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Recycling of Brick Aggregate Concrete : An Extended Study on Some Key Issues

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ABSTRACT

An extensive investigation was conducted for recycling of demolished concrete as coarse aggregate for new constructions works. Properties of recycled aggregate and properties of recycled aggregate concrete are summarized separately. In this study, the results of investigations on some important issues associated with recycling of demolished concrete are summarized, such as comparison of recycled brick and stone aggregate concrete, the ways of improvement of workability of concrete made with recycled aggregate, performance of recycled aggregate concrete made with different replacement ratio, compressive strength of recycled aggregate concrete made with a low W/C (less than 0.45), mechanical properties of concrete made with recycled fine aggregate and coarse aggregate, variation of compressive strength of concrete cylinder collected from a large slab specimen made with recycled aggregate, performance of recycled aggregate concrete mixed with volume based mix design, compressive strength of concrete cores collected from an old building and compressive strength of recycled aggregate concrete produced using the recycled aggregate from the same building, and compressive strength of recycled aggregate concrete made with blended cement. Several important conclusions were made from these investigations that will be very useful for sustainable utilization of construction materials.

Keywords: Coated Recycled Aggregate, Recycling, Replacement Ratio, Compressive Strength.

INTRODUCTION

Recycling of demolished concrete is found to be an effective way for sustainable development of concrete industries (Mehta, 2001; Naik, 2002; Mohammed et al, 2011). However, most of the studies on recycling were conducted on stone recycled aggregate (Rahal, 2007;Corinaldesi, 2010) as stone aggregate is commonly used worldwide. To understand the properties of recycled brick aggregate and the properties of concrete made with recycled brick aggregate, a detailed study was conducted with recycled brick aggregate collected from 33 different building sites with variation of age from 1.5 years to 60 years.

W/C ratios of concrete were 0.45 and 0.55. The results of this comprehensive investigation was summarized separately (Mohammed et al, 2013). However, it is realized that further investigation on this topic is necessary with some important considerations, such as comparison of recycled brick aggregate concrete with recycled stone aggregate concrete, the ways of improvement of workability of concrete made with recycled aggregate, performance of recycled aggregate concrete made with different replacement ratio, performance of recycled aggregate concrete made with a low W/C (less than 0.45), recycling of demolished brick aggregate concrete as coarse and fine aggregate together, variation of compressive strength of concrete cylinder collected from a large slab specimen made with recycled aggregate, strength of recycled aggregate concrete mixed with volumetric ratio commonly used in Bangladesh, compressive strength of concrete cores collected from an old building and compressive strength of recycled aggregate concrete produced using the recycled aggregate from the same building, and properties of recycled aggregate concrete made with blended cements. The results of these investigations are summarized here.

EXPERIMENTAL METHODS, RESULTS, AND DISCUSSION

Properties of Stone Recycled Aggregate Concrete

To evaluate the properties of recycled stone aggregate (RS) and concrete made with this aggregate, recycled stone aggregate were collected from two sites (age 1.50 years and 50 years) and compared with virgin crushed stone (CS). In addition, one-year old recycled stone aggregates were obtained by crushing the cylinder specimens tested in the laboratory. Properties of recycled stone aggregates investigated are summarized in Table 1. It was observed that recycled stone aggregate shows higher absorption capacity and lower abrasion resistance compared to virgin crushed stone. Relatively soft and porous adhered mortar around original aggregate could be a reason for this. Compared to the results of recycled brick aggregates (Mohammed et al, 2013), it is found that stone recycle aggregate showed lower absorption and wear value.

After investigation of aggregates, concrete cylinders of size 150 mm in diameter and 300 mm in height were made for evaluation of compressive strength at 7, 14, and 28 days as per ASTM C39. Similar mixture proportions were followed as Mohammed et al, 2013. After mixing concrete, the workability of concrete was measured by slump cone test.

Slump of recycled stone aggregate concrete is shown in Figure 1. CSWC55 indicates crushed stone aggregate with water to cement ratio 0.55 and RSY1WC55 indicates one year old recycled stone aggregate with water to cement ratio 0.55. Slightly lower workability is found for recycled stone aggregate concrete compared to concrete made with crushed stone. Similar results were also observed for recycled brick aggregate concrete (Mohammed et al, 2013).

The compressive strength of recycled stone aggregate concrete is shown in Figure 2 with crushed stone aggregate investigated in this study. It is found that the strength of the recycled stone aggregate concrete is 20% lower than the crushed stone aggregate concrete, however, if the W/C is reduced to 0.45, the strength of recycled aggregate concrete is increased to the level or higher than the concrete made with W/C=0.55. Similar results were also observed for recycled brick aggregate concrete (Mohammed et al, 2013). It is also found that concrete strength of 20 MPa can be obtained using recycled stone aggregate concrete with W/C=0.55, the strength can be increased to 24.1 MPa if W/C is reduced to 0.45. Similar level of compressive strength of concrete can be obtained by using recycled brick aggregate (Mohammed et al, 2013).

Table 1. Properties of Stone Recycled Aggregates Investigated

Type	Age (Years)	Sp. Gr.	Absorption Cap. (%)	Abrasion (%)
CS	-	2.50	2.89	25.00
RS	1	2.60	3.00	46.00
RS	1.5	2.45	5.13	41.00
RS	50	2.36	7.70	41.90

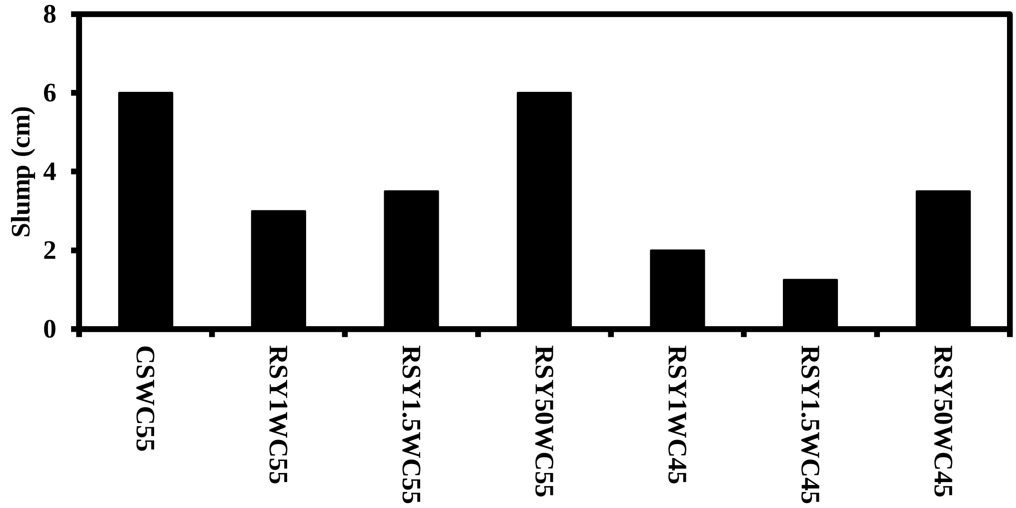

Figure 1. Workability of recycled stone aggregates concrete for W/C=0.55 and 0.45

