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Compressive and Tensile Capacity of Recycled Aggregate Concrete (RAC) with Glass as Supplement Material

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Abstract: The amount of construction waste is increased significantly over the years due to reconstruction and the demolition of old buildings. One of the major challenges of our present society is to protect the environment by recycling the existing construction waste. This study concerned on two types of variable in the production of concrete which are the utilization of coarse recycled aggregate and utilization of different supplement ratio of fine glass wastes to cement. To evaluate the viability of this study, an experimental work was performed in order to monitor the mechanical behavior of such concrete. The compression and splitting tensile strength of concrete were determined on this study. From the result, it is conclude that the utilization of recycled aggregate does not much affect in the uniaxial compressive strength and splitting tensile strength of concrete, for replacement ratio up to 25 %. However, the utilization of fine glass as supplement material to cement is increase the uniaxial compressive and splitting tensile strength of concrete, for supplement ratio up to 5 %. Thus, it can be stated that the optimum concrete mixture is the mixture of 25 % recycled aggregate and 5% glass.

Keywords: Recycled aggregate, natural aggregate, glass wastes, uniaxial compressive strength, splitting tensile strength

1. Introduction

Nowadays, the cost of materials for building house such as natural aggregates are getting more and more expensive due to the amount of the aggregates are become lesser. This will lead to increase the price of the buildings like house or office shop lots. Not only this, the construction demolition waste also causing the environment problem to the landfill due to the construction demolition waste is non-degradable waste. As time goes by, the landfills will be accumulated with the construction demolition waste.

Thus, it is necessary for us to consider the application of recycled aggregate (RA) in construction and demolition constitution. As mentioned in the Ninth Malaysian Plan, the government encouraged the use of RA and reuse material for construction industry. Although the use of RA is not a common practice in the Malaysia's construction industry nowadays because there is no depletion of natural aggregate, it is helps in reducing the amount of construction debris produced and more economical [1].

Recycled Aggregate (RA), as can be seen in Fig. 1, is the aggregate that has been recycled from the existing concrete waste. The process of recycling aggregates are involves breaking, removing, and crushing the existing concrete structures into a material with specified size and quality. Generally, RA has the properties of high water absorption, low specific gravity, low density and high porosity than those of natural aggregates [2,3]. The grading curves for RA are continuous and they have similar fineness modulus for equivalent fraction [4].

Many researchers have proven that concrete demolition waste to be an excellent source of aggregates for new concrete production [2]. There are many studies also proven that concrete made with coarse recycled aggregates have similar mechanical properties to those of conventional concretes [5]. Recycled aggregate concrete (RAC) is the concrete made from recycled aggregate from concrete waste. It was found that the workability of fresh RAC decrease with an increase of recycled aggregate due to water absorption of mortar adhered to recycled aggregate. The strength of RAC is reported to be less by about 10% compared to normal aggregate concrete (NAC) [6].

Fig.1 Recycled aggregate [7].

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This study concerns on two types of variable in the production of concrete. Firstly, the utilization of coarse recycled aggregate to partially or fully replace the natural aggregate and secondly, the utilization of different supplement ratio of nako glass to cement. The cylinder specimens (300mm x 150mm diameter) were used for the uni-axial compressive strength test and the splitting tensile strength test.

2. Experimental Work

2.1 Material Used

In this study, materials used are Ordinary Portland cement (OPC), sand, natural gravel with maximum size of 20 mm and superplasticizer. For the RCA, it was prepared by crushing the waste cubes dumped at the outside of Material Laboratory of Universiti Tun Hussein Onn Malaysia (UTHM). The waste cubes were randomly collected without considering the age of the cube. On the other hand, for glass as supplement material, the waste nako glass was collected from the landfill.

2.2 Concrete mixes

Twelve concrete mixes were prepared based on DOE design mix method. Table 1 illustrates the mix proportions for each series of concrete mixture. The target strength of the concrete at 28 days is 25MPa, while its water-cement ratio is 0.5 and the slump value is designed to has value around 60mm to 180mm. For each concrete mixture, three 150mm by 300mm concrete cylindrical specimens were prepared where an average reading was taken as data for interpretation. The concrete cylindrical specimens were cured in water until the testing day.

2.3 Testing of fresh concrete

Slump test is applied to determine the workability of the fresh concrete. The test was conducted in accordance to BS 1881: Part 102: 1983.

2.4 Testing of hardened concrete

Performance of hardened concrete was assessed using two tests which are uniaxial compressive strength and splitting tensile test. The compressive strength test was conducted according to ASTM C39, while the splitting tensile test was carried out according to ASTM C496.

