FINDING EVAPORATION RATE , POROSITY AND COMPRESSIVE STRENGTH FOR DIFFERENT MIXES OF CONCRETE WITH BRICK AGGREGATE.

SUNJIDA AKTHER LUNA

11.02.03.098

MD. KARIBUL HASNAT

11.02.03.086

MAZHARUL ISLAM

11.02.03.101

DEPARTMENT OF CIVIL ENGINEERING

AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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Declaration

This thesis titled "**FINDING EVAPORATION RATE , POROSITY AND COMPRESSIVE STRENGTH FOR DIFFERENT MIXES OF CONCRETE WITH BRICK AGGREGATE"** has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering on December 2015.

This thesis is approved by

……………………………………………

DR. Enamur Rahim Latifee

Assistant professor

Department of Civil Engineering

Ahsanullag University of Science and Technology

Dedicated to

Our parents and

Inspiring Supervisor Dr. Enamur Rahim Latifee

Sunjida Akther Luna

Md. Karibul Hasnat

Mazharul Islam

December 2015

Author Declaration

We hereby declare that the thesis work entitled "**FINDING EVAPORATION RATE , POROSITY AND COMPRESSIVE STRENGTH FOR DIFFERENT MIXES OF CONCRETE WITH BRICK AGGREGATE"** submitted to the Ahsanullah University of Science and Technology done by the members of this group collectively. It is a record of an authentic work under the supervision of Dr. Enamur Rahim Latifee . Assistant Professor, Department of civil engineering . Ahsanullah university of science & Technology. We also state that the materials embodied in this report have not been published or submitted anywhere before date . The thesis is purely done for academic interest.

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Sunjida Akther Luna

11.02.03.098

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Md. Karibul Hasnat

11.02.03.086

…………………………………..

Mazharul Hasnat

11.02.03.101

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ABSTRACT

Concrete is one of the second consuming material after water, widely used in construction work throughout the world. In most of third countries concrete made of brick chips are widely used for construction purpose. Strength, porosity, evaporation are the major properties of concrete. Those properties vary on variation of concrete mix proportion and different water cement ratio. Therefore the major concern of this research is to find out those variations of concrete properties for differ mix ratio and different water cement ratio in concrete. About 56 cylindrical molds (4 in diameter by 8 inch height) including 4 discs (4 inch diameter by 2 inch height) were prepared by concrete using brick chips to find out these properties. For this investigation different mix proportions of 1:2:4 and 1:1.5:3 with different water cement ratio of 0.5 and 0.6 were used. From this experimental work, variation of strength and porosity were observed at different curing days. To find evaporation rate in certain interval of time concrete discs were observed. After the investigation mentionable variation in strength and porosity were found in concrete made by brick chips.

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Chapter 1

Introduction

1.1 Introduction:

In our research we determined compressive strength of concrete cylinder diameter 4×8 in. with brick aggregate, different water cement ratio such as 0.5 & 0.6 and cement, sand, aggregate ratio 1:2:4, 1:1.5:3, 1:2:4. From research result of compressive strength we compare the strength result with each other to determine the strength variation.

Concrete as building material indeed marked as epoch in the history of civilization. Concrete has been used as building material for centuries. It is by far the most widely used construction material today. We can hardly find any aspect of our daily lives that does not depend directly or indirectly on concrete. We may live, work, study, or play in concrete structure to which we drive over concrete roads and bridges. Our goods may be transported by trucks travelling on concrete super-highways, by trains that run or rails supported on concrete sleepers, by ships that moor at concrete piers and harbors protected by concrete breakwater, or by airplanes landing and taking off on concrete runways. Water for drinking and raising crops is stored behind massive concrete dams and is distributed by systems of concrete waterways, conduits and pipes. The water thus stored may also be used to generate electric power. The various unique properties of concrete have marked its superiority over many other construction materials. The versatility and mouldability of concrete, its high compressive strength, and the discovery of reinforcing and prestressing techniques, which helped to make up for its low tensile strength, have contributed largely to its widespread use. The cheapness, durability, exclusive resistance to weather, fire, and water and corrosion make concrete a particularly suitable and unique material for road construction, bridges, building and dams, for the foundations, framework, floors and roofs of large buildings of all kinds and for structures in collieries and industrial plants. Hence it has proved itself conducive to form the basis of modern engineering as well as having a greater influence on dramatic impact of technology.

The strength of concrete depends on a multitude of factors, and may vary within very wide limits with the same production technology (identical composition, properties and curing). Primarily it depends on:-

- Its age and curing conditions
- The shape and dimensions
- The nature of the stressed state
- Climatic conditions etc.

Difference between the strength and actual strength to a great extent is a frequent occurrence due to lack of proper designing for the service conditions, proper handling and curing. The successful use of concrete depends on the intelligent application of its properties. For this reason, a thorough understanding of the material properties of the concrete is essential to get the material of required quality and durability. Moreover, unlike the rest of the world in a developing country like Bangladesh, the typical use of locally produced broken bricks aggregates and coarse Sylhet sands as the filler material in the production of concrete demands special attention of the researchers in regard to its method of preparation, compaction, strength and durability as all the design charts used in practice are based on the stone aggregate concrete, which is very rare in Bangladesh. The purpose of this study was therefore to select the optimum proportions of cement, water and brick aggregates to produce a concrete that satisfies the requirements of strength, workability, durability and economy in context to Bangladesh. Mix design methods are useful as guides in the initial selection of these proportions. The prime objective of this research was to compare the cylinder strength and cube strength of brick aggregate concrete.

Designing a concrete structure requires the concrete compressive strength to be used. The design strength of the concrete normally represents its 28thday strength. In construction works 28 days is a considerable time to wait for the test results of concrete strength, while it also represents the quality control process of concrete mixing, placing, compaction, proper curing etc. Concrete mix design is a process based on code recommendation and requires some previous experience. If due to some error in mix design or mix preparation at site the test results fail to achieve the designed strength, then repetition of the entire process

Becomes mandatory, which can be costly and time consuming. For every failure, it is necessary to wait at least 28 days, thus the need for an easy and reliable method for estimating the final strength at an early age of concrete is a long felt matter.

Hence, a rapid and suitable concrete strength prediction would be of great significance [Khederet al, 2003]. Researchers are very keen to explore the concrete behavior and for this reason prediction of the concrete strength is being marked as an active area of research. Many studies are being carried out in this area [Zain et al., 2010]. Different approaches using regression functions have been proposed for predicting the concrete strength [Oluokun et al., 1990; Popovics, 1998]. Traditional modeling approaches are established based on empirical relation and experimental data which are improving day by day. Some smart modeling System utilizing artificial neural network [Nathetal., 2011] and support vector machines [Gupta,2007] are developed for predicting compressive strength of concrete. Objective of all studies that have been carried out was to make the concrete strength predictable and increase the efficiency of the prediction. In this paper, an attempt is made to develop a relation between concrete strength and its age and finally express this relationship with a simple mathematical equation.

1.2 Scope of the search:

This study only deals with axial compressive strength from cylinder specimen of 4 in. diameter and 8 in. height (standard cylinder) at different aggregate size and variation of mix proportion with different days. w/c ratio varies 0.5 & 0.6 and cement, sand, brick chips contains ratio of 1:2:4, 1;1.5:3, 1:2:4. For 1:2:4 w/c ratio contains 0.5 and 1;1.5:3, 1:2:4 w/c ratio remain 0.6.

Compressive strength test results are primarily used to determine that the concrete mixture as delivered meets the requirements of the specified strength.

We also determined 4×2 in disc to find out evaporation rate in open air condition, and also determined the porosity of that disc.

Concrete mixture can be designed to provide a wide range of mechanical and durability properties to meet the design requirements of a structure. The compressive strength of concrete is the most common performance measure used by the engineer in designing building and structures. The compressive strength is measured by breaking cylindrical concrete specimens in a compressions-testing machine. The compressive strength is calculated from the future load and reported in units of pound-force per square inch (psi) in US customary units or megapascals (MPa) in SI units .Concrete compressive strength requirements can vary form 2500 psi(17MPa) for residential concrete to 4000 psi (28MPa) and higher in commercial structures. Higher strength up to and exceeding 10,000 psi (70MPa) are specified for certain applications, f_c',in the job specification. Strength test result from cast cylinder may be used for quality control, acceptance of concrete, or for estimating the concrete strength in a structure for the purpose of scheduling construction operations such as form removal or for evaluating the adequacy of curing and protection afforded to the structure. Cylinder tested for acceptance and quality control are made and cured in accordance with procedures described for standard-cured specimens in ASTM C 31 standard practice for making and curing concrete test specimen in the field. For estimating the in place concrete strength, ASTM C 31 provides procedures for field curved specimens. Cylindrical specimens are tested in accordance with ASTM C 39, Standard test method for Compressive Strength of cylindrical concrete Specimens.

1.2.1 ASTM Standards different types of compressive strength test

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens.

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.

C470/C470M Specification for Molds for Forming Concrete Test Cylinders Vertically.

C617 Practice for Capping Cylindrical Concrete Specimens.

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials.

C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders.

Chapter 2

LITARATURE REVIEW

2.1 Background:

The objective is to determine compressive strength of concrete cylinder of 4×8 in. cylinders and the variability associated with those results. The main areas that are covered in this literature review are factors that affect the compressive strength of concrete and related concrete terms.

2.1.1 Concrete

Concrete –An artificial stone –like material used for various structural purposes. It is made by mixing a binding material (such as cement) and various aggregates (inert materials), such as sand, stone, stone chips, brick chips, pebbles, gravel, shale, etc., with water and allowing the mixture to garden by hydration. It acts as a primary binder to join the aggregate into a solid mass. The chemical process called cement hydration produces crystals that interlock and bind together.

Components of concrete:

- Aggregate – Coarse and Fine
- Water
- Cement
- Supplementary cementing materials (SCMs)

Chemical admixtures

2.1.2 Advantage and Disadvantage of concrete

Advantages:

a) **Economical:** Concrete is the most inexpensive and the most readily available material. The cost of production of concrete is low compared with other engineered construction materials.

Three major components: water, aggregate and cement. Comparing with steel, plastic and polymer, they are the most inexpensive materials and available in every corner of the world. This enables concrete to be locally produced anywhere in the world, thus avoiding the transportation costs necessary for most other materials.

b). **Ambient temperature hardened material:** Because cement is a low temperature bonded inorganic material and its reaction occurs at room temperature, concrete can gain its strength at ambient temperature.

c) **Ability to be cast:** It can be formed into different desired shape and sizes right at the construction site.

d) **Energy efficiency:** Low energy consumption for production, compare with steel especially. The energy content of plain concrete is 450-750 kWh / ton and that of reinforced concrete is 800-3200 kWh/ton, compared with 8000 kWh/ton for structural steel.

e) **Excellent resistance to water.** Unlike wood and steel, concrete can harden in water and can withstand the action of water without serious deterioration. This makes concrete an ideal material for building structures to control, store, and transport water. Examples include pipelines (such as the Central Arizona Project, which provide water from Colorado river to central Arizona. The system contains 1560 pipe sections, each 6.7 m long and 7.5 m in outside diameter 6.4 m inside diameter), dams, and submarine structures. Contrary to popular belief, pure water is not deleterious to concrete, even to reinforced concrete: it is the chemicals dissolved in water, such as chlorides, sulfates, and carbon dioxide, which cause deterioration of concrete structures.

f). **High temperature resistance:** Concrete conducts heat slowly and is able to store considerable quantities of heat from the environment (can stand 6-8 hours in fire) and thus can be used as protective coating for steel structure.

g). **Ability to consume waste:** Many industrial wastes can be recycled as a substitute for cement or aggregate. Examples are fly ash, ground tire and slag.

h). **Ability to work with reinforcing steel:** Concrete and steel possess similar coefficient of thermal expansion (steel 1.2×10^{-5}; concrete $1.0\text{-}1.5 \times 10^{-5}$). Concrete also provides good protection to steel due to existing of CH (this is for normal condition). Therefore, while steel bars provide the necessary tensile strength, concrete provides a perfect environment for the steel, acting as a physical barrier to the ingress of aggressive species and preventing steel corrosion by providing a highly alkaline environment with pH about 13.5 to passivate the steel.

i) **Less maintenance required:** No coating or painting is needed as for steel structures.

2.1.3Limitations:

a) **Quasi-brittle failure mode:** Concrete is a type of quasi-brittle material. (Solution: Reinforced concrete)

b) **Low tensile strength:** About 1/10 of its compressive strength. (Improvements: Fiber reinforced concrete; polymer concrete)

c) **Low toughness:** The ability to absorb energy is low. (Improvements: Fiber reinforced concrete)

d) **Low strength/BSG ratio (specific strength):** Steel (300-600)/7.8. Normal concrete (35-60)/2.3.Limited to middle-rise buildings. (Improvements: Lightweight concrete; high strength concrete)

e) **Formwork is needed:** Formwork fabrication is labour intensive and time consuming, hence costly (Improvement: Precast concrete)

f). **Long curing time:** Full strength development needs a month. (Improvements: Steam curing)

g). **Working with cracks:** Most reinforced concrete structures have cracks under service load. (Improvements: Prestressed concrete).

2.1.4 Classification of concrete

Based on unit weight

Ultra-light concrete <1,200 kg/m^3

Lightweight concrete 1200- 1,800 kg/m^3

Normal-weight concrete ~ 2,400 kg/m^3

Heavyweight concrete > 3,200 kg/m^3

Based on strength (of cylindrical sample)

Low-strength concrete < 20 MPa compressive strength

Moderate-strength concrete 20 -50 MPa compressive strength

High-strength concrete 50 - 200 MPa compressive strength

Ultra high-strength concrete > 200 MPa compressive strength

Based on additives:

Normal concrete

Fiber reinforced concrete

Shrinkage-compensating concrete

Polymer concrete

2.1.5Workability

a) Definition

Workability is a general term to describe the properties of fresh concrete. Workability is often defined as the amount of mechanical work required for full compaction of the concrete without segregation.

This is a useful definition because the final strength of the concrete is largely influenced by the degree of compaction. A small increase in void content due to insufficient compaction could lead to a large decease in strength.

The primary characteristics of workability are consistency (or fluidity) and cohesiveness. Consistency is used to measure the ease of flow of fresh concrete. And cohesiveness is used to describe the ability of fresh concrete to hold all ingredients together without segregation and excessive bleeding.

2.1.5.1 Factors affecting workability

Water content: Except for the absorption by particle surfaces, water must fill the spaces among particles. Additional water "lubricates" the particles by separating them with a water film. Increasing the amount of water will increase the fluidity and make concrete easy to be compacted. Indeed, the total water content is the most important parameter governing consistency. But, too much water reduces cohesiveness, leading to segregation and bleeding. With increasing water content, concrete strength is also reduced.

Aggregate mix proportion: For a fixed w/c ratio, an increase in the aggregate/cement ratio will decrease the fluidity. (Note that less cement implies less water, as w/c is fixed.) Generally speaking, a higher fine aggregate/coarse aggregate ratio leads to a higher cohesiveness.

Maximum aggregate size: For a given w/c ratio, as the maximum size of aggregate increases, the fluidity increases. This is generally due to the overall reduction in surface area of the aggregates.

Aggregate properties: The shape and texture of aggregate particles can also affect the workability. As a general rule, the more nearly spherical and smoother the particles, the more workable the concrete.

Cement: Increased fineness will reduce fluidity at a given w/c ratio, but increase cohesiveness. Under the same w/c ratio, the higher the cement content, the better the Workability (as the total water content increases).

Admixtures: Air entraining agent and super plasticizers can improve the workability.

Temperature and time: As temperature increases, the workability decreases. Also, workability decreases with time. These effects are related to the progression of chemical reaction.

c). Segregation and bleeding

Segregation (separation): Segregation means separation of the components of fresh concrete, resulting in a non-uniform mix. More specifically, this implies some separation of the coarse aggregate from mortar.

Bleeding (water concentration): Bleeding means the concentration of water at certain portions of the concrete. The locations with increased water concentration are concrete surface, bottom of large aggregate and bottom of reinforcing steel. Bleed water trapped under aggregates or steel lead to the formation of weak and porous zones, within which micro cracks can easily form and propagate.

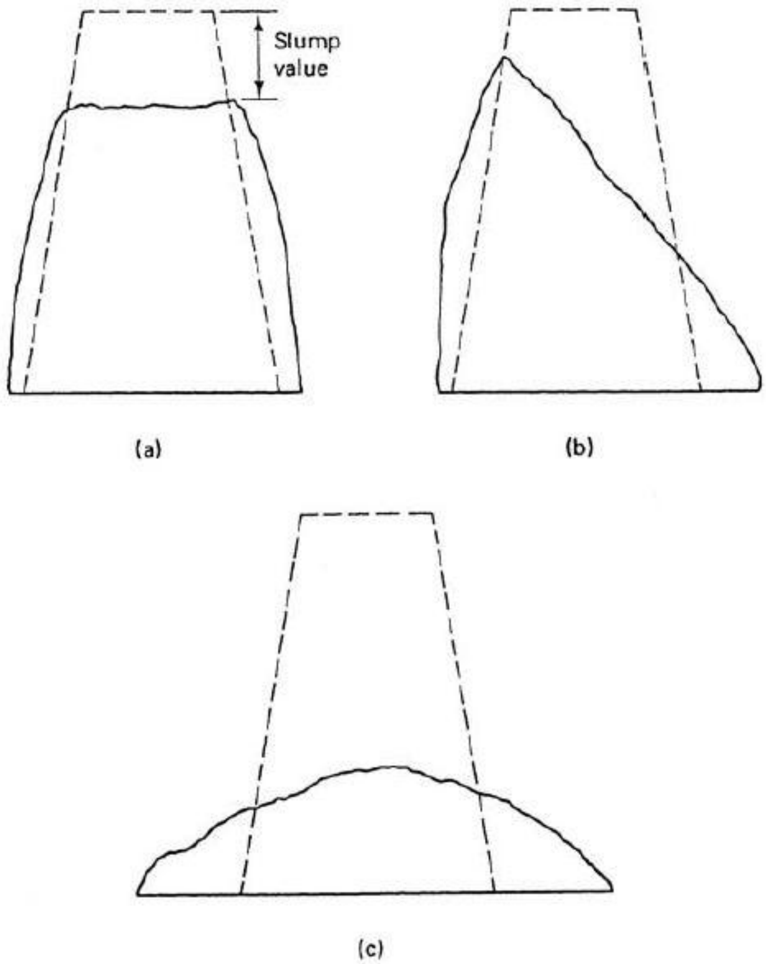
2.1.5.2 Measurement of workability

- **Slump test (BS 1881: 102, ASTM C143)**
- **Compaction factor test (BS 1881: Part 103)**
- **Vebe test (BS 1881: Part 104)**
- **Ball-penetration test**

In our compressive strength of cylinder test used slump test.

2.1.5.3 Slump Test

Three different kinds of possible slumps exist, true slump, shear slump, and collapse slump. Conventionally, when shear or collapse slump occur, the test is considered invalid. However, due to recent development of self-compact concrete, the term of collapse slump has to be used with caution.



2.1.5.4 Placing, Compacting and Curing

Concrete should be placed as close to its final position as possible. To minimize segregation, it should not be moved over too long a distance. After concrete is placed in the formwork, it has to be compacted to remove entrapped air. Compaction can be carried out by hand rodding or tamping, or by the use of mechanical vibrators. For concrete to develop strength, the chemical reactions need to proceed continuously. Curing refers to procedures for the maintaining of a proper environment for the hydration reactions to proceed. It is therefore very important for the production of strong, durable and watertight concrete. In concrete curing, the critical thing is to provide sufficient water to the concrete, so the chemical reaction will not stop. Moist curing is provided by water spraying, ponding or covering the concrete surface with wet sand, plastic sheets, burlaps or mats. Curing compounds, which can be sprayed onto the concrete surface to form a thin continuous sheet, are also commonly used. Loss of water to the surrounding should be minimized. If concrete is cast on soil subgrade, the subgrade should be wetted to prevent water absorption. In exposed areas (such as a slope), windbreaks and sunshades are often built to reduce water evaporation. For Portland cement concrete, a minimum period of 7 days of moist curing is generally recommended. Under normal curing (at room temperature), it takes one week for concrete to reach about 70% of its long-term strength. Strength development can be accelerated with a higher curing temperature. In the fabrication of pre-cast concrete components, steam curing is often employed, and the 7-day strength under normal curing can be achieved in one day. The mold can then be re-used, leading to more rapid turnover. If curing is carried out at a higher temperature, the hydration products form faster, but they do not form as uniformly. As a result, the long-term strength is reduced. This is something we need to worry about when we are casting under hot weather. The concrete may need to be cooled down by the use of chilled water or crushed ice. In large concrete structures, cooling of the interior (e.g., by circulation of water in embedded pipes) is important, not only to prevent the reduction of concrete strength, but also to avoid thermal cracking as a result of non-uniform heating/cooling of the structure. After concrete is cast, if surface water evaporation is not prevented, plastic shrinkage may occur. It is the reduction of concrete volume due to the loss of water. It occurs if the rate of water loss (due to evaporation) exceeds the rate of bleeding. As concrete is still at the plastic state (not completely stiffened), a small amount of volume reduction is still possible, and this is accompanied by the downward movement of material. If this downward movement is restraint, by steel reinforcements or large aggregates, cracks will form as long as the low concrete strength is exceeded. Plastic shrinkage cracks often run perpendicular to the concrete surface, above the steel reinforcements. Their presence can affect the durability of the structure, as they allow corrosive agents to reach the steel easily. If care is taken to cover the concrete surface and reduce other water loss (such as absorption by formwork or subgrade), plastic shrinkage cracking can be avoided. If noticed at an early stage, they can be removed by re-vibration.

