INVESTIGATION FOR REUSING RECYCLED AGGREGATES IN STRUCTURAL CONCRETE

By

Md. Aslam Hossain

Md. Imran Hossain

Md. Muklasur Rahman Mukul

Md. Khorshed Alom

Md. Shariful Islam

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

Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

Section:14A,Semester: 11th

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By

MD. ASLAM HOSSAIN ID: BCE1603009231

MD. IMRAN HOSSAIN ID:BCE1702011024

MD. MUKLASUR RAHMAN MUKUL ID:BCE1802014105

MD. KHORSHED ALOM ID: BCE1703012102

MD. SHARIFUL ISLAM ID: BCE1802014116

Supervisor

Shanjida Ahmed Shohana

Lecturer

Department Of Civil Engineering

Sonargaon University.

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Department of Civil Engineering

Sonargaon University

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BOARD OF EXAMINERS

Comparison of Reusing Recycled Aggregates in Structural Concrete, Submitted by Student-Name, Md.Aslam Hossain, ID No: BCE1603009231, Student-Name, Md.Imran Hossain, ID No:.BCE1702011024, Student-Name, Md. Muklasur Rahman Mukul, ID No: BCE1802014105, Md.Khorshed Alom ID No: BCE1703012102, Student-Name, Md.Shariful Islam ID No:BCE1802014116 Has been accepted as satisfactory in partial fulfillment of the requirement for the degree of bachelor of science in civil engineering on date-of-defense.

1. Supervisor

   Shanjida Ahmed Shohana
   Lecturer
   Department Of Civil Engineering
   Sonargaon University

2. Internal Member

3. Internal Member

DECLARATION

We hereby declare that this thesis represents our own work done after registration for a bachelor's degree in civil engineering at the university of sonargaon, and was not previously included in a thesis or dissertation submitted to this or any other degree, diploma or other degree institution. we guarantee that the current work does not infringe any copyright. we also re-initiate the reassurance of the university against any loss or damage resulting from the breach of previous obligations. Reusing Recycled Aggregates in Structural Concrete. we expect more hypotheses to continue on this topic with advanced data in the upcoming future by others.

STUDENT NAME	STUDENT ID.	SIGNATURE
MD.Aslam Hossain	BCE1603009231	
MD. Imran Hossain	BCE1702011024	
MD. Muklarsur Rahman Mukul	BCE1802014105	
MD.Khorshed Alom	BCE1703012102	
MD.Shariful Islam	BCE1802014116	

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ABSTRACT

Demolition of old structures to make way for new and modern ones is common features in metropolitan areas due to rapid urbanization. Due to strict environmental laws and lack of dumping sites in urban areas, demolished waste disposal is a great problem. The study is a part of comprehensive program wherein experimental investigations have been carried out to assess the effect of partial replacement of coarse aggregate by demolished waste on tensile and compressive strength of recycled concrete for the period of 7 and 28 days. The compressive and tensile strength thus observed on has been compared with strength of conventional concrete. Test results show that the compressive strength of recycled concrete with 10% coarse aggregate and tensile strength of recycled concrete with 15% coarse aggregate of replacement by demolished waste at the end of 28 days is marginally higher than that of conventional concrete.

TABLE OF CONTENT

ABSTRACT vi
LIST OF FIGURES x
LIST OF TABLES xi

CHAPTER 1 1
Introduction 1
1.1 Importance of the Study 1
1.2 Objective of the Study 2
1.3 Thesis Layout 2

CHAPTER 2 3
Literature Review 3
2.1 Introduction 3
2.2 Background 4
2.3 Cement 4
2.3.1 Concrete 5
2.3.2 Course Aggregate 6
2.3.3 Fine Aggregate 6
2.3.4 Function of Aggregate in Concrete 7
2.3.5 Function of Water in Concrete 7
2.3.6 Classification of Concrete 8
2.3.7 Properties of Concrete 8
2.3.8.1 Strength of Concrete 8
2.3.8.2 Elastic Properties of Concrete 9
2.3.8.3 Durability of Concrete 9
2.3.8.4 Impermeability of Concrete 9
2.3.9 Deformation of Concrete 9
2.3.10 Curing Time 10
2.4 Concrete Waste and Concrete Recycling 10

2.5 Properties of Recycled aggregate 11
2.5.1 Adhered Paste and Mortar 11
2.5.2 Bulk Density 11
2.5.3 Water Absorption 11
2.5.4 Water Cement Ratio 12
2.6 Methods Used In The Tests As Per ASTM Standards 13
2.7 Summary 13

CHAPTER 3 14
Methodology 14
3.1 Materials 14
3.1.1 Cement 14
3.1.2 Fine Aggregate 15
3.1.3 Natural Coarse Aggregate 15
3.1.4 Recycled Aggregate 16
3.2 Particle Size Distribution 16
3.2.1 Sieve Analysis 16
3.2.1.1 Apparatus 16
3.2.1.2 Test Procedure 17
3.3 Mix Proportions of Concrete 17
3.3.1 Mix Proportions for Concrete Cylinder 17
3.4 Mixing of Concrete 18
3.5 Preparation of mold and Demolding 18
3.5.1 Process of Molding 18
3.5.2 Process of Demolding 19
3.5.3 Curing 19
3.6 Compressive Strength Test 20
3.6.1 Apparatus 20
3.6 2 Procedure 20
3.7 Splitting Tensile Strength 21
3.7.1 Apparatus 21
3.7.2 Procedure 22

CHAPTER 4 23
Results and Discussion 23
4.1 Introduction 23

4.1.1 Sieve Analysis of Sand 23
4.1.2 Sieve Analysis of Natural Aggregate 24
4.1.3 Sieve Analysis of Recycled Aggregate 25
4.2.1 Compressive Strength Test Results for Varying Mixes 26
4.2.2 Compressive Strength Test 7 days 26
4.2.3 Compressive Strength Test 28 days 27
4.2.4 Compressive Strength Test Result 27
4.2.5 Tensile Strength Test 7 days 29
4.2.6 Tensile Strength Test 28 days 29
4.2.7 Tensile Strength Test Results for Varying Mixes 30

CHAPTER 5 32
Conclusions and Future Works 32
5.1 General 32
5.2 Conclusions 32

REFERENCE 33

LIST OF FIGURES

Fig-2.1 Relation between Strength & w/c ratio 12

Fig-3.1 Cement 14

Fig-3.2 Sand 15

Fig-3.3 Natural Coarse Aggregate 15

Fig-3.4 Recycled Aggregate 16

Fig-3.5 Mold of Cylinder 19

Figure 3.6: Curing of concrete specimens 19

Figure 3.7: Compressive Strength Test 21

Figure 3.8: Splitting Tensile Strength Test 22

Figure 4.1: Gradation Analysis of Aggregate 25

Figure 4.2: Compressive Strength Test Results for Varying Mixes 27

Figure 4.3 :Tensile Strength Test Results for Varying Mixes 28

LIST OF TABLES

Table 2.1: The Main Oxide Compositions and abbreviations in addition to the average of each in commercially available Portland cement 05

Table 3.1 : Estimation of materials for concrete cylinder 18

Table 3.2: Details of property, test method age at test, Number and size of specimens 20

Table 4.1: Result of Sieve Analysis of Sand 23

Table 4.2: Sieve Analysis of Natural Aggregate 24

Table 4.3: Sieve Analysis of Recycled Aggregate 25

Table 4.4: Compressive Strength Test 7 days 26

Table 4.5: Compressive Strength Test 28 days 27

Table 4.6: Compressive Strength Test Results 27

Table 4.7: Tensile Strength Test 7 days 29

Table 4.8: Tensile Strength Test 28 days 29

Table 4.9: Splitting Tensile Strength Test Results for Varying Mixes 30

CHAPTER 1
INTRODUCTION

1.1 Importance of the Study

Amidst growing awareness on protection of environment and conservation of natural resources and this study is an attempt to explore recycled concrete as a material of hope for 21st century. Demolished waste obtained from a structure mainly made up of concrete has several foreign matter such as various type of finishes, cladding materials, lumber, dirt, steel, hardware's, woods, plastics etc, attached to them directly or indirectly. The process of removal of impurities and crushing of rubble into suitable and desirable aggregate particle size can be carried out in a continuous and sequential manner using appropriate mechanical devices such as jaw crushers, impact crushers, swing hammer crushers etc. There are three processes, for processing of demolished waste: Dry, Wet and Thermal, which are used individually or in combination with one another. Due to high water absorption of recycled aggregates, it is sometimes suggested to use pre-soaked aggregates for production of recycled aggregate.

