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INFLUENCE OF RECYCLED AGGREGATE ON STRENGTH OF MORTAR WITH DIFFERENT WATER-CEMENT RATIO

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ABSTRACT
This Study is intending to provide an understanding on the influence of recycled aggregate on strength of mortar with different water cement-ratio; the use recycled aggregate can reduce the strength of mortar up to a certain percentage, which can lead to a reduction of up to 40% in compressive strength and bending strength. To reduce the usage of Natural aggregate, the recycled aggregate can be used as replacement material. In this study, water cement-ratio is adjusted three times to observe the influence it has on the strength of recycled mortar. The rate of recycled aggregate that been used to replace the natural aggregate (the river sand) was 0%, 10%, 20%, 30%, and 40% with different water cement-ratio of 0.5, 0.55 and 0.6. Also the rate of fly ash that has been used to replace the cement to make the recycled mortar was 10%, 20%, 30%, and 40% with different water cement ratio of 0.5, 0.55 and 0.6. Fly ash is also used in the mixtures in moderation as a replacement for cement. In this study, the experiment tested out the bending strengths and the compressive strengths of various specimens over certain duration of days.

KEYWORDS: recycled aggregate; recycled mortar; water cement-ratio; fly ash; compressive strength.

INTRODUCTION
In developed countries, the demand use of Natural aggregate for new buildings and infrastructure has increased for the last century, and the best solution for this pro is to use recycled aggregate as replacement of natural aggregate. The advantage use of recycled aggregate is as follows; (1) reduces the number of pure aggregates to be used (2) minimize the cost (3) creates more employment opportunities in recycling industries. After old buildings being destroyed, the removed product is usually considered as worthless and reuse as destroying waste (McNeil, 2013). (Hanžič H, 2008), investigated mortars specimens absorb more water and therefore they make the resulting mortar more consistent. (Zhao, 2015), Studied Influence of fine recycled concrete aggregates on the properties of mortars using particle size smaller than 5mm the results showed that the slump of mortars containing dried FRCA is always larger than that of mortars containing saturated FRCA. (Neno, 2013) Study three mortars using fine recycled aggregate concrete with different replacement ratios 20%, 50%, 100%. (Kim, 2014) observed that an increase in w/c ratio of cement mortar from 0.45 to 0.6, porosity went 150% and compressive has reduced to 75.6%. (Živica, 2009) Study the influence of low w/c on the pore structure and compressive strength of the cement paste Fineness modulus of sand also influences the w/c ratio of the mortar. (Singh, 2015) , Observed role of water cement-ratio on the strength development of cement mortar using empirical equation the result on compressive strength of cement mortar decreases with an increase of w/c ratio. (Hansen, 1983), Investigated the water/cement ratio of the original concrete influences the amount of adhered mortar to original aggregates. The purpose of this research paper is to observe the influence of recycled aggregate on the strength of mortar with different water cement-ratio testing on the compressive strength and flexural of the strength of recycled mortar.

EXPERIMENT

Through this Study it was used different proportions of recycled aggregate and fly ash to replace the natural aggregate (the river sand) and cements respectively to make the specimens of recycled mortar.

Materials:

The materials used to make the mortars mould (fine recycled aggregate, river sand, Portland cement; pc 32.5; GB175-2007 GB6566-2010, Grade 32.5, Fly ash and tap water.)The recycled fine aggregate that has used for this experiment it is from the abandoned concrete specimen which was in the laboratory. Crushed and screened out the recycled fine aggregate from previous abandoned concrete specimen. In the preparation process, crushed the big pieces into small pieces, then use it screening machine to screen the particles. Size of this recycled fine aggregate that has been needed to use for this study is 0.16mm and 5mm. and the water absorption of this recycled aggregate is 5%, the sample pictures are shown in (Fig.1a, b, c and d).The particle diameter of river sand is 0.16mm and 0.5mm. The mould size is 40×40×160mm.

Fig.1 a. Recycled fine aggregate

Fig.1 b. natural aggregate

Figure.1 c. Cement


Figure.1 d. Fly ash

Mix proportion.

