ANALYSIS OF COMPRESSIVE STRENGTH QUALITY OF AERATED LIGHTWEIGHT CONCRETE USING TAGUCHI METHODS AT PT. XYZ

Bianda Mayfiani Tiartanaya, Budi Aribowo[1]
E-mail: budiaribowo@uai.ac.id[1]

Penulis

Budi Ariwibowo adalah dosen sekaligus Sekretaris Jurusan program studi Teknik Industri Universitas Al-Azhar Indonesia. Saat ini beliau aktif menjabat sebagai Sekretaris Badan Kerjasama Penyelenggara Pendidikan Tinggi Teknik Industri Indonesia (BKSTI) Korwil JABODETABEK.
Bidang Peminatan: *Quality Control, Ergonomi*

Abstract

Seiring berjalannya waktu, banyak perusahaan yang bersaing dalam memasarkan produk dan kesetiaan terhadap pelanggan mereka. Hal itu penting dilakukan untuk menjaga kualitas produk dengan tujuan agar pelanggan tetap setia terhadap perusahaan. Salah satu pendekatan pengendalian kualitas adalah dengan metode Taguchi. Metode ini menggunakan pendekatan desain eksperimen, sehingga faktor-faktor yang berpengaruh dari kualitas produk dapat terlihat. PT XYZ adalah salah satu perusahaan manufaktur yang khusus menyediakan bahan untuk perumahan, yaitu produk beton aerasi ringan. Penelitian ini dilakukan berdasarkan analisis kekuatan beton aerasi ringan untuk mendapatkan kualitas yang lebih baik. Hasil perhitungan yang dihasilkan untuk mendapatkan parameter optimum dengan menggunakan metode Taguchi, setelah itu didapatkan faktor-faktor yang berpengaruh, yaitu pasir silika, semen, bubuk aluminium, gipsum dan kalsium oksida. Kombinasi optimum dari faktor yang berpengaruh terhadap kekuatan beton aerasi ringan muncul pada tingkat 2 dimana 2,1 kg pasir silika, 0,75 kg semen, 0,011 bubuk aluminium, 0,225 gipsum dan 1,125kg kalsium oksida. Selisih kerugian yang ditimbulkan akibat kualitas yang cacat antara hasil eksperimen dan data aktual sebesar Rp 0,53 per beton aerasi ringan, serta pengurangan persentase kerugian setelah diterapkan metode Taguchi sebesar 2,06%.

Keywords

Experiment Design, Taguchi Methods, Quality Loss Function, Reduction of Losses Percentage

INTRODUCTION

People needs of housing materials is improving time by time and inline with the advance of knowledge, especially in construction. This development cause the competition among the companies in marketing their product and construct a loyalty of customer. Quality control is in charge for the company to maintain the quality of resulting product. One approach in quality control is Taguchi methods. This methods is an approach that using an experiment design, to reveal the factor that influence the quality of product. PT. XYZ is one of the manufacturing company that specialized in providing housing materials, especially aerated lightweight concrete. The company wants to improve the resulting quality of product. To obtain the high quality product, determine the optimum production process parameter is necessary. One effort in improving the quality of the production process, is through design of experiments or trials. This research will discuss about the improvement of PT. XYZ aerated lightweight concrete production quality. Lead to improvements in the quality of aerated lightweight concrete, note only the compressive strength. The better compressive strength of the aerated lightweight concrete, the better quality follows.

THEORITICAL BASIS

Quality Control

Quality control related with the production process. It's function to check the quality of resulting product, whether it's appropriate with the appointed quality standard.

Cause and Effect Diagram

Cause and effect diagram developed by Dr. Kaoru Ishikawa which used to show causal factors (cause) and quality characteristics (effects) that caused by the causal factors.

Failure Mode Effect and Analysis (FMEA)

Failure mode and effect analysis (FMEA) is an important assessment tool to identify potential failure and evaluating level of reliability of a system to determine the failure effect of the system.

Analytical Hierarchy Process (AHP)

Analytical hierarchy process (AHP) is a model of decision support developed by Thomas L. Saaty. It's used to solve complex unstructured situation into several components in a hierarchical arrangement, by giving a subjective value about the relative importance influence the outcome of the situation.