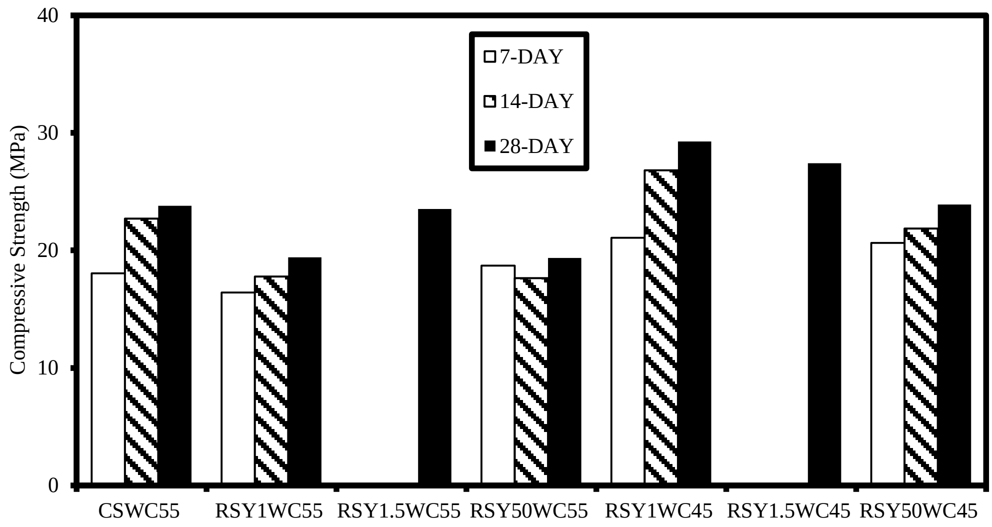

Figure 2. Compressive strength of recycled stone aggregate concrete – W/C=0.55 and 0.45

The tensile strength of stone recycled aggregate concrete is shown in Figure 3 for W/C=0.55 and 0.45. No significant difference is found in tensile strength for W/C=0.55 and 0.45.

The Young's modulus of stone recycled aggregate concrete is shown in Figure 4 with virgin aggregate (CS) investigated in this study. It is found that the Young's modulus of the recycled stone aggregate concrete is 20% lower than the normal stone aggregate concrete for W/C=0.55.

Stress-strain curves for the recycled stone and normal stone aggregate with W/C=0.55 is shown in Figure 5. It is clearly found that the recycled stone aggregate shows flatter stress-strain curves compared to the crushed stone. It is because of relatively soft old mortar around stone aggregate as well as formation of micro cracks during preparation of recycled aggregate.

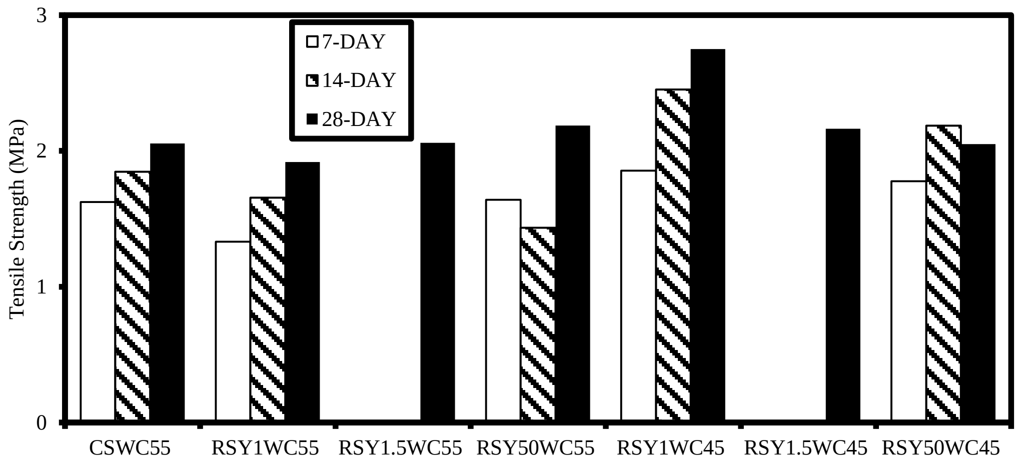

Figure 3. Tensile strength of recycled stone aggregate concrete – W/C=0.55 and 0.45

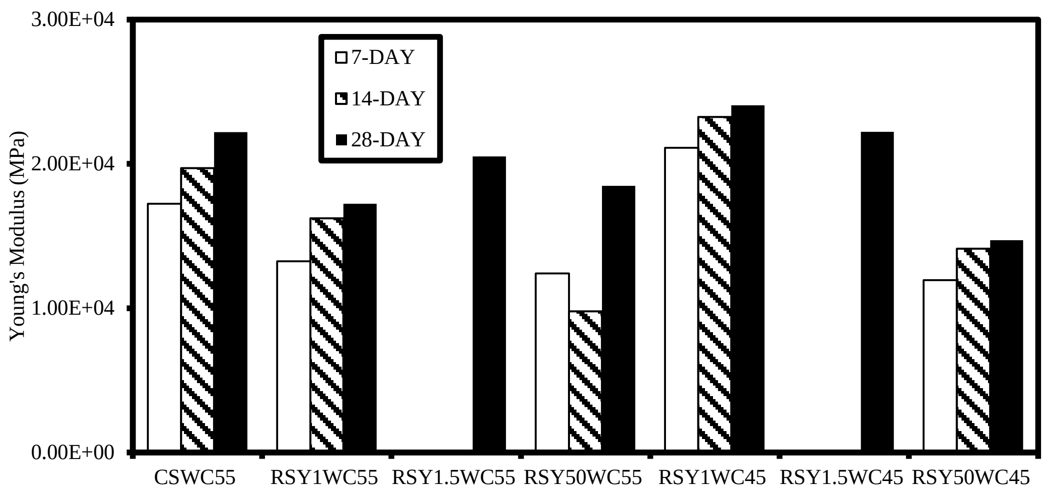

Figure 4. Young's modulus of recycled stone aggregate concrete– W/C=0.55 and 0.45

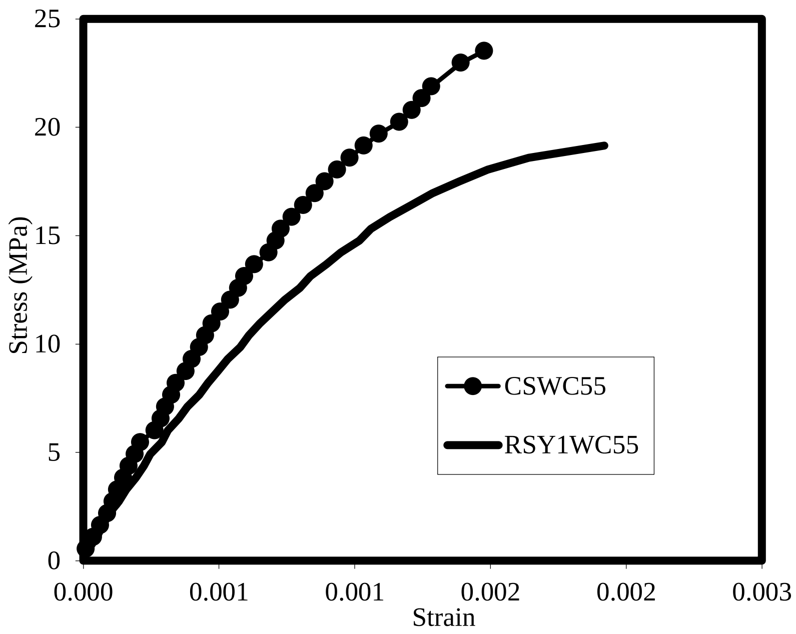

Figure 5. Stress-strain curves of recycled stone aggregate concrete – W/C=0.55

Performance of Recycled Aggregate Concrete Made with Different Replacement Ratio

The virgin brick aggregates (first class brick aggregate) were replaced by the recycled brick aggregate by 10%, 20%, 30%, 50%, and 100%. The grading of the combined aggregate (recycled plus virgin) as well as fine aggregate was same as Mohammed et al, 2013.

