The 4th ICIBA 2015, International Conference on
Information Technology and Engineering Application
Palembang-Indonesia, 20-21 February 2015

Design of Experiment (DOE) of Compessive Strength Test For Block Paving Prototype Using Thermoplastic Waste

Dian Janari

Department of Industrial Engineering, Faculty of Industrial Technology
Universitas Islam Indonesia
Yogyakarta
Email:kerjadian@gmail.com

Abstract

Waste is considered as consequences on humans activities, infrastructure developments, the raise of population and life style. Those are the determination factor for waste volume enlargement. Based on data of environmental status in 2012 that released by Environmental Board Yogyakarta province, industrial waste B3 in Yogyakarta province are accumulated as 200 ton/year and 15% of them in industrial plastic waste. Recycling process is important to be performed to reduce the wastes volume. Recycling is presumed as a process to turn waste into new product. One of the plastic wastes utilization is by using it as one of the mixture materials of block paving. The quality of block paving is determined by its compressive strength. Factors that influence the quality of its compressive strength are; type of cement, drying period, composition of water, cement, coarse aggregate, fine aggregate and plastic waste. Based on data analysis, several conclusions can be resumed. The Normality test resulted p=0,2515 ($p > 0,05$), it can be concluded as normal. Homogeneity test resulted p of 1,365 on significance level of 0,05, it can be concluded as homogenous. Best formulation for combination of optimum factor level, which is based on analysis of signal to noise ratio (SNR) and effect value on each factor isA2,B2,C1,D2,E1,F2,G1. The composition is explained as the mixture of Portland cement with 35 days drying duration, 0,5 litres water, 0,6 kg cement, 1,6 kg coarse aggregate, 1,1 kg fine aggregate and 300 gr plastic waste.

Keywords : *plastic waste, signal to noise ratio (SNR), compressive strength, block paving*

1 INTRODUCTION

Waste is considered as consequences on human activities, the raise of population and life style. Those are the determination factors for waste volume enlargement (Sari, Setiyawan 2011), besides, the rapid development on construction field (Soebandono, et al, 2013) resulted on the increasing of activities and improvements of building constructions that will cause the

raise of plastic waste (Putra, et al. tt). Based on data of environmental status that released by Environmental Board Yogyakarta province, in 2012 industrial waste B3 in Yogyakarta province are accumulated as 200 ton/year and 15% of them are industrial plastic waste (BLH, 2012). The ministry of Environment (KLH) assumes that everyday, Indonesian people produce 0,8 kg waste, or totally 189 thousand ton waste/day. From that calculation, 15% of them are plastic waste or equal to 28,4 thousand ton plastic waste/day (Surono, 2013). Daily fact reveals that domestic and industrial wastes, both organic and non-organic are thrown away in the same waste container and mixed (Zubair and Haeruddin, 2002). Recycling process is very importantto be performed to reduce the wastes volume. Recycling is presumed as a process to turn waste into new product (SNI-19-2454, 2002). Plastic is a well-known material that is recognized and used by all people. It strong, light, flexible, anti-corrosive, hard to break, easy to be colored, shapeable, heat isolator and electrical isolator (Surono, 2013). Block paving is a composition of construction that built from the mixture of Portland cement or hydraulic glue (SNI-03-0691, 1996). Block paving can be constructed from needle leaf tree that is not decay, uncovered with mold, not parted or cracked (SNI ISO 5328:2013). Block paving is manufactured under two methods: traditionally and modern.

