UTILIZATION OF BRICK FINE AGGREGATE IN CONCRETE AS PARTIAL REPLACEMENT OF NATURAL SAND APPROACH

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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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147/I, Green Road, Dhaka-1215, Bangladesh
Section: 15A
Semester-spring-2022

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Dedicated

to

"Our parents"

ACKNOWLEDGEMENTS

First of all, we would like to acknowledge the support and motivation of our thesis supervisor Angila Tabassum, Lecturer, Department of Civil Engineering. We owe our sincere appreciation for letting us be a part of her research project upon which this thesis is based. She has been a true inspiration that led us into the research field of Concrete Technology. It is only through her concern, encouragement, and motivation that this work was completed. We are forever indebted.

We wish to express our sincerest thanks and appreciation to our research group members.

Finally, we are forever indebted to our parents, who raised us with love and supported us in all our pursuits and for their understanding, endless patience, and encouragement. They form part of our vision that defined the good things that really matter in life.

ABSTRACT

Investigation was carried out to study the utilization of brick fine aggregate in concrete as partial Replacement of natural sand. For investigation, first class bricks fine aggregate (Brick Fine Aggregate) were collected from local sources. The brick fine aggregates were tested for specific gravity, absorption capacity, unit weight, and fineness modulus. Cylindrical concrete specimens of diameter 100 mm and length 200 mm were made with sand to aggregate volume ratio (s/a) (0.45), W/C ratio (.50), and cement content (400 kg/m^3). A total of 6 different cases were considered and a total of 18 concrete specimens were made with different replacement ratios (0%, 10%, 20%, 30%, 40%, and 50%) of natural sand by first class brick fine aggregate (brick fine aggregate). The specimens were tested for compressive strength at 7days and 28 days. The test results of specimens made with brick fine aggregate were compared with the results of specimens made with natural sand, i.e. without brick fine aggregate.

compressive strength of concrete is increased up to 30% of replacement of natural sand by brick fine aggregate. Based on this investigation, it is revealed that brick fine aggregate can be utilized (up to 30% replacement of natural fine aggregate) in concrete without reduction of compressive strength. Utilization of brick fine aggregate as fine aggregate will reduce the demand natural sand and finally will help toward sustainable development of construction materials in Bangladesh.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 General

Civil Engineering construction activity is always associated with new development and projects. This can be a housing project, in fine aggregate infrastructure power plants, docks and harbor works etc., large quantities of traditional construction materials like earth, sand, stones, bricks, cement concrete, steel, aluminum, wood are used. The demand for these materials is increasing in geometric progression. Sustainable development means a commitment to finding and using resources that are renewable. With this philosophy in view, there is an urgent need for optimum reuse of building waste materials available after demolition and renewal of old structures. In the recent past, attention has been shifted in finding alternative sources and materials for the replacement of fine and coarse aggregates. Many researchers have tried different options from organic materials, herbs, glass materials, demolition wastes, wooden wastes, plastic wastes, and electronic wastes and so on. It is worthwhile for exploring the possibilities of application of these materials for further reuse.

Concrete is the largest construction material in the world. Aggregates are the major constituents of concrete where coarse aggregates occupy almost half the constituents of it. They give body to the concrete, reduce shrinkage and effect economy. Moreover, physical properties of coarse aggregate also influence concrete properties. As Bangladesh is urbanizing rapidly, therefore the demand for coarse aggregates in the construction in fine aggregately is increasing rapidly. Total concrete consumption in Bangladesh is 90 million tons and concrete consumption per capita per year is 0.56 ton. Therefore, a huge supply of coarse aggregate is necessary as the demand for concrete is increasing rapidly.

Fine aggregate and coarse aggregate are used enormously in the construction of different projects like airports, highways, skyscrapers, nuclear plants, dams, etc. Also, the demand for these materials is high in privatization and globalization. To meet this high demand for coarse and fine aggregate the increased extraction from the natural resources is required. Fine aggregate is one of the important constituents in concrete and mortar. Natural resources are also getting exhausted in meeting this high demand for fine aggregate in the construction in fine aggregately.

The construction in fine aggregately will be directly affected due to the shortage or non-availability of the natural sand, as natural resources are depleting, finding an alternative material for the partial or complete replacement of natural sand is needed, such that we can prevent the damage to the environment. Else this will lead to an ecological imbalance due to the increasing use of natural fine aggregate. Thus, the need of an hour is to find the partial replacement of fine aggregate for construction in fine aggregate. Many Researcher's and Engineers are working with their ideas to find an alternative way to partial or complete replacement of fine aggregate, so that the natural resource consumption can be decreased. These days' sustainable infrastructural development needs an alternative material that can satisfy technical properties of fine aggregate and should be available easily economically, domestically with a great amount.

In Bangladesh, the most commonly used fine aggregate is sand. The number of fine aggregates is rapidly used on construction, which responsible for various environmental effects. It is estimated that about 5% of the total flood plant of Bangladesh is directly affected by river erosion. Excessive sand extraction causes to river erosion. To overcome this problem, we need to focus on alternative building materials such as brick fine aggregate. Commonly these brick wastes are dumped of by land filling. Bricks are also used as land filling material. Brick waste used as fine or coarse aggregate is easily available, cheap and enhances strength in mortar and concrete. It also affects the different properties in the fresh state and hardened state of the concrete and mortar.

The advantage of brick fine aggregate is that, it is available and economical. Brick fine aggregate available everywhere. The increase in demand may be met by partial replacement natural sand by the brick fine aggregate which are obtained from various brick factory and constructs site.

In light of the above discussion, it is expected that a study that utilization of brick fine aggregate in Concrete is effective. Thus, this study has been planned to investigate the compressive strength of concrete. Another proposal of this study is to study the effects of sand to aggregate volume ratio and water/cement ratio on properties of concrete. With this view, a research project was undertaken in the Department of Civil Engineering (CE) of Sonargaon University (SU), under the supervision of Angila Tabassum, Assistant Professor & Exam Controller, and Department of Civil Engineering Sonargaon University (SU).

to study the variation of the fresh properties as well as hardened properties compressive strength of concrete with partial replacement of brick fine aggregates.

1.2 Background

A brick is an artificial kind of stone made of clay whose chief characteristics are a plasticity when wet and stone like hardness after being heated to high temperature. When it's crushed due to make aggregate purpose then its produced brick fine aggregate.

During produced of brick fine aggregate its significant portion of 1st class brick. The process brick fine aggregate of 1st class brick which produced of weathered clay. Brick fine aggregate is a waste material. No investigation on Utilization of Brick Fine Aggregate in Concrete as partial of Natural Sand has been carried out yet in Bangladesh as a replacement of natural sand.

1.3 Research Objectives and Overview

The objectives of this study are as follows:

1.3.1 To find out the possibility of utilization of brick fine aggregate in concrete.

To study the fresh and hardened properties of concrete made with Bick Fine Aggregate.

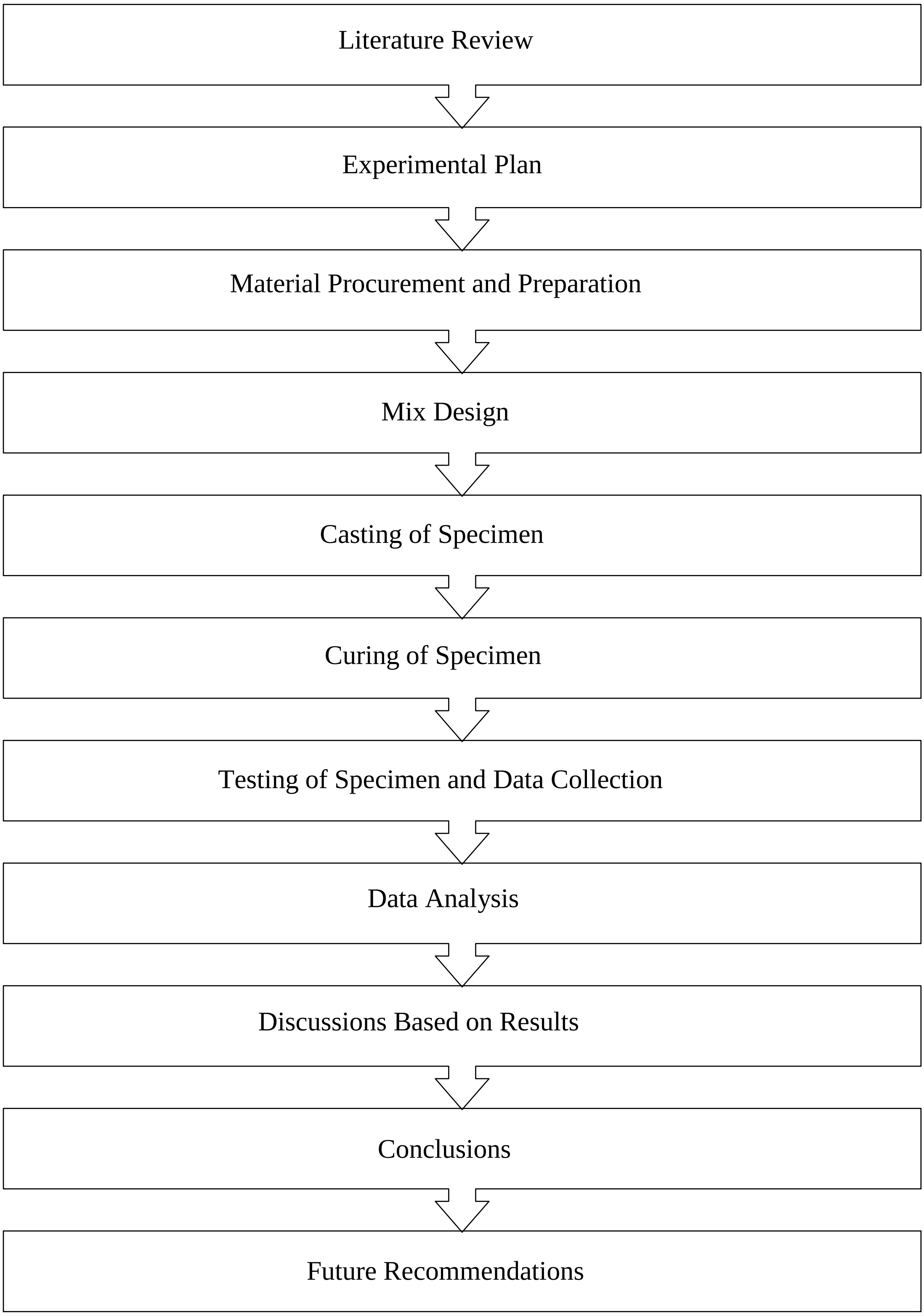
1.3.2 To find out the mechanical properties of concrete by using brick fine aggregate in Concrete as partially replacement of natural sand.

And, to understand the effects of variation of sand to aggregate volume ratio (s/a) in concrete.

1.4 Methodology

This study investigated the Utilization of Brick Fine Aggregate in Concrete as partial of Natural Sand on concrete. For investigation, first class bricks fine aggregate collected from construction site and brick chips seller market. Brick fine aggregate is termed as brick fine aggregate. Brick was broken manually and we get brick fine aggregate. The aggregates were tested for specific gravity, absorption capacity and unit weight. CEM Type II/A-M cement (as per BDS EN 197–1:2000) was used. Tap water was used for mixing and curing of concrete. Cylindrical concrete specimens of 100 mm diameter and 200 mm height were made. There were three cylinders were made for each case. 3 cylinders were used for 7day; 28 day and compression test each cylinder also tensile test.

1.5 Research Flow Diagram



1.5.1 Layout of the Thesis

Chapter 1. Thoroughly discusses the background and objectives of this study.

Chapter 2. Discusses the possibility of utilization of brick fine aggregate in concrete as partial of natural sand based on literature review.

Chapter 3. Presents information on the development of methods used to design a concrete mixture, as well as the cases investigated in this study. In addition, it outlines the actual mix designs studied. It also includes background information on the key components of concrete and their respective properties. The chapter concludes with information pertaining to the test methods and procedures followed in this study.

Chapter 4. Presents the results of the tests performed on specimens in both fresh and hardened state. The test results from the experimentation program in the fresh state and hardened state are discussed separately. The workability, compressive strength, splitting tensile strength are analyzed and discussed. In addition, several relationships between concrete properties are also presented in this chapter.

