MBS as a Potential Cement Replacement Material In Recycled Aggregate Concrete

Adnan, Suraya Hani[1]; Lee, Yee Loon [1], Abdul Rahman, Ismail [1], Mohd Saman, Hamidah [2], Soejoso, Mia Wimala [1]

Faculty of Civil and Environmental Engineering, UTHM, 86400, Batu Pahat, Johor[1]
Faculty of Civil Engineering, UiTM, 40450, Shah Alam, Selangor [2]

ABSTRACT

Recycled Aggregate Concrete (RAC) was known as concrete which used partly or fully waste material as coarse or fine aggregate. This concrete was identified to have a lower compressive strength than Normal Aggregate Concrete (NAC). As alternative, Micronised Biomass Silica (MBS) was applied as cement replacement material in concrete mixes. This is as an effort to increase the compressive strength of RAC. For this study, MBS was used at 0%, 4%, 8% and 12% was used as cement replacement material. Meanwhile, Recycled Aggregate (RA) from waste cube concrete was used to replace a normal aggregate as coarse aggregate at various percentages (0%, 25%, 50%, 75% and 100%). The results showed that compressive strength of the RAC at all ages were lower than control concrete. Also, it was found that RAC that contains MBS attained higher compressive strength than RAC with 0% MBS.

Keywords: Recycled Aggregate Concrete, Recycled Aggregate, Micronised Biomass Silica, Compressive Strength

1.0 INTRODUCTION

Recycled Aggregate Concrete or RAC, is a manufactured product which essentially consisting cement, partially or fully Recycled Aggregate (RA) and water. Many studies have been conducted to improve the performance of RAC. This is accordance to some of the findings which have been conducted by some researchers [1,2,3,4]. Most of them found the unsatisfactory results of RAC. Some of the studies have identified that RAC contained a weakness performance in compressive strength compared to that of Natural Aggregate Concrete (NAC) which containing natural aggregate in concrete mixes.

Topcu, I.B. [1] have found that compressive strength of RAC was decreased by 36.4% and 81.8 %, for 50% and 100% replacement of normal coarse aggregate by recycled aggregate in concrete mixes. Meanwhile Limbachiya, M.C. [2] have revealed that replacement of RA in concrete mixes is decrease by 5.4% and 13.5% for 50% and 100% replacement of normal coarse aggregate by recycled aggregate in concrete mixes. Also, Ridzuan, A.R.M. *et. al*, Poon, C.S. *et. al.*, Topcu, I.B. and Sengel, S.[3,4,5], have found that the compressive strength of RAC at 50% replacement was decreased by 5%, 6.52% and 15%, respectively. But, Ridzuan, A.R.M. *et al.* [3] have obtained increasing in compressive strength for 100% replacement of RA in concrete. He stated that grainy texture and flaky shape of RA were the reasons for higher compressive strength of RAC.

Pozzolan which is defined by ASTM C 618-93 is siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties [11]. It has been widely used as cement replacement material for improving the quality of concrete. Some researchers Khan, M.I. *et.al.*, Mahmud, H. *et.al.*, Ikpong, A.A. and Okpala, D.C.,[6,7,8] have conducted study on application of pozzolan like silica fume, fly ash and rice husk ash to improve the compressive strength of NAC. Khan *et. al.* [6] had revealed that silica fume have an ability to reduce the porosity and increased the strength at early age. Meanwhile, Mahmud, H. *et.al* [7] have revealed that application of fly ash as cement replacement material can improved the workability and strength of concrete. On the other hand, rice husk ash can improve the performance in compressive strength at later age [9].

Thus, the good performance which has shown by these pozzolan materials in NAC is led into application of pozzolan materials for improving RAC properties in compressive strength for this study. Micronised Biomass Silica (MBS) have been produced by using rotary furnace in Material Laboratory at Universiti Tun Hussein Onn Malaysia (UTHM) and was used as cement replacement material in RAC. Compressive strength development in RAC with MBS as cement replacement was observed and analyzed.

