PROSPECT OF USING RECYCLED CONCRETE AS COARSE AGGREGATE IN BANGLADESH

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ABSTRACT

One of the major challenges of our present society is to construct the environment friendly structures with low cost technology. The use of recycled aggregates from construction sites and demolished concrete wastes is showing prospective application in construction as alternative to virgin (fresh) coarse aggregates. To focus the prospect of using recycled aggregate in the construction of Bangladesh, concrete cylinders were prepared by recycled aggregate and obtained laboratory results were compared to concrete cylinders made of virgin (fresh) coarse aggregates. This paper represents comparative study of the experimental results of concrete made of recycled coarse aggregate and virgin (fresh) coarse aggregate. In Bangladesh, due to the rapid growth of real estate business, many low rise buildings are need to be demolished to replace by relatively high rise buildings. Therefore, this study was carried out to check the possibility of using demolished concrete as coarse aggregate for new construction.

KEY WORDS: Recycled coarse aggregate (RCA), virgin (fresh) coarse aggregate (VCA), compressive strength.

1.0 INTRODUCTION

1.1 General

Generally, aggregates are collected by cutting mountains or breaking river gravels or boulders, or by breaking clay bricks. A significant amount of natural resources can be saved if the demolished concrete is recycled for new constructions. In addition to the saving of natural resources, recycling of demolished concrete will also provide other benefits, such as creation of additional business opportunities, saving cost of disposal, saving money for local government and other purchaser, helping local government to meet the goal of reducing disposal, etc.

In Bangladesh, the volume of demolished concrete has been increasing due to the demolition of concrete structures. Disposal of the demolished concrete is a great concern to the construction industries. If the demolished concrete is used for new construction, the disposal problem will be solved, the demand for virgin coarse aggregates will be reduced, and finally consumption of natural resources for making aggregate will also be reduced. In some construction sites, it is also found that a portion of demolished concrete is used as aggregate in foundation works without any research on the recycled aggregate. In most of the old buildings, brick chips are used as coarse aggregate of concrete. Studies related to the recycling of demolished concrete are generally found for stone concrete. Therefore, investigation for recycling of brick and stone made demolished concrete is necessary. Based on this background, this experimental research study was carried out. Demolished concrete collected from construction sites and used as coarse aggregate after crushing. Before making concrete, the aggregates were investigated for absorption capacity, unit weight and abrasion. Standard grading of the aggregates was controlled. Cylinder concrete specimens of diameter 150 mm and height 300 mm were made and tested for compressive strength, Young's modulus, and stress-strain curves. The workability of concrete was also measured by slump test. The results of RCA concrete were compared to VCA concrete.

1.2 Objective of the Research

To investigate the properties of RCA and compare the properties of RCA with VCA.

1.3 Current Situation of the Recycled Coarse Aggregate in Bangladesh

There is a shortage of infrastructural facilities like houses, hospitals, roads etc. in Bangladesh and large quantities of construction materials for creating these facilities are needed. Rapid infrastructural development for housing sectors has led to scarcity and rise in cost of construction materials. Most of waste materials produced by demolished structures are disposed of by dumping them as land fill. Dumping of wastes on land is causing shortage of dumping place in urban areas. Therefore, it is necessary to start recycling and re-use of demolition concrete waste to save environment, cost and energy.

2.0 RECYCLED COARSE AGGREGATE (RCA)

2.1 General

From the previous studies, RCA is examined visually and found to contain particles of different appearances. This depends on the amount of old cement paste or mortar adhered to the particle. The attachment of old mortar makes the shape of RCA somewhat rounder than virgin coarse aggregate, and this may be beneficial for the rheological properties of fresh concrete. The coarse aggregate could be in its original size or may be broken down.

Increasing the amount of old mortar attached to the coarse aggregate may has detrimental effects on the properties of concrete produced by RCA, but this depends on the characteristics of the original concrete. Weaker original concretes have greater adverse effects than stronger original concretes, but the strength of the original concrete cannot be assessed for a commercially produced RCA, which is inevitably a mixture of different concretes. However, the characteristics of RCA are influenced by the attached old mortar with the coarse aggregate which can be obtained from the aggregate density and water absorption capacity

2.2 Properties of Recycled Coarse Aggregate

RCA is different in many ways from virgin coarse aggregates. This can be found from the Table 1[1].