Properties of aggregates investigated are summarized in Table 2. No significant difference in specific gravity was found with the variation of replacement ratio. However, abrasion value is reduced if replacement ratio is increased. It is because of lower abrasion of recycled brick aggregate (RB). Mixture proportion and other experimental procedures were same as Mohammed et al, 2013.

The workability of concrete with different replacement ratio is shown in Figure 6 for W/C=0.55. FB80RB20Y55WC55 indicates the case with 80% first class brick aggregate and 20% recycled brick aggregate of age 55 years and W/C=0.55. It is found that with the increase of recycled aggregate portion, the workability of concrete is improved. It is expected due to the lower absorption capacity of the recycled brick aggregate compared to the virgin first class brick aggregate.

Compressive strength of concrete with the variation of replacement ratio is shown in Figure 7. No significant difference in strength of concrete is found upto the 50% replacement of virgin aggregate by recycled aggregate. The results indicate that recycled aggregate can be mixed with brick aggregate without significant loss in strength of concrete upto 50% of replacement.

Tensile strength of concrete with the change of replacement ratio is shown in Figure 8. A 20% reduction of tensile strength of concrete is found irrespective of the replacement ratio.

Table 2. Properties of Aggregates Investigated

Case	Sp. Gr.	Absorption Capacity (%)	Abrasion (%)
FB100RB0	2.20	21.06	47.80
FB90RB10	2.18	19.52	46.60
FB80RB20	2.16	20.00	45.20
FB70RB30	2.15	20.40	43.80
FB50RB50	2.14	21.00	42.00

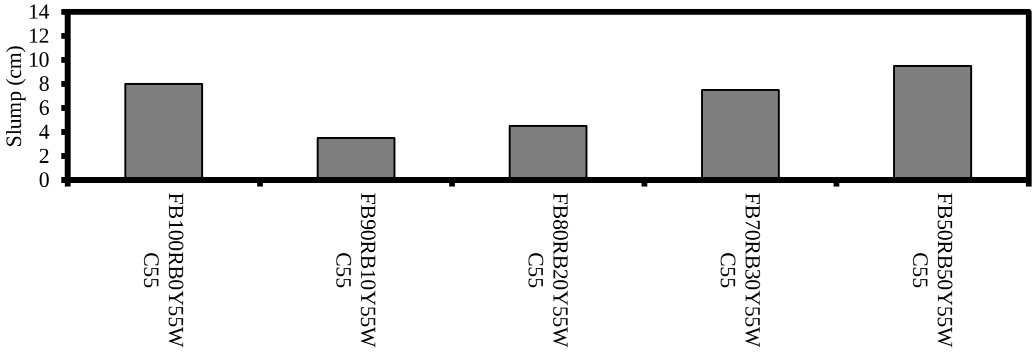

Figure 6. Workability of concrete – W/C=0.55, partial replacement

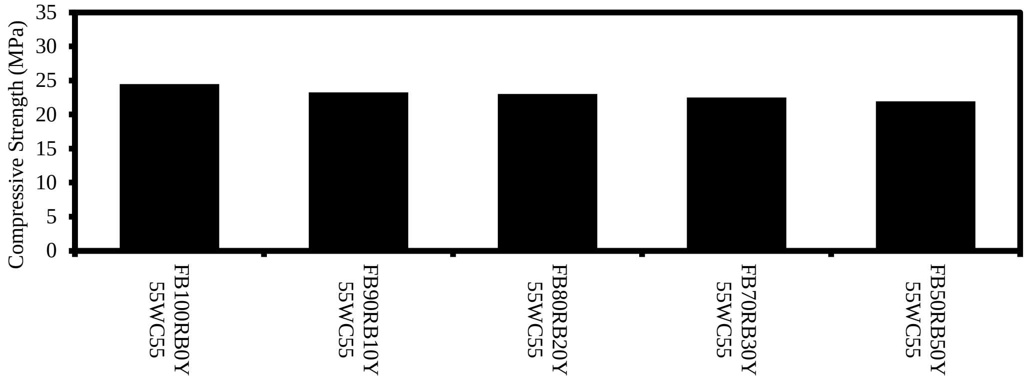

Figure 7. Compressive strength of concrete – replacement of recycled aggregate by virgin aggregate

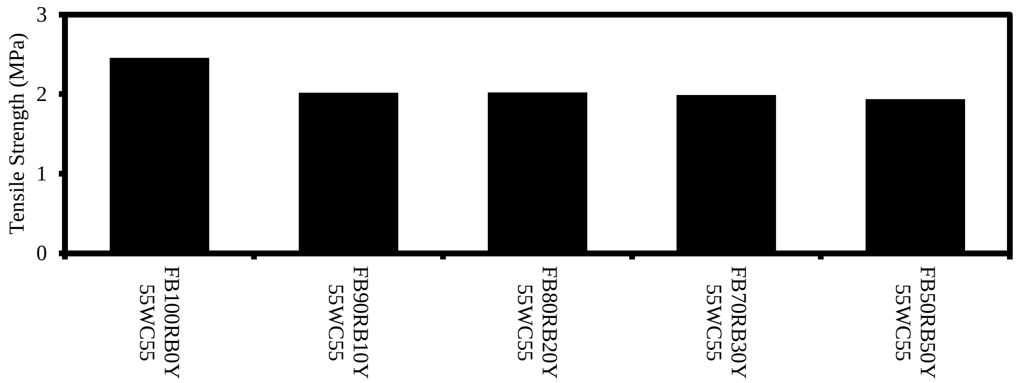

Figure 8. Tensile strength of recycled aggregate concrete – partial replacement

Cement Paste and Polymer Cement Paste Coated Aggregates

To improve workability of recycled aggregate concrete, some recycled aggregate were coated with cement paste and some were coated with polymer cement paste. To increase the thickness of coating, in some cases double coating were applied. In the case of cement paste coating, aggregates were coated with a cement paste of W/C=0.5. At first, cement paste was made in a mixture machine and then aggregates were added and mixed for about five minutes. After removing from the mixture machine, the aggregate were spread on a polythene sheet and allowed for drying for one day. In the case of polymer paste coating, a polymer (styrene-butadiene copolymer, FOSROC NITOBOND SBR) was added with cement (for 50 kg of cement 9 liter of polymer was added). The solid portion of the polymer was 41% and liquid portion was 59% in the polymer used in this investigation. Adjustments for water were made accordingly. The amount of cement was 8% as per SSD weight of the aggregates and W/C=0.5. Same as cement paste coated recycled aggregate, single coat and a double coat was applied over the recycled aggregate to improve the workability and reduce the water absorption. Photographs of coated recycled aggregates are shown in Figure 9. Details of the cases investigated are summarized in Table 3. It can be mentioned that when a single coat was applied over the aggregate, the aggregate is not covered and to improve the performance double coating was applied. After drying the first coat, the second coat was applied. The grading of the aggregates was same as Mohammed et al, 2013. SSD aggregates were used for making concrete.