The design mix proportion is in of terms of ratios of cement, sand and water. The study have used three different mix proportion of C: S: W =1:3:0.5, 1:3:0.55 and 1:3:0.6. First the study use mix proportion of 1:3:0.5 then changed the mix proportion into 1:3:0.55 and 1:3:0.6 due to high water absorption of recycled aggregate. The mixed proportion is divided into six groups. First three groups use w/c of 0.5, 0.55 and 0.6 respectively and each group has sub groups with replacement rate of recycled aggregate of 0%, 10%, 20%, 30% and 40%. For these first three groups, didn't use any fly ash replacement rate. For the last three groups have similar w/c ratio as the first three groups 0.5, 0.55, and 0.6. But for these last three groups it has been used 30% of recycled aggregate to replace natural aggregate(river sand), and also used 10%, 20%, 30% and 40% of fly ash to replace the cement. The experiment is made of 27 moulds and each mould has 3 specimens. The total test for this study is 81 specimens.

The following tables are different mix proportions of each group.

Table 1 mix proportion for group A with W/C of 0.5

Group	Sub-Group	Cement (g)	Sand (g)	Water (g)	RA(%rate)	RA (g)
A	A1	2000	6000	1000	0	0
	A2	2000	5400	1030	10	600
	A3	2000	4800	1060	20	1200
	A4	2000	4200	1090	30	1800
	A5	2000	3600	1120	40	2400

Table 2 mix proportion for group B with W/C of 0.55

Group	Sub-Group	Cement (g)	Sand (g)	Water (g)	RA(%rate)	RA (g)
	B1	2000	6000	1100	0	0
	B2	2000	5400	1130	10	600
B	B3	2000	4800	1160	20	1200
	B4	2000	4200	1190	30	1800
	B5	2000	3600	1220	40	2400

Table 3 mix proportion for group C with W/C of 0.6

Group	Sub-Group	Cement (g)	Sand (g)	Water (g)	RA(%rate)	RA (g)
	C1	2000	6000	1200	0	0
	C2	2000	5400	1230	10	600
C	C3	2000	4800	1260	20	1200
	C4	2000	4200	1290	30	1800
	C5	2000	3600	1320	40	2400

Casting process

According to each mix proportion and replacement ratio, it was weighted the cement, fly ash, recycled fine aggregate, natural aggregate (river sand) and water to make the mixture. After the prepared of all raw materials it started to mix them together. First it was started to mix the mixture of the first group according to its mix proportion design. Put the natural aggregate (river sand) first then cement and water into the mixing pool and then mixed them uniformly until it was completely mixed together. The mixing process was quick and uniform.

After mixing the mixture uniformly it was put them into the moulds, and then put them on the vibrating machine to remove voids in the mortar. For this process the time for each vibration is 60s, after finishing the vibration marked the moulds according to their mix proportion and then put them into the curing room. The condition of the curing room the temperature is 20°C±2°C and relative humidity is above

Figure.2: Casting specimens

Testing

In order to measure the bending strength and compressive strength of mortar strength it must first refer to the procedure of mortar strength experiment. For each mix proportion it was measured three modules that have three specimens. Since there are three specimens in each mould, it will be three bending strengths. After measuring the bending strength of the three specimens in each mould, the study used to get two separate pieces from each specimen. Then measure the compressive strength of the two separate pieces from each specimen; which are a total of six from each mould.

RESULT ANALYSIS AND DISCUSSION

The data that have found from the experiments of the bending strength and compressive strength are analyzed after 7 days, 14 days and 28 days. For each of the strength experiments, the result shows the

influence of recycled aggregate on strength of mortar based on of the water cement ratio. With the results from these two experiment tests, it can observe the influence of recycled aggregate and water cement ratio on the strength of recycled mortar.
Bending Strength

1. Influences of Fine recycle aggregate

In figure 3; it can see that the specimens gain the bending strength after 7 days, and then go higher after 14 days and 28 days. This shows that the specimen gets stronger, the more given curing time. The highest bending strength in this test is in mixture A1, since there is no recycled aggregate in this mixture, in the other hand, A2, A3, A4, A5, were used (10%, 20%, 30% and 40%) of recycled aggregate as a substitute of natural aggregate respectively; therefore, this test indicates that the higher percentage of recycled aggregate used the lower bending strength it gets, which means that bending strength decreases with the increase of the percentage of recycle aggregate. If we replace natural aggregate with recycled aggregate, the property of recycled aggregate must influence the bending strength. Thus we can say that the small crack in the recycled aggregate is the source of the decrease of the bending strength. And if we use more recycled aggregate the bending strength will decrease more. Also In figure 4; we can see that the highest bending strength test is in mixture B1, since there is no any substitute of recycled aggregate in this mixture, in the other hand, B2, B3, B4, B5; were used (10%, 20%, 30% and 40%) of recycled aggregate as a substitute of natural aggregate respectively. This indicates that the increase of recycled aggregate the bending strength decreases.

