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USE OF SUPPLEMENTARY CEMENTITIOUS MATERIALS IN RECYCLED BRICK AGGREGATE CONCRETE

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ABSTRACT

Recycling of construction and demolition waste could be a great source of concrete aggregates. The use of waste concrete as recycled concrete aggregate conserves natural aggregate, reduces the impact on landfills, save energy and can provide a cost benefit. The scope of this project was to compare the concrete properties between recycled brick aggregate concrete and natural brick aggregate concrete by using a different percentage of fly ash, blast furnace slag, and super plasticizers to enhance the durability of the recycled concrete. Residual strength of structural members was determined by core cutting and the residual strength was around 15 MPa. The properties of recycled brick aggregate slightly varied from the natural brick aggregate. The specific gravity and unit weight of recycled brick aggregate was less than that of natural brick aggregate. The absorption capacity of recycled brick aggregate (12.84%) was higher than the absorption capacity of natural brick aggregate (11.26%). Total 18 batches of cylindrical specimens were cast for compressive strength, water permeability, and rapid chloride permeability test. The compressive strength was 20.09 and 24.27 MPa, respectively for the concrete made by recycled brick aggregate and natural brick aggregate at 28 days. By using 10%, 15%,and 20% blast furnace slag with recycled brick aggregate, the compressive strength at 28 days was found to be 21.81, 24.52 and 25.30 MPa, respectively. By increasing the percentage of fly ash to 10%, 15%, 20%, 25%, 30% and 35% with recycled brick aggregate, the compressive strength was decreased at 28 days but at 60 days the compressive strength was increased gradually up to 30% of fly ash. Water permeability and rapid chloride permeability was decreased with the increase of the compressive strength at 28 days. Properties like compressive strength, permeability, and rapid chloride permeability were comparable to that of the natural aggregate concrete.

Keywords: *Recycle Aggregate, Fly Ash, Blast Furnace Slag, Permeability, RCPT*

1. INTRODUCTION

In recent years, the escalating urbanization has led to excessive demolition work and construction activities, which consequently resulted in the production of large quantities of construction and demolition (C&D) waste, especially concrete waste. A huge amount of C&D waste has become available a seriously significant impact on the environment and society. The great recycling of concrete waste was identified as the most feasible way to minimize the growing problem of waste disposal through landfills. The application of recycled aggregates is important in providing alternative material sources to reduce the dependence of the construction industry on natural aggregates. A critical curtailment in the sources of natural aggregates is becoming a worldwide problem, especially in the face of the development of major urban centers. Demolition and construction waste produce a large amount of crushed concrete which increasing day by day. The annual rate of generation of construction waste is 1,183 million ton worldwide (Khaitan, 2013).In the year of 2011 to 2016, about 82,646,051 m^3 of C&D waste (average 16,529,210 m^3 per year) were generated in Tehran which only about 26% of them have been recycled (Asgari, A et al., 2017).Huge land area required for accompanied this huge amount of waste. Therefore, recycling construction waste is vital, to reduce land filling and to preserve the environment. Also, from the viewpoint of sustainable and green building technologies, the use of recycled aggregate (RA) in new concrete production has enlarged globally.

On the other hand, production and utilization of concrete are rapidly increasing, which results in increased consumption of natural aggregate as the largest concrete component. For example, two billion tons of aggregate are produced each year in the United States. Production is expected to increase to more than 2.5 billion tons per year by the year 2020 (Gonzalez & Young, 2004). This situation leads to a question about the preservation of natural aggregates sources. A possible solution to these problems is to recycle demolished concrete and produce an alternative aggregate for structural concrete in this way.

Moreover, Bangladesh is a developing country and her population is increasing day by day. Consequently, it is facing an alarming population explosion which is overshadowing all other fundamental problems. At the initial period of this century has to meet the increased demand for shelter for an increasing population, there will be a lot of demand for building materials. However, as the cost of building materials is becoming higher and higher, it has become necessary to search for low-cost available materials. So, increase in demand and decrease in supply of conventional aggregate for the production of concrete result in the need to identify new source of aggregate. At the same time, increasing quantities of demolished concrete from deteriorated and absolute structure are generated as waste materials in the same areas. Utilization of recycled concrete as an aggregate will contribute to the solution of the problem.

Almost every year Bangladesh is affected seriously by the conventional calamity. Flood is an annual affair in Bangladesh. A large portion of roads is damaged by this conventional calamity. It is to be noted that some old buildings, bridges, and culverts are also damaged by conventional calamity. In some areas, heavy urban expansion has depleted. So, as a developing country, the proper utilization of waste concrete as a coarse aggregate is an important national aspect. For this reason, in developing countries, restrictions and regulations on disposal sites will require greater recycling of this industrial waste.

2. METHODOLOGY

This study was divided into two parts, determination of Residual Strength before demolition the existing building and determination of the property of concrete after made with recycled aggregate with supplementary cementations materials &admixture.

