COMBINED EFFECTS OF MAXIMUM AGGREGATE SIZE, W/C RATIO AND CEMENT CONTENT VARIATIONS ON COMPRESSIVE STRENGTH OF CONCRETE MADE WITH RECYCLED BRICK AGGREGATE

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ABSTRACT.

Thorough investigation on the effect of maximum aggregate size (MAS) of coarse aggregate on fresh and hardened properties of low-strength, high strength and traditional concrete were done by researchers; and their findings indicate that MAS highly influences the structural and durability performances of concrete. These researches mostly used stone, granite, brick and basalt aggregates. However, for sustainable development researchers are focusing on utilizing recycled brick aggregate (RBA) as coarse aggregate. But proper investigation on the effects of MAS of recycled brick aggregate on properties of concrete is still limited. Investigation was carried out to study the effects of maximum aggregate size (MAS) of recycled brick coarse aggregate (12.5 mm, 19.0 mm, 25.0 mm, and 37.5 mm) on compressive strength of concrete. For investigation, recycled bricks were collected and broken into pieces to make coarse aggregate according to the gradation requirements of ASTM C 33. Varying water to cement ratio (W/C) of 0.45 and 0.55 were used in mix design to evaluate the effects of W/C variations on compressive strength of concrete. To evaluate the effects of cement content on compressive strength two values of cement content 340 kg/m^3 and 400 kg/m^3 were used. A total of 12 different cases were considered and a total of 108 concrete cylindrical (100 mm diameter and 200 mm height) specimens were made for testing. The specimens were tested for determining compressive strength, at the age of 7 days, 14 days, and 28 days.

Experimental data has revealed that with the increase of MAS with lower cement content (340 kg/m3), compressive strength of concrete increases. On the contrary, with the increase of MAS with higher cement content (400 kg/m3) compressive strength of concrete decreases. Concrete made with higher W/C exhibits lower compressive strength irrespective to MAS. Structural grade concrete can be prepared using RBA as coarse aggregate ensuring higher cement content and lower W/C ratio in the mix design with respect to compressive strength property.

Keywords: *Maximum aggregate size, recycled brick aggregate, aggregate gradation, compressive strength.*

1 INTRODUCTION

Properties of concrete is highly influenced by its consitutent materilas such as types of cement, coarse aggregate, fine aggregate and if any other admixtures are used. Any alteration of coarse aggregate can highly change various hardened as well as fresh properties of concrete such as compressive stregth, tensile stregth, workability etc. as coarse aggregate comprises 60% – 75% of total volume of concrete. By increasing the size of coarse aggregates used in concrete it inccreases the tendency of shrinkage and creep of concrete (Ioannides and Jeff, 2006). On the contrary, increment of size of coarse aggregates, it

reduces the water demand resulting a lower water to cement ratio (W/C), which consequently provides higher strength in concrete (Neville, 2011). Several studies have been conducted considering the maximum aggregate size of concrete but there is no elaborate study on maximum aggregate size considering recycled brick aggregate. At present we are highly dependent on natural resources for acquaring the required coarse and fine aggregate for our construction works. With the rapid growing of construction sector, demand of these natural aggregates are also being increased. At the same time various existing structures are now being demolished to rebuild high rise structures and other facilities. Demolished aggregates from these destructions are being disposed as land fills which creating various problems in the corresponding land zones and on overall environment. The most efficient method of managing the construction and demolition waste is recycling and reusing of these products in an effective economic way. Considering this situations, currently researchers are focusing on the utilization of recycled waste materials as aggregate in construction works. It will drcrease the consumption of natural resouces as well as the amount of disposing of waste aggregates in landfills. So, overall it will enhance the environmental sustainibility. Since research work on maximum aggregate size on recycled brick aggregate is still limited, that's why this study has been planned.

2 METHODOLOGY

Materials

The type of coarse aggregate that was used in this investigation was recycled brick aggregate (RBA) and as fine aggregate, natural coarse sand (NS) was used. As a binding material CEM Type -1 (Ordinary Portland Cement (OPC)) was used. RBA was collected from a 12 year old demolished building situated at Baridhara, Dhaka and were broken and sived carefully as per ASTM C33. Gradation for maximum aggregate size were 37.5, 25, 19 and 12.5 mm. Potable tap water was used in the preparation of concrete. The material properties of coarse and fine aggregates are summarized in Table 1.

Specimens and Cases Investigated

Total 12 different cases were investigated for this study. For each case, nine 100 mm x 200 mm sized cylindrical specimens and total 108 cylindrical specimens were casted. Details of 12 cases are shown on Table 2 and their gradition are shown in Table 3. After 24 hours of casting, the specimens were de-molded and cured by immersing under water for 28 days.