3.0 PRODUCTION OF RECYCLED COARSE AGGREGATE

3.1 Availability of RCA

Considerable amount of demolished concrete is generated in Dhaka and other large cities in Bangladesh. In this research, the recycled concrete was collected form the demolished building and previously crushed concrete cylinder from the laboratory.

Mainly two types of recycled coarse aggregate used in this research work which are recycled brick chips and recycled stone chips.

Table 1: Properties of VCA and RCA

Property	VCA	RCA
Shape and Texture	Well rounded, smooth (gravels) to angular and rough (crushed rock).	Angular with rough surface
Absorption Capacity	0.8% – 3.7%	3.7% – 8.7%
Specific Gravity	2.4 – 2.9	2.1 – 2.4
L. A. Abrasion Test Mass Loss	15% – 30%	20% – 45%
Sodium Sulfate Soundness Test Mass Loss	7% – 21%	18% – 59%
Magnesium Sulfate Soundness Mass Loss	4% – 7%	1% – 9%
Chloride Content	0 – 1.2 kg/m^3	0.6 – 7.1 kg/m^3

3.2 Collection of recycled coarse aggregate

Collected aggregate was crushed by using crushing machine shown in Figure 1. The sieve analysis was performed to get the graded coarse aggregate.

Three different sizes of aggregate were considered from the crushed recycled aggregate which were 1 inch passing and ¾ inch retained, ¾ inch passing and ½ inch retained, ½ inch passing and #4 retained in the sieve. Figure 2 shows the virgin and recycled coarse aggregates after crushing.

Gradation curve of crushed aggregate is shown in Figure 3 and Figure 4. From that gradation curve it is clearly seen that the proportion of aggregate is required 10%, 32% and 58% from 1 inch passing and ¾ inch retained, ¾ inch passing and ½ inch retained and ½ inch passing and # 4 sieve retained size of aggregate respectively. According to this proportion, the aggregates were mixed to get the graded mixing of RCA. In case of arbitrary mixing, 1 inch down-graded coarse aggregate was considered.

Figure 1: Locally available stone and brick crushing machine in Bangladesh

a. Virgin brick chips

b. Recycled brick chips

c. Virgin stone chips

d. Recycled stone chips

Figure 2: Pictorial view of different types of coarse aggregates

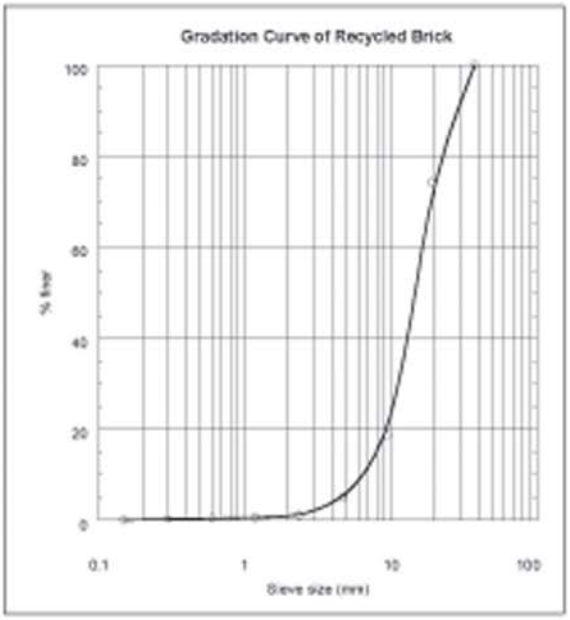

Figure 3: Gradation curve of RCA (brick)

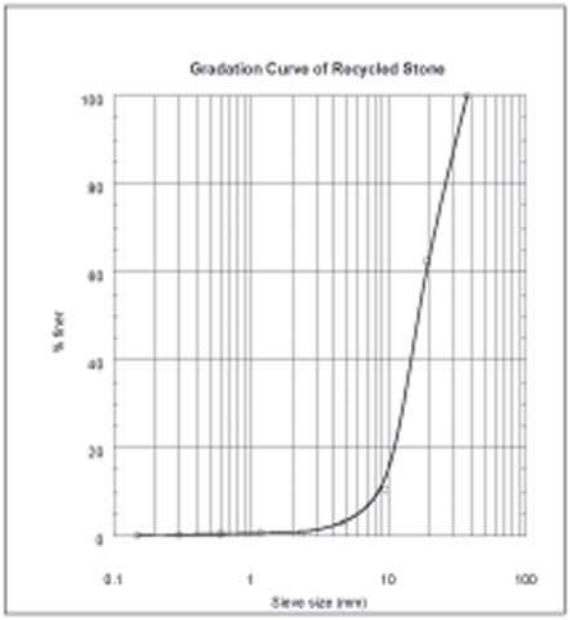

Figure 4: Gradation curve of RCA (stone)

4.0 MATERIAL PROPERTIES OF COARSE AGGREGATE

To determine the different properties of RCA (stone and brick) and VCA (stone and brick), different tests were performed and the obtained results are shown in Table 2.