(Hansen, 1992) found that based on equal slump, the water requirement of recycled aggregate concrete made with both coarse and fine recycled aggregate was 14% higher than that of control concretes made with natural sand and gravel. When concrete was produced with coarse recycled aggregate and natural sand, the increase in water demand was only 6%. Compared the strength and economy of standard and recycled concrete with partial replacement of cement and fine aggregates. The recycled concrete achieved up to 77% compressive strength, and above 90% for splitting tensile and flexural strength and a cost saving of 15%

These indicate the potential of C and D wastes as valuable building materials on technical, environmental and economic grounds. Concrete produced with these aggregates does not perform as well as concretes produced with natural aggregates in terms of strength. However, concrete still has a strength that would make it suitable for some applications, with the added benefit that density values are much lower; making it suitable in situations where self-weight is a problem and very good fire resistance is required. Against these backdrops, this study was aimed to assess the effect of partial replacement of fine aggregate by demolished waste on workability and compressive strength of recycled concrete for t a period of 7 and 28 day. (Srivastava, 2012)

1.2 Objective of the Study

The objective of thesis are :

- To observe the compressive and tensile strength of recycled & normal concrete cylinder using different percentage of recycled aggregate.
- To compare between compressive and tensile strength results for different mixes.
- To evaluate prospect of using recycled aggregate concrete (RAC) as coarse aggregate.

1.3 Thesis Layout

This thesis consists of five chapter organized as follows :

Chapter 1 : Introduction

Introduction is an introductory chapter that gives the reader the background to the topic, the objective and scope of the thesis.

Chapter 2 : Literature Review .

- This paper reviews the long-term properties of recycled aggregate concrete (RAC), including long-term strength, shrinkage, creep, impermeability. Most studies have shown that the long-term properties of RAC are inferior to those of natural aggregate concrete (NAC), and some researchers have observed that the long-term properties are better than those of NAC.
- RAC's long-term properties are affected by many factors such as recycled coarse aggregate (RCA) replacement percentage, water-cement ratio, mineral admixtures and mix proportions. The long-term properties of RAC can be improved through better control of these factors.
- This paper will be helpful for a comprehensive understanding of and further research on RAC, and provides an important basis and references for the engineering applications of RAC.

Chapter 3 : Research Method

This is the experimental methodology of this thesis is shown. This chapter will present the basic properties of recycled aggregate, concrete mix proportions and test methods.

Chapter 4 : Results and Discussion

This Chapter presents the general results and discussion of the study on Recycled Concrete Aggregate.

Chapter 5 : Conclusions and Further Study

This Chapter presents the conclusions and recommendations for further work on Research.

CHAPTER 2

Literature Review

2.1 Introduction

With the ever-increasing world population there is a growing need for facilities, which in turn requires finite natural resource. For this reason, many industries, backed by government support and regulations, are now looking for ways of re-using materials in manufacture of new products. This process has been in operation for a number of years and the construction industry worldwide is no exception. In Europe and other developed countries, recycling of building materials started about the end of World War II when bricks and other materials that were recovered from the ruins of war were utilized for reconstruction of amenities. However, recycling as a means of sustainable use of materials started in Asia until fairly recently. For a variety of reasons, reuse of construction and demolition (C&D) waste by the construction industry is becoming increasingly important day by day. In addition to environmental protection, conservation of natural aggregate resources, shortage of waste disposal land, and increasing cost of waste treatment prior to disposal are the principal factors responsible for the growing interest in recycling C&D waste.

Among the inert C&D Waste, the concrete rubble has the largest proportion and hence its recycling is most important. Many laboratory and field studies have shown that the size fraction of the concrete rubble corresponding to coarse aggregate can be satisfactorily used as a substitute for natural aggregate and the recycled concrete aggregate shows that the later would give at-least two third of the compressive strength and the elastic modulus of the natural aggregate. On the other hand, there are some drawbacks in using recycled aggregates: for example, they have to be separated from other demolition debris before use, and special care is necessary to ensure they are not contaminated. Consequently a lot of potentially useful material is placed in landfills. However, many countries increasingly concern with environmental protection and sustainable development, are introducing legislation and policy measure to encourage the use of recycled aggregates. The incentive to the construction industry often comes in the form of higher landfill costs, and therefore more inspiration towards the production of recycled aggregates. This policy is particularly well established in the Netherlands and the Copenhagen district of Denmark; both of these areas now recycle over 80% of their demolition waste (Collins, 1996). In recent years certain countries have considered the reutilization of construction and demolition waste as a new construction material as being one of the main objectives with respect to sustainable construction activities. This thesis focuses on recycling of C&D waste as an aggregate in structural concrete. From the mid 70s, many researchers have dedicated their work to describe the properties of these kinds of aggregates, the minimum requirements for their utilization in concrete and the properties of concrete made with recycled aggregates. However, minor attention has been paid to both reuse recycled aggregate in structural concrete and the durability of recycled aggregate concretes.

The curing method used for precast concrete products differs from the normal curing method. Steam curing is usually employed in precast concrete because it accelerates the rate of strength development. However, this curing method alters the properties of the produced concrete. It was found that steam curing reduced the creep of concrete by up to 50 % compared to that of normal mosit-cured concrete. Although plenty of information is available on the effect of steam curing on conventional concrete properties, there is limited data relating to steam cured recycled aggregate concrete. There is a need to gain more information on the effect of steam curing on the strength and durability of concrete produced with high percentages of recycled aggregates. (Shicong, 2006)

2.2 Background

Recycled aggregates are produced from reprocessing old or used concrete, with the largest source being construction, renovation, and demolition waste. During this process of crushing, desired aggregate size can be obtained. The concerns about the physical and mechanical properties have limited the use of the recycled aggregates to specific applications.

An estimated 95 million metric tons of concrete are recycled each year in the United States. Approximately 68% of the recycled concrete is used as a road base, while the remainder is used for new concrete mixes (6%), asphalt hot mixes (9%), high volume riprap (3%), low value products like general fill (7%), and others (7%). However, many State Departments of Transportation (DOTs) either specify a limited spectrum of applications for Recycled Aggregates (RA) in concrete or do not allow its use in concrete at all. These limitations are influenced by the perceived variation in quality and the lack of available acceptance criteria of the recycled aggregate.

