ANALYSIS OF COMPRESSIVE STRENGTH AND FAILURE PATTERN OF CONCRETE MADE OF DIFFRENT RATIO OF RECYCLED CONCRETE AGGREGATE AND NORMAL AGGREGATE

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering

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Argentina :18C
Summer-2023

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DECLARATION

It is hereby declared that this thesis any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated

to

"Our Beloved Parents & Teachers"

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ABSTRACT

In Bangladesh a huge development is in the part for recent year. For sustaining this development, huge amount of construction material is required. For continuing this, raw materials are required from natural resources from far side which is very much costly. Other hand a lot of old structures that had been constructed a quite long time are being demolished in recent times. Removing the debris from these demolished structures are also costly as well as they required a huge space for landfill. Rather than processing the new aggregate for construction work from bricks/Bolder is not environment friendly.

In this study, an attempt has been made to Recycled the old debris from demolished structures. The aggregate was separated from old debris with necessary screening, resizing as per construction codes & standards. Similarly regular aggregate was selected & mixed with Recycled aggregate with different mixing combinations. With same amount of cement, sand & water was mixed to form concrete cylinder to obtain concrete compressive strength. Then concrete compressive strength was compared to each other to evaluate the performance of Recycled aggregate.

From the study it is observed that compressive strength of concrete, containing regular aggregate has greater value than the concrete containing Recycled aggregate. Concrete containing more Recycled aggregate has least compressive strength. So, for low-rise Building/Structures proposed in locations where seismic zone is not severe, this Recycled aggregate can be used according proper guideline of Building Engineer. Thus, Recycled aggregate can play a vital role for development of country

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CHAPTER 1
INTRODUCTION

1.1 Background and Motivations

Concrete is one of the most widely used materials construction works. In Bangladesh a huge development is in the part for recent year. Construction of thousands of structures i.e. building, bridges, culverts, roads, railways, soil protection etc. a huge amount of construction material is required.

For continuing this, raw materials are required from natural resources from far side which is cost is not a little bit. on the other side, developing country like Bangladesh has little free land compared to a huge population. Some city in Bangladesh i.e., Dhaka is very dense with a huge old building constructed during 1960-1990. These structures are very much old & obviously they required demolition work to start new construction. This may include demolishing concrete foundations, driveways, sidewalks, walls and other building elements. The process results in large amounts of heavy construction materials that usually go to waste.

Furthermore a huge land will be required to dispose these demolished materials as well as requiring a huge transportation cost to land fill [1,2]

To mitigate the problems reusing this old concrete can be a better option. By Recycled of concrete construction costs can be minimized, since it saves the cost of transporting concrete to the landfill. Recycled also eliminates disposal costs, while reducing the environmental impact of the project.

Concrete that is recycled will not end up in landfills and can also replace raw materials. It can be used instead of gravel, for example, which must otherwise be collected and transported to the job site [3]

Hence from above short descriptions definition of concrete Recycled is "the use of rubble from demolished concrete structures is called Recycled Concrete" [4]

1.2 Research Objectives and Overview

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The objectives of the research work are as follows:

a) To obtain in-depth knowledge about Recycled of Concrete

b) To evaluate the compressive strength of concrete using Recycled aggregate & normal aggregate with different mixing ratio

c) To evaluate & differentiate the strength of normal concrete & concrete using Recycled aggregate. Hence finally evaluate the feasibility of Recycled concrete as buildings / structural materials

1.3 Organization of the thesis

Chapter 1: Introduction and Objective. provides a statement of the objectives of the study, followed by the methodology and a brief description of the contents of the chapter.

Chapter 2: Literature Review. Introduces Recycled Concrete, importance of Recycled concrete, process of Recycled concrete, Uses with precautions of Recycled concrete.

Chapter 3: Methodology. Deals with the details about preparation of samples using coarse aggregates from recycled concrete & Normal aggregates, curing procedure, testing procedure etc**.**

Chapter 4: Results and Discussion. This is the chapter where the actual comparisons were documented. The results are also discussed here.

Chapter 5: Conclusions and Future Work. Documents the conclusions and recommendations based on the analysis results.

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CHAPTER 2
Literature Review

2.1 Introduction

Concrete is one of the most widely used materials globally. In 2009, the International Energy Agency reported that ~25 Gt (Metric Gigaton) of concrete is used each year globally,[4] which is equivalent to > 3.8 tons of concrete per person per year. The demand of construction aggregate was projected to reach 48.3 billion metric tons by 2015; the highest consumption was to be in Asia and the Pacific.[5] Demolition to make space for new structures generates a large volume of waste. Among various types of construction and demolition waste, concrete waste accounts for 50% of the total waste generation. So, Recycled concrete is the probable & realistic solve in this huge demand of construction aggregate.

2.2 Concrete Recycled:

Concrete Recycled is the use of rubble from demolished concrete structures. Recycled is cheaper and more ecological than trucking rubble to a landfill.[6] Crushed rubble can be used for road gravel, revetments, retaining walls, landscaping gravel, or raw material for new concrete. Large pieces can be used as bricks or slabs, or incorporated with new concrete into structures, a material called urbanite [7,8]

2.3 Source of Recycled Concrete:

Recycled of waste concrete is done to reuse the concrete rubble as aggregates in concrete [10, 21]. The recycled aggregate has less crushing strength, impact resistance, specific gravity and has more absorption value as compared to fresh aggregates. Millions of tons of waste concrete are generated every year around the world due to following reasons [11, 12]:

(a) Demolition of old structure.

(b) Destruction of buildings and structures during earthquakes and wars.

(c) Removal of useless concrete from structures, buildings, road pavements etc.

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(d) Waste concrete generated due to concrete cube and cylinder testing, destructive methods of testing of existing structures etc.

2.4 Process of Recycled Concrete

Recycled concrete Particles processed in steps with time and effort involved in some steps i.e., crushing, pre-sizing, sorting, screening, and contaminant elimination. The process is to start with clean; quality rubble in order to meet design criteria easily and ultimately yield a quality product that will go into end use shown in Figure 1

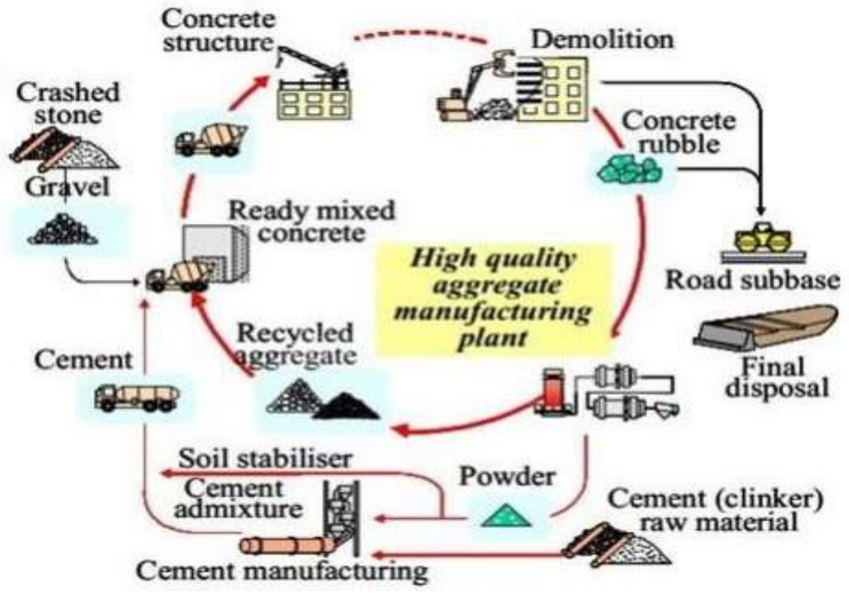

Figure 2.1 Process of waste concrete Recycled

Crushing and screening systems start with primary jaws, cones & large impactors taking rubble from 30 inches to 4 feet. A secondary cone or impactor may or may not need to be run, and then primary and secondary screens may or may not be used, depending upon the project, the equipment used and the final product desired. A

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scalping screen will remove dirt and foreign particles. A fine harp deck screen will remove fine material from coarse aggregate [14, 17].

Further cleaning is necessary to ensure the recycled concrete product is free of contamination i.e., dirt, clay, wood, plastic, and organic materials. This is assured by water floatation, hand picking, air separators, and electromagnetic separators. Occasionally asphalt overlay or patch is found. A mixture of asphalt and concrete is not recommended but small patches are not detrimental. The more care that is put into the quality, the better product can be received. With sound quality control and screening one can produce material without having to wash it as with virgin aggregate which may be ladened with clay and silt [18, 19].
Usually, demolished concrete was shipped to landfills for disposal, but due to greater environmental awareness, the concrete is being recycled for reuse in concrete works.

2.5 Benefits of Recycled Concrete

There are a lot of advantages in Recycled concrete rather than dumping it or burying it in a landfill. Keeping concrete debris out of landfills saves space there. Other benefits of Recycled of concrete are [20, 21]

(a) Local product – local sources.

(b) Reduces truck traffic.

(c) Alternative to a non-renewable resource.

(d) Cost savings.

(e) No disposal fees.

(f) Better trucking utilization (reduced costs). Using recycled material as gravel reduces the need for gravel mining.

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There are also economic benefits. Recycled concrete is a construction material that the community does not need to pay for; those who generated the concrete waste pay a fee to have it recycled [22, 28].

The strength of recycled aggregate concrete is about 10 to 15 per cent less as compared to concrete with fresh aggregate. However suitable mix designs may be made and reliable results obtained. The mix requires slightly higher quantity of cement or using admixtures to reduce water requirement. Recycled aggregate concrete can be safely used as plain concrete. With proper corrections in mix design, it can be used for R.C.C. works also. There are no longer any

regulatory or legal barriers to the use of recycled concrete as concrete aggregate. ASTM includes crushed hydraulic-cement concrete in its definition of concrete aggregates [13, 31]. The Federal Highway Administration and the U.S. Army Corps of Engineers has encouraged the use of recycled concrete in their projects [14, 31]. Collection and sorting of construction debris is becoming a standard practice required by many states and municipalities. For example, authorities in Hawaii issued the publication, A Contractor’s Waste Management Guide, which requires the use of recycled concrete and establishes policies and practices for managing waste materials [14, 27]. In Europe, Canada, and Japan, concrete Recycled is regulated and often mandated. In particular, Germany promulgated the national setting the guidelines for recycled concrete content in concrete aggregate [14].

