Nile Higher Institute for Engineering & Technology

Department of Civil Engineering

Properties and Strenth of Materials Project

"مشروع خواص ومقاومة المواد"

Supervisors

Eng. Mahmoud Shoaib
Assistant Lecturer at
Civil Engineering Department

Eng. Yasmeen Wed
Teaching Assistant at
Civil Engineering Department

Dr. Amr El-Boghdady
Assist. Prof. at Civil Engineering Department

Head of Civil Engineering Department
Assoc. Prof. Dr. Mohamed Tarek Shamaa

Dean
Prof. Dr. Ahmed Refaat Azmy

2023-2024

Nile Higher Institute for Engineering & Technology

Department of Civil Engineering

Properties and Strenth of Materials Project

"مشروع خواص ومقاومة المواد"

Name	Code
Mohamed Ahmed Abdelfattah	190073
Ahmed Sameh Ahmed	190055
Ahmed Ramdan Abdelal	190054
Elsayed Elsayed ELkhodary	190009
Omar Maged Elnagar	190027

Name	Code
Omar Ramadan ELnagar	160384
Ahmed Mohamed Elattar	190121
Ahmed Maher Ashor	190101
Ahmed Essam Mohamed	190171

Supervisors

Eng. Mahmoud Shoaib
Assistant Lecturer at
Civil Engineering Department

Eng. Yasmeen Wed
Teaching Assistant at
Civil Engineering Department

Dr. Amr El-Boghdady
Assist. Prof. at Civil Engineering Department

Head of Civil Engineering Department
Assoc. Prof. Dr. Mohamed Tarek Shamaa

Dean
Prof. Dr. Ahmed Refaat Azmy

Table of Contents

CHAPETER 5 INTRODUCTION TO ADMICTURES ……39

CHAPTER 6 SPECIAL TYPES OF CONCRETE…………………………………………….……49

CHAPTER 7 ULTRA-HIGH PERFORMANCE CONCRETE ……………………………………………………………...……72

Acknowledgments

First and foremost, praise and thanks for God. We would like to express our deepest gratitude and appreciation to our supervisors **Assist**. **Prof. Dr. Amr ELBaghdady , Eng. Mahmoud Shoaib and Eng. Yassmen Wed** for their kind supervision, support, guidance planning, generous support, helpful advice, encouragement, useful suggestions since the start of the work and their continues revision of this project.

The experimental part of this study was carried out at the laboratory of materials, Faculty of Engineering at Nile institute for engineering and technology. Special thanks to all technicians of the laboratory for their assistance during the conduct of this research work.

ABSTRACT

Concrete is a hardened building material created by combining a chemically inert mineral aggregate (usually sand, gravel, or crushed stone), a binder (natural or synthetic cement), chemical additives, and water. Although people commonly use the word "cement‖ as a synonym for concrete, the terms in fact denote different substances: cement, which encompasses a wide variety of fine-ground powders that harden when mixed with water, represents only one of several components in modern concrete.

As concrete dries, it acquires a stone-like consistency that renders it ideal for constructing roads, bridges, water supply and sewage systems, factories, airports, railroads, waterways, mass transit systems, and other structures that comprise a substantial portion of the U.S. wealth. According to the National Institute of Standards and Technology (NIST), building such facilities is in itself one of the nation's largest industries and represents about 10 percent of the gross national product. Over $4 billion worth of hydraulic cement, a variety that hardens under water is produced annually in the United States for use in $20 billion worth of concrete construction. The value of all cement-based structures in the United States is in the trillions of dollars—roughly commensurate with the anticipated cost of repairing those structures over the next twenty years. Contractors often come across problems, which call for special solutions involving concrete. A special concrete made with special ingredients or by a special process may be ideally suited to the need. Special types of concrete are those with out-of-the ordinary properties or those produced by unusual techniques. Concrete is by definition a composite material consisting essentially of a binding medium and aggregate particles, and it can take many forms.

Chapter 1 Initial Report

1.1 Project Definition

The field of strength of materials, also called mechanics of materials, typically refers to various methods of calculating the stresses and strains in structural members, such as beams, columns, and shafts, Designers and contractors often come across problems, which call for special solutions involving concrete. A special concrete a concrete made with special ingredients or by a special process may be ideally suited to the need.

The research work is divided into the following activities in order to resolve the given issues:

- Literature review: The aim is get knowledge about the current state of the art in field of concrete technology in general.
- General information: The aim is to understand how special types of concrete are made and the contribution of such materials.
- Experimental investigations: The aim is to perform experiments in laboratory controlled environments in order to obtain better understanding of properties of SCC and understand failure mechanisens, in order to develop mote efficient concrete material.

1.2 The Problem

Explore the properties of Self Compacted Concrete (SCC) as special type of concrete material.

1.3 Study Objectives

In this research, the concentration was on:

- Define the SCC and its components and material properties.
- find the results of fresh and hardened concrete tests.
- reach a final conclusion of the best properties and component of SCC.

1.4 Existing Solutions

Compare the results of the tests with other researches or previous work to reach a better judgement of such material

To understand the effect of using such materials at different fields, the following parameters have been investigated:

- The type and properties of SCC.
- The configuration of the tests and their results.
- The amount of components materials..

1.5 Design Constraints

The primary constrains faced during our research work are classified into these categories:

1.5.1 Economic

There is a need to search for financial support sources for students or full or partial grant contribute to solving some of the problems of the students.

1.5.2 Environmental

No direct environmental constraints, but the process of cement manufacture is affecting the environment.

1.5.3 Sustainability

No sustainability constrains

1.5.4 Ethical

No ethical constrains

1.5.5 Health and Safety

No Health and Safety constrains

1.5.6 Social and Political

The establishment of a number of seminars and meetings involving students and professors, which pose acadernic and administrative problems and everyone, is working to provide appropriate solutions, which increase the bond between students and their teachers.

Chapter 2 Introduction to Concrete Technology

2.1 Introduction:

The words cement and concrete are both of Latin origin, reflecting the likelihood that the ancient Romans were the first to use the substances. Many examples of Roman concrete construction remain in the countries that encircle the Mediterranean, where Roman builders had access to numerous natural cement deposits. Natural cement consists mainly of lime, derived from limestone and often combined with volcanic ash. It formed the basis of most civil engineering until the eighteenth century, when the first synthetic cements were developed.

The earliest manmade cement, called hydraulic lime, was developed in 1756, when an English engineer named John Smeaton needed a strong material to rebuild the Eddy stone lighthouse off the coast of Devon. Although the Romans had used hydraulic cement, the formula was lost from the collapse of their empire in the fifth century A.D. until Smeaton reinvented it. During the early nineteenth century, several other Englishmen contributed to the refinement of synthetic cement, most notably Joseph Aspdin and Isaac Charles Johnson. In 1824, Aspdin took out a patent on a synthetic blend of limestone and clay, which he called Portland cement because it resembled limestone quarried on the English Isle of Portland. However, Aspdin's product was not as strong as that produced in 1850 by Johnson, whose formula served as the basis of the Portland cement that is still widely used today. Concrete made with Portland cement is considered superior to that made with natural cement because it is stronger, more durable, and of quality that is more consistent. According to the American Society of Testing of Materials (ASTM), Portland cement is made by mixing calcareous (consisting mostly of calcium carbonate) material such as limestone with silica, alumina, and iron oxidecontaining materials. These substances are then burned until they fuse together, and the resulting admixture, or clinker, is ground to form Portland cement.

Although Portland cement quickly displaced natural cement in Europe, concrete technology in the United States lagged considerably behind. In America, natural cement rock was first discovered during the early 1800s, when it was used to build the Erie Canal. The construction of such inland waterways led to the establishment of a number of American companies producing natural cement. However, because of Portland cement's greater strength, many construction engineers preferred to order it from Europe, despite the additional time and expense involved. Thomas Edison was very interested in Portland cement and even cast phonograph cabinets of the material. When United States industry figured out how to make Portland cement during the early 1870s, the production of natural cernent in America began to decline.

After the refinement of Portland cement, the next major innovation in concrete technology occurred during the late nineteenth century, when reinforced concrete was invented. While concrete easily resists compression, it does not tolerate tension well, and this weakness meant that it could not be used to build structures like bridges or buildings with arches that would be subject to hending action. French and English engineers first rectified this deficiency during the 1850s by embedding steel bars in those portions of a concrete structure subject to tensile stress. Although the concrete itself is not strengthened, structures built of reinforced concrete can better withstand bending, the technique was used internationally by the early twentieth century.

Another form of strengthened concrete, prestressed concrete, was issued a U.S. patent in 1888. However, it was not widely used until World War II, when several large docks and bridges that utilized it were constructed. Rather than reinforcing a highly stressed portion of a concrete structure with steel, engineers could now compress a section of concrete before they subjected it to stress, thereby increasing its ability to withstand tension.

Figure 1.1 Concrete Mix

Today, different types of concrete are categorized according to their method of installation. Ready- or pre-mixed concrete is batched and mixed at a central plant before it is delivered to a site. Because this type of concrete is sometimes transported in an agitator truck, it is also known as transit-mixed concrete. Shrink-mixed concrete is partially mixed at the central plant, and its mixing is then completed in route to the site. Concrete is one of the oldest and most common construction materials in the world, mainly due to its low cost, availability, its long durability, and ability to sustain extreme weather environments. The worldwide production of concrete is 10 times that of steel by tonnage. On the other hand, other construction materials such as steel and polymers are more expensive and less common than concrete materials. Concrete is a brittle material that has a high compressive strength, but a low tensile strength. Thus, reinforcement of concrete is required to allow it to handle tensile stresses. Such reinforcement is usually done using steel.

2.2 Concrete Components:

Structural concrete normally contains one part cement to two parts fine mineral aggregate to four parts coarse mineral aggregate, though these proportions are often varied to achieve the strength and flexibility required in a particular setting. In addition, concrete contains a wide range of chemicals that imbue it with the characteristics desired for specific applications. Portland cement, the kind most often used in concrete, is made from a combination of a calcareous material (usually limestone) and of silica and alumina found as clay or shale. In lesser amounts, it can also contain iron oxide and magnesia. Aggregates, which comprise 75 percent of concrete by volume, improve the formation and flow of cement paste and enhance the structural performance of concrete. Fine grade comprises particles up to. Twenty percent of an inch (five millimeters) in size, while coarse grade includes particles from 20% to 79% of an inch (20 millimeters). For massive construction, aggregate particle size can exceed 1.50 inches (38 millimeters).

Aggregates can also be classified according to the type of rock they consist of: basalt, flint, and granite, among others. Another type of aggregate is pozzolana, a siliceous and aluminous material often derived from volcanic ash. Reacting chemically with limestone and moisture, it forms the calcium silicate hydrates that are the basis of cement. Pozzolana is commonly added to Portland cement paste to enhance its densification. One type of volcanic mineral, an aluminum silicate, has been combined with siliceous minerals to form a composite that reduces weight and improves the bonding between concrete and steel surfaces. Its applications have included precast concrete shapes and asphalt/concrete pavement for highways. Fly ash, a coal-burning power plant byproduct that contains an aluminosilicate and small amounts of lime, is also being tested as a possible pozzolanic material for cement. Combining fly ash with lime (CaO) in a hydrothermal process (one that uses hot water under pressure) also produces cement.

Fig1: Concrete components

Wide ranges of chemicals are added to cement to act as plasticizers, superplasticizers, accelerators, dispersants, and water-reducing agents. Called admixtures, these additives can be used to increase the workability of a cement mixture still in the non-set state, the strength of cement after application, and the material's water tightness. Further, they can decrease the amount of water necessary to obtain workability and the amount of cement needed to create strong concrete. Accelerators, which reduce setting time, include calcium chloride or aluminum sulfate and other acidic materials. Plasticizing or super plasticizing agents increase the fluidity of the fresh cement mix with the same water/cement ratio, thereby improving the workability of the mix as well as its ease of placement. Typical plasticizers include poly-carboxylic acid materials; superplasticizers are sulphenated melamine-formaldehyde or sulphanated naphthalene formaldehyde condensates. Set retarders, another type of admixture, are used to delay the setting of concrete. These include soluble zinc salts, soluble borates, and carbohydrate-based materials. Gas forming admixtures, powdered. zinc or aluminum in combination with calcium hydroxide or hydrogen peroxide, are used to form aerated concrete by generating hydrogen or oxygen bubbles that become entrapped in the cement mix.

Cement is considered a brittle material; in other words, it fractures easily. Thus, many additives have been developed to increase the tensile strength of concrete. One way is to combine polymeric materials such as polyvinyl alcohol, polyacrylamide, or hydroxyl-propyl methylcellulose with the cement, producing

What is sometimes known as macro-defect-free cement. Another method entails adding fibers made of stainless steel, Marble, or carbon. These fibers can be short, in a strand, sheet, non-woven fabric, or woven fabric form. Typically, such fiber represents only about one percent of the volume of fiber-reinforced concrete. So in summary, Concrete is a heterogeneous mixture that consists of the following components:

- **Aggregate**: forms about 75% of the concrete volume. Aggregates can be sand or crushed rock or recycled concrete rubbles, or other materials.
- **Cement**: comprises about 7-14% of concrete. The purpose of cement is to bind the concrete. The American Society for Testing and Materials (ASTM) classifies Portland cement into five types.

✓ **Type I cement**: this is the standard general-purpose Portland cement and the most common type of cement. It is used when sulphate exposure is minimal.

✓ **Type Il** cements: used for concrete that may be exposed to a low sulphate content such as soils that contain a low concentration of sulfate.

- ✓ **Type Ill** cements: used for applications that require strength at an early age.
- ✓ **Type IV** cements: used for applications that require a fast setting time, such as in dams and places that require large amounts of concrete.
- ✓ **Type V** cements: these are the high sulphate-resistant Portland cements, there are used in applications where concrete is exposed to a high concentration of sulphate, such as sewer water.

- **Water:** The higher the content of water in concrete, the higher the concrete workability, as water makes the concrete thinner. When water is added to concrete, it results in concrete hydration reaction, Water should have a pH value in the range 6-8. Water should not contain salt in it if used for reinforced concrete, because it can cause the reinforcement steel material to corrode.
- **Additives:** many additives are used to increase concrete workability. They are added in ratios that do not exceed 2% of cement content, usually 1-2%. It must be noted that as the additive content increases,.

There are many types of additives:

- ➢ **Superplasticizer additives:** used to improve concrete workability and reduce the amount of water required for the concrete mixture.
- ➢ **Accelerator additives:** these additives are used to shorten the setting time and increase early concrete strength. Accelerator additives are used in cold weather environments that cause the concrete setting time to be delayed. Calcium chloride (CaCk) is the most commonly used material as an accelerator additive. A disadvantage of these additives is that they can cause corrosion of reinforcing steel (the chloride additives in particular), and reduce concrete strength.

- **Retarding additives:** these additives are added to concrete to delay the concrete setting time. They are used in hot weather environments, or when concrete has to be transported for a construction site that is far from the mixing site. Retarding additives also improve concrete workability. One of the most common retarders is sugar.

2.3 Hardened Concrete

One of the main fields of research in civil engineering is improving the durability of concrete structures. In 2013, it was estimated by the American Society of Civil Engineers (ASCE) that $3.6 trillion should be invested in the United States infrastructure to bring it to a "good condition". With an average grade of D+, the study highlights the importance of improving durability of concrete in infrastructure. The infrastructure conditions in some categories are displayed in the table below:

Table

Infrastructure category	Letter Grade Ref. [8]
Aviation	D
Bridges	C+
Dams	D+
Energy	D+
Schools	D
Roads	D

2.3.1 Properties of Hardened concrete

2.3.1.1 Compressive strength of Concrete

One of the most common methods to evaluate concrete performance is by measuring the compressive strength of hardened concrete (fc') at an age of 28 days. This test can be done by breaking a concrete specimen in a compression-testing machine. The specimens can be a standard cube specimen of 150 × 150 × 150 mm^3 or a standard cylindrical concrete specimen of 150 mm × 300 mm.

Strength of cylinder is roughly 80% of the strength of the cube.

There are other tests that can be used to find the compressive strength of in-place concrete such as the hammer test and the coring test, the coring test is more expensive to perform than the hammer test. In practice, fc' at an age of 7 days is about 75% of fc' at the age of 28 days. fcaccelerated' is approximately 0.2 - 0.25 of fc' at an age of 28 days.

The long time span needed for the 28 day test, makes it more advantageous to use other tests that predict the strength of hardened concrete. Methods for early estimation of concrete strength are presented by Tantawi and Gharaibeh.

2.3.1.2 Elasticity of Concrete

Three types of moduli are found from the stress strain diagram of concrete:

a. Initial tangent modulus El=tanθ1

b. Tangent to stress strain curve:

σ=0.5 σ' where (σ ' is maximum stress) E2= tanθ2

c. Secant modulus E3 = tanθ3 where the θ3 is the angle of secant to point on the stress strain curve at σ=0.5 σ'

In general, the modulus of elasticity of concrete in compression (Ec) is calculated from several formulas.

The empirical formula provided by the American Concrete Institute (ACI) code is given by:

EC = $33w^{1.5}\sqrt{fc'}$ where fc' is in Psi and w is concrete weight density in lb/ft3 The weight density w of concrete depends on the mixture ratio and the type of aggregate used. If w is taken to be 144 lb/ft3 then:

Ec=57,000 $\sqrt{fc'}$ where fc' is again in Psi

Ec=0.043w $\sqrt{fc'}$ where fc' is in MPa and w is taken to be 2400 kg/m3

Ec=4,700 $\sqrt{fc'}$ where fc' is in MPa

2.3.1.3 Tensile Strength of Concrete:

Tensile strength of concrete is significantly smaller than its compressive strength. It is usually negligible in the design of reinforced concrete, however, in some cases, it must be considered. Tensile strength of concrete is given as:

ft=6 to 7 times the value of $\sqrt{fc'}$ if fc' is given in psi ft=50-60% of $\sqrt{fc'}$ if fc' is given in Mpa

2.3.1.4 Modulus of Rupture:

Method to describe the tensile strength of concrete, is to use the modulus of rupture. Modulus of rupture depends on the size of concrete beams. If concrete is subjected to a tensile stress that is equal to its modulus of rupture, cracks develop in the concrete. Tensile strength of concrete may also be characterized using the splitting tensile strength, which is equal to about 50-80% of the modulus of rupture. Modulus of rupture is given by the formula: fr =7.5 $\sqrt{fc}$'

Where fr is the concrete modulus of rupture.

2.3.1.5 Creep and Shrinkage of Concrete

Creep in concrete is the change of the shape of the structure that results from a stress that is sustained for a long duration of time. Creep increases as the cement content increases in the concrete mixture. For this reason, one common method to reduce creep in concrete is to use Roller-compacted concrete which needs less water and cement than standard concrete mixtures. There are many methods deployed to reduce shrinkage in concrete, such as using a special type of concrete that is shrinkage compensating, or using reinforced concrete, or using a shrinkage-reducing chemical additive.

Creep and shrinkage must be taken into consideration in the design process of structures. As an example, creep and shrinking resulted in shortening in the Lake Shore Towers in Chicago by 2.5 mm per floor.

2.4 Concrete Reinforcement:

Although concrete can withstand high compressive stresses, its ability to withstand tensile stresses is small compared to that of compressive stresses. Thus, tensile reinforcement is required. Steel bars or steel wires are used to reinforce concrete to increase its ability to handle tensile stresses. Generally, in structures, concrete carries the compressive and shear loads, and the reinforcing steel carries the tensile load.