The research of Syukur Sebayang, 2011 was conducted by comparing traditional and machine block paving manufacturing. From the research, the quality specification III was resulted, the traditional manufacturing performed compressive strength of 21, 26 Mpa and 23, 07 Mpa for machine (Sebayang et al, 2011). Plastic waste is also used for vertical drainage. The research showed that soil improvement method, which was used vertical drainage that employed plastic waste as the filler, was better than vertical drainage that applied coconut fiber and sand to accelerate the lowering. It emphasized by the raise of vertical consolidation coefficient as 812, 414% if compared with consolidation coefficient on soft round without vertical drainage (Maheri, 2012). The research that conducted by Pratikno, 2010 stated that the utilization of plastic waste PET on concrete building will produce light concrete with density of 1700 kg/m3, the decreasing of concrete density will reduce the moment of inertia when the earthquake taken place (Pratikno, 2010). Bagus Soebandono, et al, 2013 observed on the combination of compressive strength behavior with tension of concrete that mixed with plastic waste HDPE. It can be concluded that the value of compressive strength will decrease as the increasing of plastic waste HDPE amount (Soebandono, et al, 2013). Yessi Rismayasari et al, 2012 stated that concrete construction, which used the waste plastic of polypropylene (pp) under variation of 0%, 2%, 4%, 6%, 8%, 10% by using Portland cement type 1, resulted density value ranged between $(16 \pm 6)x102kg/m^3 upto (22 \pm 4)x102kg/m^3$. Compressive strength ranged between $(16 \pm 0,1)x106N/m^2$ up to $(21,8 \pm 0,2)x106N/m^2$ (Rismayasari, et al, 2012). The construction of rough specimen employs mix concrete or locked concrete beam such as block paving, grass block (Sebayang, 2011).

Generally, design of experiment (DOE) by using quality engineering technique is the description of product quality or production process on designated product. Quality is defined as the description of direct product characteristics such as: performance, reliability, easy to use, esthetics and others. While, strategic quality is defined as everything that able to fulfill customers expectation and necessities (meeting the needs of customers) (Gesperz V., 2001). Quality control is divided into two categories: off-line controlling and on-line controlling. Off-line controlling is divided into three stages, as follows: first stage is designing the concept, ideas and product development based on customer. Second stage is parameter

design and third stage is tolerance design. On line quality design is the activity of direct supervision for production process (Belavendram, N. 1995., Peace, G. 1993., dan Ross, P. 1998). Quality control should in line with design of experiment scheme, so the result of quality design could be well monitored (Sudjana, 1991). Design of experiment is classified into two, which are: conventional design of experiment and taguchi design of experiment. In Taguchi, orthogonal array is employed as the calculation to determine the minimum experiments to obtain maximum information (Peace, G, 1993). The Philosophy of Taguchi is to design the quality inside the product, the cost reducing should be measured in all system and the product should well designed so the product robustcan be controlled (Montogomrey, 1998). The purpose of this research is to design block paving prototype using aggregate thermoplastic waste and to conduct quality engineering on block paving compressive strength that uses aggregate thermoplastic waste.

2 RESEARCH METHODOLOGY

2.1 Research Object

The object of the research is block paving prototype that uses thermoplastic waste. It is performed in production process laboratory, Mechanical Engineering Department, Universitas Islam Indonesia. The object was measured as 200 mm x 100 mm x 60 mm, press mold technique is applied to construct product.

2.2 Type and Source of Data

Primary data is field research data that obtained from previous activities. Primary data uses as respond variable is compressive strength of block paving of thermoplastic waste, while the secondary data is derived indirectly from references, research literatures that related to Taguchi, researches on product quality of chicken feather composite, journals, magazines and other potential data that support recent research.

2.3 Tools and Materials

Materials that applied to support the research are described as follows:

1. Office tools, to record all stages of research literally
2. Digital camera, for taking the pictures and recording the working process
3. Pressing tools UTM with capacity of 100 ton, that is used to press the mould
4. Plastic crusher with electrical motor HP, that is used to mash the plastic
5. Block paving mould with dimension of 20 cm x 10 cm x 6 cm, that is used to shape the block paving
6. Waterpass, that is used to measure the surface flatness balance of block paving
7. Stirred tools, shovel and hoe, that are used to stir up all materials
8. Bucket and basin with 50 ltr capacity that are used as container for mixed materials

9. Rectangle rasp and half round rasp that are used to soften the surface
10. Big hammer, that is used to unleash the mould
11. Water container with dimension of 1 m x 1m x 0,5 m, that is used to examine the absorption level
12. Vernier calliper, that is used to measure the dimension of block paving

Materials that applied in this research are:

1. Plastic waste, that is used as one of the composition of block paving
2. Portland cement, that is used as the mixture reinforcement
3. Sand, that is used as fine aggregate of block paving
4. Water, that is used as homogenous blender

2.4 Method of Data Collection

The data collection in research defines as the efforts to accumulate facts and information intensively that followed by data analysis and test. Study literature is data collection that conducted by searching information from references as theory background, writing systematic and framework. They are derived from previous literatures and reports to support recent research.