2.1.5.5 Admixtures used in concretes

Admixture is defined as a material other than water, aggregates, cement and reinforcing fibers that is used in concrete as an ingredient and added to the batch immediately before or during mixing.Nowadays, as we mentioned earlier, admixtures are important and necessary components for modern concrete technology. The concrete properties, both in fresh and hardened states, can be modified or improved by admixtures. In some countries, 70-80% of concrete (88% in Canada, 85% in Australia, and 71% in US) contains one or more admixtures. It is thus important for civil engineers to be familiar with commonly used admixtures.

2.1.5.6 Admixtures can be roughly divided into the following groups.

i). Air-entraining agents (ASTM C260): This kind of admixture is used to improve the frost resistance of concrete (i.e., resistance to stresses arising from the freezing of water in concrete).
ii). Chemical admixtures (ASTM C494 and BS 5075): This kind of admixture is mainly used to control the setting and hardening properties for concrete, or to reduce its water requirements.
iii). Mineral admixtures: They are finely divided solids added to concrete to improve its workability, durability and strength. Slags and pozzolans are important categories of mineral admixtures.

Water reducing admixtures
Water reducing admixtures lower the water required to attain a given slump value for a batch of concrete.Water-reducing admixtures are surface-active chemicals. The use of water reducing admixture can achieve different purposes as listed in the following table.

2.1.5.7 Strength of hardened concrete:

Strength is defined as the ability of a material to resist stress without failure. The failure of concrete is due to cracking. Under direct tension, concrete failure is due to the propagation of a single major crack. In compression, failure involves the propagation of a large number of cracks, leading to a mode of disintegration commonly referred to as 'crushing'. The strength is the property generally specified in construction design and quality control, for the following reasons: (1) it is relatively easy to measure, and (2) other properties are related to the strength and can be deduced from strength data. The 28-day compressive strength of concrete determined by a standard uniaxial compression test is accepted universally as a general index of concrete strength**.** Applied load on concrete specimen like as cylinder or cube strength measured, reached final strength point by cracking the surface of concrete specimen. Compressive test, friction exists at the top and bottom surfaces of a concrete specimen, to prevent the lateral movement of the specimen. As a result, confining stresses are generated around the two ends of the specimen. If the specimen has a low aspect ratio (in terms of height vs. width), such as a cube (aspect ratio = 1.0), the confining stresses will increase the apparent strength of the material. For a cylinder with aspect ratio beyond 2.0, the confining effect is not too significant at the middle of the specimen (where failure occurs). The strength obtained from a cylinder is hence closer to the actual uniaxial strength of concrete. Note that in a cylinder test, the cracks propagate vertically in the middle of the specimen. When they get close to the ends, due to the confining stresses, they propagate in an inclined direction, leading to the formation of two cones at the ends.

2.1.6 Description of concrete components:

2.1.6.1 Aggregate

Introduction

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete. The most popular use of aggregates is to form Portland cement concrete. Approximately three-fourths of the volume of Portland cement concrete is occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should have an important effect on the properties of both the fresh and hardened products. As another important application, aggregates are used in asphalt cement concrete in which they occupy 90%

or more of the total volume. Once again, aggregates can largely influence the composite properties due to its large volume fraction.

2.1.6.2 Classification of aggregate:

Aggregates can be divided into several categories according to different criteria.

a) **In accordance with size:**
Coarse aggregate: Aggregates predominately retained on the No. 4 (4.75 mm) sieve. For mass concrete, the maximum size can be as large as 150 mm.
Fine aggregate (sand): Aggregates passing No.4 (4.75 mm) sieve and predominately retained on the No. 200 (75 μm) sieve.

b) In accordance with sources:
Natural aggregates: This kind of aggregate is taken from natural deposits without changing their nature during the process of production such as crushing and grinding. Some examples in this category are sand, crushed limestone, and gravel.
Manufactured (synthetic) aggregates: This is a kind of man-made materials produced as a main product or an industrial by-product. Some examples are blast furnace slag, lightweight aggregate (e.g. expanded perlite), and heavy weight aggregates (e.g. iron ore or crushed steel).

c) In accordance with unit weight:
Light weight aggregate: The unit weight of aggregate is less than 1120 kg/m^3. The corresponding concrete has a bulk density less than 1800 kg/m^3. (cinder, blast-furnace slag, volcanic pumice).

Normal weight aggregate: The aggregate has unit weight of 1520-1680 kg/m^3. The concrete made with this type of aggregate has a bulk density of 2300-2400 kg/m^3.
Heavy weight aggregate: The unit weight is greater than 2100 kg/m^3. The bulk density of the corresponding concrete is greater than 3200 kg/m^3. A typical example is magnesite limonite, a heavy iron ore. Heavy weight concrete is used in special structures such as radiation shields.

2.1.6.3 Properties of aggregate:

<u>Moisture conditions</u>

The moisture condition of aggregates refers to the presence of water in the pores and on the surface of aggregates. There are four different moisture conditions:

a) Oven Dry (OD): This condition is obtained by keeping aggregates at temperature of 110^0C for a period of time long enough to reach a constant weight.

b) Air Dry (AD): This condition is obtained by keeping aggregates under room temperature and humidity. Pores inside the aggregate are partly filled with water.

c) Saturated Surface Dry (SSD): In this situation the pores of the aggregate are fully filled with water and the surface is dry. This condition can be obtained by immersion in water for 24 hours following by drying of the surface with wet cloth

d) Wet (W): The pores of the aggregate are fully filled with water and the surface of aggregate is covered with a film of water.

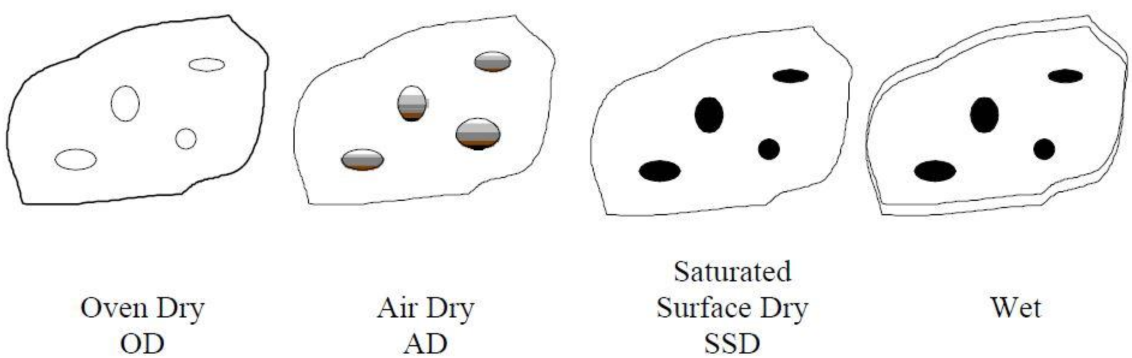


Fig 1.1: Different moisture condition of Aggregate

To make concrete, aggregates are mixed with water and cement. Since concrete properties at both the fresh and hardened states are strongly affected by the water content, it is very important to ensure that the right amount of water is added to the mix. In designing concrete mix, the moisture content under SSD condition is used as reference because that is an equilibrium condition at which the aggregates will neither absorb water nor give up water to the paste. Thus, if MC_{SSD} value for a batch of aggregates is positive, there is surface moisture on the aggregates. If it is negative, it means that the pores in aggregates are only partly filled with water. Since the aggregates may give out or absorb water, the amount of water added to the mix need to be adjusted according to the MC_{SSD} value. This is particularly important for concrete with low water content as the amount of adjusted water can be a significant portion of the total amount.

2.1.6.4 Density and specific gravity:

Density (D): Weight per unit volume (excluding the pores inside a single aggregate)

$$D = \frac{Weight}{Volume\ of\ solid}$$

Bulk density: The volume includes the pores inside a single aggregate

$$BD = \frac{Weight}{volume\ of\ Solid + Volume\ of\ pores}$$

BD can be either BD_{SSD} or BD_{AD} according to the moisture condition of aggregate when it is weighed.

Specific gravity (SG): Mass of a given substance divided by unit mass of an equal volume of water (it is the density ratio of a substance to water).

Depending on the definition of volume, the specific gravity can be divided into absolute specific gravity (ASG) and bulk specific gravity (BSG).

$$ASG = \frac{\frac{Weight\ of\ particle}{volume\ of\ solid}}{Density\ of\ Soil} = \frac{D}{\rho_w}$$

$$BSG = \frac{\frac{Weight\ of\ particle}{volume\ of\ solid + Volume\ of\ Solid}}{Density\ of\ Water} = \frac{BD}{\rho_w}$$

In practice, the BSG value is the realistic one to use since the effective volume that aggregate occupies in concrete includes its internal pores. The BSG of most rocks is in the range of 2.5 to 2.8. Similar to BD, BSG can be either BSG_{SSD} or BSG_{AD} according to the moisture condition of aggregates. The BSG can be determined using the displacement method. In this method, Archimedes' principle is utilized. The weight of aggregate is first measured in air, e.g. under SSD condition, this is denoted as $W_{SSD\ in\ air}$. Then, the weight of the sample is measured in water, the value being denoted as $W_{SSD\ in\ water}$. So,

$$\textbf{BSG (SSD condition)} = \frac{W_{SSD\ in\ air}}{W_{dispalcement}} = \frac{W_{SSD\ in\ air}}{W_{SSD\ in\ air} - W_{SSD\ in\ Water}}$$

Where, $W_{displacement}$ is the weight of water displaced by the aggregates.

Unit Weight (UW) (except for pores inside every aggregate, the bulk volume includes the spacing among aggregate particles).

The unit weight is defined as weight per unit bulk volume for bulk aggregates. Besides the pores inside each aggregate, the bulk volume also includes the space among the collection of particles. According to the weight measured at different conditions, the unit weight can be divided into UW (SSD) and UW (OD).

$$\textbf{UW (SSD)} = \frac{W_{SSD}}{V_{Solid} + V_{pores} + V_{spacing}}$$

$$\textbf{UW (OD)} = \frac{W_{OD}}{V_{Solid} + V_{pores} + V_{spacing}}$$

The percentage of spacing (voids) among the aggregates can be calculated as

$$\textbf{Spacing (void)} = \frac{BD - UW}{BD} 100\%$$

2.1.6.5 Grading of aggregates

Grading - size distribution

The particle size distribution of aggregates is called grading. The grading determine the paste requirement for a workable concrete since the amount of void requires needs to be filled by the same amount of cement paste in a concrete mixture. To obtain a grading curve for aggregate, sieve analysis has to be conducted. The commonly used sieve designation is as follows:

Sieve designation	Nominal size of sieve opening
3″	**75mm**
1.5″	**32.5mm**
3/4″	**19mm**
3/8″	**9.5mm**
No. 4	**4.75mm**
No. 8	**2.36mm**
No. 30	**1.18mm**
No. 50	**600µm**
No. 100	**300µm**
No. 200	**150µm**

Table 1.1- Sieve No & Sieve opening

Five different kinds of size distributions, dense graded, gap-graded, uniformly graded, well graded and open graded are illustrated in the figure below. Dense and well-graded aggregates are desirable for making concrete, as the space between larger particles is effectively filled by smaller particles to produce a well-packed structure. Gap-grading is a kind of grading which lacks one or more intermediate size. Gap-graded aggregates can make good concrete when the required workability is relatively low. When they are used in high workability mixes, segregation may become a problem. For the uniform grading, only a few sizes dominate the bulk material. With this grading, the aggregates are not effectively packed, and the resulting concrete will be more porous, unless a lot of paste is employed. The open graded contains too much small particles and easy to be disturbed by a hole.

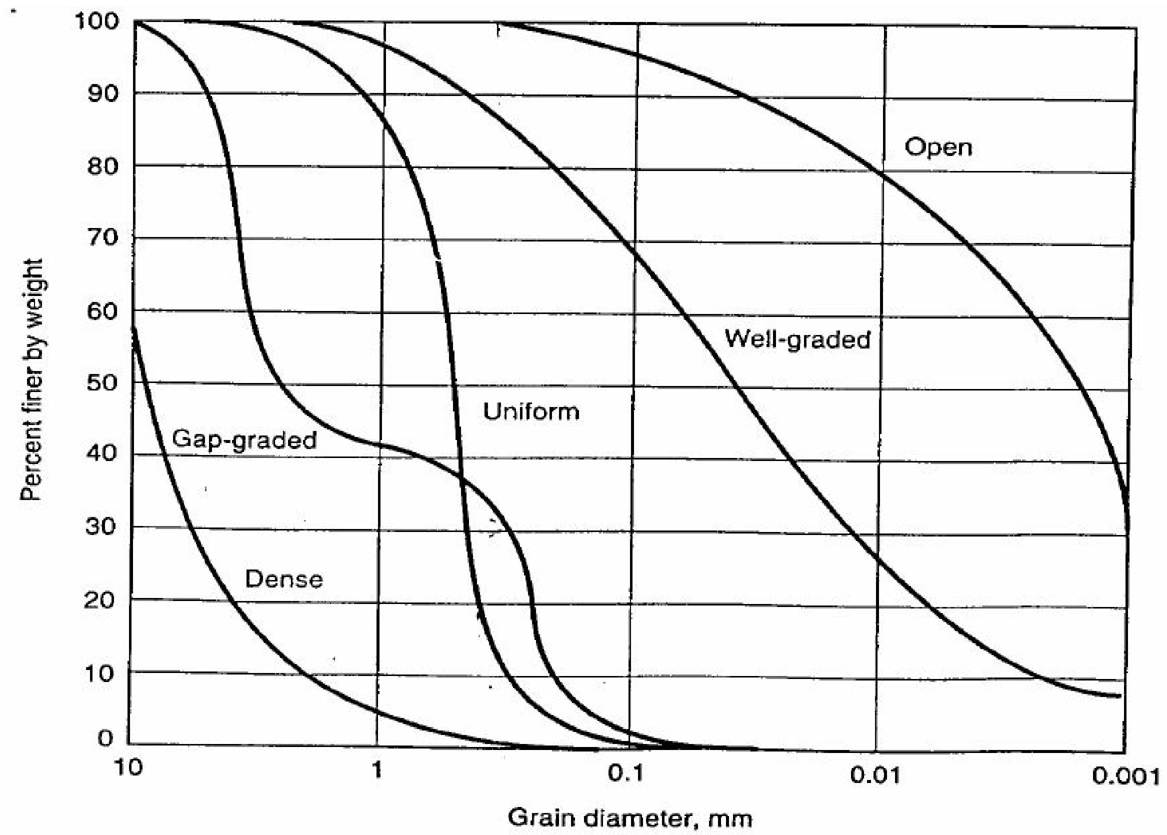


Fig1.2 : Five types gradiation

A wide range of grading curves is acceptable for the economic production of concrete with good quality. Both British Standards (B.S.) and American Standards of Testing and Measurements (ASTM) provide grading limits (which are essentially upper and lower bounds of the grading curve) that can be used in practice. As long as the grading curve lies within the recommended grading limits, the aggregate can be employed.

2.1.6.6 Fineness modulus:

To characterize the overall coarseness or fineness of an aggregate, a concept of fineness modulus is developed. The Fineness Modulus is defined as

$$\mathbf{FM}=\frac{\sum \textit{Cumulative retained perchantage}}{100}$$

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. The sieves specified for the determination of fineness modulus are No. 100, No. 50, No. 30, No. 16, No. 8, No. 4, 3/8", 3/4", 1.5", 3", and 6".

The Fineness Modulus for fine aggregates should lie between 2.3 and 3.1. A small number indicates a fine grading; whereas a large number indicates a coarse material. The fineness modulus can be used to check the constancy of grading when relatively small change is expected; but it should not be used to compare the grading of aggregates from two different sources. The fineness modulus of fine aggregates is required for mix proportion since sand gradation has the largest effect on workability. A fine sand (low fineness modulus) needs more water for good workability. ASTM specifies that the variation of fineness modulus for different batches of a given mix should not exceed 0.2.

2.1.6.7 Shape and texture of aggregate:

Aggregate shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio. However, with rough aggregates, there is better mechanical bond in the hardened concrete, so strength is higher (if concrete with the same w/c ratio is compared). Hence, when smooth aggregates are replaced with rough aggregates, concrete of similar flow properties and strength can be produced by adding a little bit more water.

The surface/volume ratio of spherical aggregates is the smallest. Near-spherical aggregates need less water for mixing and are desirable. Flat, needle-shaped and elongated particles should be avoided, as they require more water and are prone to segregation. When used in concrete, these aggregates can also lead to high stress concentrations and hence a reduction in strength. Generally, flat and elongated particles should be limited to about 15 percent by weight of the total aggregate.

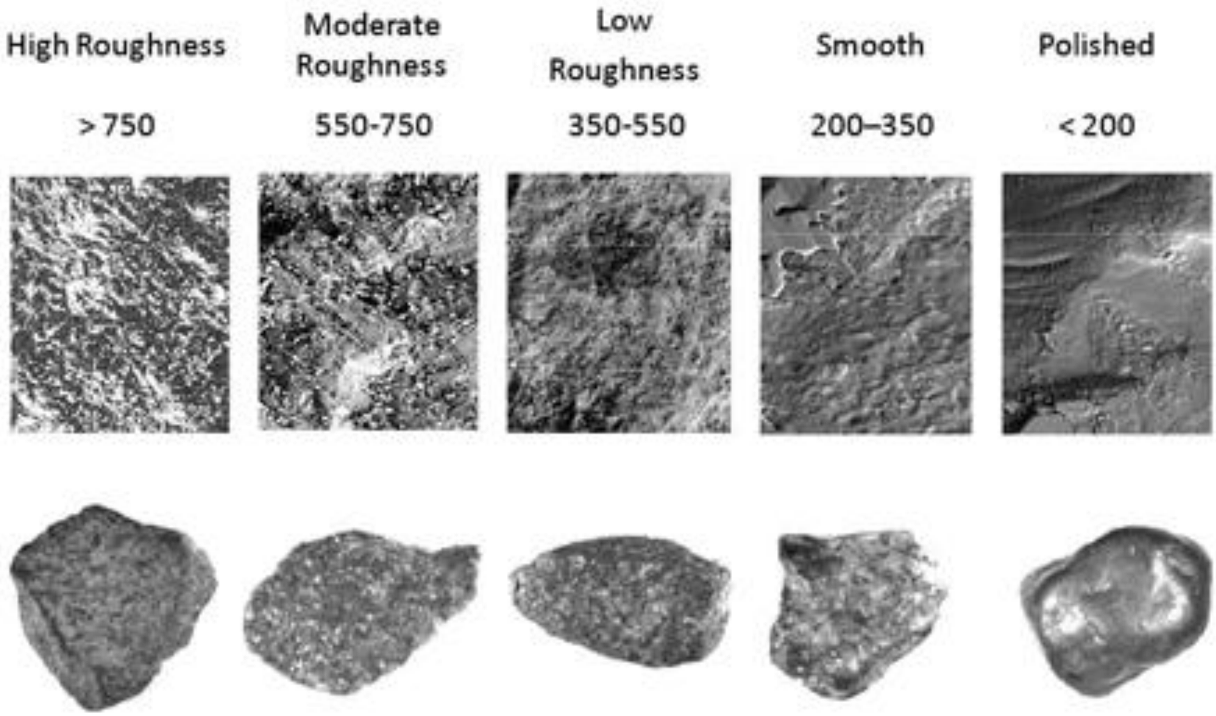


Figure:2.1.6.7 Shape and texture of aggregate

2.1.7 Cement and Its Classification:

Technical knowledge of making hydraulic cement was later formalized by French and British engineers in the 18th century. Tabby, a building material using oyster-shell lime, sand, and whole oyster shells to form a concrete, was introduced to the Americas by the Spanish in the sixteenth century.

John Smeaton made an important contribution to the development of cements while planning the construction of the third Eddystone Lighthouse (1755–59) in the English Channel now known as Smeaton's Tower. He needed a hydraulic mortar that would set and develop some strength in the twelve hour period between successive high tides. He performed experiments with combinations of different lime stones and additives including truss and pozzolanas and did exhaustive market research on the available hydraulic lines, visiting their production sites, and noted that the "hydraulicity" of the lime was directly related to the clay content of the limestone from which it was made. Smeaton was a civil engineer by profession, and took the idea no further.

In the South Atlantic seaboard of the United States, tabby relying upon the oyster-shell middens of earlier Native American populations was used in house construction from the 1730s to the 1860s.

In Britain particularly, good quality building stone became ever more expensive during a period of rapid growth, and it became a common practice to construct prestige buildings from the new industrial bricks, and to finish them with a stucco to imitate stone. Hydraulic limes were favored for this, but the need for a fast set time encouraged the development of new cements. Most famous was Parker's "Roman cement". This was developed by James Parker in the 1780s, and finally patented in 1796. It was, in fact, nothing like material used by the Romans, but was a "natural cement" made by burning septaria – nodules that are found in certain clay deposits, and that contain both clay minerals and calcium carbonate. The burnt nodules were ground to a fine powder. This product, made into a mortar with sand, set in 5–15 minutes. The success of "Roman cement" led other manufacturers to develop rival products by burning artificial hydraulic lime cements of clay and chalk. Roman cement quickly became popular but was largely replaced by Portland cement in the 1850s.