Table 1: Properties of Coarse and Fine Aggregate

Items	Coarse Aggregate	Fine Aggregate	Testing Method
	RBA	Natural Sand	
Specific Gravity (SSD)	2.45	2.58	ASTM C127
Absorption Capacity (%)	13.35	3.67	ASTM C127
Abrasion Value (%)	43.5	-	ASTM C131
Unit Weight (kg/m^3)	1241	1576	ASTM C29
Fineness Modulus (FM)	6.85	2.6	ASTM C136

Table 2: Cases of Investigation and Mixture Proportions

Cases	Notation	MAS (mm)	W/C	Cement (kg/m^3)	Sand (kg/m^3)	Aggregate (kg/m^3)	Water (kg/m^3)
1	RBA-NS-0.45-340-12.5	12.5	0.45	340	677	953	143
2	RBA-NS-0.45-340-19.0	19	0.45	340	677	953	143
3	RBA-NS-0.45-340-25.0	25	0.45	340	677	953	143
4	RBA-NS-0.45-340-37.5	37.5	0.45	340	677	953	143
5	RBA-NS-0.45-400-12.5	12.5	0.45	400	657	926	180
6	RBA-NS-0.45-400-19.0	19	0.45	400	657	926	180

7	RBA-NS-0.45-400-25.0	25	0.45	400	657	926	180
8	RBA-NS-0.45-400-37.5	37.5	0.45	400	657	926	180
9	RBA-NS-0.55-340-12.5	12.5	0.55	340	618	871	187
10	RBA-NS-0.55-340-19.0	19	0.55	340	618	871	187
11	RBA-NS-0.55-340-25.0	25	0.55	340	618	871	187
12	RBA-NS-0.55-340-37.5	37.5	0.55	340	618	871	187

Table 3: Gradation of Coarse Aggregate as per ASTM C33

Nominal size	**Amounts finer than each laboratory sieve, Mass percent**					
	37.5 mm	**25.0 mm**	**19.0 mm**	**12.5 mm**	**9.5 mm**	**4.75 mm**
37.5 to 12.5 mm	90	40	10	-	0	-
25.0 to 9.5 mm	100	90	50	15	0	0
19.0 to 4.75 mm	-	100	90	-	40	0
12.5 to 4.75 mm	-	-	100	90	50	0

Compressive Strength

Cylindrical concrete specimens of diameter 100 mm and height 200 mm were made to measure the compressive strength of concrete at age of 7 days, 14 days and 28 days as per standard guideline (ASTM C39, 2016).

3 RESULTS AND DISCUSSIONS

Compressive Strength

From Fig. 1-3 it is seen that overall compressive strength increased accordingly for 7 days, 14 days and 28 days irrespective to type of cases. Among all the cases, case no. 5 (RBA-NS-0.45-400-12.5) showed highest compressive strength of around 3000 psi (21 MPa) which satisfies the compressive strength of 20 grade concrete. For this case, higher cement content of 400 kg/m3 and lower W/C ratio of 0.45 was used. So, from these data it is assured that replacement of recycled brick aggregate can exhibit sufficient compressive strength for construction works.

On, the contrary, from Fig. 3 least amount of compressive strength of around 1800 psi (12.5 MPa) is found for Case no. 9 (RBA-NS-0.55-340-12.5) where higher W/C ratio of 0.55 and lower cement content were maintained for the mixture proportions. For both the cases, maximum aggregate size was 12.5 mm which provided highest and at the same time lowest compressive strength. So, it is evident that, maximum aggregate size is not the only factor that controls the compressive strength. The effect of W/C ratio and cement contents are shown graphically in Fig.4 and Fig.5.

The 7 days, 14 days and 28 days compressive strengths for all the 12 cases are shown in Fig 1-3 accordingly.

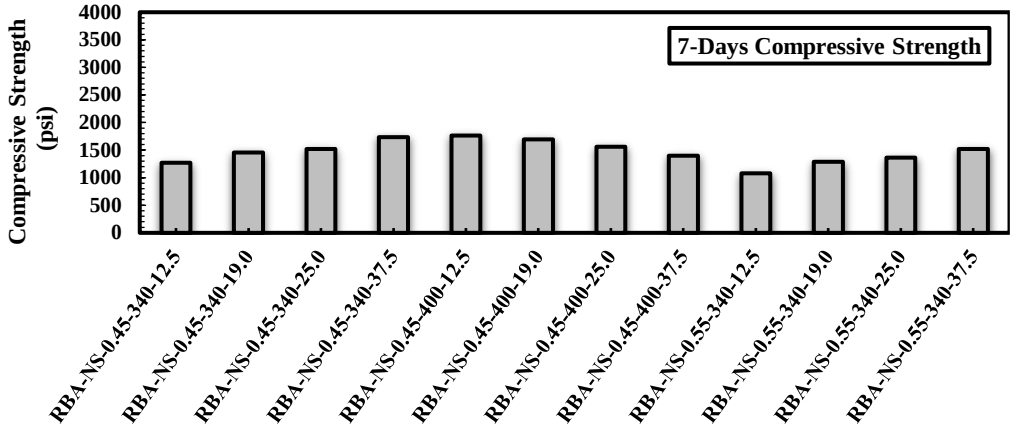

Figure 1. Compressive Strength of Concrete (7 days)