The results of workability of concrete made with coated recycled aggregates are shown in Figure 10. It is found that the workability of concrete is improved with application of coating over the recycled aggregates. The improvement is significant in the case of double coating irrespective of the type of coating. Due to the application of coating the absorption capacity of the aggregate is reduced and also the internal friction of the aggregate is reduced, as a result the workability of the coated recycled aggregate concrete is improved. The improvement of workability is not as significant as in the case of W/C=0.55.

Compressive strength of concrete made with coated aggregates are shown in Figure 11. A 10 ~ 20% increase in strength of concrete is found compared to the non-coated cases for W/C=0.55. However, no significant improvement of strength of concrete is found for W/C=0.45. Perhaps, the ITZ of aggregate is improved with the application of coating for the case of W/C=0.55. The same is not found for a low W/C. For this reason, even reduction in strength is found for a low W/C. Further investigations are necessary to clarify the observation. For coated aggregate, failure surface was observed around the coated surface. It indicates the formation of a weaker interfacial transition zone (ITZ) around coated aggregate.

Figure 9. Coated aggregate

Table 3. Details of the Cases Investigated

Case	Details
RBY1WC55	Recycled Brick Aggregate (Not Coated) -1 Year's Old- W/C Ratio 0.55
RBCY1WC55	Recycled Brick Aggregate (Coated) -1 Year's Old- W/C Ratio 0.55
RBY1WC45	Recycled Brick Aggregate (Not Coated) -1 Year's Old- W/C Ratio 0.45
RBCY1WC45	Recycled Brick Aggregate (Coated) -1 Year's Old- W/C Ratio 0.45
RSY1WC55	Recycled Stone Aggregate (Not Coated) -1 Year's Old- W/C Ratio 0.55
RSCY1WC55	Recycled Stone Aggregate (Coated) -1 Year's Old- W/C Ratio 0.55
RSY1WC45	Recycled Stone Aggregate (Not Coated) -1 Year's Old- W/C Ratio 0.45
RSCY1WC45	Recycled Stone Aggregate (Coated) -1 Year's Old- W/C Ratio 0.45
RBY30WC45	Recycled Brick Aggregate (Not Coated) -30 Year's Old- W/C Ratio 0.45
RBCY30WC45	Recycled Brick Aggregate (Coated) -30 Year's Old- W/C Ratio 0.45
RBCY50WC55	Recycled Brick Aggregate (Coated) -50 Year's Old- W/C Ratio 0.55
RBY50WC45	Recycled Brick Aggregate (Not Coated) -50 Year's Old- W/C Ratio 0.45
RBCY50WC45	Recycled Brick Aggregate (Coated) -50 Year's Old- W/C Ratio 0.45
RBDCY55WC55	Recycled Brick Aggregate (Cement Double Coated)-55 Year's Old-W/C Ratio 0.55
RBDPCY55WC55	Recycled Brick Aggregate (Polymer Double Coated)-55 Year's Old-W/C Ratio 0.55.

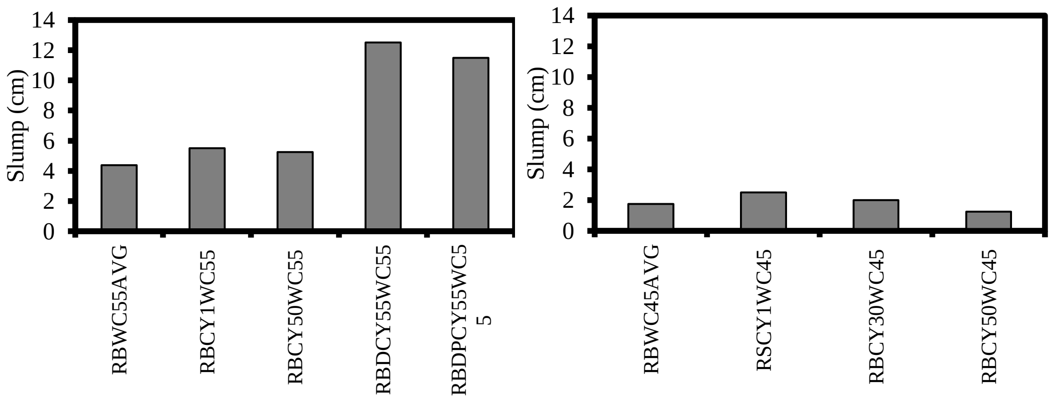

Figure 10. Workability of concrete – W/C=0.55 and 0.45, coated recycled aggregates

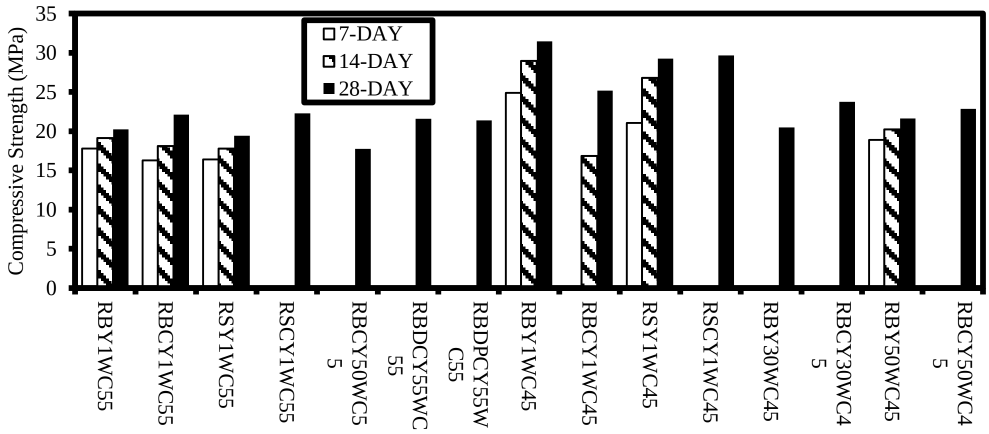

Figure 11. Comparison of compressive strength of concrete – coated and non-coated aggregate

The tensile strength of concrete made with coated and non-coated aggregates are shown in Figure 12. Same as compressive strength, the benefits of coating is found for W/C=0.55 but not for W/C=0.45. The reasons are same as explained before.

The Young's modulus of concrete made with coated aggregates is shown in Figure 13 for coated and non-coated aggregates. An increase of Young's modulus of recycled aggregate concrete is found for W/C=0.55, but no significant improvement of Young's modulus is found at W/C=0.45. Further investigations are necessary to clarify the observation.

