

Performance of Recycled Aggregate Concrete Containing Micronised Biomass Silica

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ABSTRACT

This paper presents a study on Micronised Biomass Silica (MBS) that was produced from the controlled burning of waste Rice Husk. The MBS was used as pozzolan material to enhance the performance of Recycled Aggregate Concrete (RAC). Various percentages by mass of Micronised Biomass Silica were applied in the normal and recycled aggregate concrete cube samples. Compressive strength and water permeability tested on the samples at the age of 7, 14, 28 and 90 days showed that concrete containing MBS has attained higher compressive strength. Furthermore, the test on MBS also showed its ability to enhance the concrete water permeability. Lengthen to this; the study established a good correlation between the MBS content with compressive strength and water permeability coefficient.

Keywords: *Recycled Aggregate Concrete, Micronised Biomass Silica, Compressive strength, water permeability*

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1.0 INTRODUCTION

Recycled Aggregate Concrete (RAC) is a concrete that use partly or fully Recycled Aggregate (RA) as coarse or fine aggregate. RAC has been widely used and accepted in world wide. For example in United Kingdom, increasing cost of landfill, anxiety of decreasing in natural resources and increasing in aggregate requirement for construction work has attract the RA application in construction industry [1]. Meanwhile in United States, for encouraging the RA application, special incentives for transportation of waste concrete and processed aggregates from production sites were given [2]. Asia countries also participated in experiencing the RA application in their construction industry. Hong Kong and Japan are two countries which seriously have utilized RA as their construction material. For example, RA has been applied as construction material in Hong Kong Wetland Park project [3]. Meanwhile Japan in May 2000 has published a law on recycling construction materials [4]. These efforts had shown that RA has become an important alternative material in construction industry.

Many concerns have been raised by researchers about the poor performance of RAC. Topcu and Sengel [5], Ridzuan et. al. [6] and Limbachiya [7] have identified that fresh RAC concrete performed lower compared to normal concrete. Meanwhile in compressive strength, RAC also performed lower ability that of Normal Aggregate Concrete (NAC) [8]-[10]. For improvement, Ravindrarajah [11] suggested the application pozzolan material in RAC.

Thus in this study, Micronised Biomass Silica (MBS) was used as pozzolan material to improve the performance of RAC. MBS containing high silica content has an ability to enhance the performance of RAC. Micronised Biomass Silica which produced from rice husk has amorphous properties, [12]. The performance of RAC containing MBS was evaluated based on the compressive strength and water permeability tests.

2.0 RECYCLED AGGREGATE

Recycled Aggregate used in this study was derived from crushed waste concrete cubes. It is then compared with normal aggregate of crushed granite. The physical properties for both of the aggregates are as illustrated in Table 1. The table shows that RA has lower in specific gravity compared to NA. This is because of loose paste existence in RA [13]. Aggregate Impact value for RA is double than normal aggregate. Bigger value for AIV means that the aggregate is less strong. This indicates that RA is not suitable for heavy duty floor but appropriate to be used in other concrete application and comply with BS 812: Part 112:1990. RA absorbed significant amount of water compared to normal concrete. According to Chen H.J. et. al.[14] RA has immense porosity that will result to higher water absorption of the aggregate.

Table 1. Physical Properties of Aggregate

Aggregate Properties	Natural Aggregate (NA)	Recycled Aggregate (RA)
Specific Gravity in SSD condition	2.48	2.39
Aggregate Impact Value (%)	17.6	36.3

Water Absorption (%)	0.83	3.34
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3.0 PROPERTIES OF MBS

MBS was produced by burning rice husk in rotary reactor furnace as shown in Figure 1. The furnace temperature of 500⁰C was fixed for producing MBS that achieve amorphous properties. The burning took about an hour and the MBS produced was with the mean size of 48 µm. The MBS was further crushed into smaller size using Jar Mill machine. This process took about 60 minutes for producing smaller size of MBS particles. Particle Size Analyzer equipment was used to determined the particle size of MBS. It was found that the average particle size of MBS is about 25 µm. The MBS was further tested using Nitrogen Adsorption Test equipment to determine its surface area. It was found that MBS has a surface area of 24.4039m²/g. This value is very much higher than that of Ordinary Portland Cement (OPC) which has a surface area of 2.693m²/g.