German researchers demonstrated that recycled aggregate does not affect most performance characteristics of concrete, although it tends to increase drying shrinkage and creep, and reduce modulus of elasticity [14, 16]. In Canada, the C-2000 Green Building Standards aim at making recyclable up to 75% of the existing structure and shell.

However, this program does not require any processing of concrete other than separation from other demolition debris [17, 32]. In Japan, the draft standard for use of recycled concrete was published in 1977 [18, 24]. According to [19,33], Florida Statutes (F.S.), construction and demolition debris is currently defined as discarded materials generally considered to be not water-soluble and non-hazardous in nature, including, but not limited to, steel, glass, brick, concrete, asphalt roofing material, pipe, gypsum wallboard, and lumber, from the construction or destruction of a

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structure as part of a construction or demolition project or from the renovation of a structure, and including rocks, soils, tree remains, trees, and other vegetative matter that normally results from land clearing or land development operations for a construction project, including such debris from construction of structures at a site remote from the construction or demolition project site.

The North Carolina Solid Waste Management Act of 1989 requires that construction and demolition debris be separated from the waste stream and segregated at sanitary landfills [20, 25, 26].

To encourage Recycled and reuse, regulations divide the waste stream into four categories: construction or demolition wastes, land-clearing wastes, inert wastes, and yard trash. They recommend the following methods for handling these materials: (a) construction and demolition debris should be separated into recyclable and non-recyclable material; (b) _inert debris (defined by the state as concrete, brick, concrete block, uncontaminated soil, rock, and gravel) should be recycled and reused as clean fill material; (c) yard trash and land-clearing debris should be reduced, reused, or recycled as mulch or compost [21, 27, 34]

2.6 Properties of Recycled Concrete

This section discusses the properties of Recycled concrete aggregate (RCA) as compared to Normal aggregate (NA). An understanding of how the aggregate changes after already being used in concrete can improve the ability to describe why Recycled concrete aggregate may perform differently when used in new concrete than Normal aggregate. The main aggregate properties that are presented are the density, porosity, and water absorption of the aggregate, the shape and gradation of the aggregate, and the aggregate resistance to crushing and abrasion.

2.6.1 Density, Porosity, and Water Absorption:

Residual adhered mortar on aggregate is a main factor affecting the properties of density, porosity, and water absorption of RCA. The density of RCA is generally lower than NA density, due to the adhered mortar that is less dense than the underlying rock. The variation in density is dependent on the specific aggregate in question. A study by Limbachiya et al. (2000) showed that the relative density of

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RCA (in the saturated surface dry state) is approximately 7–9 % lower than that of NA. Sagoe-Crentsil et al. (2001) reported bulk densities of 2,394 and 2,890 kg/m3 for RCA and NA, respectively, approximately a 17 % difference. The adhered mortar can be lightweight compared to aggregate of the same volume, which causes the decrease in density.

Porosity and water absorption are related aggregate characteristics, also attributed to residual mortar. NA generally has low water absorption due to low porosity, but the adhered mortar on RCA has greater porosity which allows the aggregate to hold more water in its pores than NA. Shayan and Xu (2003) found water absorption values of 0.5–1 % for NA and 4–4.7 % for RCA in the saturated surface dry condition, up to a 4.2 % difference. Other studies showed differences where RCA absorption was 5.6 and 4.9–5.2 % compared to NA absorption of 1.0 and 2.5 % (Sagoe-Crentsil et al. 2001; Limbachiya et al. 2000).

The aggregate characteristics of density, porosity, and water absorption are a primary focus in determining the proper concrete mix. These characteristics should be known to limit absorption capacity of aggregates to no more than 5 % for structural concrete, and thus the proportion of RCA is often limited in concrete mixes (Exteberria et al. 2007), as is discussed later in this paper. Table 1 summarizes acceptance criteria for RCAs used worldwide.

2.6.2 Shape and Gradation:

The shape of the aggregate pieces is influential on the workability of the concrete. Exteberria et al. (2007) warned that the method of producing RCA and the type of crusher that is used in this process is influential in the shape of RCA produced. NA is generally an angular shape with smooth sides. Sagoe-Crentsil et al. (2001) initially described the plant-produced RCA as grainy in texture and later discussed that the RCA has a more rounded, spherical shape which seemed to improve workability. The residual mortar on RCA can smooth out the hard edges of the original aggregate. This allows the new mortar to flow better around the aggregate. The effects of the aggregate shape on workability and strength parameters of concrete are discussed further later in this paper.

Standards for concrete aggregate define a range within which the gradation of aggregate must lie in order to be acceptable aggregate for structural concrete. Both Sagoe-Crentsil et al. (2001) and Shayan and Xu (2003) found that the gradation

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curves of RCA were within this specified range. This indicates that RCA should have acceptable gradation by applicable standards without adjustments being made.

2.6.3 Crushing and L.A. Abrasion:

Crushing and Los Angeles (L.A.) abrasion tests are measures of the durability of aggregate material on its own. There is a general trend that RCA has higher values for crushing and L.A. abrasion than NA, meaning when the aggregate is contained and crushed or impacted by steel balls in the L.A. abrasion test RCA has more fine particles break off of than NA. Crushing tests resulted in values of 23.1 % for RCA vs. 15.7 % for basalt (a NA) and 24 % for RCA vs. 13 % for basalt in two separate studies (Sagoe-Crentsil et al. 2001; Shayan and Xu 2003). L.A. abrasion values for RCA versus NA were found in two studies as 32 vs. 11 % and 26.4–42.7 vs. 22.9 % (Shayan and Xu 2003; Tavakoli and Soroushian 1996). This is a reasonable result for these tests, in that the RCA has residual mortar that can break off easily at the interfacial transition zone (ITZ), which is the typically weak area of concrete. It is logical that, when subjected to loading, the residual mortar on RCA would break off, while NA does not have a similar coating to lose.

The behavior of RCA in crushing and abrasion tests demonstrates the weakness of the adhered mortar. Since this layer is most likely to break off the aggregate itself, it is predicted that the adhered mortar layer may also create a weak connection within concrete.

2.7 Recycled Concrete Aggregate Materials Properties

Since the recycled aggregate has different properties than NA, it behaves differently in concrete mixes and causes the finished concrete to perform unlike conventional concrete. This section describes the variation between the properties of RCA concrete compared to conventional NA concrete.

2.7.1 Compressive Strength:

Compressive strength of RCA concrete can be influenced by the properties and amount of recycled aggregate. Several factors can influence the compressive strength in RCA concrete, including the water/cement (w/c) ratio, the percentage of coarse aggregate replaced with RCA, and the amount of adhered mortar on the RCA. Most research recommended that, without changes to the mix involving adjustments to the

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w/c ratio, up to 25 or 30 % of coarse aggregate can be replaced with RCA before the ceiling strength is compromised. In a study by Limbachiya et al. (2000), concrete specimens made with up to 30 % RCA had equal compressive strengths for w/c ratios greater than 0.25 as seen in Fig. 2, which shows trends for compressive strengths for three RCA fractions as they vary with w/c ratio. The data for 30 % RCA follows that of 0 % RCA for almost every w/c ratio tested, while the 100 % RCA data lie at compressive strength values below that of 0 or 30 % RCA by about 5 N/mm2. At the lowest w/c ratios, the compressive strengths for mixes with RCA become more dissimilar to conventional concrete.

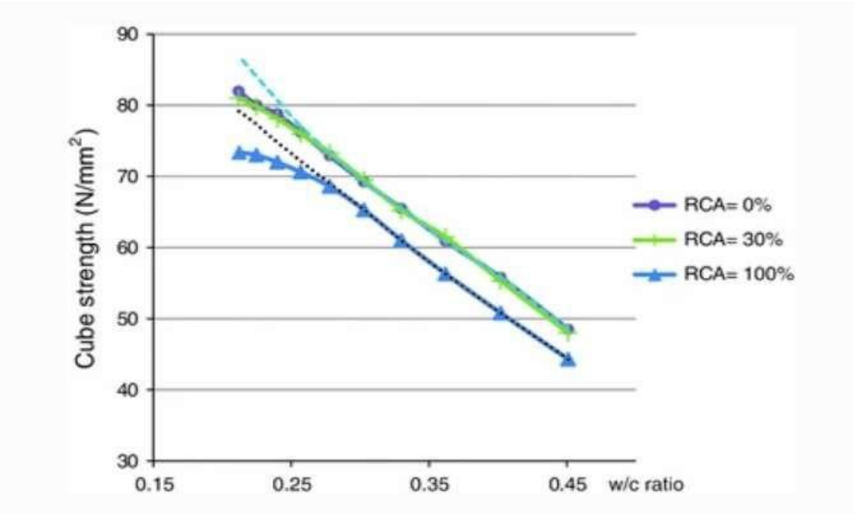

Figure 2.2 Concrete compressive strength versus water-to-cement ratio for RCA contents of 0–100 % (plotted using data from Limbachiya et al. 2000).

Exteberria et al. (2007) found similar behavior with tests using 25 % RCA that performed as well as conventional concrete with the same w/c ratio. This study tested concrete made with 0, 25, 50, and 100 % RCA concrete mixes and concluded that up to 25 % could be replaced without significant change in compressive strength or a different w/c ratio; however, to obtain the same strength with 50–100 % RCA, w/c ratio needed to be 4–10 % lower, and without this alteration, the compressive strength for 100 % RCA mixes was reduced by 20–25 % (Exteberria et al. 2007). Recent tests by Kang et al. (2012) also showed that the compressive strength was reduced by about 25 % for the same mix but with 50 % RCA, and reduced by up to 18 % for 15–30 % RCA mixes (Table 2).