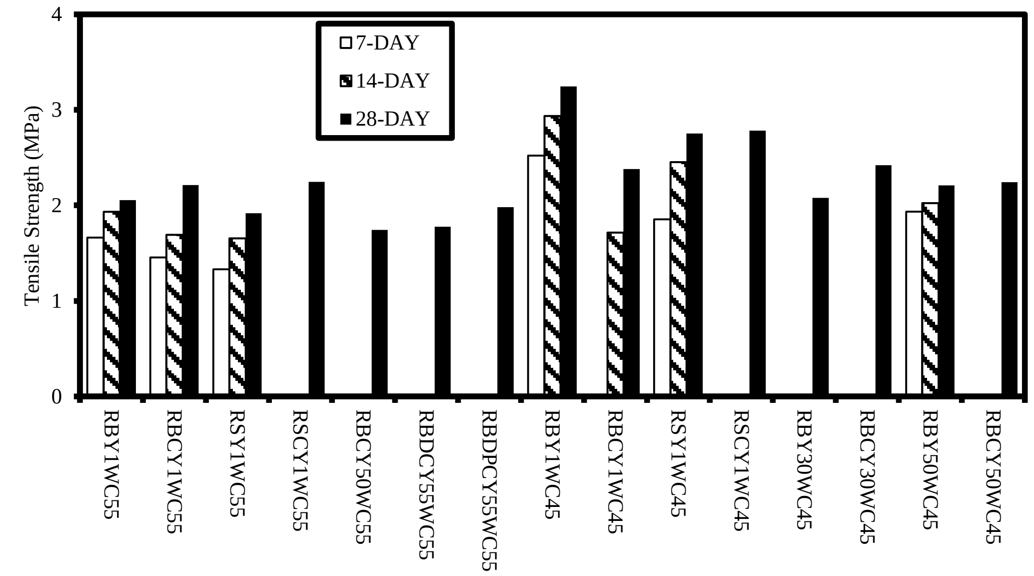

Figure 12. Tensile strength of recycled coated and non-coated aggregate

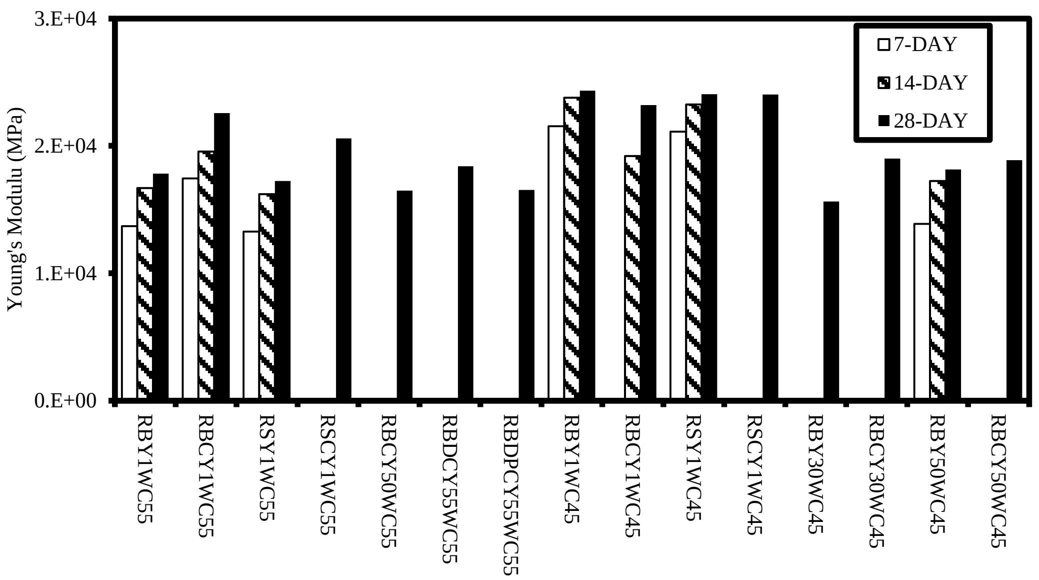

Figure 13. Comparison of Young's modulus of concrete – coated and non-coated aggregate

Volumetric Mixing of Concrete

Generally in Bangladesh, concrete is mixed based on the volume ratio of cement, sand, and coarse aggregate. Commonly used volume ratios (cement: sand: coarse aggregate) are 1:1.5:3 and 1:2:4. Therefore, concrete samples were made with 1:1.5:3 and 1:2:4 volumetric ratios and tested accordingly for comparison with virgin aggregates. For these cases, only the aggregate collected from 35 years old building was investigated. Grading of recycled aggregate was same as Mohammed et al, 2013.

The workability of recycled aggregate concrete made with volumetric mixture proportions is shown in Figure 14. Both fine sand (FS), and coarse sand (CS) were investigated separately as these types of sand are commonly used in Bangladesh. RBY35FS1:2:4 indicates the case with recycled brick aggregate of age 35 years and fine sand and ratio is 1:2:4. RBY35CS1:2:4 indicates the case with recycled brick aggregate of age 35 years and coarse sand and ratio is 1:2:4 .For cases with fine sand shows lower slump compared to the case with coarse sand. Also, 1:1.5:3 ratio shows lower slump compared to 1:2:4 ratio.

The 28 day Compressive strength test results are shown in Figure 15. It is found that concrete strength of 20.7 MPa can be obtained for 1:1.5:3 ratio and the same becomes 17.9 MPa for 1:2:4 ratio. If fine sand is used, concrete strength is reduced to the level of 13.8 MPa for 1:2:4 ratio.

The results of tensile strength are shown in Figure 16. It is found that tensile strength of 2.1 MPa can be obtained for 1:1.5:3 ratio and the same becomes 1.9 MPa for 1:2:4 ratio. If local sand is used, tensile strength is reduced to the level of 1.6 MPa for 1:2:4 ratio.

The Young's modulus of concrete are shown in Figure 17. It is found that Young's modulus of 1.45×10^4 MPa is obtained for 1:1.5:3 ratio and the same becomes at 1.38×10^4 MPa for 1:2:4 ratio with coarse sand. If fine sand is used, Young's modulus is reduced to the level of 1.1×10^4 MPa for 1:2:4 ratio.

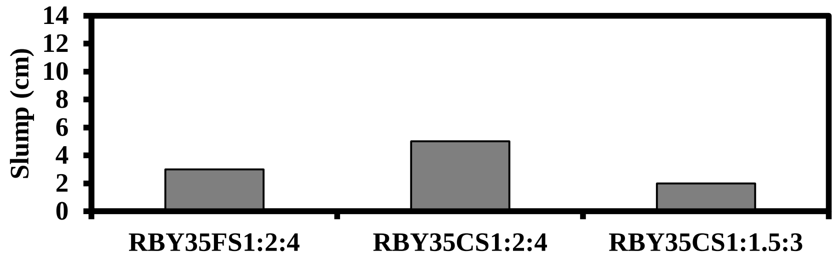

Figure 14. Workability of concrete – volumetric ratios commonly used in Bangladesh