3. Results and Discussion

3.1 Workability

Table 2 shows that the control concrete has highest slump value and the RA100-G10 has the lowest slump value. CCAA [6] reported that the workability of fresh concrete with RA decreased as an increased in the amount of RA used due to water absorption of mortar adhered to aggregate. The additional material in this study like glass has also a water absorption or water reducing property. However, the slump test shows that the RAC have value in the range of 100mm to 170mm, which is suitable for used of concrete pump car to travel the concrete.

Table 1 Mix proportions for concrete mixture.

Concrete Series	Cement (kg/m^3)	Coarse Aggregate		FA (kg/m^3)	Water (kg/m^3)	G (kg/m^3)
		NA (kg/m^3)	RA (kg/m^3)			
Control Concrete	450	780.6	0	692.3	225	0
RA25	450	585.5	195.2	692.3	225	0
RA50	450	390.3	390.3	692.3	225	0
RA100	450	0	780.6	225	0	0
G5	450	780.6	0	692.3	225	22.5
RA25- G5	450	585.5	195.2	692.3	225	22.5
RA50-G5	450	585.5	195.2	692.3	225	22.5
RA100-G5	450	585.5	195.2	692.3	225	22.5
G10	450	780.6	0	692.3	225	45
RA25-G10	450	585.5	195.2	692.3	225	45
RA50- G10	450	390.3	390.3	692.3	225	45
RA100- G10	450	390.3	390.3	692.3	225	45

Note : RA = Recycled aggregate content
NA = Natural aggregate content
G = Glass conten

Table 2 The result of slump test.

Concrete Series	Slump Height (mm)
Control Concrete	142
RA25	138
RA50	136
RA100	125
G5	133
RA25- G5	125
RA50-G5	125
RA100-G5	118
G10	123
RA25-G10	125
RA50- G10	118
RA100- G10	113

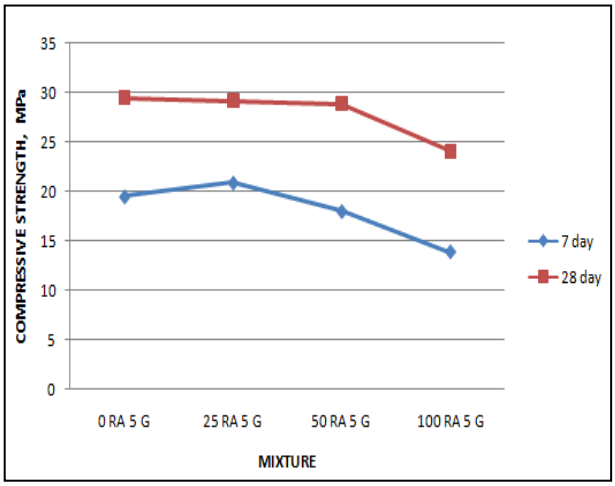

Fig. 2 Compressive strength of concrete series without containing glass at age of 7 days and 28 days.

3.2 Uniaxial-compression test

Fig. 2 to Fig. 4 show the compressive strength result for concrete series without containing glass, compressive strength result for concrete series with 5% glass and compressive strength result for concrete series with 10% glass.

By observing Fig. 2, Fig. 3 and Fig. 4, as the RA replacement ratio was increased, the concrete strength significantly decreases. This situation was caused by the mortar adhered to the surface of aggregate, thus, weakened the bonding strength between aggregate and cement. Previous researches have stated that the addition of RA to concrete mixture will able to reduce the strength by 10% when compared to original concrete [8, 9].

In this study, glass was also used as the supplement material to cement. By comparing Fig. 2, Fig. 3 and Fig. 4, the 5% supplement ratio of glass on the RAC was increased the compression strength of concrete. In addition, the addition of 5% of glass in concrete mixture was able to increase the concrete strength by 11.06% to 24.56% when it was compared to concrete series without containing glass in concrete. The increment of strength may due to high strength of glass particle and smaller grading size of fine glass compared to sand. The small particle of fine glass was filled up the void in the concrete, thus, increase the concrete strength. However, an addition of 10% of glass initially presenting with increased in the concrete strength about 7.2% with 0% of RA replacement ratio. However, it was decreased the concrete strength about 8.57% to 24.88% with 25%, 50 % and 100 % of RA replacement ratio.