Figure 1. Rotary Reactor Furnace

4.0 PERFORMANCE OF MBS-RA CONCRETE

The performance of Recycled Aggregate Concrete containing MBS known as MBS-RA concrete was done using concrete cubes of 100mm x100mmx 100mm size with variety mixes. Table 2 presents concrete mix for different series of concrete. The concrete mixes were prepared according to DOE method.

The slump test for all the specimens was designed between 60mm to 180 mm. The compressive strength tests were conducted for concrete cubes at 7, 14, 28 and 90 days and the test was carried out according to BS 1881: Part 116:1983. For water permeability, GWT test was conducted to determine the coefficient of water permeability of concrete at 7, 14, 28 and 90 days. Three (3) duplicate concrete cubes were used as specimens and an average value was taken as reading data.

Table 2 Concrete Mixes for Different Series of Concrete

Percentage of RA (%)	Percentage of MBS (%)	Cement (kg/m ³)	MBS (kg/m ³)	Coarse Aggregate		Fine Aggregate (kg/m ³)	Water (kg/m ³)	Superplasticizer (ml/kg ³)
				Natural Aggregate (kg/m ³)	Recycled Aggregate (kg/m ³)			
0	0	450	0	1115	0	892	225	4500
50	0	450	0	558	558	892	225	4500
100	0	450	0	0	1115	892	225	4500
0	4	432	18	1115	0	892	225	4320
50	4	432	18	558	558	892	225	4320
100	4	432	18	0	1115	892	225	4320
0	8	414	36	1115	0	892	225	4140
50	8	414	36	558	558	892	225	4140
100	8	414	36	0	1115	892	225	4140
0	12	396	54	1115	0	892	225	3960
50	12	396	54	558	558	892	225	3960
100	12	396	54	0	1115	892	225	3960

5.0 WORKABILITY OF FRESH MBS-RA CONCRETE

Table 3 shows the workability performance of MBS-RA concrete samples. Slump test conducted was to determine the workability of the produced concrete cubes. The results show that as recycled aggregate content increased the slump value of RAC decreases. These outcomes are expected because recycled aggregate has higher water absorption capacity. The remaining mortar in recycled aggregate causes it to increase the potential absorption capability. Furthermore, as MBS content in RAC increases, slump value will decrease. Water absorption properties in MBS have contributed for these results. Decreasing value of slump indicates the harsh and less cohesive of concrete mixes. However the slump value is still within workability design value (60-180mm).

Table 3 Workability of different concrete samples

Percentage of RA (%)	Percentage of MBS (%)	Slump value (mm)
0	0	173
50	0	165
100	0	153
0	4	169
50	4	150
100	4	135
0	8	166
50	8	142
100	8	127
0	12	150
50	12	130

100	12	70
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6.0 COMPRESSIVE STRENGTH OF MBS-RA CONCRETE

The results obtained from the compressive strength test are presented in Figure 2 (a)-(c). Figure 2(a) shows the compressive strength development for MBS-RA concrete with 0% RA for different age of curing. This figure revealed that compressive strength of concrete with MBS is higher than that of 0% MBS. At early age, additional 4% of MBS and 8% MBS in concrete has increased the compressive strength about 20% and 25%. However, the addition of 12% MBS in concrete has obtained a quite large percentage number of increasing in the compressive strength in concrete, which is about 50% than that of 0% MBS. At 28 days, addition of 4%, 8% and 12% MBS in concrete has increased the compressive strength about 7%, 24% and 29%. Meanwhile at 90 days, 10%, 24%, 43% the increasing strength development than that of 0% MBS is obtained when MBS is used as cement replacement material for 4%, 8% and 12%, respectively.