Definition:

Cement is a cementing or binding material that can hold thing together. It is manufactured from calcareous material (compounds of calcium and magnesium, example limestone) and argillaceous material mainly silica, alumina and oxides of iron, example clay), . In the most general sense of the word, cement is a binder a substance which sets and hardens independently and can bind other materials together)

2.1.8 Types of Cement:

Those obtained by calcining and grinding to fine powder controlled quantities of lime and clay mixed thoroughly in order to ensure a product of homogenous composition and of known properties. Various types of artificial cements i.e. Ordinary Portland Cement (O.P.C) available are enumerated below:

Ordinary Portland cement White cement

Low Heat Cement Sulphate Resistant cement

High Alumina Cement

Portland Pozzolana Cement

Colored Cement

Super Sulphate Cement

Rapid Hardening or High Early Strength Cement

Quick Setting Cement

Blast Furnace Cement

Besides the natural and artificial cements, there are some special cements as well. Special cements include:

Masonry Cement

Oil Well Cement

Water Proof Cement

Expansive Cement

Hydrophobic Cement

2.1.9 Portland Cement:

Portland cement is by far the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix to form calcium silicates and other cementitious compounds. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement', the most commonly used type of cement (often referred to as OPC). Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Portland cement may be grey or white.

2.1.9.1 Types of Portland cement

Ordinary Portland cement (OPC):

Ordinary Portland cement Type-I is the most common type of cement in use around the world. It is a basic ingredient of concrete, mortar, stucco and most non-specialty grout cement. It is a fine powder produced by grinding clinker (95%) and a limited amount of Gypsum which controls the setting time. It conforms with the Bangladesh Standard BDS EN 197-1:2003 CEM-I 42.5 N and 52.5 N, European Standard EN 197 type CEM I, and American Standard ASTM C 150 Type-I mark.

Portland Composite Cement (PCC):

Premier Cement also manufactures Portland Composite Cement in response to the local demand as it is the most common type of cement used in Bangladesh. This type of cement basically consists of Clinker, Slag, PFA (Pulverized Fly Ash), Gypsum, and Limestone. It fully confirms with the Bangladeshi Standard BDS EN 197-1:2003 CEM II/AM or BM 42.5N.

Till 2002, only one type of cement was available in Bangladesh was Ordinary Portland Cement (OPC) which is made following the American Standard Method (ASM). From the year 2003, various types of cements became available in Bangladesh which helped the cement industry to provide differentiated and improved products to the customers. The cement which is widely used from the year 2003 is the Portland Composite Cement (PCC) which is made following European Standard Methods (ESM). Holcim (Black Cement) was the first company to launch this type of cement in the market. Currently ratio of production of PPC and OCC is 95:5.

PCC gives equal strength and durability like OPC. The basic difference between them is in the manufacturing technology. Only 65%-80% of clinker is required to produce PCC while 95% of clinker is required to produce OPC. So, worldwide PCC has become popular which requires less clinker.

Ingredients used in PCC	Ratio
Clinker	65-80%
Slag	
Fly Ash	21-35%
Limestone	
Gypsum	0-5%

Ordinary Portland cement (OPC) Ingredients used in PCC	Ratio
Clinker	95-100%
Gypsum	0-5%

In Our research we used (Brand name Fresh Cement) Portland composite cement that contains.

Clinker- (65-79)%

Slag & Fly ash (21-35)%

Gypsum-(0-5)%

2.1.9.2Table 2.1-List of Cement Company available in Bangladesh& Capacity of production:

Serial	Name of Cement Companies	Types	Present capacity (MT/year)	Probable capacity Expansion(MT/year)	Total capacity (MT/year)	Probable completion year
1	Shah Cement	OPC PCC Ready Mix	2.25	1.86	4.11	Jan-11
2	Meghna Cement Mills Ltd. (King cement,Fresh Cement)	OPC PCC	1.44	4.80	6.24	Jun-11
3	Akij Cement Ltd.	PCC	1.26	-		
4	Heidelberg (Scan)	PCC	1.20	-		
5	Lafage Cement		1.20	-		
6	Premier Cement	OPC &PCC	1.20	0.60	1.80	Sep-10
7	Seven Circle cement Ltd.	OPC PCC	1.02	1.54	2.56	Jun-11
8	Heidelberg (Rubi)	PCC	0.90	0.75	1.65	End of2011
9	Holcim Cement (BD) ltd. (Dhaka)	OPC PCC Ready Mix	0.90	1.98	2.88	Not finalized
10	Holcim Cement (BD) ltd.(Mongla)	OPC PCC	0.18			
11	M.I Cement Factory (300 days) (Crown cement)	OPC PCC	0.84	1.65	2.49	
12	Unique Cement	Not found	0.80	-		

13	**Royal Cement**	**OPC PCC**	**0.72**	**-**		
14	**Mongla Cement Factory (Elephant cement)**	**Portland Grey Cement, OPC Composite Portland Cement.**	**0.72**	**-**		
15	**Emirates**	**PCC**	**0.60**	**-**		
16	**Diamond Cement Factory**	**OPC PCC**	**0.60**	**-**		
17	**M.T.C Cement Ltd.**	**Not required**	**0.36**	**1.26**	**1.62**	**End 2011**
18	**Aramit Cement Ltd.**	**OPC PCC**	**0.51**	**0.81**	**1.32**	**Not finalized**
19	**Confidence Cement Ltd.**	**PC PCC**	**0.50**	**0.60**	**1.10**	**2011**
20	**S.Alam Cement Mills Ltd.**	**OPC PCC**	**0.40**	**-**		
21	**Cemex (BD) Ltd.**	**PCC**	**0.35**	**-**		
22	**Olympic Cement**	**Grey cement**	**0.25**	**-**		
23	**Anwar cement Ltd.**	**Not required**	**0.21**	**-**		
24	**N.G.Saha Cement Mills Ltd.**	**Not required**	**0.18**	**-**		
25	**Chatak Cement Ltd.**	**OPC**	**0.18**	**-**		
26	**Aman Cement Factory Ltd.**	**OPC**	**0.18**	**-**		
27	**Mir Cement**	**OPC PCC**	**0.18**	**-**		
28	**Metropoliatan Cement Ltd.**	**OPC**	**0.18**	**0.47**	**0.65**	**Dec-11**
29	**Eastern Cement Ltd.**	**OPC**	**0.18**	**-**		
30	**Dubai (BD) Cement Mills Ltd.**	**PCC**	**0.18**	**-**		

31	**Alhaj Mustafa Hakim Cement**	**OPC**	**0.18**	**-**		
32	**Noapara Cement Mills Ltd.**	**OPC**	**0.10**	**-**		

Source: IDLC Research Report on cement Sector of BD-initiation, April 05,2011www.idlc.com

2.1.10 Brick chips for the compressive strength test:

An investigation was conducted to achieve concrete of higher strength using crushed brick as aggregate and study the mechanical properties. It was found that higher strength concrete ($f'c$= 4500 to 6600 psi1) with brick aggregate is achievable whose strength is much higher than the parent uncrushed brick. Test results show that the compressive strength of brick aggregate concrete can be increased by decreasing its water-cement ratio and using admixture whenever necessary for workability. The compressive strength as well as the tensile strength and the modulus of elasticity of the concrete were studied. The cylinder strength is found about 90% of the cube strength. The ACI Code relations for determining the modulus of rupture was found to highly underestimate the test values., whereas the code suggested expression for elastic modulus gives much higher values than the experimental ones for brick aggregate concrete. Relations were proposed to estimate the modulus of rupture and the modulus of elasticity of brick aggregate concrete of higher strengths.

In Bangladesh and parts of West Bengal, India, where natural rock deposits are scarce, burnt clay bricks are used as an alternative source of coarse aggregate. In Bangladesh the use and performance of concrete made with broken brick as coarse aggregate are quite extensive and satisfactory. Clay can be burnt in its natural form as is done in brick-making and the product may be a source of coarse aggregate for concrete.

The practical experiences confidently showed us that the maximum range of compressive strength of concretes made with brick aggregate but without using any admixture is around 3000 psi. However, higher strength concrete ($f'c$ much greater than 3000 psi).

The mix proportion of the concrete is usually done either by the ACI method (1994) or the BS method (1985). In both methods, the coarse aggregate is the crushed natural stones and the unit weight of this concrete ranges from 140 to 152 pounds per cubic foot (pcf2) (Nilson and Darwin, 1997), whereas brick aggregate concrete weighing between 125-130 pcf**(1 pcf = 16.01 kg/m3)** can be termed as medium weight concrete in comparison with normal weight and light weight concrete (Akhteruzzaman and Hasnat 1983). Besides, the texture and surface roughness of brick aggregates are different from those of stone aggregate. So the properties of brick aggregate concrete may not follow exactly the same trends as those of stone aggregate concrete. Consequently, the present codal specifications, which are based on stone aggregate concrete may not be applicable for brick aggregate concrete.

Akhtaruzzaman and Hasnat (1983) investigated the various engineering properties of concrete using crushed brick as coarse aggregate. Khaloo (1994) studied the properties of concrete using crushed clinker brick as coarse aggregate. In both the above-mentioned studies, investigations were also done by comparing the properties of brick aggregate concrete with those for stone aggregate concrete. On the other hand, studies were done by Mansur et al. (1999) comparing the properties of stone aggregate concrete with those of equivalent brick aggregate concrete obtained by replacing stone with an equal volume of crushed brick, everything else remaining the same.

2.1.11 COMPARISON BETWEEN AASHTO AND ASTM STANDARDS

In the United States, most transportation agencies abide by The American Association of State and Highway Transportation Officials (AASHTO) or The American Society for Testing and Materials (ASTM) standards. The Alabama Department of Transportation uses AASHTO standards exclusively. Methods of curing, consolidating, sulfur capping, preparing, and loading specimens are identical between AASHTO and ASTM standards. The main differences between these standards include how they address the allowable specimen size and capping method.

2.1.12 Testing for Compressive Strength

One of the most important properties of concrete is its compressive strength. Testing for compressive strength helps determine whether a product meets specified strength requirements, when to strip forms, and when a product is ready for shipping and service. Strength results are also used for evaluating mix designs. Cylinders are usually tested in pairs to verify results and to rule out erroneous information based on unsatisfactory breaks.

The objective of compressive-strength testing of concrete cylinders is to determine the amount of force it takes to break a cylinder of concrete. A test cylinder is placed in a compression-testing machine, and a constant load is applied to the cylinder until it breaks. The compressive strength is calculated based on the applied load and the size of the test cylinder. It is important to center the cylinder between the loading plates and to apply the load at a constant rate.

Loading rates, sample alignment and capping procedures can affect the results. Improper capping or surface irregularities of specimens will cause a non-uniform load, yielding improper results. The proper method for capping is described in ASTM C 617, “Practice for Capping Cylinders.” End grinders or rubber caps can also be used to prepare and test concrete test specimens. The type of break of a cylinder needs to be assessed and should be classified according to Figure 2 of ASTM C39. The break type that yields the most accurate reading is the hourglass. Other types may yield erroneous strength values. Compressive testing machines require proper calibration to ensure accurate results and should be re-calibrated according to applicable standards.

Applicable Standards

• ASTM C39/C39M-12a, “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens”
• ASTM C617/C617M-12, “Standard Practice for Capping Cylindrical Concrete Specimens”.

2.1.13 Specimen Size

ASTM, AASHTO, and Canadian Standards Association (CSA) allow the use of 4 x 8 in. cylinders. CSA standards state that if non-standard cylinders are used, then strengths must be correlated to strengths of 6 x 12 in. cylinders (Day 1994 b). ASTM and AASHTO both state that “cylinders for suchtests as compressive strength, Young’s modulus of elasticity, creep, and splitting tensile strength maybe of various sizes with a minimum of 2-in. diameter by 4-in. length. Where correlation or comparison with field-made cylinders is desired, the cylinders shall be 6 x 12 in.” (ASTM C 192-00, AASHTO T126-93). There are certain restrictions placed on the use of 4 x 8 in. cylinders. AASHTO T 126-93and ASTM C 192-00 states that “the diameter of a cylindrical specimen or minimum cross-sectional dimension of a rectangular section shall be at least three times the nominal maximum size of the coarse aggregate in the concrete.” This limits the nominal maximum size of coarse aggregate in a 4x 8 in. cylinder to 1 inch, which effectively limits the maximum aggregate gradation to a No. 57 stone.

2.1.14 FACTORS THAT AFFECT THE COMPRESSIVE STRENGTH OF CONCRETE

In general, there are many factors associated with the compressive strength of concrete, most of them being interdependent. Some of the important parameters that may affect the compressivestrength of concrete are discussed in the following sections.

2.3.14.1 Water-Cement Ratio

Under full compaction, compressive strength is inversely proportional to the water-cement ratio as

shown in Figure 2.1 and is given by the relationship developed by Duff Abrams (1919):

$$f_c = \frac{K1}{K2^{w/c}} \qquad \text{Equation 2.2}$$

where, fc = concrete compressive strength,
$K1$ = empirical constant,
$K2$ = empirical constant, and
w/c= water to cement ratio

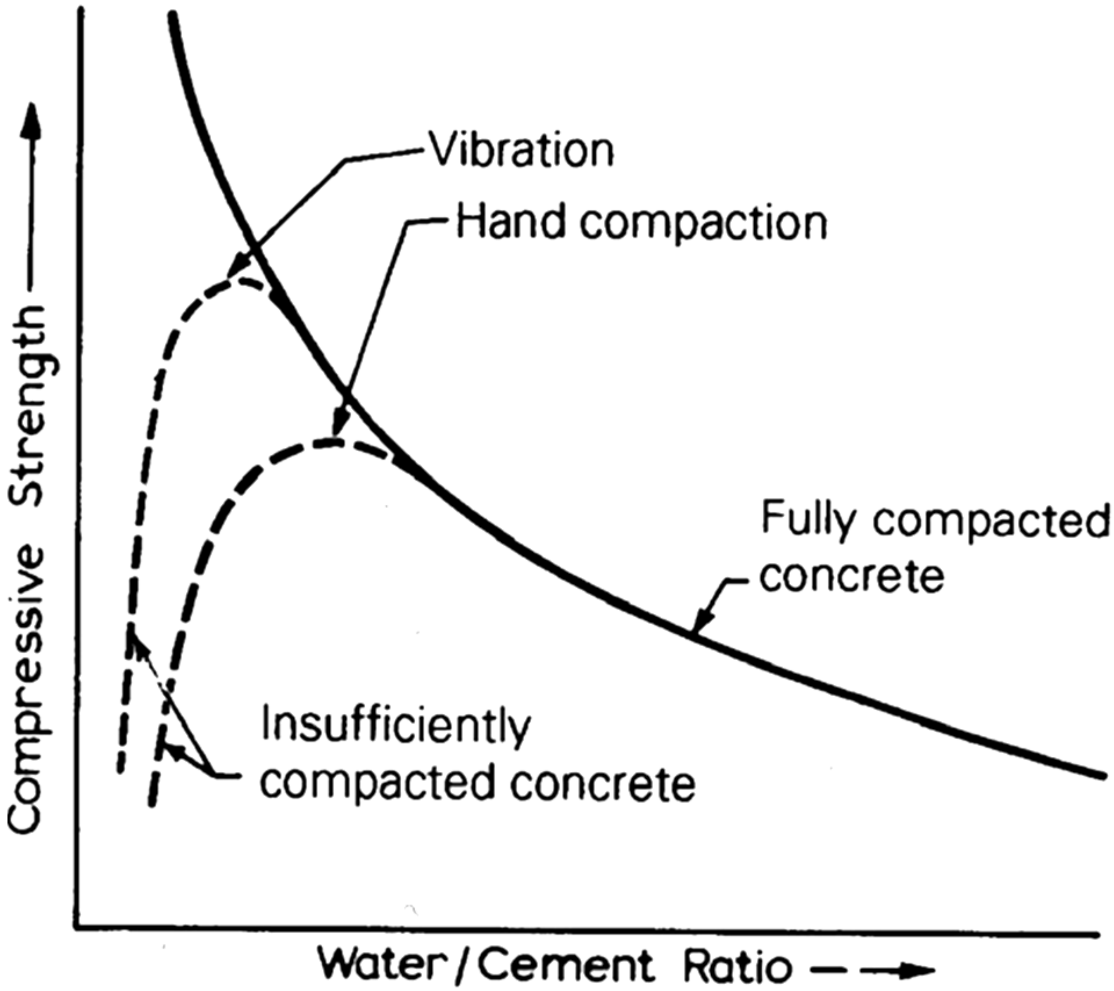


Figure 2.1: Compressive strength and water-cement ratio (Neville 1996)

The water-cement ratio is a very important factor in the determination of porosity and eventually the strength of concrete (Neville 1996). An increase in temperature increases the rate of the exothermic hydration reaction and also the development of strength with time (Neville 1996).In practical applications it is found that the water-cement ratio is usually the most important factor with respect to strength (Neville 1996). However the situation is best summarized by Gilkey (1961) who states that "for a given cement and acceptable aggregates, the strength that may be developed by a workable, properly placed mixture of cement, aggregate, and water (under the same mixing, curing, and testing conditions is influenced by the 1) ratio of cement to mixing water 2) ratio.of cement to aggregate 3) grading, surface texture, shape, strength, and stiffness of aggregate particles 4) maximum size of aggregate. "An exception to the theory given by Abrams (1919) is the behavior of strength at very low water-cement ratio which is explained in the following discussion by Mehta and Monteiro (1993).Mehta and Monteiro (1993) stated that “in low and medium-strength concrete made with normal aggregate, both the transition zone porosity and the matrix porosity determine the strength, and a

direct relation between the water-cement ratio and the concrete strength holds. This seems no longer to be the case in high-strength concretes.

2.1.14.2 Moisture content

Concrete is a construction material that is widely used in many different structures including houses, commercial building, roadway, underground structures, and waterfront structures. These structures are dynamic systems subjected to continuous changes in moisture content. More importantly, parts of these structures are exposed to extreme environmental conditions such as with bridge piers, dams, and waterfront structures. They experience variations in the tidal zone, hence continuous changes in the moisture content.Concrete contains a great number of voids comprising gel pores, capillary pores and flaws. At the two extremes, these voids may either be full (filled with water when the concrete saturated) or empty (filled with air) when the concrete is fully dry. Under intermediate conditions, a mixture of water, water vapor and air may be present. The change in moisture content caused by wetting and drying has a considerable effect on the mechanical properties of the concrete. This strength of concrete is one of the basic engineering indicators in the design of concrete structures, but in practice the influence of moisture on the strength of concrete is not usually taken into account.Mechanical tests have been used to evaluate the variations due to moisture difference. From literature the it can be found that that exists uncertainly ib the moisture effects on strength and elastic modulus.Result on compressive strength variations, which are reported in the literature, are ambiguous. It is well known that the compressive strength of concrete in water is 10-20% smaller than in air. Studies have shown progressive increase or decrease. However, two phases are sometimes present; a decrease in strength in the range 100% to 50% of moisture content followed by an increase for lower content. The variation of elastic modulus with relation to moisture content has been observed with axial compressive tests. Haque and cook found that there was no variation down to 50% relative humidity. On the other hand, Brooks and Neville observed a 7 % decrease was measured for a concrete under60% relative humidity compared with the same concrete wet cured for 56 days. A 25% decrease was also observed by Burliom et al. for a concrete stored at 60%relative humidity.

The presence of moisture content in the test specimen also affects the test result to a great extent. If two cubes (one is wet & another is dry) prepared from the same concrete, are tested at the same age, then the dry cube will give higher strength than the wet cube. This may be caused due to the reduction of cohesion of concrete ingredients due to presence of water.

To get reproducible results, it is advised that the concrete cubes or cylinders should be tested immediately on removal from the curing tank. Because if you test concrete in dry condition then the test results will vary largely.

2.1.14.5 Testing Parameters

Compressive strength is the most important property of concrete. The compressive strength of concrete is determined in the laboratory in controlled conditions. On the basis of this test result we judge the quality of concrete. But sometimes the strength test results vary so widely that it becomes difficult to reach at any conclusion. This variation in test results can be avoided by taking necessary steps.

The compressive strength of concrete depends on two sets of testing parameters, i.e., specimen and loading. Specimen parameters include size, specimen shape, curing conditions and height-to-diameter ratio. Loading parameters include load rate and the different load conditions prevailing on site and in the laboratory.

2.1.14.6 Specimen Parameters

Shape & size of specimens affect the strength test result of concrete to a large extent. If two cylinder of different sizes but prepared from the same concrete, are tested then they will show different test results.

Shape & size of specimens affect the strength test result of concrete to a large extent. If two cubes of different sizes but prepared from the same concrete, are tested then they will show different test results. For example, strength of a cube specimen having 10 cm in size is 10% less than strength of a cube specimen having 15 cm in size.

If two cubes of different shapes (such as cube & cylinder) are tested, then they will show different test results. From experiment it has been found that strength of the cylinder of size 15 cm diameter and 30 cm long is equal to 0.8 times the strength of 15 cm cube

The product of this correction factor and the measured compressive strength will give the corrected compressive strength. This corrected compressive strength is equivalent to the strength of a cylinder having height / diameter ratio of 2.