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Yang et al. (2008) attributed a reduction in compressive strength for RCA concrete to the increased water absorption of the aggregate and found that at relatively low water absorption (relatively low RCA fraction) concrete had equivalent compressive strengths while higher RCA fractions and absorption compressive strengths were 60–80 % of that of conventional control concrete, but that the compressive strength improved with age. Since the aggregate can store
more water, this water can be released into the new mortar over time to continue to feed the cement for longer time, which improves strength.
The degree of strength reduction in RCA concrete does vary with each source aggregate. Froudinstou-Yannas (1977) also found that some mixes replacing 100 % of coarse aggregate with RCA had about 76 % of the compressive strength of conventional concrete, while mixes using different w/c ratios had as low as 4 % reduction in compressive strength. Furthermore, a report by Tavakoli and Soroushian (1996) studied compressive strength of concretes made with two different sources for RCA side-by-side. It is found that while RCA usually reduces concrete compressive strength due to higher water absorption of the aggregate and the weak residual mortar layer.
It is possible to produce concrete that is stronger than a conventional concrete if the source concrete is stronger than that at which the RCA concrete is intended to perform. It would be recommended that when using RCA for structural concrete applications, strength tests be performed to ensure what strength of concrete the RCA is capable of producing and verify what RCA fraction is acceptable or if there are changes in the w/c ratio needed in order to produce concrete of the desired strength.

2.8 CONCRETE CURING:

Curing is the process of maintaining satisfactory moisture content and temperature in freshly cast concrete for a definite period immediately following placement. The process serves two major purposes:
It prevents or replenishes the loss of moisture from the concrete;
It maintains a favorable temperature for hydration to occur for a definite period.

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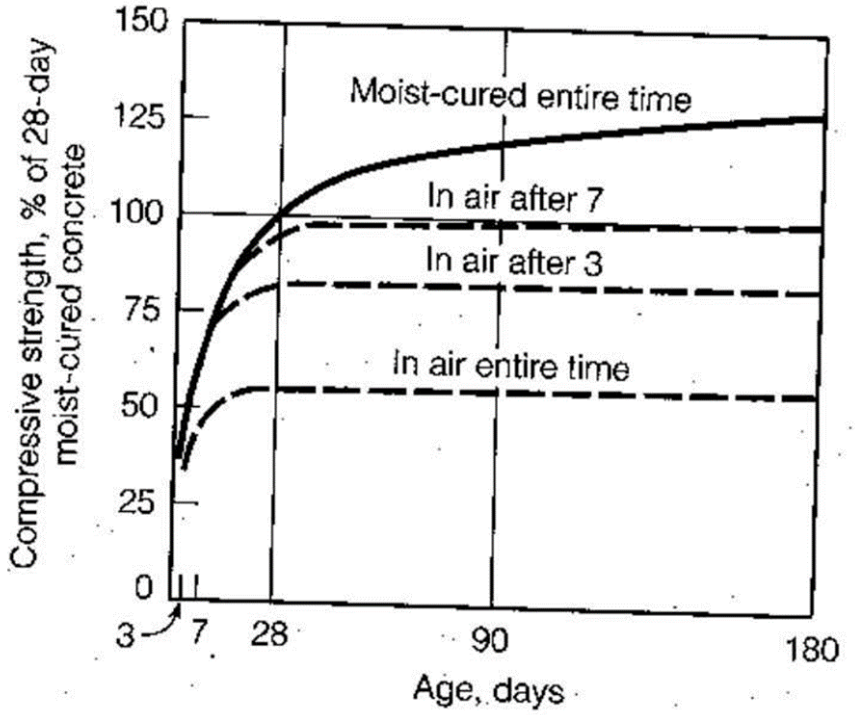

Variation of concrete strength with curing environment [Source: Mamlouk & Zaniewski]

Figure 2.3 Variation of concrete strength with curing environment [source: Mamlouk & Zainewski]

The most crucial time for strength gain of concrete is immediately following placement. In field conditions, heat and wind can dry out the moisture from the placed mixture. The accompanying figure shows how concrete strength varies with curing conditions. Concrete that is allowed to dry in air will gain only 50% of the strength of continuously moist-cured concrete.

Lack of water also causes the concrete to shrink, which leads to tensile stresses within the concrete. As a result, surface cracking may occur, especially if the stresses develop before the concrete attains adequate tensile strength.

Hydration is an exothermic chemical process, increasing the ambient temperature will increase the rate of hydration, and hence of strength development, while lowering it will have the opposite effect. Too much heat reduces the final concrete strength. Selecting an appropriate curing process helps in temperature control during hydration

2.9 CONCRETE COMPRESSIVE STRENGTH (CYLINDER TEST):

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The compressive strength of the concrete cylinder is one of the most common performance measures performed by the engineers in the structural design. Here, the compressive strength of concrete cylinders is determined by applying continuous load over the cylinder until failure occurs. The test is conducted on a compression-testing machine.

The sample cylinder prepared can be any of the two dimensions as mentioned below. The diameter of the cylinder cast must be at least 3 times the nominal maximum size of the coarse aggregate employed in the concrete manufacture. The apparatus required is mentioned below:

Compression testing machine Cylinder mold of 150mm diameter and 300mm height or 100 x 200mm Weighing balance.

2.9.1 Sample Preparation:

The cylinder specimens are cast in steel, cast iron or any mold made of non-absorbent material. Even under severe conditions, the moulds used must retain its original shape and dimensions. The mold must hold the concrete without any leakage. Before placing the concrete mix within the mold, the interior of the mold must be properly greased to facilitate easy removal of the hardened cylinder. The mixed concrete is placed into the molds in layers not less than 5cm deep. The strokes per layer during the compaction must not be less than 30 in number. Compaction must reach the underlying layers allowing most of the air voids to escape. The specimens are stored undisturbed in a place with at least 90% relative humidity at a temperature of 27° ± 2°C for 24 hours. After this period, the samples are taken and submerged in clean and fresh water until the testing age is reached.

Test Procedure:

1. The concrete cylinder is cast for standard size and allowed to cure for 28 days. Three specimens of the same dimension are cast for testing.

2. Takeout the specimen from the curing tank.

3. Wipe out the excess water from the surface of the specimen.

4. Place the specimen vertically on the platform of compression testing machine. Uniform load application and distribution is facilitated by having pad caps at the ends of the cylinders.

5. Before starting to apply the load, make it sure that the loading platforms touch the top of the cylinder.

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6. Apply the load continuously and uniformly without shock at the rate of 315 kN/min. And continue the loading until the specimen fails.

7. Record the maximum load taken.

8. The test is repeated for the remaining two specimens.

Figure.2.3 Concrete Cylinder for Compression Test

Figure.2.4 Fractured Concrete Cylinder Specimen at Failure

2.9.2 Compressive Strength of Concrete Cylinder:

Compressive strength = (Maximum load/ Cross-sectional area**)**

2.9.3 Result of Cylinder Test:

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The 28th day compressive strength of cylinder = 20 N/sqmm

2.10TYPE OF CONCRETE FAILURE:

Figure 1, from ASTM C 39 "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens Concrete Specimens, " shows six different types of fracture. This standard requires that reports This standard requires that reports include the type of fracture "if other than the usual cone."

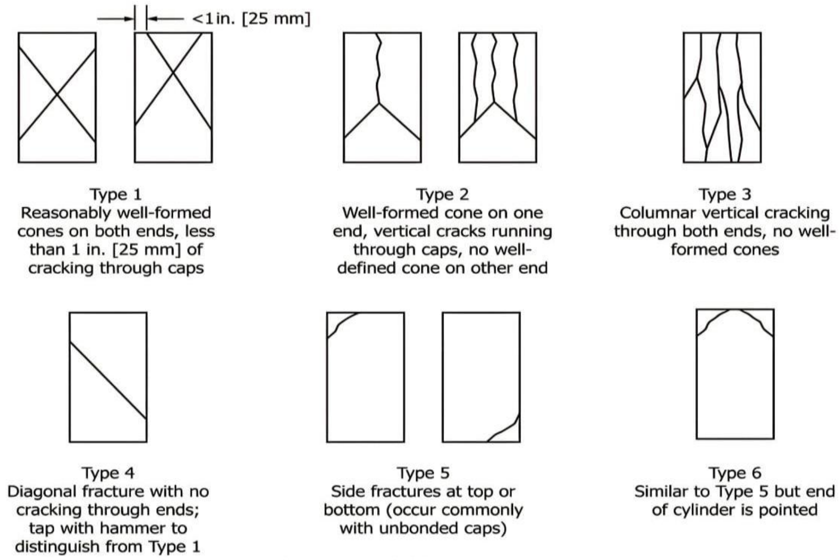

Figure 2.5 concrete failure type as per ASTM C39/C39M-10

A cone failure results when friction at the platens of the testing machine restrains lateral expansion of the concrete as the vertical compressive force is applied. This restraint confines the concrete near the platens and results in two relatively undamaged cones when the cylinder is tested to fracture.

If the friction were eliminated, the cylinder would expand more laterally and exhibit a splitting failure like that shown in Fig l Such vertical splitting has been observed in similar to that shown in Fig. . Such vertical splitting has been observed in numerous tests on high-strength specimens made of mortar or neat cement paste, but the effect is

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less common in ordinary concrete when coarse aggregate is present (Neville, A., Properties of Concrete, 4th Ed., Prentice Hall, 1995).

The "Manual of Aggregate and Concrete Testing," included as related material in Volume 4.02 of the 2003 Annual Book of ASTM Standards, states that the type of fracture may be of assistance in determining the cause for the compressive strength of a tested cylinder being less than anticipated. The manual describes a case in which a fracture type that didn't match any of those in Fig. 1 had been noted in a large number of tested cylinders. A photo of the atypical failure shows a crack parallel to the ends and at about mid height in the cylinder.