Chapter 5. Presents a summary of the conclusions drawn from the results of this research and also suggests recommendations for future works.

CHAPTER 2
Literature Review

2.1 Introduction

This Chapter elaborates the increasing demand of brick fine aggregates and represents the facts that are responsible for the search of alternative materials. This chapter discusses the possibilities of using brick fine aggregate as a replacement of natural sand. Here a brief comparison is being carried out between brick fine aggregate and natural sand by doing partial replacement of these constituents in concrete and see if fine aggregate can be replaced by brick fine aggregate based on literature review.

2.2 Aggregate in Concrete as an Ingredient

Concrete is an artificial, stone like, composite material used for various structural purposes and which is made by mixing cement as well as coarse and fine aggregate as an important constituent. Sand, pebbles, gravel or shale is also available in this mixture which is being hardened in the presence of sufficient amount of water. Other constituents such as admixtures, pigments, fibers, polymers and reinforcement can be incorporated to modify the properties of hardened concrete. The properties of the plastic and hardened concrete are determined by the combination of constituents used. Concrete Mix design is the name for the procedure for choosing a particular combination of constituents.

2.3 Alternative Materials for Fine Aggregate

As the demand for natural sand in the making of cement concrete is increasing day by day the search for alternative material has become a crying need. Natural sand is the most widely used fine aggregate in Bangladesh and the continuous using of the natural sand hampering the environment to a great extent. Moreover, the price of natural sand is also going higher as its demand gets higher. In this existing condition the waste materials such brick fine aggregate can be considered as a possibility which can be used instead of Natural sand.

The mechanical strength of brick fine aggregate concrete is acceptable; though slightly lower flexural strength than that of conventional concrete. The expansion induced form brick fine aggregate using as natural sand concrete may lower the shrinkage and expansion to a certain extent.

2.4 Aggregate

Concrete is an artificial stone manufacture form a mixture of binding materials and inert materials with water. The inert materials used in concrete are termed as aggregate. It is defined as: “Aggregates are the inert materials that are mixed in fixed proportions with a binding material to produce concrete”. These act as fillers or volume increasing components on the one hand and are responsible for the strength, hardness, and durability of the concrete on the other hand. Aggregate is an essential ingredient to make concrete used in construction. The quality of the material strongly influences the performance of concrete including how well it mixes and hardens as well as its durability long term. A quality aggregate will be clean and free of any soft particles or vegetable matter. If organic compounds such as soil are included in the mix, this can cause chemical reactions that can compromise the strength and properties of the concrete.

2.5 Function of Aggregate in concrete

Aggregates are the important constituents of the concrete which give body to the concrete and also reduce shrinkage. Aggregates occupy 70 to 80 % of total volume of concrete. The aggregate give volume to the concrete, around the surface of which the binding materials adheres in the form of a thin film. In theory the voids in the coarse aggregate is filled up with fine aggregate and again the voids in the fine aggregate is filled up with the binding materials. Finally, the binding materials as the name implies, binds the individual units of aggregates into a solids mass with the help of water. The aggregate gives volume, stability, resistance to wear or erosion, and other desired physical properties to the finished product. Using aggregate as a filler can help concrete producers save a lot of money. Cement usually costs seven-or eight-times what stone and sand cost. Cement is necessary, but the strength can still be retained when using well-graded aggregates that cost significantly less. Aggregates make up 60-80% of the volume of concrete and 70-80% of the mass of concrete. Aggregate is also very important for strength, thermal and elastic properties of concrete, dimensional stability and volume stability. Cement is more likely to be affected by shrinkage. Including aggregate in the mix can control the shrinkage level and prevent cracking.

2.6 Strength of Aggregate

The water and Binding materials an important factor affecting the strength of concrete. The size of the aggregates, shape, surface texture, grading and mineralogy are known to affect concrete strength in varying degrees. So the strength of concrete depends on the type of aggregate used and it is a mere obligatory approach to find out suitable composition of aggregate in order to attain desired concrete strength. Generally in Bangladesh frequently two types of coarse aggregates are being used in construction work. One of them is brick aggregate and other is stone chips. Amongst them generally stone chips give higher strength than brick aggregates. As the availability of natural sand in Bangladesh are huge demand, the investigators find it imperative to look forward to enhance the concrete strength by finding and utilizing alternative sources and also try different partial replacement with the brick fine aggregates. Again some investigators have found some progressive results while using Brick fine aggregate as an alternative material of natural sand at different ratios which influence our search for finding the suitable alternative material in brick fine aggregate.

Use of 1stclass brick fine aggregate accelerates the rate of gain in compressive strength at the early age of concrete which is a very good sign as it gives desired strength even before the probable time period estimated.

So, we can clearly see that the compressive strength of aggregate is being dictated to a great extent by the nature of aggregate and hence finding a suitable alternative of coarse aggregate in the form of slag has become more essential. Since the testing of crushing strength measurement of individual aggregate particle is very difficult, the desired information has to be obtained from indirect test like crushing value of bulk aggregate or resistance to abrasion.

2.7 Types of Aggregate

Classification of Aggregates Based on Size

Aggregates are available in nature in different sizes. The size of aggregate used may be related to the mix proportions, type of work etc. the size distribution of aggregates is called grading of aggregates.

Following are the classification of aggregates based on size:

Aggregates are classified into 2 types According to Size:

- Fine aggregate
- Coarse aggregate

Fine Aggregate

When the aggregate is sieved through 4.75mm sieve, the aggregate passed through it called as fine aggregate. Natural sand is generally used as fine aggregate silt and clay are also come under this category. The soft deposit consisting of sand, silt and clay is termed as loam. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. The fine aggregate should not be larger than 3/16 inch in diameter.

Table No: 2.1 Size of Fine Aggregate

Fine aggregate	**Size variation**
Coarse Sand	2.0mm – 0.5mm
Medium sand	0.5mm – 0.25mm
Fine sand	0.25mm – 0.06mm
Silt	0.06mm – 0.002mm
Clay	<0.002

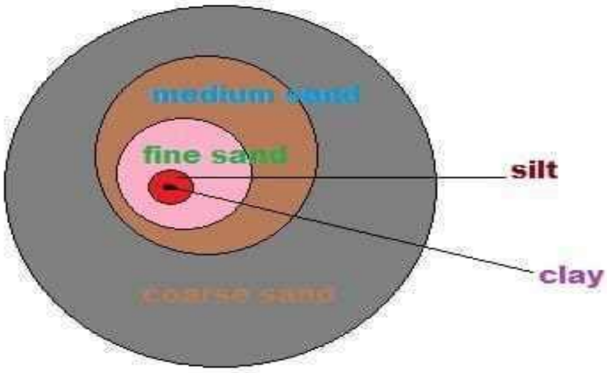


Figure No: 2.1 Size of Fine Aggregate.

Coarse Aggregate

When the aggregate is sieved through 4.75mm sieve, the aggregate retained is called coarse aggregate. Gravel, cobble and boulders come under this category. The maximum size aggregate used may be dependent upon some conditions. In general, 40mm size aggregate used for normal strengths and 20mm size is used for high strength concrete. The size range of various coarse aggregates given below.

Table No: 2.2 Size of Coarse aggregate

Coarse aggregate	**Size**
Fine gravel	4mm – 8mm
Medium gravel	8mm – 16mm
Coarse gravel	16mm – 64mm
Cobbles	64mm – 256mm
Boulders	>256mm

2.8 Brick Fine Aggregate

A brick is an artificial kind of stone made of clay whose chief characteristics are a plasticity when wet and stone like hardness after being heated to high temperature.

Brick fine aggregate is a waste material obtained from the brick chips. Brick aggregates are produced by breaking bricks into pieces manually or mechanically. It is produced in large quantities during the broken the brick chips. Brick fine aggregate can also be produced by brick chips and brick factory. Brick fine aggregate currently not use in the construction site, but there is a need for some additional work such as lime terracing.

Brick fine aggregate occurs from loading or unloading, construction sites and brick kilns. This fine aggregate is used in dumping and filling. There are thousands ton of brick waste generated each year around the world which goes in unplanned way. Pozzolanic materials such as brick fine aggregate and other ceramics powder has-been used in concrete since ancient times. In ancient times the brick fine aggregate was used according to experiences and experiments as they were unaware of the properties of brick fine aggregate. Bricks are made up of different types of clays and other materials like sand. Clay composed up of 20-30% Alumina, 50-60% Silica and other carbonates and oxides. Clay is responsible for the pozzolanic behavior of brick. Clay itself has no pozzolanic properties but when fired together with Lime during brick making process it gains pozzolanic nature.

Table No: 2.3 Physical properties of brick fine aggregate

Properties	Brick Fine aggregate
Moister Content (%)	4.7
Specific Gravity (unit)	2.44
Fineness modulus	2.68

2.9 Chemical Reaction of Brick Fine aggregate in Concrete

Brick fine aggregate as pozzolana reacts with lime in presence of water to form hydraulic compounds. Calcium carbonate and water is produced when carbon dioxide reacts with calcium hydroxide. The chemical reactions are following:

Portland cement + Water → Calcium Silicate Hydrate

$Ca(OH)_2 + CO_2 \rightarrow CaCo_3 + H_2O$----------------------------(i)

Extra amount of hydraulic cement is formed when reacts with lime. The reaction is following:

Pozzolana + $Ca(OH)_2$ + water → C-H-S (Glue)-----------(ii)

The former reaction of Portland cement with water is fast reaction which provides early strength to concrete where the later reaction of pozzolana with liberated lime in presence of water is slow reaction which effect early age strength. But after some time, the brick fine aggregate provides extra amount of C-H-S which contribute to strength of concrete.

2.10 Qualities of Aggregates

Since at least three quarters of the volume of concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. Not only the aggregate is limiting the strength of concrete, as weak aggregates cannot produce a strong concrete, but also the properties of aggregate greatly affect the durability and structural perform of the concrete.

- Aggregates should be strong, hard, dense, durable, clear and free from veins and adherent coating.
- Aggregates should be free from injurious amounts of disintegrated pieces, alkalis, vegetable matter and other deleterious substances.
- Flaky and elongated pieces should not be present in aggregate mass.
- Aggregate crushing value should not exceed 45 percent for aggregate used for concrete other than for wearing surfaces, and 30 percent for concrete for wearing surfaces, such as runways, roads and pavements.

- Aggregate should not exceed 45 percent by weight for aggregates used for concrete other than for wearing surfaces and 30 percent by weight for concrete for wearing surfaces, such as runways, roads and pavements.
- Abrasion value of aggregate when tested using Los Angeles machine, should not exceed 30 percent by weight for aggregates to be used in concrete for wearing surfaces and 50 percent by weight for aggregates to be used in other concrete.

2.11 Sand Aggregate Ratio (s/a)

Sand-coarse Aggregate Ratio is defined as the Ratio of fine to coarse Aggregate in batch of concrete, by mass or by volume. The strength of concrete is related to the composition of sands used in concrete mix. Hence, the content and type of clay, percentage of feldspar and mica in the aggregates should always be determined before they are used in the concrete mix. The presence of clay in the natural sand reduces the concrete strength by nearly 10 MPa (Hasdemir et al. 2016).

Hasdemir et al. 2016) also stated that an important constituent of concrete is natural sand, which makes up about (25%-28%) of the volume of aggregate used in the construction in fine aggregately. Aggregates containing material such as coatings, reactive silica, sulfate, clay, feldspar and mica can potentially cause damage to the short and long-term performance of the concrete.

The Technical literature gives quite contradictory data on the effect of sand to aggregate volume ratio (s/a) on strength of concrete. However, Sizov (1997) stated that, an excessive amount of sand compared with the optimal causes a high consumption of cement and it's too low content leads to segregation and bleeding of concrete. Thus, it is important to study the strength of concrete for various s/a ratios and find the optimum s/a ratio for brick aggregate concrete.

Literature review also shows that the compressive strength of concrete fluctuates with the increase or decrease of s/a ratio rather than specific types of sand. Long-term

Compressive strength for concrete with manufactured sand is similar with the ordinary concrete.