2.5 Design of Experiment

Design of experiment defines as provision of necessary information to perform experiment. The stages are explained as follows:

1. The selection of product quality
2. Identification and selection of influenced factors toward quality characteristics
3. Determination of controlled factors and noise factor toward factor level
4. Selection of orthogonal matrices for control factor (Inner Array) and uncontrollable factor (Outer Array)
5. Determination of combination matrices (Product Array)

2.6 Implementation of Experiment

This stage describes the level of experiments result collection that is resumed from parameter design. The experiments implementation is executed under following steps:

1. Preparation, it is designated to prepare the tools, materials, pressing tools, mould and work environment
2. Block paving manufacturing, by combining cement, water, sand and heated plastic waste, to be poured to the mould and pressed using hydraulic press

3. Block paving quality control, it is designated to enhance the quality of block paving, started from surface softening to identify possible crack.

4. Compressive strength test, it is conducted to calculate the block paving compressive strength. The result will be used as preliminary data for data processing using Taguchi method

2.7 Analysis of Experiment

On the stage of data processing, analysis of the result is conducted statistically. Analysis procedure can be explained as follows:

1. Data Normality Test, it is conducted to find out whether the observation data normally distributed or not. Chi-square calculation is formulated, as follows:

$$X^2 = \sum_{k}^{i-1} \left(\frac{Oi - Ei}{Ei} \right) \tag{1}$$

2. Homogeneity of Variance Test, this test is conducted to analyze the homogeneity of k (k2) of population variance that normally distributed by using Bartlett test.

$$X^2 hitung = (In\ 10)\{B - \Sigma(n_1 - 1) log\ s_1^2\} \tag{2}$$

$$S_i^2 = \frac{1}{n-1} \left[\sum_{t}^{i-1} y_1^2 - \left(\sum_{t}^{i-1} (y_i)^2 / n \right) \right] \tag{3}$$

$$B = (log\ s^2)\Sigma(n_i - 1) \tag{4}$$

$$s^2 = \frac{\Sigma(n_i - 1) S_i^2}{\Sigma(n_i - 1)} \tag{5}$$

3. Signal to Noise Ratio (SNR) the experiment result and each factors effect, S/N ratio is explained as logarithm of quadratic loss function that used to evaluate products quality. S/N ratio is applied to figure out which level factor effects the result of experiment. S/N ratio consists of several type of quality characteristics, as follows:

   (a) Smaller the Better (STB)

   Characteristic of quality states that, the smaller value, the better quality. S/N value for this characteristic is formulated as follows:

$$S/N_S TB = -10 log \left[\frac{1}{n} \sum_{n}^{i=n} Y_i^2 \right] \tag{6}$$

(b) Larger-the-Better

Characteristic of quality states that the bigger the value, the better quality. S/N value for this characteristic is formulated as follows:

$$S/N_STB = -10log\left[\frac{1}{n}\sum_{n}^{i=n}\frac{1}{Y_i^2}\right] \quad (7)$$

(c) Nominal-the-Better

It is defined as characteristic of quality with determined nominal. If the value reaches closer to the determined nominal, the quality will consider as better. S/N value for this characteristic is formulated as follows:

$$S/N_STB = -10log\left[\frac{\mu}{\sigma}\right] \quad (8)$$

$$\sigma = \frac{\Sigma(y_1 - \overline{y})^2}{n-1} \quad (9)$$

3 RESULTS AND DISCUSSION

3.1 Identification and Selection of Factor

Factors that involve in this experiments are explained as follows:

1. Type of cements that used are regular Portland and mixed Portland, the levels that used are mixed level and regular level, it applied to recognize the characteristic of Portland cement on block paving prototype
2. Drying durations are 30 days level and 35 days level. If it is applied less than 30 days, the mixture will experience uneven dryness while 35 days level will resume the opposite result, which is the complete dryness
3. 0,5 lt and 0,6 lt water level will be used. If the water level sets less than 0,5 Lt, it will experience fragile condition, while, more than 0,6 Lt will provide soft state material
4. 0,5 kg and 0,6 kg of cement will be employed. If it is less than 0,5 kg, the material compound will not blend perfectly, on the other hand, if it is more than 0,6 kg, the materials blend will vulnerable.
5. 1,5 kg and 1,6 kg coarse aggregate will be utilized, if it is less than 1,5 kg, the geometric size of block paving will be small. While, if it is more than 1,6 kg, the size will be grown bigger
6. 1 kg and 1,1 kg fine aggregate will be employed, if it is less than 1 kg, the geometric size of block paving will be small. While, if it is more than 1,1 kg, the size will be grown bigger
7. 300 gr and 600 gr plastic waste will be employed, if it is used less than 300 gr, the effect of waste utilization will be small, while, if it is more than 600 gr, the usage of waste is excessive,

Table 1: Controlling Factors

No	Material	Level 1	Level 2
A	Type of Cement	Regular Portland	Mixed Portland
B	Drying Duration	30 days	35 days
C	Water	0,5 Lt	0,6 Lt
D	Cement	0,5kg	0,6kg
E	Coarse Aggregate	1,5 kg	1,6 kg
F	Fine Aggregate	1 kg	1,1 kg
G	Plastic Waste	300gr	600gr

Table 2: Examples of writing table

Trial	1	2	3	4	5	6	7	Y1	Y2	Y3	Y4
1	1	1	1	1	1	1	1	13,5	14	12,7	13,9
2	1	1	1	2	2	2	2	14	12,5	12,4	12,7
3	1	2	2	1	1	2	2	13,2	13,2	13,8	12,9
4	1	2	2	2	2	1	1	13,2	13,5	14	13,8
5	2	1	2	1	2	1	2	12,9	11,9	13,9	11,8
6	2	1	2	2	1	2	1	12,8	12,1	13,6	11,7
7	2	2	1	1	2	2	1	14,1	14,6	12.8	13,2
8	2	2	1	2	1	1	2	11,8	12,4	13,9	12,6

3.2 Implementation of Experiment

It holds to discover compressive strength using L8 for inner array. The result data of experiment is shown by below table:

3.3 Data Processing

1. Normality Test, the result of this test by using Kolmogorov-Smirnov test shows that data fit with normal distribution with p =0,2515 (p¿0,05)

2. Homogeneity Test, states that group data possesses the same variance that indicates by p equal to 1,365 on the significance level of 0,05

3. Signal to Noise Ratio (SNR) to experiments result and effect on each factor shows that the best formulation is A2,B2,C1,D2,E1,F2,G1 under following composition; mixed Portland cement, 35 days drying duration, 0,5 lt water, 0,6 kg coarse aggregate, 1,1 kg fine aggregate and 300 gr plastic waste

4 CONCLUSION

Based on data analysis, can be concluded that normality test p=0,2515 (p¿0,05) has normal characteristics, homogeneity test with p equal to 1, 365 on significance level of 0,05 indicates the homogenous characteristics. Combination of optimum factors based on analysis of

Signal to Noise Ratio and effect on each factor for compressive strength is A2,B2,C1,D2,E1,F2,G1 under following composition; mixed Portland cement, 35 days drying duration, 0,5 lt water, 0,6 kg coarse aggregate, 1,1 kg fine aggregate and 300 gr plastic waste.

References

Assauri, S., (1985), Manajemen Produksi dan Operasi, Lembaga Pemerintah, Jakarta.