The reinforcing steel is found in several types according to the percentage of carbon as:

1. Mild steel: has a low carbon content, less than 0.15%. Its yield stress: Fyeild ≈ 240-280 MPa

2. medium steel: Fyeild ≈ 280 — 350 MPa

3. high strength steel: Fyeild ≈ 350 — 600 MPa

As the percentage of carbon increases in steel, the strength increases.

In Jordan, reinforcing steel is identified as 12020, which corresponds to 12 bar

20mm diameter.

European sizes are given as 12R20, where R stands for regular steel. If high strength steel is used then R is replaced by the letter T.

In the United States, The American Concrete Institute (ACI) sizes are given in increments of 1/8 inch, for example, #6 corresponds to a 12 bar with a 6/8 in diameter.

The reinforcement steel must be free of dust, rust, or oil, or any organic materials. High strength steel is generally not used in the stirrups due to its lack of the needed ductility.

2.5 The Manufacturing Process

The manufacture of concrete is fairly simple. First, the cement (usually Portland cement) is prepared. Next, the other ingredients—aggregates (such as sand or gravel), admixtures (chemical additives), any necessary fibers, and water—are mixed together with the cement to form concrete. The concrete is then shipped to the work site and placed, compacted, and cured.

2.5.1 Preparing Portland cement

The limestone, silica, and alumina that make up Portland cement are dry ground into a very fine powder, mixed together in predetermined proportions, preheated, and calcined (heated to a high temperature that will burn off impurities without fusing the ingredients). Next the material is burned in a large rotary kiln at 2,550 degrees Fahrenheit (1,400 degrees Celsius). At this temperature, the material partially fuses into a substance known as clinker. A modern kiln can produce as much as 6,200 tons of clinker a day.

The clinker is then cooled and ground to a fine powder in a tube or ball mill.

A ball mill is a rotating drum filled with steel balls of different sizes (depending on the desired fineness of the cement) that crush and grind the clinker. Gypsum is added during the grinding process. The final composition consists of several compounds: tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite.

Fig.2: Cement Manufacting

2.5.2 Mixing

3 The cement is then mixed with the other ingredients: aggregates (sand, gravel, or crushed stone), admixtures, fibers, and water. Aggregates are pre-blended or added at the ready-mix concrete plant under normal operating conditions. The mixing operation uses rotation or stirring to coat the surface of the aggregate with cement paste and to blend the other ingredients uniformly. A variety of batch or continuous mixers are used.

4 Fibers, if desired, can be added by a variety of methods including direct spraying, premixing, impregnating, or hand laying-up. Silica fume is often used as a dispersing or densifying agent.

2.5.3 Transport to work site

5 Once the concrete mixture is ready, it is transported to the work site. There are many methods of transporting concrete, including wheelbarrows, buckets, belt conveyors, special trucks, and pumping. Pumping transports large quantities of concrete over large distances through pipelines using a system consisting of a hopper, a pump, and the pipes. Pumps come in several types—the horizontal piston pump with semi-rotary valves and small portable pumps called squeeze pumps. A vacuum provides a continuous flow of concrete, with two rotating rollers squeezing a flexible pipe to move the concrete into the delivery pipe.

Fig.2: Ready mix concrete truck

2.5.4 Placing and compacting

6 Once at the site, the concrete must be placed and compacted. These two operations are performed almost simultaneously. Placing must be done so that segregation of the various ingredients is avoided and full compaction—with all air bubbles eliminated—can be achieved. Whether chutes or buggies are used, position is important in achieving these goals. The rates of placing and of compaction should be equal; the latter is usually accomplished using internal or external vibrators. An internal vibrator uses a poker housing a motor-driven shaft. When the poker is inserted into the concrete, controlled vibration occurs to compact the concrete. External vibrators are used for precast or thin in situ sections having a shape or thickness unsuitable for internal vibrators. These type of vibrators are rigidly clamped to the formwork, which rests on an elastic support.

Both the form and the concrete are vibrated. Vibrating tables are also used, where a table produces vertical vibration by using two shafts rotating in opposite directions.

Fig.3: Placing and compacting concrete

2.5.5 Curing

Once it is placed and compacted, the concrete must cured before it is finished to make sure that it doesn't dry too quickly. Concrete's strength is influenced by its moisture level during the hardening process: as the cement solidifies, the concrete shrinks. If site constraints prevent the concrete from contracting, tensile stresses will develop, weakening the concrete. To minimize this problem, concrete must be kept damp during the several days it requires to set and harden.

2.6 Quality Control

Concrete manufacturers expect their raw material suppliers to supply a consistent, uniform product. At the cement production factory, the proportions of the various raw materials that go into cement must be checked to achieve a consistent kiln feed, and samples of the mix are frequently examined using X-ray fluorescence analysis.

The strength of concrete is probably the most important property that must be tested to comply with specifications. To achieve the desired strength, workers must carefully control the manufacturing process, which they normally do by using statistical process control. The American Standard of Testing Materials and other organizations have developed a variety of methods for testing strength. Quality control charts are widely used by the suppliers of ready-mixed concrete and by the engineer on site to continually assess the strength of concrete. Other properties important for compliance include cement content, water/cement ratio, and workability, and standard test methods have been developed for these as well.

2.7 The Future

Though the United States led the world in improving cement technology from the 1930s to the 1960s, Europe and Japan have since moved ahead with new products, research, and development. In an effort to restore American leadership, The National Science Foundation has established a Center for Science and Technology of Advanced Cement-Based Materials at Northwestern University. The ACBM center will develop the science necessary to create new cement-based materials with improved properties. These will be used in new construction as well as in restoration and repair of highways, bridges, power plants, and waste-disposal systems.

The deterioration of the U.S. infrastructure has shifted the highway industry's emphasis from building new roads and bridges to maintaining and replacing existing structures. Because better techniques and materials are needed to reduce costs, the Strategic Highway Research Program(SHRP), a 5-year $150 million research program, was established in 1987. The targeted areas were asphalt, pavement performance, concrete structures, and highway operations. The Center for Building Technology at NIST is also conducting research to improve concrete performance. The projects include several that are developing new methods of field testing concrete. Other projects involve computer modeling of properties and models for predicting service life. In addition, several expert systems have been developed for designing concrete mixtures and for diagnosing causes of concrete deterioration.

Another cement industry trend is the concentration of manufacturing in a smaller number of larger-capacity production systems. This has been achieved either by replacing several older production lines with a single, high-capacity line or by upgrading and modernizing an existing line for a higher production yield. Automation will continue to play an important role in achieving these increased yields. The use of waste byproducts as raw materials will continue as well.

Chapter 3 Workability

3.1 Workability

Workability is defined as the amount of energy required to overcome internal friction and cause complete compaction.
Workability is completely depending upon the properties of various ingredients of concrete.

3.2 Factors Affecting Workability

-Cement content of concrete -Water
content of concrete
-Mixproportions of concrete
-Size of aggress
-Shape of aggregates
-Grading of aggregates
-Surface texture of aggregates
-Use of admixtures in concrete
-Use of supplementary cementations materials

3.3 General factors affecting concrete workability:

3.3.1 Cement Content of Concrete

Cement content affects the workability of concrete in good measure. More the quantity of cement, the more will be the paste available to coat the surface of aggregates and fill the voids between them. This will help to reduce the friction between aggregates and smooth movement of aggregates during mixing, transporting, placing and compacting of concrete.

Also, for a given water-cement ratio, the increase in the cement content will a increase the water content per unit volume of concrete increasing the workability of concrete. Thus, increase in cement content of concrete also increases the workability of concrete.

3.3.2 Type and Composition of Cement

There are also effect of type of cement or characteristics of cement on the workability of concrete. The cement with increase in fineness will require more water for same workability than the comparatively less fine cement. The water demand increased for cement with high A1203 or C2S contents.

3.3.3 Water/Cement Ratio or Water Content of Concrete

Water/cement ratio is one of the most important factors, which influence the concrete workability. Generally, a water cement ratio of 0.45 to 0.6 is used for good workable concrete without the use of any admixture. Higher the water/cement ratio, higher will be the water content per volume of concrete and concrete will be more workable.

Higher water/cement ratio is generally used for manual concrete mixing to make the mixing process easier. For machine mixing, the water/cement ratio can be reduced. These generalized methods of using water content per volume of concrete is used only for nominal mixes.

For designed mix concrete, the strength and durability of concrete is of utmost importance and hence water cement ratio is mentioned with the design. Generally, designed concrete uses low water/cernentratio so that desired strength and durability of concrete can be achieved.

3.3.4 Mix Proportions of Concrete

Mix proportion of concrete tells us the ratio of fine aggregates and coarse aggregates w.r.t. cement quantity. This can also be called as the aggregate cement ratio of concrete. The more cement is used, concrete becomes richer and aggregates will have proper lubrications for easy mobility or flow of aggregates. The low quantity of cement w.r.t. aggregates will make the less paste available for aggregates and mobility of aggregates is restrained.

3.3.5 Size of Aggregates

Surface area of aggregates depends on the size of aggregates. For a unit volume of aggregates with large size, the surface area is less compared to same volume of aggregates with small sizes.

When the surface area increases, the requirement of cement quantity also increases to cover up the entire surface of aggregates with paste. This will make more use of water to lubricate each aggregate.

Hence, lower sizes of aggregates with same water content are less workable than the large size aggregates.

3.3.6 Shape of Aggregates

The shape of aggregates affects the workability of concrete. It is easy to understand that rounded aggregates will be easy to mix than elongated, angular and flaky aggregates due to less frictional resistance.

Other than that, the round aggregates also have less surface area compared to elongate or irregular shaped aggregates. This will make less requirement of water for same workability of concrete. This is why river sands are commonly preferred for concrete as they are rounded in shape.

3.3.7 Grading of Aggregates

Grading of aggregates has the maximum effect on the workability of concrete. Well-graded aggregates have all sizes in required percentages. This helps in reducing the voids in a given volume of aggregates.

The less volume of voids makes the cement paste available for aggregate surfaces to provide better lubrication to the aggregates.

With less volume of voids, the aggregate particles slide past each other and less compacting effort is required for proper consolidation of aggregates. Thus, low water cement ratio is sufficient for properly graded aggregates.

3.3.8 Surface Texture of Aggregates

Surface texture such as rough surface and smooth surface of aggregates affects the workability of concrete in the same way as the shape of aggregates. With rough texture of aggregates, the surface area is more than the aggregates of same volume with smooth texture. Thus, concrete with smooth surfaces are more workable than with rough textured aggregates.

3.3.9 Use of Admixtures in Concrete

There are many types of admixtures used in concrete for enhancing its properties. There are some workability enhancer admixtures such as plasticizers and super plasticizers, which increases the workability of concrete even with low water/cement ratio.

They are also called as water reducing concrete admixtures. They reduce the quantity of water required for same value of slump.

Airs entraining concrete admixtures are used in concrete to increase its workability. This admixture reduces the friction between aggregates by the use of small air bubbles, which acts as the ball bearings between the aggregate particles.

3.4 Measurement of Workability:

3.4.1 Slump Test

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

The slump test is the simplest workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests since 1922. The slump is carried out as per procedures mentioned in ISO 456: 2000

Generally concrete slump value is used to find the workability, which indicates water-cementation, but there are various factors including properties of materials, mixing methods, dosage, admixtures etc. also affect the concrete slump value.

3.4.1.1 Factors that influence the concrete slump test:

-Material properties like chemistry, fineness, particle size distribution, moisture content and temperature of cementitious materials.

- Size, texture, combined grading, cleanliness and moisture content of the aggregates,

-Chemical admixtures dosage, type, combination, interaction, sequence of addition and its effectiveness,

-Air content of concrete,

-Concrete batching, mixing and transporting methods and equipment,

-Temperature of the concrete,

-Sampling of concrete, slump-testing technique and the condition of test equipment,

-The amount of free water in the concrete, and

-Time since mixing of concrete at the time of testing.

3.4.1.2 Equipment Required for Concrete Slump Test:

Mold for slump test, non-porous base plate, measuring scale, temping rod. The mound for the test is in the form of the frustum of a cone having height 30 cm, bottom diameter 20 cm and top diameter 10 cm. The tamping rod is of steel 16 mm diameter and 60cm long and rounded at one end.

3.4.1.3 Sampling of Materials for Slump Test:

A concrete mix (M15 or other) by weight with suitable water/ cement ratio is prepaid in the laboratory similar to that explained in 5.9 and required for casting six cubes after conducting Slump test.

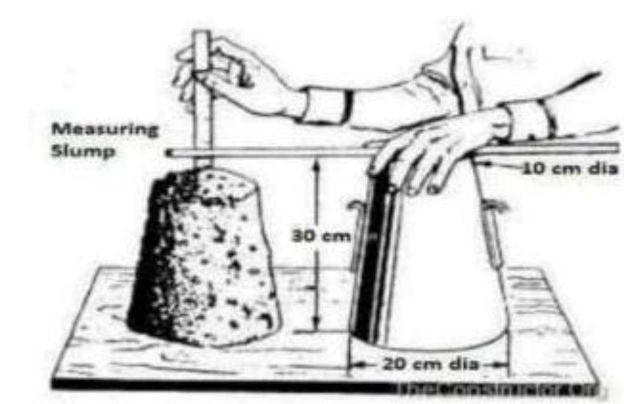


Fig.3: Slump test

3.4.2 Compaction Factor Test

Compaction factor test is the workability test for concrete conducted in laboratory. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. It was developed by Road Research Laboratory in United Kingdom and is used to determine the workability of concrete. The compaction factor test is used for concrete, which have low workability for which slump test is not suitable.

3.4.2.1 Apparatus

Compaction factor apparatus consists of trowels, hand scoop (15.2 cm long), a rod of steel or other suitable material (1.6 cm diameter, 61 cm long rounded at one end) and a balance.

3.4.2.2 Sampling

Concrete mix is prepared as per mix design in the laboratory.

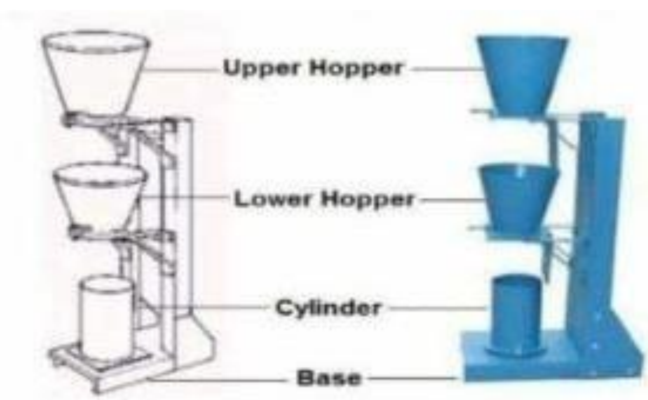


Fig.4 : Compaction Factor test on concrete

3.4.2.3 Procedure of Compaction Factor Test on Concrete

-Place the concrete sample gently in the upper hopper to its brim using the hand scoop and level it. -Cover the cylinder.

-Open the trapdoor at the bottom of the upper hopper so that concrete falls into the lower hopper. Push the concrete sticking on its sides gently with the road. -Open the trapdoor of the lower hopper and allow the concrete to fall into the cylinder below.

-Cut of the excess of concrete above the top level of cylinder using trowels and level it.

-Clean the outside of the cylinder.

-Weight the cylinder with concrete to the nearest 10 g. This weight is known as the weight of partially compacted concrete (W1).

-Empty the cylinder and then refill it with the same concrete mix in layers approximately 5 cm deep, each layer being heavily rammed to obtain full compaction.

-Level the top surface.

-Weigh the cylinder with fully compacted. This weight is known as the weight of fully compacted concrete (W2).

-Find the weight of empty cylinder (W).

3.4.3 VEE-BEE CONSISTOMETER TEST

Fig 5 :VEE-BEE CONSISTOMETER TEST

3.4.3.1 SUITABILITY

This method is suitable for dry concrete having very low workability

3.4.3.2 PROCEDURE

The test is performed as given described below

- Mix the dry ingredients of the concrete thoroughly until a uniform color is obtained and then add the required quantity of water.
- Pour the concrete into the slump cone with the help of the funnel fitted to the stand.
- Remove the slump mold and rotate the stand so that transparent disc touches the top of the concrete.
- Start the vibrator on which cylindrical container is placed.
- Due to vibrating action, the concrete starts remolding and occupying the cylindrical container. Continue vibrating the cylinder until concrete surface becomes horizontal.

- The time required for complete remolding in seconds is the required Measure of the workability and it is expressed as number of Vee-bee seconds.

3.5 Workability Measurements by Various Methods

Workability Description	Slump in mm	Vee-bee Time in seconds	Compacting Factor
Extremely dry	-	32 - 18	
Very stiff	-	18 - 10	0.70
Stiff	0 - 25	10 - 5	0.75
Stiff plastic	25 - 50	5 - 3	0.85
Plastic	75 - 100	3- 0	0.90
Flowing	150 - 175	-	0.95

Chapter 4 Concrete Mix Design

4.1 Introduction

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass. Concrete mix design may be defined as the art of selecting suitable ingredients of concrete and determining their relative proportions to producing concrete of certain minimum strength & durability as economically as possible

4.2 Objectives of Mix Design

- To achieve the designed/ desired workability in the plastic stage
- To achieve the desired minimum strength in the hardened stage
- To achieve the desired durability in the given environment conditions
- To produce concrete as economically as possible

4.3 Factors to be considered for mix design

- The grade designation giving the characteristic strength requirement of concrete
- The type of cement influences the rate of development of compressive strength of concrete.

- Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.
- The cement content is to be limited from shrinkage, cracking and creep.
- The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction

4.4 Basic Considerations

- Cost
- Specification
- Workability
- Strength and Durability

4.5 Cost

The cost of concrete is made up of :

- Material Cost
- Equipment Cost
- Labor Cost

The variation in the cost of materials arises from the fact that cement is several times costlier than aggregates. Therefore, it is natural in mix design to aim at as lean a mix as possible. Therefore, all possible steps should be taken to reduce the cement content of concrete mixtures without sacrificing the desirable properties of concrete such as strength and durability

4.6 Specifications

- Minimum Compressive Strength required

- Minimum water/cement ratio
- Maximum cement content to avoid shrinkage cracks
- Maximum aggregate/cement ratio
- Maximum density of concrete in case of gravity dams

4.7 Workability

The consistency of concrete should no more than that necessary for placing, compacting and finishing. For concrete mixes required high consistency at the time of placing, the use of water- reducing and set-retarding admixtures should be used rather than the addition of more water.

Wherever possible, the cohesiveness of concrete should be improved by increasing sand/ aggregate ratio than by increasing the proportion of the fine particles in the sand

4.8 Strength and durability

Strength and durability require lower w/c ratio. It is usually achieved not by increasing the cement content, but by lowering the water at given cement content. Water demand can by lowered by throughout control of the aggregate grading and by using water-reducing admixtures

Group	Grade designation	Characteristics compressive strength of 150 mm cube at 28 days
Ordinary concrete	M10 M15 M20	10 15 20
Standard concrete	M25 M30 M35 M40 M45 M50 M55	25 30 35 40 45 50 55
High Strength Concrete	M60 M65 M70 M75 M80	60 65 70 75 80

TABLE 5.1 :Grade of concrete

4.9 Types of Concrete Mixes

4.9.1 NOMINAL MIX

The wide use of concrete as construction materials has led to the use of mixes of fixed proportion, which ensures adequate strength. These mixes are called nominal mixes.