Again, we get some contradictory reviews regarding the sand type affecting the compressive strength as

Stated that the behavior of concrete is influenced by sand type. It depends on the rate of fines and particle shape. Concrete with few fine particles has better performance if mineral additions and dune sand are used as a crushed sand replacement to fill granular voids. In the other side, concrete with a high rate of fine particles may have better performance if river sand is used as a crushed sand replacement to reduce percent finer.

Yoo, Zi, Kang, &Yoon (2015) stated that, the s/a ratio is an important parameter and Rheological properties such as, the compressive and tensile strength of concrete increase with an increase in the s/a ratio.

2.12 Water to Cement Ratio

In concrete, the single most significant influence on most or all of the properties is the amount of water used in the mix.

In concrete mix design, the ratio of the amount of water to the amount of cement used (both by weight) is called the water to cement ratio (w/c). These two ingredients are responsible for binding everything together.

The water to cement ratio largely determines the strength and durability of the concrete when it is cured properly. The w/c ratio refers to the ratio of the weights of water and cement used in the concrete mix. A w/c ratio of 0.4 means that for every 100 lbs of cement used in the concrete, 40 lbs of water is added.

The water-cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers.

The notion of water–cement ratio was first developed by Duff A. Abrams and published in 1918. Refer to concrete slump test. The 1997 Uniform Building Code specifies a maximum of 0.5 ratios when concrete is exposed to freezing and thawing in a moist condition or to de-icing chemicals, and a maximum of 0.45 ratio for concrete in a severe or very severe sulfate condition.

Concrete hardens as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every pound (or kilogram or any unit of weight) of cement, about 0.35 pounds (or 0.35 kg or corresponding unit) of water is needed to fully complete hydration reactions.

However, a mix with a ratio of 0.35 may not mix thoroughly, and may not flow well enough to be placed. More water is therefore used than is technically necessary to react with cement. Water–cement ratios of 0.45 to 0.60 are more typically used. For higher-strength concrete, lower ratios are used, along with a plasticizer to increase flow ability.

Too much water will result in segregation of the sand and aggregate components from the cement paste. Also water that is not consumed by the hydration reaction may leave concrete as it hardens, resulting in microscopic pores (bleeding) that will reduce final strength of concrete. A mix with too much water will experience more shrinkage as excess water leaves, resulting in internal cracks and visible fractures (particularly around inside corners), which again will reduce the final strength.

Mindess et al. (2003) proposed that the strength of concrete decreases with an increase in W/C ratio and proposed a relationship between compressive strength and W/C ratio as shown in

Fig.2.2 Similar conclusion was also drawn by Wassermann et al. (2009), Dhir et al. (2004), Kosmatka et al. (2002), Schulze (1999), Mehta and Monteiro (1993). Popovics (1990) suggested that to increase the concrete strength, it is more efficient and economical to reduce the water content than to use more cement.

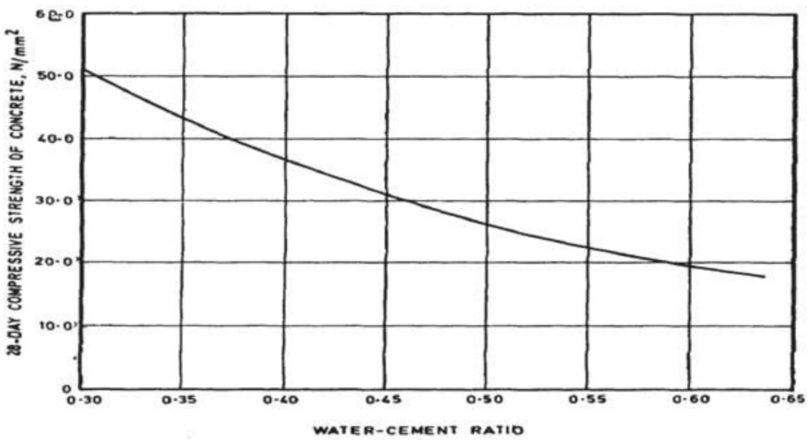


Fig 2.2: Relationship between compressive strength and W/C ratio

A well establish fact in the cement in fine aggregately speaks that an excessive water content leads to reduction in strength in the cement mortar, but insufficient water content incurs a poor workability. Hence, a method for determining the optimum water content and influence of w/c ratio on cement mortar is obviously desirable.

Haach, Vasconcelos, & Lourenço investigated the influence of aggregate grading and w/c ratio on the workability and compressive strength of mortar. Authors observed that increase in w/c ratio has reduced the value of mechanical properties and increased the workability.

Zhou et al observed that dynamic compressive strength of cement mortar increased with decrease in water content. The dynamic compressive strength of saturated specimen was 23% lower than that of totally dry specimen.

They observed that fracture behavior of low w/c ratio mortar is more brittle than that of mortar with high w/c ratio.

The compressive strength of cement mortar is considered to be one of the most important aspects of masonry structures. The compressive strength of cement mortar at the age of 28 days has decreased with an increase in cement-to-sand proportions. The decrease in cement content requires more water for making mortar workable

CHAPTER 3
Methodology

3.1 Introduction

As the study has a wide insight on a variety of aspects, different methods were adopted in order to achieve the objective of this study properly. In this chapter, the experimental method of the study is summarized. It includes the mix proportion of concrete, cases investigated in the study, collection and preparation of materials, material properties, experimental setup, and sample preparation, curing, and testing.

3.2 Concrete Mixture Proportion and Cases Studied

100 mm by 200 mm cylindrical concrete specimens were made with varying s/a ratio (0.45); W/C ratio (0.50), and cement content 400 kg/m^3). Mixed Brick fine aggregate and natural sand were used using aggregate with these aggregates, concrete is to be made and hence the main approach is to build a relationship between their compressive strength and different mixing proportions of brick fine aggregate and natural sand. In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. Nominal mixes offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength. Nominal mix ratios for concrete are **1:2:4** A total of 6 independent cases and 18 cylindrical specimens were investigated; the case plan of all 6 cases is summarized in **Table 3.1** and the mixture proportion is summarized in **Table 3.2**. For each different mixture proportions of 0% brick fine aggregate(BFA) and 100% natural sand (NS), 10% BFA and 90% NS, 20% BFA and 80% NS, 30% BFA and 70% NS, 40 BFA and 60% NS, 50% BFA and 50% NS, total 18cylinders were casted.

Cylinder per case = 3 (compressive strength at 7days &28 days)

Table No: 3.1 Case Plan

Brick fine aggregate	Natural sand	Cement content (kg/m^3)	s/a	W/C	No. of cylinders
0%	100%	400	0.45	0.50	3x12=36
10%	90%				
20%	80%				
30%	70%				
40%	60%				
50%	50%				

Table No: 3.2. Mixture Proportion of Concrete

% Replacement of Natural sand	Cement content (kg/m^3)	s/a	W/C	Unit Content,(kg)				
				Cement	Coarse Aggregate	Water	Fine Aggregate	
							BFA	NS
0% BFA +100% NS	400	0.45	0.50	8.16	7.16	4.08	0	15.23
10% BFA +90% NS				8.16	7.16	4.08	1.42	13.69
20% BFA +80% NS				8.16	7.16	4.08	2.87	12.06
30% BFA +70% NS				8.16	7.16	4.08	4.30	10.65
40% BFA +60% NS				8.16	7.16	4.08	5.75	9.12
50% BFA +50% NS				8.16	7.16	4.08	7.18	7.61

3.3 Property of Test Aggregate

Some major tests have been done for both coarse aggregate and fine aggregate. The tests are the following

- ✓ Determination of specific gravity and absorption capacity
- ✓ Determination of unit weight
- ✓ Sieve Analysis

3.3.1 Bulk Specific Gravity of Coarse Aggregate

This test method confirms to the ASTM standard requirements of specification C 127.

Apparatus

Balance: Sensitive to 0.05% of sample weight at any point within the range used for the test, or 0.5g, whichever is greater.

Sample Container*:* A bucket of approximately equal breadth and height; with a capacity of 4 to 7 liter for 37.5 mm (1.5 in.) nominal maximum size aggregate.

Water tank*:* A watertight tank into which the sample container can be placed while suspended below the balance.

Sampling

Sample has been thoroughly mixed. All materials passing 2.36 mm sieve have been rejected.

Procedure

- ❖ The test sample has been dried to constant weight at a temperature of 110 ± 5°C (230 ± 9°F), cooled in air at room temperature for 1 to 3 hr. for test samples of 19 mm (3/4 in) nominal maximum size. Subsequently the aggregate has been immersed in water at room temperature for a period of 24 ± 4 hr.
- ❖ The test sample has been removed from water and rolled in a large absorbent cloth until all visible films of water have been removed. Care has been taken to avoid evaporation from aggregate pores during the operation of surface drying. The test sample has been weighted in saturated surface-dry condition. All subsequent weights have been recorded to nearest 0.5g. or 0.05% of the sample weight, whichever is greater

- After weighing, test sample has been immediately placed in the sample container and its weight has been determined in water at 23 ± 1.7°C (73.4 ± 3°F), having a density of 997 ± 2 kg/m3. Care has been taken to remove all entrapped air before weighing by shaking the container while immersed.

Figure No: 3.1 Weighing Test Sample in Saturated Surface-Dry Condition

The test sample has been dried to a constant weight at a temperature of 110 ± 5°C (230 ± 9°F), cooled at room temperature 1 to 3 hr. and weighted.

Calculation

Bulk specific gravity (oven-Dry-basis)

Bulk specific gravity = $\frac{A}{S-C}$-------------------(iii)

Where,

A= weight of oven-dry specimen in air, gm

S= weight of the saturated-surface-dry specimen in air, g and

C= weight of saturated specimen in water, gm

Bulk Specific Gravity (Saturated- surface –Dry basis)

Bulk specific gravity = $\frac{S}{S-C}$-------------------(iv)

Apparent Specific Gravity:

Apparent Specific Gravity = $\frac{A}{A-C}$------------(v)

Specific Gravity result have been reported to nearest 0.01.

Table: 3.3 Determination of Specific Gravity of coarse aggregate

Properties of aggregate	Name of Aggregate
	Stone Chips
Bulk Specific Gravity (oven-dry-Basis)	2.70
Apparent Specific Gravity (oven-dry-basis)	2.71
Moisture Content	0.47%

3.3.2 Bulk Specific Gravity of Fine Aggregate

This test method conforms to the ASTM C127

Apparatus

Balance: Sensitive to 0.1 g

Pycnometer: A flask of 1000 ml capacity.

Mold: A metal mold in the form of a frustum of a cone with dimensions as follows:

40 ± 3 mm inside diameter at the top

90 ± 3 mm inside diameter at the bottom

75 ± 3 mm in height

0.8 mm minimum thickness of metal

Temper: A metal tamper weighing 350 ± 15 g and having a flat circular tamping face 25 ± 3 mm in diameter.

Sampling

- Approximately 306 gm sample of fine aggregate has been taken.

- It has been dried at a temperature of 110 ± 5°C (230 ± 9°F) and allowed to cool to comfortable handling temperature, covered with water by immersion for 24 ± 4 hrs.
- The sample has been spread on a flat non-absorbent surface exposed to a gently moving current of warm air, and stirred frequently to secure homogeneous drying. This operation has been continued until the test specimen approaches a fresh-flowing condition.

Procedure

- ✓ The pycnometer has been partially filled with water. 500 ± 10 (S) gm of saturated surface-dry fine aggregate has been immediately introduced into the pycnometer. Then the pycnometer has been filled with additional water to approximately 90% of capacity. The pycnometer has been rolled, inverted and agitated to eliminate all air bubbles. The total weight of pycnometer, specimen, and water (C) has been determined.
- ✓ The fine aggregate has been removed from the pycnometer, dried to constant weight at a temperature of 110 ± 5°C (230 ± 9°F), cooled in the room temperature for 1 ± 12 hr., and weight. (A)

- ✓ The weight of the pycnometer filled to its calibration capacity with water at 23 ± 1.7°C (73.4 ± 3°F). (B)

Calculation

Bulk Specific Gravity (oven-Dry basis):

Bulk Specific Gravity = $\frac{A}{B+S-C}$-----------------------------------(vi)

Where,

A = weight of oven-dry specimen in air, gm
B = weight of pycnometer filled with water, gm
S = weight of the saturated surface-dry specimen, gm
C = weight of pycnometer with specimen and water to calibration mark, gm

Bulk Specific Gravity (Saturated- Surface-dry basis)

Bulk specific Gravity = $\frac{S}{B+S-C}$-------------------------(vii)

Apparent Specific Gravity:

Apparent Specific Gravity =$\frac{A}{B+A-C}$------------(viii)

Specific gravity have been reported to nearest 0.01.