2.1.14.7 Loading Conditions

ASTM C 39-01 requires that the loading rate for cylindrical specimens be maintained between 20 and 50 psi/sec. Generally, the higher the rate of loading, the higher the apparent compressivestrength.

If the rate of application of load is slow, or there is some time lag,. Then it will result into lower values of strength. The reason behind this is creep. Due to slower application of load, the specimen will undergo some amount of creep which in turn increases the strain. And this increased strain is responsible for failure of test sample, resulting lower strength values.

2.1.14.8Age effect on compressive strength test:

The relationship between strength and porosity is an indicator to extent which the hydration process is completed and the amount of hydration products present. Different cements require differentlengths of time to achieve a particular strength and the rate of hydration is different for different typesof cement.

The water-cement ratio influences the rate of the hydration process and consequently the rate of strength gain.Meyer (1963) found that when low water-cement ratios are considered there is a rapid gain in early strength as compared to higher water-cement ratios. He also found that the rateof strength gain at lower water-cement ratio decreased at later ages as compared to higher watercementratios.

2.2 Overview definition Related that Test

Compressive strength:

- The maximum compressive stress that under gradually applied load a given solid material will sustain without fracture.

Specific Gravity:

- Ratio of the mass of a substance relative to the mass of an equal volume of water at a specified temperature.
- The density of water is 62.4 lb/ft3.

Bulk Dry Specific Gravity:

- Bulk dry specific gravity includes thevolume of bothpermeable andimpermeable pores.

Bulk SSD Specific Gravity:

- All permeable poresfilled with water(saturated) Particles appear moist but not shiny (surface dry).

Absorption:

- The penetration of a liquid into aggregate particles with resulting increase in particle Weight. Amount of water absorbed into poresof aggregate particles.

Density (D):

- Weight per unit volume (excluding the pores inside a single aggregate)

Stress

- Stress is "force per unit area" - the ratio of applied force and cross section - defined as "force per area".

$$\sigma = \frac{F}{A}$$

Compressive stress:

- Compressive stress normal to the plane is usually denoted "normal stress" or "direct stress"

Strain:

- Strain is defined as "deformation of a solid due to stress" and can be expressed as

$\varepsilon = dl / lo$

$= \sigma / E$

where

dl = change of length (m, in)

lo = initial length (m, in)

ε = unit less measure of engineering strain

E = Young's modulus (Modulus of Elasticity) (N/m2 (Pa), lb/in2 (psi))

Concrete:

Concrete –An artificial stone –like material used for various structural purposes. It is made by mixing a binding material (such as cement) and various aggregates (inert materials), such as sand, stone, stone chips, brick chips, pebbles, gravel, shale, etc., with water and allowing the mixture to garden by hydration. It acts as a primary binder to join the aggregate into a solid mass. The chemical process called cement hydration produces crystals that interlock and bind together.

Cement:

Cement is a cementing or binding material that can hold thing together. In the most general sense of the word, cement is a binder a substance which sets and hardens independently and can bind other materials together)

Aggregate:

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids

Chapter 3
Methodology

3.1. Testing Compressive Stress of Concrete

3.1.1. General:

Concrete mixture can be designed to provide a wide range of mechanical and durability properties to meet the design requirements of a structure. The compressive strength of concrete is the most common performance measure used by the engineer in designing buildings and other structures. The compressive strength is measured by breaking cylindrical concrete specimens in a compression-testing machine. The 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) in US Customary units of megapascals (MPa) in SI units. Concrete compressive strength requirements can vary from 2500 psi (17 MPa) for residential concrete to 4000 psi (28 MPa) and higher in commercial structures. Higher strength up to and exceeding 10,000 psi (70 MPa) are specified for certain applications.

3.1.2. Test procedure:

Compressive strength test results are primarily used to determine that the concrete mixture as delivered meets the requirements of the specified strength *f'c*, in the job specification. Strength results from cast cylinders may be used for quality control, acceptance of concrete, or for estimating the concrete strength in a structure for the purpose of scheduling construction operations such as from removal or for evaluating the adequacy of curing and protection afforded to the structure. Cylinder tested for acceptance and quality control are made and cured in accordance with procedures described for *standard-cured* specimen in ASTM C 31 *Standard Practice for Making and Curing Concrete Test Specimens in the Field.* For estimating the in-place concrete strength, ASTM C 31 provides procedures for *field-cured* specimens. Cylindrical specimens are tested in accordance with ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. A test result is the average of at least two standard-cured strength specimens made from the same concrete sample and tested at the age. In most cases strength requirements for concrete are at an age of 28 days. Design engineers us the specified strength *f'c* to design structural elements. This specified strength is incorporated in the job contract documents. The concrete mixture is designed to produce an average strength, *f'cr*, higher than the specified strength such as that the risk of not complying determine that the concrete mixture as delivered meets the requirements of the specified strength, f'c, in the job specification. Strength test results from cast cylinders may be used for quality control, acceptance of concrete, or for estimating the concrete strength in a structure for the purpose of scheduling construction operations such as from removal or for evaluation the adequacy of curing and protection afforded to the structure. cylinders rested for acceptance and quality control are mader and cured in accordance with procedures described for *standard-cured*

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• The average of 3 consecutive tests should equal or exceed the specified strength, *f´*c
• No single strength test should fall below *f´*c by more Than 500 psi (3.45 MPa); or by more than 0.10 *f´*c when *f´*c is more than 5000 psi (35 MPa) It is important to understand that an individual test falling below *f´*c does not necessarily constitute a failure to meet specification requirements. When the average of strength tests on a job are at the required average strength, *f′*cr, the probability that individual strength tests will be less than the specified strength is about 10% and this is accounted for in the acceptance criteria. When strength test results indicate that the concrete delivered fails to meet the requirements of the specification, it is important to recognize that the failure may be in the testing, not the concrete. This is especially true if the fabrication, handling, curing and testing of the cylinders are not conducted in accordance with standard procedures. *See CIP 9, Low Concrete Cylinder Strength.* Historical strength test records are used by the concrete producer to establish the target average strength of concrete mixtures for future work.

- Cylindrical specimens for acceptance testing should be 6 x 12 inch (150 x 300 mm) size or 4 x 8 inch (100 x 200 mm when specified. The smaller specimens tend to be easier to make and handle in the field and the laboratory. The diameter of the cylinder used should be at least 3 times the nominal maximum size of the coarse aggregate used the concrete.
- Recording the mass of the specimen before capping provides useful information in case of disputes.
- To provide for a uniform load distribution when testing, cylinders are capped generally with sulfur mortar (ASTM C 617) or neoprene pad caps (ASTM C 1231). Sulfur caps should be applied at least two hours and preferably one day before testing. Neoprene pad caps can be used to measure concrete strengths between 1500 and 7000 psi (10 to 50 MPa). For higher strengths up to 12,000 psi, neoprene pad caps are permitted to be used if they are qualified by companion testing with sulfur caps. Durometer hardness requirements for neoprene pads vary from 50 to 70 depending on the strength level tested. Pads should be replaced if there is excessive wear.

- Cylinders should not be allowed to dry out prior to testing.

- The cylinder diameter should be measured in two locations at right angles to each other at mid-height of the specimen and averaged to calculate the cross- sectional area. If the two measured diameters differ by more than 2%, the cylinder should not be tested.
- The ends of the specimens should not depart from perpendicularity with the cylinder axis by more than 0.5º and the ends should be plane to within 0.002 inches (0.05 mm).
- Cylinders should be centered in the compression-testing machine and loaded to complete failure. The loading rate on a hydraulic machine should be maintained in a range of 20 to 50 psi/s (0.15 to 0.35 MPa/s) during the latter half of the loading phase. The type of break should be recorded. A common break pattern is a conical fracture (*see figure*).
- The concrete strength is calculated by dividing the maximum load at failure by the average cross-sectional area. C 39 has correction factors if the length-to-diameter ratio of the cylinder is between 1.75 and 1.00, which is rare. At least two cylinders are tested at the same age and the average strength is reported as the test result to the nearest 10 psi (0.1 MPa)
- The technician carrying out the test should record the date they were received at the lab, the test date, specimen identification, cylinder diameter, test age, maximum load applied, compressive strength, type of fracture, and any defects in the cylinders or caps. If measured, the mass of the cylinders should also be noted.
- Most deviations from standard procedures for making, curing and testing concrete test specimens will result in a lower measured strength.
- The range between companion cylinders from the same set and tested at the same age should be, on average, about 2 to 3% of the average strength. If the difference between two companion cylinders exceeds 8% too often, or 9.5% for three companion cylinders, the testing in procedures at the laboratory should be evaluated and rectified.
- Results of tests made by different labs on the same concrete sample should not differ by more than about 13% of the average of the two test results.
- If one or both of a set of cylinders break at strength below $f'c$, evaluate the cylinders for obvious problems and *hold the tested cylinders* for later examination. Frequently the cause of a failed test can be readily seen in the cylinder, either immediately or by petrographic examination. If it is thrown away an easy opportunity to correct the problem may be lost. In some cases additional reserve cylinders are made and can be tested if one cylinder of a set broke at a lower strength.
- A 3 or 7-day test may help detect potential problems with concrete quality or testing procedures at the lab but is not a basis for rejecting concrete, with a requirement for 28-day or other age strength.
- ASTM C 1077 requires that laboratory technicians involved in testing concrete must be certified.

- Reports of compressive strength tests provide valuable information to the project team for the current and future projects. The reports should be forwarded to the concrete producer, contractor and the owner's representative as expeditiously as possible.

(a)

(b)

(c)

(d)

(e)

(f)

figure 3.1.2.1: Casting of 4"x8" concrete cylinders (a) Coarse aggregates (<19mm) (b) Aggregates submerged in water (c) Concrete mix ratio 1:2:4, means 1 part of cement, 2 parts of fine aggregates & 4 parts of coarse aggregates (d) Preparation of Cylindrical mold (adding oil in inner surface) (e) Cylindrical molds with appropriate tamping (f) Demolding of concrete cylinder.

3.1.3.Type of fractures:

Figure 1, from ASTM C 39-03, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," shows five different types of fracture. This standard requires that reports include the type of fracture "if other than the usual cone."

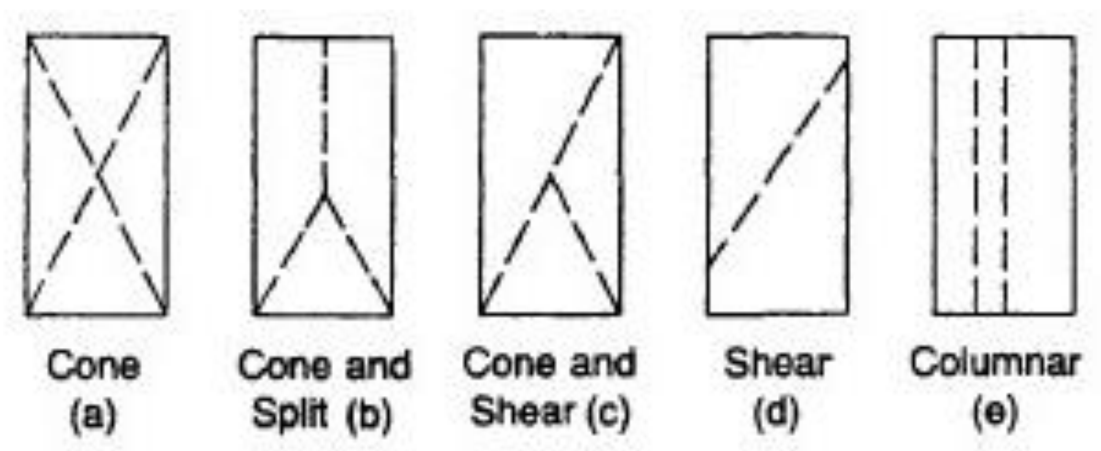


*Figure***3.1.3***: Sketch of type of figure*

A cone failure results when friction at the platens of the testing machine restrains lateral expansion of the concrete as the vertical compressive force is applied. This restraint confines the concrete near the platens and results in two relatively undamaged cones when the cylinder is tested to fracture. If the friction were eliminated, the cylinder would expand more laterally and exhibit a splitting failure similar to that shown in Fig. 1(e). Such vertical splitting has been observed in numerous tests on high-strength specimens made of mortar or neat cement paste, but the effect is less common in ordinary concrete when coarse aggregate is present (Neville, A., Properties of Concrete, 4th Ed., Prentice Hall, 1995).

The “Manual of Aggregate and Concrete Testing,” included as related material in Volume 4.02 of the 2003 Annual Book of ASTM Standards, states that the type of fracture may be of assistance in determining the cause for the compressive strength of a tested cylinder being less than anticipated. The manual describes a case in which a fracture type that didn't match any of those in Fig. 1 had been noted in a large number of tested cylinders. A photo of the atypical failure shows a crack parallel to the ends and at about mid height in the cylinder. This failure mode was taken as an indicator of nonstandard testing procedures. The ASTM documents don't give any further information regarding causes for types of fracture other than the typical cone or whether any of the types shown are bad or good.

When unbonded neoprene caps are used to determine concrete compressive strength, the broken cylinder only rarely exhibits the conical fracture typical of capped cylinders, and the sketches shown in Fig. 1 aren't descriptive (ASTM C 1231, “Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders”). When neoprene caps are used, if requirements for perpendicularity of the cylinder ends or vertical alignment during loading aren't met, load applied to the cylinder may be concentrated on one side of the specimen. This can cause a short shear failure similar to that shown in Fig. l(d), except that the failure plane intersects the end of the cylinder. This type of fracture generally indicates the cylinder failed prematurely, yielding results lower than the actual strength of the concrete (Kosmatka, Kerkhoff, and Panarese, “Design and Control of Concrete Mixtures,” PCA, 2002).

Figure 3.1.3a. Various failure mode of concrete Cylindrical specimen under the compression loading test

Figure3.1.3b: Failure samples

3.2. Concrete slump test

3.2.1. General:

The concrete slump test is an empirical test that measures workability of fresh concrete.
The test measures consistency of concrete in that specific batch. It is performed to check consistency of freshly made concrete. Consistency refers to the ease with which concrete flows. It is used to indicate degree of wetness. Consistency affects workability of concrete. That is, wetter mixes are more workable than drier mixes, but concrete of the same consistency may vary in workability. The test is also used to determine consistency between individual batches. It is used, indirectly, as a means of checking that the correct amount of water has been added to the mix. The test is carried out in accordance with BS EN 12350-2, *Testing fresh concrete. Slump test*. This replaces BS 1881: Part 102.
The test is popular due to the simplicity of apparatus used and simple procedure. Unfortunately, the simplicity of the test often allows a wide variability in the manner in which the test is performed. The slump test is used to ensure uniformity for different batches of concrete under field condition, and to ascertain the effects of plasticizers on their introduction.

3.2.2. Principle:

The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.

3.2.3. Apparatus:

1. Metal mould, in the shape of the frustum of a cone, open at both ends, and provided with the handle, top internal diameter 4 in (102 mm), and bottom internal diameter 8 in (203 mm) with a height of 1 ft (305 mm). A 2 ft (610 mm) long bullet nosed metal rod, 5/8 in (16 mm) in diameter.
2. Scale for measurement,
3. Temping rod (steel).

3.2.4. Procedure of Concrete Slump test:

1. The mold for the slump test is a frustum of a cone, 300mm (12 in) of height. The base is 200 mm (8in) in diameter and it has a smaller opening at the top of 100 mm (4 in).
2. Dampen inside of cone and place it on a smooth, moist, nonabsorbent, level surface large enough to accommodate both the slumped concrete and the slump cone. Stand or, foot pieces throughout the test procedure to hold the cone firmly in place.
3. Fill cone 1/3 full by volume and rod 25 times with 5/8-inch diameter x 24-inch-long hemispherical tip steel tamping rod. (This is a specification requirement which will produce nonstandard results unless followed exactly.) Distribute rodding evenly over the entire cross section of the sample.
4. Fill cone 2/3 full by volume. Rod this layer 25 times with rod penetrating into, but not through first layer. Distribute rodding evenly over the entire cross section of the layer.
5. Fill cone to overflowing. Rod this layer 25 times with rod penetrating into but not through, second layer. Distribute rodding evenly over the entire cross section of this layer.
6. Remove the excess concrete from the top of the cone, using tamping rod as a screed. Clean overflow from base of cone.
7. Immediately lift cone vertically with slow, even motion. Do not jar the concrete or tilt the cone during this process. Invert the withdrawn cone, and place next to, but not touching the slumped concrete. (Perform in 5-10 seconds with no lateral or torsional motion.)
8. Lay a straightedge across the top of the slump cone. Measure the amount of slump in inches from the bottom of the straight edge to the top of the slumped concrete at a point over the original center of the base. The slump operation shall be completed in a maximum elapsed time of 2 1/2 minutes. Discard concrete. DO NOT use in any other tests.
9. The decrease in height of concrete to that of mould is noted with scale. (usually measured to the nearest 5 mm (1/4 in)

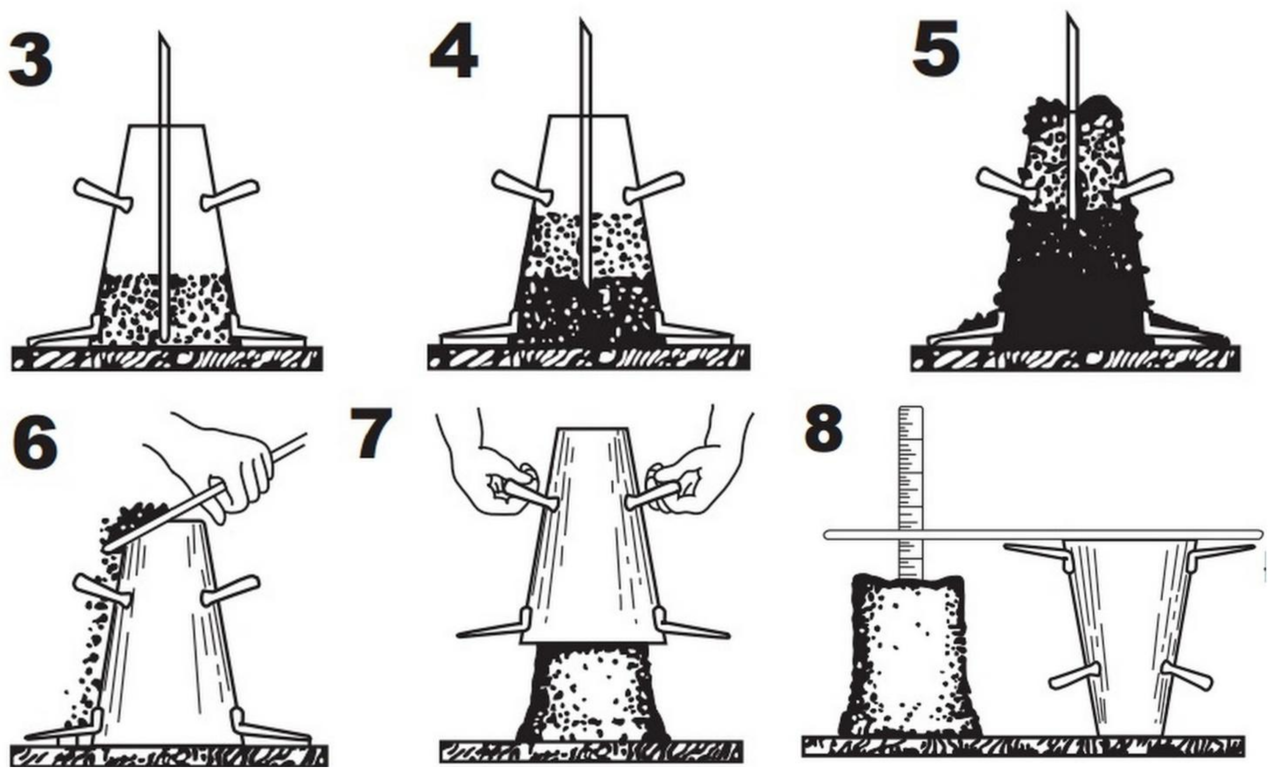


Figure 3.2.4: Slump test

3.2.5. Precautions:

In order to reduce the influence on slump of the variation in the surface friction, the inside of the mould and its base should be moistened at the beginning of every test, and prior to lifting of the mould the area immediately around the base of the cone should be cleaned from concrete which may have dropped accidentally.

3.2.6. Types Of Slump:

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as;

1. Collapse Slump

In a collapse slump the concrete collapses completely. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate.