They offer simplicity and under normal circumstances, has margin of strength above that specified. Nominal mix concrete may be used for concrete of grades M5, M 7.5, M10, M15 and M20.

Mixes of fixed proportions, IS: 456-2000 permits nominal mixes for concretes of strength M20 orlower.

TABLE 5.1- Proporties of ingredients in nominal Mixes

Grade	Proportions C:FA:CA
M5	1:5:10
M7.5	1:4:8
M10	1:3:6
M15	1:2:4
M20	1:1.5:3

4.9.2 DESIGN MIX

Designed based on requirements of the concrete in fresh and hardened states

4.10 Factors Influencing Choice of Mix Design

According to IS 456:2000 and IS 1343:1980 the important influencing the design of concrete mix are :

- Grade of Concrete
- Type of Cement
- Maximum nominal Size of Aggregate
- Grading of Combined aggregate
- Maximum Water/ Cement Ratio
- Workability – Durability - Quality Control

4.10.1 Grade of Concrete

The grade of concrete gives characteristic compressive strength of concrete. It is one of the important factors influencing the mix design. The grade M 20 denotes characteristic compressive strength of 20 N/mm^2. Depending upon the

degree of control available at site, the concrete mix is tobe designed for a target mean compressive strength applying suitable standard deviation

TABLE 5.3 Grade of concrete

<table>
<tr><th>DESIGNATION</th><th>MIX PROPORTION</th><th>CHARACTERISTIC COMPRESSIVE STRENGTH</th><th>GROUP AS PER IS 456-200</th></tr>
<tr><td>M 5</td><td>1:5:10</td><td>5</td><td rowspan="2">LEAN MIX</td></tr>
<tr><td>M 7.5</td><td>1:4:8</td><td>7.5</td></tr>
<tr><td>M 10</td><td>1:3:6</td><td>10</td><td rowspan="3">ORDINARY CONCRETE</td></tr>
<tr><td>M 15</td><td>1:2:4</td><td>15</td></tr>
<tr><td>M 20</td><td>1:11.2:3</td><td>20</td></tr>
<tr><td>M 25</td><td>1:1:2</td><td>25</td><td rowspan="7">STANDARD CONCRETE</td></tr>
<tr><td>M 30</td><td rowspan="7">DESIGNED</td><td>30</td></tr>
<tr><td>M 35</td><td>35</td></tr>
<tr><td>M 40</td><td>40</td></tr>
<tr><td>M 45</td><td>45</td></tr>
<tr><td>M 50</td><td>50</td></tr>
<tr><td>M 55</td><td>55</td></tr>
<tr><td>M60</td><td>60</td><td>HIGH STRENGTH CONCRETE</td></tr>
</table>

4.10.2 Type of Cement

The rate of development of concrete strength is influenced by the type of cement. The higher the strength of cement used in concrete, lesser will be the cement content. The use of 43 grade and 53 grades of cement, gives saving in cement consumption as much as 15% and 25% respectively, as compared to 33 grades of cement. For concrete of grade M25, it is advisable to use 43 and 53 grades of cement

4.10.3 Maximum nominal Size of Aggregate

The maximum size of C.A is determined by sieve analysis. It is designated by the sieve size higher than larger size on which 15% or more of the aggregate is retained. The maximum nominal size of C.A. should not be more than one-fourth of minimum thickness of the member. For heavily reinforced concrete members as in the case of ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to sum less than the minimum clear distance between the main bars or 5 mm less the minimum cover to the reinforcement, whoever is smaller

4.10.4 Grading of Combined aggregate

The relative proportions of the fine and coarse aggregate in a concrete mix is one of the important factors affecting the strength of concrete. For dense concrete, it is essential that the fine and coarse aggregate be well graded. In the case when the aggregate available from natural sources do not confirm to the specified grading, the proportioning of two or more aggregate become essential

4.10.5 Maximum Water/ Cement Ratio

Abram's water/Cement ratio states that for any given condition of test, the strength of a workability concrete mix is dependent only on water/cement ratio. The lower the water/Cement ratio, the greater is the compressive strength

4.10.6 Workability

Workability of fresh concrete determines the case with which a concrete mixture can be mixed, transported, placed, compacted and finished without harmful segregation and bleeding

4.10.7 Durability

Durability require low water/Cement ratio. It is usually achieved not by increasing the cement content, but by lowering the water demand at a given cement content. Water demand can be lowered by through control of the aggregate grading and by using water-reducing admixtures

4.11 Procedure for Concrete Mix Design - IS456:2000

- Determine the mean target strength f, from the specified characteristic compressive strength at 28-day fa and the level of quality control
- $F_t = f_{ck} + 1.65$ S
- Where, S is the standard deviation obtained from the Table of approximate contents given after the design mix.
- Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The chosen water cement ratio is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.
- Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

- Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.

- Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.
- Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate, the values are given in table.
- Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
- From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of course and fine aggregates per unit volume of concrete Where, V= absolute volume of concrete = gross volume ($1m^3$) minus the volume of entrapped air S_c = specific gravity of cement

  W = Mass of water per cubic meter of concrete, kg C = mass of cement per cubic meter of concrete, kg

P = ratio of fine aggregate to total aggregate by absolute volume fa,

Ca = total masses of fine and coarse aggregates, per cubic meter of concrete, respectively, kg, and S_{fa} ,S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively

- Determine the concrete mix proportions for the first trial mix.

- Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.
- Prepare trial mixes with suitable adjustments until the final mix proportions are arrived at.

4.12 Difference between nominal and controlled concrete

- **NOMINAL MIX**

It is used for relatively unimportant and simpler concrete works. In this type of mix, all the ingredients are prescribed and their proportions are specified. Therefore, there is no scope for any deviation by the designer. Nominal mix concrete may beused for concrete of M-20 or lower.

- **DESIGN MIX**

It is a performance-based mix where choice of ingredients and proportioning are left to the designer to be decided. The user has to specify only the requirements of concrete in fresh as well as hardened state. The requirements in fresh concrete are workability and finishing characteristics, whereas in hardened concrete these are mainly the compressive strength and durability.

Chapter 5 Introduction to Admixtures

5.1 What is admixtures?

Admixtures are chemicals, added to concrete, mortar or grout at the time of mixing, to modify the properties, in the wet state immediately after mixing or after the mix have hardened. They can be a single chemical or a blend of several chemicals and may be supplied as powders but most are aqueous solutions because in this form, they areeasier to accurately dispense into, and then disperse through the concrete.

- Admixtures are ingredients other than basic ingredients cement, water and aggregates that are added to concrete batch immediately before or during mixing to modify one or more of the specific properties ofconcrete in fresh and hardened state

- Added in small quantity either in powder or liquid form

- Combination is used when more than one property to be altered.

5.2 Admixtures can be divided into three categories

- Active materials, which react chemically with a component within the Cementations materials

- Surface-active admixtures (surfactants). These are generally split into two components (one positively charged and the other negatively charged) and react with the air water solid material interface withinthe mortar thereby resulting in orientation and adsorption

- Passive or inert admixtures. These do not change their form but have a physical effect such as light absorption and reflection as in the case of pigments.

5.3 Function

- Increase slump and workability
- Retard or accelerate initial setting; Reduce or prevent shrinkage
- Modify the rate or capacity for bleeding; Reduce segregation
- Decrease weight of concreteImprove durability
- Decrease the rate of heat of hydration Reduce permeability
- To make porous concrete
- To make coloring concrete To protect chemical attack
- Increase bond of concrete to steel reinforcement
- Increase strength compressive, tensile, or flexural
- Increase bond between existing and new concrete

5.4 Types of admixture

- Accelerating admixtures
- Retarding admixtures
- Water-reducing admixtures
- Air-entrainment admixtures
- Super plasticizers admixtures
- Pozzolana admixtures
- Grouting admixtures
- Waterproofing admixtures
- Air-detraining admixtures
- Bonding admixtures
- Corrosion inhibiting admixtures
- Gas forming admixtures
- Coloring admixtures
- Alkali-aggregate expansion inhibiting admixtures
- Fungicidal, germicidal, insecticidal admixtures

5.4.1 Accelerators

Main objective of using accelerators in concrete is to increase speed ofsetting and hardening.

5.4.1.1 Advantages of using Accelerators

- To remove formwork quickly
- To reduce the curing time
- To use structure earlier
- To finish the surface fast
- To increase the speed of construction
- For quick repairing work

5.4.1.2 Main Accelerators

- Calcium Chloride ($CaCl2$)
- Soluble Carbonates Silicates

$CaCl2$ is a most using accelerator in construction. If 2% $CaCl_2$ by weight of cement is added in concrete, then it decreases the setting time from three to 1 hour and final setting time from six to 2 hour. We can get a two days strength in 1 day at 21 °C temperature. If the proportion of $CaCl2$ is more than 3% then flash set of concrete take place and drying shrinkage and creep will increase.

5.4.2 Retarders

To decrease the speed of Hydration and setting, Retarders are used in concrete. Retarders make concrete plastic and workable for long time.

5.4.2.1 Objectives of using Retarders

To decrease the setting time To increase strength by decreasing W/C Ratio. To do concreting in hot area. For grouting of oil wells.

5.4.2.2 Main Retarders

- Calcium Sulphate (Gypsum) Starches
- Sugars
- Cellulose Products Acids or Salts

  Gypsum is most commonly used retarder. Generally, 2 to 3% gypsum is added. We can also use gypsum as a plaster of parries. By using more of gypsum, expansion of concrete will occur and setting of concrete will be very slow.

5.4.3 Plasticizers

Workability is a most important property of concrete. Workability of concrete will change according to situation of construction. For deep beam, light partition wall, beam-column junction, concrete pumping, tremie concreting high workable concrete is used. Many time plasticizers also known as "Water Reducing Admixture". Plasticizer increases the workability without adding much water. It decreases the W/C Ratio, which increase the strength.

5.4.3.1 Main plasticizers used in Construction

- Calcium ligno-sulphonates
- Sodium ligno-sulphonates
- Ammonium ligno-sulphonates

Quantity of this type of plasticizers is up to 0.1 to 0.4%

By using this admixture, we can reduce the use of water up to 5 to 15% without changing workability. Main function of plasticizers is to improve the workability. The commonly used admixtures are Ligno-sulphonates and hydrocarbolic acid salts. Plasticizers are usually based on lignosulphonate, which is a natural polymer, derived from wood processing in the paper industry.

5.4.3.2 Uses of plasticizers

The plasticizers are used:

- To achieve a higher strength by decreasing the water cement ratio atthe same workability as an admixture free mix
- To achieve the same workability by decreasing the cement content toreduce the heat of hydration in mass concrete.
- To increase the workability to ease placing in accessible locations Water reduction more than 5% but less than 12%

5.4.3.3 The plasticizers have a retarding effect

Plasticizers get adsorbed on the surface of the cement particles and form a thin sheath.

This sheath inhibits the surface hydration reaction between water andcement as long as sufficient plasticizers molecules are available

5.4.3.4 Effects of plasticizers on the properties of concrete

The effect of water-reducing admixtures is dependent on: dosage of the admixture, cement type, aggregate type and grading, mix proportions and temperature.

Workability: Typically, an initial slump in the range 25-75 mm can be increased by 50-60 mm.

Compressive Strength: The compressive strength of concrete is increased by using water reducing admixtures to reduce water content while maintaining workability. The increase in strength is a direct resultof the lower water/cement ratio.

5.4.4 Super Plasticizers

In 1960, japan made a first Super plasticizer and then in 1970 Germany made it. By using Super Plasticizers, we can reduce the 30% of water. It is also called "High Range Water Reducers". It is strong dispersing agent.

5.4.4.1 Advantages and disadvantages of Super-plasticizers

- The advantages of Super-plasticizers are:

- Significant water reduction
- Reduced cement contents

- Reduce water requirement by 12-30%
- Increased workability of concrete
- Reduced effort required for placement
- More effective use of cement
- More rapid rate of early strength development
- Increased long-term strength
- Reduced permeability of concrete

5.4.4.2 The disadvantages of Super-plasticizers are

- ✓ Additional admixture cost (the concrete in-place cost may be reduced)
- ✓ Slump loss greater than conventional concrete
- ✓ Modification of air-entraining admixture dosage
- ✓ Less responsive with some cement
- ✓ Mild discoloration of light –coloured concrete

5.4.4.3 Polymers used as super plasticizers

- Sulphonates melamine formaldehyde condensates (SMF) Sulphonates naphalene formaldehyde condensates (SNF)
- Modified ligno - sulphonates (MLS)
- Acrylic polymer (AP)

- Poly carboxylate ester (PC)

5.4.5 Air Entraining Admixtures:

Air entraining agent is used to get an air entrained concrete. This air entraining agent produces small air bubbles in concrete and works asball bearing. So the propertics of the concrete like workability, segregation, blecding...etc. will change.

5.4.5.1 Air entraining agents:

- Aluminium Powder Hydrogen peroxide
- Alkali salts
- Vegetable Oils and Fats.Zinc Powder.
- Natural wood resing...etc.

5.4.5.2 Effect of Air entraining agents:

- Decrease in strength of concrete.
- Decrease in volume of concrete.
- Increasc in permeability of concrete.
- Workability increase.
- Decease in Alkali-aggregate reaction.
- Resistance against Sulphate attack.
- Decrease in heat of hydration.

5.4.6 Sikament Concrete

- Sikament R 2004 is a strong plasticizer that has a retarding effect on concrete setting to produce concrete that is workable and flowable in hot weather, and also as a basic agent to reduce the water content to improve increased early and final stresses ASTM C-494 Type G and BS 5075 part 3.
- Sikament R 2004 is used as a strong plasticizer to produce highly workable and flowable concrete in floors, slabs, walls, columns, foundations, beams, ceilings, and thin structural elements with dense reinforcement.

5.4.6.3 Advantages of Sikament

- Seacament R 2004 is characterized by the following features:
- Workability is greatly improved without increasing the amount of water or causing granular separation.
- Controlling the prolongation of the loss of landing (loss of operability).
- The water reduction rate reaches 20% with a noticeable increase in early and final stresses. Suitable for hot climates and free of chlorides

Fig 5 : Sikament R2004

Chapter 6 Special Types of Concrete

6.1 Introduction

- Special concretes are the concrete prepared for specific purpose which meets special performance an uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices, like light weight, high density, fire protection, radiation shielding etc. concrete is a versatile material possessing good compressive strength. However, it suffers from many drawbacks like low tensile strength, permeability to liquids, corrosion of reinforcement, susceptibility to chemical attack and low durability.
- Modification has been made from time to time to overcome the deficiencies of cement concrete. The recent developments in the material and construction technology have led to significant changes resulting in improved performance, wider and more economical use.
- Research work is going on in various concrete research laboratories to get improvement in the performance of concrete.
- Attempts are being made for improvements in the following areas.
- Improvement in mechanical properties like compressive strength, tensile strength, impact resistance.
- Improvement in durability in terms of increased chemical and freezing resistances.
- Improvements in impermeability, thermal insulation, abrasion, skid resistance etc.

- This chapter discusses some of the broad possibilities of special concretes. In addition, it discusses few special concretes which are still in research stage.

6.2 Difference between Ordinary and Special Concrete

Table -1 Difference between Ordinary and Special Concrete

Ordinary Concrete	Special Concrete
Ordinary concrete is used for normal works like building. bridges, road etc.	This type of concrete is used for special type of structures like nuclear reactor, buildings with acoustic treatment, air conditioned buildings etc.
Ingredients of ordinary concrete are cement, sand, aggregate and water.	In case of light weight aggregate concrete, light weight aggregates are used. In polymer concrete, polymer binder is used instead of water.
Construction is carried out by conventional method.	Concreting is done by special techniques
Properties of Concrete like density, strength etc. are of normal range.	Properties of concrete like density strength are of higher range. For example, density of light weight concrete is about 500 to 2000 kg/m and that of heavy weight concrete is about 3000 to 5000 kg.m
It is economical	It is costly

6.3 Different Types of Special Concrete

- Lightweight concrete
- High strength concrete
- Fiber reinforced concrete
- Ferrocement
- Ready mix concrete
- Shotcrete
- Polymer concrete
- Self-Compacted Concrete

6.3.1 Light Weight Concrete

- The density of conventional concrete is in order of 2200 to 2600 kg/m
- This heavy self-weight will make it uneconomical structural material. The dead weight of the structure made up of this concrete is large compared to the imposed load to be carried. A small reduction in dead weight for structural members like slab, beam and column in high-rise buildings, results in considerable saving in money and manpower.
- Attempts have been made in the past to reduce the self-weight of the concrete to increase the efficiency of concrete as a structural material. The light weight concrete with density in the range of 300 to 1900 kg/ m3have been successfully developed.

Fig-1 Light weight concrete

6.3.1.1 The Light Weight Concrete Offers the Following Advantage:

- Reduction of Dead Load
- Smaller section of structural members can be adopted.
- Lowerhaulage and handling costs
- Increase in the progress of work.
- Reduction of foundation costs, particularly in the case of weak soil and tall structures.
- Lightweight concrete has a lower thermal conductivity. In case of buildings where air conditioning is to be installed, the use of lightweight concrete will result in better thermal comforts and lower power consumption.
- The use of light weight concrete gives an outlet for industrial wastes such as fly ash, clinkers, slag etc. which otherwise create problem for disposal.
- It offers great fire resistance.
- Lightweight concrete gives overall economy.
- The lower modulus of elasticity and adequate ductility of lightweight concrete may be advantageous in the seismic design of structures.

6.3.1.2 The Light Weight Concrete Is Achieved by Three Different Ways:

- By replacing the normal mineral aggregate, by cellular porous orlightweight aggregate.
- By introducing air bubble in mortar this is known as ''aeratedconcrete'.
- By omitting sand fraction from the aggregate This is known as 'no fines concrete'.

6.3.1.3 Light Weight Aggregates

6.3.1.3.1 Natural lightweight aggregate:

- Pumice: These are rocks of volcanic origin. They are light colouredor nearly white and has a fairly even texture of interconnected voids. Its bulk density is
- 500 - 800 kg/ m3.
- Scoria: Scoria is light weight aggregate of volcanic origin, they are dark in colour It is slightly weaker than pumice.
- Rice Husk: Use of rice husk or groundnut husk has been reported as light weight aggregate.
- Saw dust: Saw dust is used as light weight aggregate in the flooring and in the manufacture of precast elements. But the presence of carbohydrates in the wood, adversely affect the setting and hardening of Portland cement.
- Diatomite: It is derived from the remains of microscopic aquatic plants called
- diatoms. It is also used as a pozzolanic material.

Fig-2 Natural lightweight aggregate: Pumice Scoria Rice Husk SawDust Diatomite

6.3.1.3.2 Artificial Light Weight Aggregates:

- Sintered flash (Pulverized fuel ash): The fly ash collected from modern thermal power plants burning pulverized fuel, is mixed with water and coal slurry in screw mixers and then fed on to rotating pans, known as pelletizers, to form spherical pellets. The pellets are then fed on to a sinster strand at a temperature of 1000 OC to 1200 OC. Due to sintering the fly ash particles coagulate to form hard brick like spherical particles. The produces material is screened and graded. In UK it is sold by the trade name ' Lytag'.

