Jurnal APLIKASI
ISSN.1907-753X
Volume 12, Nomor 2, Agustus 2014

Microwave Incinerated Rice Husk Ash Influence on Foamed Concrete Workability

Ridho Bayuaji
Civil Engineering Department, Institut Teknologi Sepuluh Nopember
Email: *bayuaji@ce.its.ac.id*

Abstrak

Pnelitian ini menjelaskan pengaruh abu sekam padi (MIRHA) terhadap sifat kelecakan beton porus. Komposisi beton porus didesain menggunakan metode Taguci dengan orthogonal arral L_{16} yang meliputi 5 parameter, yaitu: kandungan MIRHA, air/semen, pasir/semen, superplasticizier, dan densitas. Uji kelecakan beton porus menggunakan standar ASTM -230. Hasil penelitian ini menunjukkan kandungan MIRHA pada beton porus mengakibatkan kelecakan lebih rendah dibandingkan beton porus tanpa MIRHA. Kandungan MIRHA sebanyak 5-10% dapat memberi pengaruh stabil dan konsisten pada kelecakan beton porus. Kontribusi parameter MIRHA sebesar 12,06% terhadap persyaratan sifat kelecakan beton porus.

Kata kunci: beton porus, *Microwave Incinerated Rice Husk Ash (MIRHA)*, kelecakan, *spread test*.

Abstract

This paper presents the study of Microwave Incinerated Rice Husk Ash (MIRHA) Influence on Foamed Concrete (FC) Workability. The mix proportion of the MIRHA FC was designed using the Taguchi method with L_{16} orthogonal array with five parameters, namely, MIRHA contents, water cementitious ratio (w/c), sand cement ratio (s/c), superplasticizer (SP) content, and foam content. The workability of the foamed concrete was evaluated through spread measurement in accordance with ASTM-230. The results showed that FC incorporating MIRHA shows lower spread result than normal FC. MIRHA content has contribution 5-15% for workability which a stabled and consistent FC could be achieved. The contribution of MIRHA parameter to achieve the required workability of FC was 12.06%.

Keywords: foamed concrete, Microwave Incinerated Rice Husk Ash (MIRHA), workability, spread test

1. Introduction

Foamed concrete (FC) is one of the solutions in support of green building materials that were introduced several decades ago. The concept of green building associates with sustainability, which incorporates and integrates a variety of strategies during the design, construction, and operation of building projects.

Foamed concrete is flowable material which cannot be subjected to any type of compaction or vibration that would affect its design density. Hence, the important fresh state characteristics of foam concrete is workability.

Several kind of cement replacement materials such as fly-ash (Jones and McCarthy, 2005; Kearsley and Wain-wright, 2001, 2002), GGBS (Tiong-Huan Wee, 2006), bottom ash (Lee et al., 2010), sewage sludge ash (Wang et al., 2005), ultra fine granulated blast-furnace slag, and condensed silica fume

Jurnal APLIKASI
ISSN.1907-753X

(Pan et al., 2007) have proved effective application in since Rice Husk Ash (RHA) has shown better effects in normal concrete, these fore it may add value in FC. However, there are some concerns regarding the use of RHA, which may complicate its applications.

Very high water demand due to refined porous structure of RHA, the particle size ranges between 10 and 75 μm. When added to a FC mixture, it absorbs water into the pores like a sponge. Hence, in order to obtain a workable FC mixture, it is necessary to use a considerable proper amount of mixing water. FC is more sensitive to water demand than normal concrete. If too little water is added to the mixture, the water will not be sufficient for initial reaction of the cementitious material and the cementitious material will withdraw water from foam, causing rapid degeneration of the foam. If too much water is added segregation takes place, causing a variation in density. Based on the gaps and issues derived from previous research, this study was mainly focused to investigate the influence of Microwave Incinerated Rice Husk Ash (MIRHA) on the workability of FC.

2. Metodology

Rice husk used in this research was taken from rice milling plant of Bernas, Malaysia. Rice husk was dried under direct sunlight to reduce its moisture content so that when it was burnt, it would not produce large amount of smoke. Dried rice husk was then burnt in automatic microwave incinerator to produce amorphous ash called MIRHA.