Table: 3.4 Determination of Specific Gravity of Fine Aggregate

Properties of Aggregate	Name of Aggregate	
	Sylhet sand	Brick fine aggregate
Bulk Specific Gravity (oven-dry basis)	2.59	2.44
Apparent Specific Gravity (oven-dry basis)	2.63	2.51
Moisture content	3.01%	4.7%

Figure No: 3.2 Brick Fine Aggregate

3.3.3 Unit weight of coarse Aggregate

This test method conforms to the ASTM standard requirements of specification C 29.

Apparatus

Balance: Accurate within 0.1% of the test load and graduated to at least 0.1 lb (0.05 kg).

Tamping rod a round steel rod, 5/8 in (16mm) in diameter and approximately 24 in (600 mm) in length having one end round to a hemispherical tip of the same diameter as the rod.

Measure: A cylindrical metal measure preferably provided with handles. It has been watertight, with the top and bottom true and even, and sufficiently rigid to retain it's from under rough usage. The measure has been a height approximately equal to the diameter.

Calibration equipment: A piece of plate glass, ¼ in. (6 mm) thick and 1 in. (25 mm) larger than the diameter of the measure to be calibrated.

Sampling

The size of the sample has been approximately 125 to 200% of the quantity required to fill the measure, and has been handled in a manner to avoid segregation. The aggregate has been dried to constant mass in an oven at 110 ± 5°C (230 ± 9°F).

Procedure (Rodding procedure)

- ✓ The measure has been filled one-third full and the surface has been leveled with the fingers. The layer of aggregate has been rodded with 25 strokes of the tamping rod evenly distributed over the surface. The measure has been filled two-thirds full and again levelled and rodded as above. Finally, the measure has been filled to overflowing and rodded again in the manner previously mentioned. The surface of the aggregate has been leveled with fingers in such a way that any projections of larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.
- ✓ In rodding the first layer, the rod has not been allowed to strike the bottom of the measure forcibly. In rodding the second and third layers, vigorous effort has been used, but such a force has not been applied to cause the tamping rod to penetrate to the previous layer of aggregate.
- ✓ The mass of the measure plus its contents, and the mass of the measure alone have been determined, and the values have been recorded to the nearest 0.1 lb (0.05 kg).

Lose Unit Weight (shoveling procedure)

- Fill the measure to overflowing by means of a scoop, discharging the aggregate from a height not to exceed 2 in. (50 mm) above the top of the measure.
- Level the surface of the aggregate with a straightedge.

- Determine the weight of the measure plus content, and the weight of the measure alone, recording values to the nearest 0.1 lb. (0.05 kg)

Calculation

$$\mathbf{M} = \frac{G-T}{V} \text{ ---(ix)}$$

Where,

M = unit weight of aggregate, kg/m3
G = mass of the aggregate plus measure, kg
T = mass of the measure, kg
V = volume of the measure, m3
The results for the dry rodded unit weight have been 1610 kg/m3.

3.3.4 Sieve Analysis of Fine and coarse Aggregate

This test method conforms to the ASTM standard requirements of specification C 136.

Apparatus

Balance: sensitive to within 0.1% of the weight of the sample
Sieves: ASTM Standard

Mechanical sieve shaker

Sampling

Sieve analysis of fine aggregate has been performed according to ASTM C 136/C (2004) standard specification. The procedure is as follows:

Procedure:

Step- 1
Take sample of fine aggregate (as per ASTM standard specification, the aggregates must be completely dry). This is determined by weighing the material on a digital scale. Also weigh each sieve of the mechanical sifter, and the pan, and record the weights.

Step-2

Place the aggregate in the top sieve of the well-cleaned mechanical sifter (sieves used are # 4, # 8, # 16, # 30, # 50 & # 100). This apparatus is used for shaking the aggregates (similar to the principle used in a paint-mixing machine) and sieving them. The mechanical sifter has a bottom pan (to receive the material passing # 100 sieve) and a lid to close the sifter during the test. After placing the lid on the sifter, agitate the sifter for about 10 minutes.

Step-3

Determine the weight of aggregates that are retained in each of the sieves, by weighing each of the sieves (along with the retained aggregates), and subtracting the weight of each sieve. Also record all the weights of aggregates retained in each of the sieves. To ensure that all materials are collected, clean each sieve carefully using the proper type of brush. Use the paint brush for the finer sieves, the copper brush for intermediate sieves and the steel wire brush for the coarse sieves. Also verify whether the sum of weights of aggregates, retained in all the sieves, and the bottom pan is equal to the initial weight of the aggregates taken.

Step-4

Tabulate the data and determine the percent retained in each sieve. From these values calculate the (cumulative) percentage of material that would have been retained in the sieve if the whole volume of material was to be sifted in that sieve alone. Then add the percentage of material retained in all the sieves and divide by 100 to get the fineness modulus. Also prepare a column to determine the cumulative percentage passing through the sieve to plot the fineness modulus curve (as specified in CSA 23.1).

Step-5

- Aggregate with at least 85% passing no. 4 sieve and more than 5 % retained on a No. 8 sieve.
- Aggregate with at least 95% will be passing by No. 8 sieve.

To calculate the fineness modulus, the sum of the cumulative percentages retained on a definitely specified set of sieves needs to be determined, and the result is then divided by 100.

$$F.M = \frac{\Sigma(\text{Cumlative Percent retained})}{10}$$

Table: 3.5 sieve analysis of Fine Aggregate (Sylhet Sand)

Sieve Number	Sieve opening (mm)	Materials Retained (gm)	Percent Materials Retained	Cumulative Percent Retained	Percent Finer	Fineness Modulus
1/2 "	12.5	0.00	0.00	0.00	100.00	2.52
3/8 "	9.5	0.00	0.00	0.00	100.00	
1/4 "	6.3	1.65	0.55	0.55	99.45	
4	4.75	4.3	1.43	1.98	98.02	
8	2.36	25.95	8.65	10.63	89.37	
16	1.18	36.52	12.17	22.80	77.2	
30	0.6	95.85	31.95	54.75	45.25	
50	0.3	65.55	21.85	76.60	23.4	
100	0.15	24.75	8.25	84.85	15.15	
Pan	-	10.43	-	-		
		265		252.16		

So, Fineness Modulus =2.52

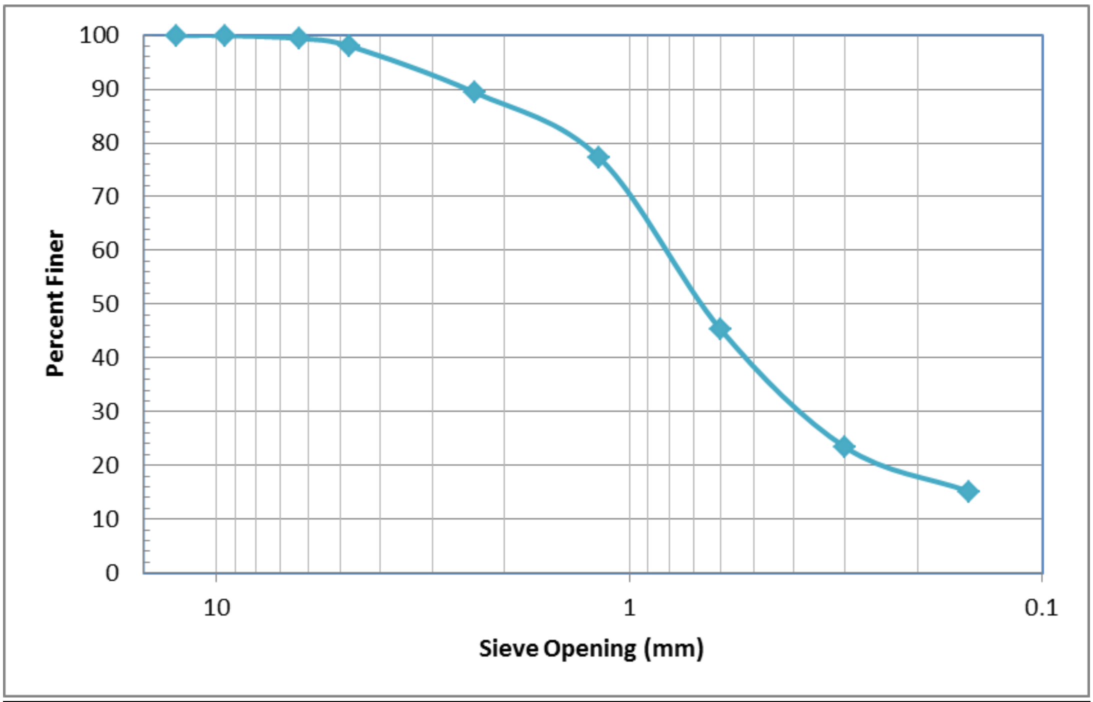


Figure No: 3.3 Gradation curve Fine Aggregate (Sand)

Table: 3.6 sieve analysis of Fine Aggregate (Brick)

Sieve Number	Sieve opening (mm)	Materials Retained (gm)	Percent Materials Retained	Cumulative Percent Retained	Percent Finer	Fineness Modulus
1/2 "	12.5	0.00	0.00	0.00	100.00	2.68
3/8 "	9.5	0.00	0.00	0.00	100.00	
1/4 "	6.3	7.55	2.52	2.52	97.48	
4	4.75	12.85	4.28	6.8	93.2	
8	2.36	25.95	8.65	15.45	84.55	
16	1.18	35.55	11.85	27.3	72.7	
30	0.6	55.55	18.52	45.82	54.18	
50	0.3	102.33	34.11	79.92	20.08	
100	0.15	32.25	10.75	90.67	9.33	
Pan	-	27.97	-	-	-	
		300		268.48		

So, Fineness Modulus =2.68

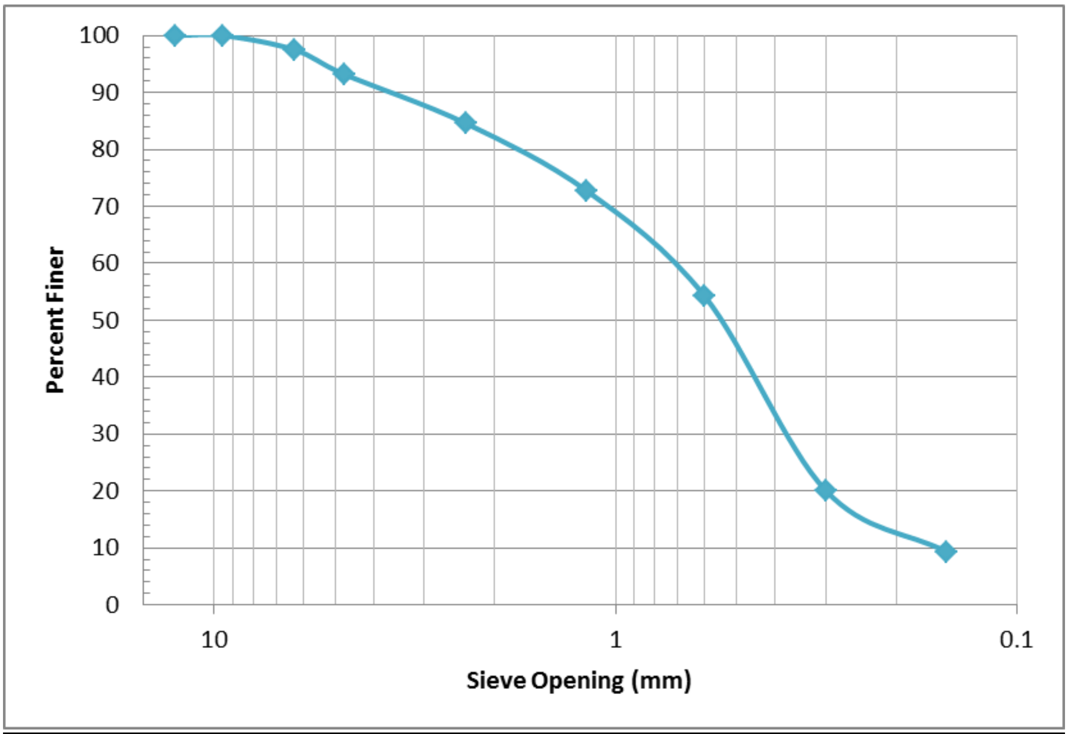


Figure No: 3.4 Gradation curve Fine Aggregate (Brick)