Table 2: Material Properties of coarse aggregate

Material Properties	Bulk Specific Gravity (OD)	Bulk Specific Gravity (SSD)	Absorption Capacity (%)	Unit Weight (SSD) kg/m^3	Unit Weight (OD) kg/m^3	Los Angeles Abrasion Value (%)
VCA (stone)	2.46	2.48	0.52	1527	1501	30.92
VCA (brick)	1.85	2.15	16.48	1079	947	35.54
RCA (stone)	2. 54	2.54	3.65	1328	1317	36.75
RCA (brick)	1.8	1.99	10.26	1263	1136	39.37

5.0 COMPRESSIVE STRENGTH TEST RESULT OF CONCRETE CYLINDER

The compressive strength of concrete cylinders was tested based on the following two categories as per ASTM C39:

i. Arbitrary mixing of coarse aggregate

ii. Graded mixing of coarse aggregate

For the preparation of concrete cylinder, recycled brick chips, recycled stone chips and virgin brick chips and virgin stone chips used as coarse aggregate.

5.1 Arbitrary mixing

In case of arbitrary mixing of coarse aggregate, two mixing ratio were considered. The ratio of cement, sand and coarse aggregate for concrete mixture was 1:2:4 and 1:1.5:3. Compressive strength test result of concrete cylinder in case of arbitrary mixing for recycled and virgin (fresh) coarse aggregate is shown in Table 3 and Table 4.

5.2 Graded mixing

For the graded mixing, 1:2:4 and 1:1.5:3 concrete mixing ratios were followed as well. The tested values of the compressive strength in case of graded concrete mixing for recycled and virgin (fresh) coarse aggregate are shown in Table 5 and Table 6.

Table 3. Compressive strength of concrete cylinder (Arbitrary Mixing, Ratio 1:2:4)

Material Type	7 days	14 days	28 days
	Strength , MPa (Psi)		
Virgin (fresh) Brick chips	7.01 (1017)	8.73(1266)	12.63 (1832)
Virgin (fresh) stone chips	13.03 (1890)	15.63 (2267)	18.00 (2610)
Recycled brick chips	7.74 (1123)	9.33 (1353)	14.62 (2120)
Recycled stone chips	12.10 (1755)	14.78 (2144)	17.08 (2477)

Table 4. Compressive strength of concrete cylinder (Arbitrary Mixing, Ratio 1:1.5:3)

Material Type	7 days	14 days	28 days
	Strength , MPa (Psi)		
Virgin (fresh) Brick chips	10.28 (1491)	11.71(1698)	14.73 (2136)
Virgin (fresh) stone chips	15.20 (2204)	17.60 (2552)	20.70 (3000)
Recycled brick chips	11.65 (1690)	13.15 (1907)	16.34 (2370)
Recycled stone chips	14.75 (2139)	16.48 (2390)	18.64 (2700)

Table 5: Compressive strength of concrete cylinder (Graded Mixing, Ratio 1:2:4)

Material Type	7 days	14 days	28 days
	Strength , MPa (Psi)		
Virgin (fresh) Brick chips	6.57 (953)	7.53(1092)	11.26 (1633)
Virgin (fresh) stone chips	10.83 (1570)	15.91 (2307)	17.83 (2586)
Recycled brick chips	8.71 (1263)	10.50 (1523)	12.86 (1865)
Recycled stone chips	10.53 (1527)	13.08 (1897)	16.03 (2325)

Table 6. Compressive strength of concrete cylinder (Graded Mixing, Ratio 1:1.5:3)

Material Type	7 days	14 days	28 days
	Strength , MPa (Psi)		
Virgin (fresh) Brick chips	10.65(1545)	11.37(1650)	12.18 (1767)
Virgin (fresh) stone chips	15.56(2257)	17.93 (2600)	19.55 (2835)
Recycled brick chips	10.94 (1587)	11.79 (1710)	13.02 (1888)
Recycled stone chips	14.84 (2152)	16.16 (2344)	18.83 (2730)

6.0 COMPARISON OF CONCRETE COMPRESSIVE STRENGTH FOR VIRGIN (FRESH) AND RECYCLED COARSE AGGREGATE

28 days compressive strength comparison of arbitrary and graded mixing for 1:2:4 and 1:1.5:3 ratios in respect of RCA and VCA are shown in Figure 5 and Figure 6 respectively. Comparison of recycled brick chips to virgin brick chips and recycled stone chips to virgin stone chips exhibit a close value of compressive strength in both arbitrary mixing and graded mixing.