Taguchi Methods

Taguchi Methods triggered by Dr. Genichi Taguchi on 1949. This methods purposing to improve the quality and process of product, also compress cost and resource as minimum as possible. The target of Taguchi methods is to make the product sturdy or robust against interference factor or noise.

Taguchi design of experiment has several phase, namely:

1. Plannning Phase

The most important phase in providing the expecting information. The obtained information regarding the influential and not influential factors and levels on the performance of product or process.

2. Excercise Phase

Excercise phase is performing work based on factor setting on orthogonal matrix with number of trials corresponding with number of replication and sequences such as randomization.

3. Analysis Phase

Data collecting and processing done in this phase, to get the optimum process condition.

- Calculation of Main Effect

Calculation of Main effect divided into two methods, namely Means method and S/N Ratio method (Signal to Noise).

a. Means Method

The calculation with this method has a purpose to observe the influence from each factor and the interaction to mean of expecting results.

b. S/N Ratio Method (Signal to Noise)

The purpose of S/N ratio method is to minimizing quality sensitivity characteristics toward interference factor (noise).There are several types of S/N ratio with type of quality characteristics, which are smaller the better, larger the better, and nominal the best.This research is using S/N ratio for larger the better type. The equation used on S/N ratio for larger the better type:

$$S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{r}\frac{1}{Y_i^2}\right) \text{ ....equation(1)}$$

4. Confirmation Experiment Phase

Confirmation experiment phase performed to test the combination of factors and levels. The following steps on confirmation experiments:

   a. Arrange the optimal condition for factor and significance level.

b. Determine sample size of confirmation experiment.
c. Compare the actual data with the result of confirmation experiment.
d. Calculate quality loss function.
e. Calculate loss reduction level.