Table: 3.7 sieve analysis of coarse aggregate (stone chips)

Sieve Number	Sieve opening (mm)	Materials Retained (gm)	Percent Materials Retained	Cumulative Percent Retained	Percent Finer	Fineness Modulus
2”	50	0.00	0.00	0.00	100.00	9.82
1.5”	37.5	0.00	0.00	0.00	100.00	
1”	25.4	479.00	5.00	5.00	95.00	
3/4"	19.05	3057.00	31.00	36.00	64.00	
1/2”	12.5	3072.00	31.00	67.00	33.00	
3/8”	9.5	1536.00	15.00	82.00	18.00	
1/4”	6.3	1192.00	12.00	94.00	6.00	
4	4.75	350.00	4.00	98.00	2.00	
8	2.36	181.00	2.00	100.00	0.00	
16	1.18	57.00	1.00	100.00	0.00	
30	0.6	29.00	0.00	100.00	0.00	
50	0.3	0.00	0.00	100.00	0.00	
100	0.15	0.00	0.00	100.00	0.00	
200	0.075	0.00	0.00	100.00	0.00	
Pan		47.00				
		10000.00		982.00		

So, Fineness Modulus =9.82

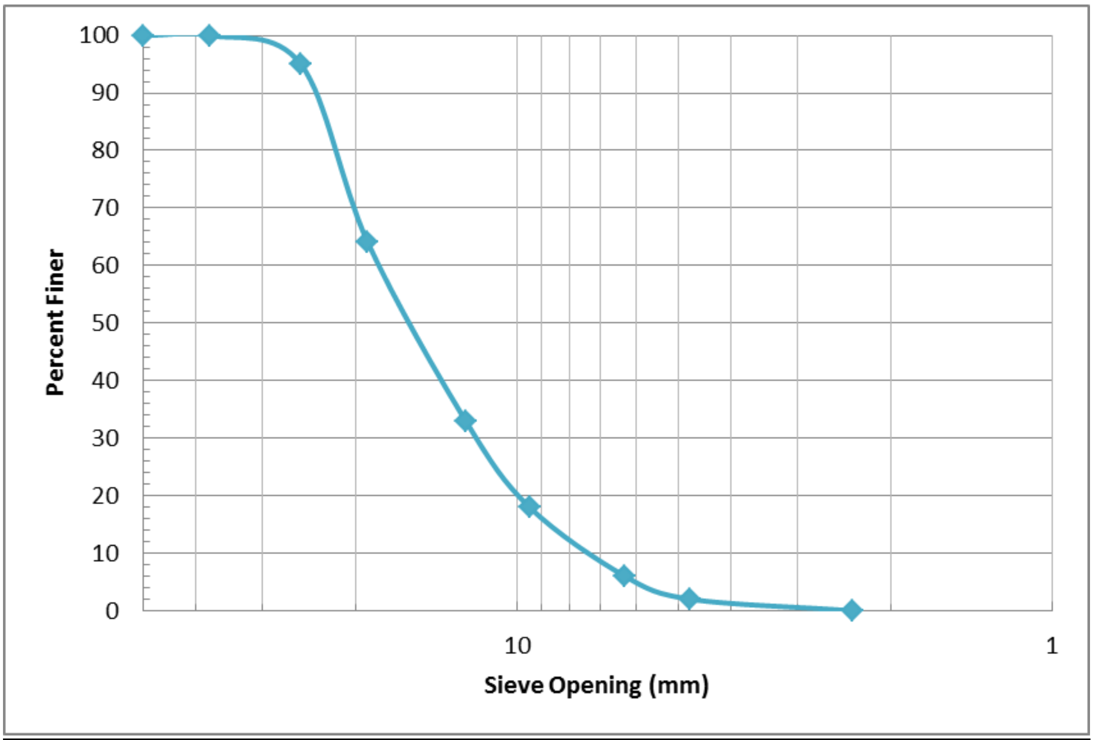


Figure No: 3.5 Gradation curve of coarse aggregate

3.3.5 Cement

CEM Type II A–M cement was used in this study that conforms to BDS EN 197 – 1: 2000, and ASTM C595. The composition of the mineral components is given in **Table3.6** (as specified by the manufacturer). It is manufactured by inter-grinding three major mineral components – Pulverized Fuel Ash (PFA), Blast Furnace Slag, and Limestone with common raw materials, clinker, and gypsum.

Table 3.8 Composition of cement

Component	Percentage
Clinker	80–94%
Slag, Fly Ash, and Limestone	6–20%
Gypsum	0–5%

3.3.6 Water

Water used in this study for concrete mixing and curing was potable tap water whose unit weight was 1000 kg/m^3.s

Generally, Quality of water for construction works is same as drinking water. This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc.

This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc.

The water shall be clean and shall not contain sugar, molasses or Gur or their derivatives, or sewage, oils, organic substances.

If the quality of water to be used for mixing is in doubt, cubes of 75 mm in cement mortar 1:3 mix with distilled water and with the water in question shall be made separately. The latter type of cubes should attain 90% of the 7 days' strength obtained in cubes with same quantity of distilled water.

Alternatively, the water shall be tested in an approved Laboratory for its use in preparing Concrete/Mortar.

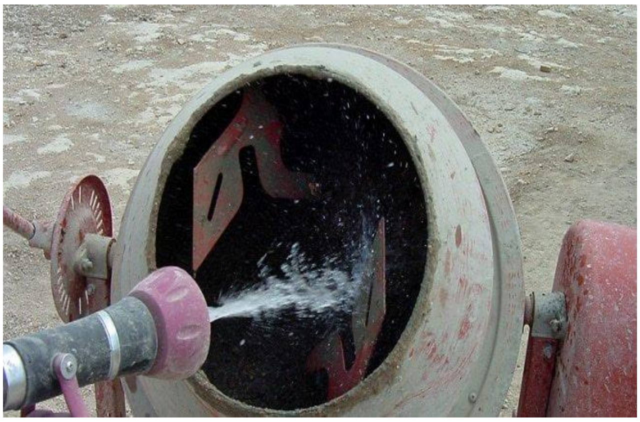


Figure No: 3.6 Concrete Mixing

The water quality for construction shall be tested or monitored regularly, as it affects the overall strength of concrete. For plain and reinforced cement concrete permissible limits for solids shall be as follows:

Table 3.9. Type of solid in water and Permissible Limits for Construction

Type of Solid in water	**Permissible Limits for Construction**
Organic matter	200 mg/l
Inorganic matter	3000 mg/l
Sulphates (SO4)	500 mg/l
Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg/l

3.4 Preparation of Materials

Before casting, the materials were prepared to satisfy the specifications of ASTM C 39 (2003). For each day of casting, the total number of cylinders to be made was calculated. Then on the basis of the mixture proportion shown in **Table 3.1**, and the material properties shown in **Table 3.4** and **Table 3.5**, the total amount of material required for each day of casting was calculated on a weight basis. Prior to casting, coarse aggregates were brought to saturated surface dry (SSD) condition to ensure that the W/C ratio of the mix remained as specified by the mixture proportion. The W/C ratio of the mix was monitored carefully.

Prior to casting, these coarse aggregates were sieved separately to satisfy ASTM C 33 (2003) and mixed according to proportion. Once the batch was prepared, the aggregates were kept in submerged condition for 24 hours and before casting, were rubbed with a clean cloth to eliminate excess water from the aggregate surface and ensure SSD condition of the aggregates.

The fine aggregate used in this study was Sylhet sand and was procured from local market. Prior to casting, the sand was sieved through No. 4 (4.75 mm) sieve to separate any coarse aggregate from the mix and then washed to avoid mud and other organic materials. Sufficient water was mixed with sand several hours before casting and lump of sand was made in the palm of the hand. If the lump broke when the palm was stretched, the sand was considered to be in SSD condition. Once SSD sand was prepared, it was stored in air tight bags to avoid moisture loss.

3.5 Experimental Setup

After casting of concrete specimens, they were cured initially for 24 hours by covering the cylindrical molds with wet clothes to prevent moisture loss. The specimens were de molded after 24 hours of casting, followed by curing under water till the age of testing according to ASTM C31.

The strain of concrete specimens was measured by a strain measurement setup of gauge length 100 mm with two dial gauges. The stress of concrete at strain level 0.0005 was used to determine the Young's modulus of concrete. The splitting tensile strength of concrete was tested at 28 days. The failure surfaces of broken concrete specimens were also checked carefully after crushing of the concrete cylinders to corroborate the findings of this investigation.

3.5.1 Mold Preparation

The cylinder specimens are cast in steel, cast iron or any mold made of non-absorbent material. Even under severe conditions, the mold 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.

For studying the effects of partial replacement of brick fine aggregate with natural sand, cylindrical molds of diameter 100 mm and height 200 mm were used. Prior to casting, the cylinders were made air-tight by adjusting the screws, and the inner surface was lubricated by sing grease according to ASTM C 31 (2003).

3.5.2 Mixing and Casting of Concrete

For the casting of concrete of specimens, ASTM C31 was followed for standard procedure. Coarse aggregates were brought up to surface saturated dry (SSD) condition before casting.

Figure No: 3.7 Mixing of Concrete

Following precautions were observed:

a) Prevention of drying of the bed on which casting is to be done.

b) Dampening of the sheet on which slump is to be taken is also prevented.

c) To prevent mortar attack and mixing, the sheets and wall of mixing machine are washed Every time before a batch is mixed and casted

d) Made sure that grease is applied to the wall of all cylindrical molds.

e) Made sure that proper distribution of paste and aggregate is done in casting all specimens.

f) The top surface of specimens must have a smooth surface, if that is not possible during casting, ten capping with a thick mortar after half an hour of casting is provided.

g) It is mandatory to cast a specimen with a proper distribution of materials, such as, the top must get as much aggregate as the middle and bottom part of the specimen.

For casting of fresh concrete, mixture machine available in the Concrete Lab. of Sonargaon University (SU) was used. Trial mix was done for every case before the final mix. The mixing procedure followed in this study was quite different than the conventional mixing technique followed in construction sites in Bangladesh. The conventional technique is to put all the ingredients (cement, sand, coarse aggregate, water) simultaneously in the mixture. But in fact, it is not the best way to attain the desired strength of concrete. To ensure the quality of concrete, the following steps were followed to mix concrete:

Step 1: The inner surface of the mixing machine was wiped with a moist piece of cloth, so that the
Surface wouldn’t absorb the mixing water

Step 2: Half of the sand was poured into the machine and spread to give a notable bed like Surface
For the cement to put upon it Step 3: Cement was then placed on the sand bed.

Step 4: Rest of the sand was then poured on top of the cement. Step 5: The sand and cement were then mixed for 30 seconds.

Step 6: Water was then poured into the sand-cement mixture carefully to avoid accidental spillage from the mixture machine. The machine was let to rotate and mix the cement-sand paste for one and a half minute more.

Step 7: The coarse aggregate was then introduced inside the mixing machine and the mixing was continued for further 3 minutes.

The total mixing time was 5 minutes. After five minutes, the concrete mix was poured on a non-absorbent sheet to continue with the slump test and casting procedure simultaneously.

3.5.3 Slump Test

Slump test is a laboratory or at site test used to measure the consistency of concrete. Slump test shows an indication of the uniformity of concrete in different batches. The shape of the concrete slumps shows the information on the workability and quality of concrete. The characteristics of concrete with respect to the tendency of segregation can be also judged by making a few tamping or blows by tapping rod on the base plate. This test continues using since 1922 due to the simplicity of apparatus and simple procedure. The shape of the Slump cone shows the workability of concrete.

Principle of Slump test

The slump value of concrete is just a principle of gravity flow of surface of the concrete cone that indicates the amount of water added to it, which means how much this concrete mix is in workable condition.