Badan Lingkungan Hidup Yogyakarta, (2012). Laporan Standar Pelayanan Minimal Bidang Lingkungan Hidup Daerah Istimewa Yogyakarta. Dibaca Tanggal 27 Februari 2014. *Tersedia di www. blhdiy.go.id*

Badan Pusat Statistik (2012). Statistik ternak unggas, dilihat 23 Desember 2013, tersedia_di:*http://yogyakarta.bps.go.id/flipbook/2013/Statistik%20Daerah%20Istimewa%20Y ogy akar a%202013/HTML/files/assets/basic-html/page49.html*

Belavendram, N. (1995). *Quality By Design.* Prentice Hall, Internasional.

Gasperz, Vincent., (2001). *total quality management.* Gramedia Pustaka Utama. Jakarta.

Maheri, I, A. 2012. Studi Perbandingan Pasir, Ijuk dan Limbah Plastik SebagaiDrainaseVertikal. *Skripsi. Fakultas Teknik. Universitas Atma Jaya* . Yogyakarta.

Montgomery. (1998). *Pengantar Pengendalian Kualitas.* UGM Press. Yogyakarta.

Peace, G. S. (1993). *Taguchi Methods* . Addison - Wesley Publishing Company.

Pratikto, 2010. Beton Ringan Ber-Agregat Limbah Botol Plastik Jenis PET (poly ethyleneterephthalate). *Prosiding Seminar Nasional Teknik Sipil.* Politeknik Negeri Jakarta.

Putra, Y, H, S,. Indah Yulian dan Yayuk Sri Rahayu. tt. *Pendampingan Kemitraan Pengelolaan Limbah Botol Plastik Menjadi Produk Bernilai Ekonomis Pada Masyarakat Desa Girimoyo Karangploso Malang.* Fakultas Ekonomi. UIN Maulana Malik Ibrahim. Malang.

Rismayasari, Y., Utari, Usman Santosa (2012). Pembuatan Beton dengan Campuran Limbah Plastik dan Karakterisasinya. *Indonesian Journal of Applied Physics.*Vol.*2*, No.1, Hal 21-31.

Ross, P.J.(1998). *Taguchi Techniques For Quality Engineering.* McGraw-Hill,Inc., New York.

Sari, D,M. dan Dadang Setiyawan., (2011). Peluang Bisnis Pemanfaatan Limbah Botol Plastik Menjadi Aneka Soevenir Hajatan. *Seminar Hasil Penelitian Dan Pengabdian Masyarakat.* Universitas Bantara Sukoharjo.

Sebayang, S., I Wayan Diana dan Alexander Purba. (2011). Perbandingan Mutu Paving block Produksi Manual Dengan Produksi Masinal. *Jurnal Rekayasa* Vol. *15* No. 2, Agustus 2011

Soebandono, B., Asat Pujianto dan Danar Kurniawan. (2013). Perilaku Kuat Tekan dan Kuat Tarik Beton Campuran Limbah Plastik HDPE. *Jurnal Ilmiah Semesta Teknika.* Vol. *16*, No. 1, Hal 76-82, Mei 2013

Standar Nasional Indonesia. SNI 03-0691-1996. *Bata Beton (paving block)*. Badan Standar Nasional Indonesia.

Standar Nasional Indonesia. SNI 19-2454-2002. *Proses Daur Ulang Sampah*. Badan Standar Nasional Indonesia.

Standar Nasional Indonesia. SNI ISO 5328:2013.*Paving Blok Kayu Solid-Paving Blok Kayu Daun Jarum- Persyaratan mutu*. Badan Standar Nasional Indonesia.

Sudjana. (1991). *Desain dan Analisis Eksperimen*. Penerbit Tarsito : Bandung.

Surono, U, B. (2013). Berbagai Metode Konversi Sampah Plastik Menjadi Bahan Bakar Minyak. *Jurnal Teknik*, Vol-*3*, No-1, hal 32-40

Zubair, A. Haeruddin, (2012). Studi Potensi Daur Ulang Sampah di TPA Tamangapa Kota Makassar. *Prosiding Hasil Penelitian Fakultas Teknik*. Vol-*6*, Hal TS1-TS10, Desember 2012.