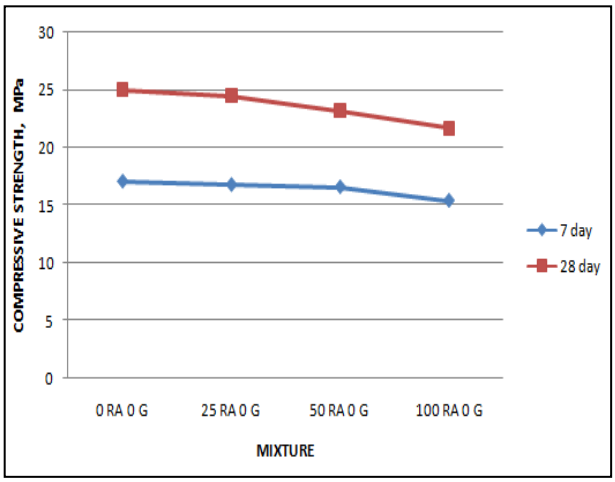

Fig. 3 Compressive strength of concrete series with 5% glass at age of 7 days and 28 days.

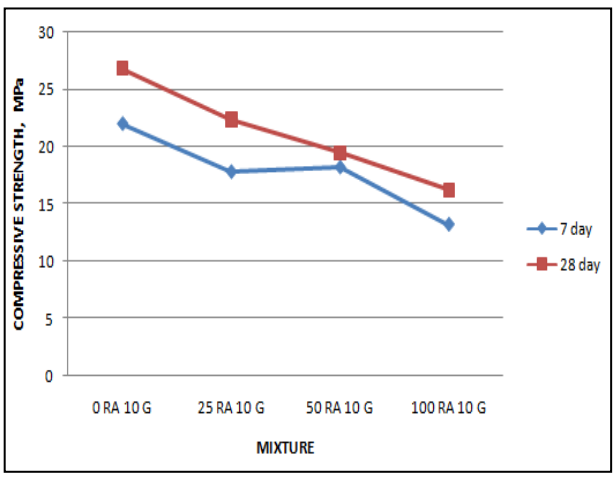

Fig. 4 Compressive strength of concrete series with 10% glass at age of 7 days and 28 days.

3.3 Tensile splitting test

Tensile strength in this study was measured by using the splitting tensile test procedure according to ASTM C496. The results of the findings for tensile strength values of the specimen for 7 days and 28 days can be referred in Table 3.

According to Table 3, the 25 % of RA replacement ratio in concrete mixture has affected the tensile strength, with increment of strength by 9.14% from 3.5MPa to 3.82MPa on the age of 28 days. However, when 50 % of RA replacement ratio was used in the concrete mixture, the tensile strength was decreased by 1.14% from 3.5MPa to 3.46MPa at 28 days. The tensile for concrete mixes with 100 % of RA replacement show significant decreases by 8.57% from 3.50MPa to 3.20MPa.

On the other hand, when 5% of glass was added to the concrete mixture, the tensile strength was increased from 0.5% to 8.09% at the age of 28 days compared to concrete mixes without containing glass. The increases of strength, same as compressive strength, may due to high strength of glass particle and smaller grading size of fine glass compared to sand. An increased of small particle like fine glass was filled up the void in the concrete, thus, the micro structural particle of concrete was close packed. Hence, tensile strength was increased. However, an addition of 10% of glass was decreased the tensile strength. The reduction of tensile strength was caused by high amount of smaller particle in the mixture, thus, the bonding between the cement and aggregate is very poor.

Table 3 The tensile strength result at age of 7 days and 28 days.

Concrete Series	Tensile Strength, MPa	
	7 days	28 days
Control Concrete	2.32	3.50
RA25	2.64	3.82
RA50	2.29	3.46
RA100	2.14	3.20
G5	2.56	3.55
RA25- G5	2.80	3.84
RA50-G5	2.67	3.75
RA100-G5	2.53	3.40
G10	2.51	3.03
RA25-G10	2.43	2.98
RA50- G10	2.47	2.96
RA100- G10	2.13	2.88

4. Conclusion

From this study, it can be concluded that:

i. The workability of RAC obtained from the slump test showed that the fresh RAC was within the acceptable range, proving that the high water absorption rate of RA does not noticeably affect the workability of RAC, if the surface dried saturated recycled aggregate was used.

ii. The result of compressive strength shows that the strength of NA mix is much higher than any RAC mixtures. From the comparison of compressive strength between the mixtures, the control concrete has a highest compressive strength and then followed by RA25, RA50 and RA100 at age of 28 days. However, the addition of 5% of glass is increased the compressive strength up to 11% until 24.5%. In contrast, an addition of 10% of fine glass is decreased the compressive strength.

iii. The result of tensile strength for 25% of coarse recycled aggregate replacement is higher than other mixtures of recycled aggregate concrete. The RA25 has highest tensile strength and followed by control concrete, RA50 and RA100 at the age of 28 days. Besides that, an addition of 5% of fine glass is increased the tensile strength up to 8%. However, an addition of 10% of fine glass is decreased the tensile strength.

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