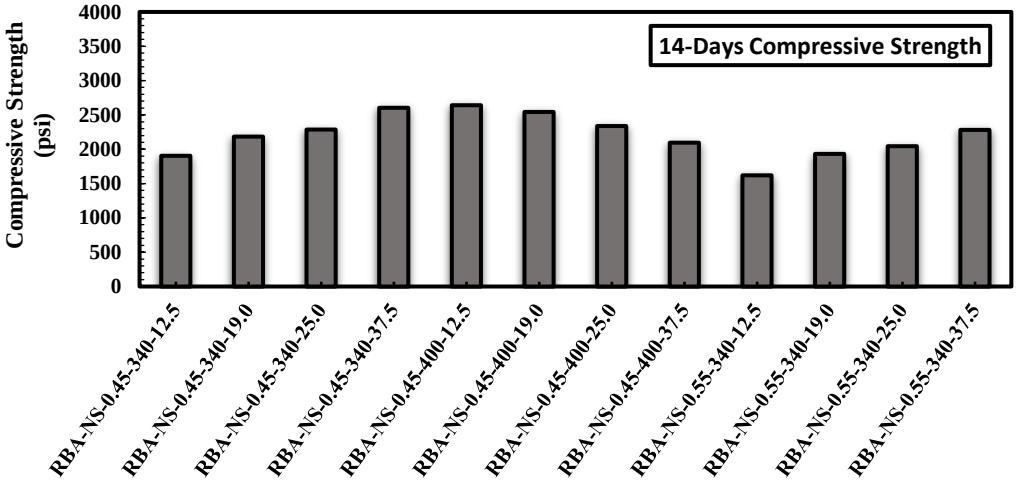

Figure 2. Compressive Strength of Concrete (14 days)

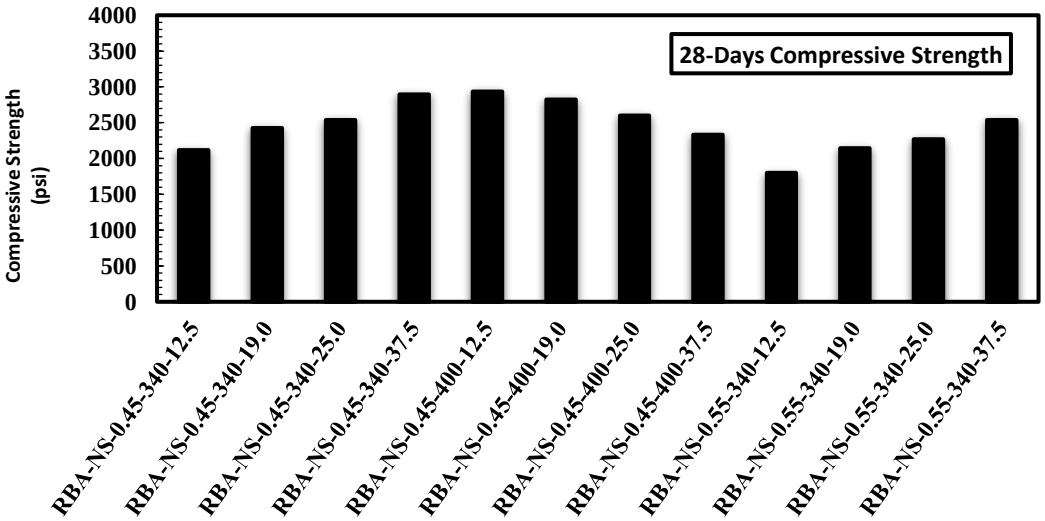

Figure 3. Compressive Strength of Concrete (28 days)