2.1 Determination of Residual Strength

Cores were cut by a rotary cutting tool according to ASTM C-42. Three specimens were cut from 3 different columns before the demolition of the building behind the Civil Building of Khulna University of Engineering & Technology. Then the specimens were cut such as H/D ratio was 2. Then takes the dimension of the sample and weight. After 5 days the samples we recapped with lime and tested for compressive strength.

Figure 1: Core Sample

2.2 Determination of Recovered Strength

Recovered strength means the strength developed in the concrete made with recycled aggregate with supplementary cementations materials & admixture. This was including collection of materials, concrete casting and curing finally testing of strength.

2.2.1 Collection of Materials

Demolished concrete was collected from the demolished building behind the Civil Building of Khulna University of Engineering & Technology. This concrete was crushed as coarse aggregate by using hand tools. This aggregate denoted as Recycled Coarse Aggregate (RCA). New bricks were collected & crushed into natural coarse aggregate (NCA) Sylhet sand is used as natural fine aggregate. Blast Furnace Slag (BFS) and Fly Ash (FA) were collected from Seven Rings Cement, Khulna. Figure 2 shows Natural and Recycled coarse aggregate and Figure 3 shows Fly Ash and Blast Furnace Slag.

Figure 2: Natural Aggregate & Recycled Aggregate

Figure 3: Fly Ash and Blast Furnace Slag

2.2.2 Concrete Mixture Proportioning

A mix proportion (1:2:3.5) was selected for the concrete mixing with a water-cement ratio of 0.45. Concrete was mixed according to ASTM C192 (ASTM 2007) using a standard concrete mixture. (100mm×200mm) concrete cylinders were cast and compacted according to ASTM C39 (ASTM 2001). In this study total, eighteen batches of concrete were cast. Among the one batch were cast with Natural Coarse Aggregates (NCA), Natural Fine Aggregate (Sand) and Ordinary Portland Cement (OPC) another other seventeen batches were cast with Recycled Coarse Aggregate (RCA), Natural Fine (NFA) Aggregate and OPC. Three of them were cast by replacing natural fine aggregate with 10% to 20% blast furnace slag (BFS), six of them were cast by replacing 10% to 35% of cement with Fly Ash.

Table 1: Proportion of different materials

Specimen ID	**Coarse Aggregate (%)**		**Fine Aggregate (%)**		**Binder (%)**		**Admixture (%)**
	NCA	**RCA**	**Sand**	**BFS**	**OPC**	**FA**	
TSN-1	-	100	100	-	100	-	-
TSN-2	-	100	90	10	100	-	-
TSN-3	-	100	85	15	100	-	-
TSN-4	-	100	80	20	100	-	-
TSN-5	-	100	100	-	90	10	-
TSN-6	-	100	100	-	85	15	-
TSN-7	-	100	100	-	80	20	-
TSN-8	-	100	100	-	75	25	-
TSN-9	-	100	100	-	70	30	-
TSN-10	-	100	100	-	65	35	-
TSN-11	-	100	90	10	90	10	-
TSN-12	-	100	85	15	85	15	-
TSN-13	-	100	80	20	80	20	-
TSN-14	-	100	100	-	75	25	0.3
TSN-15	-	100	100	-	70	30	0.3
TSN-16	-	100	100	-	65	35	0.3
TSN-17	-	100	100	-	100	-	0.3
TSN-18	100		100	-	100	-	-

Three of them were cast by replacing natural fine aggregate with blast furnace slag and cement with fly ash other three batcheswas cast by replacing 25% to 35% cement with fly ash & 0.3% plasticizing admixture. Rest one batch was cast with recycled coarse aggregate, natural fine aggregate cement & 0.3% plasticizing admixture. The details mix design are shown in Table 1.

2.2.3 Determination of Compressive Strength

The compressive strength of concrete is one of the most important and useful properties of concrete. The compressive strength of concrete determined by testing cylinder made in the laboratory according to ASTM C39 (ASTM 2001). The details of compressive strength test are shown in Figure 4.

Figure 4: Illustration of prepared sample for compressive strength test

2.3 Determination of Permeability

Figure 5: Specimen for permeability test & experimental setup

Eighteen group of consisting of 10 cm diameter and 5 cm height cylindrical sample were tested. The sample was saturated and the standpipes were filled with de-aired water to a given level. The test then starts by allowing water to flow through the sample until the water in the standpipe reaches a given lower limit. The time required for the water in the standpipe to drop from the upper to the lower level was recorded. Often, the standpipe was refilled and the test was repeated for a couple of times. Each group contained one specimen. Figure 5 shows the specimen & experimental setup for permeability test. The test was performed at 28 days curing and the test was run for 16 hours. The recorded time should be the same for each test within an allowable variation of about 10%.