On the other hand, Figure 2 (b) shows the compressive strength development for MBS-RA concrete with 50% RA replacement in concrete for different age of curing. At 7 days, MBS-RA concrete with 4%, 8% and 12% MBS, have increased the compressive strength at about 50%, 60% and 82% than 0% MBS. Meanwhile for 28 days, concrete with 4%, 8% and 12% MBS has increased the compressive strength about 21%, 35% and 44% than that of 0% MBS. After 90 days, the compressive strength of 4% MBS, 8% MBS and 12% MBS has increased about 17%, 20% and 24% than that of 0% MBS.

Lastly, Figure 2 (c) shows the compressive strength development for MBS-RA concrete containing 100% RA for different age of curing. At 7 days, the compressive strength of MBS-RA concrete has increased the compressive strength than that of 0% MBS at about 51.5%, 55.2% and 68.5% for incorporation of 4%, 8% and 12% MBS, respectively. Meanwhile for 28 days, the compressive strength for concrete with 4% MBS, 8% MBS and 12% MBS has increased to 29.2%, 34.3% and 50% than that of 0% MBS. At 90 days, the compressive strength of 4% MBS, 8% MBS and 12% MBS has increased about 15%, 20% and 28% than that of 0% MBS.

From all these figures, it showed that the compressive strength for RAC decreases as RA content increases. Approximately, this decreasing trend is similar to the previous findings from [8]-[10] studies. At the early ages, shows the ability of MBS in enhancing the compressive strength performance for both recycled and natural aggregate concrete. These incidents were resulted from the pozzolanic properties of MBS. This trend continues until 90 days. At 90 days, RAC with 12% of MBS obtained highest in compressive strength compared to other series of RAC. The pozzolanic reaction occurred when calcium hydroxide that was produced from the cement hydration reacted with SiO₂ of MBS. This pozzolanic reaction produces CSH gel which can improve the compressive strength development for the concrete.