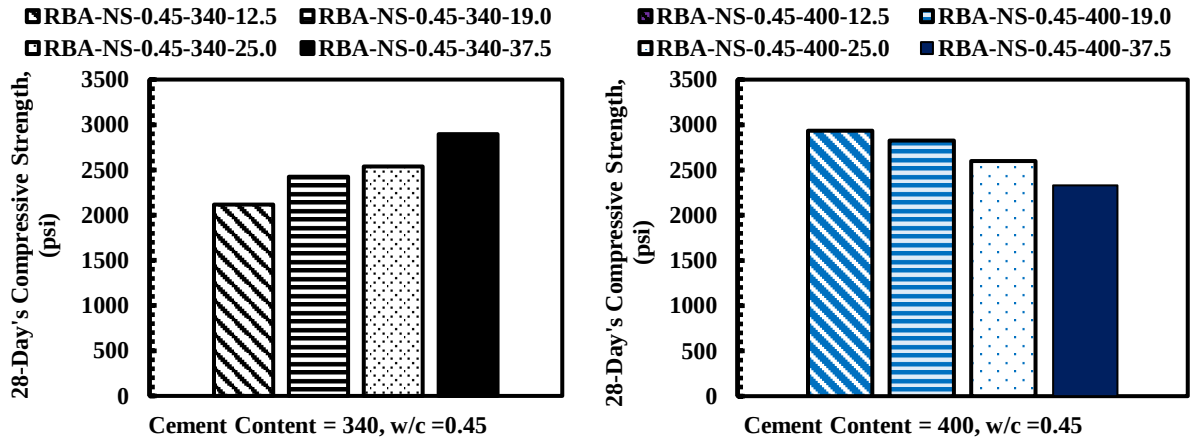

Figure 4: Combined Effect of Cement Content and MAS on Compressive Strength of Concrete

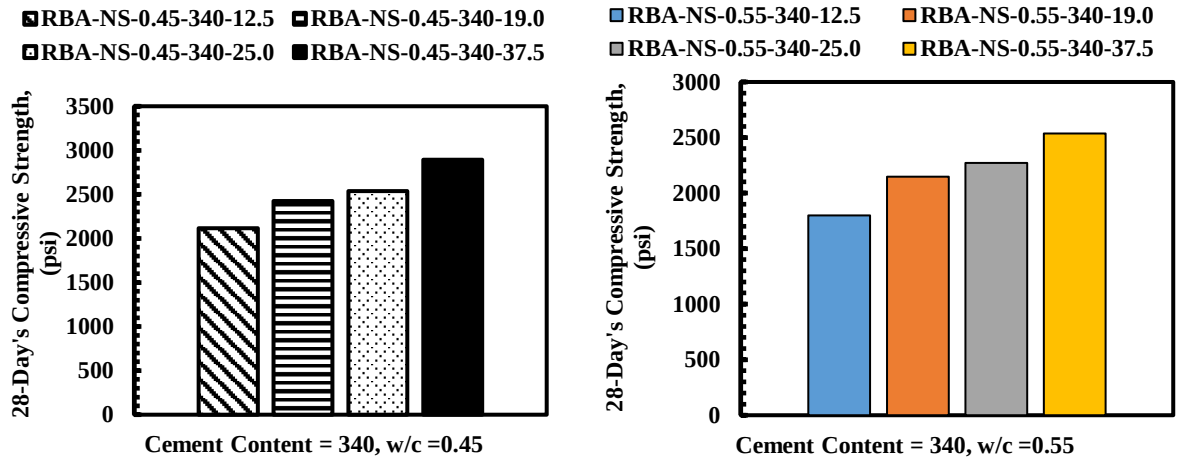

Figure 5: Combined Effect of w/c and MAS on Compressive Strength of Concrete

From Fig.4 and Fig.5 it is observed that, at lower cement content of 340 kg/m3, and W/C ratio of 0.45 and 0.55, the compressive strength increases with the increase of MAS. But at higher cement content of 400 kg/m3, the compressive strength reduces with the increase of MAS, irrespective to the change in W/C ratio. At lower cement content, the failure in concrete specimen is initiated in the aggregate-mortar interface, and visual inspection of broken samples suggests mortar failure. In such cases, with the increase in aggregate size, the amount of aggregate-mortar interface is reduced, and this results in a higher compressive strength for larger sized aggregates. In contrast, at higher cement content, the failure initiates in the interface as well as within the aggregate, and visual inspection suggests combined failure. In such cases, lower sized aggregates imparted more compressive strength than larger sized aggregates. Moreover, the strength reduces by increasing W/C ratio for all cases. Findings of our research work align with the results of other research works (Mosa, et al., 2017), (Salau, M. A. and Busari, A. O., (2015).

CONCLUSION

1. M20 structural grade concrete can be prepared using recycled brick aggregate as coarse aggregate.

2. With the increase of maximum aggregate size, the compressive strength values get increased accordingly in general. While using recycled brick aggregate with relatively low cement content,

compressive strength increases with the increase of aggregate size of coarse aggregate. Vice versa effects take place with higher cement content concrete made of recycled brick aggregate.

3. Lower W/C ratio contributes to higher compressive strength and vice versa effect for higher W/C ratio.

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