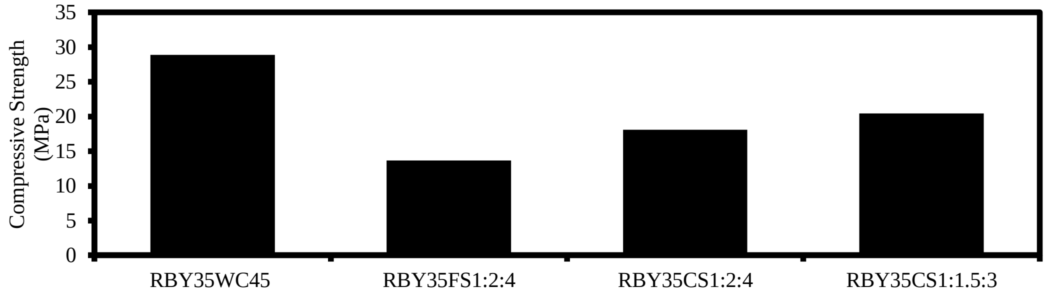

Figure 15. Compressive strength with volumetric mixture proportions-28 day

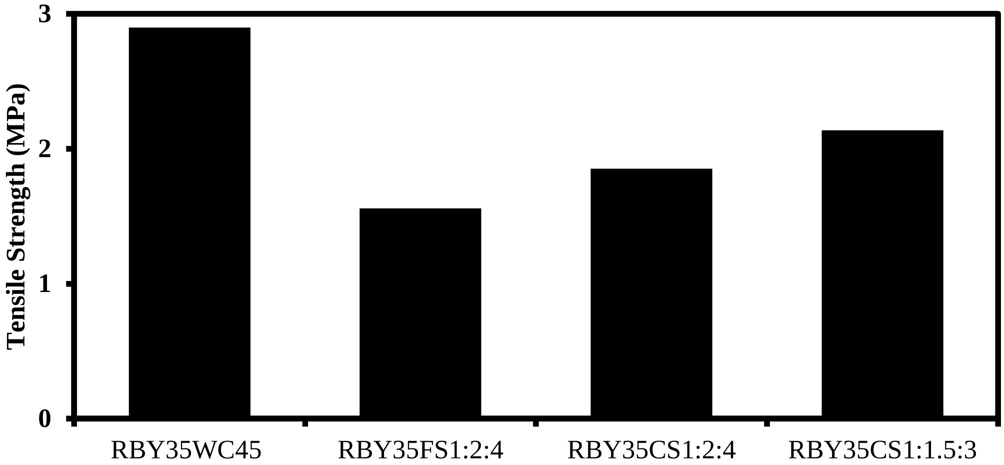

Figure 16. Tensile strength with volumetric mixture proportions-28 day

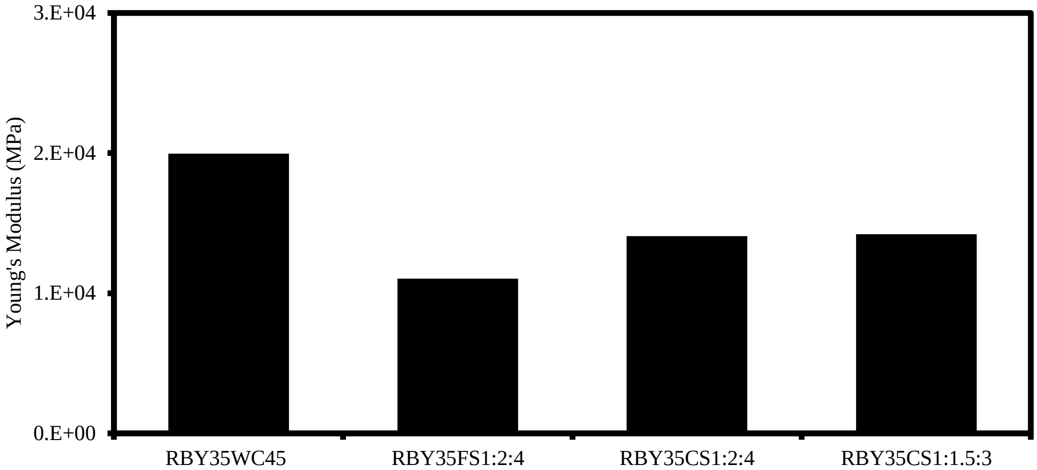

Figure 17. Young's modulus of recycled concrete with volumetric mixture proportions

Recycling of Recycled Fine Aggregate and Recycled Coarse Aggregate

Concrete specimens were also made by replacing the both fine and coarse aggregates by recycled fine aggregates and recycled coarse aggregates. Natural sand was replaced by 0% to 100% by recycled fine aggregate. Grading and mixture proportion was similar as Mohammed et al, 2013. Compressive strength and tensile strength of concrete for W/C=0.55 and W/C=0.45 is shown in Figure 18 and Figure 19. 100%SANDWC55 indicates 100% natural sand was used as fine aggregate and W/C was 0.55, 50%SAND50%RFAWC55 indicates 50% natural sand and 50% recycled fine aggregate was used as fine aggregate and W/C was 0.55. The average compressive strength of total green concrete (100% recycled fine aggregate and 100% recycled coarse aggregate) is found 22.2 and 20.3 MPa for W/C=0.45 and 0.55 respectively. The average tensile strength of total green concrete is found 1.43 and 1.39 MPa for W/C=0.45 and 0.55 respectively. It was observed that total green concrete (100% replacement of natural fine aggregate with recycled fine aggregate) gives 5-10% lower compressive strength compared to 100% virgin fine aggregate concrete.

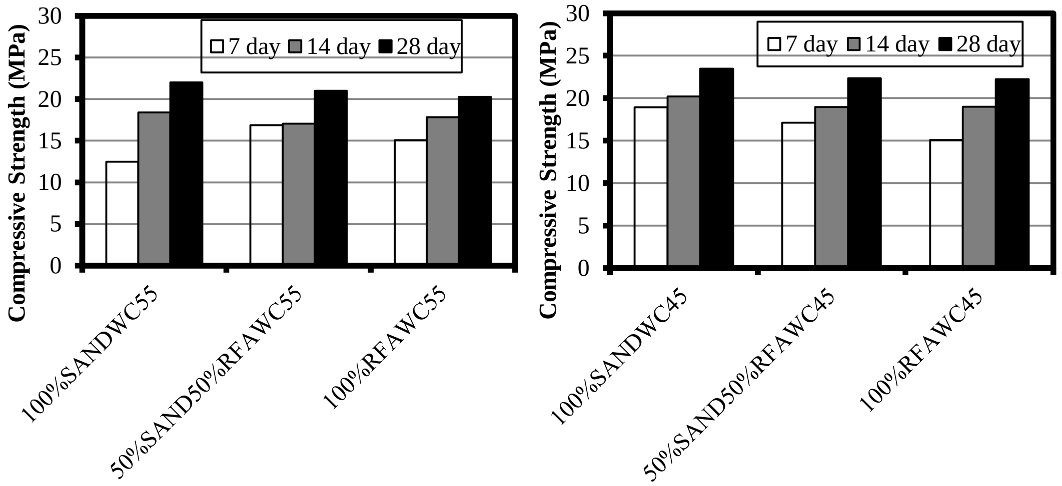

Figure 18. Compressive strength of concrete with different replacement of fine aggregate- (A)W/C=0.55, (B) W/C=0.45