Figure 1 shows the process of MIRHA production the burning procedure was based on one-stage burning technique at a constant temperature of 500^{o}C for 2 hours. The incinerated ash ground in a ball mill to achieve the require fineness. As cement replacement material (CRM), RHA should have particle size smaller than cement so it will able to function as micro structure filler in the Interfacial Transition Zone (ITZ). Chemical analysis MIRHA was preformed using X-Ray Fluorescence (XRF) technique. Chemical analysis indicated that the ash obtained essentially consisted of silica content of more than 90% by weight. The detail of the chemical composition is shown in Table.1. X-Ray Diffraction (XRD) is used to analyze the grain size structural properties of material. Graph patterns of XRD analysis can show whether the material is in amorphous, partially crystalline, or crystalline state. Figure 2 describes the properties of MIRHA that was obtained from microwave combustion. The results of physical properties of MIRHA are shown in Table 2.

The relative density of MIRHA was 2.23 using ultrapycnometer methods. It generally varies in the range of 2.05 to 2.30 for most sources of RHA (Nehdi M. et al., 2003).

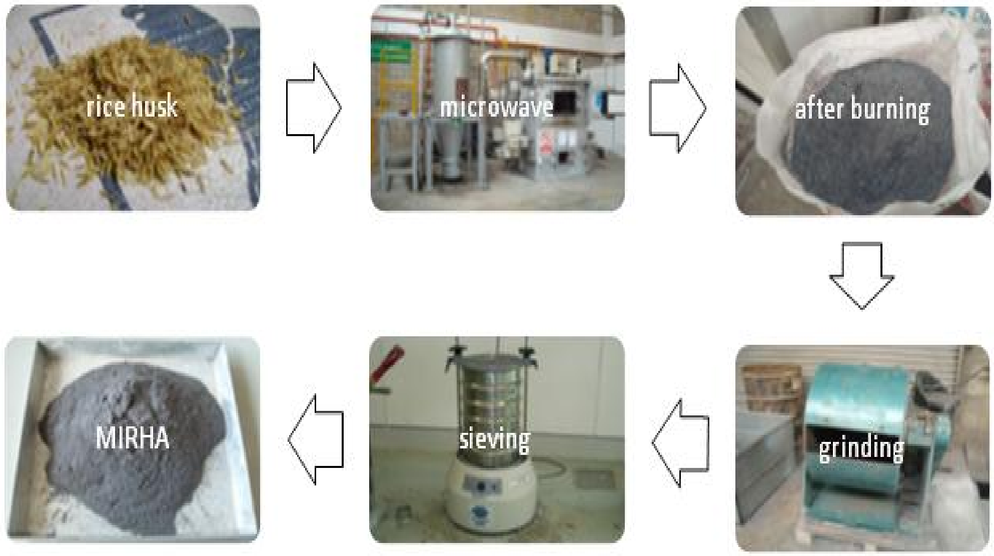

Figure 1. The process of Microwave Incinerated Rice Husk Ash (MIRHA) production

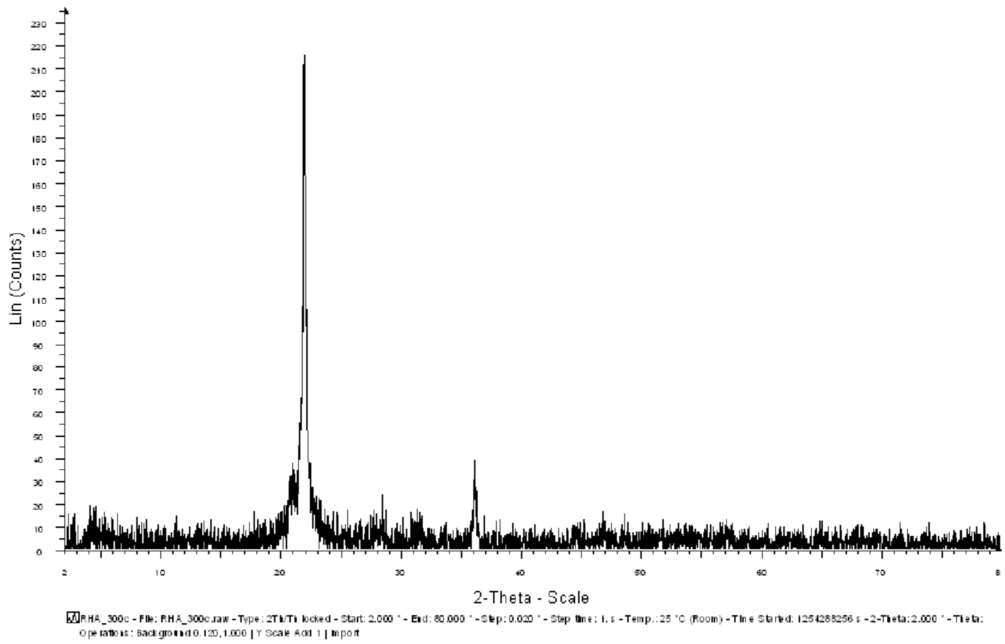

Figure 2. X-Ray Diffraction (XRD) Graph of MIRHA

The results of physical properties of MIRHA are shown in Table 2 The relative density of MIRHA was 2.23 using ultrapycnometer methods. It generally varies in the range of 2.05 to 2.30 for most sources of RHA (Nehdi M. et al., 2003).

Table 1. MIRHA Chemical Composition

Chemical Content	Mass content (%)
Silicon dioxide or silica (SiO_2)	90.75
Aluminum oxide or alumina (Al_2O_3)	0.75
Iron oxide (Fe_2O_3)	0.28
Calcium oxide or lime (CaO)	0.87
Magnesium oxide or magnesia (MgO)	0.63
Sodium oxide (Na_2O)	0.02
Potassium oxide (K_2O)	3.77
Equivalent alkalis (Na_2O + 0.658 K_2O)	2.50
Titanium oxide (TiO_2)	0.02
Phosphorous oxide (P_2O_5)	2.5
Manganese oxide (MnO)	0.08
Sulfur trioxide (SO_3)	0.33