2.4 Rapid Chloride Permeability Test (RCPT)

The ability of concrete to resist permeability from aggressive elements (i.e., chloride ions) is key to the durability of reinforcing steel in concrete. To evaluate the resistance of concrete against chloride penetration, this test was performed according to ASTM C1202-5 one specimen per mixture at the age of 28 days. Concrete cylinders 100×200mm in size were prepared and cut into 50mm thick disks from the center of the specimen. Subsequently, the specimens were loaded into two Plexiglas half cells and sealed using silicone rubber. Each half cell had a reservoir filled with a solution of 3.0% NaCl at negative side and 0.3N NaOH at positive side. The cells were subjected to a 60-volt DC voltage across the specimen's cross section. The voltage was applied for 6h, and average charge passed (Coulombs) was recorded every 30 min. These values were adjusted by converting the charge passed through the diameter of the test specimens (100 mm) to the equivalent charge passed through a standardized diameter (95 mm). The schematic diagram of RCPT test is given in Figure 6. The rating of chloride ion penetrability Based on charged passed as per ASTM C1202 is given in Table 2:

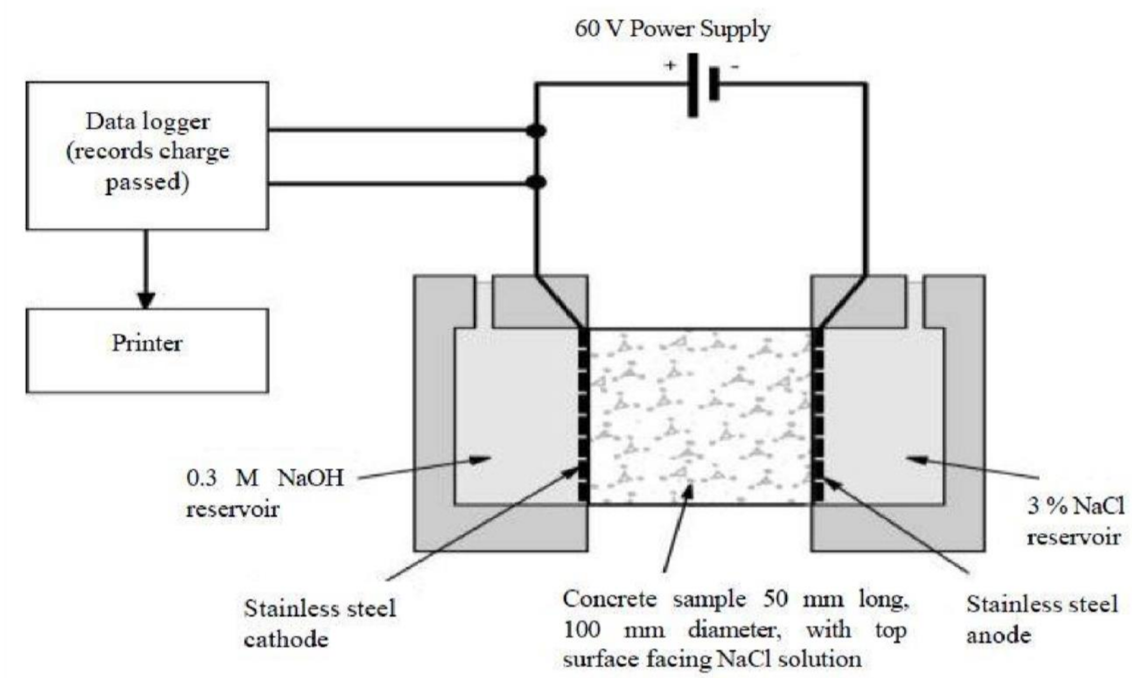

Figure 6: Schematic diagram of RCPT test

Table 2: Rating of chloride ion penetrability Based on charged passed (ASTMC1202)

Chloride Ion penetrability	Charge Passed (coulomb)
High	>4000
Moderate	2000-4000
Low	1000-2000
Very low	100-1000
Negligible	<100

3. RESULTS AND DISCUSSION

3.1 Core Cutting Test

The result of core cutting test is shown in Table3. The residual strength of existing column was 15MPa.

Table 3: Result of Core Cutting

Column	C1	C2	C3
Length of Cylinder (cm)	13.7	13.2	13.8
Diameter of Cylinder (cm)	6.9	6.9	7.0
Area of Cylinder (cm^2)	37.39	37.39	38.48
Volume of Cylinder (cm^3)	512.28	493.59	531.09
Weight of Cylinder (gm.)	1001.3	983.6	1039.8
Unit Weight of Cylinder (gm./cc)	1.95	1.99	1.96
Applied Load (KN)	57.8	55.4	53.0
Compressive Strength (MPa)	15.46	14.84	13.78
Compressive Strength (psi)	2240	2150	2000

3.2 Materials Properties

3.2.1 Grain Size Distribution

The result of the grain size distributions of the recycled coarse aggregate and natural coarse aggregate are shown in Figure 7 and the grain size distributions of fine aggregate (Sand) and Blast Furnace Slag (BFS) are shown in Figure 8. The natural coarse aggregate used for casting was same graded as the recycled coarse aggregate.