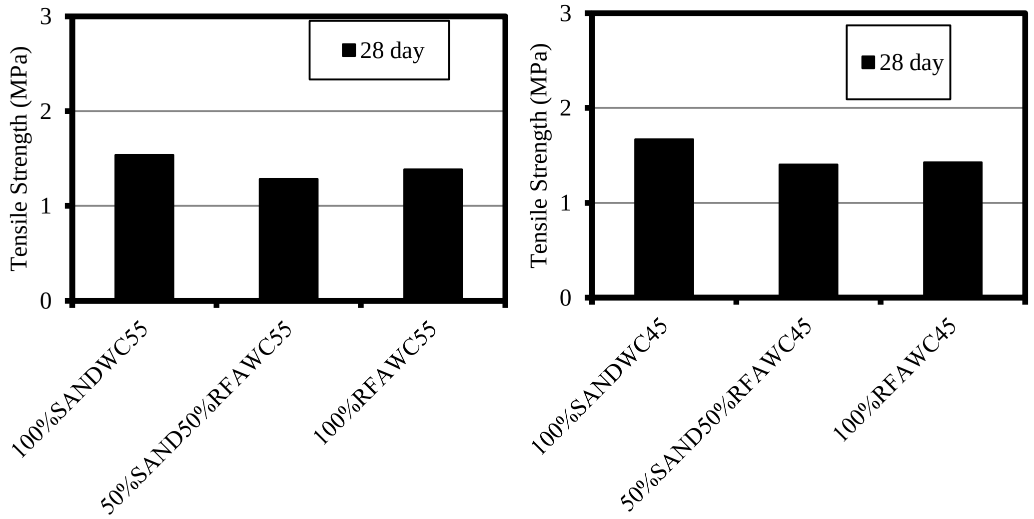

Figure 19. Tensile strength of concrete with different replacement of fine aggregate- (A)W/C=0.55, (B) W/C=0.45

Behavior of Recycled Concrete Made with Blended Cement

To determine the effect of blended cement, recycled concrete was made by blended cement, such as CEM II A-M, and CEM II B-M. Mineral content in CEM II A-M is less than 20% and CEM II B-M is from 20 to 35%. Due to slower hydration rate of blended cement, tests were continued till 51 days. Grading and mixture proportion was similar as Mohammed et al, 2013. Compressive strength of recycled concrete is shown in Figure 20 (a). It is found that use of blended cement has no adverse effect on compressive strength of concrete. Young's modulus of recycled concrete is shown in Figure 20 (b). Slightly higher Young's modulus was found for cases with CEM II B-M, that is for cases with high amount of mineral content in cement.

Behavior of Recycled Concrete with Low W/C and High Cement Content

To evaluate the behavior of recycled concrete at low W/C ratio and high cement content, recycled concrete was made with W/C=0.40 and cement content=400 kg/m^3 and compared with normal aggregates ((first class brick (FB), and crushed stone (CS)). Compressive strength and tensile strength of concrete are shown in Figure 21 (a) and Figure 21(b). RBY38CC400WC40 indicates recycled brick of age 38 years with cement content=400 kg/m^3 and water to cement ratio was 0.40. It was found that, 29.0 MPa concrete can be made by using recycled concrete at W/C=0.40 and cement content=400 kg/m^3. Tensile strength of recycled concrete is increased significantly compared to crushed stone concrete. It is due to improvement of the interfacial transition zone (ITZ) of concrete.

Compressive Strength of Concrete in a Real Size Structural Member Made with Recycled Aggregate

300mm thick concrete slabs were made for checking the strength of concrete in structural members made with recycled aggregate. The slabs were made based on the volumetric mixture proportions of 1:2:4 and 1:1.5:3 ratios. After 28-day wet curing, cylinder cores (4 inch) were collected and tested for tensile and compressive strength. From each slabs 12 cylinders were collected as shown in Figure 22.

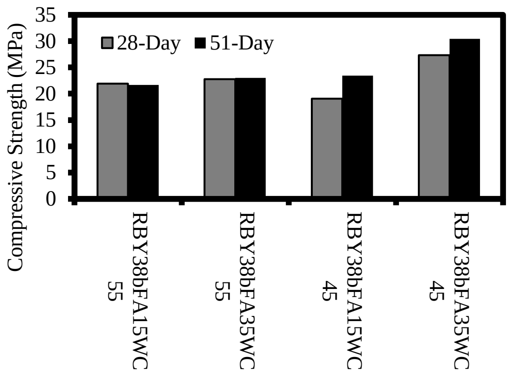

Figure 20. (a) Compressive strength of concrete with different w/c ratio

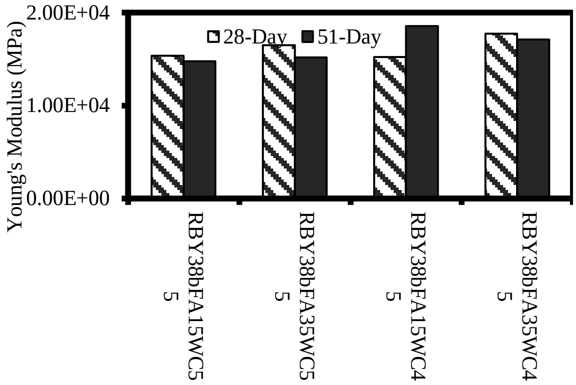

Figure 20. (b) Young's modulus of concrete with different W/C ratio

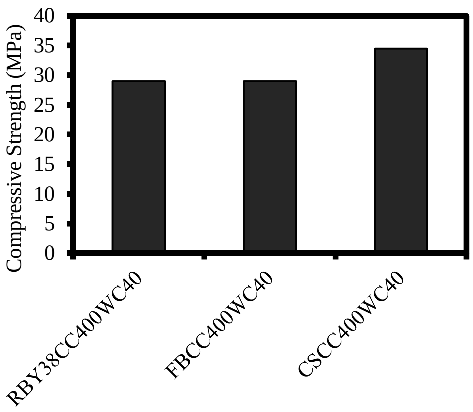

Figure 21. (a) Compressive strength of concrete

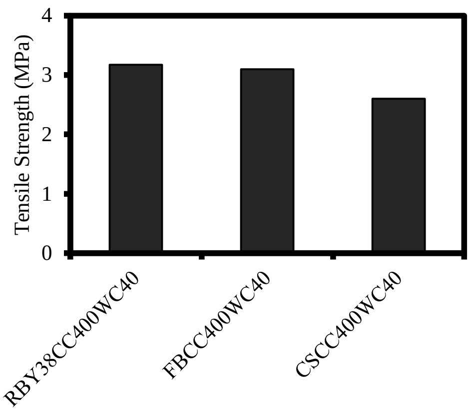

Figure 21. (b) Tensile strength of concrete

Nine cylinders were tested for the compressive strength and three were tested for tensile strength. Average compressive strength and tensile strength of the slab concrete and separately made cylinder concrete (of same size, i.e., 4 inch diameter) are shown in Figure 23. It is found that the average compressive strength of concrete collected from slab is 22.1 and 19.2 MPa for 1:1.5:3 and 1:2:4 ratios, respectively. The results for cylinder concrete specimens were 19.3 MPa and 16.6 MPa, for 1:1.5:3 and 1:2:4 ratios, respectively. Higher tensile strength was also found in the cylinder cores compared to the cylinder concrete specimens. The results indicate that the findings observed by investigating cylinder concrete specimens can be adopted for structural elements made with recycled concrete.

Compressive Strength of Cored Concrete Samples Collected from Demolished Building and Concrete Made with Recycled Aggregate

Concrete cores (100mm diameter) were collected from a building under demolition at age of 35 years. Concrete samples were also made using the aggregate collected from the same building site as shown in Figure 24.

