Compressive Strength and Water Permeability Performance of Micronised Biomass Silica Concrete

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Abstract

Concrete is a common material that is widely used in construction industry. Cement is the main material component for producing concrete but its production has lead into CO2 emission. This work presents a study on Micronised Biomass Silica (MBS) that can be used as pozzolan material which can enhance the quality of concrete. The material can be produced from a by-product of biomass agricultural waste but for this study rice husk has been used. From the chemical analysis, MBS has a chemical composition that is fulfill the standard requirement for becoming pozzolan material. The result of MBS concrete shows that the MBS material can enhance the performance of concrete by increasing the compressive strength development and reducing the water permeability. The drawback of MBS is the workability of fresh concrete but can be rectify by using superplasticizer. By replacing up to 12% of cement, MBS material gives the highest performance in term of strength and permeability of the concrete.

Keywords: cement, Micronised Biomass Silica, strength, water permeability.

1. INTRODUCTION

Good quality of concrete is normally determined by its ability to withstand compressive strength and water permeability. To achieve a good quality of concrete, various materials have been used by researchers in their studies to produce a good quality of concrete. Pozzolans materials have been used to enhance the quality of the concrete as well as cement replacement material in studies which have been conducted by Basri, Mannan and Zain (1999), Speare et. al. (1999), Nikam and Tambvekar (2003) and Gemma (2006). Most of their findings showed that pozzolan application has produced good quality concrete.

Pozzolan material should have properties complying ASTM C 618-93 standard. Pozzolan material should be siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value. With the presence of moisture the material will chemically react with lime (*from hydrated Portland cement*) at normal temperature to produce compounds possessing cementitious properties.

Normally, pozzolan material is natural or by-product materials. Fly ash, silica fume, palm oil fuel ash, ground granulated blast furnace slag (ggbs), rice husk ash and timber industrial ash are some of pozzolan materials which familiarly known. The materials are either natural or artificial contains silica in a reactive and amorphous form. It had attracted many researchers to study the ability of the pozzolan material for producing good concrete. The application of industrial by-product pozzolan can lower concrete cost and substantial energy saving (Sampaio *et.al.* (2000)). Thus this application will also conserve our environment. In India, many prestigious projects use pozzolan materials purpose to achieve higher strengths and better in durability (Kumar and Kaushik (2003)). Hence, with this great interest, Micronised Biomass Silica (MBS) has been introduced in this study as pozzolanic material. The study is conducted to determine the compressive strength and water permeability performance of MBS concrete compared to control concrete.

2. MICRONISED BIOMASS SILICA

Micronised Biomass Silica (MBS) used in this study was produced by using reactor rotary furnace. Rice husk was taken from Bernas Malaysia rice milling plant and fed into the furnace. The husk contains high silica content and is suitable for biomass agro waste material. It is fed into a furnace in a continuous process through multiple distributed inlets. The furnace temperature regime is controlled at 500 0 to produce the Micronised Biomass Silica. The controlled temperature will turn the husk into amorphous biomass silica ash. The furnace is equipped with a controller for air (oxygen) to enter and assist a complete burning process in order to produce low carbon content of white amorphous biomass silica ash. Perforated trays in furnace rotated to enhance the mixing process, heat distribution and optimizing the burning efficiency. The burning process takes an hour for white biomass silica ash to fall through the perforated trays and to a collecting funnel at the downstream of the furnace via gravity. The weight loss during this process is about 77.1%. Figure 1 show the rotary rector furnace that was used to generate the silica for this study. The average diameter size of the biomass silica is about 48 µm. In order increase the fineness of biomass silica, the silica is crushed using Jar Mill. The fineness will employed effective biomass silica as a micro structure filler in concrete. The fineness process of the Jar Mill takes 60 minutes and the Micronised Biomass Silica (MBS) produced has a mean particle size diameter of 25 µm. Figure 2 shows the MBS which has been produced for this study.

Physical and chemical properties of MBS are as illustrated in Table 1 and 2, respectively. From the table, MBS has higher surface area compared to Ordinary Portland Cement (OPC). Its surface area is higher than OPC by 800%. The higher specific surface of area of MBS indicates that the material can achieve higher hydration process. This property led MBS to contribute better strength development of concrete. MBS size is about 25µm and this size will contribute into better strength and water permeability performance in concrete.

Table 2 shows the chemical composition for MBS compared to OPC. From this table, a main oxide for MBS is SiO_2 + Al_2O_3 + Fe_2O_3. This oxide is 88.54% of the overall chemical composition of MBS. This percentage is greater than the minimum percentage required by ASTM C-618 which is 70%. The content of SO_3 for MBS is 0.590% which is lower than OPC and also complies with the standard which is not exceeding 5%. Loss On Ignition (LOI) for MBS also follow the standard which is not exceeding 6%.