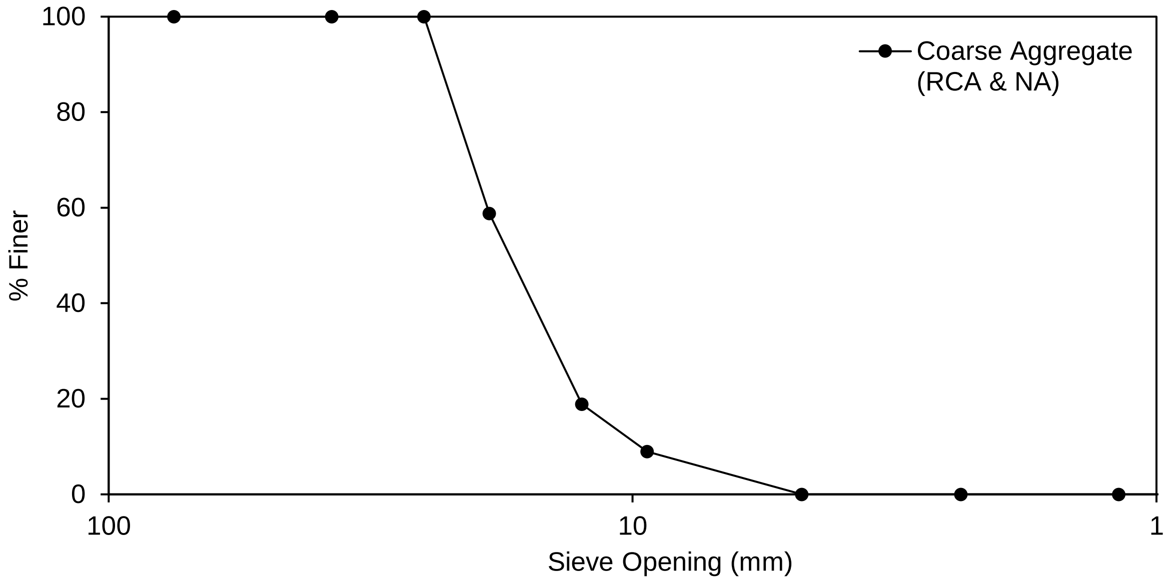

Figure 7: Grain size distribution curve of Coarse Aggregate

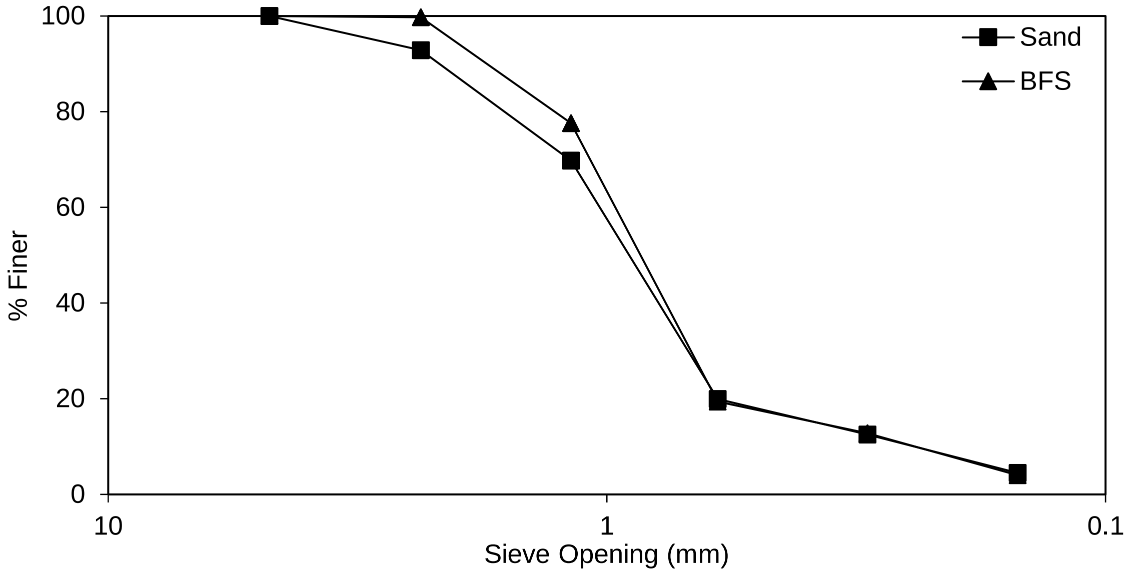

Figure 8: Grain size distribution curve of sand and Blast Furnace Slag (BFS)

3.2.2 Physical Properties

The specific gravity, unit weight, moisture content, absorption capacity & fineness modulus of coarse and fine aggregate was determined and the results are shown in Table 4. The specific gravity & unit weight of recycled coarse aggregate is lower than of thespecific gravity of the natural coarse aggregate. The specific gravity, unit weight, moisture content & absorption capacity of blast furnace slag is lower than that of the natural fine aggregate.