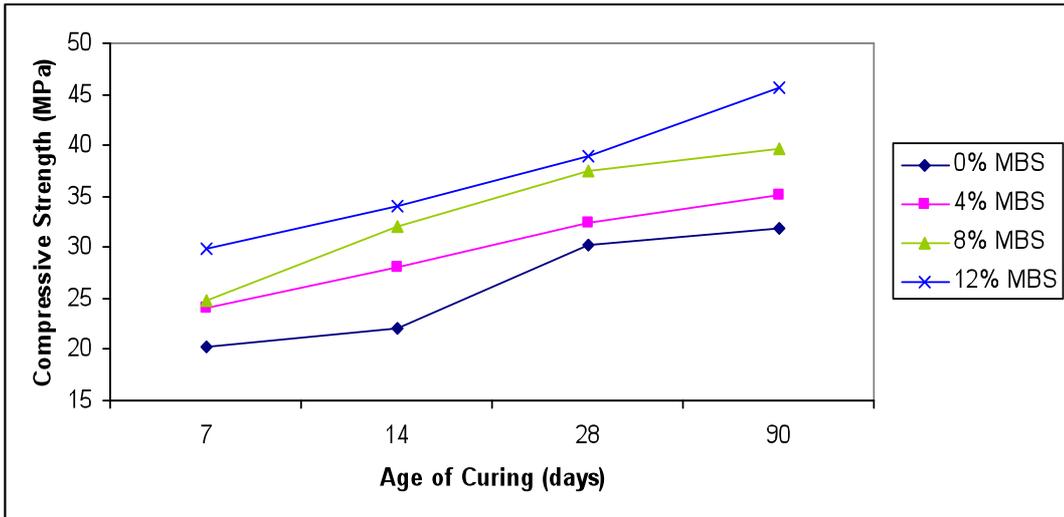


Figure 2 (a): Compressive Strength Development for MBS-RA concrete with 0% RA

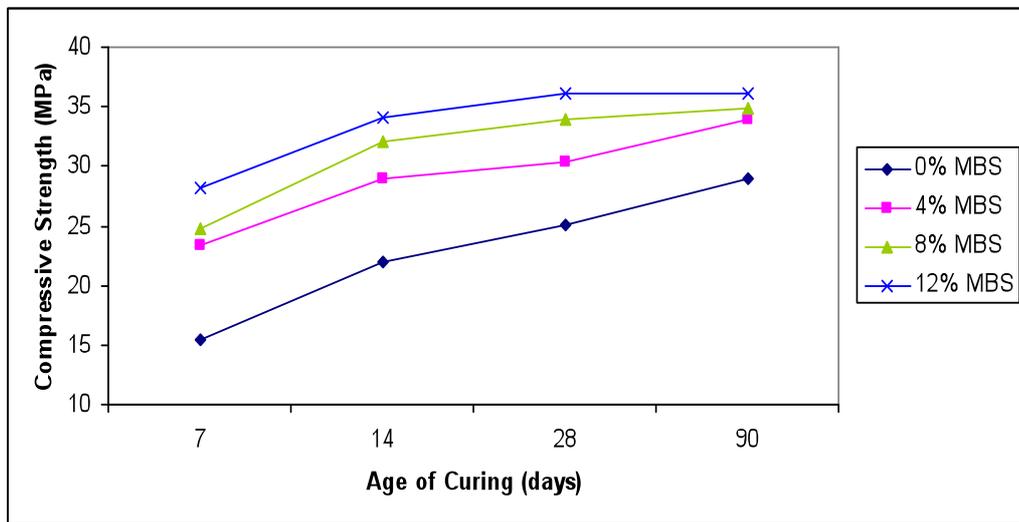


Figure 2 (b): Compressive Strength Development for MBS-RA concrete with 50% RA

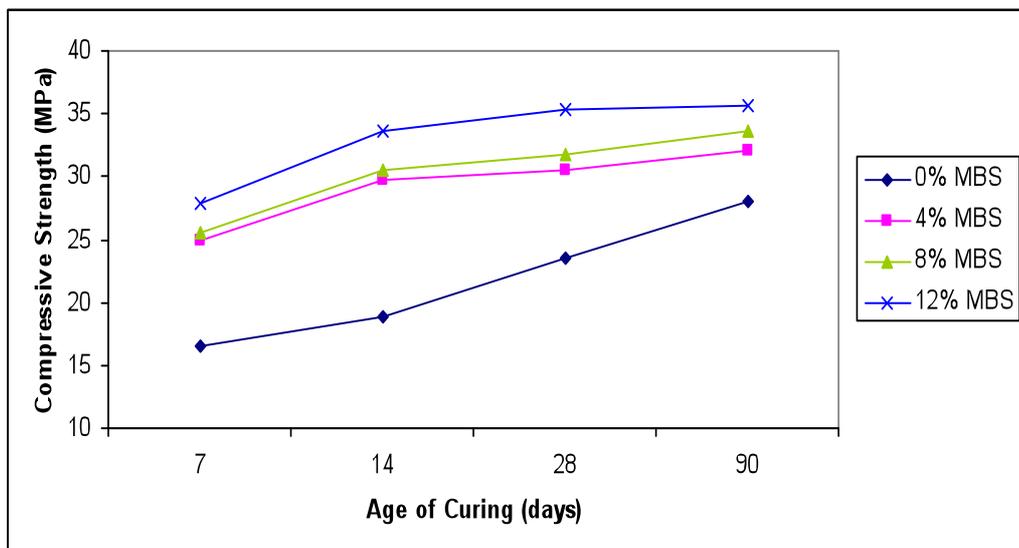


Figure 2 (c): Compressive Strength Development for MBS-RA concrete with 100% RA

7.0 WATER PERMEABILITY OF MBS-RA CONCRETE

Water permeability can be defined as a flow of water through a material which occurs due to difference in pressure [16]. For this study, GWT test was conducted to determine the water permeability of specimens. The results of water permeability were showed in Figure 3(a) – (c).

