine with 3-Day Compressive Strength of PCC Products.

Table 2. Linearity Test in Blaine with 3-Day Compressive Strength of PCC Products.

			Sum of Squares	df	Mean Square	F	Sig.
7 Days Press Strength Blaine	Between Groups	(Combined) Linearity	16948.412	41	413.376	1.288	.184
		Linearity Deviation from Linearity	2309.090	1	2309.090	7.197	.009
	Within Groups		14639.321	40	365.983	1.141	.318
Total			18928.539	59	320.823		
			35876.950	100			

c. Multicollinearity Test

Multicollinearity test is based on Variance Inflation Factor (VIF) and tolerance value; if the value of VIF value is <10 and the value of tolerance is > 0.1, then it can be said that the multicollinearity test is fulfilled [9]. Multicollinearity test of 7 days compressive strength model is VIF value <10 and tolerance value > 0.1.

Table 3. Multicollinearity Test for 7-Day PCC Product Presses Strong Model

Model	Collinearity Statistics	
	Tolerance	VIF
Blaine	.866	1.154
SO3	.875	1.143
Sieving on 45	.746	1.340
LOI	.673	1.486
BTL	.863	1.159

^a Dependent Variable: 7 Days Press Strength

d. Heteroscedasticity Test

Heteroscedasticity test is fulfilled if there is no specific pattern on the Scatterplot graph or the resulting points spread above and below the zero on the Y-axis. Figure 2 is the result of heteroscedasticity test of 7 days PCC compressive strength model.

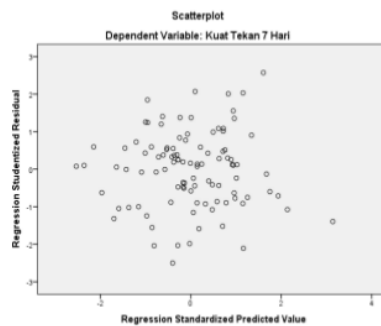


Figure 1. Heteroscedasticity test for PCC product 7-day strength press model

Heteroscedasticity test results do not form a particular pattern and the resulting points spread above and below zero on the Y-axis.

e. Autocorrelation Test

Autocorrelation test using the Durbin-Watson method, with the decision-making criteria used [10]:

- 1) DW values below -2 mean positive autocorrelation.
- 2) DW values between -2 to 2 mean there is no autocorrelation.
- 3) DW value above 2 means there is a negative autocorrelation.

Table 4 is the result of autocorrelation test of PCC cement compressive strength 7 days.

Table 4. Autocorrelation test of 7-Day Compressive Strength Model.

Model	Durbin-Watson
	1.198

^b Dependent Variable: 7 Days Press Strength

Classic assumption tests are carried out for each compressive strength model 3rd, 7th and 28th days PCC, with the same steps and the same decision making. The three models have been fulfilled by the classical assumption test.

3.1.3. Model Estimation. Estimation of the regression model obtained is the regression model coefficient equation, the overall hypothesis test (F Test) and individual hypothesis test (t-test). Decision making used in hypothesis testing is if the significance value is <0.05 so that it accepts H₀. H₀ is the influence of the independent variable on the dependent variable. Table 5 shows the results of estimation of PCC compressive strength models 3rd, 7th and 28th days.

Table 5. Estimation Results of The Model.

Compressive Strength	Model Estimation	Results
3rd Day		It has a positive effect: sieving on 45 μm, LOI, interaction between Blaine and SO3, the interaction between Blaine and sieving on 45 μm, the interaction between Blaine and BTL, the interaction between SO3 and LOI, the interaction between sieving on 45 μm and LOI and the interaction between sieving on 45 μm and BTL.
	Model Coefficient	Has a negative influence: Blaine, SO3, BTL, the interaction between Blaine and LOI, the interaction between SO3 and sieving on 45 μm, the interaction between SO3 and BTL, and the interaction between LOI and BTL.
	F Test	Blaine, SO3, sieving on 45 μm, LOI and BTL simultaneously have significant influence and coefficient value.
	t-Test	Significant factors influence: interaction of factor SO3 and sieving on 45 μm
7th Day	Model Coefficient	Has a positive effect: Blaine, SO3, and sieving on 45 μm Has a negative influence: LOI and BTL
	F Test	Blaine, SO3, sieving on 45 μm, LOI and BTL simultaneously have significant influence and coefficient value.
	t-Test	Significant factors influence: Blaine, sieving on 45 μm, LOI and BTL

Table 5. Estimation Results of The Model (Cont.).

Compressive Strength	Model Estimation	Results
28th Day	Model	Has a positive effect: Blaine, SO ₃ , and sieving on 45 μm.
	Coefficient	Has a negative influence: LOI and BTL.
	F Test	Blaine, SO ₃ , sieving on 45 μm, LOI and BTL simultaneously have significant influence and coefficient value.
	t-Test	Significant factors influence: Blaine and LOI

Significant factors that influence each compressive strength are based on the characteristics of PCC. PCC is more efficient in using clinker, and there are additional materials that can improve better quality. At compressive strength 3 and seven days is the initial compressive strength achieved from cement as a reference to the final compressive strength (compressive strength 28 days) achieved by cement. At 28 days compressive strength, significant factors that influence are Blaine and LOI, where Blaine is the smoothness of cement extending the cement surface while LOI can describe the amount of limestone material added in cement. Limestone has fine characteristics which can close the cavities in cement. Therefore the final compressive strength of Blaine and LOI has a significant effect.

