MICRONISED BIOMASS SILICA AS CEMENT REPLACEMENT MATERIAL IN CONCRETE

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ABSTRACT

Micronised Biomass Silica (MBS) is an agricultural waste product which comprises of high content of silica. This study was conducted on the off-white amorphous biomass silica ash derived from the rice husk with pozzolanic index 69%. Various percentages of MBS ranging from 0% to 20% by mass have been used as cement replacement material. Compressive strength and water permeability of concrete with MBS incorporation were investigated. From the results obtained, it was identified that up to 12% of MBS is able to produce concrete with higher strength and lower in water permeability compared to control concrete.

KEYWORDS*: Micronised Biomass Silica, pozzolanic index, compressive strength, water permeability.*

1.0 INTRODUCTION

Concrete is produced when cement, coarse aggregate, fine aggregate, water and admixtures are mixed thoroughly. Concrete is defined as a good quality concrete when it enables to achieve good strength and durability (A.M.Neville, 1999). Good strength is achieved when concrete can sustained the maximum load. Meanwhile good durability is achieved when concrete can resist the attack from aggressive ion which delivered externally and internally.

Good quality concrete can be produced by using several methods. One example is utilization of pozzolanic material. According to ASTM 618-94a, pozzolans is siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Recently, pozzolanic material like fly ash, silica fume and ground granulated blastfurnace slag has been widely used in construction industry. Moreover, pozzolanic material has some benefits such as it can encourage the application of natural waste product and for environmental conservation (J.Sampaio *et.al*, 2000) This is because; generally pozzolanic material is produced from by-product waste. Normally these pozzolanic materials functioning as cement replacement material which substitute a part of cement content.

In this study, Micronised Biomass Silica (MBS) is produced as cement replacement material. Various percentages of MBS are used to produce the concrete. Thus optimum percentage of MBS is recognized. On the other hand, compressive strength and water permeability were conducted as measurement of MBS concrete's performance.

2.0 EXPERIMENTAL WORK

For experimental work, the materials used and testing conducted for fresh and hardened concrete are described as below.

2.1 Materials Selection

The raw materials used in this study are listed as below:

a) Ordinary Portland Cement (OPC)
b) Coarse Aggregate
c) Fine Aggregate
d) Superplasticizer

2.2 Micronised Biomass Silica

Micronised Biomass Silica (MBS) is prepared at Material Laboratory of Universiti Tun Hussein Onn Malaysia (UTHM). In this study, rice husk has been selected as biomass waste material. The findings from other researchers like (A.A.Ikpong *et.al*, 1992), (S.Mindess *et.al*, 2003), (J.Paya *et.al*, 2001) have confirmed the presence of high silica content in rice husk. Thus utilization of rice husk as raw material is the best choice. MBS is prepared by burning the rice husk into rotary furnace. Rice husk is manually fed into the rotary furnace. This rotary furnace has the ability to synthesis any biomass silica material with different regime of temperature. To obtained an amorphous material, the temperature for rotary furnace is fixed at 500 ^{0}C. Off white amorphous material is obtained after one (1) hour. To obtain finer biomass silica, jar mill has been used. After being grinding by Jar Mill for one (1) hour, the particle size of MBS is reduced from 48 μm to 25 μm. On the other hand, pozzolanic activity index was carried out to MBS for 7 and 28 days. The results obtained from pozzolanic activity index are shown in Table 1. It can be seen from the data in Table 1 that up to 12% of MBS, its pozzolanic activity index is increases. The highest pozzolanic activity index is 69.42% which is for MBS content 12% at 28 days.

TABLE 1
Pozzolanic Activity Index for MBS

MBS CONTENT (%)	PAI (7 d) %	PAI (28 d)%
4	31	48.68
8	34.97	50
12	46.46	69.42
16	13.94	57.79
20	13.54	52

* PAI = Pozzolanic Activity Index

2.3 Concrete Mixes Specimens

Twenty four (24) concrete mixes have been prepared for this experimental work. Various percentage replacements of MBS in cement content have been used. 0%, 4%, 8%, 12%, 16% and 20% replacement of MBS as cement material has been investigated and abbreviated as M0, M4, M8, M12, M16 and M20. The concrete mixes were designed according to DOE method. Slump value is designed for range 60mm – 180mm. Target strength of concrete for 28 days is 25 MPa.

2.4 Fresh Concrete

The performance in fresh concrete is determined by slump value test. This test is conducted according to ASTM C 143-90a.

2.5 Hardened Concrete

Compressive strength of concrete is determined by using compression machine. Compressive strength is carried out for age of concrete at 7, 14, 28 and 90 days. This test is conducted according to BS 1881: Part 116:1983. Meanwhile for determining the water permeability of concrete, two (2) different tests were conducted. First is GWT test which is conducted according to ISO/DIS 7031. Meanwhile the second test is Water Impermeability Apparatus Three-Place Model. This test is prescribed by modified DIN 1048. Former test is conducted to determine the coefficient of water permeability. Meanwhile the latter is to determine the depth of water penetration in concrete. GWT test is carried out for age of concrete at 7, 14, 28 and 90 days. Meanwhile, Water Impermeability Apparatus Three-Place Model test is for 28 and 90 days.