Table 4. Properties of Aggregate

Types of Aggregate	RCA	NCA	Sand	BFS
Specific Gravity	1.79	1.86	2.36	2.31
Unit Weight (kg/m^3)	1070	1148	1589	1339
Moisture Content (%)	3.46	1.40	2.40	1.25
Absorption Capacity (%)	12.84	11.26	5.82	4.17
Fineness Modulus	8.13	8.13	3.0	3.1

3.3 Properties of Concrete

3.3.1 Recovered Strength

Figure 9 shows the effects of Blast Furnace Slag (BFS) on the compressive strength of concrete. It shows that by increasing the amount of BFS replacing the natural fine aggregate (Sand) was increasing the compressive strength of concrete at 7 days, 28 days & 60 days. TSN-1 (RCA + sand + OPC) was a 28-day's compressive strength of 20.09MPa which was 17% lower thanTSN-18 (NCA + sand + OPC) was a compressive strength of 24.27MPa but TSN-4 (RCA + 80% sand + 20% BFS+ OPC) was a compressive strength of 25.21MPa which comparable with TSN-18.

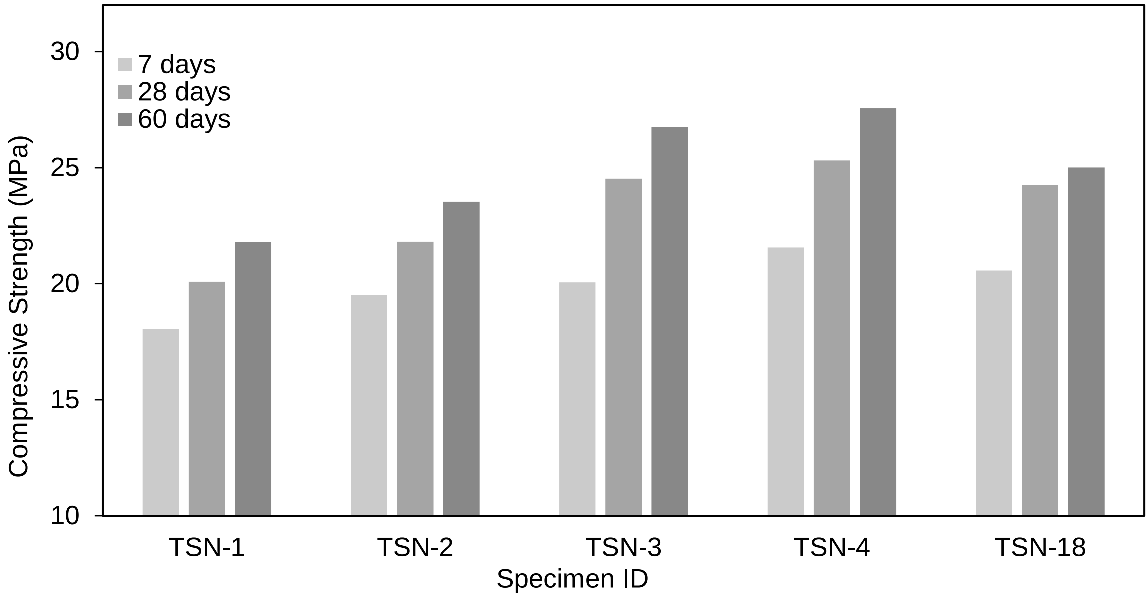

Figure 9: Effect of Blast Furnace Slag (BFS) on compressive strength of concrete

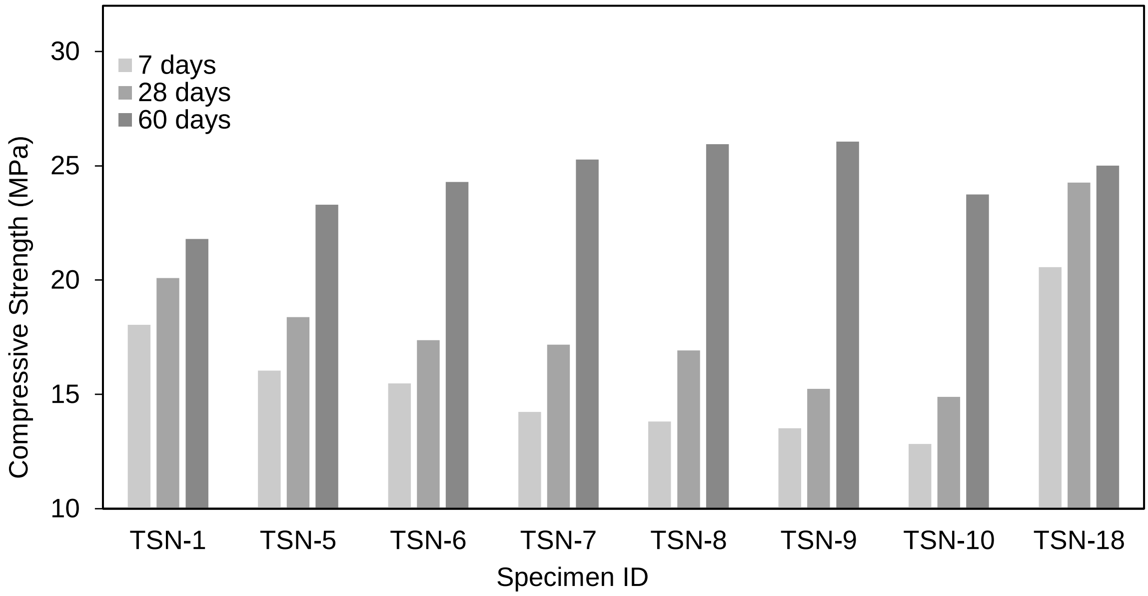

Figure 10: Effect of Fly Ash (FA) on compressive strength of concrete

Figure 10 shows the effect of fly ash on the compressive strength of concrete. It shows that by increasing the amount of fly ash replacing Ordinary Portland Cement (OPC) the compressive strength of concrete was decreasing at 7 days & 28 Days but increasing the compressive strength at 60 days up to replacing 30 % OPC by