Other	
Sulfur (S)	< 0.01
Carbon (C)	0.15
Chloride (Cl):	110 g/t

Table 2. Physical properties of MIRHA

Properties	Value
Relative density	2.23
Accelerated pozzolanic activity (%)	92.3
Passing 45μm (%)	95.15
Specific surface area (m^2/g)	7.81
The average particle (μm)	16.22
Loss on ignition (%)	5.02

Natural quartzite sand as fine aggregate was used in this study; it was obtained from the deposit of Tronoh, Perak. The fine aggregate was recommended for use in foamed concrete which has the particle size up to 5 mm (Jones and McCarthy, 2005) and even distribution. The fine aggregate used was natural sand with 100% passing 425 mm sieve BS EN 12620 and its density was 2.65. Figure 3 and Figure 4 show the mechanical sieve used to sieve fine aggregate and fine aggregates obtained from sieving process, respectively.

Figure 3. Mechanical sieve used for this research

Figure 4. Fine aggregate obtained from sieving process

The absorption of sand obtained was 1.0%. The absorption of fine aggregate generally varies in the range of 0.2 to 3.0% (Neville, 2006). The mass passing 75 mm sieve was obtained 1.38% that is lower than the value of ASTM-C33 standard 3 to 5% (ASTM-C33, 2003). The superplasticizer incorporated in this research was in the form of liquid, known as Sulfonated Naphthalene Formaldehyde condensate. The surfacetant used for the production of the preformed foam was by aerating palm oil based, this is typical of industry practice which has a ratio of 1:30 by volume and has aerated to a density of 110 kg/m^3 (ASTM-C796-97, 1997; ASTM-C869-2006, 2006)

In this research 5 design parameters have been identified, they are: Microwave Incinerated Rice Husk Ash Content (MIRHA); sand/cement (s/c); water/cementitious (w/c); Superplasticizer (SP) content; Foam content (fc). To have good quality of FC these parameters need to be carefully combined. It means that the experiments will have to study huge number of combinations. An appropriate combination of parameters should be chosen to solve the problem of huge number of experiments. Taguchi's method (Roy, 1990.) was used to solve the problem.