This failure mode was taken as an indicator of nonstandard testing procedures. The ASTM documents do not give any further information regarding causes for types of fracture other than the typical cone or whether any of the types shown are bad or good. When unbonded neoprene caps are

used to determine concrete compressive strength, the broken cylinder only rarely exhibits the conical fracture typical of capped cylinders, and the sketches shown in Fig. 1 are not descriptive (ASTM C 1231, "Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders"). When neoprene caps are used, if requirements for perpendicularity of the cylinder ends or vertical alignment during loading aren't met, load applied to the cylinder may be concentrated on one side of the specimen.

This can cause a short shear failure similar to that shown in Fig. l(d), except that the failure plane intersects the end of the cylinder. This type of fracture generally indicates the cylinder failed prematurely, yielding results lower than the actual strength of the concrete (Kosmatka, Kerkhoff, and Panarese, “Design and Control of Concrete Mixtures,” PCA, 20

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CHAPTER 3
Methodology

3.1 Introduction

Development of project is described in this chapter. One of the major objectives of this work is to evaluate compressive strength of concrete using regular aggregates & concrete using recycled aggregates with different mixing ratio.

3.2 Materials Selection

The materials were selected from different source which is stated elaborately in the following.

3.2.1 Selection of Coarse Aggregate

In the development of this study, some pieces of concrete rubble as Recycled concrete from demolished residential buildings from Jatrabari, Dhaka were collected. The concrete was the composition of brick chips as coarse aggregate. Then these concrete rubbles were crushed manually using hammer and graded with proper screening with sieve analysis according to the Standard Specification. A flow chart was shown in the below figure for development Recycled coarse aggregate.

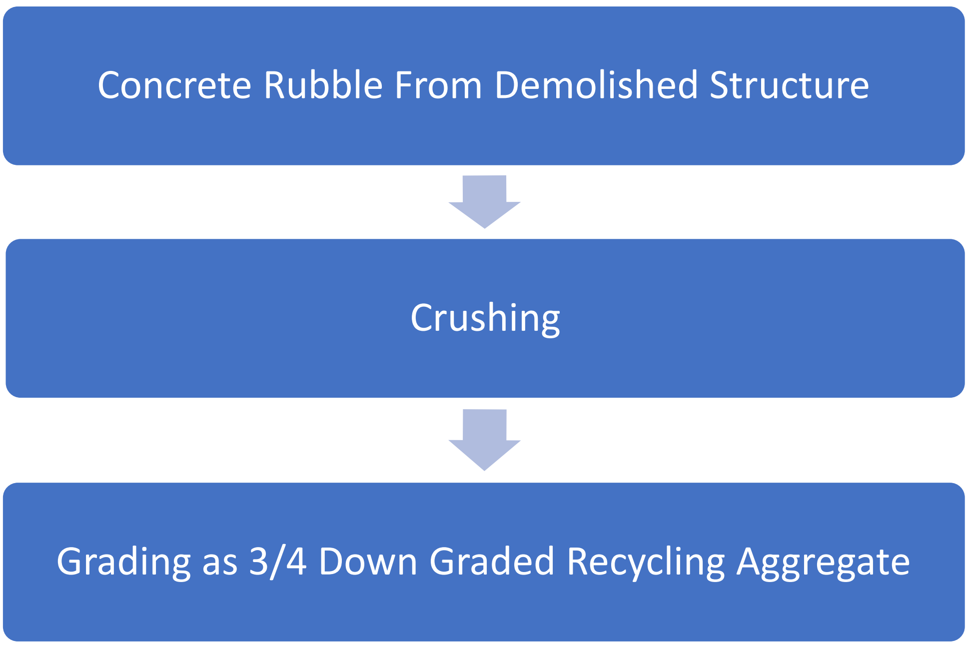

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Figure 3.1 Flow chart for selection of Recycled aggregate

Figure 3.2 selection & preparation of Recycled aggregate

In the similar way some regular brick chips were collected from local source with proper screening with standard sieve analysis. A flow chart was shown in the below figure for development coarse aggregate.

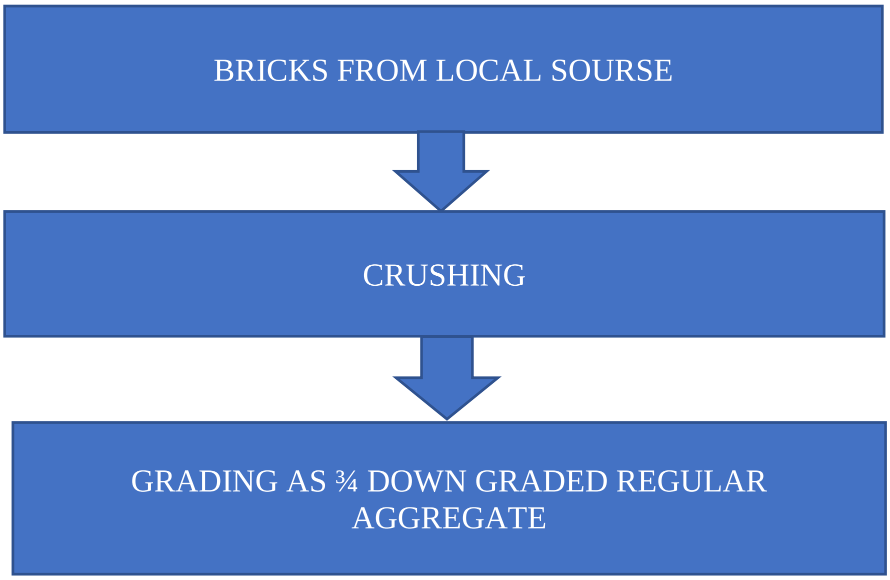

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Figure 3.3 Flow chart for selection of regular aggregate

Figure 3.4 Selection & preparation of Regular aggregate

3.2.2 Selection of fine aggregate (Sand)

Sand was collected from local source. The Fineness Modulus (FM) test was performed for Sand specifications using standard sieve analysis. FM value of sand was found 1.2

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Figure 3.5 Selection of Sand

3.2.3 Selection of fine aggregate (Cement)

Cement was collected from local market. Ordinary Portland Cement (OPC) was used as cement material to obtain different type of concrete.

Figure 3.6 Selection of cement

3.2.4 Selection of water

Water was collected from local source. it was contamination free of sodium & potassium. So the water was free of any type of saline & it was fit for using as construction materials. Water cement ratio 45%

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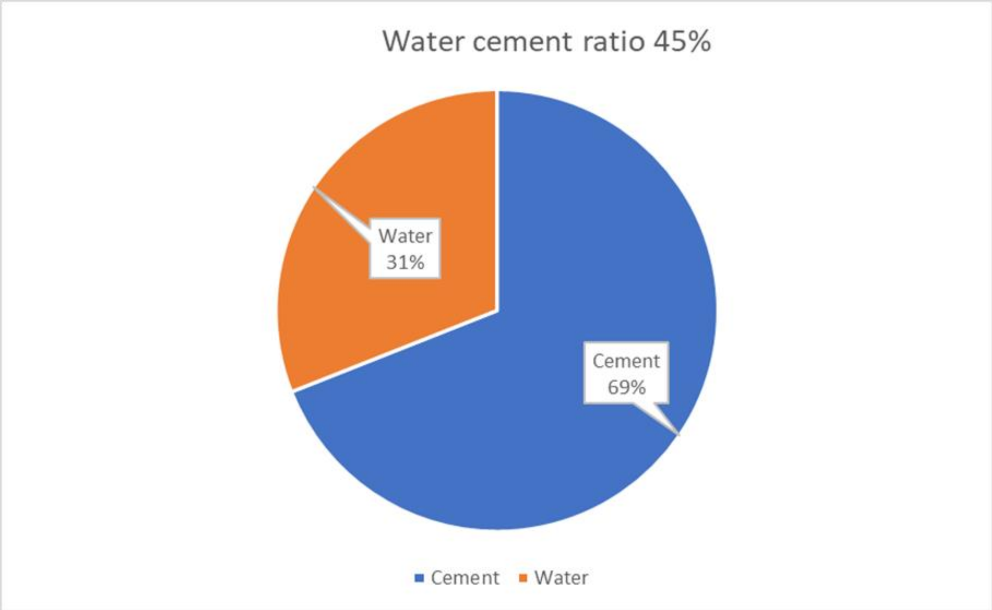

Figure 3.7 water cement ratio 45%

3.3 MATERIAL PREPARATION

Material was prepared to obtain different type of concrete.

3.3.1 Mixing of Regular & Recycled aggregate

Regular brick chips & the brick chips from Recycled concrete were mixed in different ratio. The mixing between regular & Recycled aggregate is provided in the flowing Table 3.1 This mixed aggregate was used as coarse aggregate.