Foamed Slag: Foamed slag is a by-product produced in the manufacture of pig iron. It is a porous, honeycombed material which resembles pumice.

fig 3 Foamed Slag

- Bloated Clay: When special grade of clay and shales are heated to the point of incipient fusion, there will be expansion due to formation of gas within the mass. The expansion is known as bloating and the product so formed is used as light weight aggregate.

Fig.4:B;oated Clay

- Exfoliated vermiculite: The raw vermiculite material resembles mica in appearance and consists of thin flat flakes containing microscopic particles of water. On heating with certain percentage of water it expands by delamination in the same way as that of slate or shale. This type of expansion is known as exfoliation. The concrete made withvermiculate as aggregate will have very low density and very low strength.

  • Ciders, clinkers, breeze: The partly fused or sintered arising from the combustion of coal, is termed as cinder or clinker or breeze. Cinder aggregate undergo hig drying shrinkage and moisture movement. These are used for making building blocks for partition walls,for making screening over flat roofs and for plastering

Fig 5 : Exfoliated vermiculite

6.3.1.4 No Fines Concrete

- No fines concrete' is obtained by omitting fine aggregate fraction (below 12 mm) from the conventional concrete. It consists of cement, coarse aggregates and water only. Cement Content is correspondingly increased. Very often only single sized coarse aggregate, of size passing through 20 mm and retained on 10 mm is used. By using single sized aggregate, voids can be increased. The actual void content may vary between 30 to 40 percent depending upon the degree of consolidation of concrete.

- No fines concrete is generally made with the aggregate/ cement ratio 6:1 to 10:1. The water/ cement ratio for satisfactory consistency will vary between 0.38 to 0.50. The strength of no fines concrete is dependent on the water/ cement ratio, aggregate/ cement ratio and unit weight ofconcrete
- When conventional aggregate is used, no-fines concrete show a density of about 1600 to 2000 kg/ m3. but by using light weight aggregate, the density may reduce to about 350 kg/m3. Through the strength of no fines concrete is lower than ordinary concrete, the strength is sufficient for use in structural members and load bearing wall in normal buildings up to 3 stories high. Strengths of the order of 15 N/mm 2 have been attained with no fines concrete. The bond strength ofno-fines concrete is very low and therefore, reinforcement is not used in no-
  - fines concrete. However, if reinforcement is required to be used in no fines concrete, it is advisable to smear the reinforcement with cement paste to improve the bond strength and to protect it from rusting.

Fig-6 No Fines Concrete

6.3.1.4.1 Advantages of Lightweight Concrete with no fine aggregate:

a) Reduced dead load of the concrete allows longer span. This savesboth labor and time.

b) Screeds and walls where timber has to be attached by nailing.

C) Casting structural steel to protect it against fire and corrosion or as acovering for architectural purposes.

d) Gives heat insulation on roofs.

e) Used in insulation of water pipes.

f) Construction of partition walls and panel walls in frame structures.

g) Fixing bricks to receive nails from joinery, mainly in domestic ordomestic type construction.

h) General insulation of walls.

i) It is also being used for reinforced concrete.

6.3.2 HIGH STRENGTH CONCRETE

- High strength concrete can be defined by compressive strength of concrete at 28 days of water curing.
- When the grade of concrete exceeds M35, then the concrete may be called as high strength concrete.
- In general, producing of HSC is difficult with the use of conventional materials like cement, aggregate and water alone and it can be achievedby using of chemical and mineral admixtures or any one of the following methods.

(a) Seeding

(b)Re vibration

(c) High speed slurry mixing

(d) Use of admixtures

(e) Inhibition of cracks

(f) Sulphur Impregnation

(g) Use of cementitious aggregates

A. Seeding:

- In this method, small percentage of finely ground, fully hydrated Portland cement is added to fresh concrete mix B. Re vibration:

Mixing water to concrete mix creates continuous capillary channels, bleeding and accumulates of water at some selected places. All these reduce the strength of concrete.

Hence controlled re-vibration is given after suitable time and it isincreasing the strength of concrete. C. High speed slurry mixing:

- This process involves advanced preparation of cement water mixture which is then blended with aggregate to produce HSC D. Use of admixtures:

The high strength can be achieved by adding chemical admixtures such as super plasticizer and mineral admixtures such as fly ash, silica fume etc... E. Inhibition of cracks:

Inhibition or arresting of crack is needed to improve the strength of concrete. Normally, it is achieved by replacing 2-3% of fine aggregate (polytheneof 0.025 mm thick and 3 to 4 mm in diameter).

The polythene is act as a crack arrester. By this method the strength ismuch improved up to 105 MPa

F. Sulphur Impregnation:

Satisfactory high strength concrete has been produced byimpregnating low strength porous concrete by sulphur.

The process consists of the harden concrete (drying them at 120° C for24 hours), immersing in molten sulphur under vacuum for 2 hours.

By this method the strength is improved up to 58 MPa. G.

Use of cementitious aggregates:

Some kind of clinkers are used as aggregate in concrete and is called cementitious aggregate (E.g. ALAG).

It gives high strength to the concrete up to 125 MPa with very lowwater cement ratio of 0.32.

6.3.3 Fibre Reinforced Concrete (FRC)

- Fibre reinforced concrete (FRC) can be defined as a composite material consisting of concrete and discontinuous, discrete, uniform dispersed fine fibres. The continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres. • The inclusion of fibres in concrete and shotcrete generally improves material properties like ductility, flexural strength, toughness impact resistance and fatigue strength. There is little improvement in compressive strength. The type and amount of improvement in compressive strength. The type andamount of improvement is dependent upon the fibre type, size, strength and configuration and amount of fibre

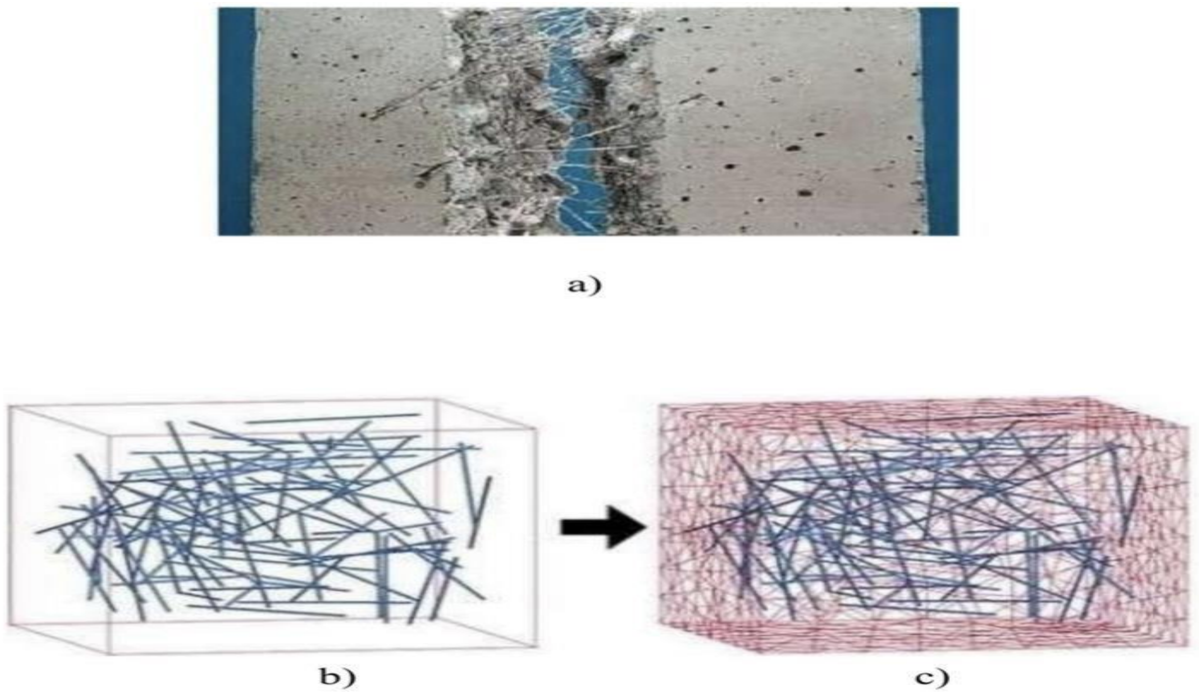


FIG-Fibre Reinforced Concrete (FRC)-8-(A, B, C)

6.3.3.1 Types of fibre

Following are the different type of fibres generally used in the construction industries.

- Steel Fibre
- Polypropylene Fibre
- GFRC Glass Fibre
- Asbestos Fibres
- Carbon Fibres
- Organic Fibres

- Natural fibre (Coir fibre, Cotton fibre, Sisal fibre, Jute fibre and Wool fibre)

Fibre is a small discrete reinforcing material produced from steel, polypropylene, nylon, glass, asbestos, coir or carbon in various shape and size. They can be circular or flat.

* Steel fibres: Steel fibre is one of the most commonly used fibre. Theyare generally round. The diameter may vary from 0.25 mm to 0.75 mm. The steel fibre is likely to get rusted and lose some of its strength. Use of steel fibre makes significant improvements in flexural impact and fatigue strength of concrete. Steel fibres have been extensively used in overlays or roads, pavements, air fields, bridge decks, thin shells and floorings subjected towear and tear and chemical attack.

FIG-9 Steel Fibres

• Glass Fibres: These are produced in three basic forms:

a) Roving's

b) Strands

c) Woven or chopped strand mats.

- Major problems in their use are breakage of fibre and the surface degradation of glass by high alkalinity of the hydrated cement paste. However, alkali resistant glass fibre has been developed now. Glass fibre reinforced concrete (GFRC) is mostly used for decorative application rather than structural purposes.
- With the addition of just 5 % glass fibers, an improvement in the impact strength of up to 1500 % can be obtained as compared to plain concrete. With the addition of 2 % fibers the flexural strength is almost doubled.

FIG-10 Glass Fibers

FIG-12 Carbon Fiber

- Plastic fibers: Fibers such as polypropylene, nylon, acrylic, aramid and polyethylene have high tensile strength thus inhibiting reinforcing effect. Polypropylene and nylon fibers are found to be suitable to increase the impact strength. Their addition to concrete has shown better distribute cracking and reduced crack size.

FIG.11 : Plastic fibers

- Carbon Fibers: Carbon fibers possess high tensile strength and high young's modulus. The use of carbon fibre in concrete is promising but is costly and availability of carbon fibre in India is limited.

- Asbestos fibers: Asbestos is a mineral fibre and has proved to be most successful fibre, which can be mixed with OPC. The maximum length of asbestos fibre is 10 mm but generally fibers are shorter than this. The composite has high flexural strength.

FIG-13 Asbestos fibers

6.3.3.2 Factors Affecting Properties of Fiber Reinforced Concrete The important factors affecting properties of FRC are as follows:

- Volume of fibers
- Aspect ratio of fibers
- Orientation of fibers
- Size of coarse aggregate
- Workability and compaction of Concrete
- Mixing

6.3.3.3 Necessity of Fiber Reinforced Concrete:

a) It increases the tensile strength of the concrete.

b) It reduces the air voids and water voids the inherent porosity of gel.

c) It increases the durability of the concrete.

d) Fibres such as graphite and glass have excellent resistance tocreep.

e) Deferential deformation is minimized

f) It has been recognized that the addition of small, closely spacedand uniformly dispersed fibers to concrete would act as crack arrester

g) It substantially improves its static and dynamic properties.

6.3.4 FERROCEMENT

Ferro cement is a type of thin wall reinforced concrete, commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh may be made of metallic or other suitable materials."

6.3.4.1 Materials for ferrocement

a) Cement mortar mix

b) Skeleton steel

C) Steel mesh reinforcement

Fig-14 ferro concrete

6.3.4.2 Advantages of ferrocement

- It is highly versatile and can be formed into almost any shape for awide range of uses
- 20% savings on materials and cost
- Suitability for pre-casting
- Flexibility in cutting, drilling and jointing
- Very appropriate for developing countries; labour intensive
- Good fire resistance
- Good impermeability
- Low maintenance costs

- Reduction in self-weight & Its simple techniques require a minimumof skilled labour.
- Reduction in expensive form work so economy & speed can beachieved
- Only a few simple hand tools are needed to build any structures
- Structures are highly waterproof & Higher strength to weight ratiothan R.C.C.

6.3.5 READY MIX CONCRETE

"Ready mix concrete is concrete mixed away from the construction site and then it is delivered to the construction site by the truck in a ready-to-use condition is called ready mix concrete."

6.3.5.1 Advantages of Ready Mixed Concrete:

- Concrete is produced under controlled conditions using consistentquality of raw material.
- Speed of construction can be very fast in case RMC is used.
- Reduction in cement consumption by 10 - 12 % due to betterhandling and proper mixing.
- The mix design of the concrete can be tailor made to suit the placingmethods of the contractor.
- Since ready mixed concrete (RMC) uses bulk cement instead ofbagged cement, dust pollution will be reduced
- Conservation of energy and resources because of saving of cement.
- Environment pollution is reduced due to less production of cement.

- Better durability of structure
- Minimizing human error and reduction in dependency on labour.
- Timely deliveries in large as well as small pours.
- No need for space for storing the materials.
- Reduced noise and air pollution; less consumption of petrol anddiesel and less time loss to business.

FIG-15 RMC

6.3.6 SHOTCRETE or GUNITE

Process of conveying dry (or damp) sand and cement by means of compressed air through material hose to a nozzle where water is added before the material is sprayed on the construction surface is called shotcrete or Gunite.

6.3.6.1 Methods:

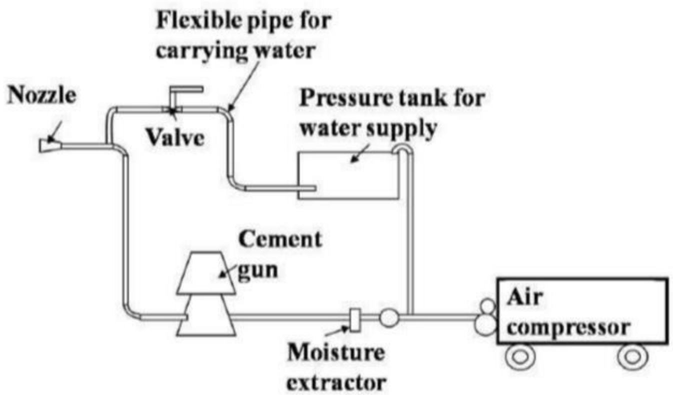


FIG-16 SHOTCRETE

- Dry mix - In this dry mix the cement and sand is mixed thoroughly in dry state
- Wet mix - Concrete is mixed with water before conveying through delivery pipe and not suitable like dry mix

6.3.6.2 Procedure of shotcrete on surface:

- Thoroughly clean all surfaces to receive shotcrete by removing
- loose materials and dust, pressure washing and dampen the surface to a saturated surface dry condition.
- Fix wire mesh to the concrete surface. The steel wire mesh has to be placed in position keeping the mesh within 10-15 mm fromthe surface. Suitable fixing pins are to be inserted to keep the mesh in proper position and to ensure that the weld mesh is not disturbed during shotcreting.
- Prepare a cement-sand / water mix and pour this mix into Pumphose for lubrication before starting to pump the productionmixture
- When the pumped mixture reaches the nozzle, turn on compressed air.

- Apply shotcrete evenly to targeted surfaces. Built-up the desired
- Thickness of shotcrete in layers of about 30 mm thick each. The presence of voids can be found by hollow hammering soundafter the shotcrete has attained strength after around 3 days.

6.3.6.3 Application of Shotcrete:

- Shotcrete can be used to repair the damaged surface of concrete
- Shotcrete repair can be used for bridge deck rehabilitatio
- Repair of fire and earthquake damage and deterioration,strengthening walls.
- To marine structures can result from deterioration of the concreteand of the reinforcement.
- Shotcrete is used in underground excavations in rock
- Used for temporary protection of exposed rock surfaces that will deteriorate when exposed to air to construct concrete swimming pools.
- Shotcrete floors in tanks and pools on well compacted sub-base

6.3.7 POLYMER CONCRETE

Polymer concrete is nothing but impregnations of monomer into the pores of harden concrete and then getting it polymerized by thermal process is called polymer concrete. By this polymerization, the strength of the concrete is much improved.

6.3.7.1 Types of polymer concrete:

-Polymer Impregnated concrete

-Polymer cement concrete

-Polymer concrete

-Partially impregnated and surface coated polymer concrete

6.3.7.2 Types of monomer:

- Methyl methacrylate
- Styrene
- Acrylonitrile
- T-butyl styrene
- Thermoplastic monomer

6.3.7.3 Advantages of polymer concrete:

- It has high impact resistance and high compressive strength.
- Polymer concrete is highly resistant to freezing and thawing.
- Highly resistant to chemical attack and abrasion.
- Permeability is lower than other conventional concrete.

6.3.7.4 Application of polymer concrete:

- Nuclear power plants
- Kerbstones.
- Prefabricated structural element.
- Precast slabs for bridge decks.

- Roads.
- Marine Works.
- Prestressed concrete.
- Irrigation works.
- Sewage works.
- Waterproofing of buildings. • Food processing buildings etc.

6.3.8 Self-compacting concrete

Self-compacting concrete is the highly flowable, non-segregating concrete that can spread into place, fill formwork, and encapsulate even the most congested reinforcement by means of its own weight, with little or no vibration. It delivers these attractive benefits while maintaining or enhancing all of customary mechanical and durability characteristics of concrete. Adjustments to traditional mix designs and the use of superplasticizers create this concrete that can meet flow performance requirements. The self-compacting concrete is ideal to be used for casting heavily reinforced sections or be placed where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible to cast, giving a far superior surface to conventional concrete. His will be fully discussed in chapter 8.

Chapter 7 Ultra-High Performance Concrete

7.1 Introduction

Ultra-high-performance concrete (UHPC) was first introduced as reactive powder concrete (RPC) in the early 1990s by employees of the French contractor Bouygues.

Over the last twenty years, remarkable advances have taken place in the research and application of ultra-high performance concrete (UHPC), which exhibits excellent rheological behaviors that include workability, self-placing and self- densifying properties, improved in mechanical and durability performance with very high compressive strength, and nonbrittleness behavior. It is the future' material with the potential to be a viable solution for improving the sustainability of buildings and other infrastructure components. UHPC has several advantages over conventional concrete but the use of it is limited due to the high cost and limited design codes. UHPC is an advanced cementitious material with high strength and excellent durability. Most projects have been motivated by government agencies as initial demonstration projects intended to encourage further implementation. However, for most of the countries, these demonstration projects did not create the anticipated acceptance with slow follow-up implementation. It appears that the lack of design codes, limited knowledge on both the material and production technology, and high costs limit the implementation of this outstanding material beyond the initial demonstration projects.

7.2 Definition and development of UHPC

7.2.1 Definition of UHPC

UHPC is a relatively new generation of cementitious material with very high strength, ductility and durability. UHPC strengthened with fiber can be treated as a combination of three concrete technologies of self-compacting concrete (SCC), fiber reinforced concrete (FRC) and high-performance concrete (HPC). French interim recommendations (AFGC 2002) defined UHPC as a concrete with a characteristic compressive strength of at least 150 MPa with the use of steel fiber reinforcement to ensure ductile behavior under tension. UHPCs with compressive strength of 130 MPa — 150 MPa strengthened with either steel or other fibers are considered as lower strength UHPC. Normally, the term UHPC is used to describe a fiber reinforced, superplasticized, silica fume (SF)-cement mixture with a very low water to cement ratio (W/C), characterized by the presence of a very fine quartz sand that ranges from 0.15-0.60 mm in diameter, instead of the ordinary aggregate. In fact, some researchers have suggested that UHPC is not a concrete, due to the absence of coarse aggregate in the mixture. However, the term ‗concrete' is selected rather than ‗mortar' to describe UHPC added with fine steel fibers to enhance the ductility. To date, there are several types of UHPC that have been developed in different countries and by different manufacturers such as Ceracem 1, BSI 1, compact reinforced composites (CRC), multi-scale cement composite (MSCC), and reactive powder concrete (RPC).