RESEARCH METHODOLOGY

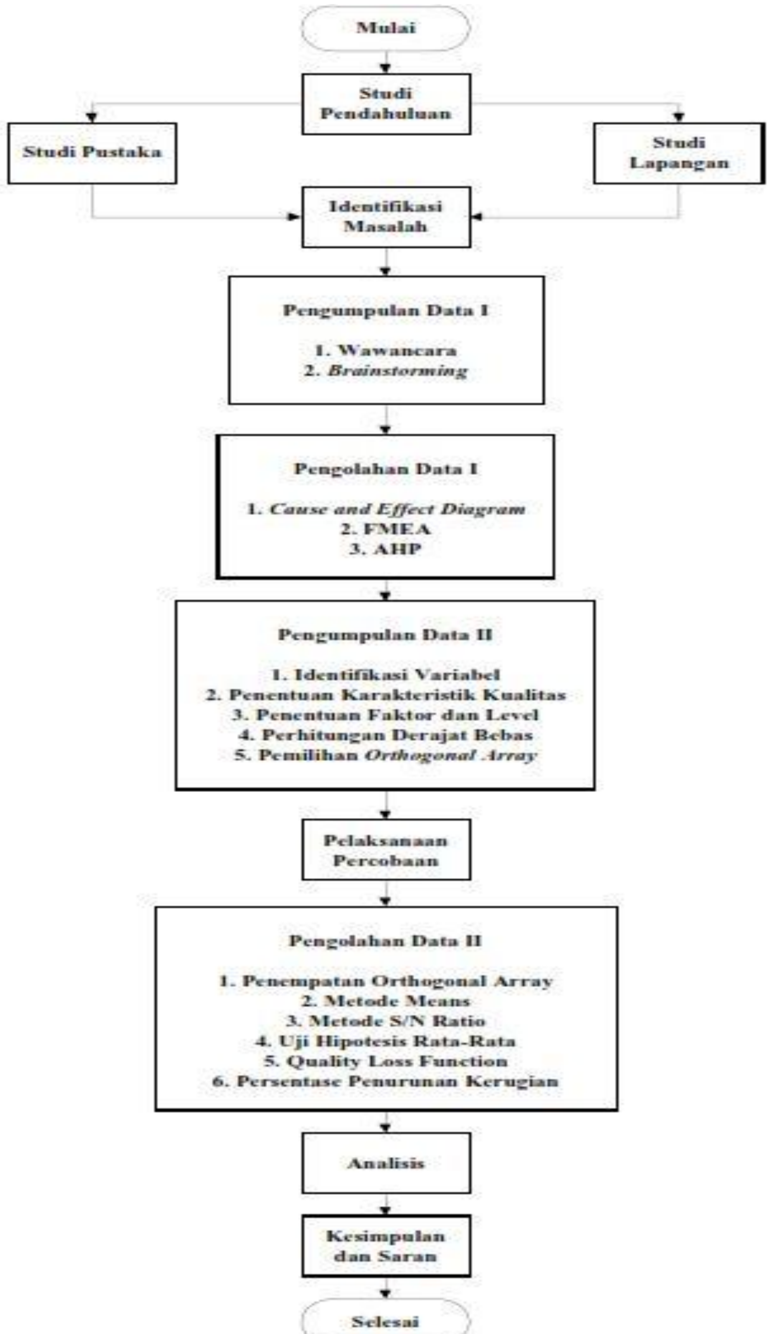

Figure 1. Research Methodology Flowchart

DISCUSSION AND ANALYSIS

Product Election

Product used in this research is aerated lightweight concrete with size (20 x 20 x 7,5) cm^3. The compressive strength of aerated lightweight concrete will be measured by compressive test press. To determine the factors that affect the quality of aerated lightweight concrete compressive strength then performing some analysis:

1. Cause and Effect Diagram Analysis

Cause and effect diagram is used to discover the problems that company face. Based on interview and brainstorming with the company side, then perceived factors that influence to the aerated lightweight concrete process so it influencing the result of aerated lightweight concrete compressive strength quality. Based on cause and effect diagram analysis, note that there are four kinds of common factor affecting the compressive strength of aerated lightweight concrete, namely machines, materials, methods, and human beings.

2. FMEA Analysis

Based on brainstorming result with the company and analysis of cause and effect diagram, then obtained the highest value of RPN that contain on several product which has a crack with score 42. So there’s need an action to overcome those problems and surveillance to the materials used.

3. AHP Analysis

The FMEA analysis explanation shows the major problem factor on aerated lightweight concrete is the materials. Based on cause and effect explanation, the materials are contain of cement, silica sand, calcium oxide, fly ash, perlite, aluminum powder, foaming agent, and gypsum. In choosing any significant materials to the compressive strength of aerated lightweight concrete, then engage a decision analysis approach, namely analytical hierarchy process (AHP). By using expert choice software, then obtain AHP result as follow:

Table 1. AHP Calculation Result

No.	Nama Bahan	Nilai
1	Pasir *Silica*	0,326
2	Semen	0,218
3	Kapur Tohor	0,168
4	*Gypsum*	0,094
5	*Aluminum Powder*	0,067
6	Perlit	0,057

7	Abu Terbang (*fly ash*)	0,039
No.	Nama Bahan	Nilai
8	*Foaming Agent*	0,033

Based on table 1 then concluded that the materials which influence to the compressive strength of aerated lightweight concrete are silica sand, cement, calcium oxide, gypsum, and aluminum powder. The AHP calculation declared consistent since the value of inconsitency < 0,1.

Taguchi Experiment

The phases on Taguchi Experiments are:

1. Planning Phase

The phase provide the expecting information. The quality characteristics used in this research is larger the better. Factors and levels used as follows:

Table 2. Factors and Level

No.	Faktor	Level 1 (kg)	Level 2 (kg)
1	Pasir *Silica*	1,875	2,1
2	Semen	0,6	0,75
3	*Aluminum Powder*	0,008	0,011
4	*Gypsum*	0,15	0,225
5	Kapur Tohor	0,9	1,125

There is an interaction between the factors which is silica sand with cement and silica sand with aluminum powder. Orthogonal array used is L8 (27) as it has degrees of freedom of 7.