2. Shear Slump

In a shear slump the top portion of the concrete shears off and slips sideways. OR

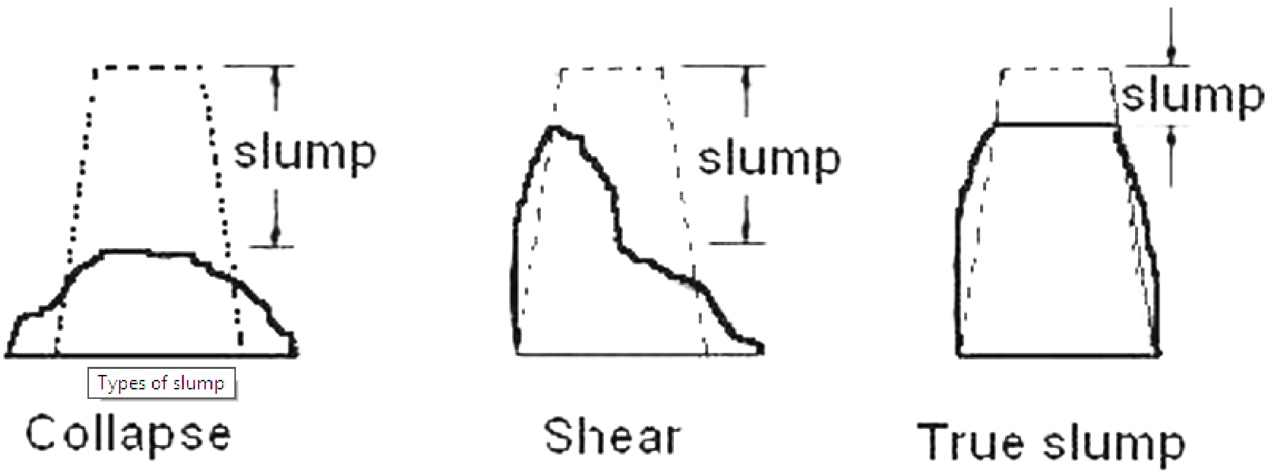
If one-half of the cone slides down an inclined plane, the slump is said to be a shear slump.

1. If a shear or collapse slump is achieved, a fresh sample should be taken and the test is repeated.
2. If the shear slump persists, as may the case with harsh mixes, this is an indication of lack of cohesion of the mix.

3. True Slump

In a true slump the concrete simply subsides, keeping more or less to shape

1. This is the only slump which is used in various tests.
2. Mixes of stiff consistence have a Zero slump, so that in the rather dry range no variation can be detected between mixes of different workability.



Types of slump

However , in a lean mix with a tendency to harshness, a true slump can easily change to the shear slump type or even to collapse, and widely different values of slump can be obtained in different samples from the same mix; thus, the slump test is unreliable for lean mixes.

3.2.7.European classes of slump: According to European Standard EN 206-1:2000 five classes of slump have been designated, as tabulated below.

Table:.European classes of slump

Slump class	Slump in mm
S1	10-40
S2	50-90
S3	100-150
S4	160-210
S5	≥220

3.2.8. Applications of Slump Test

1. The slump test is used to ensure uniformity for different batches of similar concrete under field conditions and to ascertain the effects of plasticizers on their introduction.
2. This test is very useful on site as a check on the day-to-day or hour- to-hour variation in the materials being fed into the mixer. An increase in slump may mean, for instance, that the moisture content of aggregate has unexpectedly increases.
3. Other cause would be a change in the grading of the aggregate, such as a deficiency of sand.
4. Too high or too low a slump gives immediate warning and enables the mixer operator to remedy the situation.
5. This application of slump test as well as its simplicity, is responsible for its widespread use.

Table: Workability, Slump and Compacting Factor of concrete with 19 or 38 mm (3/4 or $1^1/_2$ in) maximum size of aggregate.

Degree of workability	**Slump**		**Compacting Factor**	**Use for which concrete is suitable**
	mm	**in**		
Very low	0-25	0-1	0.78	Very dry mixes; used in road making. Roads vibrated by power operated machines.
Low	25-50	1-2	0.85	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated Machines.
Medium	50-100	2-4	0.92	Medium workability mixes; manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations.
High	100-175	4-7	0.95	High workability concrete; for sections with congested reinforcement. Not normally suitable for vibration

3.2.9. Difference in Standards

The slump test is referred to in several testing and building code, with minor differences in the details of performing the test.

United States

In the United States, engineers use the ASTM standards and AASHTO specifications when referring to the concrete slump test. The American standards explicitly state that the slump cone should have a height of 12-in, a bottom diameter of 8-in and an upper diameter of 4-in. The ASTM standards also state in the procedure that when the cone is removed, it should be lifted up vertically, without any rotational movement at all The concrete slump test is known as "Standard Test Method for Slump of Hydraulic-Cement Concrete" and carries the code (ASTM C 143) or (AASHTO T 119).

United Kingdom & Europe

In the United Kingdom, the Standards specify a slump cone height of 300-mm, a bottom diameter of 200-mm and a top diameter of 100-mm. The British Standards do not explicitly specify that the cone should only be lifted vertically. The slump test in the British standards was first (BS 1881-102) and is now replaced by the European Standard (BS EN 12350-2)

3.2.10. Limitations of the slump test:

The slump test is suitable for slumps of medium to high workability, slump in the range of 5 – 260 mm, the test fails to determine the difference in workability in stiff mixes which have zero slump, or for wet mixes that give a collapse slump. It is limited to concrete formed of aggregates of less than 38 mm (1.5 inch).

Chapter – 4
Data collection and calculation

4.1.Data collection:

Concrete specimens are tested using the ASTM39 Test Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens by using two samples made from the same test at the same age, usually at strength of 7,14,21,28,35,… days old.

Figure 4.1: Mold are submerged into water tank

To determine the porosity of cylindrical mold in different days 7,14,21,28, molds were submerged into a water tank. SSD weight, weight into the water and oven dry weight were collected to calculate porosity. Those obtained values were put on this given equation to find required porosity.

Equation of porosity= $\frac{W_{ssd}-W_{od}}{W_{ssd}-W_{water}} X\ 100\%$

Here, Wssd = weight of concrete in ssd (air) condition

Wod= weight of concrete in oven dry condition

Wwater= weight of concrete saturated in water condition

The evaporation data is collected from 4”x2” cylindrical disc. Discs are kept into normal temperature and air weight is collected in the interval of two-three days. Finlay a spline curve is plotted over the percentage of evaporation rate. To find out percentage of evaporation the required formula is given bellow:

Percentage of evaporation= $\left(\frac{Weight\ in\ air\ at\ zero\ days - Weight\ in\ air\ at\ "X"\ days}{Weight\ in\ air\ at\ zero\ days}\right) * 100$

Design engineers use the specified strength $f'c$ to design structural elements. This specified strength is incorporated in the job contract documents. The concrete mixture is designed to produce an average strength ($f'cr$) higher than the specified strength, such that the risk of not complying with the strength specification is minimized.

Cylindrical specimens for acceptance testing should be 6 x 12 inch (150 x 300 mm) size or 4 x 8 inch (100 x 200 mm) when specified. The Concrete strength is calculated by dividing the maximum load at failure by the average cross sectional area.

Concrete compressive strength requirements can vary from 2500 psi (17 MPa) for residential concrete to 4000 psi (28 MPa) and higher in commercial structures. Higher strengths up to and exceeding 10,000 psi (70 MPa) are specified for certain applications.

Cylinders are placed in a Compression testing machine and loaded to failure from 20 to 50psi. The type of break should be recorded by a Certified Technician.

Before compression testing of each cylinder it was demerged on the day before crushing. Therefore, it was in room temperature for 24 hours to get a satisfactory result.

Table 4.1 *Sample table for compressive strength data*.

	ratio 1:2:4	w/c: 0.6	4"X8"	
Number	**Sample Name**	**Condition**	**Curing Days**	**Compressive Stress (PSI)**
1	AHR 1	SSD	7	964.9
2	AHR 2	SSD	7	1258
3	AHR 3	SSD	7	1109
4	AHR 4	SSD	14	1315
5	AHR 5	SSD	14	1576

4.2 Calculation:

For compressive strength:

A concrete sample that is broken after 28 days

The cylinder is 4” diameter, so it has an area of 3.14 x Diameter squared /4

A = 3.14 x 4 x 4/4

A = 8107.32 mm square

If the force required to break the cylinder was 49226 N

Then the compressive strength is 49226 N / 8107.32 mm square = 880.41 psi.

880.41 psi needs to be compared to the Design strength determined by the Design Strength determined by the Design Engineer.

Similarly, if compressive stress of similar mold in that day is 900.90 psi and 896.32 psi then average compressive stress is 892.54 psi

For porosity:

For an example, porosity at 14 days

weight of cylinder in SSD (air) = 3489 gm

weight in water = 1715 gm

weight in Oven dry condition = 3173.5 gm

Therefore, Porosity= $\frac{3489-3173.5}{3489-1715} X\ 100$ =17.78%

For percentage of evaporation:

For an example, Weight of disc in air at zero days is 827 gm

Weight of disc in air at12 days is 807 gm.

Therefore,

The percentage of evaporation is= $\left(\frac{827-807}{827}\right) * 100$ =2.418 %

Chapter 5

Result & Discussion

For different water – cement ratio and different mixing proportion, different properties of concrete were studied. The results of the test , as well as some properties of using aggregate for making concrete which was observed, were presented and discussed.

5.1 Some important properties of materials:

For the concrete cylinder our used materials are-

1. brickchips
2. cement
3. sand
4. water

At a glance ,some important properties of our used materials:

Table **5.1** properties of our used materials

Material	specific gravity	other properties
Brickchips	2.68	1.passing through 19mm sieve. 2. void-57.257% 3. FM value 6.6595
sand	2.49	1. used sylhet sand. 2. void-33.36% 3.FM value 3.18
cement	3.15	1.Used fresh cement. 2.portland composite cement. 3. Clinker (65-79)%, Slag & fly ash (21-35)%, Gypsum(0-5)%

Formula of void %= $\left(\frac{specific\ \ gravity\ X\ 1000-DRUW}{Specific\ gravity\ X\ 1000}\right) X100\%$

Fig 5.1: finding of void% for brick chips

5.2 Sieve analysis result of Sand and Brick chips:

Fig 5.2: Sieve analysis machine

Fig 5.3: After sieve analysis of sand

Fig 5.4: After sieve analysis of Brick chips

5.2.1 Sieve analysis of Sand:

Table 5.2a: Table showing the sieve analysis result of sand

Sieve Opening (mm)	Material retained (gm)	%Material retained	Cumulative %retained	%Finer
4.75	11.5	1.15	1.15	98.85
2.36	94.5	9.45	10.6	89.4
1.18	278.5	27.85	38.45	61.55
0.6	378	37.8	76.25	23.75
0.3	168	16.8	93.05	6.95
0.15	54.5	5.45	98.5	1.5
Pan	15	1.5	100	0
Total=	1000			

FM= 3.18

After sieve analysis for sand (Sylhet sand), observed result are shown in the table 5.2. From the value of the table a gradation graph for sand is given at the next page.

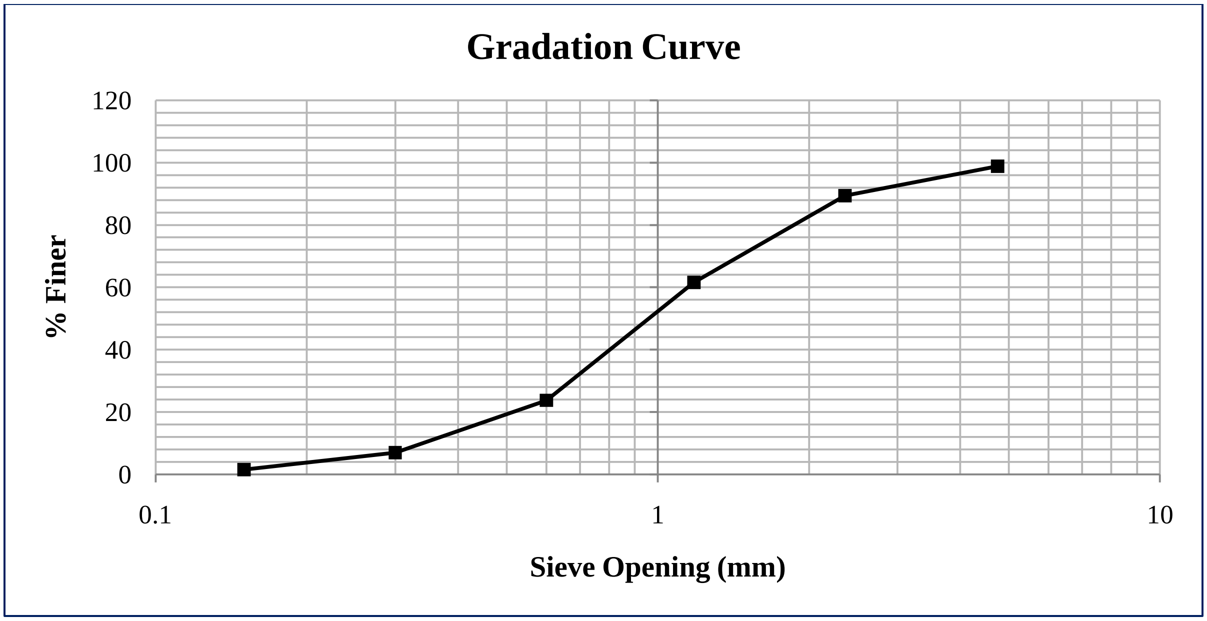


Fig 5.5: Gradation curve for sand

From the graph observation, it is a S shape graph which indicate a well gradation curve.

5.2.2 Sieve analysis of Brick chips:

Table 5.2b: Table showing the sieve analysis result of Brick chips

Sieve Opening (mm)	Material retained (gm)	%Material retained	Cumulative %retained	%Finer
37.5	0	0	0	100
19	122	12.2	12.2	87.8
9.5	573	57.3	69.5	30.5
4.75	180	18	87.5	12.5
2.36	99	9.9	97.4	2.6
1.18	23	2.3	99.7	0.3
0.6	1	0.1	99.8	0.2
0.3	1	0.1	99.9	0.1
0.15	0.5	0.05	99.95	0.05
Pan	0.5	0.05	100	0
Total=	1000			

FM= 6.6595

After sieve analysis of our using brick chips (passing through 19mm sieve), observed result are shown in the table 5.2. From the value of the table a gradation graph plotted for sand which is given below-

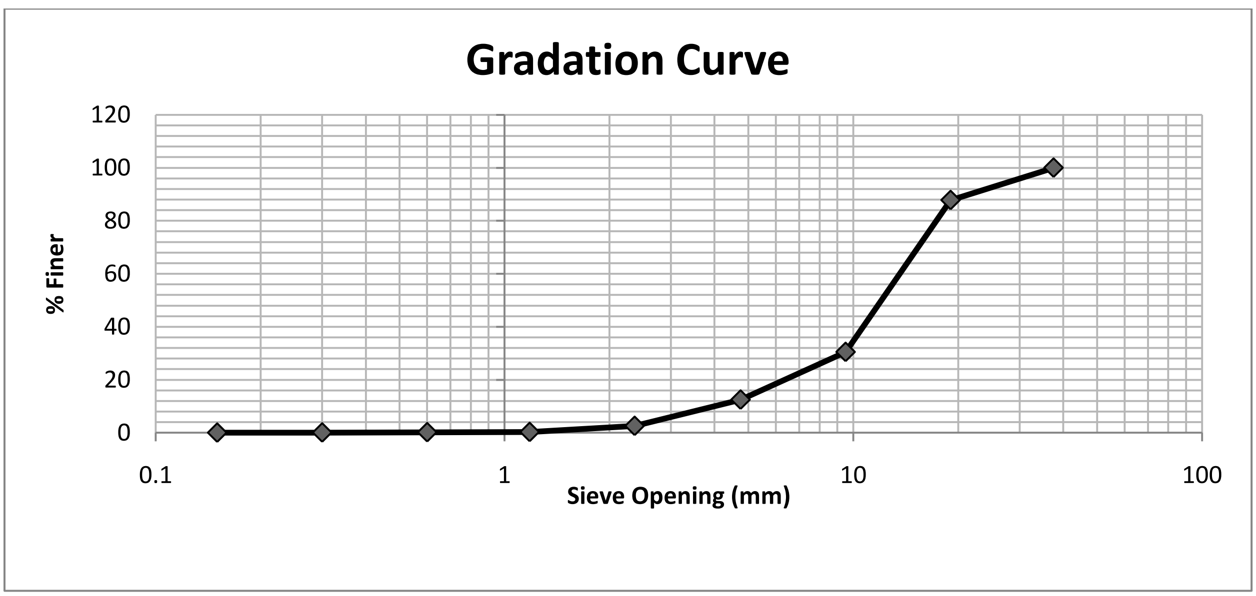


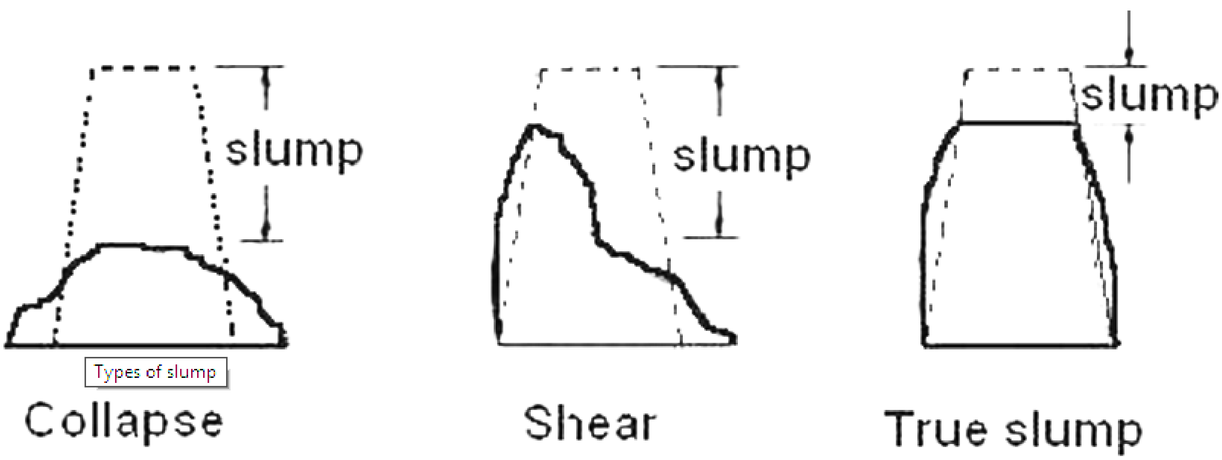
Fig 5.6: Gradation curve for brick chips

From the value of the table, by plotting the graph it can be said that it also shows a well graded curve.

1:2:4 , 1:1.5:3 & 1:2:4 ratios were used for preparing concrete and water cement ratio are 0.5 , 0.6 & 0.6.

5.3: Result of slump test:

In chapter 3 there are broadly discussed about slump test. According to slump test observed slump value was more than 1inch.



Types of slump

Fig 5.7: compare of slump

According to shape or profile of slumped concrete it can be said that it was similar to true slump.

In a true slump the concrete simply subsides, keeping more or less to shape

3. This is the only slump which is used in various tests.
4. Mixes of stiff consistence have a Zero slump, so that in the rather dry range no variation can be detected between mixes of different workability.

5.4 Result and Discussion of Evaporation Test:

For Evaporation test, disc of 4inch diameter and 2inch height were prepared. The concrete of 1:2:4 mix with 0.5 water cement ratio was used. For Evaporation rate, after 5weeks of disc prepared , the required tests were started. The observed values are given here.

From the Data Table 5.3 (table given in Appendices) using the values a Evaporation VS Days graph were plotted here.

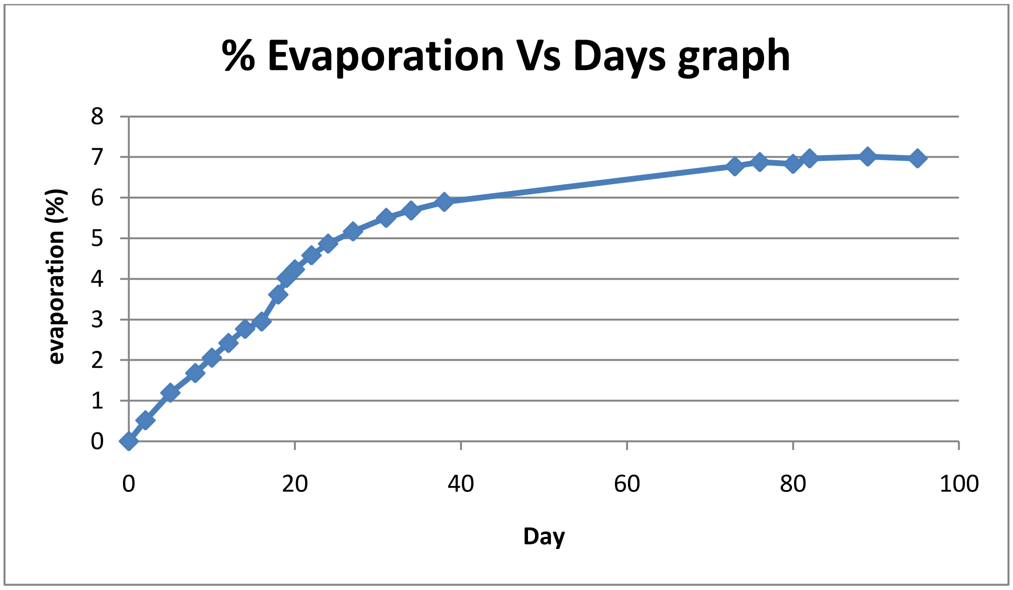


Fig 5.8 : % Evaporation Vs days graph for 4”X2” disc of 1:2:4 mix & 0.5 w/c ratio.