Figure No: 3.8 Slump Test Apparatus

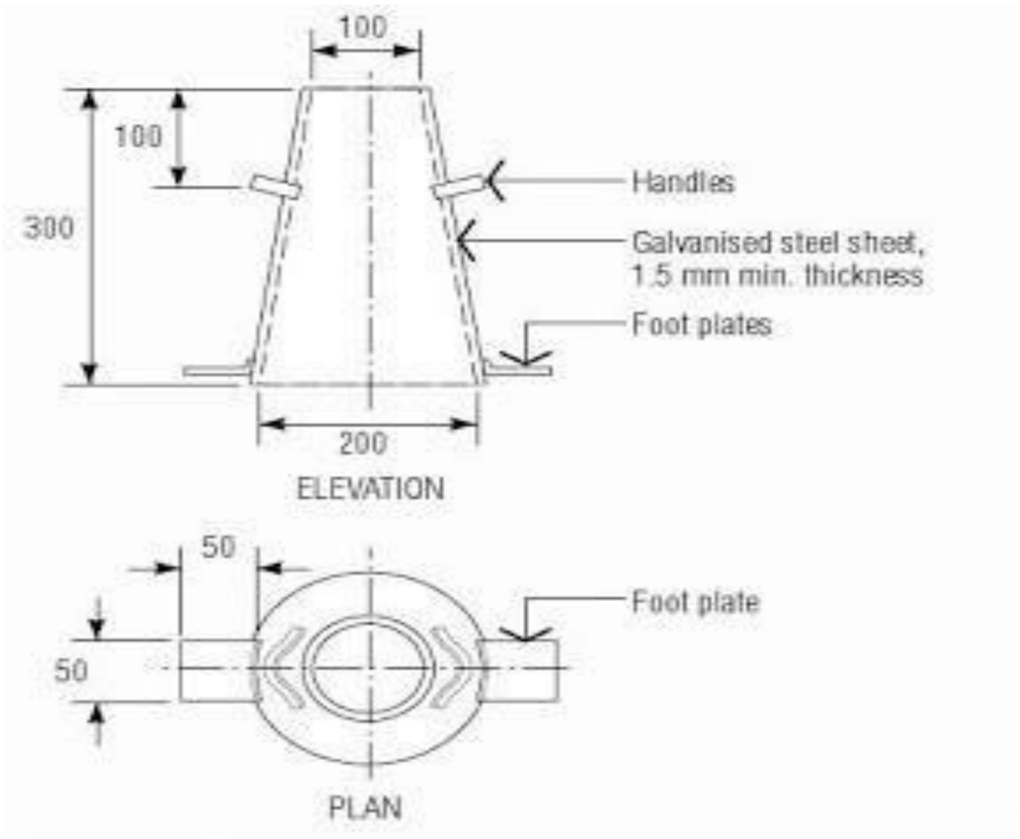


Figure No: 3.9 typical cone for slump test

Apparatus for Slump test

Followings apparatus are used in the slump test of concrete:

Table No: 3.10 Differences between 100 mm diameter and 150mm diameter Concrete cylinder specimens

Apparatus	**100 mm diameter and 200 mm height**
Tamping rod diameter	60 mm
Length of tamping rod	300 mm
No. of concrete layers in the mold to be tamped	3
No. of tamping	25 times

- Metallic mound in the shape of a frustum of cone having bottom diameter 20 cm (8 in), top diameter 10 cm (4 in) and height 30 cm (12in).
- Steel tamping rod having 16 mm (5/8 in) diameter, 0.6 m (2 ft.) long with bullet end.

Procedure of Slump Test

During Slump test following steps are followed:

- First of all, the internal surface of the mound is cleaned and free from moisture and free from other old sets of concrete.
- Then place the mould on the smooth horizontal, rigid, and non-absorbent surface.
- The mould is then filled with fresh concrete in four layers with taping each layer 25 times by taping rod, and level the top surface with a trowel.
- Then the mould is slowly pulled in vertical and removed from concrete, so as not to disturb the concrete cone.
- That subsidence of concrete in the periphery is a slump of concrete.
- The height difference between the height of subsidence concrete and mould cone in mm is 'slump value of concrete'.

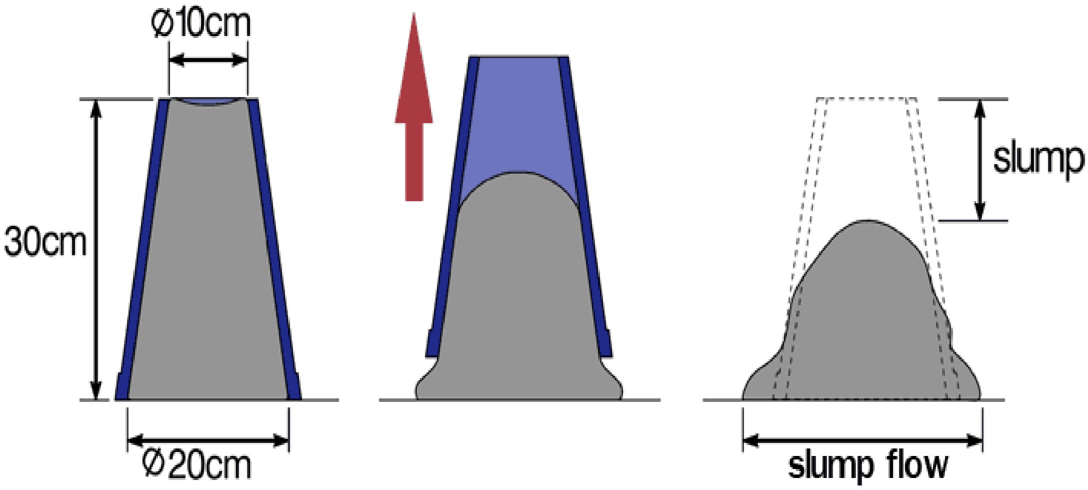


Figure No: 3.10 Slump test of concrete – Apparatus

Precaution during test

- The internal surface of the mould should be cleaned and free from moisture.

- The base plate or surface should be free from vibrations or shocking.
- This test is done just after sampling nearly after 2 minutes.

Uses and Drawbacks of slump test

This test does not give good results for very wet and dry concrete. Also for stiff-mix, it is not sensitive. The table below shows the various values of slump with the workability of concrete.

Following chart shows the Slump Value of concrete for different **Degree of workability** for various placing conditions:

Table No 3.11 Degree of Workability

Degree of workability	Placing Conditions	Slump (mm)
Very Low	Binding concrete (member of concrete by spreading, shallow sections, Pavements using pavers (mixer with spreading arrangements)	**Compaction factor 0.75 – 0.8**
Low	Mass concrete, lightly reinforced slab, beam, wall, column sections, canal lining, strip footing (ling wall with smaller width)	**25 – 75**
Medium	Heavily Reinforced sections in slab, beams, walls, columns. Slip formwork (slope concrete), pumped concrete.	**50-100**
High	Trench fill, in-situ piling	**100-150**
Very high	Termite concrete (concreting in water by using water tight pipe to pour concrete.)	**Flow test.**

Much research shows that for the “very high” category of workability, the flow test is more suitable for workability measurement.

For large construction projects, a slump test is a very useful tool to check day-to-day or hour-to-hour variation of the quality of the concrete mix, and by observing slump reading we can easily change the moisture (water) content and grading of concrete. Due to that reason, it is the most common method of test.

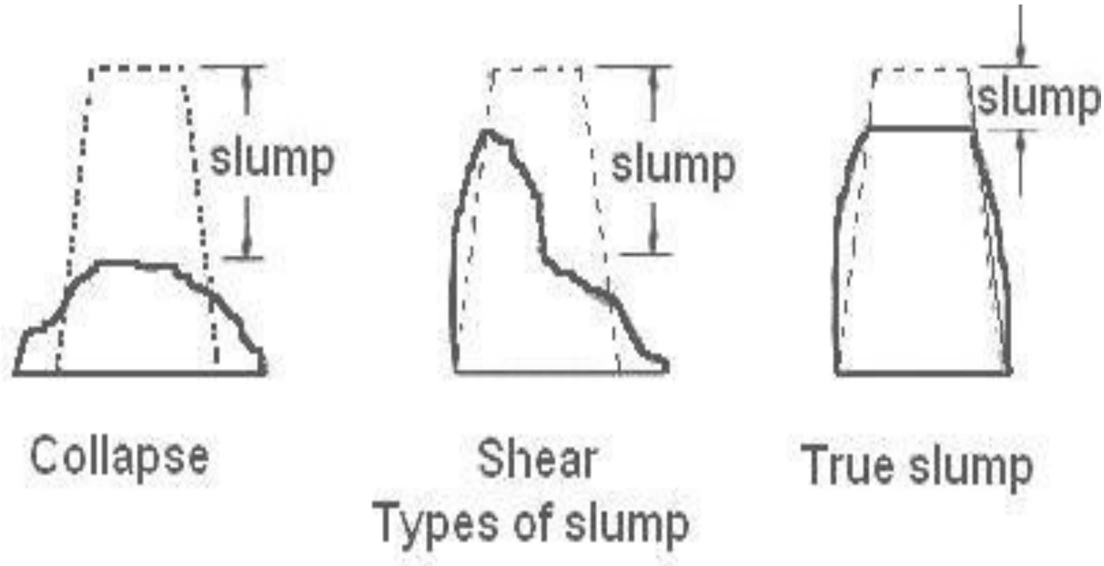


Figure 3.11 Shapes of Concrete Slump

Shape of concrete slump

When the metal mound is removed from the concrete cone, the slump takes the following shapes:

- **True Slump:** True shape of a slump is only a verified slump. This shape is measure as the difference between the top layers of the cone to the top of the slump concrete.
- **Collapse Slump:** It shows that due to a high water-cement ratio, the shape of a slump is not a clear dimension. It means, concrete is very high workability, for which slump test is not suitable.
- **Shear Slump:** This shape of slump is the same as shear failure of soil. This is an indication of a lack of cohesion of the concrete mix ingredients. So, a fresh sample is taken and the test is repeated.

Factors influencing Slump Cone:

Followings factors influence concrete Slump value:

1. Water –cement ratio of concrete.

2. The quality of coarse aggregate and fine aggregates, their shape, moisture content, texture, and grading.
3. The use of plasticizer, super plasticizer admixture, and the sequence of their mixing.
4. The void ratio of concrete and air content of concrete.
5. The time of the test after mixing of concrete

Figure No: 3.12 Slump Measurement

3.5.4 Curing of Specimen

Curing plays an important role on strength development and durability of concrete. Curing takes place immediately after concrete placing and finishing, and involves maintenance of desired moisture and temperature conditions, both at depth and near the surface, for extended periods of time. Properly cured concrete has an adequate amount of moisture for continued hydration and development of strength, volume stability, resistance to freezing and thawing, and abrasion and. Scaling resistance

The length of adequate curing time is dependent on the following factors:

- Mixture proportions
- Specified strength
- Size and shape of concrete member
- Ambient weather conditions
- Future exposure conditions

Slabs on ground (pavements, sidewalks, parking lots, driveways, floors, canal linings) and structural concrete (e.g., bridge decks, piers, columns, beams, slabs, small footings, cast-in-place walls, and retaining walls) require a minimum curing period of seven days for ambient temperatures above 40 degrees Fahrenheit[1]. American Concrete Institute (ACI) Committee 301 recommends a minimum curing period corresponding to concrete attaining 70 percent of the specified compressive strength[2]. The often specified seven-day curing commonly corresponds to approximately 70 percent of the specified compressive strengths. The 70 percent strength level can be reached sooner when concrete cures at higher temperatures or when certain cement/admixture combinations are used. Similarly, longer time may be needed for different material combinations and/or lower curing temperatures. For this reason, ACI Committee 308 recommends the following minimum curing periods:

- ASTM C 150 Type I cement seven days
- ASTM C 150 Type II cement ten days
- ASTM C 150 Type III cement three days
- ASTM C 150 Type IV or V cement 14 days
- ASTM C 595, C 845, C 1157 cements variable

Effect of curing duration on compressive strength development is presented in Figure 1.