Many research efforts have demonstrated an inverse relationship between the amount of RA used and the quality of the new concrete mix. Durability, porosity, and mechanical properties of concrete made with recycled aggregate were affected by the percentage of recycled aggregate used. Results indicated that 50% recycled aggregates content was the optimum amount that can be used in a concrete mix for structural applications to meet specific mix requirements. In addition, physical properties of recycled aggregates must be evaluated to adjust the mixture proportioning to achieve the required behavior. Summarizes some of recycled aggregate properties which were reported in the literature. The experimental results presented in this paper discuss the effect of absorption capacity and effect of using admixtures on strength of concrete produced with different recycled aggregates. (Akmal Abdelfatah, 2011)

2.3 Cement

Portland cement is obtained by heating limestone and clay or other silicate mixtures at high temperatures (>1500°C) in a rotating kiln. The resulting clinker, when cooled, is mixed with gypsum (calcium sulfate) and ground to a highly uniform fine powder. Anhydrous Portland cement consists mainly of lime (CaO), silica (SiO_2), and alumina (Al_2O_3), in addition to small amounts of magnesia (MgO), ferric oxide ($Fe2O_3$), sulfur trioxide (SO_3), and other oxides that are added as impurities in the raw materials during its manufacture. When these oxides are blended together, they form the four basic components of Portland cement, namely: tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. Table 2.1 describes the main oxide compositions and abbreviations, in addition to listing the average of each in commercially available ordinary Portland cement (OPC) (wt.%). (Hosam M. Saleh, 2020)

Table 2.1 : The Main Oxide Compositions and abbreviations in addition to the average of each in commercially available Portland cement(wt%)

Oxide constituent	**Oxide composition and abbreviation**	**Average weight (%)**
Tricalcium silicate	$3CaO{\cdot}SiO_2$ (C_3S)	40–60
Dicalcium silicate	$2CaO{\cdot}SiO_2$ (C_2S)	13–50
Tricalcium aluminate	$3CaO{\cdot}Al_2O_3$ (C_3A)	4–11
Tetracalcium aluminoferrite	$4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$ (C_4AF)	7–13
Others		7–10

2.3.1 Concrete

Recycled concrete aggregate (RCA)

The use of RCA in Ontario is gaining acceptance as more performance information is becoming available and political pressure to use less natural aggregate is increasing. Organizations such as Aggregate Recycling Ontario, which advocate for the use of RCA have begun to affect some change in the practices of municipalities throughout Ontario. Recently Bill 56 has been proposed to the Legislative Assembly of Ontario. The bill aims to prohibit the practice of limiting public sector construction projects to virgin materials. Previous practice has allowed for bids proposing the use of recycled material to be rejected based on this fact. The bill has been carried through the first and second readings in the house and has been referred to the standing committee on Finance and Economic Affairs (Assembly, 2013).

The most common practices for RCA use in Ontario involve placement of RCA as a fill type material. This includes use as granular base and sub-base for pavements, trench backfill material, engineered fill, stabilization of soft sub grades, fill under concrete slab-on-grade, and pavement shoulder construction.

In 2007, it was estimated that approximately 13 million tones of RCA was used in Ontario. This corresponds to about 7% of the total aggregate used in that year. Most of this RCA was used in the construction of roadways as outlined previously (MNR, 2010). There is currently no widespread use of RCA in the production of concrete in Ontario.

RCA is a material that has a large potential supply which currently outstrips its demand. This potential supply consists of every existing concrete structure that will eventually be demolished. One of the prominent issues associated with this large supply however is that each concrete structure is composed of different materials. These differences depend on factors such as structural requirements, available materials, the year in which the concrete was produced, and many others. This wide variation in concrete composition results in a similar variation in the RCA, which is produced when the concrete is crushed. The wide variation in RCA results in some materials with intrinsic properties that lend themselves well to the production of high quality concrete and other materials, which could be detrimental to the performance of any concrete. Between these two extreme RCA types exists a wide spectrum of RCAs that perform variably in concrete.

While some of the RCAs on this spectrum may not be feasible for use in concrete, they are often found to be acceptable for use as granular material in fill or base applications.

The inherent variability of RCA causes concern amongst concrete producers and specifies in Canada, which often results in avoiding the use of RCA completely or to limiting its use to lean concrete or other similar low-demand applications. Given the findings of this previous research, limiting the use of RCA is often considered as a reasonable way to limit the risk associated with the material.

Some RCAs have been found to have properties that are not detrimental to concrete production or performance when incorporated. In these cases, the practice of avoiding the use of RCA results in the loss of significant potential value, in terms of available construction materials.

Previous research performed at the University of Waterloo produced an RCA classification framework that served to classify different RCAs according to their best potential use or application. These applications ranged from use in reinforced structural concrete to use only as a fill material. The framework was developed such that classification depended largely on aggregate tests. This allows for classification to be performed without knowledge of RCA's source concrete, since this information is often unknown for a given RCA. The framework developed is an excellent step towards the development of a widely source-inclusive tool that could be used industry-wide to achieve much more effective use of existing and future RCAs (Butler, 2013).

According to the classification framework developed through previous research at the University of Waterloo, RCA1 was classified as Class A1 (or Class A2), and RCA2 was classified as C. This implies that RCA1 is "high quality" material and would be suitable for use in structural and non-structural concrete applications. Conversely, RCA2 would be considered "low-grade" material and would be suitable only for use in structural and non-structural fill applications (Butler, 2013) (Pickel, 2014)

2.3.2 Coarse Aggregate

The coarse aggregate was prepared according to the specified mix type. The mix types included fully saturated coarse aggregate, partially saturated coarse aggregate, and oven dry coarse aggregate. In each case, a water content sample was taken following the saturation procedure in order to gauge the actual water content of each mixture. (Pickel, 2014)

2.3.3 Fine Aggregate

Locally procured natural sand was used in the experimental program. Fine aggregate resulting from the natural disintegration of rocks and which has been deposited by streams or glacial agencies.

2.3.4 Function of Aggregate in Concrete

Functions of Fine Aggregate in Concrete

Fine aggregates perform the following functions:

1. It assists in producing workability and uniformly in mixture.
2. It assists the cement paste to hard the coarse aggregate particles.
3. It helps to prevent possible segregation of paste and coarse aggregate particularly during the transport operation of concrete for a long distance.
4. Fine aggregate reduces the shrinkage of binding material.
5. It prevents the development of a crack in the concrete. (Sautya, 2019)

Functions of Coarse Aggregate in Concrete

Coarse aggregate is used in concrete to achieve the following functions:

1. It makes a solid & hard mass of concrete with cement and sand.
2. It provides bulk to the concrete.
3. It increases the crushing strength of concrete.
4. It reduces the cost of concrete by using cheaper material. (Sautya, 2019)

2.3.5 Function of water in Concrete

Water Cement Ratio signifies the ratio among the weight of water to the weight of cement applied in concrete mix.

Generally, water cement ratio remains under 0.4 to 0.6 with adherence to IS Code 10262 (2009) for nominal mix (M10, M15 …. M25)

The strength of concrete is directly impacted by the water cement ratio. It enhances the strength if employed in perfect ratio and if the ratio is improper, the strength will be reduced.

The importance of Water in Concrete :

Concrete refers to a macro content. It comprises of micro constituents like cement, sand, fine aggregate &Coarse aggregate. With the purpose of obtaining high strength concrete to resist the desired compressive strength, it is required to set exact ratio of admixture to unite these materials.

The function of water is important here to accelerate this chemical process by adding 23%-25% of the cement volume. It produces 15% of water cement paste also called gel to fill the voids in the concrete.

Impact of too much water in concrete: If additional water is added more than the permissible limit of 23%, the strength of concrete will be significantly affected.

If the task of adding water is continued to improve the workability then the concrete contains lots of fluid materials where the aggregates will settle down. As soon as the water is evaporated it puts down lots of voids in concrete which influences the concrete strength.

But if the guidelines are followed to retain the strength of the concrete then it will change the concrete workability and makes it difficult to manage and place them.

Workability signifies the capacity of concrete to manage, convey and place devoid of any segregation. The concrete becomes perfectly workable if it can be easily dealt with, placed and transported devoid of any segregation at the time of being placed in construction site.