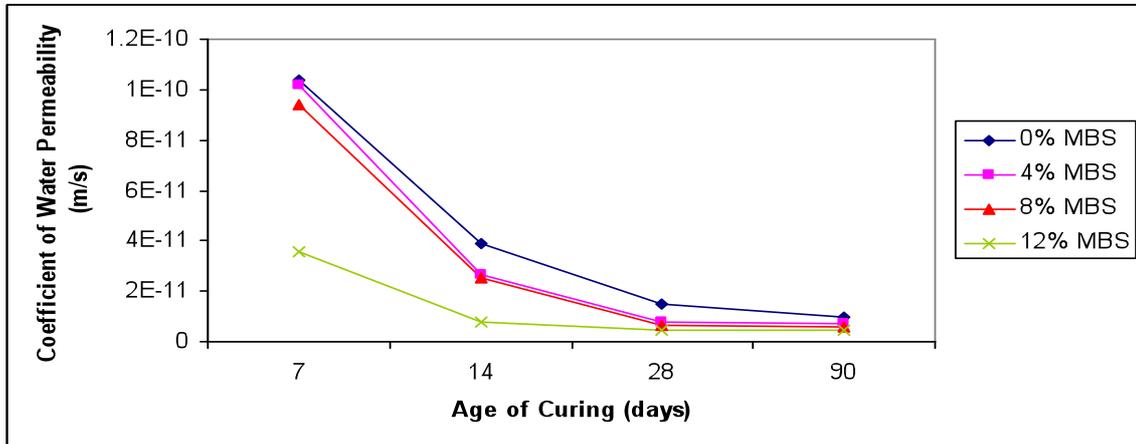


Figure 3(a): Coefficient of Water Permeability for MBS-RA Concrete with 0% RA

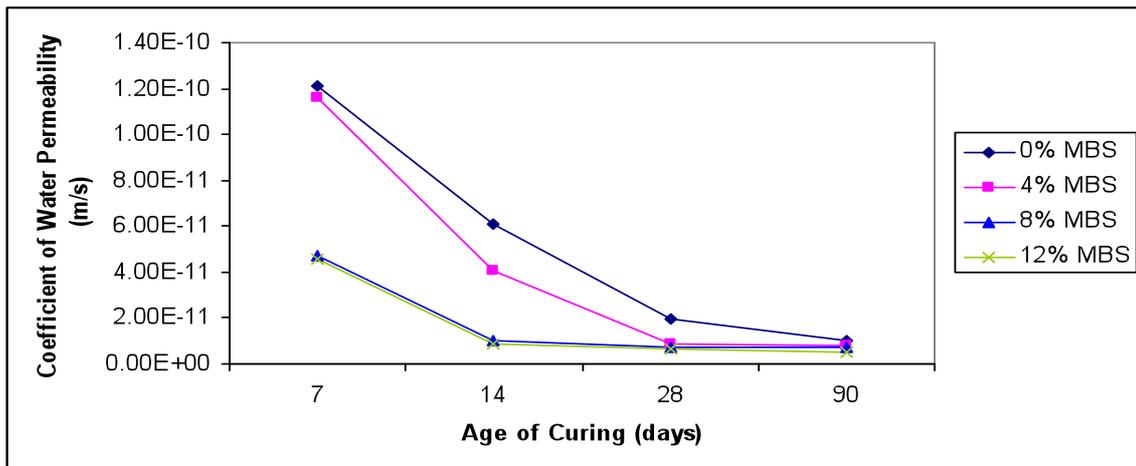


Figure 3(b): Coefficient of Water Permeability for MBS-RA Concrete with 50% RA

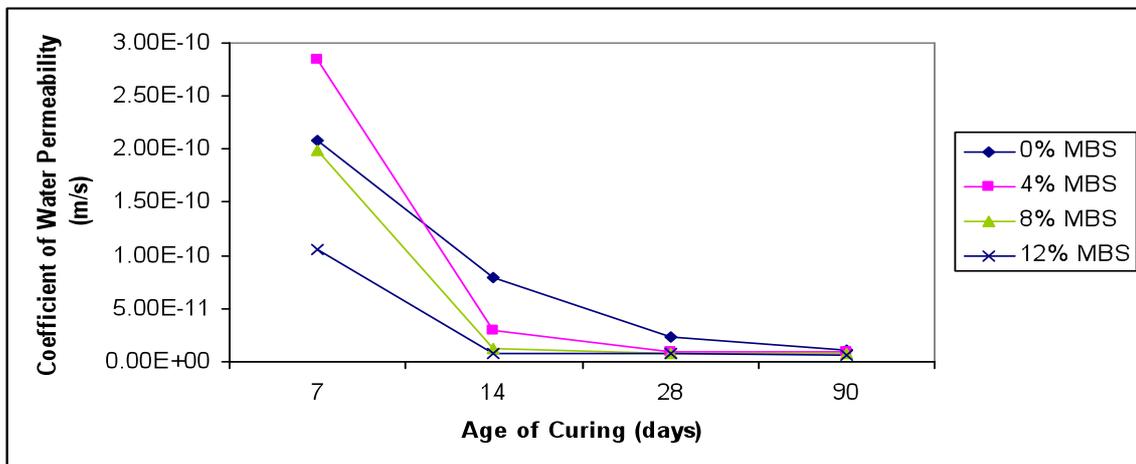


Figure 3(c): Coefficient of Water Permeability for MBS-RA Concrete with 100% RA

Figure 3 (a) shows the result for GWT test which is coefficient of water permeability for MBS concrete with 0% RA. For 7 days it showed that the coefficient is decreasing when MBS is been adding in concrete for various replacement percentage. At 7 days, the coefficient of water permeability is decreasing to 1.92%, 9.71% and 65.4% than that of 0% MBS concrete when 4%, 8% and 12% MBS were incorporated into concrete. Meanwhile for 28 days, when 4%, 8% and 12% MBS were used as cement replacement material, the coefficient of water permeability was decreased about 49.9%, 58.3% and 69.6% than the 0% MBS concrete. At 90 days, the coefficient of water permeability was decreased about 28.2%, 11.2% and 30% than the 0% MBS concrete when 4%, 8% and 12% MBS were used as cement replacement material.