fly ash. Further increasing the amount of fly ash was reducing the compressive strength of concrete at 60 days also. From this figure of TSN-1 (RCA + sand + OPC) was a 28 days' compressive strength of 20.09MPa which was less than the compressive strength of TSN-18 (NCA + sand + OPC) was25.27MPa but by increasing the amount of fly ash TSN-5, TSN-6, TSN-7, TSN-8, TSN-9 and TSN-10 decreasing compressive strength at 28 days but TSN-9 (30% FA) was a compressive strength of 26.06MPa at 60 days which was comparable with the compressive strength of TSN-18 at 60 days.

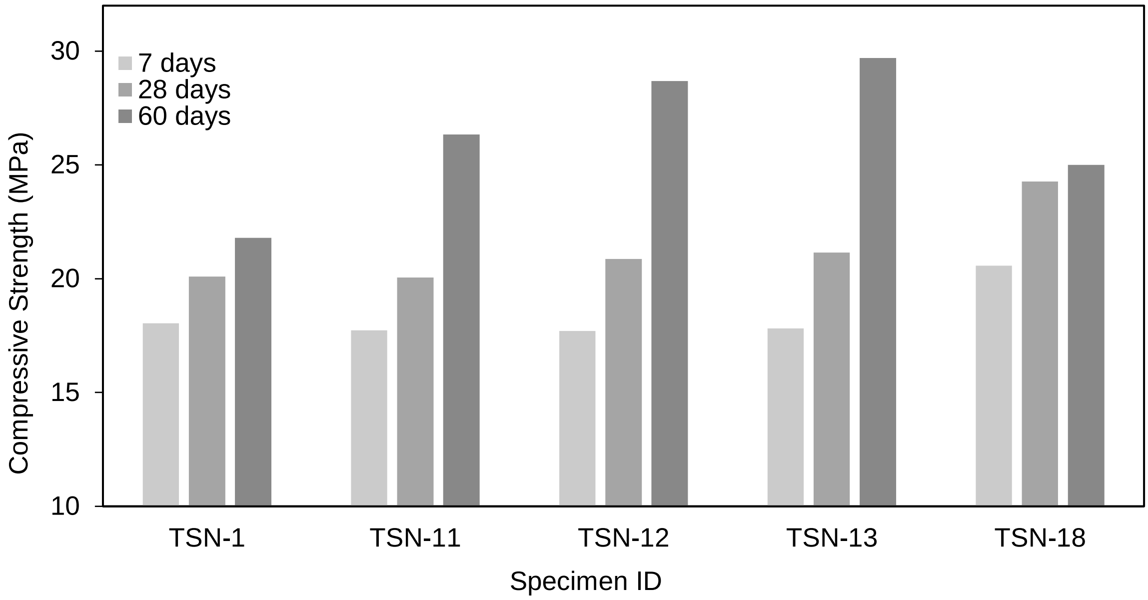

Figure 11: Effect of Fly Ash and Blast Furnace Slag on compressive strength of concrete

Figure 11: shows the combined effect of FA and BFS on the compressive strength of concrete. It shows that by increasing the amount of BFS replacing fine aggregate and FA replacing OPC was fewer effects on 7days & 28 days' compressive strength but increasing 60 days' compressive strength. TSN-11 (RCA + 90% sand + 10% BFS + 90% OPC + 10% FA) has a 28 days' compressive strength of 20.06MPa which is almost same of TSN-1 (RCA + sand + OPC) but TSN-12 (RCA + 85% sand +15% BFS + 85% OPC + 15% FA) & TSN-13 (RCA + 80% sand +20% BFS + 80% OPC + 20% FA) was slightly higher compressive strength than TSN-1, in 28 days' but at 60 days the compressive strength was higher than the compressive strength of TSN-18 (RCA + sand + OPC).