For this purpose, plasticizers & super plasticizers are utilized to enhance the workability by keeping the W/C Ratio unchanged. (Roy, 2018)

2.3.6 Classification of Concrete

The most commonly used classification of concrete is according to:

1. The terms of the mixing of concrete
2. Bulk density of the concrete
3. The type of binder
4. The consistency of the fresh concrete
5. Concrete class
6. The purposes of concrete and other. (BIS)

2.3.7 Properties of Concrete

Concrete is a composite material obtained by mixing Cement, sand, aggregates, and water in suitable proportions. Concrete has become a universal building material which is extensively used in civil engineering construction.
It is necessary to know about important properties of concrete for every civil engineer to design a structure. Properties of concrete are controlled and influenced by the various factors, out of them mix proportions plays an important role in concrete strength and these proportions control the properties of strength. (Krishna, 2018)

2.3.8.1 Strength of Concrete

Type of Concrete Strength:

1. **Compressive Strength:**

   Compressive strength of specimen Treated in a standard manner which includes full compaction and wet curing for a specified period give results representing the potential quality of the concrete. There are three types of loading in compressive test:

a. uniaxial loading
b. biaxial loading
c. triaxial loading

There are three types of failure

a. tension failure
b. shear failure
c. companied failure.

2. **Tensile Strength:**

There is no field test for direct determination of tension under axial loading. It is a difficult test to perform and the results are not reliable. There is, however, an indirect method called the splitting tensile test, in which a standard test cylinder is loaded in compression on its side.

Concrete in the structure is rarely loaded in pure tension, the tensile stresses being in connection with flexure, torsion or a combination of loadings. Awareness of the importance of tensile strength has increased, however, because of the significance of tension on the control of cracking. Research indicates that direct tension averages about 10 percent of the compressive, being about 7 or 8 percent for high-strength concrete (8000 to 10,000 psi compressive) and going as high as 11 or 12 percent for low-strength concrete in the range of 1000 psi compressive.

2.3.8.2 Elastic Properties of Concrete

Concrete isn't flawlessly versatile for any scope of stacking, Flexible properties of cement change with the extravagance of cement change with the power of pressure. (powers, 1968)

2.3.8.3 Durability of Concrete

Concrete durability depends upon the degree of exposure, the concrete grade (or strength) and the cement content. A high density, alkali-resistant concrete will better resist the effects of moisture penetration. Since concrete is a porous material reinforcement bars within the concrete will be subject to possible corrosion if safeguards are not taken. Adequate concrete 'cover' to the reinforcement should be included in the specifications in order to reduce moisture or salts penetrating to the rebar. Should the rebar corrode it will expand and the considerable forces involved cause the concrete to crack. (Dr C.R. Bayliss Eng FIET, 2012)

2.3.8.4 Impermeability of Concrete

Impermeability is the ability of a material to resist the pressure water or the infiltration of other liquids. It plays an important role in the durability of concrete moreover, it also directly affects the frost-resistance and anti-corrosion of concrete. (Engineering, 2011)

2.3.9 Deformation of Concrete

As with all other materials, concrete is deformable, and is considered to exhibit linear elastic behavior under short duration moderate loads. This means that its deformation is proportional to the applied loads.

The instantaneous elastic modulus of concrete is between 30,000 and 35,000 MPa.

Deformation under long duration loads: creep

When loads exceed a certain level, concrete behaves as a plastic body. After removal of the load there is still a residual permanent deformation, known as creep.

The deformation due to the process of creep, which continues for months or even years, is of the order of three times the instantaneous deformation. (ASCO-TP, 2008)

2.3.10 Curing Time

Curing of concrete:

Curing plays a vital role in concrete strength development and durability. After adding water to the concrete mix (Cement, Sand & Aggregate), the exothermic reaction (hydration) takes place, which helps the concrete to harden. Hardening of concrete is not instant and continues for a longer period, which requires more amount of water for processing hydration. So, the concrete kept moist until the hydration reaction in concrete completes. This process called the curing of concrete. (Krishna, 2020)

Minimum curing time for cement concrete:-

The early strength of concrete is most important, and it is responsible for the ultimate strength of concrete. We should do proper curing by considering the environmental conditions, type of structural members, atmospheric temperature. Maintaining the proper temperature also plays a vital role in concrete as mentioned, it should not be colder than 5^0C. Concrete is kept moist for at least 28 days. Nowadays, due to lack of time, the curing can be achieved by following modern techniques in 14-20 Days. Nevertheless, it is always advisable to keep concrete moist for at least 14 days.

As per IS 456 – 2000, concrete should not be cured less than 7 days for ordinary Portland Cement, & it must be at least 10 days for concrete with mineral admixtures or blended cement. In case of hot weather and arid temperature conditions, the curing should not be less than 10 Days for OPC and 14 days for concrete with blended cement & mineral admixtures. (Krishna, 2020)

2.4 Concrete Waste and Concrete Recycling

The early phases of many construction projects involve the demolition of concrete foundations, sidewalks, driveways, and other concrete structures, which can leave a contractor with a sizable volume of heavy, dense materials to deal with. Fortunately, concrete can be recycled and reused in many ways. Typically (but not always) the process involves crushing or pulverizing the concrete rubble near the demolition or building site. Choosing the best method often depends on the size and shape of the concrete pieces to be recycled.

Reusing concrete can a good way to reduce construction costs while providing some benefits to the environment. Recycled concrete not only stays out of landfills, but it also replaces other materials such as gravel that must otherwise be mined and transported for use. (Rodriguez, 2007)

2.5 Properties of Recycled Aggregate

The use of recycled aggregate obtained from the waste concrete, as a component of the new concrete mixture, implies a thorough understanding of its basic properties, considering that some of them may significantly differ from the properties of aggregates obtained from natural resources. In addition, their differences primarily depend on the quantity and quality of cement mortar, which is attached to the grains of recycled aggregate, then, on the quality of the original concrete from which the aggregate is made by recycling and also on recycling methods. Nonetheless, in cases where the recycled aggregate comes from many different sources, the uneven quality, i.e. variations in the properties of recycled aggregate are much more pronounced than as is the case with natural aggregates. Grading of recycled coarse aggregate normally satisfies the standards for natural aggregate, while in the case of recycled fine aggregate, composition corrections are often necessary, because, according to many practical experiences, it was found that there was often a certain amount of grains larger than what is required by standards for natural aggregate. It has been shown that the presence of recycled fine aggregate has a negative impact on the physical-mechanical properties of concrete, therefore, even though through a careful mix design and application of appropriate production technology these effects can be reduced to an acceptable level, in practical application, a fine fraction of recycled aggregate is usually left out, in a way that it is completely replaced by the river sand. (Malešev, 2014)

2.5.1 Adhered Paste and Mortar

Adhered mortar content is an aggregate property unique to recycled aggregates. The term refers to the amount of original cement matrix, which constitutes the particles of RCA. The content is expressed as a percent (by mass) of the overall RCA’s oven-dry mass. In order to determine a given aggregate’s adhered mortar content, an acceptable method for separating the original aggregate from the mortar is required. Various methods for removing the adhered mortar have been examined, however previous research found that a method employing thermally induced stresses provided an effective means to do this (Pickel, 2014)

2.5.2 Bulk Density

The bulk density of RCA is lower than that of NCA. The lower value of loose bulk density of RCA may be attributed to its higher porosity than that of NCA. (Wagih)

2.5.3 Water Absorption

The water absorption capacity of the recycled aggregate in the mixture represents one of the main difference between the recycled and raw aggregates. It is reported to depend on:

a) Size of aggregate.

The capacity of absorption of the aggregate increases with its smaller size increased. The smaller size aggregates having a greater water absorption capacity.

The absorption capacity of recycled aggregate increased with a higher amount of adhered mortar. The high amount of adhered mortar in recycled aggregate also produced a decrease in density. In all case it was accepted that absorption capacity was not dependent on the strength of the original concrete.

b) Quantity of adhered mortar. There is a relationship between absorption and amount of adhered mortar. Demonstrated with 15 samples, that the average value of water absorption in recycled aggregate was 6.35%, whereas in raw aggregate it was 0.90%.The absorption capacity of recycled aggregates depends on the quantity and quality of adhered mortar.

c) Density- There is dependence between density and absorption capacity. Recycled aggregates with adhered mortar have lower density and higher absorption capacity.