Meanwhile Figure 3 (b) shows the coefficient of water permeability for MBS-RA concrete containing 50% RA versus age of curing. At 7 days, the coefficient of water permeability is decreased about 4.13%, 61.07% and 62.23% than that of 0% MBS when 4%, 8% and 12% of MBS is used as cement replacement material in concrete. Meanwhile at 28 days, the coefficient of water permeability is decreased about 55.96%, 62.32% and 68.38% than the corresponding 0% MBS when 4%, 8% and 12% of MBS is incorporated in concrete with 50% RA. At 90 days the coefficient of water permeability is decreased about 20%, 31.4% and 51.3% than that of 0% MBS when 4%, 8% and 12% of MBS is used as cement replacement material in concrete.

Lastly Figure 3 (c) shows the coefficient of water permeability for MBS-RA concrete containing 100% RA versus age of curing. At 7 days, the coefficient of water permeability was increased about 37.02% than that of 0% MBS when 4% of MBS was used in concrete. Meanwhile, the coefficient of water permeability was decreased about 4.33% and 49.04% than the corresponding 0% MBS when 8% and 12% of MBS were used as cement replacement material in concrete. At 28 days, the coefficient of water permeability was decreased about 60.25%, 67.17% and 66.92% than that of 0% MBS when 4%, 8% and 12% of MBS were incorporated in concrete with 100% RA. At 90 days, the coefficient of water permeability was decreased about 17.3%, 33.5% and 37.3% than that of 0% MBS when 4%, 8% and 12% of MBS were incorporated in concrete with 100% RA.