7.2.2 Development of UHPC

Over the last decades, large progress has been taking place on the field of concrete development. Intensive research efforts began in 1930s to improve concrete compressive strength. Fig. 1 shows the significant concrete technology achievements for the last 40 years. From the graph, it can be seen that the concrete technology progressed slowly during the 1960s with the maximum compressive strength of 15 MPa to 20 MPa. The concrete compressive strength tripled to 45 MPa to 60 MPa over a period of about 10 years. Concrete strength reaches its plateau at about 60 MPa in early 1970s believed due to the technological barrier of the existing water reducer. The available water reducer at that particular time failed to reduce the water to binder ratio (W/ B) any further. During 1980s, it is realized that the highrange water reducers, called superplasticizers (SP), can be used to progressively reduce W/B down to 0.30. Reducing the W/B below this was considered a taboo until Bache reported that, with high dosage of SP and silica fume (SF), it was possible to reduce W/B to 0.16. Concrete compressive strength of up to 280 MPa was achieved through compacted granular materials by optimizing the grain size distribution of the granular skeleton. These resulted in the creation of a material with a minimum number of defects, such as micro

cracks and interconnected pore spaces, to achieve ultimate strength and durability enhancement.

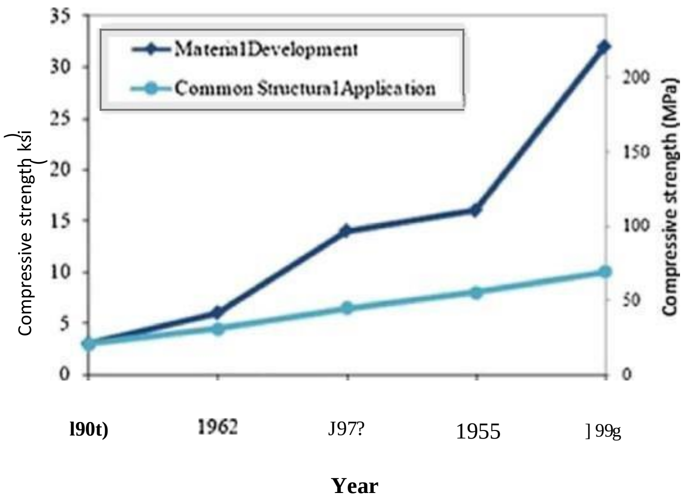


Figure 7.1: The development of concrete compressive strength for over 100 years

Fiber types often used in UHPC include high carbon steel, PVA, Glass, Carbon or a combination of these types or others. The ductile behavior of this material is a first for concrete, with the capacity to deform and support flexural and tensile loads, even after initial cracking. The high compressive and tensile properties of UHPC also facilitate a high bond strength allowing shorter length of rebar embedment in applications such as closure pours between precast elements. UHPC construction is simplified by eliminating the need for reinforcing steel in some applications and the materials high flow characteristics that make it self- compacting. The material's low permeability prevents the ingress of harmful materials such as chlorides, which yields superior durability characteristics. In the PCI research project, it is recommended that the ASTM C1609-determined flexural strength be above 10 MPa at first cracking and above 14 MPa at peak value with a significant deflection (ductility) beyond cracking (Figure 1).

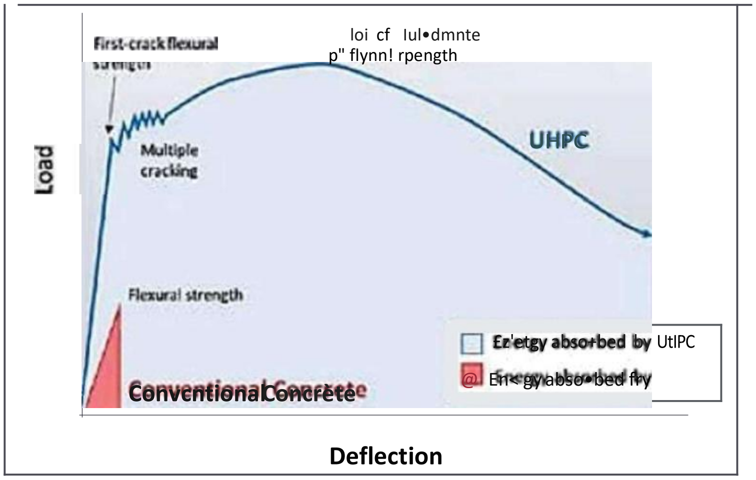


Figure 7.2: Energy absorption of UHPC vs. conventional concrete

This high strength allows for much higher shear resistance and the possibility of total elimination of shear reinforcing bars. The following Table 1 is an example of the range of material characteristics for UHPC.

Table 7.1: UHPC material Characteristic according to strength and durability

Strength	Durability
Compressive: (150 to 250 MPa) **Flexural: (15 to 25 MPa)** **Modulus of Elasticity: (45 to 50 GPa)**	**Freeze/thaw (after 300 cycles): l00^0/o** **Salt-scaling (loss of residue): (< 60 g/m^2)** **Abrasion (relative volume loss index): 1.7** **Oxygen permeability: (<l0-20 m^2)**

Figure 7.3: shows the advantages of using UHPC in reinforced structures

The only disadvantage of using UHPC is the high cost of such material components. Pre-bagged UHPC has been selling for over $2600 per cubic yard. In addition, fibers cost between $300 and $650 per cubic meter depending on dosage and source of fibers. It is therefore sometimes difficult to justify using materials that cost nearly $3200 per cubic meter. This is why UHPC usage has been limited to joints, where low volume use, although expensive, does not significantly affect the total cost of the project. The price of concrete is now not the cost of cubic yard of concrete but rather the cost of 1 MPa or 1 year of life cycle of a structure.

7.3 Materials and Mix Proportions

UHPC formulations often consist of a combination of Portland cement, fine sand, silica fume, high-range water-reducing admixture (HRWR), fibers (usually steel), and water. Small aggregates are sometimes used, as well as a variety of chemical admixtures.

Table 7.2: Typical composition of different materials %

	Ductal		CRC	Schmidt	COR-TUFF	CEMTEC
	kg/m^3	Percentage by Weight	proportion	kg/m^3	proportion	kg/m^3
Portland Cement	1200	28.5	1	580	1	1050
Fine Sand	1720	40.8	0.92	354	0.967	514
Silica Fume	390	9.3	0.25	177	0.66	268
Ground Quartz	355	8.4	-	456	-	-
Glass powder	-	-	0.25	-	-	-
HRWR	51.8	1.2	0.0108	33.4	0.0171	44
Accelerator	50.5	1.2				
Steel Fibers	263	6.2	0.22 : 0.31	192	0.31	858
Water	184	4.4	0.18 : 0.2	141	0.208	180

Figure 7.4: Main components of UHPC

7.4 Material and structural design considerations

Several researchers identified the basic principle in designing UHPC, which can be summarized as follows:

1. Minimizing composite capillary porosity by optimizing the granular mixture through a wide distribution of powder size classes and
2. Reducing the W/B by using SP, resulting in good durability and self-healing of crack capacity, which ensures long-term retention of tensile strength, provided certain crack width limits.
3. Enhancement of the microstructure by the post set heat treatment to speed up the pozzolanic reaction of SF and to increase mechanical properties.
4. Improvement of homogeneity by eliminating coarse aggregate resulting in a decrease in the mechanical effects of heterogeneity.
5. Increase in ductile behaviour by adding adequate volume fraction of small steel fibers (more than 2% in volume) in order to achieve ductile behaviour under tension dispense with the need for traditional passive steels in many cases

Application of the first four principles leads to a concrete with a very high compressive strength and the addition of the steel fibers helps to improve both tensile strength and ductility of the concrete.

7.5 Reduction in porosity

Pore structure plays an important role in determining the strength of hardened cement-based materials. The pore size distribution, shape and position of pores are also important, but it is both difficult and impractical to include all these

parameters. Many experimental results have confirmed that an acceptable prediction of strength can be obtained by using total porosity. The most common relationships between porosity and compressive strength of cement-based materials are:

Balshin's Equation: $\sigma = \sigma_o . (1\text{-}P)^A$ Eq. (1)

Ryshkevitch's Equation: $\sigma = \sigma_o . \exp(-BP)$ Eq. (2)

Schiller's Equation: $\sigma = D. \ln\left(\frac{P_0}{P}\right)$ Eq. (3)

Hasselmann's Equation: $\sigma = \sigma_o . (1\text{-}AP)$ Eq. (4)

where σ_o is the compressive strength at zero porosity; P is the porosity; P_o is the porosity at zero strength; σ is the compressive strength at porosity P; A, B, and D are the experimental constants. Most other relationships are variations of one of the four types. Eq. (2) is especially suitable for low porosity systems and Eq. (3) for high porosity systems. All these four equations clearly indicated the lower the porosity is, the higher the strength is.

7.6 Heat Curing

The compressive strength of UHPC can be increased considerably by using post- set heat curing. Some researchers showed that the heat curing at various temperatures between 149 and 356 °F (65 and 180 °C) produced 28-day compressive strengths as high as 41 ksi (280 MPa) compared with strengths of 25 and 27 ksi (178 and 189 MPa) when cured at 68 °F (20 °C).

Higher curing temperatures resulted in higher compressive strengths. In addition, the strengths at the end of the curing period at about 48 hours after casting were about the same as the corresponding 28-day strengths. They also concluded that curing at 194 °F (90 °C) presented no danger of delayed ettringite formation.

7.7 Increase in toughness

Toughness is a measure of the energy absorption capacity of a material, and is used to characterize its ability to resist fracture. Concrete is a typical quasi-brittle material with low tensile strength, strain capacity, and fracture toughness. Incorporation of fibers into concrete can prevent and control initiation, propagation or coalescence of cracks. In addition, Fibers - especially steel fibers- can cause tensile strain hardening behavior, as shown in figure 5.

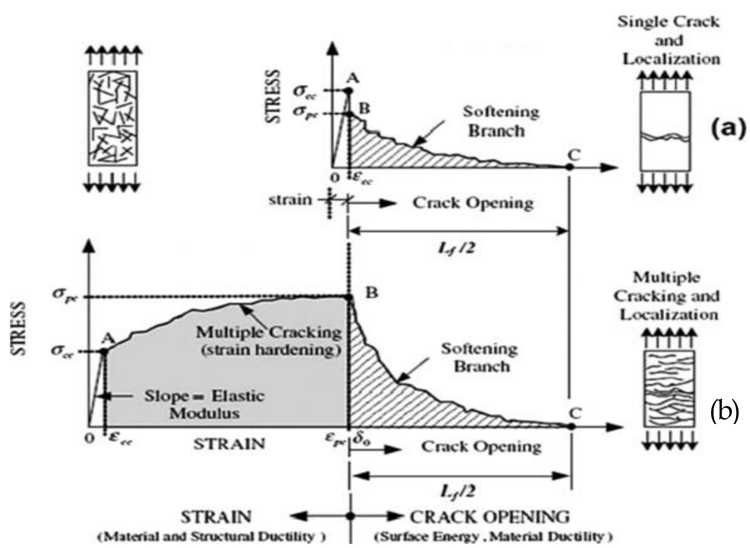


Figure. 7.5. Typical tensile strain softening and hardening behavior of FRC

When a load acts on fiber reinforced concrete, the fibers do not sustain the load directly, but the matrix does. The load is transferred to the fibers through the interface between the fibers and the matrix. Figure 6 demonstrates how fibers absorb energy and control crack growth. Starting from the leftmost fiber element and proceeding along the crack towards the right in the figure, they represent fiber rupture, pullout, bridging by tension through the fiber, and debonding at the fiber— matrix interface.

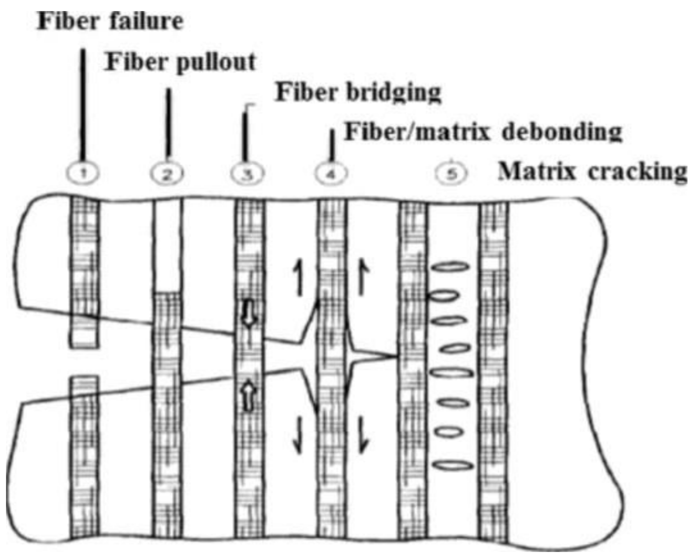


Figure 7.6: Energy-absorbing mechanisms of fiber—matrix

In the U.S., structural design criteria for UHPC have not been fully developed. However, enough knowledge exists to perform conservative designs until refinements are published.

Various terms are used to refer to cementitious-based composite materials with high compressive strength and enhanced durability. These include the following:

- Compact reinforced composite (CRC).
- Densified small-particle (DSP) concrete.
- Fiber-reinforced high-performance concrete (FRHPC).

- High-performance fiber reinforced cement composite (HPFRCC), -OR- Engineered cementitious composites (ECC).
- Macro defect free (MDF) concrete.
- Multi-scale fiber-reinforced concrete (MSFRC).
- Reactive powder concrete (RPC).
- Steel fibrous cement-based composite (SFCBC).
- Ultra-high performance concrete (UHPC).
- Ultra-high performance fiber-reinforced cementitious composite (UHPFRCC).
- Ultra-high performance fiber-reinforced concrete (UHPFRC).
- Ultra-high strength concrete (UHSC).
- Ultra-high strength cement-based composite.
- Ultra-high strength cementitious material.
- Ultra-high strength fiber-reinforced cementitious composite.

7.8 AFGC-SETRA Recommendations

The French recommendations are composed of three parts. The first part provides specifications regarding the mechanical properties to be obtained, procedures to be used for placement, and checks and inspection during construction and of the finished product. The second part deals with the design and analysis of UHPC structures and accounts for the participation of fibers, nonprestressed reinforcement, and non-reinforced elements. The third part deals with durability of UHPC. The first part provides design information for compresslve strength, tensile strength, modulus of elasticity, Poisson's ratio, coefficient of thermal expansion, shrinkage, creep, and impact behavior. Mix design, mixing procedures, placement practices, and tests are addressed. The design methods in the second part are based on the French codes for prestressed and reinforced concrete but take into account the strength provided by the fibers. The recommendations include an orientation coefficient that accounts for the alignment of fibers that may occur during placement. A minimum fiber content and non-brittleness check is also required. The stresses at the serviceability limit state are addressed in the same way as conventional reinforced or prestressed structures. When no prestressing steel or nonprestressed reinforcement is provided, a crack width criterion is used. For the ultimate flexural strength limit state, the recommendations propose a stress-strain relationship that is linear for the compressive stress range but multilinear in the tensile stress range to account for the effect of the fibers. At the serviceability limit state for shear, the recommendations use the shear stress limits of the French Code for prestressed concrete. Shear strength is calculated as the summation of the shear resistances provided by the concrete, reinforcement, and fibers. The components of the third part address water porosity, oxygen permeability, chloride ion diffusion, portlandite content, stability of admixtures, delayed hydration, corrosion of steel fibers, and durability of polymer fibers.

7.9 Structural Design Methods

The design methods presented below are based on Euro code 2 [EC2-1] (Design of concrete structures — Part 1.1: General rules and rules for buildings and Part 2 Concrete bridges [EC2-2]).

7.9.1 K-factor

The K factor is a reduction factor used to take into account the difference between the fiber orientation of the cast prism used to determine the intrinsic post-cracking law and the actual orientation of the fibers in the future structure. The different values of the K factor are determined considering the tensile strength of the material in the principal directions of tension in the structure. In order to take into account the possible inability to redistribute a stress due to the cross-sectional dimensions, a local value and an overall or global value of the K factor are distinguished. K corresponds to local stresses that require good fiber resistance in much localized areas (for example, prestressing stress distribution). K,lob.ml concerns the overall effects corresponding to stresses, which require good fiber resistance in larger areas, which will not be affected by a local defect (for example, the shear or the bending strength of a slab). The K factor only applies to the post-cracking part of the tensile law. In order to take into account disparity in fiber orientation due to placement (see chapter l), the design formulae include an ―orientation coefficient‖ or ―factor‖ 1/K. For each verification, it is indicated whether the local or global value is to be taken into account. A K value of less than 1 would assume that a beneficial preferential orientation effect in a given direction would be taken into account. The resistance of the structure in ALL the other directions in which the K values are generally greater than 1 (negative fiber orientation effect) would then need to be validated even if the said directions do not correspond to those of the principal loads. Before implementing the validation process, the designer can begin with the following K values: KU b 1 = 1.25 for all loading other than local effects, Klocal 1.75 for local effects.

For thin plates, a o- E constitutive law is used, and characterization of the concrete with a representative element of the actual structure shows that K=1, unless a different concrete placement method is used for the preliminary tests and the actual structure. In this latter case, the K values used for thick elements will be kept.

7.9.2 Creep

The creep of UHPFRC is similar to that of HPC if there is no treatment. It is considerably reduced by heat treatment of the second type. If nothing is known during the preliminary design phase of the project, the following indicative values of the long-term creep & will be adopted:

- $\emptyset = 0.8$ if there is no treatment;

- $\emptyset = 0.4$ With treatment of the first type;

- $\emptyset = 0.2$ With treatment of the second type;

7.9.3 Partial safety factor, ycf

A partial safety factor, γcf for fiber-reinforced concrete under tension has been introduced in ULS verifications in order to take manufacturing defects into account. Its value is (AFREM rules): γcf = 1.3 in the case of durable/transient situations, γcf = 1.05 in the case of accidental situations. The usual coefficients γc and γs defined in Eurocode 2 apply to the compressive strength of the concrete and the tensile strength of the reinforcing steel or prestressing tendons.

7.9.4 Concrete tensile strength — Notion of characteristic length lc (used for strain softening or low strainhardening UHPFRC)

The characteristic length, l„, is a quantity used to go from a constitutive law of the s = /{w) type (stress —crack width) to a constitutive law of the s = E) type (stress - strain) in order to perform equilibrium calculations for cracked sections.

Y— “q -1-*w*—is adopted

The value of I, depends on the cross-section. For a rectangular or T- cross-section, a value of - 3/2 h can be used, where h is the depth of the cross-section.

7.9.5 Minimum ductility condition

In order to guarantee that the material will have adequate ductility in bending, the following criterion must be respected for strain-softening and low strain-hardening materials:

J(vr)

$$\frac{1}{w_{lim}} \int_0^{w_{lim}} \quad dw \quad \text{Max (0.4f m. eli 3 MPa}$$

k g lobat

Where w i, can be chosen equal to 0.3 mid Jctin,el iS the mean elastic limit stress in tension, o(w) is the characteristic post-cracking stress.