Orthogonal array is the significant step for Taguchi's approach which employed parameters and levels. Table 3 shows the details of the variables used in the experiment. It is noted that the parameters are at four levels. Only 16 experiments are needed to study the whole experimental parameters using the standard L_{16} (4^5) orthogonal arrays (Table 4).

Table 3. Parameters and their variation levels

Variable	unit	Level 1	Level 2	Level 3	Level 4
MIRHA	(%)	0	5	10	15
w/c	ratio	0.35	0.4	0.45	0.5
s/c	ratio	0.25	0.5	0.75	1
SP	(%)	1	1.5	2	2.5
FC	(%)	20	25	30	35

Table 4. Standard L_{16} orthogonal array

Exp. no	Independent variables					Code
	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5	
1	1	1	1	1	1	FC-1
2	1	2	2	2	2	FC-2
3	1	3	3	3	3	FC-3
4	1	4	4	4	4	FC-4
5	2	1	2	3	4	FC-5
6	2	2	1	4	3	FC-6
7	2	3	4	1	2	FC-7
8	2	4	3	2	1	FC-8
9	3	1	3	4	2	FC-9
10	3	2	4	3	1	FC-10
11	3	3	1	2	4	FC-11
12	3	4	2	1	3	FC-12
13	4	1	4	2	3	FC-13
14	4	2	3	1	4	FC-14
15	4	3	2	4	1	FC-15
16	4	4	1	3	2	FC-16

Table 5 Mixture proportion of foamed concrete

Code	Cement (kg/m³)	Sand (kg/m³)	Water (kg/m³)	MIRHA (kg/m³)	Vol Foam (liter/m³)	SP (kg/m³)
FC-1	1050	263	368	0	200	0
FC-2	828	414	331	0	250	4
FC-3	666	500	300	0	300	7
FC-4	544	544	272	0	350	8
FC-5	779	195	312	39	350	8
FC-6	797	398	279	40	300	12
FC-7	668	501	334	33	250	0
FC-8	685	685	308	34	200	3
FC-9	827	207	372	83	250	12
FC-10	761	381	381	76	200	8
FC-11	653	490	229	65	350	3
FC-12	614	614	246	61	300	0
FC-13	715	179	357	107	300	4
FC-14	635	318	286	95	350	0
FC-15	749	562	300	112	200	11
FC-16	674	674	236	101	250	7

The mix proportions of binders are presented in Table 5. The mixes are prepared at about 5.5 min with a rotating planetary mixer. The fine aggregate is first mixed with 1/2 of water followed by the addition of PC and MIRHA. Afterwards, the rest of water and chemical admixtures are pre-mixed and added to the mix. Finally, the appropriate volume of the foam is generated and added immediately to the base mix and mixed for a duration until there was no physical sign of the foam on the surface and all the foam is uniformly distributed and incorporated into the mix.

The workability of the foamed concrete was evaluated through spread measurement in accordance with ASTM-230 (ASTM-C230, 2003). The truncated cone mould was placed on a glass plate, filled with paste and lifted (L. D'Aloia Schwartzentruber et al., 2006). The diameters of the flow give indications of the workability of the mix. The spread test is shown in Figure 5.

3. Result and analysis

Table 6 shows the spread test results of the various mixes with the mean spread measurement diameter ranging between 13.7 cm and 31.8 cm.

Figure 5. Spread test

The main effect plot by each factor for spread test of FC is shown in Figure 6. The degree of contribution of each factor was clearly calculated by analysis of variance (ANOVA). This is to understand the influence of there factors to the spread test of FC (Table 6). The critical value of F at 95% probability level (3.411) is much lower than the observed value of F-statistic 325.86, 1573.70, 657.01, 96.51 and 50.88 for MIRHA content, w/c, s/c, SP and foam respectively. This means that the factor which contributes to the sum of the squares is within the confidence level.