There are several authors who tried to find a correlation:

According to tested 11 samples of recycled aggregates Taken from a recycling plant in Madrid, had an absorption capacity of more than 7% and all of them had an absorption capacity of more than 5%. It was concluded that due to the aggregates having high absorption capacity; concrete should be produced with a maxim amount of 20% of recycled aggregates. (Shicong, 2006)

2.5.4 W/C Ratio

He water–cement ratio is a convenient measurement whose value is well correlated with pcc strength and durability. in general, lower water–cement ratios produce stronger, more durable pcc. if natural pozzolans are used in the mix (such as fly ash), then the ratio becomes a water-cementitious material ratio (cementitious material = portland cement + pozzolonic material). the aci method bases the water–cement ratio selection on desired compressive strength and then calculates the required cement content based on the selected water–cement ratio. table 5.17 is a general estimate of 28-day compressive strength versus water–cement ratio (or water-cementitious ratio). values in this table tend to be conservative. most state dots tend to set a maximum water–cement ratio between 0.40 and 0.50. (Dr.M.Aaziz, 2019)

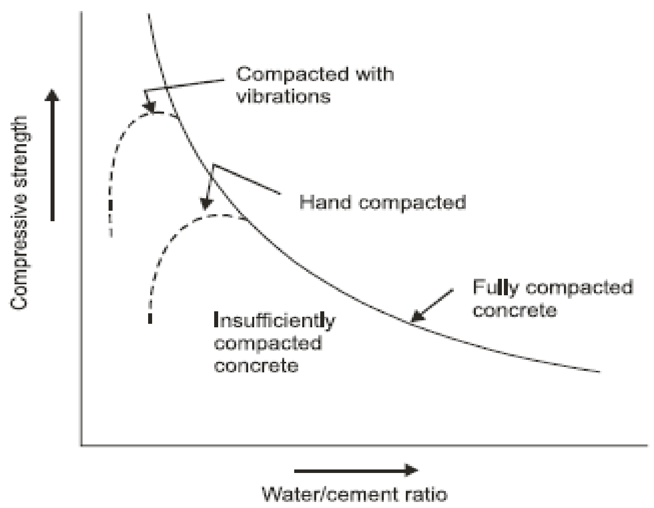


Figure- 2.1 Relation between Strength & w/c ratio

2.6 Methods Used In The Tests As Per ASTM Standards

All test in this research have been performed according to ASTM standards. This section briefly describes the methods used for conducting test activities.

2.7 Summary

The most common practices for RCA use in Ontario involve placement of RCA as a fill type material. This is a good use for RCA, but may not effectively use the full value of the material. Gauging the full value of RCA is an on-going process to which this research aims to contribute. The contributions will be towards the following gaps that have been identified in the literature review.

Coarse RCA has not been thoroughly considered as a potential internal curing agent. This is because of several factors, which include: non-ideal desorption, incomplete dispersion, and the potential for overall strength reduction. Each of these factors is a legitimate concern however if some internal curing-like benefits can be gained through proper preparation of RCA, then this could contribute to knowledge of the full value of RCA as a construction material.

A potential benefit of including saturated RCA in concrete is the possibility to provide a buffer against the negative effects of specified concrete curing, primarily in terms of compressive strength development. This benefit could further enhance the value of certain RCA as concrete aggregate.

Research into the ideal procedure for RCA concrete batching has produced one procedure that seems to improve the compressive strength development of RCA concrete. Batching procedures are variable and depend on a number of factors. In this research, the need for known coarse aggregate saturation levels requires a modified batching procedure. The observed effects of this batching procedure could help to identify the potential issues associated with this particular modification.

Some research has been conducted regarding the low-temperature thermal expansion of RCA concretes, with promising results. Since the moisture state within the concrete can have significant effects on its thermal properties, further study is required to determine whether these results can be observed in various RCA replacement levels and saturation states.

All of these contributions have the potential to help further refine the existing RCA classification framework, which could further promote the effective use of RCA in concrete.

CHAPTER 3

Methodology

3.1 Materials

In this study, five materials are used to produce desired concrete mixture. The materials are cement, fine aggregate, natural coarse aggregate, recycled coarse aggregate and potable water.

3.1.1 Cement

Cement is used as a binding materials which is used to set, harden and to bind the materials with its adhere properties. Shah Special cement is one of the most used cement in Bangladesh. We used Shah Special cement for research purpose. Shah Special cement is ordinary portland cement shown in figure 3.1. Shah Cement Portland Cement surpasses the requirements of BDS EN 197-1:2000 CEM-I 52.5 N Grade. It is produced from high-quality clinker ground with high purity gypsum. Shah Cement Portland Cement provides high strength and durability to structures because of its optimum particle size distribution, superior crystalline structure, and balanced phase composition. It was used for its high early strength and very fast setting time. Cement was uniform in color, there were no hard lumps and cement were cool when hand was plunged into the bag before using.

Figure-3.1 Cement

3.1.2 Fine Aggregate

It is the aggregate most of which passes through No.4 (4.75m) sieve and contain only that much coarser material as is permitted by the specifications. Same type of sand were used as the fine aggregate for both NAC and RAC in this study as shown in the figure. The sand were oven dried before being use to obtain SSD.

Figure-3.2 Sand

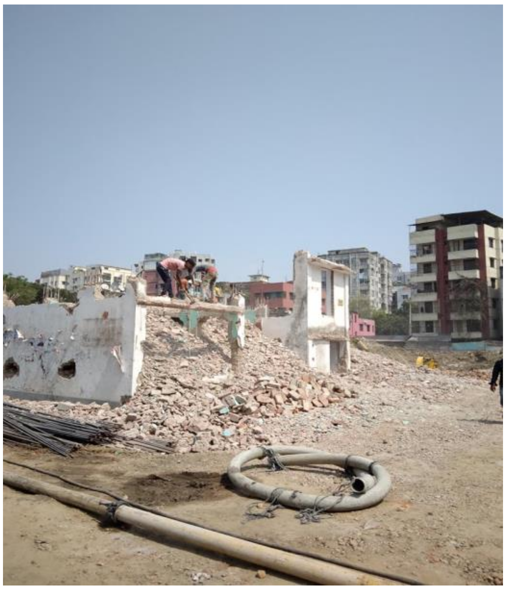
3.1.3 Natural Coarse aggregate

Brick chips were used as natural coarse aggregate for research purpose shown in figure 3.3

Figure-3.3 Natural Coarse Aggregate

3.1.4 Recycled Aggregates

Recycled aggregate was collected from debris of a demolished old building . At first, some medium portions of Slab, Beam and Wall were collected from site and brought them to the laboratory. The collected slab pieces was then crushed manually and by sieve analysis. Both crushed concrete and crushed masonry were present in recycled aggregate.


(a)


(b)

Figure-3.4 Recycled Aggregate

3.2 Particle Size Distribution

3.2.1 Sieve Analysis

For particle size distribution for both coarse and fine aggregate sieve analysis method were used according to ASTM C136.

3.2.1.1 Apparatus

For sieve analysis, following apparatuses were used-

(a) Balance;

(b) Sieves;

(c) Oven and

(d) Containers.

3.2.1. Test Procedure

The samples were dried to a constant mass at a temperature of around 110℃ and after drying samples were weighted. A set of IS sieves with suitable openings were used to sieve the samples. Quantity of materials were limited so that all the materials could reach the sieve opening a number of times during sieve analysis. Sieving process was continued for a sufficient period until the particles were not pass through the sieve. On completion of sieving, the materials retained on each sieve was weighted on balance. Cumulative weight retained into each sieve and percentage of cumulative weight retained was calculated. Fineness modulus was obtained by taking the sum of the cumulative percentage of samples retained on each sieve and dividing the sum by 100.

3.3 Mix Proportions of Concrete

For this research mixture proportion of different groups of concrete were determined in accordance with following conditions-

a) water/cement ratio 0.45,

b) Same maximum grain size (19.5mm)

c) Same type and quantity of fine aggregate

d) Variable type and quantity of coarse aggregate.

e) Mixing ratio 1:2:4.