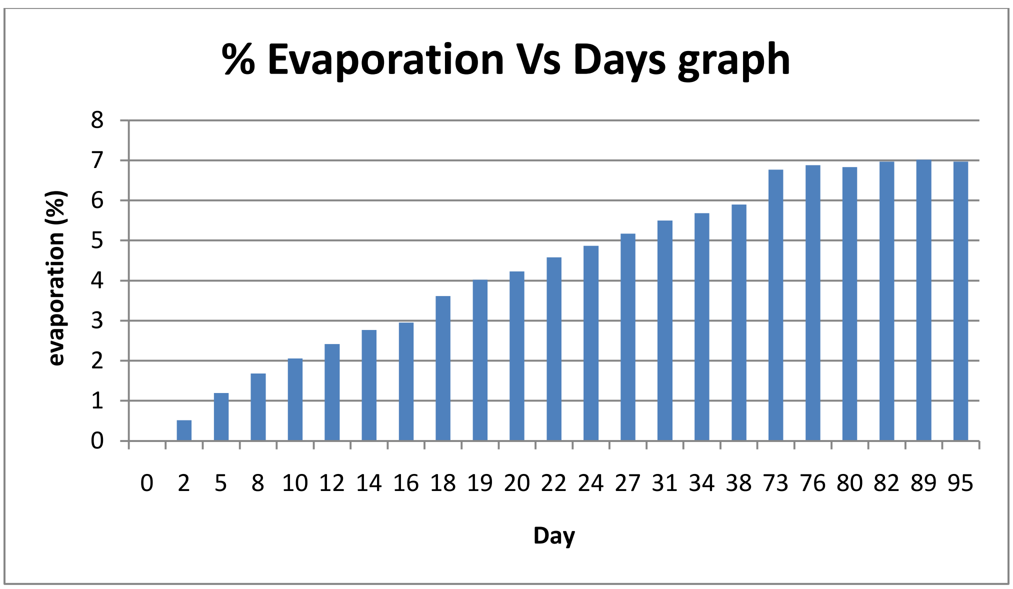


Fig 5.9: Bar chart of Evaporation Rate for 4”X2” disc of 1:2:4 mix & 0.5 w/c ratio.

From these graphs it is clearly seen that % Evaporation is increasing with the time being , which satisfied the property of evaporation for concrete sample. From these values further spline graph was plotted using Table 5.4 which is given at Appendices.

Actually the term spline is adopted from the name of a flexible strip of metal commonly used by drafters to assist in drawing curved lines. In mathematics, a spline is a numeric function that that is piecewise defined by polynomial functions, and which possesses a high degree of smoothness at the places where the polynomial pieces connect.

In interpolating problems, spline interpolation is often preferred to polynomial interpolation because it yields similar results to interpolating with higher degree polynomials while avoiding instability due to runge's phenomenon. In computer graphics, parametric curves whose coordinates are given by splines are popular because of the simplicity f their construction, their ease and accuracy of evaluation, and their capacity to approximate complex shapes through curve fitting and interactive curve design.

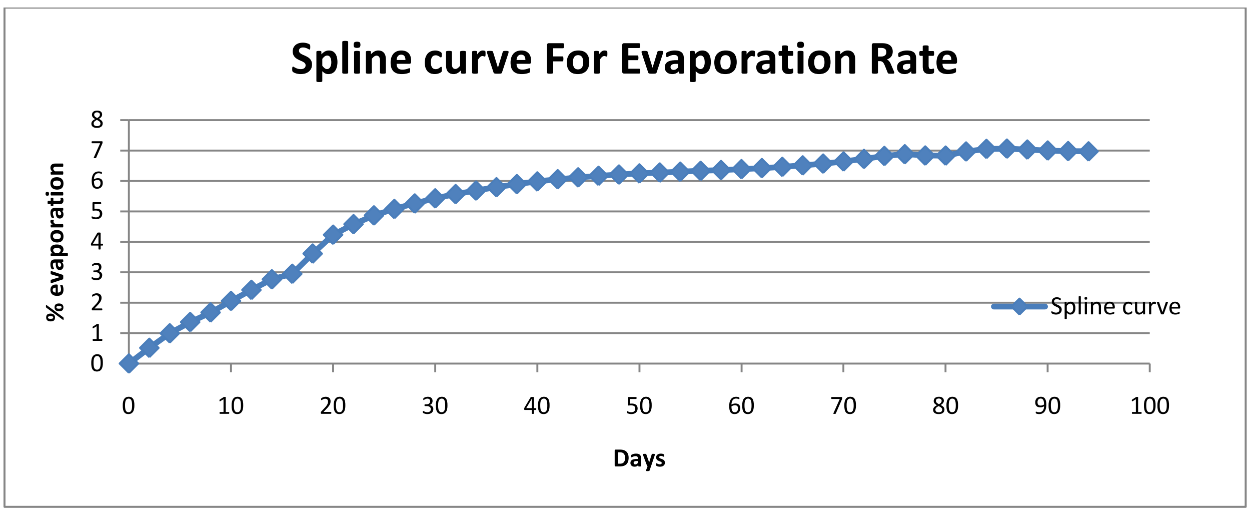


Fig 5.10 : Spline curve for 1:2:4 mix &0.5 w/c concrete

From this spline curve also got 1st & 2nd derivative spline graph. Which are also shown here.

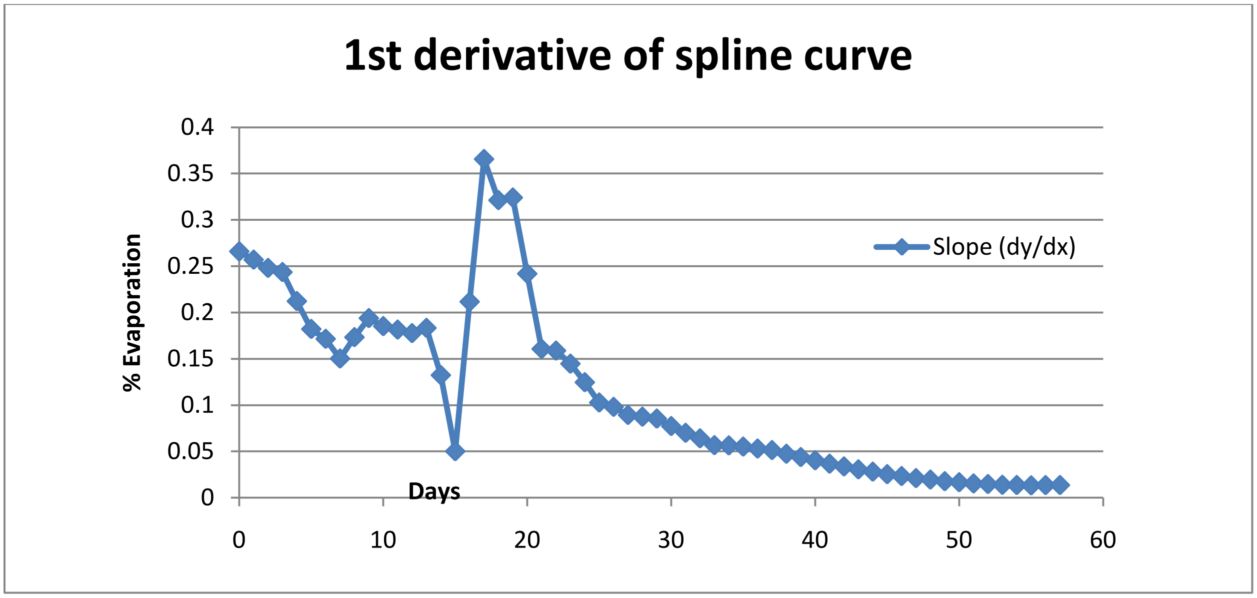


Fig 5.11 : 1st derivation of spline curve

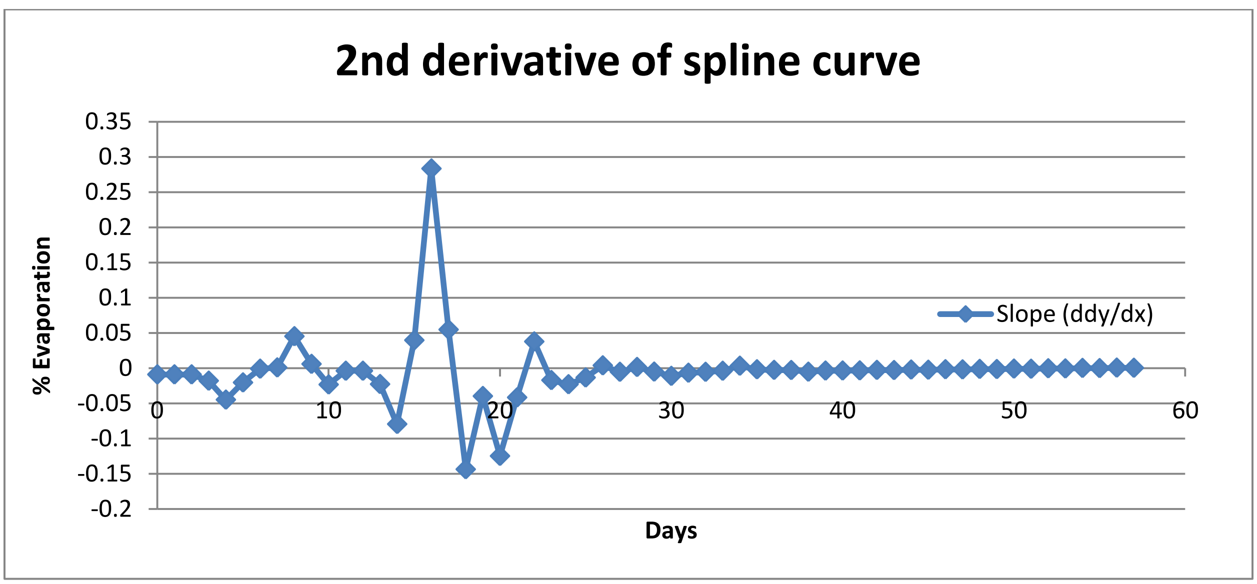


Fig 5.12: 2nd derivation of spline curve.

In fig 5.11 and 5.12 there shown the 1st & 2nd Derivative of spline curve which got from the original spline curve. All these graphs are represented the evaporation rate after the preparation of concrete disc of 4inch diameter & 2inch height for 1:2:4 mix and 0.5 w/c ratio.

5.5 Porosity test Result with Discussion:

For the used concrete sample porosity test was performed. For porosity test ,disc(4inch diameter &2inch height) made of 1:2:4 mix and 0.5 w/c ratio, and cylinder(4inch diameter & 8inch height) of 1:2:4 mix with 0.5w/c & 1:1.5:3mix with 0.6w/c & 1:2:4mix with 0.6w/c were observed . Data with porosity graph which was made by observed value are given here.

The values in the Table correspond to the significant conditions that are evaluated and presented in the graphs related to the main effect and/or interaction between factors

Equation of porosity= $\frac{W_{ssd}-W_{od}}{W_{ssd}-W_{water}} X\ 100\%$

Wssd = weight of concrete in ssd (air) condition

Wod= weight of concrete in oven dry condition

Wwater= weight of concrete saturated in water condition

5.5.1 Porosity test results for Disc:

Following to the rules of porosity test, 2 discs (Disc 1 & disc 2) were casted at one day and 2 other discs were casted (Disc 3 & Disc 4) at another day . Both observed values are shown here.

Table 5.5 : Data of disc for finding porosity.

Date of casting	**Disc 1 & 2**
27/05/2015	
Days	**Porosity %**
10	31.0580768
14	26.4315
20	28.17
28	27.81
35	26.3

Date of casting	**Disc 3 & 4**
28/05/2015	
Days	**Porosity %**
9	30.47155779
13	28.275
23	28.105
27	27.99
34	26.92

Form this values porosity graph was plotted for the discs

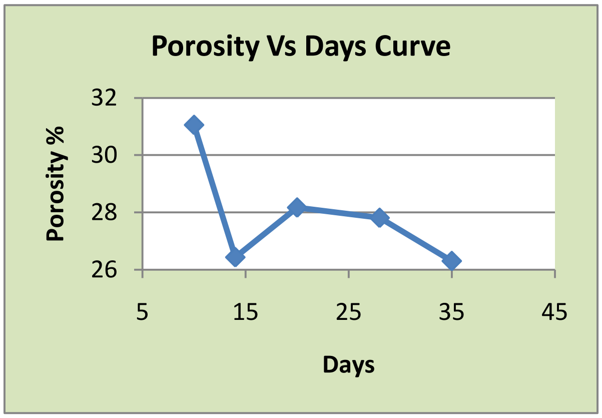


Fig 5.13 (a)

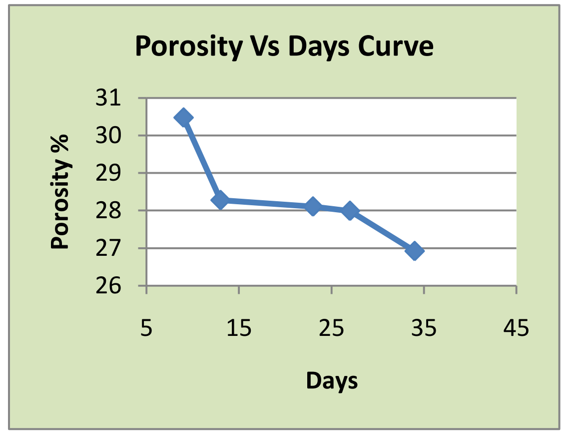


Fig 5.13(c)

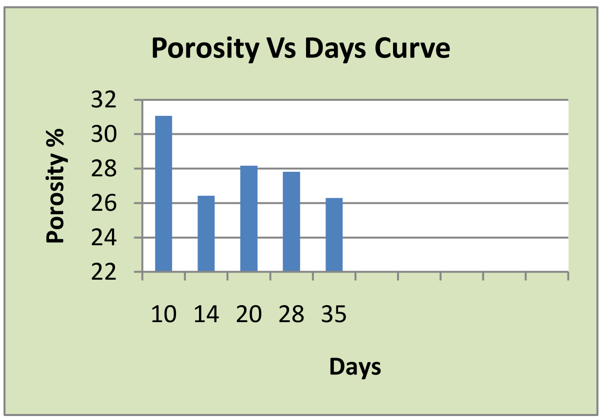


Fig 5.13 (b)

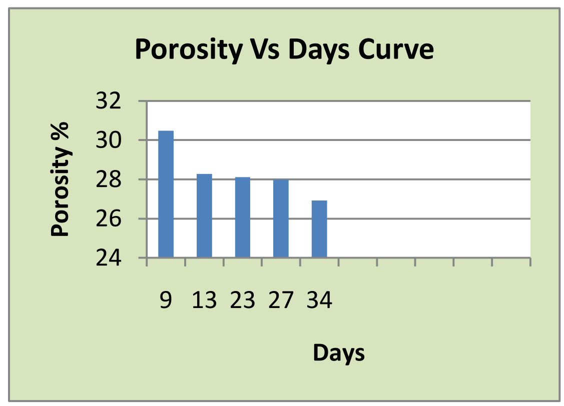


Fig 5.13 (d)

Fig 5.13: (a) & (b) represents Porosity vs. Days Normal graph & Bar chart for disc 1&2, (c) & (d) represents Porosity vs. Days Normal graph & Bar chart for disc 3&4.

From these graphs of porosity for separate disc, final graph was plotted here .

Table 5.6: combined value of porosity for disc

Days	Porosity%
10	31.058
13	28.275
20	28.17
23	28.105
27	27.99
28	27.81
34	26.92
35	26.3

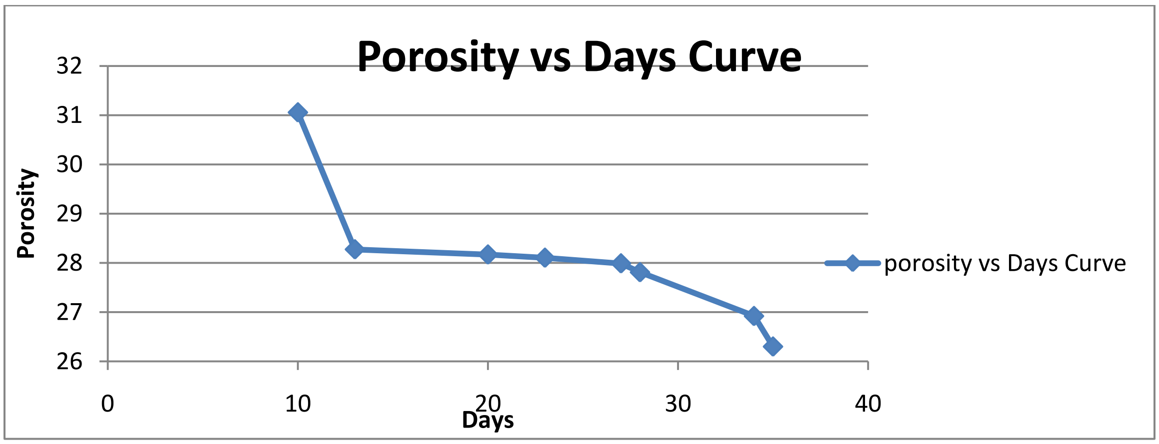


Fig 5.14(a)

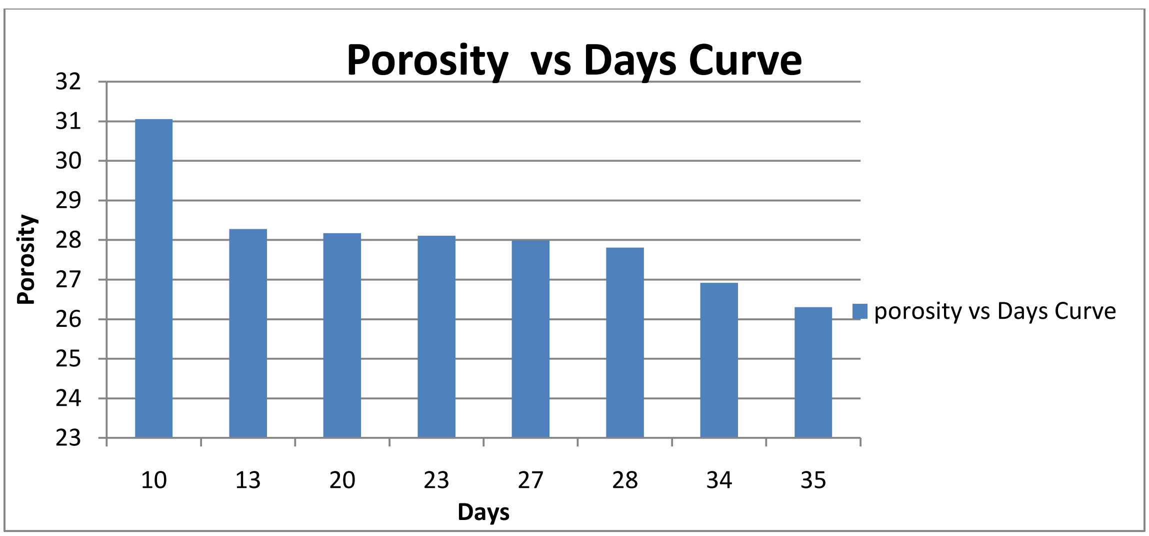


Fig 5.14 (b)

In Fig 5.14,(a) showed the graph of porosity for disc &(b) sowed a bar chart of porosity for disc.

5.5.2: Porosity result for cylinder:

For the cylinder of 1:2:4mix ratio with 0.5 w/c ratio the porosity which was observed are given here.

Table 5.7: Porosity values for cylinder (1:2:4 mix with 0.5 w/c).

Days	Porosity %
14	22.99
24	20.91
28	19.65
70	12.78
79	11.68
89	9.44
92	8.95

According this values porosity graphs are-

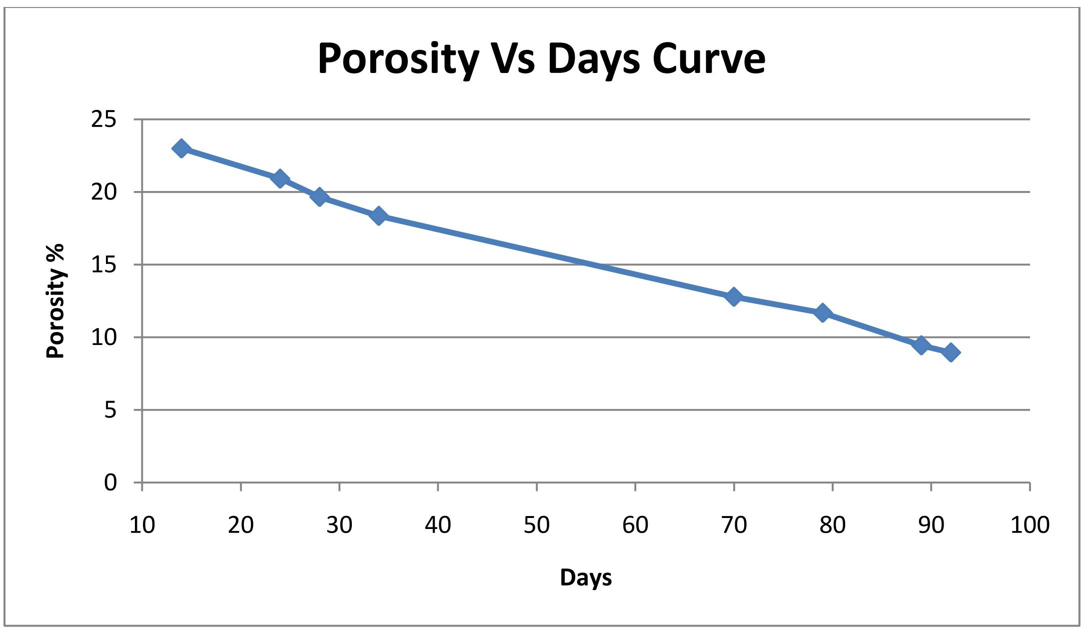


Fig 5.15: porosity graph for cylinder (1:2:4 mix with 0.5 w/c).