3.0 RESULTS AND DISCUSSION

3.1 Workability

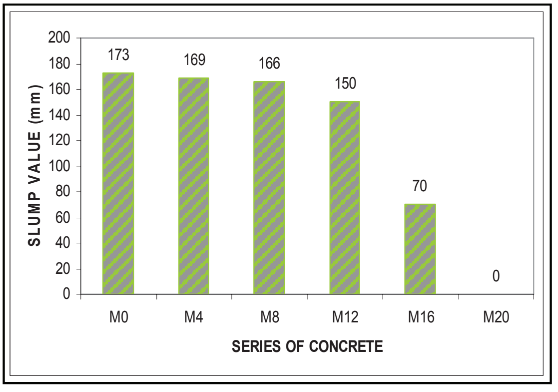

FIGURE 1
Workability Value for Various Percentages of MBS in Concrete Mixes

Figure 1 illustrates the performance of workability for up to 20% of MBS in concrete mixes. Percentage of MBS content in concrete is abbreviated with M0, M4, M8, M12, M16 and M20 which that indicates the 0%, 4%, 8%, 12%, 16%, 20% of MBS, respectively. As shown in Figure 3.1, the workability is decreases, as MBS percentage replacement in concrete is increases. When slump value is decreases, it indicates that the concrete mixes were harsh and less cohesive. Harsh and less cohesive concrete mixes will lead into difficulty in compacting progress. However, this slump value performance is affected by MBS properties which have an ability to absorb the water. Cellular characteristic of MBS lead into this matter.

3.2 Compressive strength

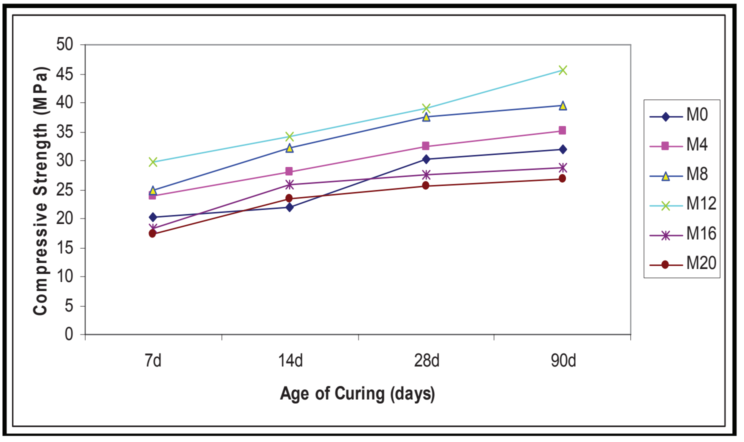

FIGURE 2
Compressive Strength of MBS Concrete

Compressive strength of concrete versus various percentages of MBS is presented in Figure 2. This figure reveals that M4, M8 and M12 attained higher in compressive strength than that of M0 (control concrete) for all age of curing. Meanwhile, M16 and M20 attained lower in compressive strength than that of M0 for all age of curing. This figure also reveals that MBS had an optimum ability in compressive strength development when its percentage as cement replacement material up to 12%. Pozzolanic reaction that occurred between cement hydration and MBS, lead to formation of CSH gel. CSH gel has an ability to enhance performance of concrete by fill up the Interfacial Transition Zone (ITZ) which located between cement paste and aggregate. Moreover, C-S-H gel able to fill up the micropores inside the concrete. Nevertheless, when 16% and 20% replacement of MBS is taking place in cement, its compressive strength obtained lower in compressive strength. This is because the increasing percentage of MBS in cement has lead into decreasing of cement content. Thus, it will reduce the formation of C-S-H gel that produced from $Ca(OH)_2$ from cement hydration and SiO_2 from MBS. So, when C-S-H gel is reducing, its ability to fill up the ITZ and micropores inside concrete is also decreasing. Then it will affect the compressive strength development in concrete.