3.3.1 Mix Proportions for Concrete cylinder

To perform compressive and tensile strength test, 100 mm x 200 mm cylinder concrete were made. Two groups of concrete samples were carried out for this research. In one group, only cement natural coarse and fine aggregates were used to made concrete. In second group, concrete were made with partial replacement of natural coarse aggregate with recycled coarse aggregate. The replacements were done by 0%, 5%, 10% and 15% by mass. The mix proportions were 1 :2 :4 for cement : sand : coarse aggregate. Amount of concrete for a cylinder of each batch are shown in the following table:

Table 3.1 : Estimation of materials for concrete cylinder

Batch No	**% Replacement**	**Cement (g)**	**Sand (g)**	**Natural Coarse Aggregate (g)**	**Recycled Coarse Aggregate (g)**	**Water(g)**
1	0%	600	1200	2400	0	270
2	5%	600	1200	2280	120	270
3	10%	600	1200	2160	240	270
4	15%	600	1200	2040	360	270

3.4 Mixing of Concrete

A smooth, watertight surface was selected as platform and it were washed before mixing of concrete. Sand were measured for each mixing batches and was spread evenly to the platform. The required quantity of cement were dumped on the sand and spread evenly. Sand and cement were mixed properly until the mixture became uniform in color. Sand and cement mixture was spread evenly and required amount of coarse aggregate was spread on the mixture. When preparing recycled aggregate concrete recycled aggregate was replaced with natural aggregate at desired percentage. After spreading coarse aggregate, whole mass were mixed with shovel properly until the mixture was uniform. Mixing ratio 1:2:4.

3.5 Preparation of mold and Demolding

3.5.1 Process of molding

1. For compressive and tensile strength test, steel cylindrical mold were used. Height and diameter of the mold were 200 mm and 100 mm respectively.
2. Molds were cleaned and grease were applied on the inner surface of the mold.
3. Concrete were filled in the mold in 3 layers.
4. Each layer were ridded 25 times in an even pattern using a tamping rod.
5. After tamping, the top surface are leveled.
6. The molded specimens were kept at normal temperature to dry.

Molding of cylinder concrete specimens are shown in figure.

Figure-3.5 Mold of Cylinder.

3.5.2 Process of Demolding

After 24 hours of casting, the concrete specimens were removed from the mold and allowed for curing.

3.5.3 Curing

After demolding, the specimens were placed under water up to 7 days and 28 days. The specimens were fully immersed under water. Figure 3.6 shows curing of cylinder concrete specimens.

Figure 3.6: Curing of concrete specimens

Total number of specimens for each test and their age and size are given below:

Table 3.2: Details of property, test method age at test, Number and size of specimens

Name of Property	Test Method	Age at Test(days)	Size of Specimens	No. of specimens
Compressive Strength	ASTM C39	7	100 mm dia × 200 mm height Cylinders	8
		28	100 mm dia × 200 mm height Cylinders	8
Splitting Tensile Strength	ASTM C496	7	100 mm dia × 200 mm height Cylinders	8
		28	100 mm dia × 200 mm height Cylinders	8

3.6 Compressive Strength Test

Compressive strength test is a method to measure the strength of concrete. In this study, the compressive strength of specimens was measured according to ASTM C39. ASTM C39 determines the compressive strength of cylindrical concrete specimens such as molded concrete cylinders and drilled cores. However, this is limited to concrete having unit weight more than 800kg/ m3.

In this method, axial compressive load is applied to the cylinder specimen at a standard load rate the machine can provide. Load is applied until the failure occurs. The strength test can be used for quality control i.e. acceptance of concrete to use in construction.

3.6.1 Apparatus

1. Compression testing machine and

2. Balance.

3.6.2 Procedure

1. The weight of specimen was measured and then it was placed on the lower bearing block so the axis of the specimen is aligned with the center of thrust of the spherically seated bearing block.

2. Age, weight, type and peak load was provided in the screen of testing machine and a compressive load of .25 MPa/s was applied continuously and without shock until failure.

3. Maximum load carried by the specimen during the test was recorded and the type of fracture pattern was noted.

Figure 3.7: Compressive Strength Test

3.7 Splitting Tensile Strength

The tensile strength of concrete is one of the important properties, which greatly affect the extent, and size of cracking in structures. Splitting test is generally an indirect way to determine tensile strength of concrete which is greater than direct tensile strength and lower than flexural strength. It is expressed as the minimum tensile stress needed to split the material apart. Splitting tensile strength is used to design the lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement.

In this study, the splitting tensile strength of specimens was measured according to ASTM C496. ASTM C496 determines the splitting tensile strength of cylindrical concrete specimens such as molded concrete cylinders and drilled cores.

3.7.1 Apparatus

1. Testing machine- Universal testing machine (UTM) according to ASTM C39 was used. The machine was able to apply the load continuously and without shock.

2. Supplementary bearing bar – As the diameter of the upper bearing face and the lower bearing block was less than the length of the cylinder to be tested, a supplementary bearing bar or plate of machined steel was used.

3. Bearing strips- The bearing strips was placed between the bearing bar and both the upper and lower bearing blocks of the testing machine.

4. Balance.

3.7.2 Procedure

1. The bearing blocks and other test fixtures were installed as necessary to complete the splitting tensile strength. The bearing faces of bearing blocks were cleaned as well as possible. The bearing bar was placed between bearing blocks and bearing strips were placed between bearing bar and bearing blocks.

2. Weight of the sample were measured.

3. Specimen were placed ensuring that it were centered along the length of the upper block and lower blocks.

4. After placing the specimen in the machine and age, weight, type and peak load were provided in the screen of testing machine.

5. A compressive load of 1.5 MPa per minute were applied continuously and without shock until failure.

6. Maximum load carried by the specimen during the test were recorded and the type of fracture pattern were noted.

Figure 3.8: Splitting Tensile Strength Test

CHAPTER 4

Results and Discussion

4.1 Introduction

Compressive strength is one of the most important engineering properties of concrete which designs are concerned of. It gives an overall view of quality of concrete as it is directly related to the structure of hardened concrete. Concrete has been made with different percentage of coarse aggregate from different sources for target strength. OPC & local sand were used as fine aggregate to make the concrete. Compressive strength has been tested for 7 & 28 days.

4.1.1 Sieve Analysis of Sand :

Fineness Modulus is defined as an index to the particle size not to the gradation. Fineness Modulus is calculated from the sieve analysis. It is defined mathematically as the sum of the cumulative percentages retained on the standard sieves divided by 100. The standard size sieves are 3/4 (19.0 mm), 3/8 (9.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600 µm), No. 50 (300µm), and No. 100 (150 µm). Always report the fineness modulus to the nearest 0.01. In fineness modulus, the finer the material the more the water demand is. It is used for the purpose of estimating the quantity of coarse aggregate to be used in the concrete mix design.