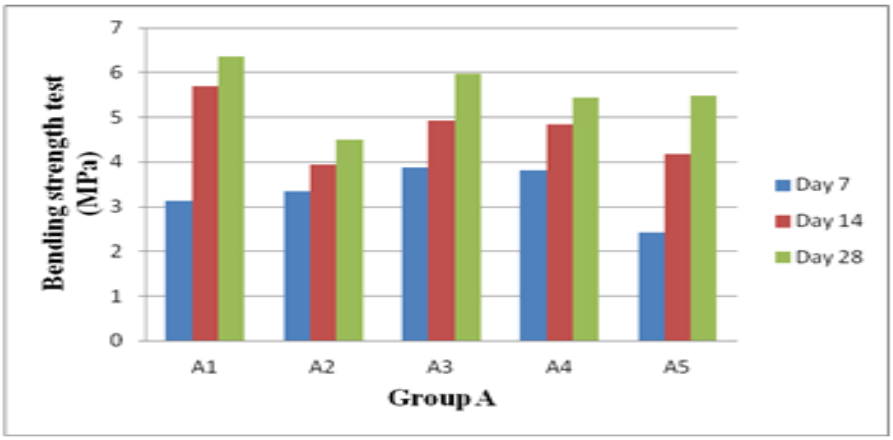

Fig 3: bending strength results in group A with W/C of 0.5

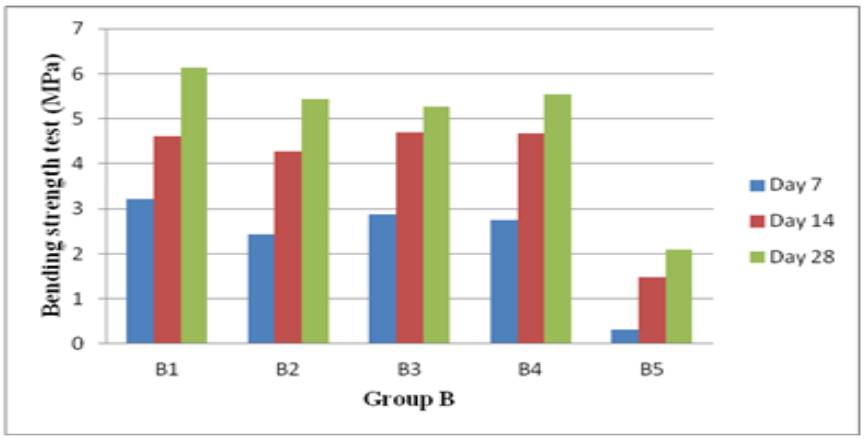

Fig4: bending strength test in group B with w/c of 0.55

Influence of water cement ratio

With the increase of water cement ratio the bending strength decreases. For example if we compare figure 3 which has water cement ratio of 0.5 and figure 5 which has water cement ratio of 0.55; the bending strength

is high in figure 5 than in figure 6 . So this shows that with the increase of w/c ratio, the bending strength decreases, but the decrease extent is different. The bending strength is higher at 28days when W/C ratio is 0.5, then when W/C ratio is 0.55; this indicates that the increase of w/c ratio leads the decrease of the bending strength.

In figure 5, we can see that the bending strength increases with the increase of recycled aggregate. And the highest bending strength at 28 days is in mixture C5 which has 40% of recycled aggregate. And the lowest bending strength at 28 days is in mixture C2 which has 10% of RA. This shows that with increase of both water cement ratio and recycled aggregate can influence the bending strength of the specimen.