Table 3.1: Concrete Type

Concrete Type	Recycled aggregate %	Regular aggregate %
Type 1	100	0
Type 2	90	10
Type 3	70	30

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Type 4	50	50
Type 5	30	70
Type 6	10	90
Type 7	0	100

3.3.2 Mixing Ratio:

Mixing ratio of cement, sand & coarse aggregate is 1:1.5:3

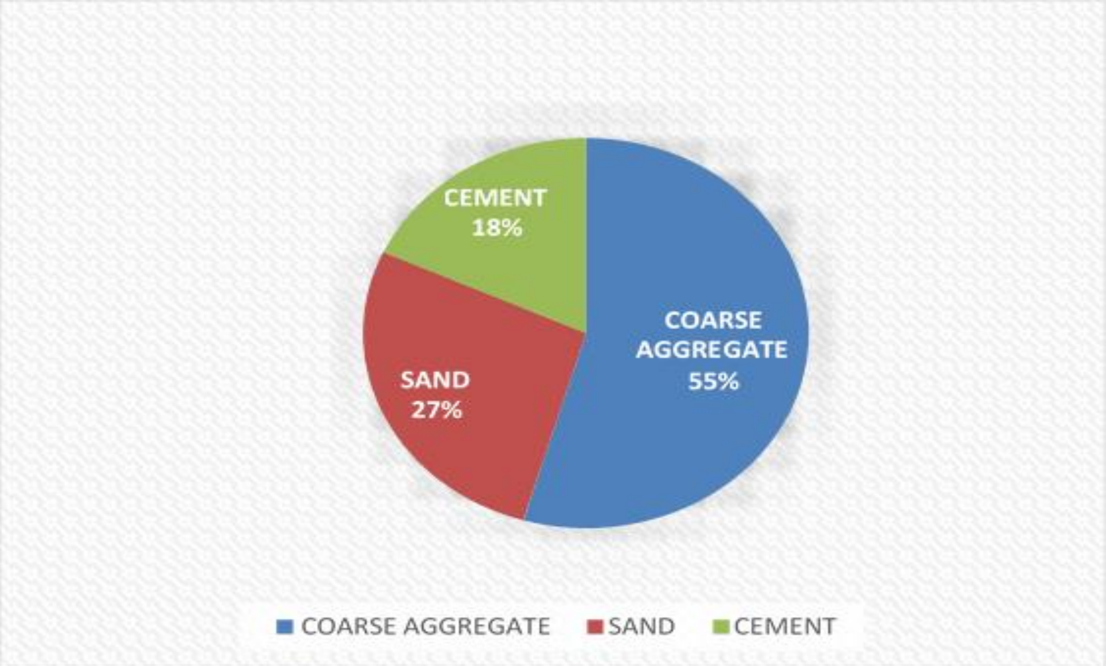

Figure 3.8 Mixing ratio of cement, sand & coarse aggregate

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Figure. 3.9 mixing of concrete

3.3.3 Slump test

Slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test was carried out from batch to batch to check the uniform quality of concrete during construction. The slump test is the simplest workability test for concrete, involves low cost and provides immediate results.

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Figure 3.10 Slum test of concrete 50% regular course aggregate & 50% recycle aggregate

3.4 S

After slum test all the casting was taken place to obtain different type of concrete. This is how Seven types of concrete were formed with different mixing ratio with regular aggregate & Recycled aggregate. Seven sets (Twenty-one) concrete cylinder (4 inch by 8 inch) was formed for testing concrete compressive strength.

Figure 3.11 making specimens

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Figure 3.12 specimens ready for curing

3.5 Specimens Curing

Concrete curing is the process of maintaining adequate moisture in concrete within a proper temperature range in order to aid cement hydration at early ages. Hydration is the chemical reaction between cement and water that results in the formation of various chemicals contributing to setting and hardening

The concrete specimens were cured properly up to 28th day for compressive strength of concrete.

Figure 3.13 Curing of specimens up to 28 days

3.6 Summary

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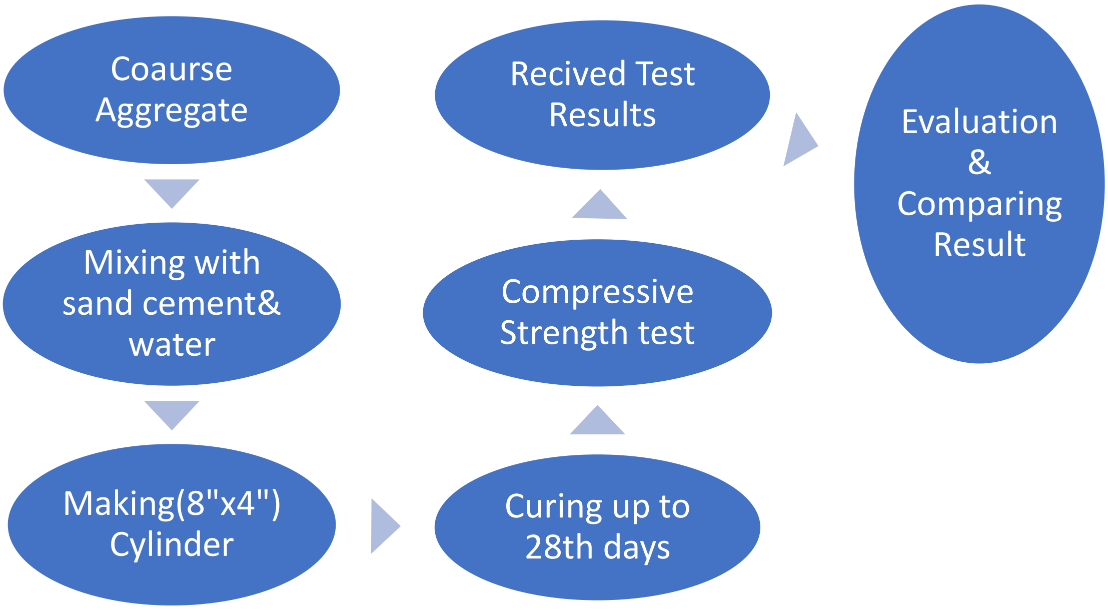

Figure 3.14 Flow Chart for Project

CHAPTER 4
Results and Discussion

4.1 Introduction

This chapter presents This chapter presents the results compressive strength of concrete developed in previous chapter consisting different concrete type. Subsequently these results are comparing with each other & justified to use Recycled concrete in construction sector.

4.2 Analysis Result

In the present study, compressive capacities of concretes are evaluated. Then the capacities are compared consisting of different combinations Recycled aggregate to regular aggregate. The discussion of mixing type & their compressive strength is discussed below.

CONCRETE TYPE 1:

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Recycled aggregate 100% + Regular aggregate 0%

The 28days concrete compressive strength is listed in the table Table 4.1 compressive strength results of concrete type 1

No	Diameter (mm)	Height (mm)	Weight (gm)	KN/sq mm	Average kn/sq mm
1	102.1	205	3390	83	86
2	102	204.2	3527	92	
3	103	205	3537	83	

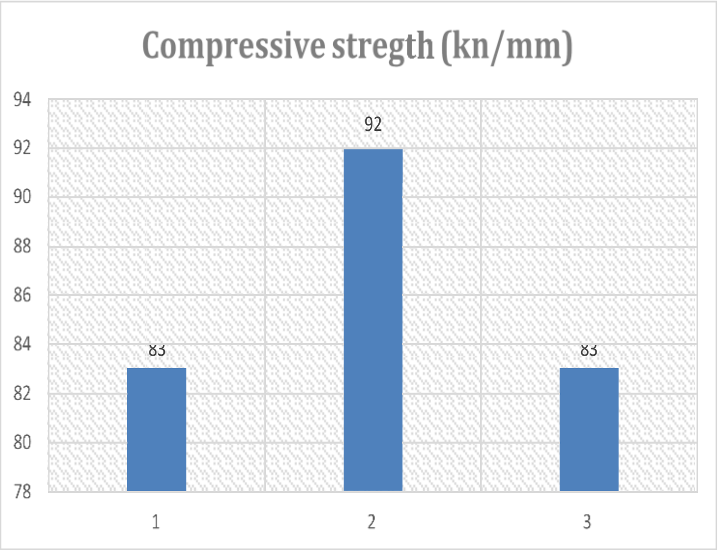

Figure 4.1 compressive strength for each set for type 1 concrete

From this figure 4.1 maximum concrete compressive strength is found 95 KN/sq mm & other two cylinder is found 83 KN/sq mm & 90 KN/sq mm . Average compressive strength is found 91 KN/sq mm

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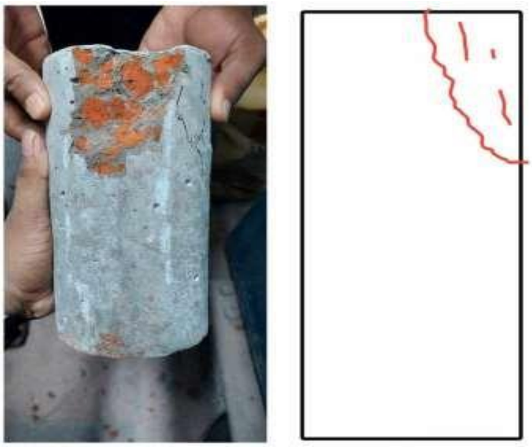

Figure 4.1.1 Failure Type 5 for Concrete type 1. result (83) KN/sq mm

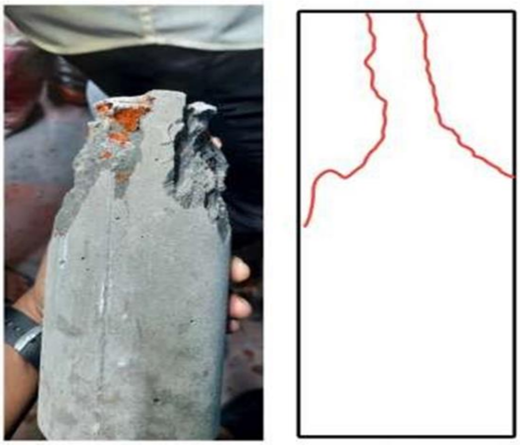

Figure 4.1.2 Failure Type 2 for Concrete type 1. result (92) kn /sqmm

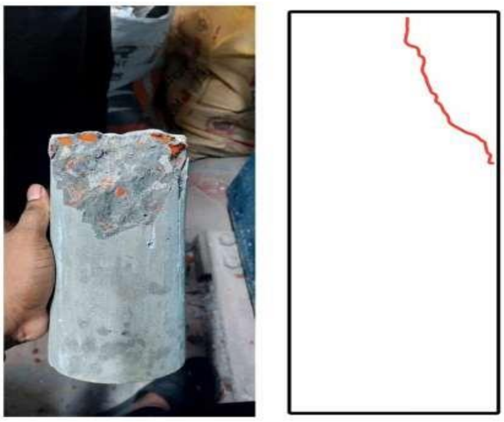

Figure 4.1.3 Failure Type 2 for Concrete type 1. result (83) KN/sq mm

A sets of cylinder failure type is given in figure 4.1.1 figure 4.1.2 & figure 4.1.3 for type 1 concrete. From the figure 4.1.1 it is seen that the failure is like columnar vertical cracking trough both ends. So as per ASTM C39/C39M-10 the concrete failure type is Type 1 for this sample. From Figure 4.1.2 it is seen that the failure type