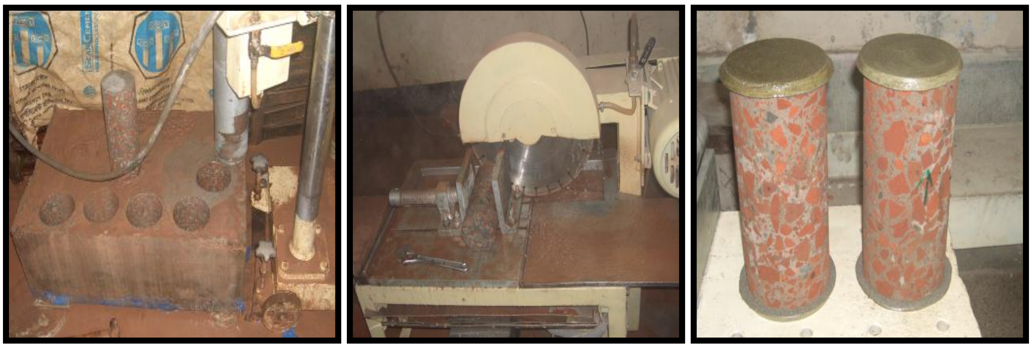

Figure 22. Coring concrete cylinder from slab, cutting and capping

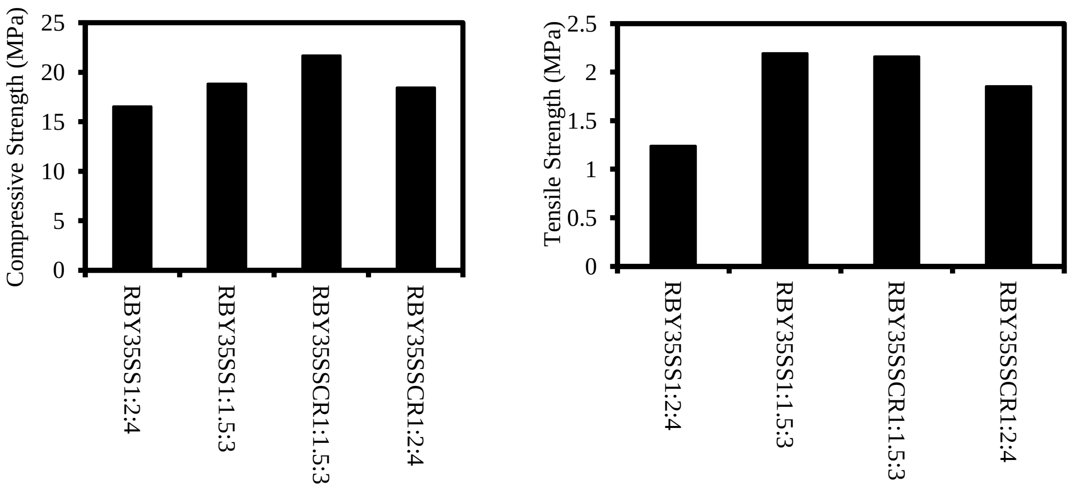

Figure 23. Compressive strength – slab core sample and cylinder specimens (a) compressive strength, (b) tensile strength

Figure 24. Coring concrete cylinders from demolished buildings

The strength of concrete of these cases is shown in Figure 25. The concrete strength at the time of demolition is 20.7 MPa, but after recycling the concrete strength, it is increased to the level of 27.6 MPa. This result indicates that it is possible to make concrete with more strength compared to the in-situ strength of concrete before demolition.

Compressive Strength of 100mm Diameter and 150mm Diameter Concrete Cylinders

To compare the variation of compressive strength of concrete with the size of specimens, cylinder specimens of diameter 100 mm and 150 mm were made. The results are shown in Figure 26. It is found that 100mm diameter cylinders give 6% higher strength compared to 150mm diameter cylinders.

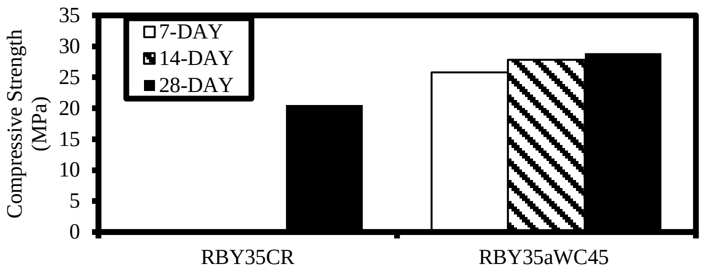

Figure 25. Cored sample from demolished blocks and concrete made with demolished concrete

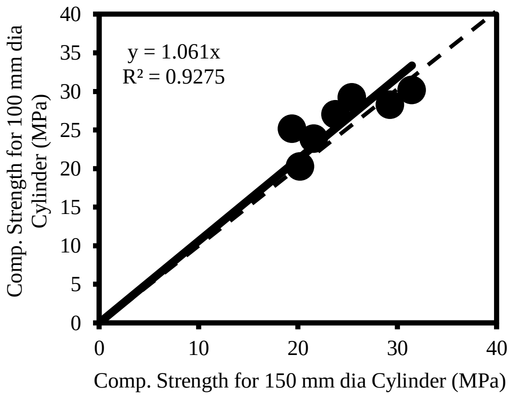

Figure 26. Compressive strength of recycled aggregate concrete – 100mm diameter and 150mm diameter cylinders

CONCLUSIONS

From the scope of this investigation on some key issues related to recycling of brick aggregate concrete, the following conclusions are drawn:

1. Compared to virgin stone aggregate, recycled stone aggregate shows higher absorption capacity and higher abrasion value. By using recycled stone aggregate, it is possible to make concrete of strength 24.1 MPa and 20.0 MPa for W/C=0.45, and 0.55 respectively,

2. It is found that application of a cement paste coat or a polymer cement paste coat on recycled aggregate improves the workability of recycled aggregate concrete,

3. By recycling, it is possible to make concrete with higher strength compared to the in-situ strength of recycled aggregate concrete before demolition,

4. It is possible to make 100% green concrete with complete recycling of fine and coarse aggregates in new construction works,

5. With W/C=0.40 and cement content=400 kg/m^3, the strength of recycled brick aggregate concrete can be increased to 29.0 MPa,

6. Use of blended cement has no adverse effect on recycled aggregate concrete.

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REFERENCES

Mehta, P. K., Reducing the Environmental Impact of Concrete, ACI Concrete International, October 2001, 61-66.

Mohammed, T. U., Hasnat, A., Awal, M. A., Bosunia, S. Z., Recycling of Demolished Brick Aggregate Concrete: Physical and Mechanical Properties, 3rd International Conference on Sustainable Construction Materials and technologies, August 2013. (Unpublished)

Mohammed T. U., A. Hasnat, N. Sarwar, H. K. Das, J. M. Miah, M. A. Awal,"Sustainable Development of Construction Works in Bangladesh", 3rd EACEF International Conference, September 2011, Indonesia, 271-277.

Naik, T. R., Greener Concrete using Recycled Materials, ACI Concrete International, July 2002, 45-49.

Rahal, K., Mechanical Properties of Concrete with Recycled Coarse Aggregate, Building and Environment, 42, 2007, 707-714.

Valeria, C., Mechanical and Elastic Behavior of Concretes Made of Recycled- Concrete Coarse Aggregates, Construction and Building Materials, 24, 2010, 1616–1620