The compressive strength vs. age graphs in Figure 7 to Figure 10 provide a better assessment for using recycled coarse aggregate instead of the virgin (fresh) ones. Test result implies the positive response of using recycled coarse aggregate. Recycled brick chips in particular shows greater potential for construction works.

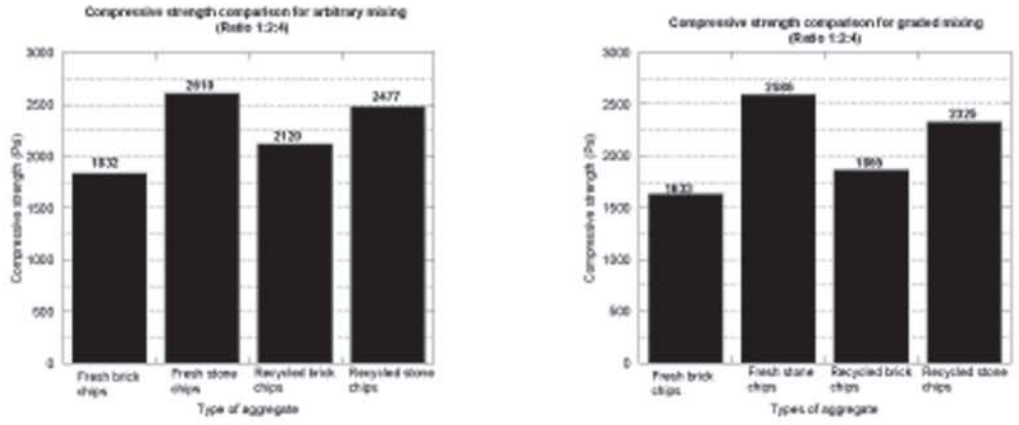

Figure 5: 28 days compressive strength comparison for 1:2:4 mixing ratio

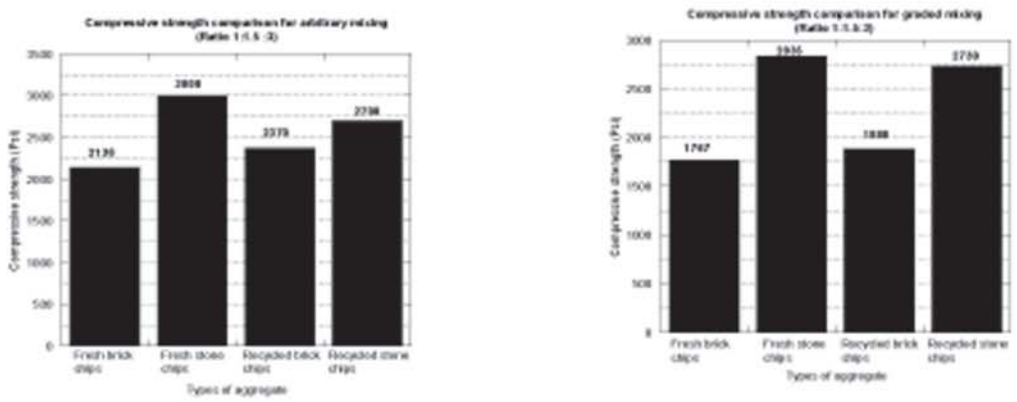

Figure 6: 28 days compressive strength comparison for 1:1.5:3 mixing ratio

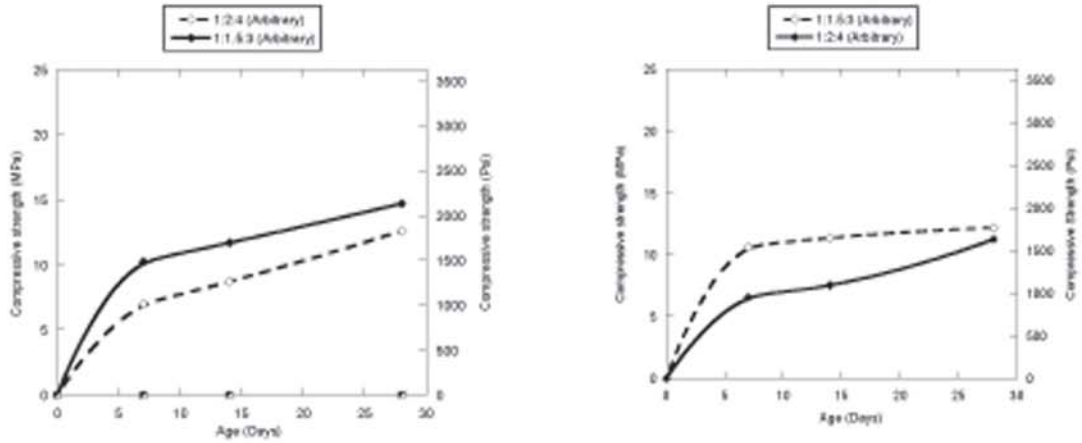

Figure 7: Compressive strength vs. age graph for brick chips

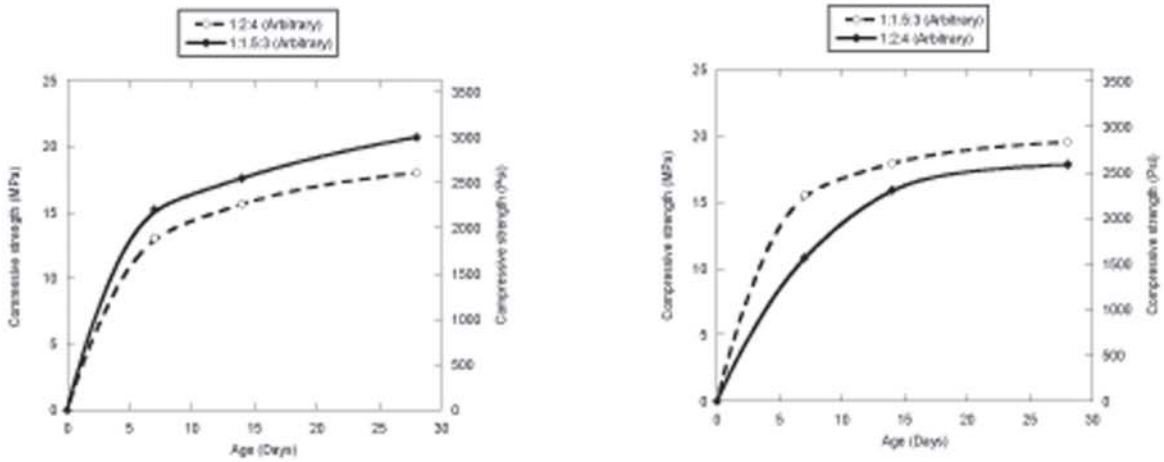

Figure 8: Compressive strength vs. age graph for stone chips

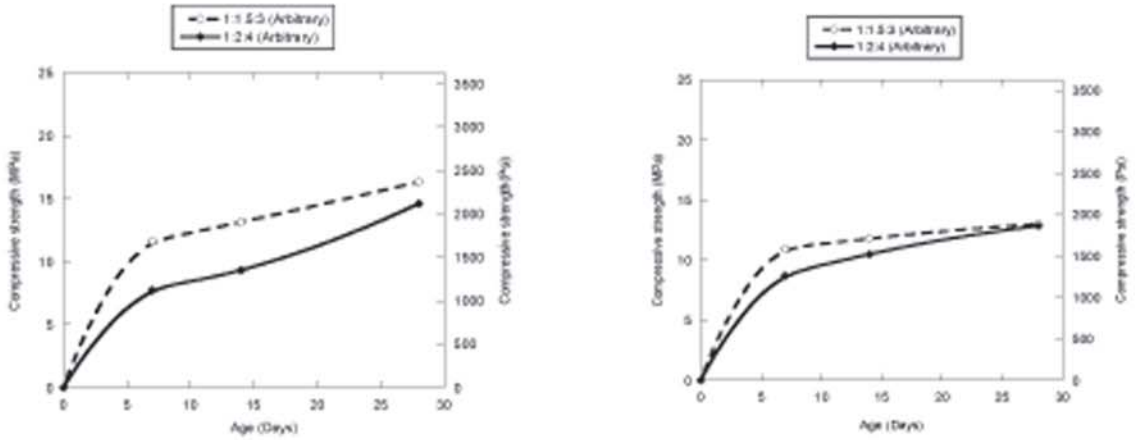

Figure 9: Compressive strength vs. age graph for recycled brick chips

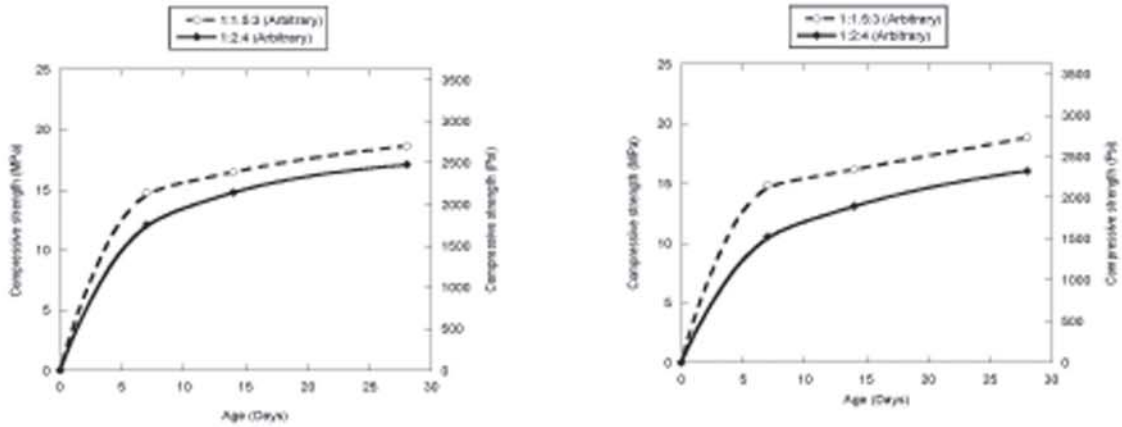

Figure 10: Compressive strength vs. age graph for recycled stone chips

7.0 RESULT AND DISCUSSION

This research work is aimed to study the concrete strength properties made of recycled coarse aggregate. Based on this research work, conclusions are drawn on the strength properties of this recycled aggregate. This led us to investigate properties of the recycled aggregate. Now, the conclusions are drawn based on the two categories.