Fig. 1 Rotary Rector Furnace

Table 1: Physical Property of MBS

Physical Properties	Ordinary Portland Cement (OPC)	Micronised Biomass Silica (MBS)
BET Surface Area (m_2/g)	2.693	24.4039
Particle Size	–	25 µm

Table 2: Chemical Composition of MBS

Chemical Compositions (%)	Ordinary Portland Cement (OPC)	Micronised Biomass Silica (MBS)
Silicon dioxide (SiO_2)	17.91	87.67
Aluminium oxide (Al_2O_3)	4.69	0.343
Iron oxide (Fe_2O_3)	2.976	0.531
Calcium oxide (CaO)	65.93	1.18
Magnesium oxide (MgO)	1.19	0.872
Potassium oxide (K_2O)	0.411	5.078
Sulfur trioxide (SO_3)	3.67	0.590
Sodium Oxide (Na_2O)	0.13	0
LOI	1.46	1.22

Fig. 2 Micronised Biomass Silica

3. CONCRETE MIXES

The coarse aggregate used in this study is a crushed aggregate with maximum size 20mm and comply with BS 812-103.2.1989. DOE method of determining concrete mix was adopted for this study. The mix was designed to have 28 day target strength at 25 MPa and the slump target is between 60 to 180mm. Four concrete mixes designed for this work are as shown in Table 3. In this study, water reducing admixture was used as super plasticizer to enhance the workability of the concrete. For each concrete mix, 6 samples of 100mm cubes were prepared using standard steel moulds. Three cubes were used to measure the compressive strength and water permeability using ISO/DIS 7031 and another three cubes were used to measure water permeability using modified DIN 1048. After 24 hours, the cubes were removed from their moulds and cured in water. The concrete mixes/cubes denoted with M0, M4, M8 and M12 are for 0%, 4%, 8%, 12% of MBS content respectively. All samples tested for compressive strength and water permeability using ISO/DIS 7031 are at 7, 14, 28 and 90 days. Meanwhile, for measuring the water permeability using modified DIN 1048, the samples tested are at 28 and 90 days.

Table 3 Mix Proportions for Concrete

Mix	Cement (kg/m^3)	MBS (kg/m^3)	Water (kg/m^3)	Aggregate (kg/m^3)	Sand (kg/m^3)
M0	450	0	225	823	892
M4	432	18	225	823	892
M8	414	36	225	823	892
M12	396	54	225	823	892

4. MBS CONCRETE PERFORMANCE

The performance of MBS concrete for this study is evaluated based on fresh concrete workability, compressive strength of the concrete cubes and finally water permeability and water penetration depth of the concrete.

4.1 Workability

Figure 3 shows the slump values for different concrete mixes which containing 0%, 4%, 8% and 12% of MBS. This result revealed that as MBS content in concrete mixes increases, its slump value will decreases. The reason for this would probably because of the high water absorption properties of MBS. Thus high content of MBS in the mix will create less workable fresh concrete.

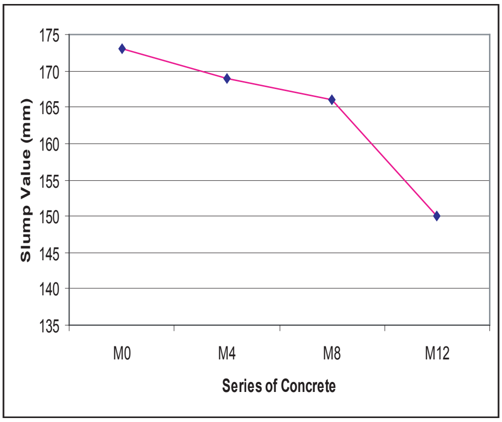

Fig. 3.1 Slump Value for MBS Concrete

4.2 Compressive Strength

The development of MBS concrete compressive strength for various percentages of MBS usage is as in Figure 3.2. Compressive Machine has been used to determine the compressive strength of the concrete cube and the testing was conducted according to BS 1881: Part 116:1983. The figure shows that concrete containing higher percentage of MBS resulted in higher compressive strength. Furthermore, the figure also illustrates that as MBS content in concrete increases, its compressive strength also increases. It clearly can be seen that at 90 days, the concrete of 12% MBS (M12) obtained the highest compressive strength compared to other MBS concrete. M12 obtained about 43.26%, 30.2% and 15.4% higher in compressive strength than that of M0, M4 and M8, respectively. Higher strength development of MBS concrete occurred because of pozzolanic reaction (between SiO2 of MBS and Ca(OH) 2 of cement). The reaction resulted to the production of CSH gel which will fill up the Interfacial Transition Zone (ITZ) and micropores. Thus, enhance the compressive strength performance of MBS concrete.