2.0 EXPERIMENTAL WORKS

2.1 MATERIAL SELECTION

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

2.2 MICRONISED BIOMASS SILICA (MBS)

In this study, Micronised Biomass Silica (MBS) which have been used as cement replacement material is produced when rice husk burnt into rotary furnace which has been located at Material Laboratory UTHM. This rotary furnace has 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 ^{o}C. Off white amorphous material is obtained after one (1) hour. Before that, rice husk is fed manually into the rotary furnace. Then, Jar Mill is used to produce finer biomass silica. After been grinding by Jar Mill for one (1) hour, the particle size of MBS is reduced from 48 µm to 25 µm. Figure 2.1 shows the Rotary Furnace which have been used in this study.

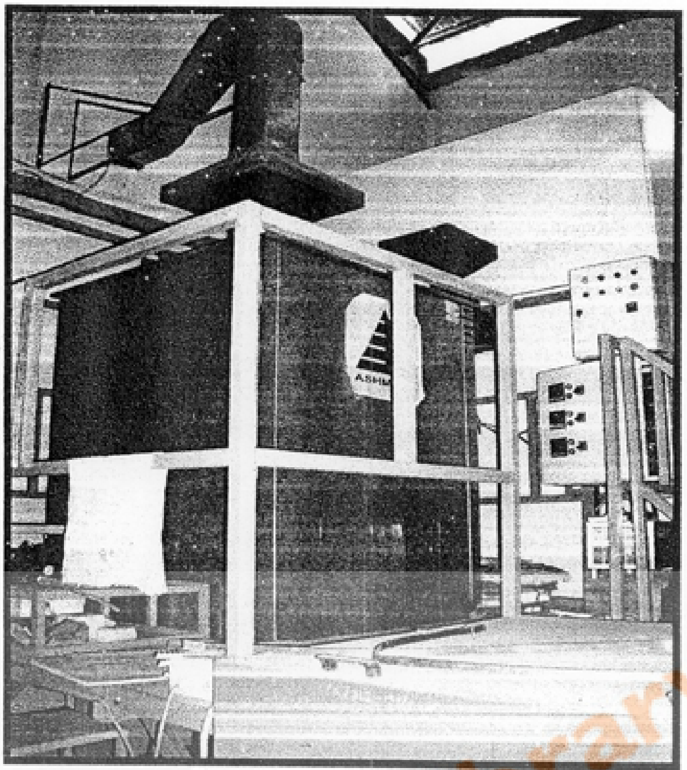


Figure 2.1 Rotary Furnace

2.3 CONCRETE MIXES

Twenty (20) concrete mixes were prepared in this study. Table 2.1 presents the concrete mixes proportions for various percentages of MBS as cement replacement material and various percentage of RA replacement as coarse aggregate. DOE method has been adopted as design mixture for concrete. The concrete mixes were denoted with M0, M4, M8 and M12 for 0%, 4%, 8% and 12% of MBS as cement replacement material in concrete mixes. Meanwhile RA00, RA025, RA050, RA075 and RA100 were notation for 0%, 25%, 50%, 75% and 100% of RA as coarse aggregate in concrete mixes, respectively. In this study, superplasticizer (SP) was used to improve the workability performance of concrete mixes. On the other hand, slump value is designed in range 60-180mm. Meanwhile, the target strength for concrete at 28 days is 25 MPa.

Mix	Cement (kg/m^3)	MBS (kg/m^3)	Water (kg/m^3)	Coarse Aggregate (kg/m^3)		Fine Aggregate (kg/m^3)	SP (ml)
				NA(kg/m^3)	RA(kg/m^3)		
M0RA00	450	0	225	823	0	892	4500
M0RA025	450	0	225	617.25	205.75	892	4500
M0RA050	450	0	225	411.5	411.5	892	4500
M0RA075	450	0	225	205.75	617.25	892	4500
M0RA100	450	0	225	0	823	892	4500
M4RA00	432	18	225	823	0	892	4500
M4RA025	432	18	225	617.25	205.75	892	4500
M4RA050	432	18	225	411.5	411.5	892	4500
M4RA075	432	18	225	205.75	617.25	892	4500
M4RA100	432	18	225	0	823	892	4500
M8RA00	414	36	225	823	0	892	4500