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is same as previous type 3. From figure 4.1.3 it is observed that the failure type is 2 (vertical cracks running through caps)

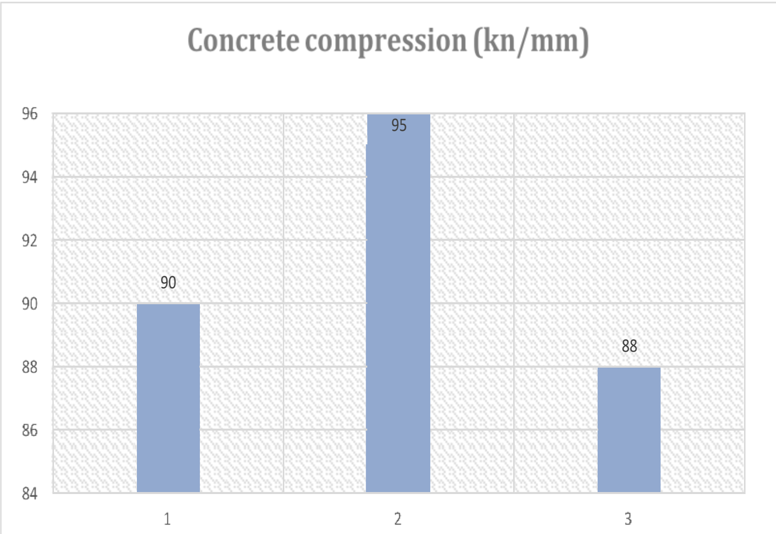
CONCRETE TYPE 2

Recycled aggregate 90% + Regular aggregate 10%

The 28 days concrete compressive strength is listed in the

Table 4.2 compressive strength results of concrete type 2

No	Diameter (mm)	Height (mm)	Weight (gm)	KN/sq mm	Average KN/sq mm
1	102	204	3566	90	
2	103	202	3513	95	
3	104	205	3590	88	91



. Figure 4.16 compressive strength for each set for type 2 concrete

Figure 4.2 compressive strength for each set for type 2

From this figure 4.16 maximum concrete compressive strength is found 95 KN/sq mm & other two cylinder is found 83 KN/sq mm & 90. Average compressive strength is found 91 kn / sq mm

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Figure 4.2.1 Failure Type 2 for Concrete type 2. result (90 kn /sqmm)

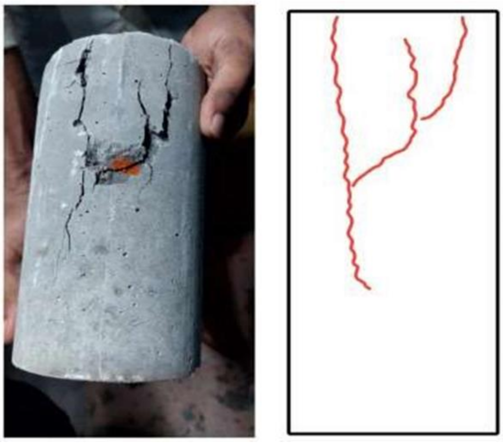

Figure 4.2.2 Failure Type 2 for Concrete type 2. result (88 kn /sqmm

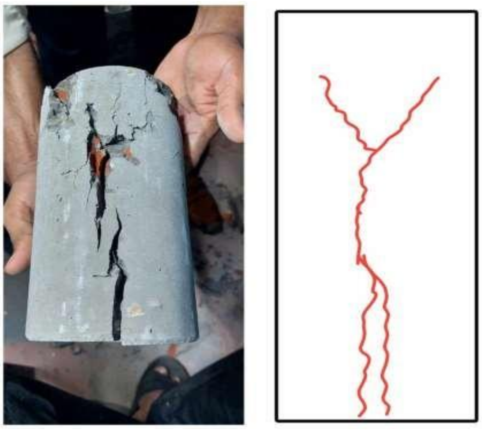

Figure 4.2.3 Failure Type 2 for Concrete type 2. result (95 kn /sqmm)

A sets of cylinder failure type is given in figure 4.2.1 figure 4.2.2 & figure 4.2.3 for type 2 concrete. From the figure 4.2.1 it is seen that the failure is like columnar vertical cracking trough both ends. So as per ASTM C39/C39M-10 the concrete

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failure type is Type 3 for this sample. From Figure 4.2.2 it is seen that the failure type is same as previous type 3. From figure 4.2.3 it is observed that the failure type is 2 (vertical cracks running through caps)

CONCRETE TYPE :3

Recycled aggregate 70% + Regular aggregate 30%

The 28 days concrete compressive strength is listed in the table table 4.3 compressive strength results of concrete type 3

No	Diameter (mm)	Height (mm)	Weight (gm)	KN/sq mm	Average KN/sq mm
1	102	230	3601	83	96
2	103	202	3600	106	
3	102	204	3550	99	

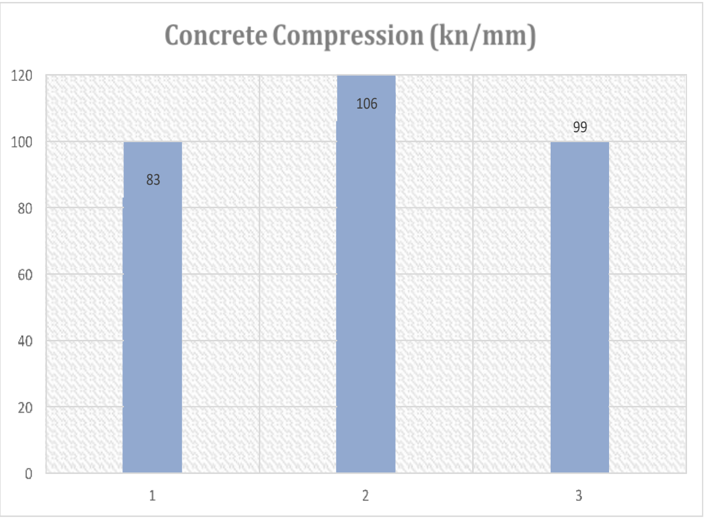

Figure 4.16 compressive strength for each set for type 3 concrete

Figure 4.3 compressive strength for each set for type 3

It is seen from this figure 4.4, maximum concrete compressive strength is found 106 KN/sq mm & other two cylinder is found 83 KN/sq mm & 99. Average compressive strength is found 96 KN/sq mm

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Figure 4.3.1 Failure Type 4 for Concrete type 3. result (83 kn /sq mm

Figure 4.3.2 Failure Type 3 for Concrete type 3. result (109 kn /sq mm)

Figure 4.3.3 Failure Type 4 for Concrete type 3. result (99 kn /sqmm)

A sets of cylinder failure type is given in figure 4.21, figure 4.22 & figure 4.23 for type 4 concrete. From the figure 4.21 it is seen that the failure is like diagonal fracture

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with no cracking through ends. So as per ASTM C39/C39M-10 the concrete failure type is Type 4 for this sample. From Figure 4.22 it is seen that the failure type is same as previous type 4. From figure 4.21 it is observed that the failure type is 3 (columnar vertical cracking)

CONCRETE TYPE :4

Recycled aggregate 50% + Regular aggregate 50%.

The 28 days concrete compressive strength is listed in the table 4.4 Table 4.4: compressive strength results of concrete type 4

No	Diameter (mm)	Height (mm)	Weight (gm)	KN/sq mm	Average KN/sqmm
1	102	203	3435	109	107
2	102.3	204	3427	107	
3	103	204	3414	105	

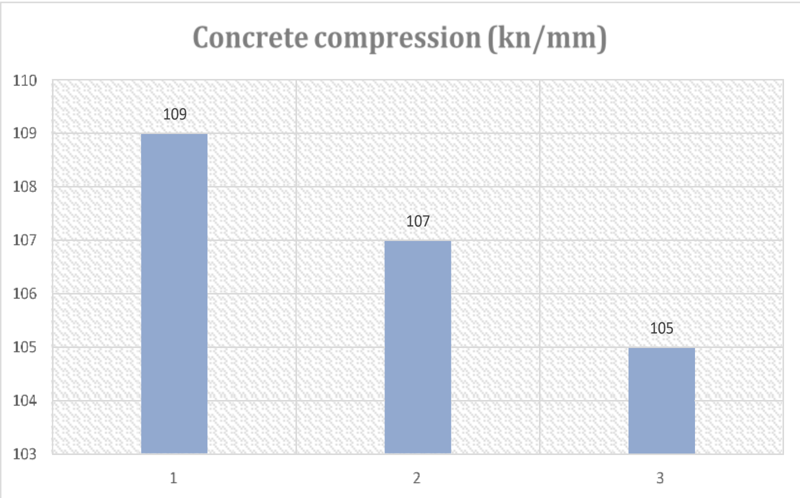

Figure 4.4: compressive strength for each set for type 4 concrete

Figure 4.4 compressive strength for each set for type 4

It is seen from this figure 4.4, maximum concrete compressive strength is found 109 KN/sq mm & other two cylinder is found 107 KN/sq mm & 105 KN/sq mm. Average compressive strength is found 107 KN/sq mm

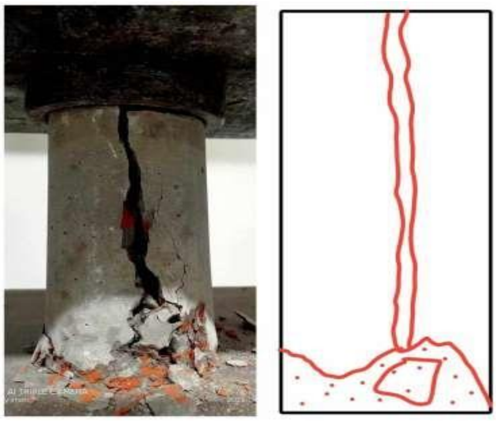

Figure 4.4.1 Failure Type 3 for Concrete type 4. result (107 kn/sq mm)