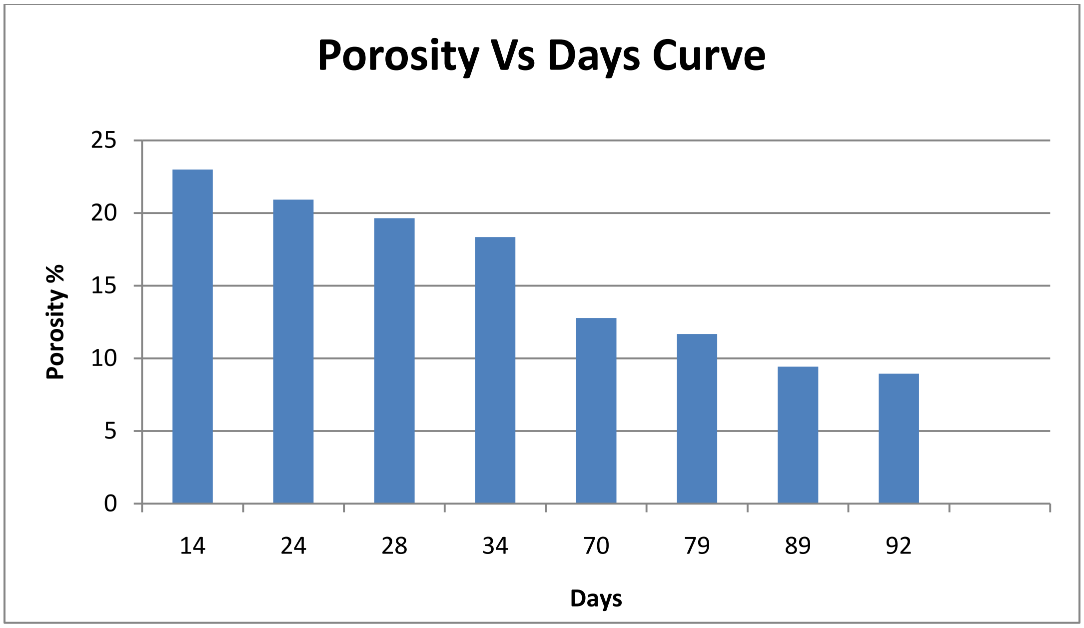


Fig 5.16: Bar chart for porosity of cylinder (1:2:4 mix with 0.5 w/c).

For these cylinders it was observed that porosity was gradually decreasing.

Now For the cylinder of 1:1.5:3 mix ratio with 0.6 w/c ratio the porosity which was observed are given here.

Table 5.8: Porosity values for cylinder (1:1.5:3 mix with 0.6 w/c).

Days	**Porosity %**
64	23.06057271
74	17.78
84	15.67
88	13.54

According these values the porosity graphs are -

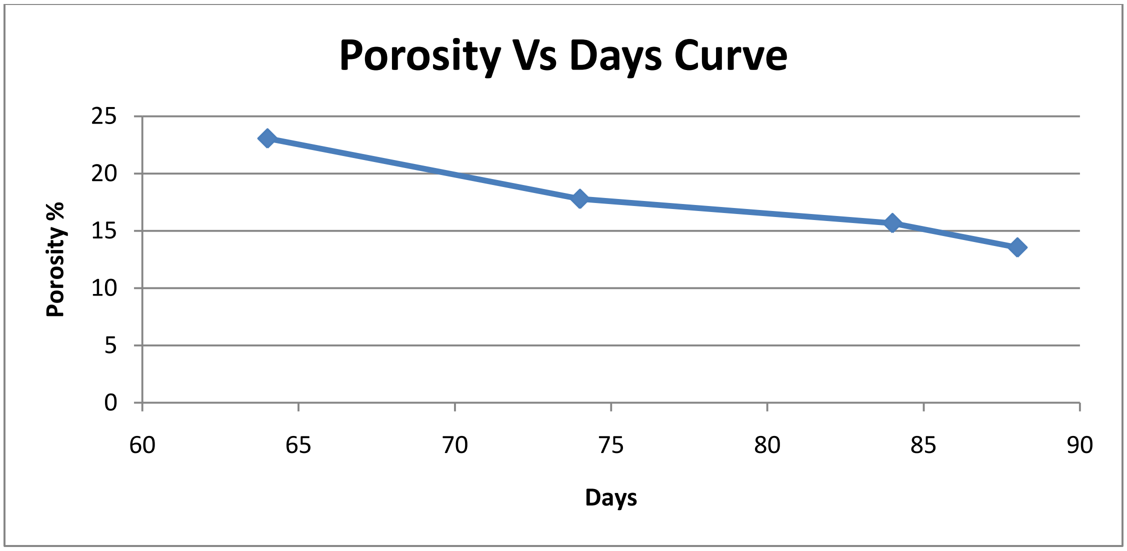


Fig 5.17: porosity graph for cylinder (1:1.5:3 mix with 0.6 w/c).

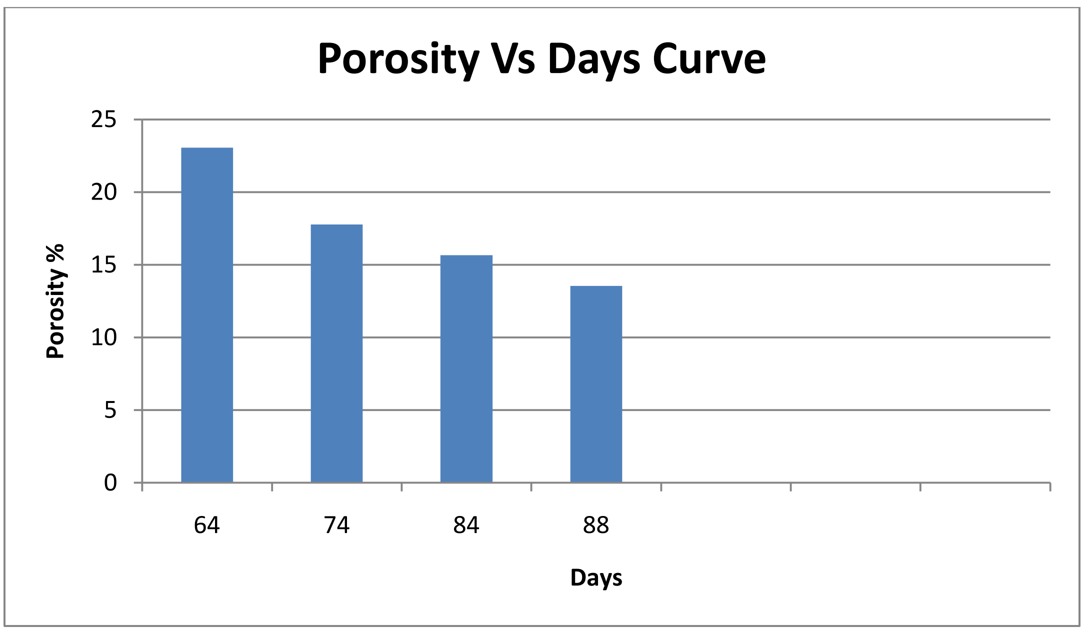


Fig 5.18: Bar chart for porosity of cylinder (1:1.5:3 mix with 0.6 w/c).

Form these graphs are also can be show that here porosity are also decreasing.

For the cylinder of 1:2:4 mix ratio with 0.6 w/c ratio the porosity which was observed are given here.

Table 5.9: Porosity values for cylinder (1:2:4 mix with 0.6 w/c).

Days	% Porosity
14	51.67
24	43.45
28	21.9375

According these values the porosity graphs are –

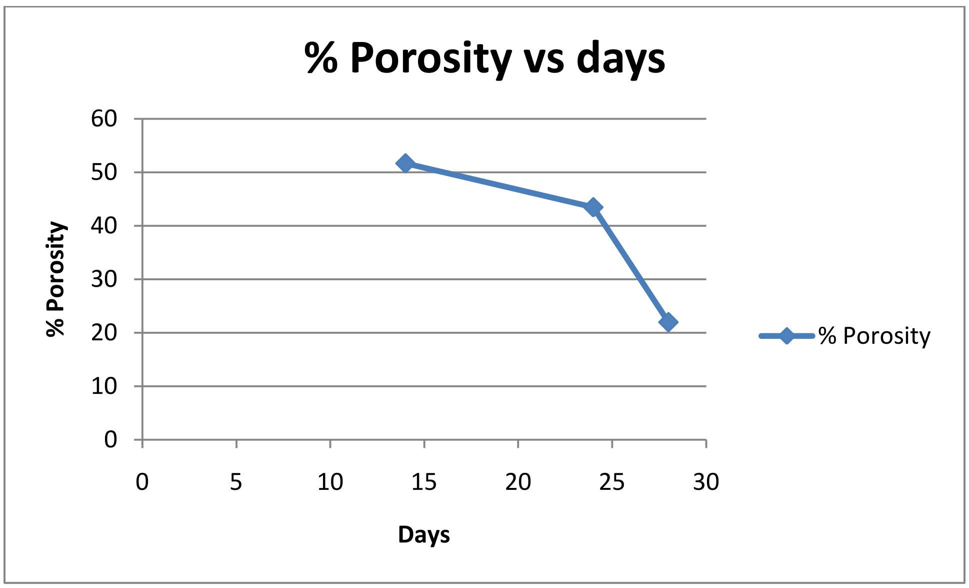


Fig 5.19: porosity graph for cylinder (1:2:4 mix with 0.6 w/c).

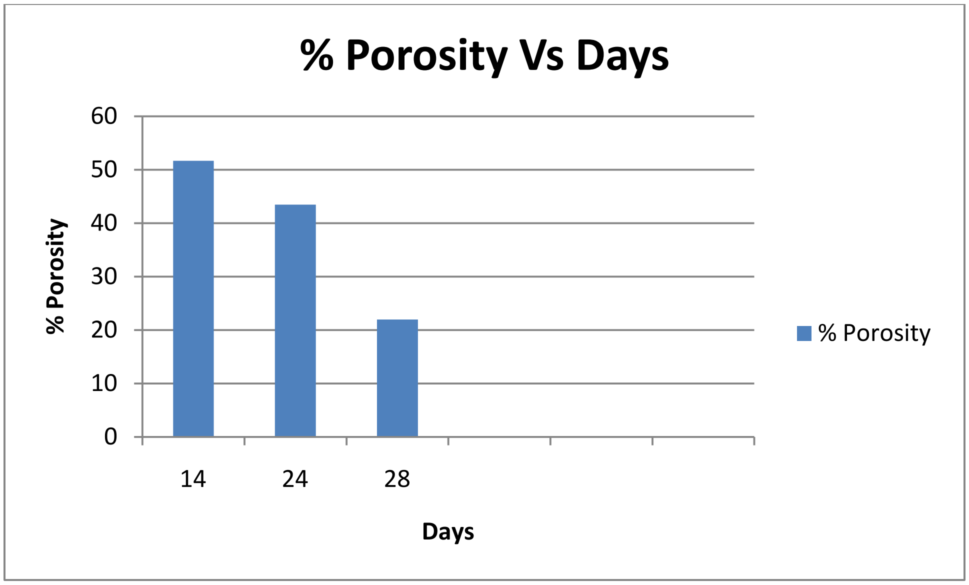


Fig 5.20: Bar chart for porosity of cylinder (1:2:4 mix with 0.6 w/c).

This graph also shows the same , with the time being porosity rate is decreasing.

Now finally from all above the graphs the combined graph is given here-

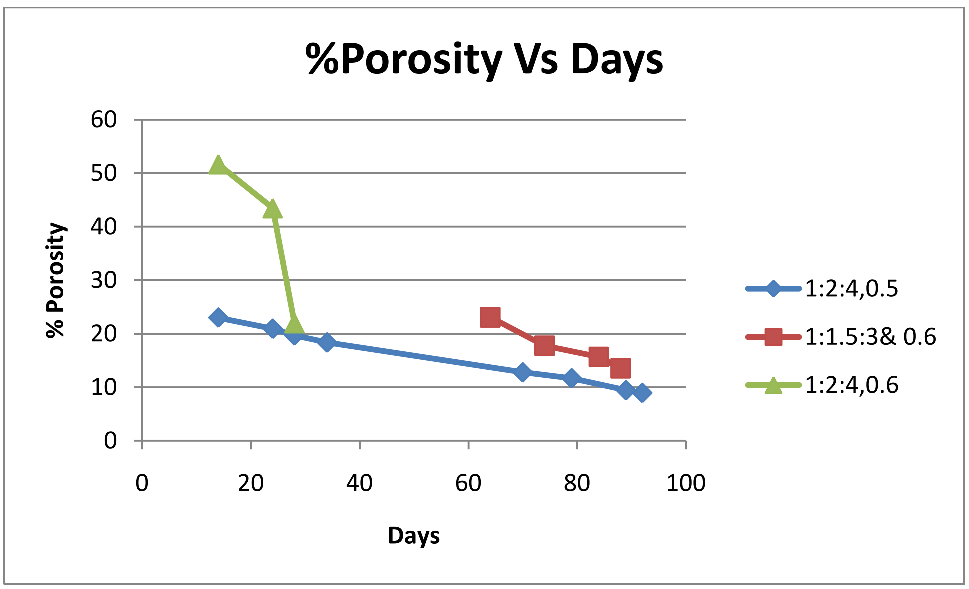


Fig 5.21: Combined graph of porosity vs days graph .

From this combined graph we can see that Porosity rate is depending on mix and water cement ratio of concrete. For mix ratio 1:2:4 & 0.5 water cement ratio the porosity rate is low whereas same mix ratio 0f 1:2:4 with different water cement ratio of 0.6 here porosity rate is very high. Again when we compare same Water cement ratio of 0.6 with different mix ratio graph also show different. For 1:2:4 the porosity rate is high then the porosity rate for 1:1.5:3 mix ratio.

So from above all we can say that porosity rate can be different for different water cement ratio and different mix ratio.

5.6 Result and Discussion for Strength Test of Concrete:

With these prepared concrete, research work was completed with strength test which was the major concern. Strength test for different mix ratio and different water-cement ratio of 1:2:4 mix with 0.5 W/c , 1:1.5:3 with 0.5w/c and 1:2:4 with 0.6 w/c were done . With this ratio concrete cylinder of 4inch diameter &8 inch height were prepared. At different days observed strength test and the results are shown here.

5.6.1 Strength test result for cylinder of 1:2:4 mix with 0.5 w/c ratio:

For 1:2:4 mix with 0.5 water cement ratio, the compressive strength values for different days are here.

Table 5.10a: Compressive strength value for cylinder of 1:2:4 mix with 0.5 water cement ratio.

Curing Days	**Compressive Stress (PSI)**
7	890.6586887
14	1029.402133
24	1228.713373
28	1291.194871
35	1046.223043
80	937.90667
90	901.9799
94	878.657
101	822.034

With the value of compressive strength at different days compressive strength graph is plotted here.

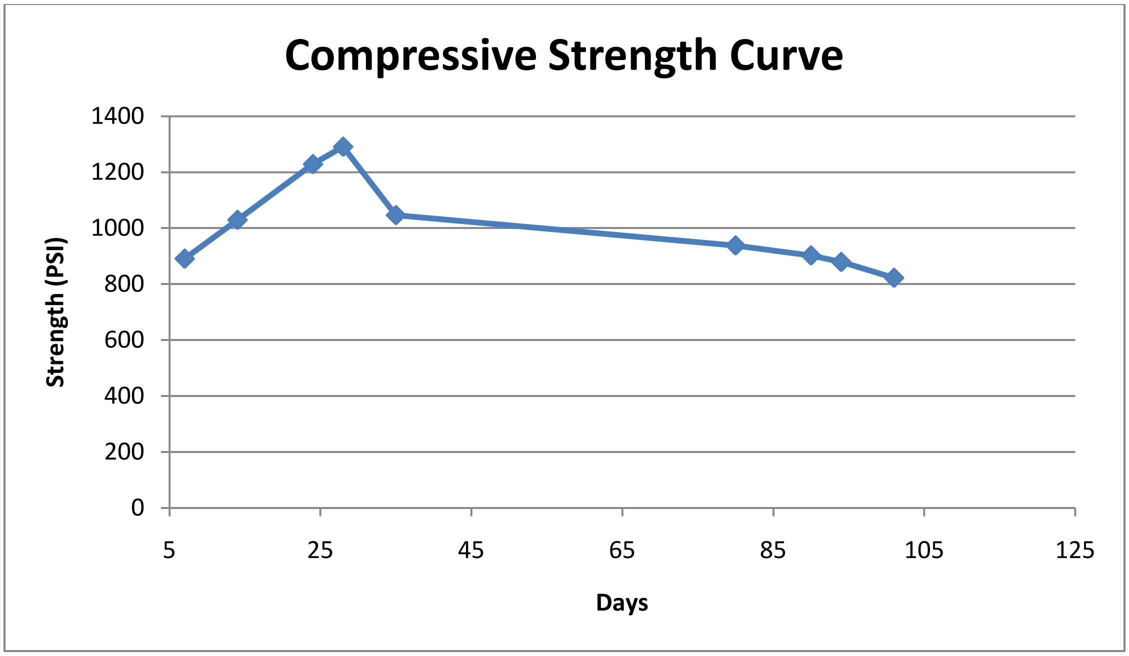
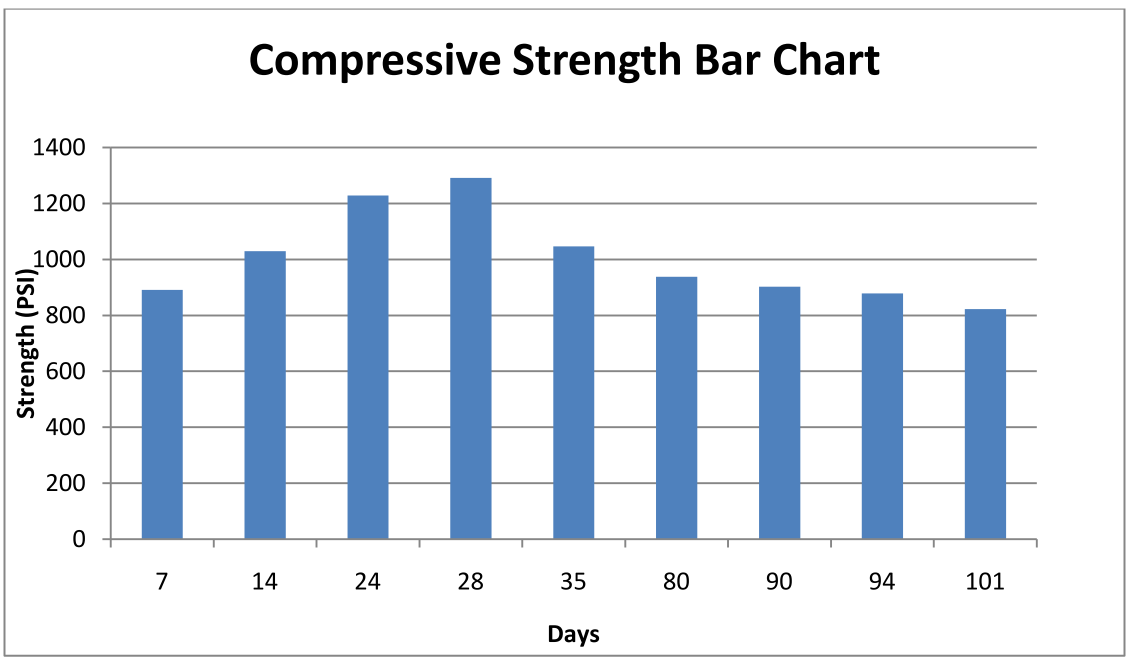


Fig 5.22: Compressive strength graph for cylinder (4X8) of 1:2;4 mix with 0.5 w/c ratio



5.23: Compressive strength Bar Chart for cylinder (4X8) of 1:2;4 mix with 0.5 w/c ratio.

Form this graph it seen that that maximum compressive strength at 28 days after the prepared concrete (1:2:4 mix with 0.5 w/c ratio) was observed. Before 28 days compressive strength value was gradually increased and then after 28 days strength value gradually decreased .

5.6.2 Strength test result for cylinder of 1:1.5:3 mix with 0.5 w/c ratio:

For 1:1.5:3 mix with 0.5 water cement ratio, the compressive strength values for different days are here.

Table 5.10b: Compressive strength value for cylinder of 1:1.5:3 mix with 0.5 water cement ratio.

Curing Days	Compressive Stress (PSI)
64	786.4960307
74	749.8316336
84	630.5203199
88	598.7564325

With the value of compressive strength at different days compressive strength graph is plotted.