M8RA025	414	36	225	617.25	205.75	892	4500
M8RA050	414	36	225	411.5	411.5	892	4500
M8RA075	414	36	225	205.75	617.25	892	4500
M8RA100	414	36	225	0	823	892	4500
M12RA00	396	54	225	823	0	892	4500
M12RA025	396	54	225	617.25	205.75	892	4500
M12RA050	396	54	225	411.5	411.5	892	4500
M12RA075	396	54	225	205.75	617.25	892	4500
M12RA100	396	54	225	0	823	892	4500

* MBS: Micronised Biomass Silica
NA: Natural Aggregate
RA: Recycled Aggregate
SP: Superplasticizer

Table 2.1 Mix Proportions for Concrete Mixes

2.4 FRESH CONCRETE

In this study, slump value test was conducted to determine the workability of concrete mixes. This test was conducted accordance to BS 1881: Part 102: 1983.

2.5 HARDENED CONCRETE

To determine the compressive strength of concrete, compression machine was used in this study. Three (3) cube samples were prepared for determining the compressive strength and average values from three (3) readings were taken as compressive strength data.

3.0 RESULTS AND DISCUSSION

3.1 WORKABILITY

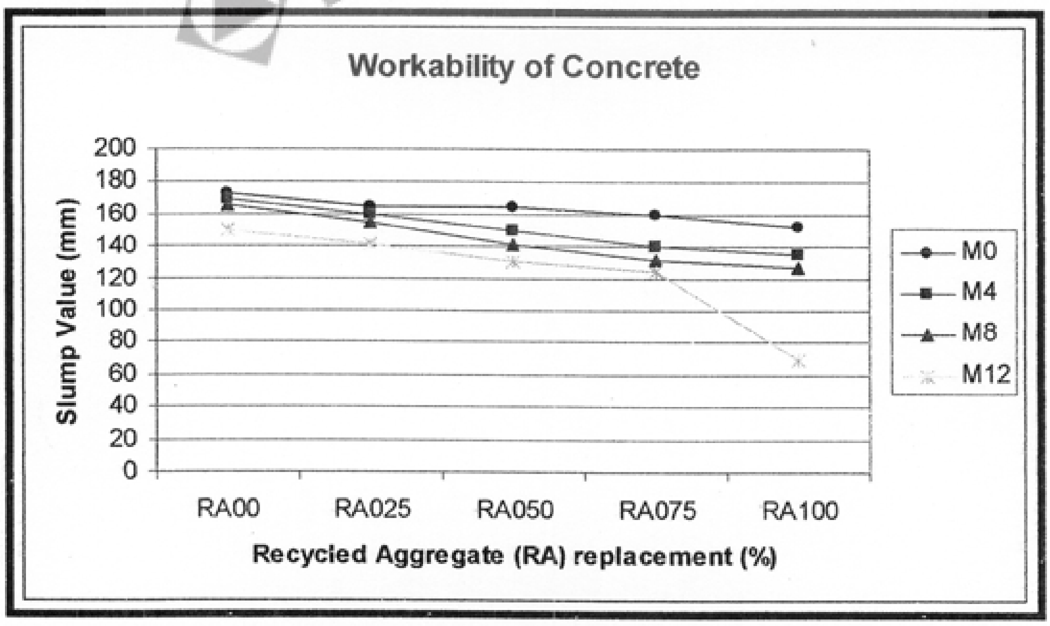


Figure 3.1 Workability of Concrete

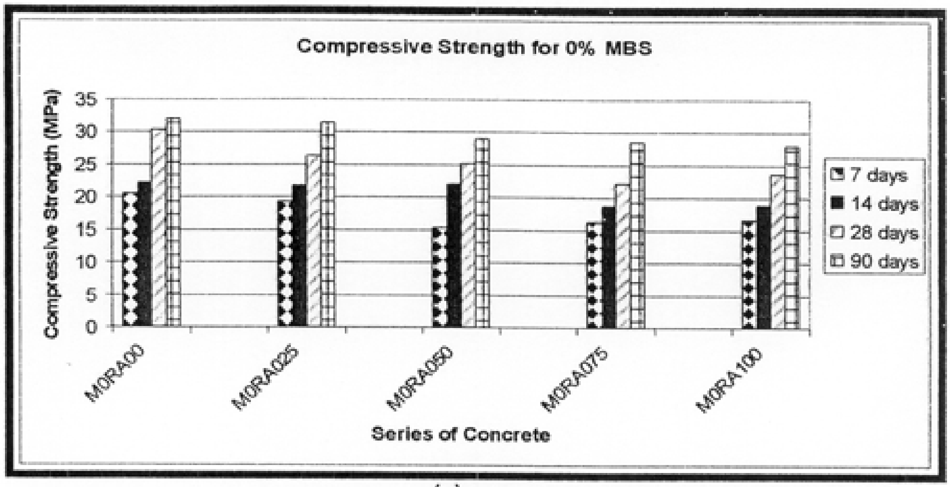