Table 4.1: Result of Sieve Analysis of Sand

Sieve No :	**Retain(gm)**	**% of Retain (gm)**	**Cumulative % Retain**	**% Finer**	**F.M**
#4 (4.75 mm)	0	0	0	100	213.3/100 = 2.13
#8 (2.36 mm)	0	0	0	100	
#16(1.19 mm)	81	8.1	8.1	91.9	
#30 (0.59mm)	100	10.0	18.1	81.9	
#50 (0.30mm)	700	70.0	88.3	11.9	
#100 (0.15mm)	109	10.9	99.0	1.0	
Pan	10				

Total = 1000 gm **Total = 213.3**

4.1.2 Sieve Analysis of Natural Aggregate :

Table 4.2: Sieve Analysis of Natural Aggregate

Sieve No :	Retain (gm)	% of Retain (gm)	Cumulative % Retain	% Finer	F.M
#3/4”(19.05mm)	70	7.0	7.0	93.0	704/100 = 7.04
#3/8”(9.52mm)	900	90.0	97.0	3.0	
#4(4.75mm)	28	2.8	100	0	
#8(2.36mm)	0	0	100	0	
#16(1.19mm)	0	0	100	0	
#30(.59mm)	0	0	100	0	
#50(.33mm)	0	0	100	0	
#100(.15mm)	0	0	100	0	
Pan	2				

4.1.3 Sieve Analysis of Recycled Aggregate :

Table 4.3: Sieve Analysis of Recycled Aggregate

Sieve No :	Retain (gm)	% of Retain (gm)	Cumulative % Retain	% Finer	F.M
#3/4”(19.05mm)	537	53.7	53.7	46.3	752.2/100 = 7.522
#3/8”(9.52mm)	448	44.8	98.5	1.5	
#4(4.75mm)	15	1.5	100	0	
#8(2.36mm)	0	0	100	0	
#16(1.19mm)	0	0	100	0	
#30(.59mm)	0	0	100	0	
#50(.33mm)	0	0	100	0	
#100(.15mm)	0	0	100	0	
Pan	0	0	-		

Total = 1000 gm **Total = 752.2**

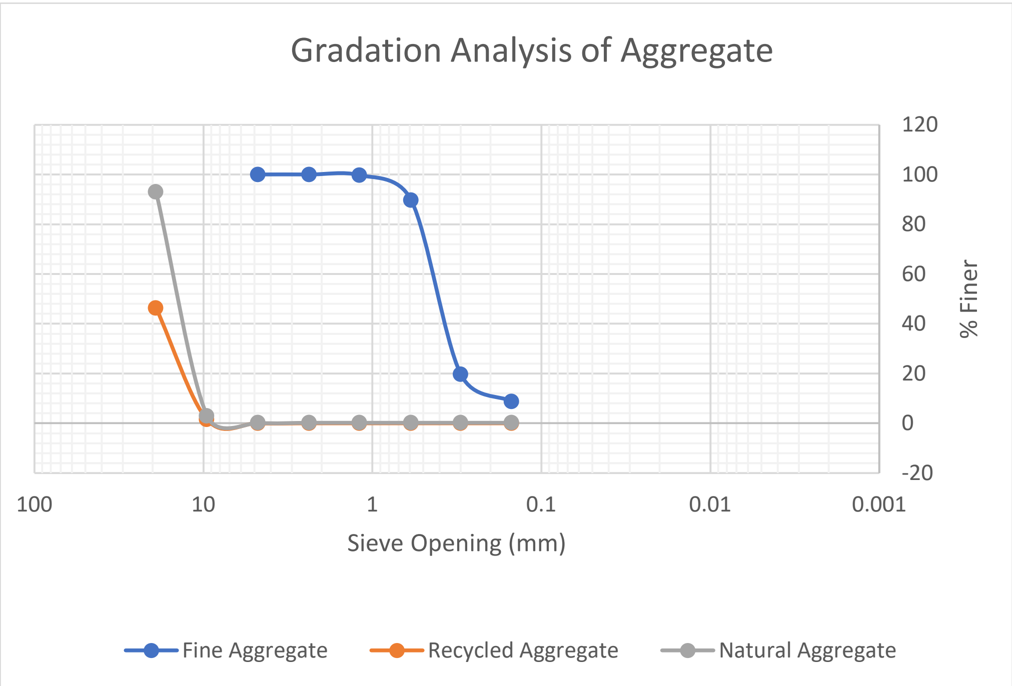


Figure: 4.1 Gradation analysis of aggregate

The figure 4.1 shows three different types of aggregates. These are fine aggregate, recycled aggregate and natural aggregate. For fine aggregate we use 4.75 mm, 2.36 mm, 1.19 mm, 0.59 micrometer, 0.300 micrometer and 150 micrometer. In sieve analysis, fine aggregate retains 0%, 0%, 0.3%, 10%, 70%, 10.9% respectively. use 19.05 mm, 9.52 mm, 4.75 mm, 2.36 mm, 1.19 mm, 0.59 micrometer, 0.30 micrometer, 150 micrometer for recycled aggregate and natural aggregate. In sieve analysis, material retains 53.7%, 44.8%, 1.5%, 0%, 0%, 0%, 0%, 0% for recycled aggregate and in case of natural aggregate material retains 7%, 90%, 2.8%, 0%, 0%, 0%, 0%, 0% respectively. In sieve analysis we have also calculated cumulative % retain and % finer (percent of material passing).

4.2 Strength Test

4.2.1 Compressive Strength Test Results for Varying Mixes

Compressive strength of concrete by using recycled aggregates and natural aggregates were compared using normal curing. The compressive strength of cylinder was determined with the help of compression testing machine (CTM). Table 4.3 gives the result of compressive strength of concrete of both fresh and recycled concrete at the age of 7 and 28 days

4.2.2 Compressive Strength Test : 7 days

Table 4.4: Compressive Strength Test 7 days

Percentage of Waste	Trial No:	Trial Value (K.N)	Avg: Trial Value (K.N)	Compressive Strength (N/mm2)	Result (N/mm2)
0%	(i) (ii)	95 90	92.5	11.40	11.40
5%	(i) (ii)	100 107	103.5	12.76	12.76
10%	(i) (ii)	92 96	94	11.59	11.59
15%	(i) (ii)	90 93	91.5	11.28	11.28

4.2.3 Compressive Strength Test : 28 days

Table 4.5: Compressive Strength Test 28 days

Percentage of Waste	Trial No:	Trial Value (K.N)	Avg: Trial Value (K.N)	Compressive Strength (N/mm2)	Result (N/mm2)
0%	(i) (ii)	145 146	145.5	17.94	17.94
5%	(i) (ii)	149 146	147.5	18.18	18.18
10%	(i) (ii)	160 166	163	20.09	20.09
15%	(i) (ii)	120 132	126	15.53	15.53

4.2.4 Compressive Strength Test Results

Table 4.6: Compressive Strength Test Results

Mixes(%)	**Days**	**Compressive Strength (Mean Strength, Mpa)**
0%	7	11.40
	28	17.94
5%	7	12.76
	28	18.18
10%	7	11.59
	28	20.09
15%	7	11.28
	28	15.53