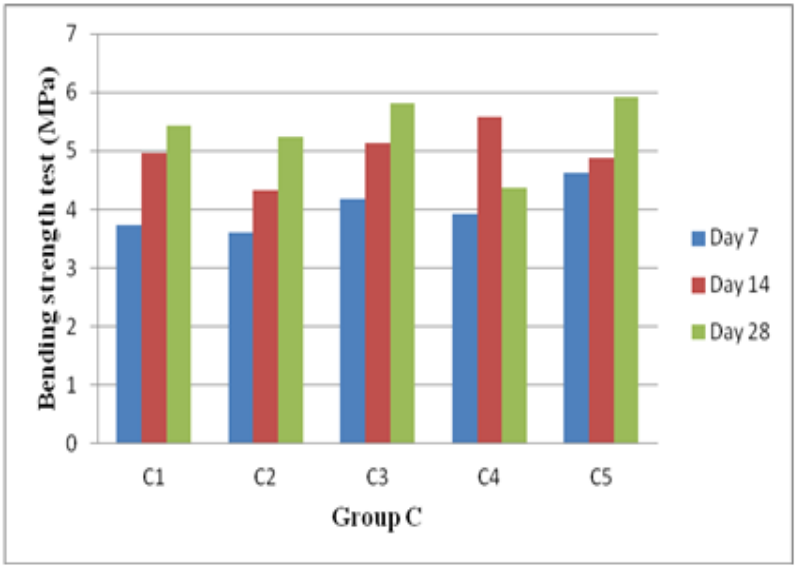

Fig 5: bending strength test in group C with W/C of 0.6

Compressive Strength

(1) Influence of recycled aggregate

In figure 6; we can see that the specimens gain the compressive strength after 7days, and then go higher after 14days and 28days. This shows that the specimen gets stronger, the more we give more curing time. The highest compressive strength in this test is in mixture A1, since there is no recycled aggregate in this mixture, on the other hand, A2, A3, A4, A5, we use (10%, 20%, 30% and 40%) of recycled aggregate as a substitute of natural aggregate respectively; therefore, this test indicates that the higher percentage of recycled aggregate we use the lower compressive strength we get, which means the compressive strength decreases with the increase of the percentage of recycle aggregate. If we replace natural aggregate with recycled aggregate, the property of recycled aggregate must influence the compressive strength. Thus we can say that the small crack in the recycled aggregate is the source of the decrease of the compressive strength. And if we use more recycled aggregate the compressive strength will decrease more. Also in figure 7 we can say that the compressive strength decreases with the increase of recycled aggregate. As we can see that the highest compressive strength is in mixture B1; which we used 0% of recycled aggregate while B2, B3, B4 and B5 we used 10%, 20%, 30% and 40% of recycled aggregate as a substitute of natural aggregate respectively. B5 which has 40% of recycled aggregate has the lowest compressive strength at 7days, 14days and 28days. We can say the recycled aggregate has big influence on the compressive strength of the specimen.