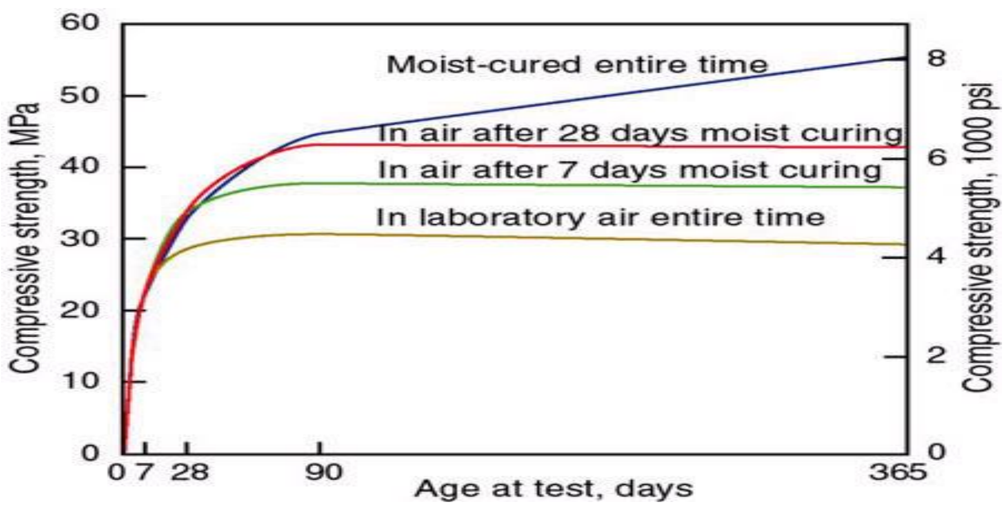


Figure No: 3.13 Moist Curing Time and Compressive Strength Gain

Higher curing temperatures promote an early strength gain in concrete but may decrease its 28-day strength. Effect of curing temperature on compressive strength development is presented in Figure 2

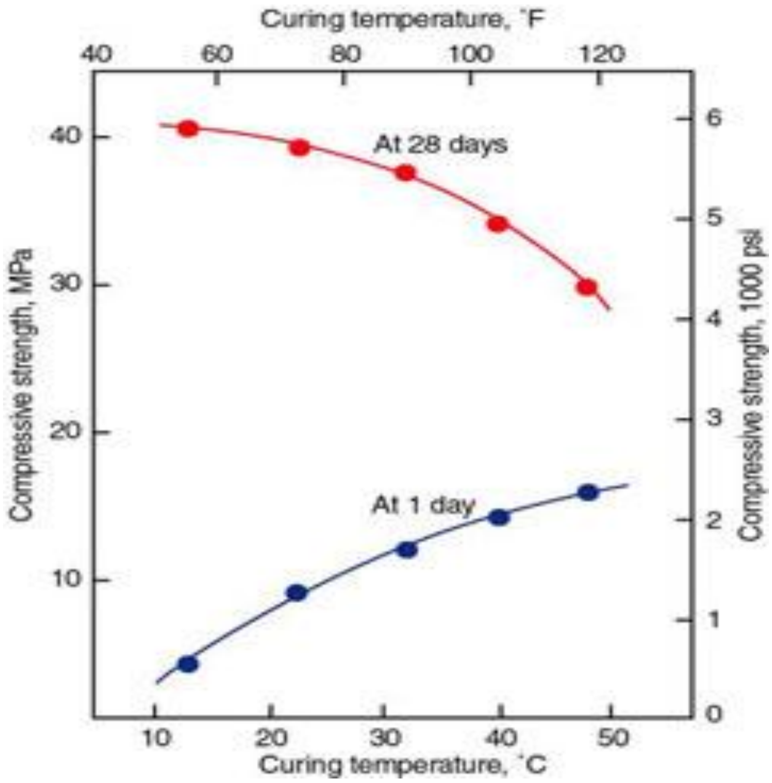


Figure No: 3.14 Effect of Curing Temperature on Compressive Strength

There are three main functions of curing

1) Maintaining mixing water in concrete during the early hardening process

Ponding and immersion

Ponding is typically used to cure flat surfaces on smaller jobs. Care should be taken to maintain curing water temperature at not more than 20 degrees Fahrenheit cooler than the concrete to prevent cracking due to thermal stresses. Immersion is mainly used in the laboratory for curing concrete test specimens.

Spraying and fogging

Spraying and fogging are used when the ambient temperatures are well above freezing and the humidity is low. Fogging can minimize plastic shrinkage cracking until the concrete attains final set.

Saturated wet coverings

Wet coverings saturated with water should be used after concrete has hardened enough to prevent surface damage. They should be kept constantly wet.

Left in Place Forms

Left in place forms usually provide satisfactory protection against moisture loss for formed concrete surfaces. The forms are usually left in place as long as the construction schedule allows. If the forms are made of wood, they should be kept moist, especially during hot, dry weather.

2) Reducing the loss of mixing water from the surface of the concrete

Covering concrete with impervious paper or plastic sheets

Impervious paper and plastic sheets can be applied on thoroughly wetted concrete. The concrete surface should be hard enough to prevent surface damage from placement activities.

Applying membrane-forming curing compounds

Membrane-forming curing compounds are used to retard or reduce evaporation of moisture from concrete. They can be clear or translucent and white pigmented. White-pigmented compounds are recommended for hot and sunny weather conditions to reflect solar radiation. Curing compounds should be applied immediately after final finishing. Curing compound shall comply with ASTM C309[4] or ASTM C1315[5].

3) Accelerating strength gain using heat and additional moisture

Live steam

Live steam at atmospheric pressure and high-pressure steam in autoclaves are the two methods of steam curing. Steam temperature for live steam at atmospheric pressure should be kept at about 140 degrees Fahrenheit or less until the desired concrete strength is achieved.

Heating coils

Heating coils are usually used as embedded elements near the surface of concrete elements. Their purpose is to protect concrete from freezing during cold weather concreting.

Electrical heated forms or pads

Electrical heated forms or pads are primarily used by precast concrete producers.

Concrete blankets

Concrete insulation blankets are used to cover and insulate concrete surfaces subjected to freezing temperatures during the curing period. The concrete should be hard enough to prevent surface damage when covering with concrete blankets.

Other forms of curing include internal moist curing with lightweight aggregates or absorbent polymer particles. For mass concrete elements (usually thicker than 3 feet), a thermal control plan is usually developed to help control thermal stresses. Additional information can be found in ACI Committee 308 report Guide to Curing Concrete[3]. For specialty concretes, it is recommended to refer to other ACI reports as follows:

- Refractory concrete ACI 547.1R
- Refractory concrete ACI 547.1R
- Insulating concrete ACI 523.1R
- Expansive cement concrete ACI 223
- Roller-compacted concrete ACI 207.5R

- Architectural concrete ACI 303R
- Shot Crete ACI 506.2
- Fiber-reinforced concrete ACI 544.3R
- Vertical slip form construction ACI 313

Curing in either cold or hot weather requires additional attention. In cold weather, some of the procedures include heated enclosures, evaporation reducers, curing compounds, and insulating blankets. The temperature of fresh concrete shall be above 50 degrees Fahrenheit. The curing period for cold weather concrete is longer than the standard period due to reduced rate of strength gain. Compressive strength of concrete cured and maintained at 50 degrees Fahrenheit is expected to gain strength half as quickly as concrete cured at 73 degrees Fahrenheit. In hot weather, curing and protection are critical due to rapid moisture loss from fresh concrete. The curing actually starts before concrete is placed by wetting substrate surfaces with water. Sunscreens, windscreens, fogging, and evaporation retardants can be used for hot weather concrete placements. Since concrete strength gain in hot weather is faster, curing period may be reduced. Additional information can be found in ACI 306.1, Standard Specification for Cold Weather Concreting, ACI 306R, Cold Weather Concreting, ACI 305.1, Specification for Hot Weather Concreting, and ACI 305R, Hot Weather Concreting. In this our experiment curing of specimens was done according to ASTM C 192 (2003). For the curing of specimens, a preliminary curing is done and followed by underwater curing. To prevent the evaporation of water from the unhardened concrete, each specimen was immediately covered with wet burlap. This initial curing of the specimens continued until the samples were de molded.

Each specimen was de molded after 24 hours of casting and taken immediately for moist curing. All specimens were moist cured at 23.0 ± 2^0 C from the time of the molding until the moment of test. Each specimen was placed in a curing bath so as to allow free water on entire surface area of the specimen. This final curing of each specimen continued until the day of testing.

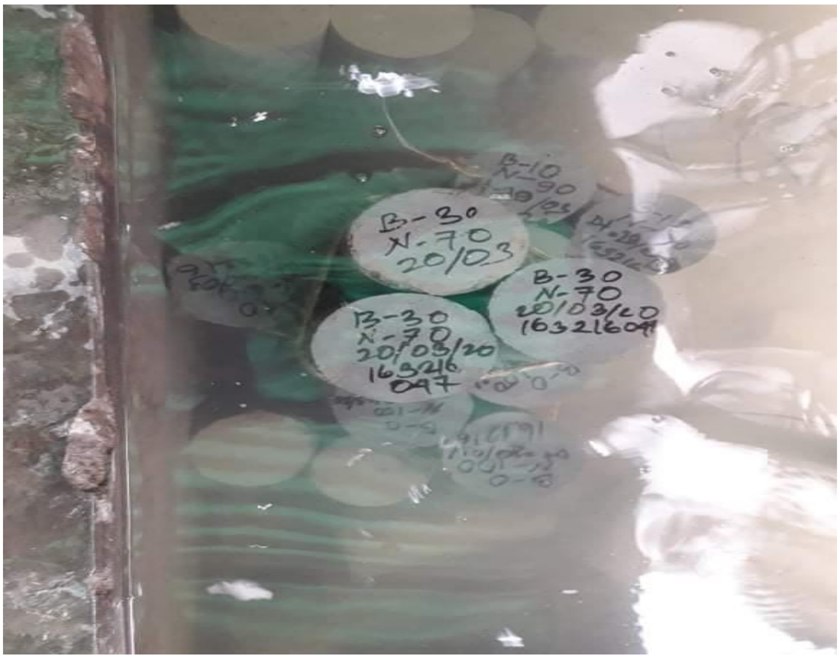


Figure No: 3.15 Curing of concrete cylinder

3.6 Testing

The properties of hardened concrete were evaluated by means of both destructive and non-destructive testing. In destructive tests (DT), a specimen is completely destroyed by applying pressure to evaluate the concrete strength, e.g. compressive strength, tensile strength. In non-destructive tests (NDT), the specimen strength is determined without damaging the specimen.

3.6.1 Compressive Strength

Compressive strength is measured by breaking cylindrical concrete specimens in a compression-testing machine. Compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load and reported in units of pound-force per square inch (psi) or mega Pascal's (MPa).

The compressive strength of concrete in this study was determined according to ASTM C 39 (2003). Crushing test is done in the semi-auto crushing machine. In this method, compressive axial load was applied to molded cylinders at a rate which is within a prescribed range of 0.15 to 0.35 MPa/s, until failure occurred. The compressive strength of the specimen was then calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen. The diameter and length of each cylinder specimen were measured using a Vernier caliper, and the cross-section was calculated. To determine the compressive strength of a particular batch of concrete on a particular age, the average compressive strength of three specimens was taken.

3.6.2 Test procedure:

1. Placing the Specimen — The plain (lower) bearing block is placed, with its hardened face up, on the table of the testing machine directly under the spherically seated (upper) bearing block. The bearing faces of the upper and lower bearing blocks are cleaned and the test specimen is placed on the lower bearing block.

2. Zero Verification and Block Seating— prior to testing the specimen, it is verified that the load indicator is set to zero. If the indicator is not properly set to zero, it is adjusted.

3. Rate of Loading— the load is applied continuously and without shock.

4. Standards specify that for testing machines of the screw type, the moving head shall travel at a rate of approximately 0.05in. (1mm)/min when the machine is running idle. While for hydraulically operated machines, the load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a loading rate on the specimen within the range of 20 to 50 psi/sec (0.15 to 0.35 MPa/sec).
5. During the application of the first half of the anticipated loading phase, a higher rate of loading is allowed.
6. No adjustment is made in the rate of movement of the platen at any time while a specimen is yielding rapidly immediately before failure.
7. Load is applied until the specimen fails, and the maximum load carried by the specimen during the test is recorded. The type of failure and the appearance of the concrete are also noted.