3.2. Calculate of Optimal Value Factors Affecting the Strength of Presses 3rd, 7th and 28th Days of PCC Products

Optimization of factor values that affect the compressive strength of 3rd, 7th and 28th days of PCC was obtained by giving treatments to the compressive strength of 3rd, 7th and 28th days of PCC based on the range of factors influencing compressive strength. **Figure 2** is a range of factor values that affect the compressive strength of 3rd, 7th and 28th days of PCC based on PT Semen Padang recommendations.

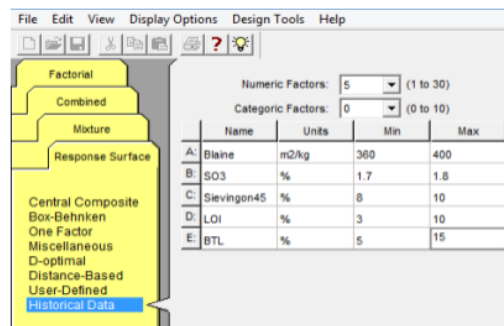


Figure 2. The range of Factors Affecting the Strengths Press 3rd, 7th and 28th days of PCC Products.

Optimization phase by using Design Expert 7 software with a range of compressive strength to be achieved, namely:

- a. 3 days compressive strength is 150 - 190 kg/cm².
- b. 7 days compressive strength is 220-260 kg/cm².
- c. 28-day compressive strength is 320-360 kg/cm².

Selection of the optimal value generated is based on the desirability value that is close to or equal to 1[11]. As well as selecting the optimal value on the compressive strength of 3rd, 7th and 28th days of PCC with minimum Blaine and SO₃ values and maximum sieving on 45 μm, LOI and BTL. Optimal values of compressive strength 3rd, 7th and 28th days of PCC in **Table 6**.

Table 6. Optimal Value Factors Affecting the Strength of Presses 3rd, 7th and 28th Days of PCC Products.

Compressive Strength	Optimal Value Factors Affecting Press Strength	
3rd Day	Blaine	379 m ² /kg
	SO ₃	1.72 %
	Sieving on 45 μm	8.78 %
	LOI	5.40 %
	BTL	7.75 %
7th Day	Compressive Strength	174.846 kg/cm ²
	Blaine	389 m ² /kg
	SO ₃	1.72 %
	Sieving on 45 μm	9.47 %
	LOI	4.17 %
28th Day	BTL	10.98 %
	Compressive Strength	244.869 kg/cm ²
	Blaine	388 m ² /kg
	SO ₃	1.78 %
	Sieving on 45 μm	8.49 %
	LOI	4.20 %
	BTL	8.18 %
	Compressive Strength	344.308 kg/cm ²

The optimal value of each factor on compressive strength 3rd, 7th and 28th days compared to obtain to obtain optimal 3-day compressive strength does not require high Blaine value, whereas to obtain 7th and 28th days compressive strength PCC requires high Blaine value. Whereas to get the optimal compressive strength 3rd and 7th days, the maximum SO₃ value is not needed, whereas to get 28 days compressive strength, SO₃ is needed which is close to the maximum value. Obtaining a 3rd-day compressive strength required a 45 μm sieving on the value that was not too high and not too low, whereas for obtaining an optimal 7th-day compressive strength, higher sieving on the value of 45 μm and sieving value were needed. On 45 μm lower than the value of sieving on 45 μm on compressive strength 3 and 7 days of PCC cement. Low LOI values are required for PCC compressive strengths 7th and 28th days, whereas a high LOI value is needed to form a 3rd-day compressive strength of PCC. If the BTL value at each compressive strength is compared, a low BTL value is needed to form a 3rd-day compressive strength of PCC, while a high BTL value is required for 7th-day compressive strength. The medium BTL value from the limit is needed to form a 28th-day compressive strength of PCC.

4. Conclusion

The conclusions are significant and optimal values of factors that affect the compressive strength of 3rd, 7th and 28th days of PCC. In the 3rd day compressive strength are interaction of SO₃ factor and sieving on 45 μm, with optimal values are Blaine: 379 m²/kg, SO₃: 1.72 %, Sieving on 45 μm: 8.78 %, LOI: 5.40 %, BTL: 7.75% and compressive strength is 174,846 kg/cm². The 7th day compressive strength, the significant factors are Blaine, sieving on 45 μm, LOI and BTL, with optimal value are Blaine: 389 m²/kg, SO₃: 1.72 %, Sieving on 45 μm: 9.47 %, LOI: 4.17 %, BTL: 10.98 % and compressive strength is 244,869 kg /cm². Significant factors in 28th day compressive strength are Blaine and LOI, while the optimal values are Blaine: 388 m²/kg, SO₃: 1.78 %, Sieving on 45 μm: 8.49 %, LOI: 4.20 % and BTL: 8.18 %, with an optimal 28-day compressive strength of 344,308 kg /cm².

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