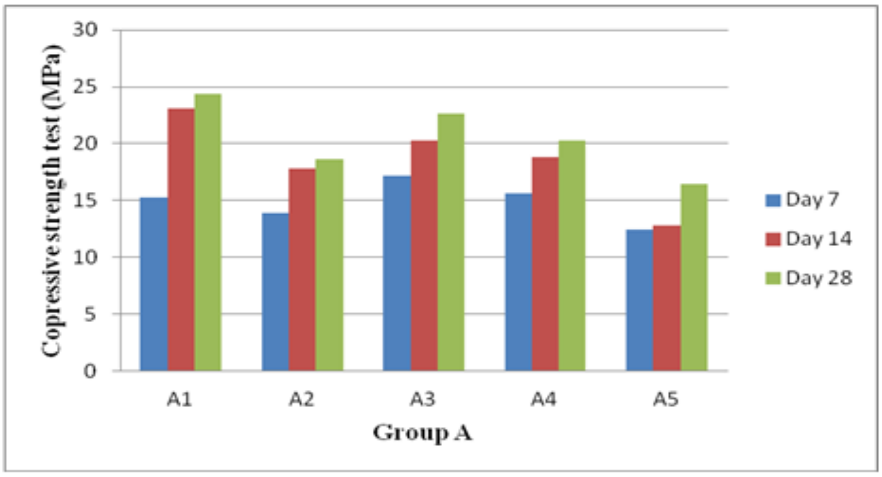

Fig.6 the results of compressive strength test in group A with w/c of 0.5

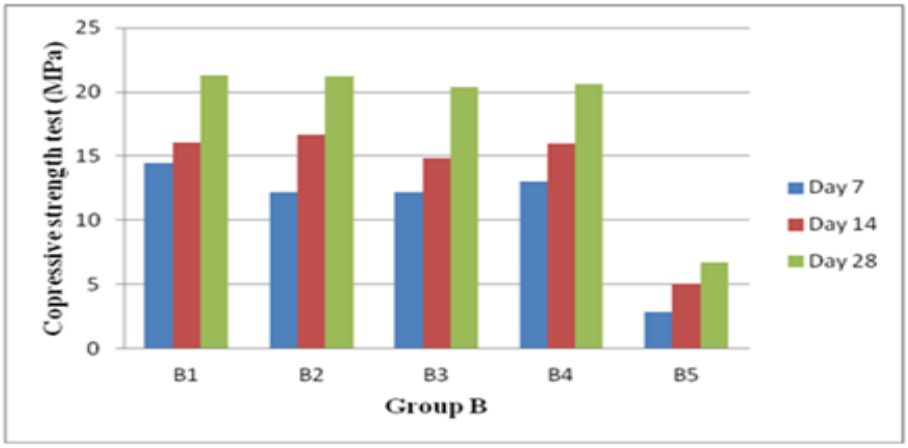

Fig. 7: the results of compressive strength test in group B with w/c 0.55

2 Influence of water cement ratio

With the increase of water cement ratio the compressive strength decreases. For example if we compare figure 6 which has water cement ratio of 0.5 and figure 7 which has water cement ratio of 0.55; the compressive strength is high in figure 6 than in figure 7. So this shows that with the increase of W/C ratio, the compressive strength decreases, but the decrease extent is different. The compressive strength is higher at 28days when W/C ratio is 0.5, then when W/C ratio is 0.55; this indicates that the increase of w/c ratio leads the decrease of the compressive strength.

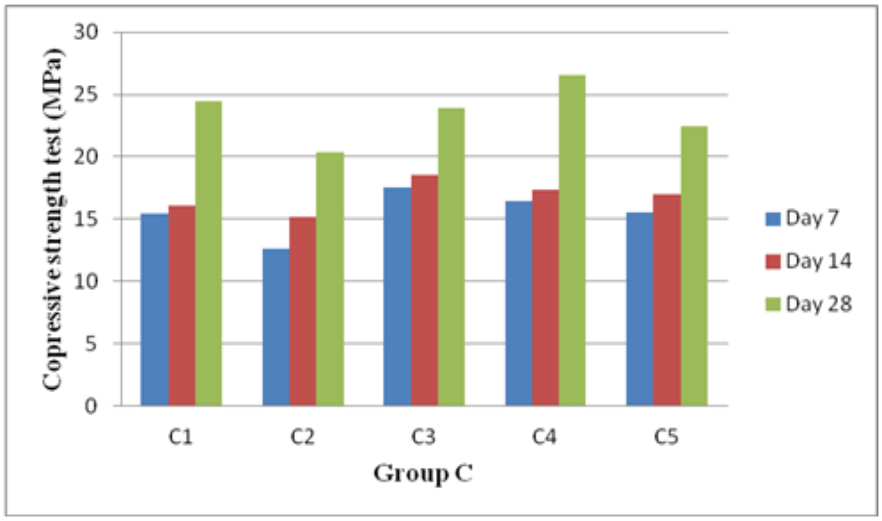

Fig. 8: the results of compressive strength test in group C with W/C of 0.6

From the above figure 7 we can say that the compressive strength decreases with the increase of recycled aggregate. As we can see that the highest compressive strength is in mixture B1; which we used 0% of recycled aggregate while B2, B3, B4 and B5 we used 10%, 20%, 30% and 40% of recycled aggregate as a substitute of natural aggregate respectively. B5 which has 40% of recycled aggregate has the lowest compressive strength at 7days, 14days and 28days. We can say the recycled aggregate has big influence on the compressive strength of the specimen.