Figure No: 3.16 Cylinder Testing on UTM

The compressive strength of concrete was measured at 28 days, using compressive strength testing machine according to ASTM C 39 (2003).

3.6.3 Precaution:

The following precautions were observed:

a) The top surface must be smooth, if not, capping is provided.

b) A base plate and top plate is applied to ensure uniform load distribution.

c) Load rate adopted from the standard (0.023MPa/s) is to be maintained throughout the crushing.

d) After each test the base plate of the machine is to be wiped for crushed particles.

3.7 Conclusion

In this chapter, different methods adopted to achieve the objectives of the study are thoroughly discussed. Different testing parameters are explained in order to relate it to the study result. Experimental method is important in order to set out the scope the study. So, the methodology is followed by result and discussion in the next chapter.

CHAPTER 4
Results and Discussion

4.1 General

In this chapter the results what we have got throughout this investigation have been summarized and discussed. The effect of partial replacement of brick fine aggregate on compressive strength discussed. The effect of s/a on compressive strength, discussed. Moreover, for different replacement of brick fine aggregate and s/a, the stress- strain relationship of concrete.

4.1.1 Workability of Concrete

The effect of Brick fine aggregate as a partial replacement of natural sand on workability of concrete for different s/a ratio and W/C ratio. The workability of concrete increases with an increase in the replacement of Brick fine aggregate and s/a. The workability of concrete as slump (in cm) for W/C = 0.50.Itis found that W/C of 0.50 shows better slump than the W/C ratio of 0.50. On the other hand, with the increase of replacement ratio of Brick fine aggregate the workability increases. It is clearly found that concrete made with a 50% brick fine aggregate shows maximum workability. It is expected due to the less water absorption capacity of Brick fine aggregate compared to the Natural sand.

It is also found that with the increase of s/a ratio, workability is reduced. It is clearly revealed that the concrete made with slag aggregate has better workability compared to the similar concrete made with brick fine aggregate. Thangaselvi (2015) also concluded that

The use of steel slag as replacement of coarse aggregate in concrete is beneficial for the better workability and strength it imparts up to 50% replacement level**.**

4.1.2 Calculation Compressive Strength of Concrete:

The effect of replacement of Brick fine aggregate on 28 days compressive strength of concrete .28 days compressive strengths of 0% brick fine aggregate(BFA) and 100% natural sand (NS), 10% BFA and 90% NS, 20% BFA and 80% NS, 30% BFA and 70% NS, 40 BFA and 60% NS, 50% BFA and 50% NS, are shown in table.

Calculation

Diameter of cylinder = 4 Inches

Area of top surface A= $(\pi/4) \times d^2$

$= (\pi/4) \times 4^2$

$= 12.45$ inch^2

Table No: 4.1 for 0% BFA and 100% Natural sand

Serial no	Crushing Load	Area	7 days crushing strength		28 days crushing strength	
			Strength (PSI)	Average	Strength (PSI)	Average
01	220	12.56	2560.28	2337.27	3941.08	3493.23
02	175	12.56	2235.91		3134.95	
03	190	12.56	2215.63		3403.67	

Table No: 4.2 For 10% BFA and 90% Natural sand

Serial no	Crushing Load (lb)	Area (in^2)	7 days crushing strength		28 days crushing strength	
			Strength (PSI)	Average	Strength (PSI)	Average
01	120	12.56	1397.29	1668.39	2149.68	2597.53
02	135	12.56	1571.96		2418.39	
03	180	12.56	2095.93		3224.52	

Table No: 4.3 For 20% BFA and 80% Natural sand

Serial no	Crushing Load (lb)	Area (in^2)	7 days crushing strength		28 days crushing strength	
			Strength (PSI)	Average	Strength (PSI)	Average
01	195	12.56	2235.75	2645.41	3493.29	4179.45
02	225	12.56	2573.86		4030.65	
03	280	12.56	3126.61		5015.92	

Table No: 4.4 For 30% BFA and 70% Natural sand

Serial no	Crushing Load (lb)	Area (in^2)	7 days crushing strength		28 days crushing strength	
			Strength (PSI)	Average	Strength (PSI)	Average
01	252	12.56	2880.97	2607.51	4514.33	4078.36
02	228	12.56	2590.86		4048.39	
03	205	12.56	2350.88		3672.37	

Table No: 4.5 For 40% BFA and 60% Natural sand

Serial no	Crushing Load (lb)	Area (in^2)	7 days crushing strength		28 days crushing strength	
			Strength (PSI)	Average	Strength (PSI)	(lb)
01	198	12.56	2302.56	2203.82	3546.97	3391.71
02	175	12.56	2036.76		3134.95	
03	195	12.56	2270.77		3493.23	

Table No: 4.6 For 50% BFA and 50% Natural sand

Serial no	Crushing Load (lb)	Area (in^2)	7 days crushing strength		28 days crushing strength	
			Strength (PSI)	Average	Strength (PSI)	(lb)
01	175	12.56	2037.45	2002.46	3134.95	3045.38
02	165	12.56	1949.06		2955.81	
03	170	12.56	2020.78		3045.38	

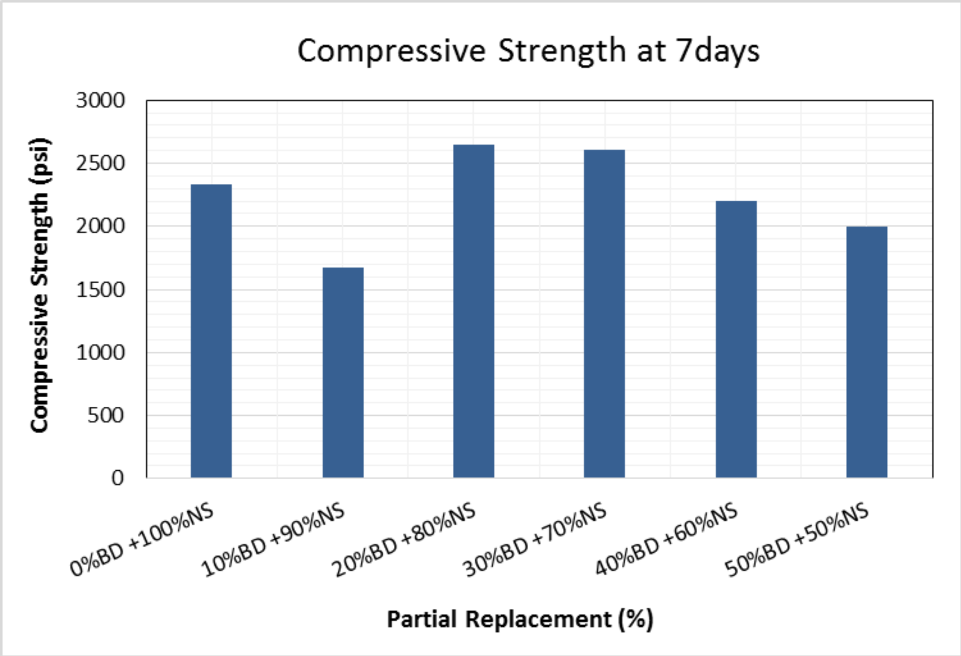


Figure No: 4.1 Variation of Compressive strength vs Partial Replacement of brick fine aggregate at 7days

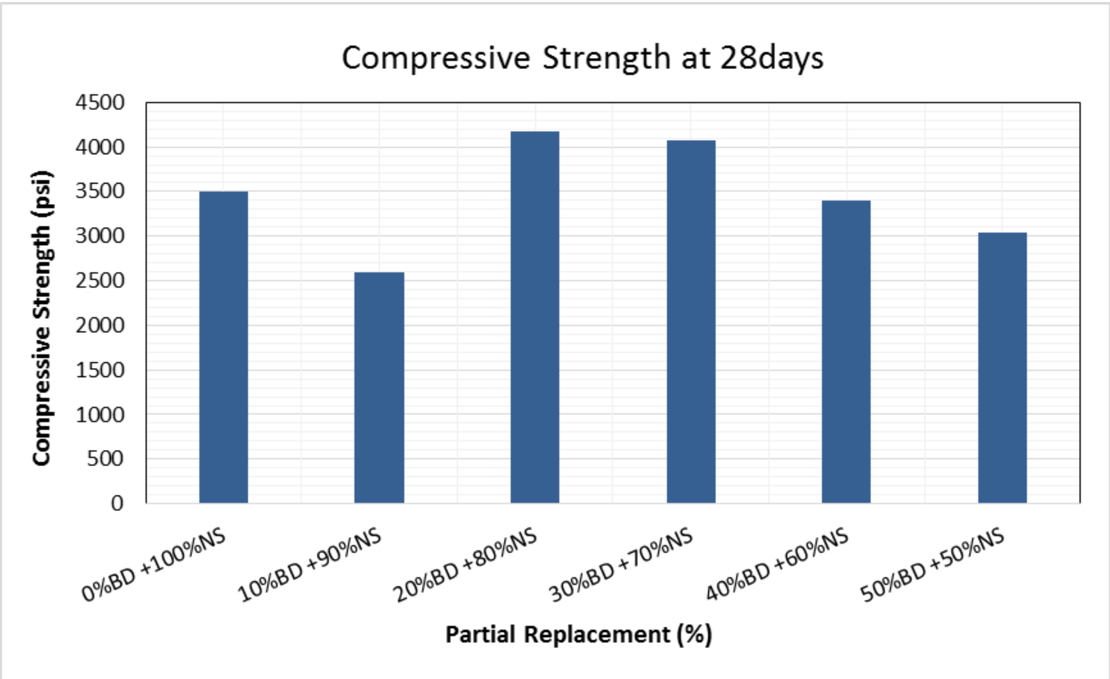


Figure No: 4.2 Variation of Compressive strength vs Partial Replacement of brick fine aggregate at 28 days

CHAPTER 5

Conclusion and Recommendation

5.1 General

This chapter describes the summary of the research findings based on the results and discussions in chapter 4. Moreover, recommendation and future works related to this investigation are also mentioned in this chapter.

5.2 Conclusions

Based on the experimental study investigating the use of crushed brick in concrete, the following conclusions which are limited to the materials used in the study.

1. This is an eco-friendly concrete as it subsides the stagnation of demolished brick waste by consuming it.
2. It was observed that at 50% replacement of brick fine aggregate with Natural sand, we found the maximum workability. But with the increase of the percent replacement beyond 50% the workability tends to follow a decree sing manner.
3. We found the maximum compressive strength of concrete at 20% replacement of brick fine aggregate with natural sand.
4. Concrete gains early strength and hence shuttering can be removed early thereby reducing the secondary overhead cost.
5. For all the variations of sand to aggregate ratios we found that the maximum compressive strength at 20% replacement of brick fine aggregate with natural sand.

5.3 Recommendations

From this study, this is evident that at a cement content of 400 kg/m^3, construction engineers can go for 20% replacement of brick fine aggregate with Natural sand without causing any decrease in the compressive strength compared to the using of conventional coarse aggregate in concrete mixture. But for 30% replacement of brick fine aggregate with Natural sand, the compressive strength tends to decrease for the variations of W/C ratios. While studying the variation of s/ratios we found that maximum compressive strength occurs at s/a ratio of 0.45 at 20% replacement of brick fine aggregate with Natural sand.

Moreover, non-destructive tests on structural members made with various percent replacements of brick fine aggregate can be conducted and results can be used to evaluate the pattern of increase or decrease of compressive strength.

5.4 Limitations and Future Work

Though this study has been primarily planned to study the scope of using brick fine aggregate as a percent replacement of natural sand, the scope was not limited to the effect of using natural sand only. This study also investigates the effect of variation of s/a ratio (0.45) and W/C ratio (0.50) on compressive strength of concrete. A total of six different percent replacements were studied, but there was no variation of cement content. Future works can be planned to study the effects of cement content variations to find an optimum s/a ratio and cement content for different percent replacement of brick aggregate with natural sand. Also, this experiment could be broadened by studying the effect of using brick fine aggregate as a partial replacement of natural sand.

Though this study discusses the effect of partial replacement of brick fine aggregate with natural sand on major concrete properties like compressive strength, stress-strain curve, the scope of the research can be expanded to study the effect of partial replacement on modulus of rupture of concrete, flexural and shear behavior of concrete under load as well.

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