This criterion does not apply to thin slabs or thick elements made of high strain- hardening material since the maximum post-cracking stress will be higher than the elastic limit stress.

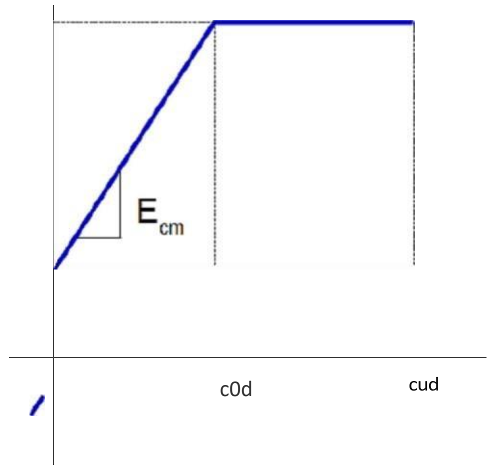
7.9.6 Design Young's modulus

To calculate the stress, the secant modulus E‹,» can be considered directly. In the case of a preliminary design, Ed..= 50 GPa can be assumed.

The creep can be taken into account directly to calculate the deformation using the effective modulus Ec.efr›defined for a load applied at instant toas :

$$E_{c,eff} = \frac{E_{cm}}{1+\Phi}$$

$$E = 3840\sqrt{f_c'}$$



$$e_{c0} = f_{ck}/E_{cm}$$
$$f_{cd} = a_{cc}\ f_{ck}\ /\ g_c$$

- go is the partial factor for concrete given in 2.4.2.4 of EN 1992-1.1.
- Andis a coefficient that takes into account the long-term effects on the compressive strength and the negative effects resulting from the way in which the load is applied. The recommended value of acc is 1 for ordinary concrete. We recommend 0.85 for UHPFRC. In the case of preliminary design, we recommend fon't 180 MPa, f,t = 150 MPa and therefore f,t

  85 MPa.

  The following value of ecud can be used: e ud' [1+14 (fctfm/fcm)].e c0d fctfq is the maximum mean post-cracking stress in tension.

  - f,q is the maximum mean stress in compression.

  In the case of preliminary design, we recommend erud' 2•7^{X} 10 ^{3} (taking fct fm =9 MPa).

7.9.7 Shear Design

The shear capacity is equal to the smaller of the two values V d and VRd. VRd,m is the resistance of the concrete compressive struts. VRCis the tensile resistance of the ties in the concrete.

VRd VRd,c + VRd,s VRd,f

- Vgt,,: concrete term
- VRd,.:shear reinforcement term
- VRd,‹: fibers term

7.9.7.1 Term VRd,c

* For a reinforced section, the design value for the shear capacity VRCprovided by concrete is given by

$$V_{Rd,c} = \frac{0,21}{\gamma_{cf}\gamma_E} k \, f_{ck}^{1/2} \, b_w \, d$$

$$k = 1 + \begin{cases} f_{ck} \\ 0,7 \cdot \frac{\sigma_{cp}}{f_{ctk,0.05}} & \sigma_{cp} < 0 \end{cases}$$

- scp NEd / AC
- News the axial force in the cross section due to loading or prestressing (NEd > 0 for compression). The influence of imposed deformations on NEd may be ignored.

7.9.7.2 VRd,f

The design value for the part of the shear capacity VRd,f provided by the fibers is given by

$$A_{Rd,f} - \frac{A}{\tan\theta}$$

In the case of strain-softening or low strain-hardening UHPFRC:

$$\frac{1}{K}\ y,\ u;_{,,,,}\ \frac{1}{}\int_0^{w_{lim}} \sigma_f(w)\,dw$$

$$w_{lim} = \max(w_u, w_{max})$$

- sz‹.f is also called the residual tensile strength of the fiber-reinforced cross- section,
- Ar, is the area of fiber effect, for rectangular or T-sections : *A f‹—b,,.*-, In the shear analysis of reinforced concrete without axial force, the approximate value z = 0.9d may normally be used. For circular section of diameter F, *,,A* 0.58 F', q is the angle between the principal compression stress and the beam axis. The stress tensor is calculated at the neutral axis, A minimum value of q = 30° is recommended by an elastic calculation based on the force tensor.

7.9.7.3 VRd,s

The contribution to shear resistance brought by the vertical shear reinforcement is as follows:

$$V_{Rds}\ \frac{A_{sw}}{}\ z\ f_{.wd} \cot\theta$$

If the element comprises inclined reinforcements, the resisting shear force provided by the reinforcements is as follows:

$$V_{Rd.s} = \frac{A_{sw}}{s}\ z\ f_{ywd}\ (\cot\theta + \cot\alpha)\sin\alpha$$

- A,p is the cross-sectional area of shear reinforcement
- s is the spacing of the stirrups fywd iS the design yield strength of the shear reinforcement

- a is the angle between the passive shear reinforcement and the beam axis. Note that in circular sections, V d. must be reduced by 30% to take into account the fact that the reinforcements do not directly act in the direction of the tie.

7.9.7.4 VRd,Max

The ultimate strength of the compressive struts is as follows:

$$V_{Rd.\max} = 2\times1{,}14\frac{\alpha_{cc}}{}b_w z\ f_{ck}{}^{2/3}/(\cot\theta+\tan\theta)$$

- z is the inner lever arm, for a member with constant depth, corresponding to the bending moment in the element under consideration.

7.10 ACTUAL AND POTENTIAL APPLICATIONS

The first highway bridge constructed in North America was the Mars Hill Bridge in Wapello County, IA. The simple single-span bridge, as shown in figure 7, comprises three 110-ft (33.5-m)-long precast, prestressed concrete.

Figure 7.7. Photo. Mars Hill Bridge, Wapello County, IA

One span of the 10 spans of the Route 624 bridge over Cat Point Creek in Richmond County, VA, was built using UHPC.(See figure 8) Bulb-tees with a depth of 45 inches (1.14 m) and a length of 8 l ft 6 inches (24.8 m) were used.

Figure 7.8. Photo. Route 64 over Cat Point Creek, Richmond County, VA

The first bridge to use UHPC in Canada was the pedestrian/bikeway bridge in Sherbrooke, Quebec, as shown in figure 9. The structural concept consists of a space truss with a top UHPC chord that serves as the riding surface, two UHPC bottom chords, and truss diagonals that slope in two directions. Each diagonal consists of UHPC confined in 6-inch (152-mm) diameter stainless steel tubes.

The Sunyudo (Peace) footbridge in South Korea is an arch bridge with a main span of 394 ft (120 m), (See figure 10) It is built from six precast, posttensioned pi-shaped sections 4.3 ft (1.30 m) deep. The upper flange is a ribbed slab 1.19 inches (30 mm) thick with transverse prestressing. The webs of the pishaped section are 6.35 inches (160 mm) thick and inclined outward at the bottom. The six precast sections are post tensioned together by tendons located in the upper and lower haunches of the section. This bridge is the longest span UHPC bridge in the world.

Figure 7.9. Photo. Pedestrian bridge, Sherbrooke, Quebec, Canada

Figure 7.10. Photo. Footbridge of Peace, Seoul, South Korea

Table 7.3. Other potential applications of UHPC

Application	Reference (First Author)
Drill bits for special foundation engineering	Ibuk
Sewer pipes	Schmidt
Precast spun columns and poles	Adam , Müller
Barrier walls	Young
Field-cast thin-bonded overlays	Young , Sritharan , Shann , Schmidt , Scheffler
Cable-stayed bridge superstructure	Kim , Park
Bridge bearings	Hoffmann
Precast tunnel segments	Randl
Seismic retrofit of bridge columns	Massicotte

7.11 Summary

UHPC exhibits very high strength, good toughness, and excellent durability. Based on the review and discussions above, it can be summarized as follows:

- The main principles for UHPC design are reduction in porosity, improvement in microstructure, enhancement in homogeneity, and increase in toughness. Raw materials, preparation technique and curing regimes have significant influence on properties of UHPC.
- The use of widely available supplementary cementitious materials, such as fly ash and slag for complete/partial replacement of cement and silica fume, could signifiCantly reduce the materials cost of UHPC. At the same time, UHPC with proper amount of those supplementary cementitious materials could achieve compressive strength of 150-250 MPa after normal curing regime.

- The use of conventional river sand to replace refined quartz sand could result in similar mechanical properties and ductility as the refined quartz sand did. In addition, the incorporation of coarse aggregate could also give very promising results.
- Steel fibers are commonly used in UHPC matrices. Proper fiber dosage could enhance the mechanical performances, and decrease autogenous shrinkage of UHPC. Moreover, a combination of macro steel fibers and micro steel fibers could produce tensile strain hardening behavior. However, the increased amount of fibers could cause balling, and decrease the workability of the mixture.
- High temperature curing are beneficial to the pozzolanic reactions between CH from the hydration of cement and supplementary cementitious materials such as silica fume, which improves the
- microstructure, and hence results in higher strength. It also increases the chain length of C—S—H.
- Most current applications of UHPC are accomplished by factory pre-fabrication and on-site assembling. In consideration of the high cost and complexity of curing process, use of conventional materials and common technology, such as conventional casting and room temperature curing are the trends for UHPC.

Chapter (8)
(Experimental work)

Effect of high temperatures on concrete manufactured by replacing fine aggregate with different proportions of Marble powder

8.1 Introduction

The use of waste materials in concrete is now a global trend for effective waste management in Order to create a sustainable, eco-friendly concrete. This has the added benefits of protecting Natural resources by means of producing more sustainable concrete that has better mechanical Properties. This study investigates the characteristics of concrete that contains 20% of Crushed Brick Powder (CBP) as partial replacement of cement and using waste marble powder with replacement ratios 0%, 20%, 40%, 60%, 80% and 100% of fine aggregate (sand).

Table (8.1): Percentages of mixture components

Mix No.	CBP % from cement	Binder (%)		Filler		
		OPC	CBP	Fine aggregate (%)		Coarse aggregate (%)
				Sand	MS	Dolomite
S1	0%	100	-----	100	----	100
S2	20%	80	20	100	----	100
S3	20%	80	20	100	20	100
S4	20%	80	20	100	40	100
S5	20%	80	20	100	60	100
S6	20%	80	20	100	80	100
S7	20%	80	20	100	100	100

OPC	CBP	MS
Ordinary Portland Cement	**Crushed Brick Powder**	**Marble sand**

Table (8.2) Constituents of the concrete mix (kg/m3)

Mix	Cement	CBP	SP	Water	Sand	MP	Total Fine aggregates	Dolomite
S1	500	0	10	150	603	0	603	1206
S2	400	100	10	150	593	0	593	1185
S3	400	100	10	150	474	119	593	1185
S4	400	100	10	150	356	237	593	1185
S5	400	100	10	150	237	356	593	1185
S6	400	100	10	150	119	474	593	1185
S7	400	100	10	150	0	593	593	1185

8.2 EXPERMENTAL WORK

8.2.1 Introduction

This chapter presents an elaborated characterization of the utilized specimens, the material properties, the testing setup, instrumentation and testing procedure.

8.2.2 Material

The concrete materials used in this experimental work were purchased from locally available materials. It includes ordinary Portland cement, sand, Fine aggregate, water and Sikament ®-R 2004. The red brick and Marble breaking process was carried out in the laboratory. This work was done in the laboratory of the Nile Higher Institute of Engineering and Technology

8.2.2.1 Cement

Ordinary Portland cement was used at a rate of 100% in the M1 mixture, and a total of 80% was used in the mixture (S2, S3, S4, S5, S6, S7). A total of 20% of these mixtures were replaced with red brick.

Fig 8.1 cement powder

8.2.2.2 Red brick powder

The red bricks were crushed and sieved on a 150µm sieve until they became a fine powder to be used as a solution for 20% cement in the mixtures (S2, S3, S4, S5, S6, S7) to extract the results of the mixtures and compare them with the basic mixture (S1).

Fig 8.2 red brick powder

8.2.2.3 Fine aggregate

The fine aggregate used was natural silicate sand. It was dry, well-graded sand, free of impurities. The percentage in the mixture was (S1 100%), (S2 100%), (S3 80%), (S4 60%), (S5 40%), (S6 20%), (S7 0%).

Fig 8.3 fine aggregate

8.2.2.4 Coarse aggregate

100% natural coarse aggregate was used in all mixture.

Fig 8.4 coarse aggregate

8.2.2.5 Water

Water free from compound or impurities was utilized in the mixture.

8.2.2.6 Marble Powder

The Marble was broken and sieved through a 4.75mm sieve to be used instead of sand. Let us extract the results from the tests, and the total percentage was (S1 0%), (S2 0%), (S3 20%), (S4 40%), (S5 60%) ,(S6 80%), (S7 100%).

Fig 8.5 marble powder

Fig 8.7 place the marble powder on sieve 4.75

8.2.2.7 Sikament®-R 2004

Sikasten R 2004 is a strong plasticizer that has a retarding effect on the setting of concrete, producing workable and flow able concrete in hot weather, and also as a basic agent for reducing water content for improvement. ASTM C-494 Type G and BS 5075 part3 and increasing early and ultimate stresses

Fig 8.9 Sikament®-R 2004

8.2.3 Concrete mix

This figure (8.10),(8.11),(8.12) (8.13) (8.14) (8.15) (8.16) shows the mixtures (S) produced in the concrete plant by pouring trial batches. This mixture (S) is designed to reduce air pollution, improve the quality of concrete, and increase its resistance. Mixing (S) was performed mechanically by mixing the materials in a dry state for 2 minutes, then gradually adding water plus additives and continuing mixing for another 5 minutes.

Seven concrete mixers were made , consisting of cement , sand , aggregate , brick powder and marble powder and here are the sizes.

Table 8.2.3.1 : Constituents of the concrete mix (kg/m3)

Mix	cement	CBP (kg/m^3)	SP (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	Gp (kg/m^3)	Total fine aggregates (kg/m^3)	Dolomite (kg/m^3)
S1	500	0	10	150	603	0	603	1206
S2	400	100	10	150	593	0	593	1185
S3	400	100	10	150	474	119	593	1185
S4	400	100	12	150	356	237	593	1185
S5	400	100	12	150	237	356	593	1185
S6	400	100	12	150	119	474	593	1185
S7	400	100	12	150	0	593	593	1185

CBP	SP	GP
Crushed brick powder	Sika ment	Marble powder

Absolute volume method for calculating concrete mix components per cubic meter

$$\frac{C}{3.15}+\frac{2S}{2.65}+\frac{S}{2.65}+\frac{B}{2.30}+\frac{W}{1}+\frac{GP}{1.15}=1000$$

With compensation

$$\frac{500}{3.15}+\frac{2S}{2.65}+\frac{S}{2.65}+\frac{0}{2.30}+\frac{150}{1}+\frac{150}{1}+\frac{10}{1.15}=1000$$

Table 8.2.3.2 : Constituents of the concrete mix kg

Mix	Cement Kg/m^3	CBP Kg/m^3	SP Kg/m^3	Water Kg/m^3	Sand Kg/m^3	Gp Kg/m^3	Total Fine Kg/m^3	Doiomite Kg/m^3
S1	**14**	**0**	**0.336**	**5.320**	**16.884**	**0**	**16.884**	**33.180**
S2	**11.200**	**2.800**	**0.336**	**5.320**	**16.604**	**0**	**16.604**	**33.180**
S3	**11.200**	**2.800**	**0.336**	**5.320**	**13.272**	**3.332**	**16.604**	**33.180**
S4	**11.200**	**2.800**	**0.336**	**5.320**	**9.968**	**6.636**	**16.604**	**33.180**
S5	**11.200**	**2.800**	**0.336**	**5.320**	**6.636**	**9.968**	**16.604**	**33.180**
S6	**11.200**	**2.800**	**0.336**	**5.320**	**3.332**	**13.272**	**16.604**	**33.180**
S7	**11.200**	**2.800**	**0.336**	**5.320**	**0**	**16.604**	**16.604**	**33.180**

8.2.3.1 The First Mixture

The first mixture consists of cement, sand, and aggregate of 1 cm size and the addition of Sika Ment R2004

8.2.3.2 The Second Mixture

The second mixture contains cement. Part of the cement was replaced with brick powder, sand, aggregate and Sika Ment

8.2.3.3 The mixture is from S3 to S7

The rest of the mixtures referred to contain cement. Part of the cement was replaced with brick powder and sand, and part of the sand was replaced with Marble powder, aggregate, and Sika Ment.

fig8.10 : Place the ingredients in the blender

Fig8.11: Connect the cubes and clean

Fig8.12 : Concrete processing

Fig8.13 : Concrete after mixing

(a) Fig 8.14 concrete mixing

(b) Fig 8.15 concrete mixing

(c) Fig 8.16 concrete mixing and pouring stage

8.2.4 Casting and compaction

After mixing the concrete, it is poured into the molds and shaken with a shaking table for 0.5 minutes to compact the concrete. The top surface of the concrete was finished by hand using a trowel.

Fig 8.15 Filling cubes

Fig 8.16 concrete mixing

(c) Fig 8.17 casting and compaction

8.2.5 Curing

After 24 hours have passed from the time the concrete reaches the setting time, it is left to dry for 28 days after being immersed in the containers. They are then taken out of the molds and put to the test.

Fig 8.18 curing samples in water

8.3 Laboratory tests

8.3.1 Sieve test

Sieve analysis is a practice or procedure used to evaluate the particle size distribution of a granular material. The size distribution is often of critical importance to the way the material in use performs. Sieve analysis can be performed on any type of inorganic or organic granular material including sand, crushed rock, clay, granite, coal, soil, a wide range of manufactured powders, grains and seeds, down to the minimum size depending on the exact method. As a simple particle size determination technique, it is probably the most common. Red brick powder was sieved on a 0.15 mm sieve to replace cement Marble powder was sieved on a 4.75mm sieve to replace sand and see the figures below:

Fig 8.19 sieve works

8.3.2 Concrete Tests

Four tests were conducted on seven concrete mixes according to ECP 203-2018 and Egyptian Standard Specifications, to achieve the filling capacity, throughput, and segregation resistance of reinforced concrete with reinforced concrete.

8.3.2.1 Slump test

Slump test for concrete is a test that expresses the quality of the produced concrete and its compliance with the project specifications. The slump value indicates the proportions and quantities of materials used in the concrete. Any change in the proportion of cement or the amount of water and aggregate affects the slump value. The test is carried out immediately after mixing the materials.. or upon the arrival of the concrete truck to the site. The purpose of this test is to determine the consistency of the concrete mixture by determining the slump value in the height of the concrete after it is formed in the form of an incomplete cone, as this number has a direct indication of the mixing proportions of the concrete components, and accordingly the validity of the concrete mixture is determined. This test is considered one of the best means of quality control for the concrete mixture.Steps for conducting the slump test:

1. The mold is cleaned well, especially the inner surface.
2. The mold is placed on a completely horizontal surface that is impermeable to water.
3. The mold is filled in three batches, each layer equal to a third Of the total height of 30 cm, and compaction is carried out 25 times using the rod so that it penetrates the entire layer and the layer below it.
4. Level the final surface.
5. The mold is lifted immediately after leveling vertically upwards and with great care

6. The amount of slump is measured as the difference between the height of the mold and the height of the sample.

Fig 8.3.2.1.1 :Slump test


Fig8.3.2.1.2: Tamp the concrete into the cone

Fig 8.3.2.1.3 slump test

8.3.2.2 Concrete compression test

Compressive and flexural strength of hardened concrete A set of cubes were cast, the number of which was (18) cubes for each of the seven mixes that were cast, and the dimensions of the cube were (100×100×100) mm, and two concrete cylinders (150×300) mm, and two beams with beam dimensions (100×100×1050) from each batch, and they were treated with fresh water for 7 days, 28 days, to measure the compressive strength of the concrete. The average compressive strength values for 28 days for the batch cubes and cylinders were 330 and 380 kg/cm², respectively. The compressive strength test was carried out according to ECP 203-2018 and E.S.S 1658-1988,

1. The cubes of concrete mixes were tested after 7 days of pouring without heating to be cured in water:

Fig 8.15 weighing and testing cubes on a pressure device

2. The cubes of concrete mixes were tested after 28 days of curing in water without heating and by heating at a temperature of 150 ° C, 300 ° C and 450 ° C to compare the samples and know the effect of high temperatures on concrete mixes of all kinds.