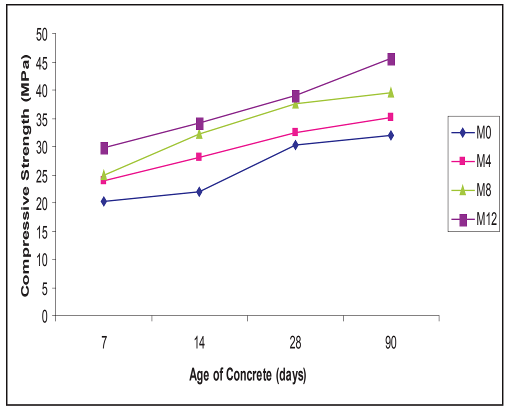

Fig. 3.2 Compressive Strength for MBS Concrete

4.3 Water Permeability

Water permeability test on MBS concrete was done according to ISO/DIS 7031 and the test results are as in Figure 3.3(a). The figure shows that MBS concretes possess lower water permeability compared to control concrete (without MBS-M0). It also shows that MBS concrete graph slope is gentler than the control concrete and this indicates that by adding MBS will makes concrete less water permeable even at early age of the concrete. At 90 days of curing, MBS concrete of M4, M8, and M12 attained 28.18%, 36.22% and 55.32% lower in coefficient of water permeability than that of M0 respectively. This incident happens is due to C-S-H gel formation from pozzolanic reaction between SiO_2 and $Ca(OH)_2$.

This study also investigated water penetration depth of MBS concrete. Figure 3.3(b) shows the control concrete - M0 obtains the highest water penetration depth compare to other MBS concrete either at the age of 28 or 90 days of the concretes. The figure also indicates that water penetration depth of concrete becomes shorter with respect to the concrete age. At 90 days age, water penetration depth for MBS concrete of M4, M8, M12 reduced for about 5.88%, 4.9% and 15.69% than that of the control (M0) respectively. This shows that pozzolanic reaction which occurred in MBS concrete has an effect that lead into lower water penetration of the concrete. From this analysis, it clearly viewed that when MBS content increases, the water permeability performance of the concrete becomes better at all ages of the concrete.

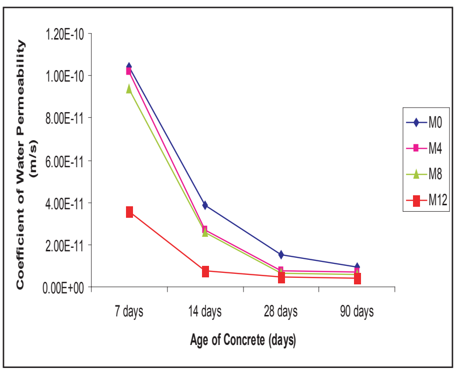

Fig. 3.3 (a) Coefficient of water permeability of MBS concrete

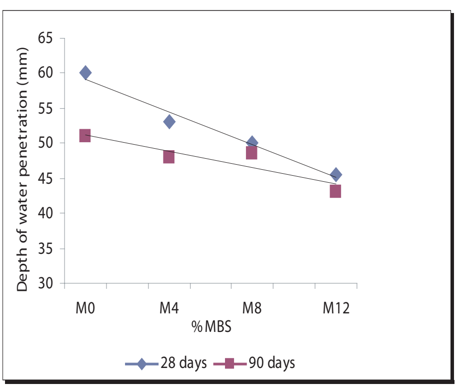

Fig. 3.3 (b) Depth of water penetration of MBS Concrete

5. CONCLUSION

The conclusions from this investigation work on Micronised Biomass Silica (MBS) material and MBS concrete (MBS) are as follow:

1. MBS material possesses 88.54% by mass of $SiO_2 + Al_2O_3 + Fe_2O_3$ with a surface area of 24.40 m^2/g and its size particle of 25μm.
2. Fresh MBS concretes have a lower workability compared to control concrete.
3. MBS as pozzolan material can increase the concrete compressive strength. As the MBS content increases, higher compressive strength of concrete can be achieved.
4. Lower water permeability is attained by MBS concrete compared to control concrete. When MBS content in concrete is increased, its water permeability will decrease. MBS can be used to reduce water permeability of concrete that is exposed to wet and moist environment.
5. MBS is a potential pozzolan material that has the ability to improve the quality of concrete.

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