Figure 4.4.2 Failure Type for 2 Concrete type 4. result (109 kn /sqmm)

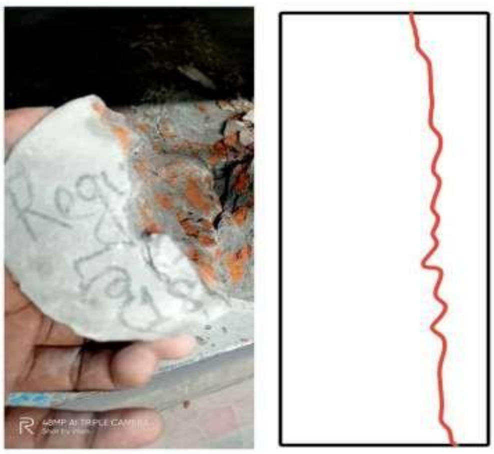

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Figure 4.4.3 Failure Type 3 for Concrete type 4. result (105 kn /sqmm)

A sets of cylinder failure type is given in figure 4.4.1, figure 4.4.2 & figure 4.4.3 for type 4 concrete. From the figure 4.4.1 it is seen that the failure is like columnar vertical cracking through both ends. So as per ASTM C39/C39M-10 the concrete failure type is Type 3 for this sample. From Figure 3.26 it is seen that the failure type is same as previous type 3. From figure 4.4.3 it is observed that the failure type is 3 (columnar vertical cracking)

CONCRETE TYPE :5

Recycled aggregate 30% + Regular aggregate 70%

The 28 days concrete compressive strength is listed in the table 4.5

Table 4.5: compressive strength results of concrete type 5

No	Diameter (mm)	Height (mm)	Weight (gm)	KN/sq mm	Average KN/sqmm
1	103.1	202	3435	107	110
2	102	203	3420	118	
3	102.5	205	3577	105	

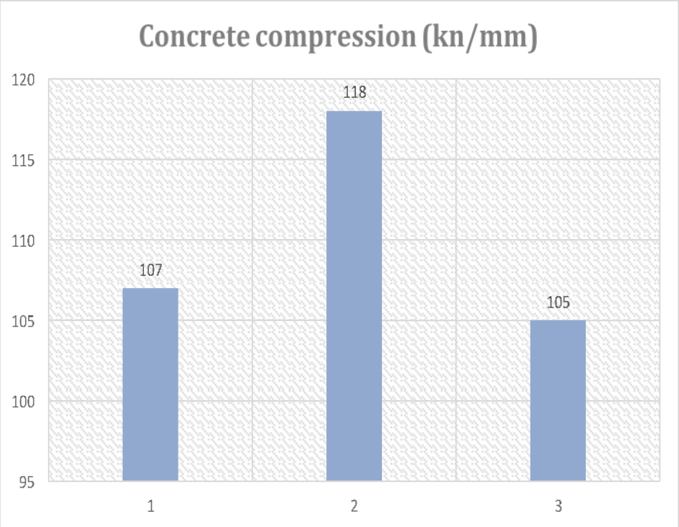

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Figure 4.5 compressive strength for each set for type 5

t is seen from two cylinder is found 107 KN/sq mm & 105. Average compressive strength is found 110 KN/sq mm this figure 4.8, maximum concrete compressive strength is found 118 KN/sq mm & other two cylinder is found 107 KN/sq mm & 105. Average compressive strength is found 110 KN/sq mm

Figure 4.5.1 Failure Type 4 for Concrete type 5 result (118 kn /sqmm)

Figure 4.5.2 Failure Type 4 for Concrete type 5 result (105 kn /sqmm)

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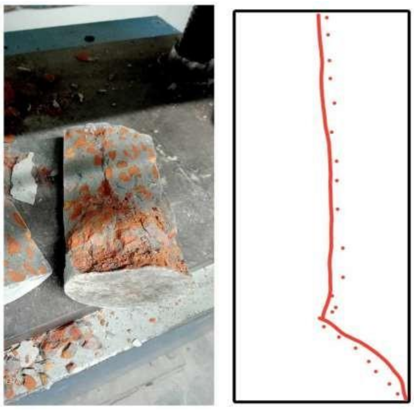

Figure 4.5.3 Failure Type 3 for Concrete type 5 result (107 kn /sqmm)

A sets of cylinder failure type is given in figure 4.5.1, figure 4.5.2 & figure 4.5.3 for type 5 concrete. From the figure 4.5.2 it is seen that the failure is like columnar vertical cracking through both ends. So as per ASTM C39/C39M-10 the concrete failure type is Type 5 for this sample. From Figure 4.5.3 it is seen that the failure type is diagonal fracture with no cracking so it is type 4 failure as per ASTM C39/c39M-10. From figure 4.5.1 it is observed that the failure type is also like type 5 (diagonal fracture with no cracking

CONCRETE TYPE :6

Recycled aggregate 10% + Regular aggregate 90%

The 28 days concrete compressive strength is listed in the table 4.6

Table 4.6 compressive strength results of concrete type 6

No	Diameter (mm)	Height (mm)	Weight (gm)	KN/sq mm	Average KN/sqmm
1	103.9	205.5	3488	103	125
2	103.2	205.4	3472	137	
3	103	206	3491	135	

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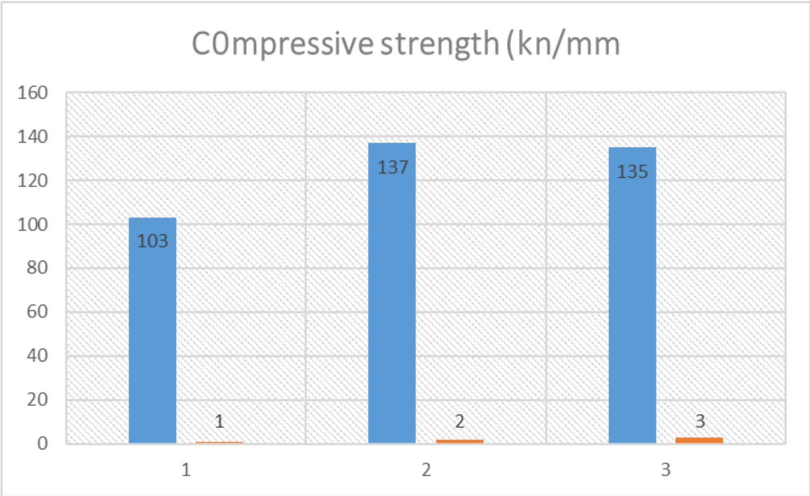

Figure 4.6 compressive strength for each set for type 6

It is seen from this figure 4.8, maximum concrete compressive strength is found 118 KN/sq mm & other two cylinder is found 107 KN/sq mm & 105. Average compressive strength is found 110 KN/sq mm

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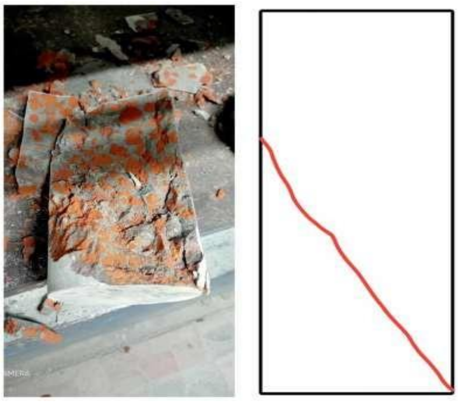
Figure 4.6.1 Failure Type 3 for Concrete type 6. result (103 kn /sqmm)

Figure 4.6.2 Failure Type 4 for Concrete type 6. result (135 kn /sqmm)



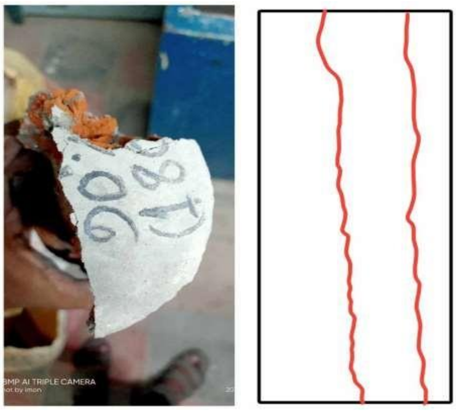


Figure 4.6.3 Failure Type 3 for Concrete type 6. result (137 kn /sqmm)

A sets of cylinder failure type is given in figure 4.6.1 figure 4.6.2 & figure 4.6.3 for type 6 concrete. From the figure 4.6.1 it is seen that the failure is like columnar vertical cracking through both ends. So as per ASTM C39/C39M-10 the concrete failure type is Type 3 for this sample. From Figure 4.6.2 it is seen that the failure type is diagonal fracture with no cracking so it is type 4 failure as per ASTM C39/c39M-10. From figure 4.6.3 it is observed that the failure type is also like type 3 (columnar vertical cracking through both ends.)