In figure8 we can see that the compressive strength in mixture C1; which has 0% of recycled aggregate is higher than C2; which has 10% of recycled aggregate. Also the increase of recycled aggregate the compressive strength increases first then decreases and again increases. Mixture C2 which has 10% of recycled aggregate has the lowest compressive strength than C3, C4, and C5 which have 20%, 30%, and 40% of recycled aggregate respectively.

Comparison of compressive strength

Figure 9; depicts the variation of compressive strength with respect to both recycled aggregate and different water cement ratio for samples after 7days, 14days and 28days. The compressive strength improved while reduction of recycled aggregate in the specimen the increase of the compressive strength.

For example in group A; by the reduction of recycled aggregate from 10% to 0%, the 7days the compressive strength increases to 15.26 MPa. Also the reduction of recycled aggregate from 20% to 0%, after 14days the compressive strength of the specimen increases to 23.1MPa. The reduction of RA from 30% to 0%, after 28days the compressive strength increased to 24.33MPa.The most growth of compressive strength from 7, 14 and 28 days relates to the samples with water cement ratio of 0.5. The growth of compressive strength for sample aged 28 days remains fixed without any significant changes.

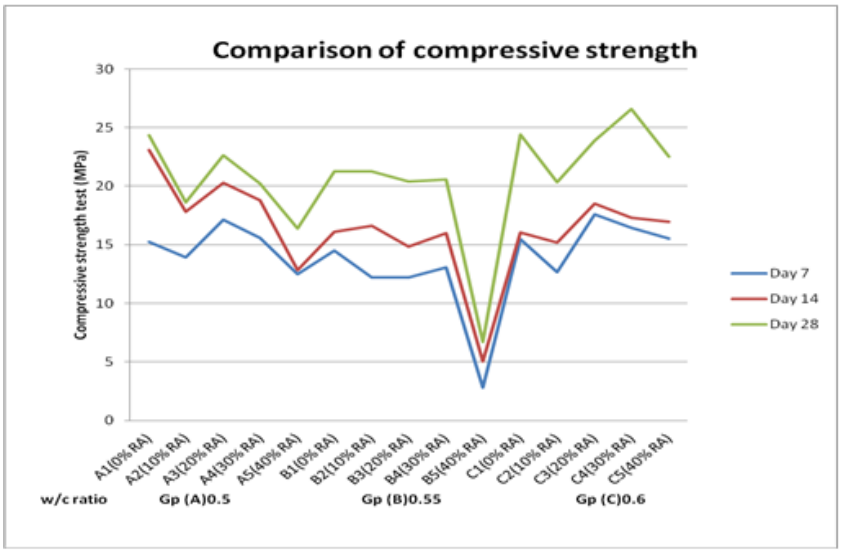

Figure .9**:** comparing the compressive strength at 7 days, 14 days and 28 days

CONCLUSION

The conclusion of this paper is as follows

1.0 Bending Strength

According to the experiment done to obtain the bending strength it see that the specimen has gained bending strength after 7 days and gradually gains more bending strength after 14 days and 28 days. This proves that the longer the specimens have to cure the more bending strength it will have. The influence of recycle aggregates depends on the bending strength. In this case when the study used 0% of recycle aggregates it can be obtained the highest bending strength out of all the specimens. Thus the more recycled strength that is used in the mixture the lower the bending strength will be. The influence of water differs when we use 0.5, 0.55 and 0.6 w/c ratio. As the w/c ratio increases the bending strength decreases.

According to the composite material theory, the recycled aggregate becomes a weak material and its bearing capacity is smaller thus leading to a decrease in mortar bending strength. This effect will dominate the strength of recycled mortar.

2.0 Compressive Strength

From the results obtained from the experiment on compressive strength it can see that the compressive strength increased with more curing time. The compressive strength is at its highest after 28 days. Also as it increases the amount of recycled aggregates in the mixture the compressive strength decreases. For example we get the highest compressive strength when we use 0% recycled aggregates and we have the lowest compressive strength when we use 40% recycled aggregates. The water cement ratio is quite odd and has a great influence on the compressive strength. When we use 0.5 w/c ratio the compressive strength is high but when we use 0.55 w/c ratio is slightly decreases and when we use 0.6 w/c ratio is increases once again.

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