Table 6. Test results of average spread test for MIRHA-FC

Mixes	Spread test (cm)
FC- 1	26.3
FC-2	25.0
FC-3	24.4
FC-4	24.3
FC-5	26.9
FC-6	24.4
FC-7	25.8
FC-8	19.5
FC-9	31.3
FC-10	29.2
FC-11	17.1
FC-12	17.2
FC-13	31.8
FC-14	23.6
FC-15	18.0
FC-16	13.7

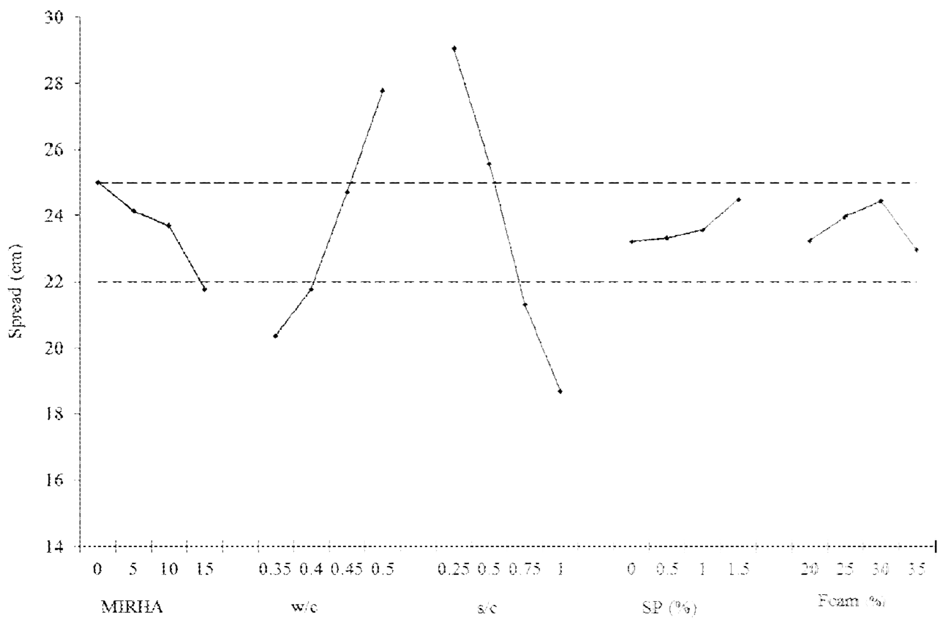

Figure 6. Main effect plot for Spread test

Jurnal APLIKASI
ISSN.1907-753X

Table 7. Analysis of variance results of Workability of foamed concrete

Parameter	statistical parameters	Workability
MIRHA	Degree of freedom (DoF)	3
	Sequential sum of square (SSS)	175.47
	Adjusted sum of square (ASS)	175.47
	Mean square /variance (MS)	58.49
	F-statistic; $F_{0.5}$ (3,13)	325.86
	Contribution (%)	12.06%
w/c	DoF	3.00
	SSS	847.41
	ASS	847.41
	MS	282.47
	F-statistic; $F_{0.5}$ (3,13)	1573.70
	Contribution	58.03%
s/c	DoF	3.00
	SSS	353.79
	ASS	353.79
	MS	117.93
	F-statistic; $F_{0.5}$ (3,13)	657.01
	Contribution (%)	24.07%
SP	DoF	3.00
	SSS	51.97
	ASS	51.97
	MS	17.32
	F-statistic; $F_{0.5}$ (3,13)	96.51
	Contribution (%)	3.96%
foam	DoF	3.00
	SSS	27.40
	ASS	27.40
	MS	9.13
	F-statistic; $F_{0.5}$ (3,13)	50.88
	Contribution (%)	1.88%

Table 7 explains the component statistical of each parameter which consists of degree of freedom (DoF), sequential sum of square (SSS), adjusted sum of square (ASS), mean square variance (MS), F-statistic and Contribution. The SSS and ASS had same value for orthogonal design. The MS value equal to the SS divided by the DoF. The F statistic, is defined the ratio of variance due to the effect of a factor and variance due the error term. The percent contribution for any factor is obtained by dividing the pure sum of squares for that factor by total of sum of square total and multiplying the result by 100.