Slump value for various replacements of MBS and RA in concrete mixes is showed in Figure 3.1. This figure reveals the increase percentage replacement of RA in concrete mixes, resulting a decreasing in the slump values. RA which had a water absorption properties, influence to the decreasing value of slump in concrete mix. On the other hand, increasing percentage replacement content of MBS in concrete mix also gave an effect to the workability of concrete. It can be seen that when percentage of MBS is increasing, its slump value is decreasing. MBS which also had the water absorption characteristic influences to the decreasing in slump value of concrete mixes. Additionally, when these two (2) materials (RA and MBS) were combined and been used for producing concrete, the slump value of concrete mixtures was decreasing thoroughly. Although the slump value is decreasing, it is still in the range for designing the concrete with slump value of 60mm-180mm.

3.2 COMPRESSIVE STRENGTH

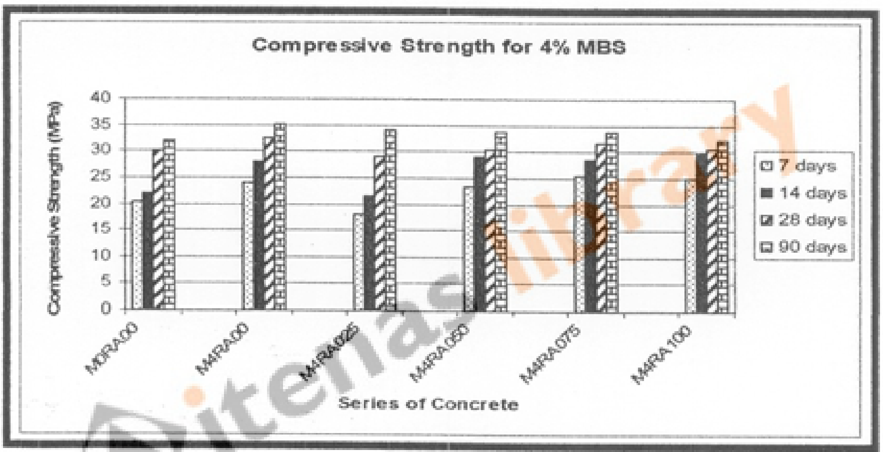
Table 3.1 presents the value for compressive strength for various percentage replacement of MBS and RA in concrete at 7, 14, 28 and 90 days. Meanwhile Figure 3.2, (a), (b), (c) and (d) shows the compressive strength result for various percentage of RA replacement with 0%, 4%, 8% and 12% MBS, respectively.