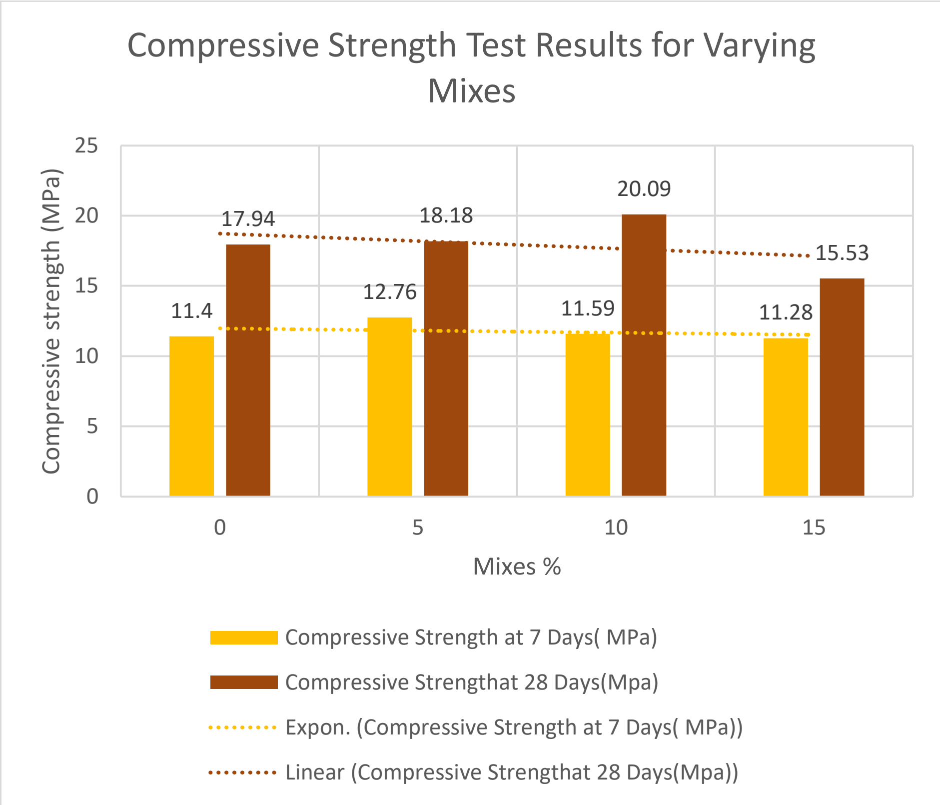


Figure 4.2 : Compressive strength test results for varying mixes

The figure 4.2 shows maximum compressive strength 12.76 MPa for 5% recycled concrete aggregate mixing for 7 days and it is gradually decreasing with the increased amount of mixes after 5% mixing. The minimum value of compressive strength at same duration is 11.28 MPa with 15% recycled concrete aggregate mixing.

The figure 4.2 also shows the compressive strength in 28 days which is gradually increasing with the increased amount of recycled concrete aggregate mixing up to 10% and it holds highest compressive strength of 20.09 MPa at 10% mixing. Then it declines and performs lowest compressive strength of 15.53 MPa at 15% mixing.

So, it is noticeable from graphical observation that compressive strength has reduced after 10% recycled concrete aggregate and the optimum value stands between 5%-10% for both 7 days and 28 days. Therefore, it is better to have recycled concrete aggregate mixing 5%-10% to perform a desired compressive strength in 7 and 28 days.

4.2.5 Tensile Strength Test : 7 days

Table 4.7: Tensile Strength Test Results for 7 days

Percentage of Waste	Trial No:	Trial Value (K.N)	Avg: Trial Value (K.N)	Tensile Strength (N/mm2)	Result (N/mm2)
0%	(i)	32			
	(ii)	33	32.5	4.00	4.00
5%	(i)	30			
	(ii)	29	29.5	3.63	3.63
10%	(i)	26			
	(ii)	25	25.5	3.14	3.14
15%	(i)	26			
	(ii)	23	24.5	3.02	3.02

4.2.6 Tensile Strength Test : 28 days

Table 4.8: Tensile Strength Test Results for 28 days

Percentage of Waste	Trial No:	Trial Value (K.N)	Avg: Trial Value (K.N)	Tensile Strength(N/mm2)	Result (N/mm2)
0%	(i)	45			
	(ii)	46	45.5	5.61	5.61
5%	(i)	46			
	(ii)	45	45.5	5.61	5.61
10%	(i)	37			
	(ii)	45	41	5.05	5.05
15%	(i)	48			
	(ii)	46	47	5.79	5.79

4.2.7 Splitting Tensile Strength Test Results for Varying Mixes

Table 4.9: Splitting Tensile Strength Test Results for Varying Mixes

Mixes(%)	Days	Splitting Tensile Strength (Mean Strength, Mpa)
0%	7	4.00
	28	5.61
5%	7	3.63
	28	5.61
10%	7	3.14
	28	5.05
15%	7	3.02
	28	5.79

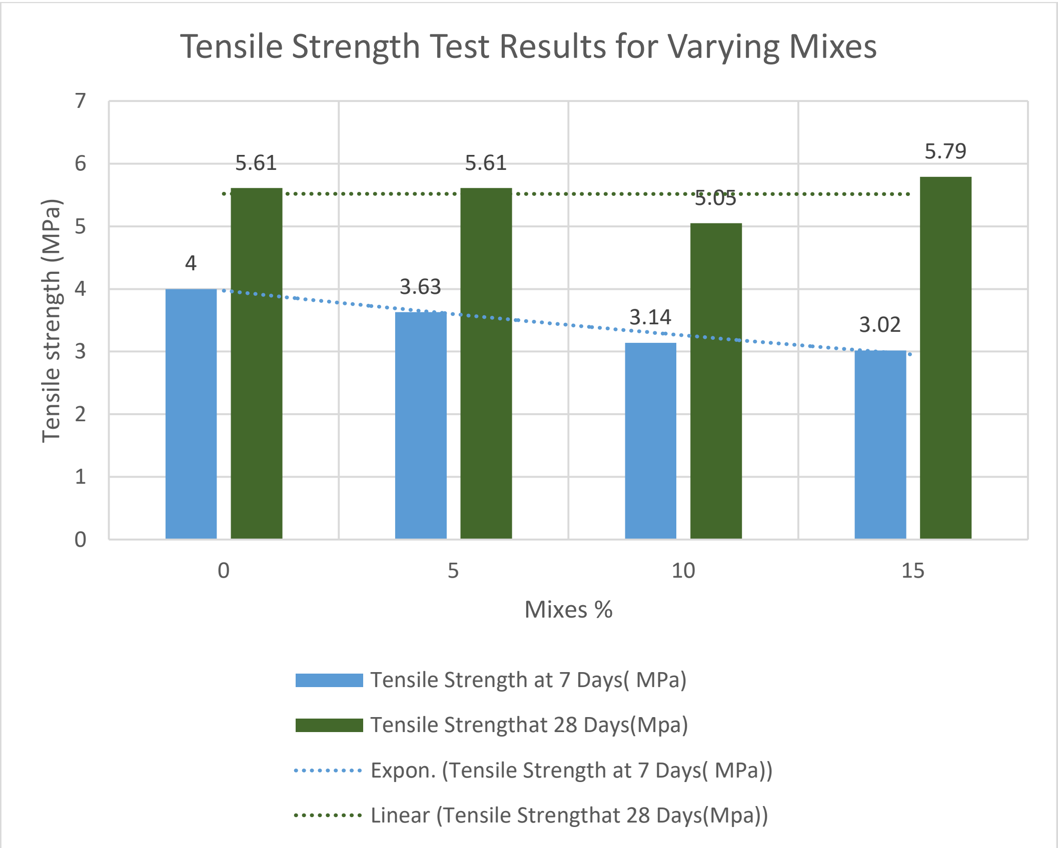


Figure 4.3 : Tensile strength test results for varying mixes

From the figure 4.5 presentation we find that tensile strength after 7 days decreases continuously after adding recycled concrete aggregate in the normal concrete and the maximum value stands for 0% mixes in the concrete.

On the other hand, tensile strength of concrete remains same in the range between 0-5% mixes and it performs sudden deflection as recycled concrete in 28 days and then gradually increases with the increased amount of recycled concrete aggregate mixing up to 10%. Then the tensile strength shows further increase between 10-15% mixes and the ultimate value of tensile strength stands 5.79 MPa for 15% mixes. So, in consideration of both 7 days and 28 days strength it is better to use recycled concrete aggregate in the normal concrete.

5

Conclusions

5.1 General

This study gives scenario of strength development characteristics of concrete for different percentage of coarse aggregate. It can be expected that these findings will be useful for construction of concrete structure.

5.2 Conclusions

The study is a part of comprehensive program wherein experimental investigations have been carried out to assess the effect of partial replacement of coarse aggregate by recycle aggregate at different percentages in concrete on tensile and compressive strength of recycled concrete for the period of 7 and 28 days. Test results indicate that recycled aggregate, an industrial by-product, is a suitable substitute of natural aggregate in concrete.

The compressive strength of concrete with 5% recycled coarse aggregate of 7 days is 12.76 Mpa and 10% coarse aggregate of 28 days is 20.09 Mpa that is maximum.

The tensile strength of concrete with 0% recycled coarse aggregate of 7 days is 4 Mpa and 15% coarse aggregate of 28 days is 5.79 Mpa that is maximum.

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