CONCRETE TYPE :7

Recycled aggregate 0% + Regular aggregate 100%

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The 28 days concrete compressive strength is listed in the table 4.7 Table 4.7: compressive strength results of concrete type 7

No	Diameter (mm)	Height (mm)	Weight (gm)	KN/sq mm	Average KN/sqmm
1	101.3	204.5	3422	122	126.6
2	102.1	205	3435	118	
3	102	204	3490	140	

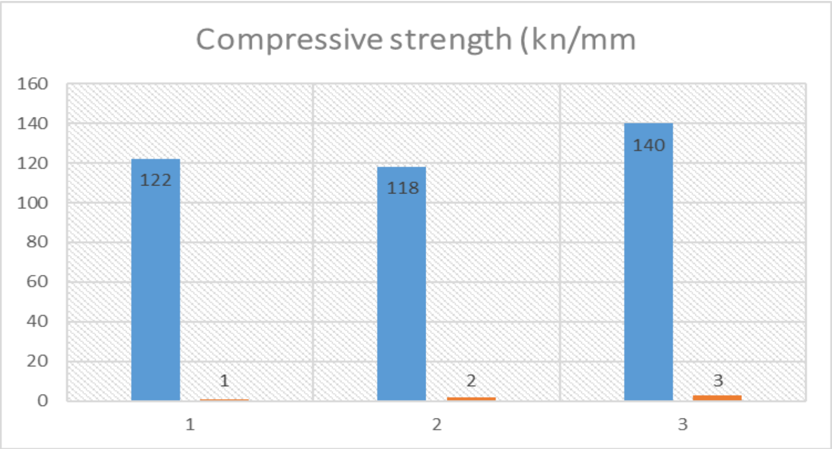

Figure 4.7 compressive strength for each set for type 7

From this figure 4.7 maximum concrete compressive strength is found 140 KN/sq mm & other two cylinder is found 122 KN/sq mm & 118 KN/sq mm. Average compressive strength is found 126.67 **KN/sq mm**

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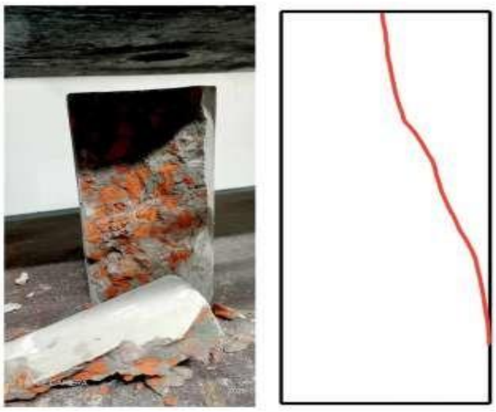

Figure 4.7.1 Failure Type 5 for Concrete type 7. result (122 kn /sq mm)

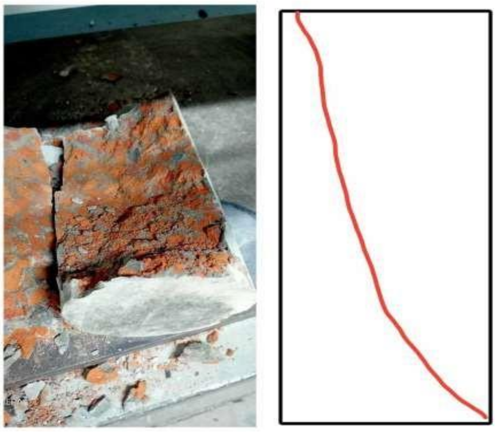

Figure 4.7.2 Failure Type 4 for Concrete type 7 result (118 kn /sq mm)

Figure 4.7.3 Failure Type 3 for Concrete type 7. result (140 kn /sqmm)

A sets of cylinder failure type is given in figure 4.7.1 figure 4.7.2 & figure 4.7.3 for type 7 concrete. From the figure 4.7.1 it is seen that the failure is like diagonal fracture with no cracking through ends. So as per ASTM C39/C39M-10 the concrete failure type is Type 4 for this sample. From Figure 4.7.2 it is seen that the failure type

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is columnar vertical cracking through both ends so it is type 3 failure as per ASTM C39/c39M-10. From figure 4.7.3 it is observed that the failure type is also like type 3 (columnar vertical cracking through both ends.)

4.3 Summary

The Test results are finally compared with different concrete type. The average concrete compressive strength is listed in the following table

Table 4.8 Average strength of test results

SL No	Concrete Type	Recycle concreteAggregate + RegularAggregate	Average Strength (KN/sqmm)
1	Concrete Type 1	100:0	86
2	Concrete Type 2	90:10	91
3	Concrete Type 3	70:30	96
4	Concrete Type 4	50:50	107
5	Concrete Type 5	30:70	110
6	Concrete Type 6	10:90	125
7	Concrete Type 7	0:100	127

From the table it is seen that Concrete Type 1 has less compressive strength. Concrete compressive strength seemed gradually increased while using much regular aggregates. Mixing with regular to Recycled concrete make an impressive value than type 1 concrete (100 % Recycled aggregate). For better realization a histogram is plotted in the following figure

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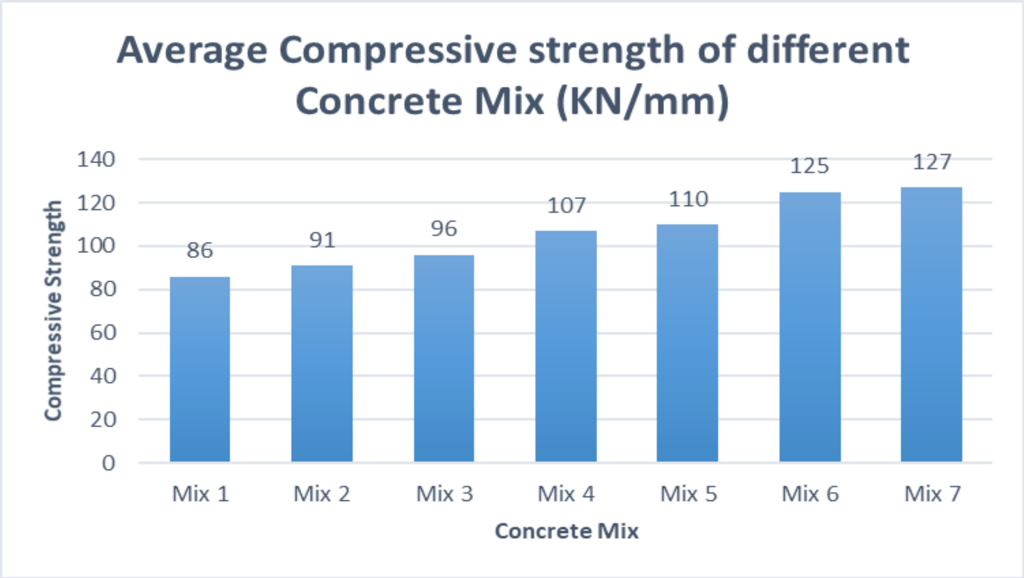

Figure 4.8: Comparison of 28 days cylinder test for different type of specimens

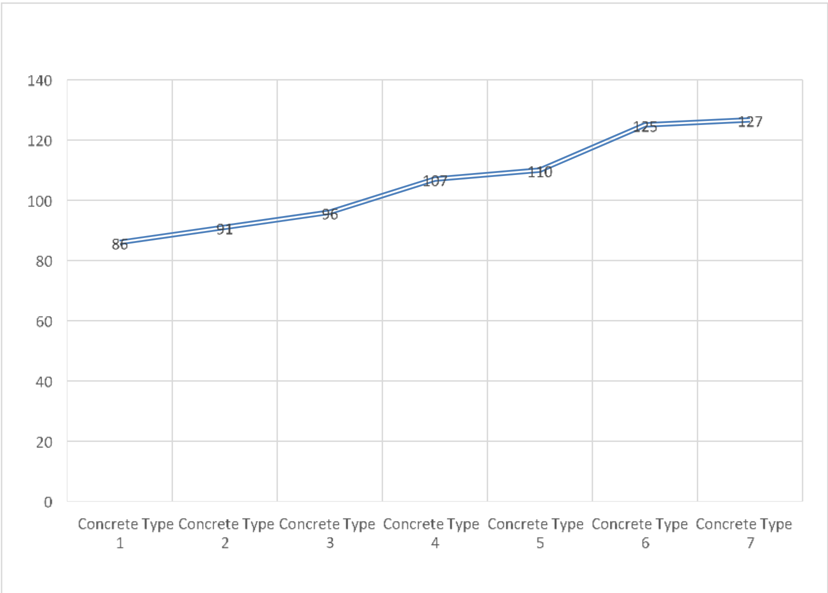

Figure 4.9: Comparison of test results for different type of specimens

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Table: 4.9: Percentage of variation respect to concrete type 1 (100 % Recycled aggregate)

Concrete Type	Average Strength (KN /sqmm)	% Increasing Percentage respect to concrete type 1	Remarks
Concrete Type 1	86	0.0	
Concrete Type 2	91	5.8	
Concrete Type 3	96	11.6	
Concrete Type 4	107	24.4	
Concrete Type 5	110	27.9	
Concrete Type 6	125	45.3	
Concrete Type 7	127	47.6	

From Table 4.5 it is observed that concrete type 1 has less value for compressive strength. Increasing % of regular aggregate concrete seemed to have more compressive strength. Concrete type 7 (100% regular aggregate) has much compressive strength than any other.

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CHAPTER 5
Conclusions and Future Works

5.1Conclusions

This study was primarily aimed to evaluate compressive strength of concrete using normal aggregates & concrete using Recycled aggregates. Compressive strength using different mixing ratio of normal aggregates & Recycled aggregates were also compared in the previous chapter. Based on the obtained results and scope of the study, following conclusions and recommendations are suggested.

Based on the study the main conclusions can be summarized as follows:

i. The least concrete compressive strength was found for concrete Type Recycled aggregate: Regular aggregate =100:0)

ii. The maximum Concrete compressive strength was found for concrete Type 7 (Recycled aggregate: Regular aggregate =0:100)

iii. The greater percentages of regular aggregate used, the higher concrete compressive strength was recorded

iv. Using 50% of regular aggregate & 50% of Recycled aggregate mixingcombinations provided optimum concrete compressive strength (Type 4 Concrete)

4.2 Limitations and Recommendations for Future Works

The following recommendations for future work may be suggested:

I. The study was performed without using any type of admixture. So, it is recommended to carry out future studies considering the effect of admixture.

II. In this study, the Recycled aggregate was used without thinking air void generation. Considering air void & minimizing its effect on concrete carry out for further investigation for great interest.

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