From these figures, it clearly showed that almost probably MBS has an ability to act as microfiller in concrete. This was due to pozzolanic reaction which had been occurred between SiO_2 from MBS with Ca(OH)_2 from cement hydration as that producing CSH gel. This gel has an ability to fill up the pores in concrete which will lead into low permeable concrete.

8.0 CORRELATION BETWEEN COMPRESSIVE STRENGTH AND WATER PERMEABILITY COEFFICIENT

Figure 4 provides a relationship between compressive strength and water permeability coefficient for various series of concrete. It can be seen from the figure that as the concrete compressive strength increases, the water permeability coefficient will decreases. This relationship pattern is similar to the findings by Khan and Lynsdale [15]. The pattern is fitted well with the RAC samples series. Meanwhile RAC with MBS 4%, MBS 8% and

MBS 12% developed a high relationship between compressive strength and water permeability coefficient. This figure also shows that MBS of 12% attained the highest compressive strength with the lowest water permeability coefficient.

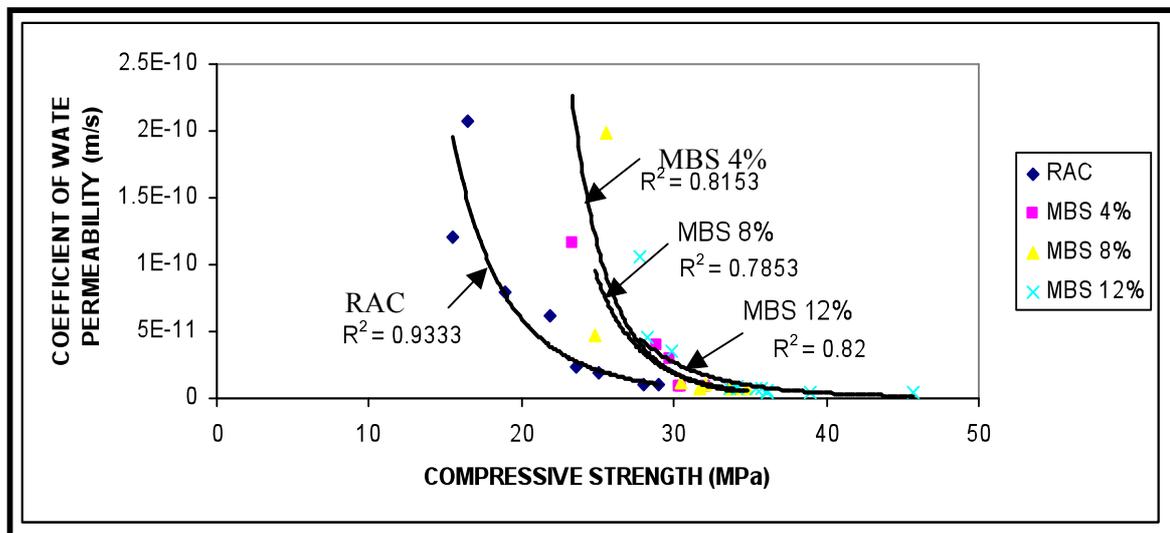


Figure 4 Relationships between Compressive Strength and Water Permeability Coefficient

9.0 CONCLUSIONS

The study has shown the potential usage of MBS generated from waste material for enhancing the concrete properties. It acts as a pozzolanic material that can improve the properties of the recycled aggregate concrete. The significant finding that can be highlighted from this research works are as followed:

1. The workability of concrete containing MBS is lower compared to normal concrete because MBS has higher water absorption properties probably resulted from bigger surface area.
2. RAC containing MBS performed higher compressive strength than that of RAC without it.
3. MBS be able to lower the water permeability of normal and recycled aggregate concrete. This is due to MBS functioning as micro-filler in the concrete.
4. There is high relationship exists between compressive strength and coefficient of water for various series of recycled aggregate concrete that contains MBS.
5. Micronised Biomass Silica (MBS) has an ability to perform as pozzolanic material that will enhance the characteristics of the normal concrete and also recycled aggregate concrete.

10.0 REFERENCES

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