2. Excercise Phase

Exercise phase corresponding with model that has been established by doing three replication. The following experiment result:

Table 3. Taguchi Experiment Result

Percobaan	Replikasi (kg/cm^2)			Jumlah	Rata-Rata
	1	2	3		
1	30,87	30,51	30,48	91,86	30,62
2	33,07	33,15	33,05	99,27	33,09
3	35,14	35,12	35,2	105,46	35,15
4	36,13	36,1	36,15	108,38	36,13
5	36,63	36,67	36,72	110,02	36,67
6	35,23	35,11	35,18	105,52	35,17
7	38,12	38,13	38,19	114,44	38,15
8	39,12	39,17	39,16	117,45	39,15

3. Analysis Phase

The phase pose analysis phase of experiment result data. Based on main effect calculation using minitab software on means methods and signal to noise ratio, then obtained an optimum factor combination that influence the compressive strength of aerated lightweight concrete on level 2, that is 2,1 kg silica sand, 0,75 kg cement, 0,011 kg aluminum powder, 0,225 kg gypsum and 1,125 kg calcium oxide.

4. Confirmation Experiment Phase

The following results of confirmation experiments and actual data.

Table 4. Confirmation Experiment & Actual Data

Percobaan	Hasil (kg/cm^2)
1	41,20
2	41,81
3	41,69
4	41,86
5	42,00
6	41,42
7	42,02
8	41,80
9	42,03
10	41,32

Data	Hasil (kg/cm^2)
1	42,00
2	40,00
3	42,00
4	37,84
5	41,66
6	40,69
7	40,53
8	42,60
9	42,00
10	43,15

1. Calculation of Average Hypothesis

The steps are as follows:

- H_0 : $\mu 1 = \mu 2$
- H_1 : $\mu 1 \neq \mu 2$
- α= 0,05
- V= 9
- t_{tabel} = 1,833

Calculation: Using software Minitab, then obtain t_{hitung} = -0,84

Conclusion: Value t tabel> t hitung then do not reject Ho which is an actual average compressive strength of aerated lightweight concrete and confirmation experiment shows no significant difference.

2. Calculation of Quality Loss Function

QLF calculations used to estimate the loss to society because the product failed to meet the value proposition for a particular characteristics performance. The following equation:

$$L(y) = k\left(\frac{1}{y}\right)^2 \text{................ equation(2)}$$

$$k = A_0 \times \Delta^2 \text{................ equation(3)}$$

Known: $A_0 = \text{Rp } 1750/\text{pc}$

$\Delta = \pm 5 \text{ kg/cm}^2$

Quality loss function 1 (actual condition)

y= 41,28

$$L(y)_1 = 43750\left(\frac{1}{41{,}28}\right)^2 = \text{Rp } 25{,}67$$

L(y)1 = Rp 25,67 which means aerated lightweight concrete quality loss of production result per unit in actual condition.

Quality loss function 2 (confirmation experiment)

y= 41,715

$$L(y)_2 = 43750\left(\frac{1}{41{,}715}\right)^2 = \text{Rp } 25{,}14$$

L(y)2 = Rp 25,14 which means aerated lightweight concrete quality loss of production result per unit in confirmation experiment. The difference between QLF 1 and QLF 2 is Rp 0,53 so that the confirmation experiment conditin is better than an actual condition.

3. Calculation of Loss Reduction

Loss reduction:

$$= \frac{\text{QLF Aktual} - \text{QLFKonfirmasi}}{\text{QLF Aktual}} \times 100\% \text{ ..equation(3)}$$

$$= \frac{25{,}67 - 25{,}14}{25{,}67} \times 100\%$$

$$= 2{,}06\ \%$$

Based on the calculation result, it can be seen that the loss reduction experienced by company after using Taguchi methods is equal to 2,06 %.

CONCLUSION

The conclusion with drawn form this research are as follows:

1. There are four general factors that influence the compressive strength on aerated lightweight concrete that based on cause and effect diagram, namely machine, materials, methods, and humans.

2. Based on failure mode and effect analysis (FMEA), the highest value of RPN appear on several product that has a crack with score 42, and caused by materials..
3. Factors that influence compressive strength based on analytical hierarchy process (AHP) are silica sand, cement, calcium oxide, gypsum, and aluminum powder.
4. For means method and signal to noise ratio, optimum combination factor that influence compressive strength appear on level 2, that is 2,1 kg silica sand, 0,75 kg cement, 0,011 kg aluminum powder, 0,225 kg gypsum, and 1,125 kg calcium oxide.
5. Decreasing level of losses experienced by the company after performing quality improvement with Taguchi methods is equal to 2,06 %.

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