For example, The SSS and ASS value on the parameter w/c was almost five times higher than MIRHA. This value explains the influence of the contribution of w/c greater than MIRHA to the workability of FC.

Figure 6 shows the lower (220 mm) and upper (250 mm) values of the spread workability test values. All the critical values attached to MIRHA, w/c, s/c, SP and foam were within the stipulated ranges. In Figure 4 FC incorporating MIRHA shows lower spread result than normal FC. The spread measurement decreased with the increase of MIRHA percentage, at was due to the high specific surface area of MIRHA, which increased the water demand. This was mainly due to the adsorptive character of MIRHA cellular particles, thus FC containing MIRHA required more water for a given consistency. However, for FC with high water cement ratio, addition of MIRHA could improve the concrete stability since it absorbed water and was able to reduce the tendency towards bleeding and segregation. The addition of MIRHA truly absorbs large amount of water in the mixture, and it also needed superplasticizer (SP) with specific amount to increase the workability and reached the similar slump as control concrete. The increment in percentage of MIRHA added was followed with the increment in percentage of SP used. The contribution of MIRHA parameter to achieve the required consistency of FC was 12.06%. A stabled and consistent FC can be achieved with 5 to 15% of MIRHA because there percentage inclusions were in the spread rest range proposed.

4. Conclusion

FC incorporating MIRHA shows lower spread result than normal FC. MIRHA content has contribution 5-15% for workability which a stabled and consistent FC can be achieved. The contribution of MIRHA parameter to achieve the required workability of FC was 12.06%.

5. References

ASTM-C33 (2003). Standard Specification for Concrete Aggregates. *In* "Annual Book ofASTM Standards, Vol.04.02," (A. S. f. T. a. Materials, ed.), Philadelphia, USA.

ASTM-C230 (2003). "Standard Specification for Flow Table for Use in Tests of Hydraulic Cement.

ASTM-C796-97 (1997). Standard Test Method for Foaming Agents for use in producing cellular concrete using Preformed Foam.

ASTM-C869-2006 (2006). Standard Test Method for Foaming Agents for used in Making Preformed Foam for cellular concrete.

Jones, M. R., and McCarthy, A. (2005). Behaviour and assessment of foamed concrete for construction applications. *In* "Proceedings of the International Conference on the Use of Foamed Concrete in Construction", pp. 61-88.

Kearsley, E. P., and Wainwright, P. J. (2001). The effect of high fly ash content on the compressive strength of foamed concrete. *Cement and Concrete Research* **31**, 105-112.

Kearsley, E. P., and Wainwright, P. J. (2002). Ash content for optimum strength of foamed concrete. *Cement and Concrete Research* **32**, 241-246.

L. D'Aloia Schwartzentruber, R. Le Roy, and Cordin, J. (2006). Rheological behaviour of fresh cement pastes formulated from a Self Compacting Concrete (SCC). *Cement and Concrete Research* **36**, 1203–1213.

Lee, H. K., Kim, H. K., and Hwang, E. A. (2010). Utilization of power plant bottom ash as aggregates in fiber-reinforced cellular concrete. *Waste Management* **30**, 274-284.

Nehdi M., Duquette, J., and El-Damatty, A. (2003). Performance of rice husk ash produced using a new technology as a mineral admixture in concrete. *Cement and Concrete Research* **Vol.33, No.8**, 1203-1210.

Neville, A. M. (2006). " Properties of Concrete (4th edn). Longman, London."

Pan, Z., Hiromi, F., and Wee, T. (2007). Preparation of high performance foamed concrete from cement, sand and mineral admixtures. *Journal Wuhan University of Technology, Materials Science Edition* **22**, 295-298.

Roy, R. (1990.). A primer on the Taguchi method.

Tiong-Huan Wee, D. S. B., T. Tamilselvan, and Hwee-Sin Lim (2006). Air-Void System of Foamed Concrete and its Effect on Mechanical Properties. *Materials Journal*.

Wang, K. S., Chiou, I. J., Chen, C. H., and Wang, D. (2005). Lightweight properties and pore structure of foamed material made from sewage sludge ash. *Construction and Building Materials* **19**, 627-633.