Series	MBS (%)	Compressive Strength (MPa)			
		7 days	14 days	28 days	90 days
M0RA00	0	20	22	30.2	31.9
M0RA025		19.2	21.7	26.2	31.3
M0RA050		15.5	21.9	25.1	29
M0RA075		16	18.6	22	28.5
M0RA100		16.5	18.9	23.6	28
M4RA00	4	24	28	32.4	35.1
M4RA025		18.1	21.6	29.1	34.1
M4RA050		23.3	28.9	30.4	33.9
M4RA075		26	28.4	31.6	33.7
M4RA100		25	29.7	30.5	32.1
M8RA00	8	25	32.1	37.5	39.6
M8RA025		19	23.5	32.3	36.7
M8RA050		24.8	32.1	33.9	34.8
M8RA075		21	23.7	32	33.8
M8RA100		25.6	30.5	31.7	33.7
M12RA00	12	30	34.1	39	45.7
M12RA025		26.7	33.3	34.3	39.3
M12RA050		28.2	34.1	36.1	36.1
M12RA075		23	28.3	33.9	34.2
M12RA100		27.8	33.6	35.4	36.1

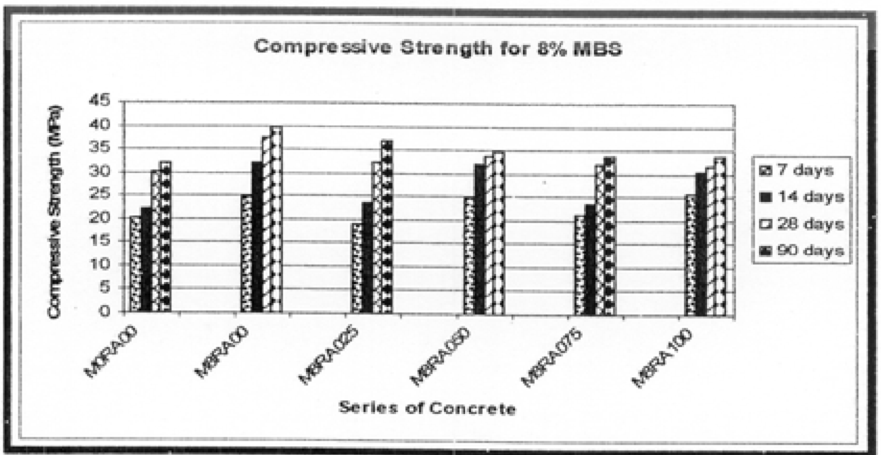
Table 3.1 Compressive Strength for Different Series of Concrete


Compressive Strength for 0% MBS
Compressive Strength (MPa)
35
30
25
20
15
10
5
0
7 days
14 days
28 days
90 days
M0RA00
M0RA025
M0RA050
M0RA075
M0RA100
Series of Concrete

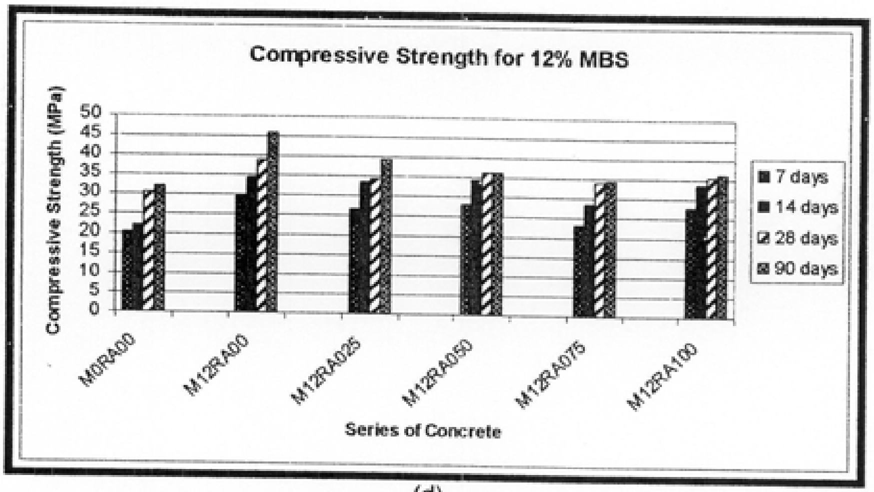
(a)


Compressive Strength for 4% MBS
Compressive Strength (MPa)
40
35
30
25
20
15
10
5
0
7 days
14 days
28 days
90 days
M0RA00
M4RA00
M4RA025
M4RA050
M4RA075
M4RA100
Series of Concrete