3.3 Water Permeability

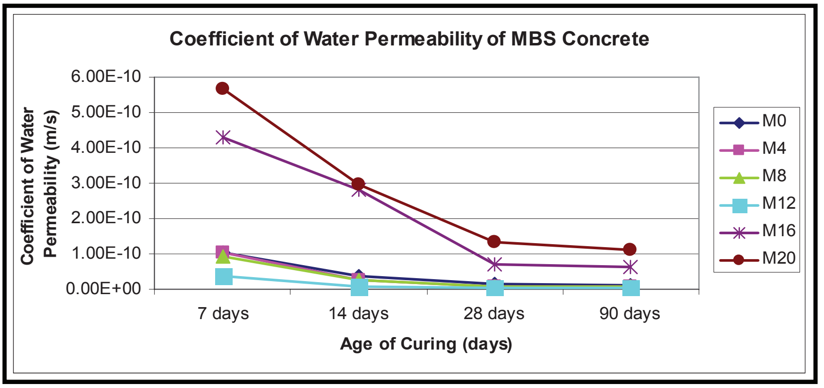

FIGURE 3
Coefficient of Water Permeability for MBS Concrete

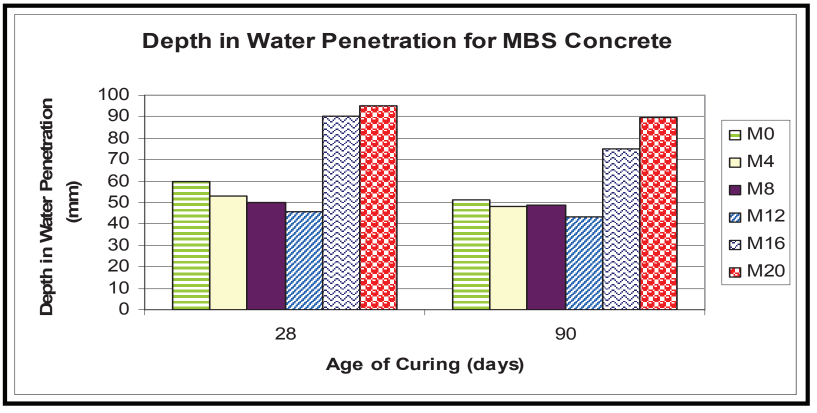

FIGURE 4
Depth of Water Penetration for MBS Concrete

Figure 3 shows the coefficient of water permeability of concrete with incorporation of MBS as cement replacement material. Meanwhile Figure 4 illustrates the depth of water penetration for MBS concrete at 28 and 90 days.

As shown in Figure 3 it recognized that up to 12% replacement of MBS in cement content, the concrete produced is obtained a lower in coefficient of water permeability than that of M0. At 90 days, the coefficient of water permeability is decreased to 28.2%, 36.2%, 55.3% from M0 for 4%, 8%, 12% replacement of MBS in concrete. Meanwhile, for 16% and 20% replacement of MBS, its coefficient of water permeability is increased to 559% and 1048% than M0.

On the other hand, Figure 4 also identified that up to 12% of MBS in concrete mixes attained lower in depth of water penetration compared to M0. At 28 and 90 days, M4 attained 11.7% and 5.9% lower in depth of water penetration compared to M0. Meanwhile for M8, it has lowering its depth of water penetration about 16.7% and 4.9% than that of M0 at 28 and 90 days, respectively. Furthermore, at 28 and 90 days, the 12% replacement of MBS (M12) in concrete has lowering the depth of water penetration about 24.2% and 15.7% than that of M0.

On the other hand, M16 has obtained higher in depth of water penetration about 50% and 47.1% compared to M0 for 28 and 90 days. Also, M20 in concrete lead into higher in depth of water penetration than that of M0 about 58.3% and 75.5% for 28 and 90 days.

Based on these results, it can be concluded that 4%, 8% and 12% of MBS are able to perform as pozzolanic and filler material which can produce an impermeable concrete. Meanwhile 16% and 20% replacement of MBS is not suitable for producing impermeable concrete.

4.0 CONCLUSIONS

This study has found that MBS has an ability to react as pozzolanic material. In fresh concrete, MBS has reduced the slump value due to increasing percentage content of MBS. Cellular characteristic of MBS lead into this performance. Meanwhile in hardened concrete performance, up to 12% of MBS has higher compressive strength compared to control concrete. Thus, in water permeability test, up to 12% of MBS concrete attained lower in water permeability performance than that of control. Taken together, these findings suggest that up to12% of MBS can produced a good strength and impermeable concrete.

5.0 ACKNOWLEDGEMENT

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6.0 REFERENCES

A.A.Ikpong, D.C. Okpala. 1992. Strenght Characteristics of Medium Workability Ordinary Portland Cement-Rice Husk Ash Concrete. *Building and Environment.* Vol 27, Issue 1. pp. 105-111.

A.M.Neville. 2009. Properties of Concrete. Pearson Education Limited.

Barbosa, R.N. Swamy and C. Lynsdale. pp. 125-137.

J.Paya, J.Monzo, M.V.Borrachero, A.Mellado, L.M.Ordonez. 2001. Determination of amorphous silica in rice husk ash by a rapid analytical method. *Cement and Concrete Research*. Vol 31, Issue 2. pp. 227-231.

J.Sampaio, J.S., Coutinho, M.N. Sampaiao. 2000. Portuguese rice husk ash as a partial cement replacement. Proceedings, International Conference: *Sustainable Construction into the next Millennium: Environmentally friendly and innovative cement based materials.* Ed. N.P.

S.Mindess, J.F.Young, D.Darwin. 2003. *CONCRETE* 2nd Edition. Pearson Education,Inc.