(a)

(b)

Fig 8.16 heating the cubes and crushing them on the testing machine

8.3.2.3 Brazilian tensile testing of concrete cylinders

1. Sample preparation

Prepare the concrete cylinder with a diameter of 150 mm and a height of 300 mm (or dimensions specified as per specifications) Make sure that the upper and lower surfaces of the sample are level and clean.

2. Putting the sample in the device

Place the concrete sample horizontally in the Brazilian device so that its horizontal axis is perpendicular to the jaws of the device. Use loading pads (usually metal or wooden) between the specimen and the jaws to ensure that the load is evenly distributed.

3. Device Setting

Make sure that the jaws of the device are positioned correctly and that the sample is secure and does not move. Set the device to start applying the load slowly and at a constant rate.

4. Pregnancy application

Begin applying the load to the specimen slowly and continuously until fracture occurs. Record the maximum load that the sample bears before fracture.

(a)

(b)

Fig 8.17 Brazilian tensile testing of concrete cylinders

8.3.2.4 Bending test for Beams

(a)

(b)

(c)

(d)

(e) Fig 8.18 Bending test for Beams

8.4 Test Resultes

8.4.1 S mixtures mixed with Marble powder

Table 8.4.1.1: shows the different concrete proportions for S1.S2.S3.S4.S5.S6.S7 concrete mixers.

Constituent of concrete mix (1 m^3)											
Mix	CBP % from cement	MP % from fine agg.	Mix	Cement	CBP (kg/m^3)	SP (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	GP (kg/m^3)	Total fine aggregates (kg/m^3)	Dolomite (kg/m^3)
S1	0%	0%	S1	500	0	10	150	603	0	603	1206
S2	20%	0%	S2	400	100	10	150	593	0	593	1185
S3	0.2	20%	S3	400	100	10	150	474	119	593	1185
S4	0.2	40%	S4	400	100	12	150	356	237	593	1185
S5	0.2	60%	S5	400	100	12	150	237	356	593	1185
S6	0.2	80%	S6	400	100	12	150	119	474	593	1185
S7	0.2	100 %	S7	400	100	12	150	0	593	593	1185

8.4.2Mixers S For cubes 7 day test

Table 8.4.2.1: Shows date of casting, testing, weight and pressure.

Mix	Mixing and casting Data	7 Days		
		Test Data	cubes	
			Weight (kg)	Comp strength(Kg/m^3)
S1	5/8/2024	5/15/2024	2.32	189
S2	5/8/2024	5/15/2024	2.385	251.5
S3	4/24/2024	5/7/2024	2.494	395.6
S4	4/24/2024	5/7/2024	2.446	434
S5	4/29/2024	5/7/2024	2.401	313.3
S6	4/29/2024	5/7/2024	2.417	315
S7	5/7/2024	5/14/2024	2.305	219.6

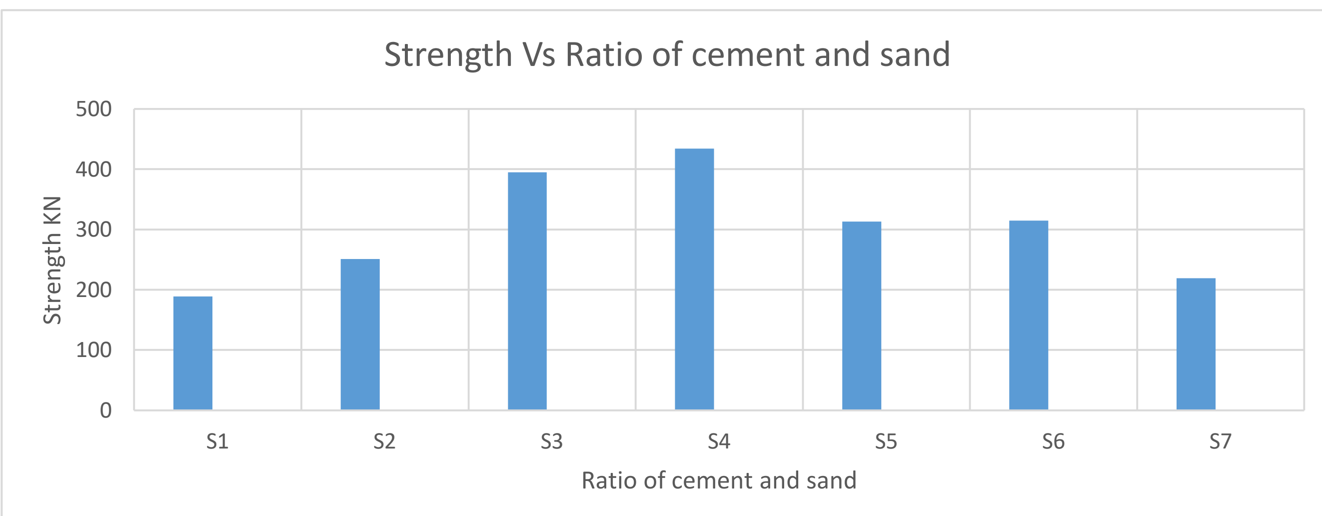


Figure 8.4.2.2 : The relationship between strength and proportions of cement and sand

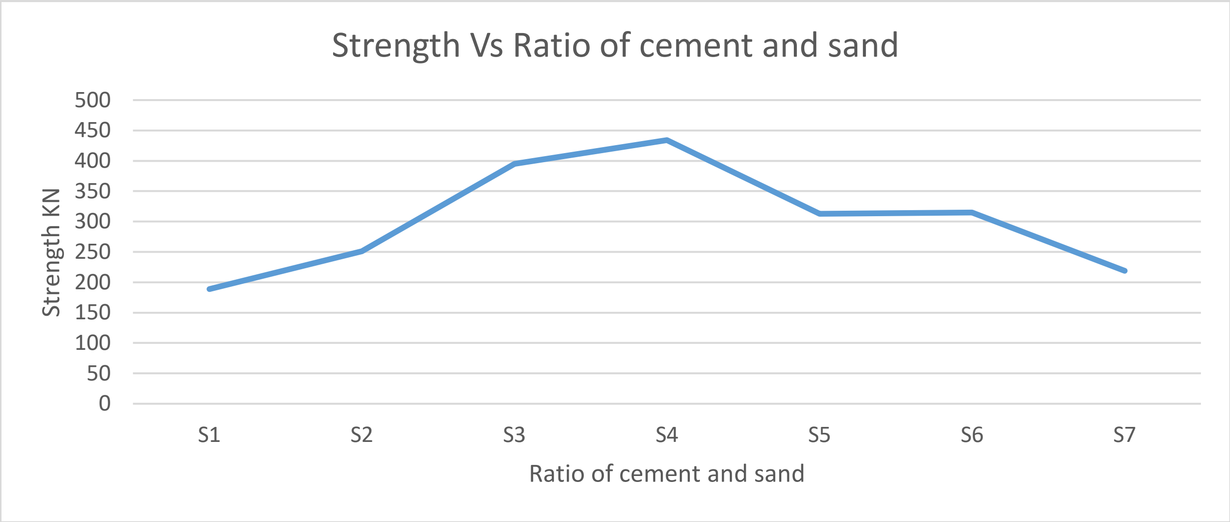


Figure 8.4.2.3: The relationship between strength and proportions of cement and sand

Table 8.4.2.1 and Figures 8.4.2.2 and 8.4.2.3 show the effect of compressive strength on the concrete mixture by changing the overall proportion designed for it, which is replacing an amount of cement amounting to 20% of the original amount and replacing an amount of 20% of each sand mixture with marble powder until we reach the complete replacement of sand Badra marble.

- Changes in the amount of compressive strength were monitored through a compressive strength test by crushing the cubes with a concrete press 7 days after pouring the concrete cubes.

8.4.3Mixers S For cubes 28 day test

Table 8.4.3.1 : Shows date of casting, testing, weight and pressure.

Mix	28 Days		
	Test Date	Cubes (lab Degree)	
		Weight (kg)	Comp strenght(Kg/m^3)
S1	6/5/2024	2.435	454
S2	6/5/2024	2.505	442
S3	5/23/2024	2.456	424
S4	5/23/2024	2.415	409.6
S5	5/27/2024	2.355	353
S6	5/27/2024	2.431	332.6
S7	6/5/2024	2.368	311.6

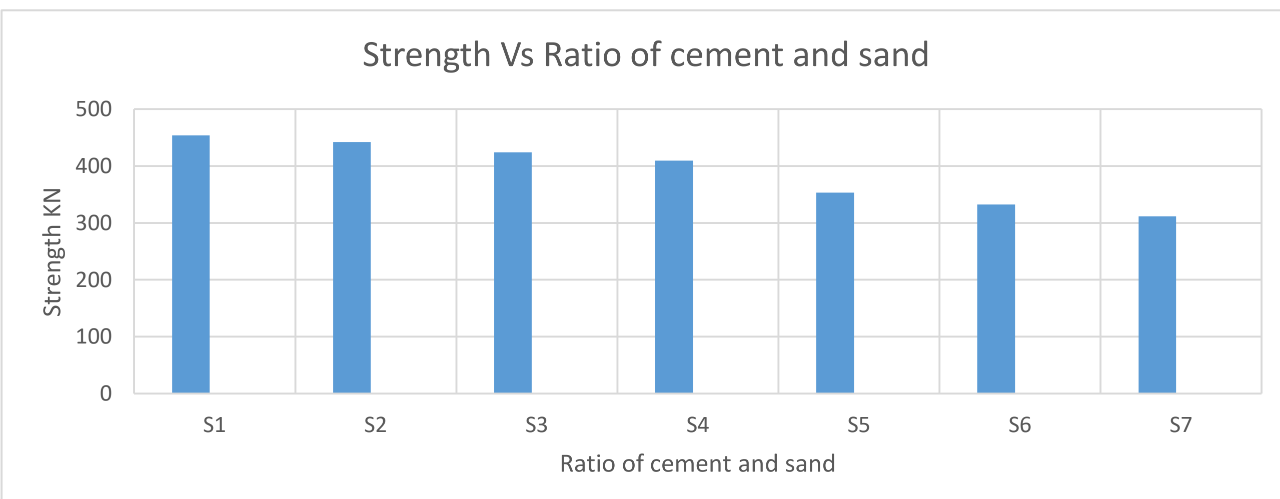


Figure 8.4.3.2 : The relationship between strength and proportions of cement and sand

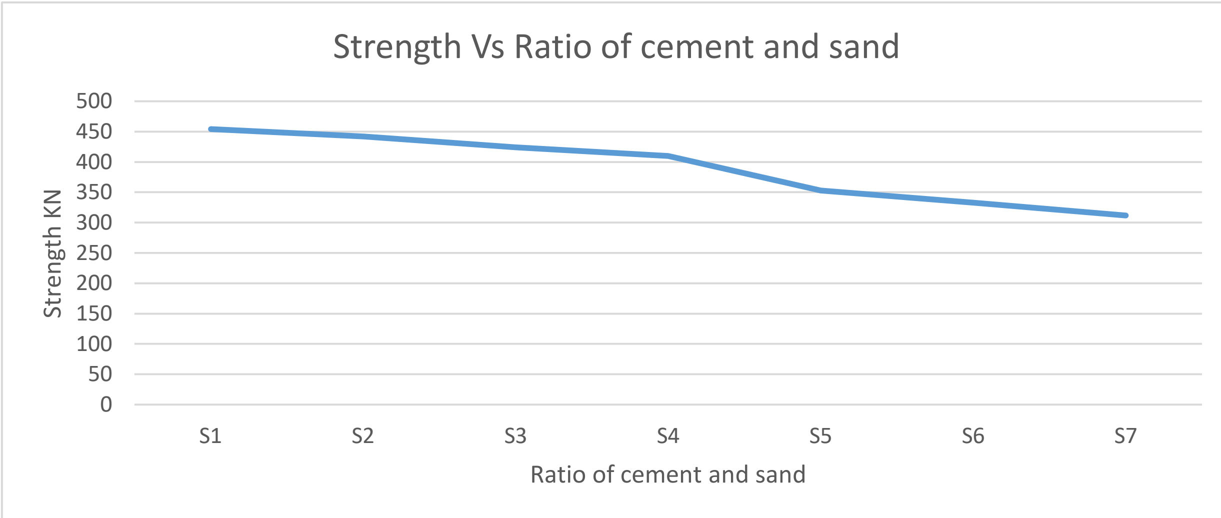


Figure 8.4.3.1 : The relationship between strength and proportions of cement and sand

Table 8.4.3.1 and Figures 8.4.3.2 and Figure 8.4.3.1 show the effect of compressive strength on the concrete mixture by changing the overall proportion designed for it, which is replacing an amount of cement amounting to 20% of the original amount and replacing an amount of 20% of each sand mixture with marble powder until we reach the complete replacement of sand. Marble powder.

□Changes in the amount of compressive strength were monitored through a compressive strength test by crushing the cubes with a concrete press 28 days after pouring the concrete cubes.

8.4.4 For Mix S1 For cubes 28 day test

Table 8.4.4.1 : Shows concrete mix proportions

Constituent of concrete mix (1 m^3)											
Mix	CBP % from cement	GP % from fine agg.	Mix	Cement	CBP (kg/m^3)	SP (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	GP (kg/m^3)	Total fine aggregates (kg/m^3)	Dolomite (kg/m^3)
S1	0%	0%	S1	500	0	10	150	603	0	603	1206

Table 8.4.4.2 : It shows the test date, temperature, cube weight and pressure value

Mix	28 days								
	Test Date	Cubes lab degree		Cubes 150 degree		Cubes 300 degree		cubes 450 degree	
		Weight (kg)	Comp.strenght	Weight	comp.srenght	Weight	comp.strenght	Weight	comp.srenght
S1	6/5/2024	2.435	454 Mpa	2.317	226.25 Mpa	2.33	259 Mpa	2.17	384.5 Mpa

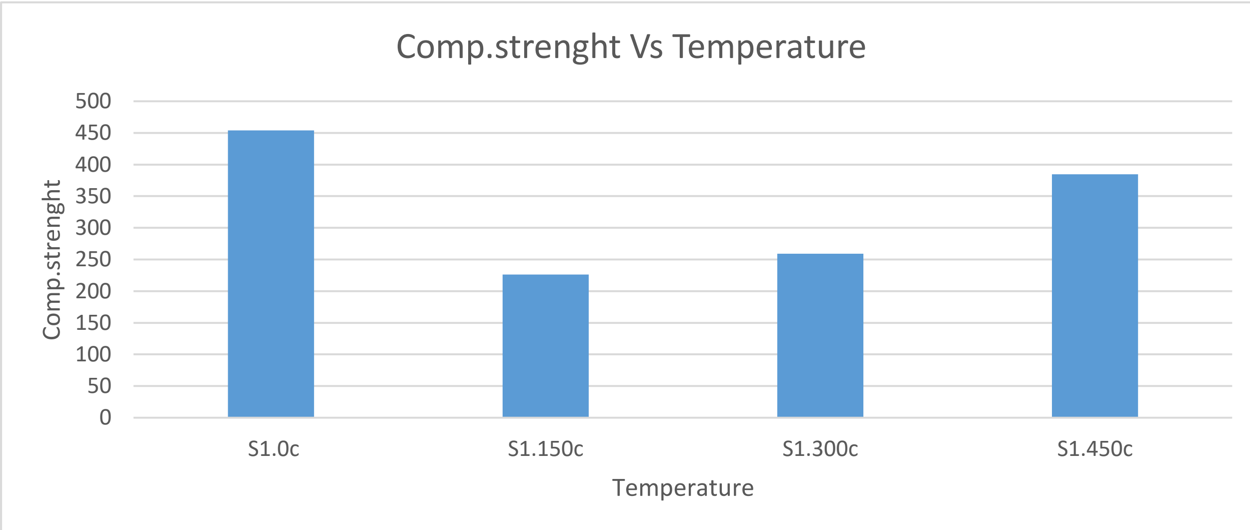


Figure 8.4.4.1 : Explains the relationship between temperature and pressure □100% cement and 100% sand□

Traditional international standard specifications for concrete mix composition

Table 8.4.4.1 and 8.4.4.2 and Figure 8.4.4.1 show the effect of test the compressive strength of Mix S1 after 28 days under the influence of different temperatures and monitor the changes that occur without any replacement or replacement of any component of the concrete mix.

8.4.5 For Mix S2 For cubes 28 day test

Table 8.4.5.1 : Shows the concrete mix proportions for S2

Constituent of concrete mix (1 m^3)											
Mix	**CBP % from cement**	**GP % from fine agg.**	**Mix**	**Cement**	**CBP (kg/m^3)**	**SP (kg/m^3)**	**Water (kg/m^3)**	**Sand (kg/m^3)**	**GP (kg/m^3)**	**Total fine aggregates (kg/m^3)**	**Dolomite (kg/m^3)**
S2	**20%**	**0%**	**S2**	**400**	**100**	**10**	**150**	**593**	**0**	**593**	**1185**

Table 8.4.5.2 : It shows the test date, temperature, cube weight and pressure value

Mix	**28 days**								
	Test Date	**Cubes lab degree**		**Cubes 150 degree**		**Cubes 300 degree**		**cubes 450 degree**	
		Weight (kg)	**Comp.strenght**	**Weight**	**comp.srenght**	**Weight**	**comp.strenght**	**Weight**	**comp.srenght**
S2	**6/5/2024**	**2.505**	**442**	**2.48**	**368**	**2.352**	**387.5**	**2.212**	**425**

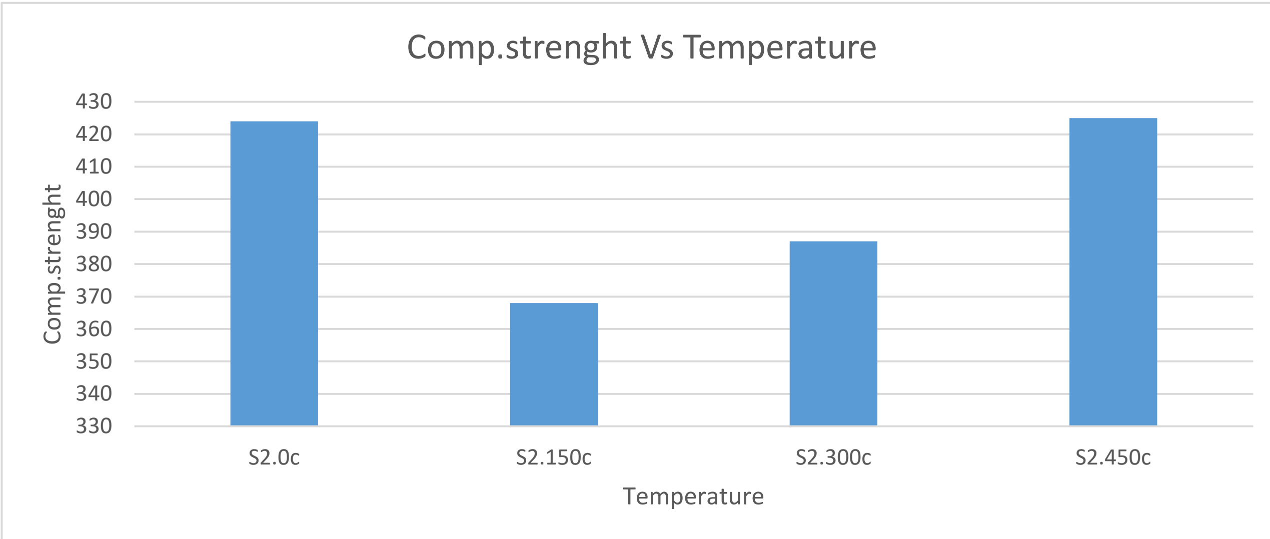


Figure 8.4.5.1 : Explains the relationship between temperature and pressure
(80% cement, 100% sand, and 20% red brick)

Table 8.4.5.1 and 8.4.5.2 and Figure 8.4.5.1 show the effect of testing the compressive strength of Mix S2 after 28 days under the influence of different temperatures and monitoring the changes that occur using a 20% cement substitute, so that the amount of cement becomes 400 kg instead of 500 kg in the components of the concrete mixture and adding bricks at a rate of 20% of the original amount of cement.