(b)


Compressive Strength for 8% MBS
Compressive Strength (MPa)
45
40
35
30
25
20
15
10
5
0
7 days
14 days
28 days
90 days
M0RA00
M8RA00
M8RA025
M8RA050
M8RA075
M8RA100
Series of Concrete

(c)



(d)

Figure 3.2 Compressive Strength of Concrete: (a) Concrete Containing 0% MBS (b) Concrete Containing 4% MBS (c) Concrete Containing 8% MBS (d) Concrete Containing 12% MBS

Figure 3.2 (a) shows the compressive strength result for concrete with 0% MBS. Control concrete that had 0% percentage RA and 0% percentage MBS (M0RA00) obtained highest in compressive strength compared to other mixture of concrete for all age of curing. In addition, this figure reveal that concrete with RA as coarse aggregate replacement obtained lower compressive strength than control concrete. The factor which has been identified that contributes into this matter is the remaining mortar in RA. Remaining mortar in RA absorbed the water in concrete mixture and led into interruption in hydration process. On the other hand, [10] has highlighted the rounder shape and smoother texture of RA is the reason for the matters. Meanwhile, [3] have stated that type of crusher also played a main role on creating a shape for RA.

Compressive strength development of concrete with 4% MBS as cement replacement material is showed in Figure 3.2 (b). At 90 days, it was recognized that M4RA00 (0% RA and 4% MBS) attained highest in compressive strength than other mixture of concrete. Compressive strength of M4RA00 is increased to 10% than M0RA00. Moreover, at 90 days, concrete with RA as coarse aggregate with MBS incorporation obtained higher in compressive strength than control concrete (M0RA00). Meanwhile, concrete with 25%, 50%, 75% and 100% RA replacement, its compressive strength decreased to 2.85 %, 3%, 4% and 9% than M4RA00. Thus, based on these results, it can show that MBS can be reacting as filler and pozzolanic material in concrete mixes.

Figure 3.2 (c) shows that with incorporation of 8% MBS in concrete, the compressive strength is increasing 24% than that of control concrete at 90 days. For concrete with 25%, 50%, 75% and 100% RA replacement, its compressive strength is decreased to 7 %, 12 %, 15 % and 15% than M8RA00. Also, 8% MBS in concrete increasing the performance of concrete with RA in compressive strength properties compared to control concrete. This is because; MBS as cement replacement material contributes into strength development of concrete.

Finally, incorporation of 12% MBS in concrete as shown in Figure 3.2 (d), it attained highest in compressive strength than control concrete at all ages. At 90 days, 12% of MBS has increased about 43% of compressive strength compared to that of control concrete. Concrete with 25%, 50%, 75% and 100% RA replacement, its compressive strength is decreased to 14 %, 21 %, 25 % and 21 % than that of M12RA00. It can be seen when concrete with MBS obtained higher in compressive strength than that of control concrete. Also, incorporation of MBS in RAC has led into better strength development. This is because, all RAC with MBS replacement (4%, 8% and

12%) obtained higher in compressive strength than that of control concrete. Incorporation of MBS in concrete has lead into pozzolanic reaction which started at early ages of concrete. Pozzolanic reaction between SiO_2 from MBS and $Ca(OH)_2$ from hydration process has occurred and led into great strength development in concrete. So, based on these results, it was identified that MBS has a potential to become as cement replacement material for improving the compressive strength of RAC.

4.0 CONCLUSIONS

From this study, some conclusions have been drawn and been listed below:

i) Workability of RAC is decreasing when RA replacement is increasing.
ii) Workability of concrete with incorporation of MBS is decreasing when MBS replacement is increasing.
iii) With addition of superplastizer (SP), concrete mixture which combining RA and MBS have obtained a slump value in range of its design mix, 60-180mm.
iv) RAC obtained lower compressive strength than control concrete.
v) MBS incorporation in RAC has improved its compressive strength development.
vi) MBS has a potential to becoming as cement replacement material for improving the compressive strength of RAC.

5.0 REFERENCE

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