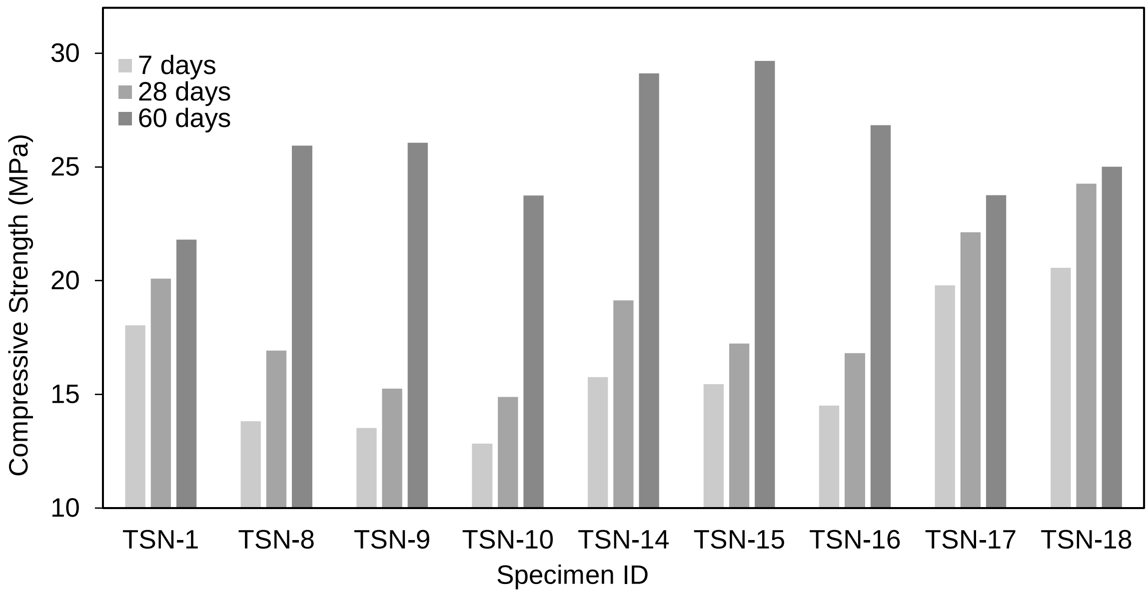

Figure 12: Effect of Fly Ash (FA) and Admixture on compressive strength of concrete

The effect of fly ash and plasticizer admixture on compressive strength is shown in Figure 12. It shows that by using of admixture the compressive strength was increased (8%-14%) Comparing TSN-1 (RCA+ sand + OPC) and TSN-17 (RCA + sand + OPC + 0.3% admixture) the compressive strength of TSN-17 was 10% higher than TSN-1 which comparable with

TSN-18. From this result, the compressive strength of the test samples was higher than the residual strength which was determined by core cutting.

3.4 Water Permeability

Figure 13 shows the results of permeability test. The permeability of concrete was decreased with the increase of 28 days compressive strength. The value of permeability was higher for TSN-10 (RCA + sand + 65% OPC + 35% FA) which was lowest compressive strength in 28 days, and lowest value for TSN-18 (RCA + sand +OPC). With the increasing of fly ash, the compressive strength in 28 days was decreased as a result permeability was increased, again with increasing of blast furnace slag the compressive strength was increased as a result the value of permeability was decreased.