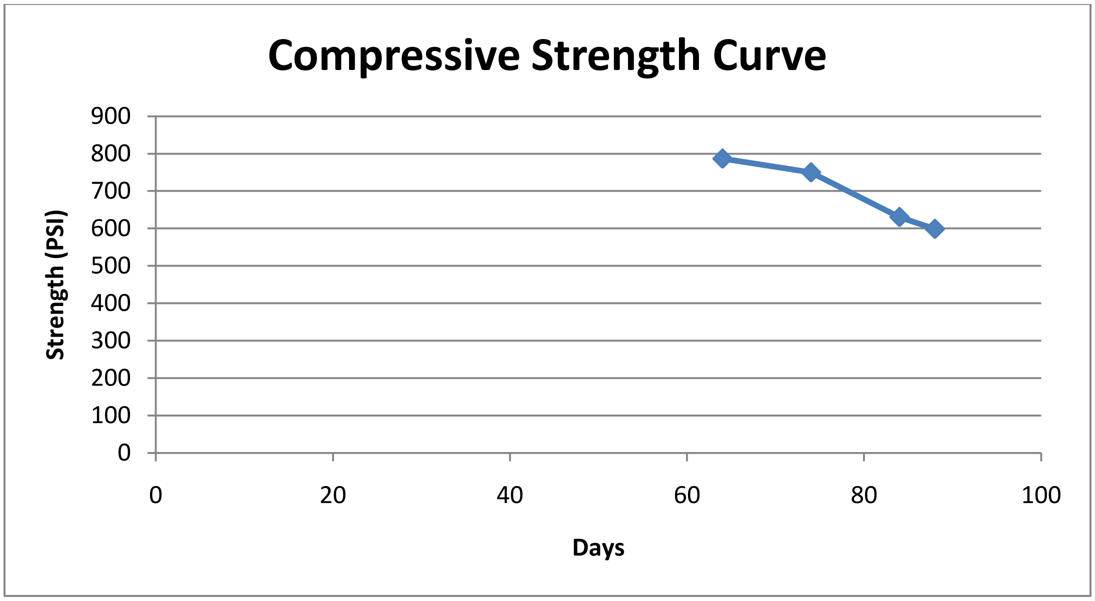
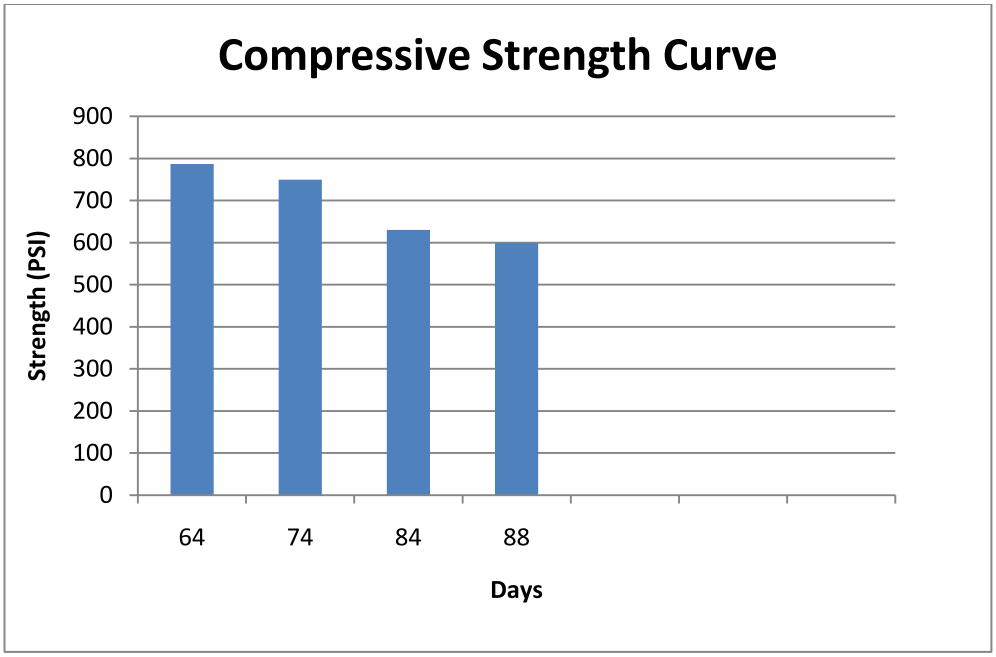


Fig 5.24: Compressive strength graph for cylinder (4X8) of 1:1.5:3 mix with 0.5 w/c ratio



5.25: Compressive strength Bar Chart for cylinder (4X8) of 1:1.5:3 mix with 0.5 w/c ratio.

From this graph and bar chart it is shown here that in the combination of 1:2:4 mix with 0.5 w/c ratio the concrete strength is decreasing after when these were tested after 64 days of its preparation.

5.6.3 Strength test result for cylinder of 1:2:4 mix with 0.6 w/c ratio:

Table 5.10c: Strength test result for cylinder of 1:2:4 mix with 0.6 w/c ratio:

	Compressive
Curing Days	**Stress (PSI)**
7	1110.633333
14	1315
21	1377
28	1433
35	1350

With the value of compressive strength at different days compressive strength graph is plotted here.

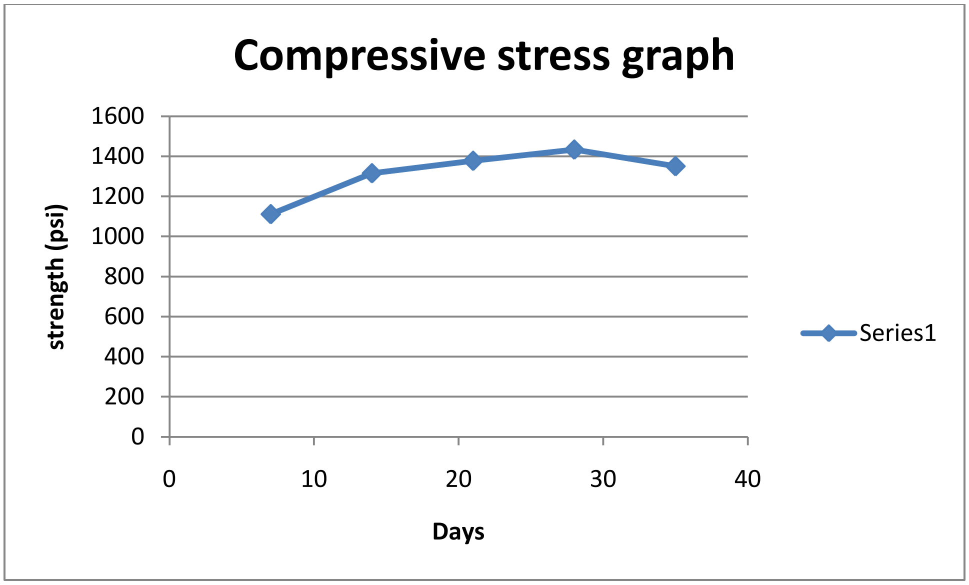
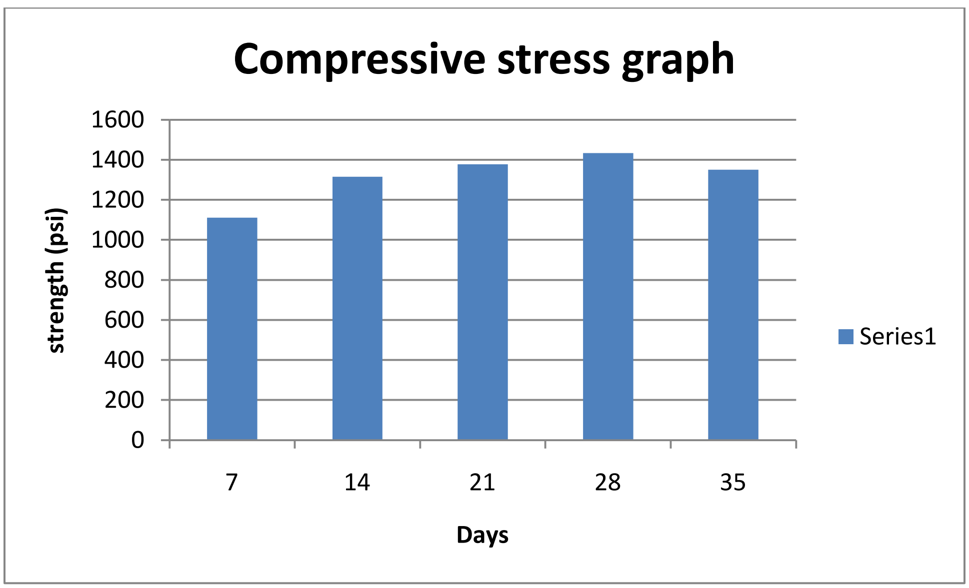


Fig 5.26: Compressive strength graph for cylinder (4X8) of 1:2:4 mix with 0.6 w/c ratio



5.2.7: Compressive strength Bar Chart for cylinder (4X8) of 1:2:4 mix with 0.6 w/c ratio.

From this graph and graph chart of compressive strength vs. days for cylinder (1:2:4 mix with 0.6 w/c ratio.) at 28 days the maximum compressive strength was observed . Before 28 days the strength value was less at first reading then gradually increased and after 28 days the strength value again starts decreasing.

From this entire graph finally the combined graph is plotted for all combination of mix and water cement ratio which were used.

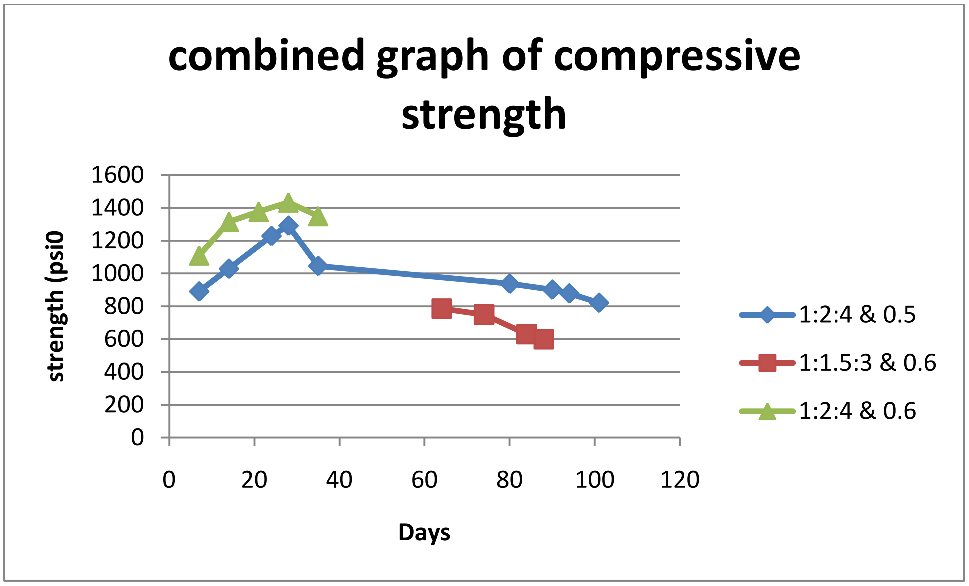


Fig 5.28: Combined graph of Compressive strength.

From the combined graph of compressive strength it can be said that for different mix and water cement ratio the strength values are different. For same water cement ratio 0.6 with different mix ratio of 1:1.5:3 and 1:2:4 the strength value is greater for 1:2:4 then 1:1.5:3. Again for same mix ratio strength value is greater for 0.6 w/c ratios then 0.5 w/c ratio.

According to practical knowledge , it was needed to find more strength value for 1:2:4mix with 0.5 Water – cement ratio then 1:2:4 mix with 0.6 water- cement ratio. But actually it was not happen. Moreover that after 28 days the strength value decreased so much which was not preferable. The cylinders were kept out from water before a day of breaking. Weather and humidity change may be most important factor moreover capping was not maintained during the time of breaking which has a great impact on strength value.

So from Compressive strength test it clearly seen that strength value differ with different mix ratio and different water cement ratio.

5.7 Failure type:

For strength test cylinder concrete were broke at different days by using compressive strength test machine. After breaking it was found that all of the cylinder were broke in brick and mortar both . So the type of failure is combined failure.

Fig 5.29: breaking of cylinder (4inchX8inch)

Fig 5.30: After breaking of Cylinder

In this figure cilynder’s breaking pictures are shown here. Which denotes the combined failure.

Chapter –6

Conclusions and Recommendations

6.1 Conclusion:

This work dealt with the experimental characterization of distinct concrete mixes with distinct composition of water/cement ratios, based on different days , and on evaporation test, porosity test , compressive tests. From the analysis of experimental results, the main following conclusion can be drawn:

1. From the research work, it found that with the increasing of time the percentage of evaporation is gradually increased.

2. Porosity rate depends on mix ratio and water cement ratio of concrete. Though porosity of concrete decreases with age. It was observed that with the increase of water cement ratio the porosity rate is high.

3. From the analysis of tests, it was revealed that increasing of water-cement ratio causes reduction effect on the compressive strength of concrete and the compressive strength of concrete increases with age.

4. The exact effects of moisture content in concrete need to be more examined and quantified. The research presented herein only analyzed the trend of the effects and did not investigate thoroughly.

5. In the compressive strength test the failure of cylindrical mold was combined failure.

6.2 Recommendations:

It was not only the intent of this study to describe the effect of water cement ratio with different mix ratio for different properties of concrete; however, it would be useful to come up with good relationship in the near future.

The results obtained in this study cannot be generalized due to the limited number of Specimens tested and the problems associated with some of the tests. A repetition of some of the tests and addition of more test data to the existing tests might be recommended before final conclusions can be obtained.

Clearly there are several factors that affect the impact tests. Sample curing, weather, humidity, temperature have a great effect on the result of any research, which need to be more informative for further a good result in future.

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Appendices for table:

Table 5.3 Data for finding Evaporation rate

		Date	**10.07.2015**	**13.07.2015**	**16.07.2015**	**19.07.2015**	**21.07.2015**
Disc	**Name**	**Day**	**0**	**2**	**5**	**8**	**10**
Disc 1	**AHR 15**	**Weight (gm)**	792	786	781	776.5	772.5
Disc 2	**AHR 16**	**Weight (gm)**	876	872.5	864.5	859	854
Disc 3	**AHR 24**	**Weight (gm)**	780	776	772.5	770	768
Disc 4	**AHR 25**	**Weight (gm)**	860	856.5	850.5	847	845.5
		Average	**827**	**822.75**	**817.125**	**813.125**	**810**
		% of evaporation	**0**	**0.5139057**	**1.194075**	**1.677751**	**2.055623**

		Date	**23.07.2015**	**25.07.2015**	**27.07.2015**	**29.07.2015**	**30.07.2015**
Disc	**Name**	**Day**	**12**	**14**	**16**	**18**	**19**
Disc 1	**AHR 15**	**Weight (gm)**	769	766	763.5	757	754
Disc 2	**AHR 16**	**Weight (gm)**	849.5	845	844.5	838.5	836
Disc 3	**AHR 24**	**Weight (gm)**	765.5	763	761.5	759.5	755
Disc 4	**AHR 25**	**Weight (gm)**	844	842.5	841	833.5	830
		Average	**807**	**804.125**	**802.625**	**797.125**	**793.75**
		% of evaporation	**2.41838**	**2.7660218**	**2.9474**	**3.612455**	**4.020556**

		Date	31.07.2015	02.08.2015	04.08.2015	08.08.2015	12.08.2015
Disc	Name	Day	20	22	24	27	31
Disc 1	AHR 15	Weight (gm)	752.5	750	748	745	742.5
Disc 2	AHR 16	Weight (gm)	833.5	829.5	827	825.5	822
Disc 3	AHR 24	Weight (gm)	753.5	751	748	745.5	743
Disc 4	AHR 25	Weight (gm)	828.5	826	824	821	818.5
		Average	792	789.125	786.75	784.25	781.5
		% of evaporation	4.232164	4.5798065	4.866989	5.169287	5.501814

		Date	15.08.2015	19.08.2015	01.11.2015	04.11.2015	8.11.2015
Disc	Name	Day	34	38	73	76	80
Disc 1	AHR 15	Weight (gm)	741	738.5	732	731	731.5
Disc 2	AHR 16	Weight (gm)	820.5	819	811	810	810.5
Disc 3	AHR 24	Weight (gm)	741.5	740.5	734	733	734
Disc 4	AHR 25	Weight (gm)	817	815	807	806.5	806
		Average	780	778.25	771	770.125	770.5
		% of evaporation	5.683192	5.8948005	6.771463	6.877267	6.831923

		Date	10.11.2015	17.11.2015	23.11.2015
Disc	Name	Day	82	89	95
Disc 1	AHR 15	Weight (gm)	730.5	730	730.5
Disc 2	AHR 16	Weight (gm)	809.5	809	809.5
Disc 3	AHR 24	Weight (gm)	732.5	732.5	732.5
Disc 4	AHR 25	Weight (gm)	805	804.5	805

		Average	**769.375**	**769**	**769.375**
		% of evaporation	**6.967956**	**7.0133011**	**6.967956**

Table 5.4 : Data for Spline curve

				Slope	**2ndDerv.**
Days	**Spline(cubic)**		**Days**	**dy/dx**	**ddy/dx**
0	0		0	0.265901215	-0.008948373
2	0.513905683		1	0.256952842	-0.008948373
4	0.992017874		2	0.248004468	-0.008948373
6	1.362636534		3	0.243537348	-0.017910878
8	1.677750907		4	0.212182713	-0.044798392
10	2.055622733		5	0.182060002	-0.020374727
12	2.418379686		6	0.171433258	-0.000878761
14	2.766021765		7	0.150165828	0.000906646
16	2.947400242		8	0.17324655	0.045254798
18	3.612454655		9	0.193802933	0.005955322
20	4.23216445		10	0.185157195	-0.0232468
22	4.57980653		11	0.181378476	-0.003778718
24	4.866989117		12	0.177599758	-0.003778718
26	5.078021388		13	0.183267836	-0.02267231
28	5.258703327		14	0.132255139	-0.079353083
30	5.427293658		15	0.050068017	0.039676542
32	5.567634878		16	0.211608222	0.283403869
34	5.683192261		17	0.365590992	0.054791415
36	5.793018639		18	0.321191052	-0.143591294
38	5.894800484		19	0.324025091	-0.039676542
40	5.982274945		20	0.241837969	-0.124697703
42	6.055668217		21	0.160595526	-0.041565901
44	6.116828755		22	0.158706167	0.037787183
46	6.167605011		23	0.14457197	-0.017076226
48	6.20984544		24	0.124553715	-0.022960285
50	6.245398497		25	0.102653637	-0.013312581
52	6.276112635		26	0.097928552	0.003862413
54	6.303836309		27	0.089199799	-0.005305242
56	6.330417972		28	0.087318067	0.00154178
58	6.357706079		29	0.08530501	-0.00504259
60	6.387549085		30	0.077232888	-0.011101654
62	6.421795442		31	0.06995403	-0.006629118
64	6.462293605		32	0.063974651	-0.00532964

66	6.510892029		33	0.05658789	-0.003814355
68	6.569439168		34	0.05634594	0.003330456
70	6.639783475		35	0.055057785	-0.001721942
72	6.723773404		36	0.052902056	-0.002589516
74	6.820930866		37	0.05128235	-0.00279399
76	6.877267231		38	0.047314076	-0.005142558
78	6.834879477		39	0.043723094	-0.003548571
80	6.831922612		40	0.040216933	-0.003463749
82	6.967956469		41	0.036581108	-0.003289241
84	7.052961234		42	0.033638452	-0.00259607
86	7.061468212		43	0.03046474	-0.002827127
88	7.031194322		44	0.027984198	-0.002133957
90	6.998947139		45	0.0252726	-0.002365013
92	6.980619369		46	0.023254171	-0.001671843
94	6.971188852		47	0.021004686	-0.0019029
			48	0.019448372	-0.00120973
			49	0.017661	-0.001440786
			50	0.016566799	-0.000747616
			51	0.015241541	-0.000978673
			52	0.014609453	-0.000285503
			53	0.013746308	-0.000516559
			54	0.013576334	0.000176611
			55	0.013175303	-5.44458E-05
			56	0.013467443	0.000638724
			57	0.013528525	0.000407668
			58	0.014282778	0.001100838
			59	0.014805974	0.000869781
			60	0.016022341	0.001562952
			61	0.01700765	0.001331895
			62	0.01868613	0.002025065
			63	0.020133553	0.001794008
			64	0.022274147	0.002487179
			65	0.024183684	0.002256122
			66	0.026786391	0.002949292
			67	0.029158041	0.002718235
			68	0.032222861	0.003411406
			69	0.035056625	0.003180349
			70	0.038583559	0.003873519
			71	0.042024846	0.003351644
			72	0.045286848	0.00317236

			73	0.05195302	-0.003456696
			74	0.038373457	-0.023702431
			75	0.031787121	-0.017443152
			76	0.003487153	-0.039156785
			77	-0.029828565	-0.007411654
			78	-0.011336155	0.044396474
			79	-0.007700922	0.022302701
			80	0.033269248	0.059637639
			81	0.079893167	0.010995204
			82	0.055259655	-0.060262227
			83	0.044094175	-0.01594086
			84	0.023377936	-0.02549162
			85	0.001896182	-0.014409832
			86	-0.005441728	-0.000265988
			87	-0.017437418	-0.00509427
			88	-0.015630268	0.00870857
			89	-0.017116886	0.001493265
			90	-0.012643738	0.00745303
			91	-0.00885	0.002852083
			92	-0.006939572	0.000968773
			93	-0.004715258	0.002224313
			94	-0.002490945	0.002224313

Appendices for Figures :

Fig 1: preparation of brick chips

Fig 2. Preparation of sand

Fig 3. Preparation of mold

Fig 4. Prepared concrete, slump test.

Fig 5. filled cylindrical mold with prepared concrete .

Fig 6. Concrete separated from mold & submerged into water

Fig 7. Compressive strength test

Fig 8. Failure surface of concrete.