Firstly, based on material properties:

i The value of unit weight of recycled stone aggregate and recycled brick aggregate is higher than virgin brick aggregate but lower than virgin stone aggregate.

ii This is expected to get more compressive strength of concrete in case of graded mixing comparing to arbitrary mixing but less concrete strength is found for graded mixing.

iii Abrasion value of Recycled coarse aggregate is close to virgin brick aggregate but higher than virgin stone aggregate.

iv Recycled stone has the higher absorption capacity than virgin stone. On the other hand, virgin brick aggregate has the higher value than recycled aggregate. It mainly occurs due to the outer surface texture of the recycled coarse aggregate. Conversely, virgin brick aggregate absorbs water through its porous portion but recycled brick aggregate has the rough cement mortar surface (lower absorption capacity) which resists the absorption of water. In case of recycled stone aggregate, outer cement mortar surface absorbs water with its lower absorption capacity whereas virgin stone cannot show this property.

Secondly, based on the tested value of the compressive strength:

i Two arbitrary mix (Cement: Sand: Coarse Aggregate, 1:2:4 and 1:1.5:3) were used for all four types of coarse aggregates (virgin brick, virgin stone, recycled brick, recycled stone). Laboratory test result shows that compressive strength of RCA (stone and brick) concrete is higher than virgin brick aggregate and to some extent; the value is close to virgin coarse aggregate.

ii In case of recycled brick aggregate, the concrete compressive strength is always higher than virgin brick aggregate. The ratio of concrete compressive strength of recycled brick aggregate and the virgin brick aggregate is around 1.12:1. So it is inferred that virgin brick aggregate is easily replaceable by the recycled brick aggregate.

iii In case of recycled stone aggregate, the concrete compressive strength is slightly lower than virgin stone aggregate. The ratio of the concrete compressive strength of recycled stone and the virgin stone is around 0.92:1.

8.0 CONCLUSION

The recycled stone aggregate can be the partial replacement of virgin stone aggregate and full alternative for both recycled and virgin brick aggregate. Based on this research, it is clearly seen that recycled coarse aggregates (stone and brick) have a bright future for the construction in Bangladesh.

9.0 RECOMMENDATION FOR FUTURE STUDY

Thermal response of the recycled coarse aggregate and detailed cost factor of using recycled coarse aggregate is good opportunity of the future study.

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