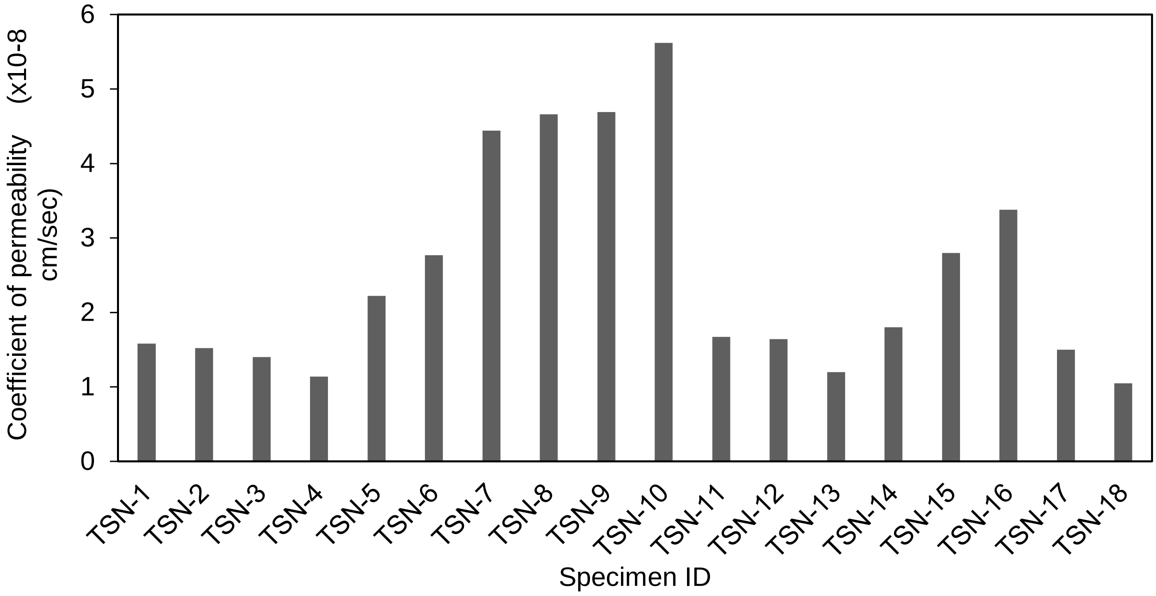

Figure 13: Water permeability of different specimen

3.5 Rapid Chloride Permeability

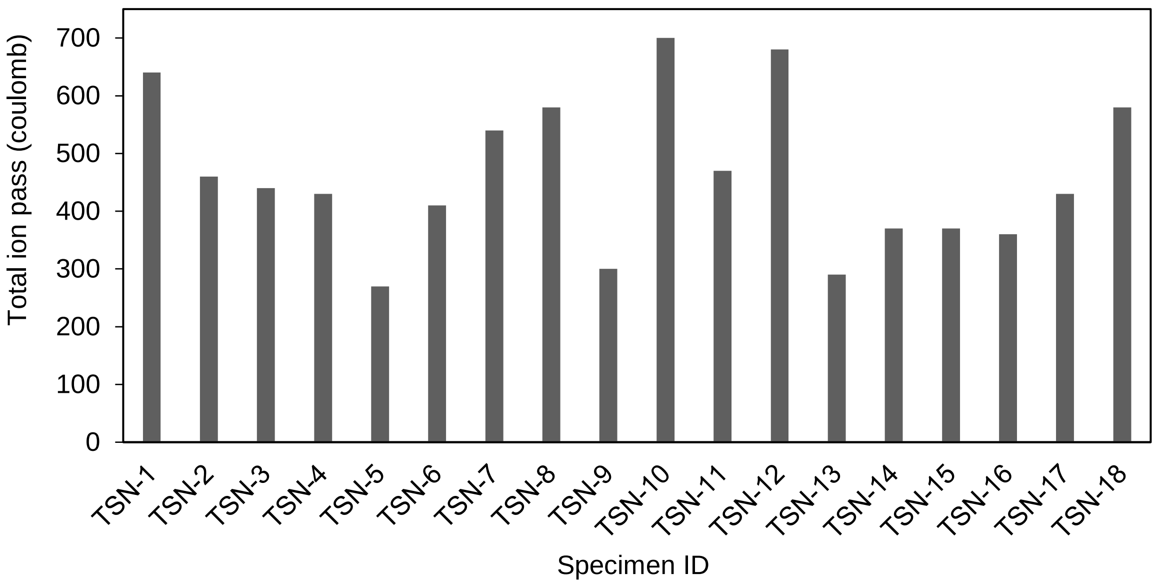

Figure 14: Rapid chloride permeability of different specimen

Figure 14 shows the result of rapid chloride permeability test. The result shows that total ion passes form TSN-1 (RCA + sand + OPC) 640 coulomb was higher than TSN-18 (RCA + sand + OPC) 580 coulomb total ion pass in TSN-17 (RCA + sand + OPC + 0.30% admixture). Figure 14 shows that by increasing the amount of blast furnace slag in TSN-2 to TSN-4 the value of passing ion was decreased. By increasing the amount of Fly Ash, the strength of concrete was decreased in 28 days and the value of passing ion was increased in TSN-5 to TSN-10. With the increased of compressive strength the value of total ion pass was decreased.

4. CONCLUSIONS

The recycled aggregate used in the present study fulfilled the requirements for RCA with respect to the physical and mechanical properties, however, the same were lower than those for natural aggregates. The natural aggregate concrete (TSN-18) and the RCA mix TSN-2, TSN-3, TSN-4,and TSN-17 exhibited similar behavior in compression. Chemical admixtures in the recycled concrete will modify significantly the properties of the fresh or hardened natural concrete. High concentration of water-soluble chloride ion in the recycled concrete may contribute to accelerated corrosion of steel embedment's in the natural concrete. It may be suggested that the properties of RCA are satisfactory for use in concrete; however, a detailed investigation on the long-term performance of RCA is needed before their actual use in structural infrastructure.

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