8.4.6 For Mix S3 For cubes 28 day test

Table 8.4.6.1 : Shows concrete mix proportions for S3

Constituent of concrete mix (1 m^3)											
Mix	CBP % from cement	GP % from fine agg.	Mix	Cement	CBP (kg/m^3)	SP (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	GP (kg/m^3)	Total fine aggregates (kg/m^3)	Dolomite (kg/m^3)
S3	0.2	20%	S3	400	100	10	150	474	119	593	1185

Table 8.4.6.2 : It shows the test date, temperature, cube weight and pressure value

Mix	28 days								
	Test Date	Cubes lab degree		Cubes 150 degree		Cubes 300 degree		cubes 450 degree	
		Weight (kg)	Comp.strenght	Weight	comp.srenght	Weight	comp.strenght	Weight	comp.srenght
S3	5/23/2024	2.456	424	2.391	440.3	2.415	447	2.316	530.6

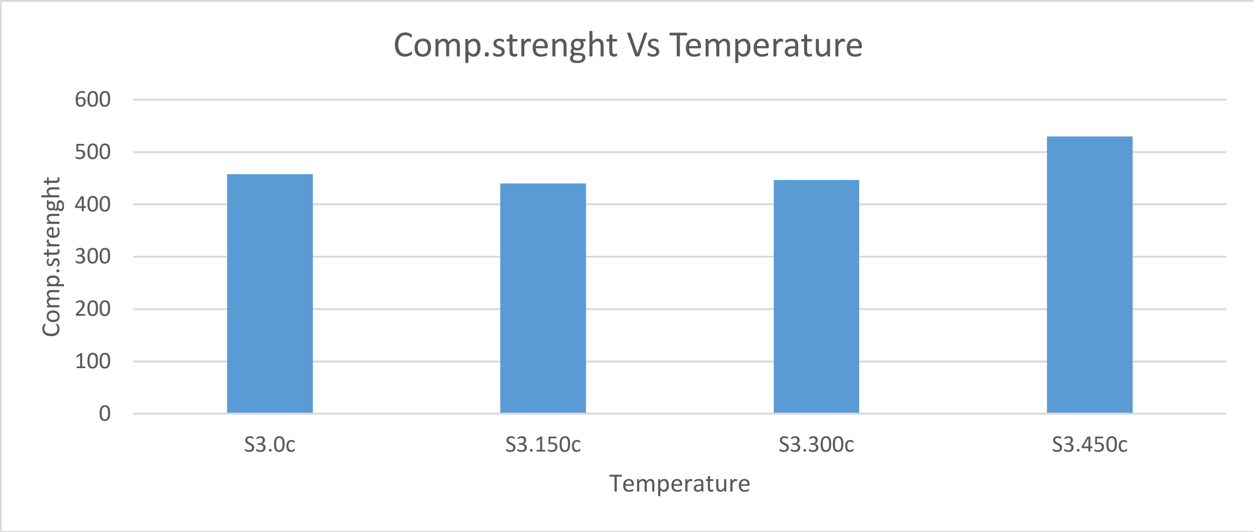


Figure 8.4.6.1 : Explains the relationship between temperature and pressure
 80% cement, 20% red brick, 80% sand, and 20% marble.

Table 8.4.6.1 and 8.4.6.2 and Figure 8.4.6.1 show the effect of test the compressive strength of Mix S3 after 28 days under the influence of different temperatures and monitor the changes that occur using a 20% cement substitute so that the amount of cement becomes 400 kg instead of 500 kg in the components of the concrete mix with the addition of brick powder at a rate of 20% of the original amount of cement and the 20% replacement the amount of sand in the mixture is 20% of the amount of main cement to the percentage of sand in the mixture in marble powder.

8.4.7 For Mix S4 For cubes 28 day test

Table 8.4.7.1 : Shows concrete mix proportions for S4

Constituent of concrete mix (1 m^3)											
Mix	CBP % from cement	GP % from fine agg.	Mix	Cement	CBP (kg/m^3)	SP (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	GP (kg/m^3)	Total fine aggregates (kg/m^3)	Dolomite (kg/m^3)
M4	0.2	40%	M4	400	100	12	150	356	237	593	1185

Table 8.4.7.2 : It shows the test date, temperature, cube weight and pressure value

Mix	28 days								
	Test Date	Cubes lab degree		Cubes 150 degree		Cubes 300 degree		cubes 450 degree	
		Weight (kg)	Comp.strenght	Weight	comp.srenght	Weight	comp.strenght	Weight	comp.srenght
S4	5/23/2024	2.415	441	2.35	372.3	2.315	376.6	2.168	484

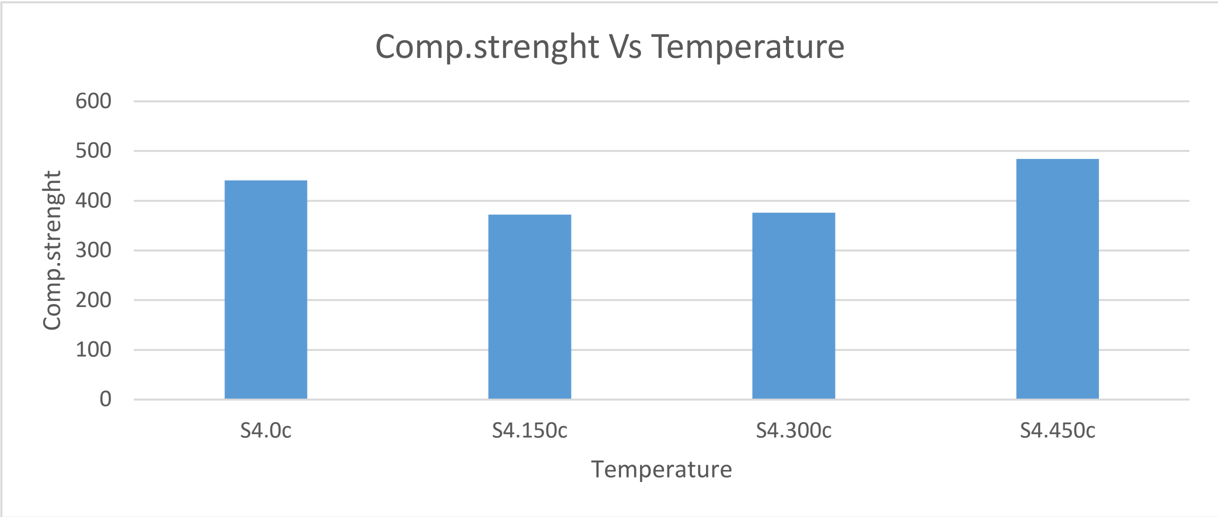


Figure 8.4.7.1 : Explains the relationship between temperature and pressure
 80% cement, 20% red brick, 60% sand, and 40% marble.

Table 8.4.7.1 and 8.4.7.2 and Figure 8.4.7.1 show the effect of test the compressive strength of Mix S4 after 28 days under the influence of different temperatures and monitor the changes that occur using a 20% cement substitute, so that the amount of cement becomes 400 kg instead of 500 kg in the components of the concrete mix, with the addition of brick powder at a rate of 20% of the original cement amount and a 40% replacement. From the amount of sand in the mixture at 40% of the base material, the percentage of sand in the mixture in marble powder.

8.4.8 For Mix S5 For cubes 28 day test

Table 8.4.8.1 : Shows concrete mix proportions for S5

Constituent of concrete mix (1 m^3)											
Mix	**CBP % from cement**	**GP % from fine agg.**	**Mix**	**Cement**	**CBP (kg/m^3)**	**SP (kg/m^3)**	**Water (kg/m^3)**	**Sand (kg/m^3)**	**GP (kg/m^3)**	**Total fine aggregates (kg/m^3)**	**Dolomite (kg/m^3)**
S5	**0.2**	**60%**	**S5**	**400**	**100**	**12**	**150**	**237**	**356**	**593**	**1185**

Table 8.4.8.2 : It shows the test date, temperature, cube weight and pressure value

Mix	28 days								
	Test Date	Cubes lab degree		Cubes 150 degree		Cubes 300 degree		cubes 450 degree	
		Weight (kg)	Comp.strength	Weight	comp.srenght	Weight	comp.strenght	Weight	comp.srenght
S5	5/27/2024	2.355	353.6	2.39	340.6	2.66	331	2.178	478.3

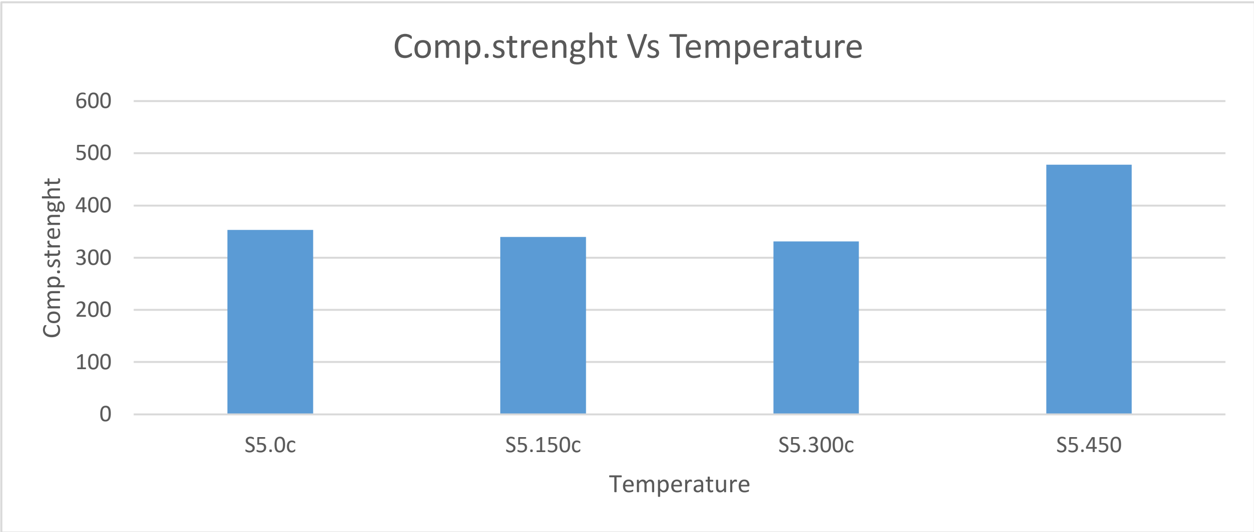


Figure 8.4.8.1 : Explains the relationship between temperature and pressure

 80% cement, 20% red brick, 40% sand, and 60% marble.

Table 8.4.8.1 and 8.4.8.2 and Figure 8.4.8.1 show the effect of test the compressive strength of Mix S5 after 28 days under the influence of different temperatures and monitor the changes that occur using a 20% cement substitute, so that the amount of cement becomes 400 kg instead of 500 kg in the components of the concrete mix, with the addition of brick powder at a rate of 20% of the original cement amount and replacing 60%. The amount of sand in the mixture is 60% of the base material to the amount of sand in the mixture in the marble powder.

8.4.9 For Mix S6 For cubes 28 day test

Tabe 8.4.9.1 : Shows concrete mix proportions for S6

Constituent of concrete mix (1 m^3)											
Mix	CBP % from cement	GP % from fine agg.	Mix	Cement	CBP (kg/m^3)	SP (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	GP (kg/m^3)	Total fine aggregates (kg/m^3)	Dolomite (kg/m^3)
M6	0.2	80%	M6	400	100	12	150	119	474	593	1185

Table 8.4.9.2 : It shows the test date, temperature, cube weight and pressure value

Mix	28 days								
	Test Date	Cubes lab degree		Cubes 150 degree		Cubes 300 degree		cubes 450 degree	
		Weight (kg)	Comp.strenght	Weight	comp.srenght	Weight	comp.strenght	Weight	comp.srenght
S6	5/27/2024	2.431	332.6	2.418	312.3	2.378	315	2.168	385

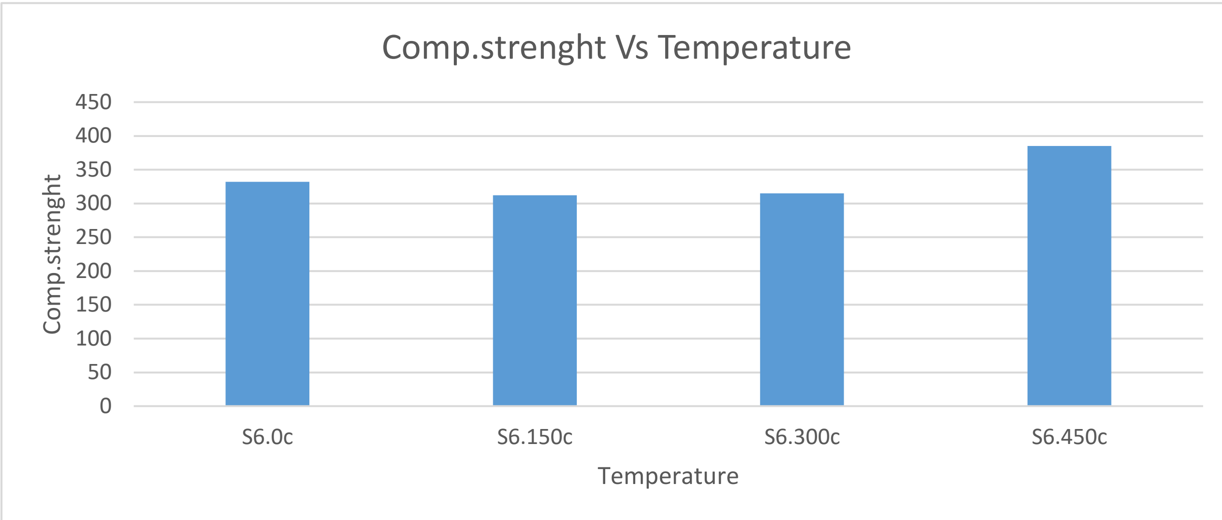


Figure 8.4.9.1 : Explains the relationship between temperature and pressure

 80% cement, 20% red brick, 20% sand, and 80% marble.

Table 8.4.9.1 and 8.4.9.2 and Figure 8.4.9.1 show the effect of compressive strength test after 28 days under the influence of different temperatures and monitoring the changes occurring using a 20% cement replacement. So that the amount of cement becomes 400 kg instead of 500 kg in the components of the concrete mixture, adding brick powder at 20% of the original amount of cement and replacing 80% of the amount of sand in the mixture with 80% of the main amount of sand in the mixture in marble powder.

8.4.10 For Mix S7 For cubes 28 day test

Table 8.4.10.1 : Shows concrete mix proportions for S7

Constituent of concrete mix (1 m^3)											
Mix	CBP % from cement	GP % from fine agg.	Mix	Cement	CBP (kg/m^3)	SP (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	GP (kg/m^3)	Total fine aggregates (kg/m^3)	Dolomite (kg/m^3)
S7	0.2	100%	S7	400	100	12	150	0	593	593	1185

Table 8.4.10.2 : It shows the test date, temperature, cube weight and pressure value

Mix	28 days								
	Test Date	Cubes lab degree		Cubes 150 degree		Cubes 300 degree		cubes 450 degree	
		Weight (kg)	Comp.strenght	Weight	comp.srenght	Weight	comp.strenght	Weight	comp.srenght
S7	6/5/2024	2.368	311.6	2.373	315	2.161	426	2.313	358

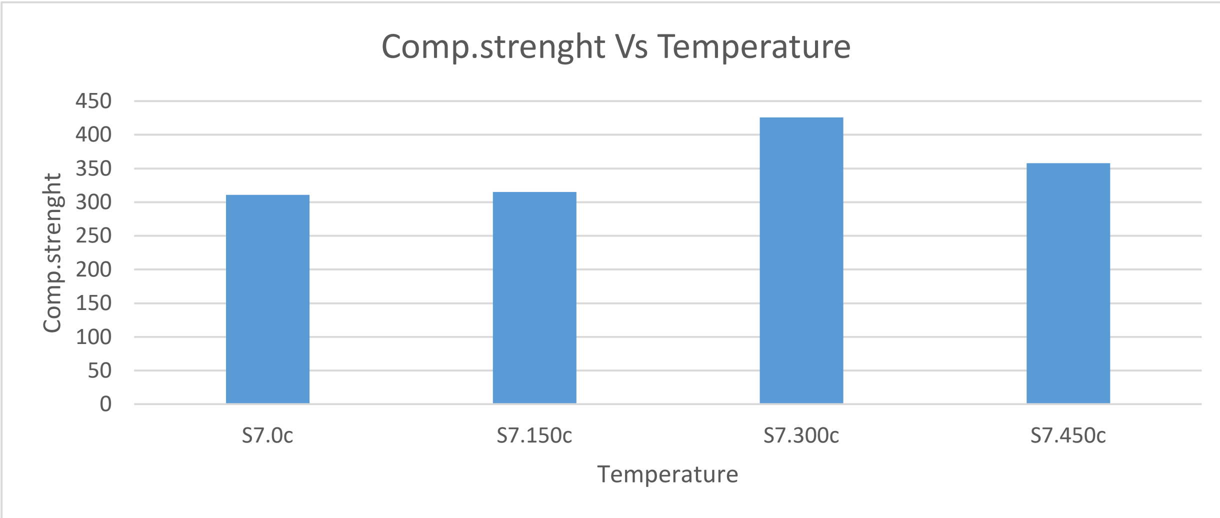


Figure 8.4.10.1 : Explains the relationship between temperature and pressure

 80% cement, 20% red brick, 0% sand, and 100% marble.

Table 8.4.10.1 and 8.4.10.2 and Figure 8.4.10.1 show the effect of compressive strength test after 28 days under the influence of different temperatures and monitoring the changes occurring using a 20% cement replacement. The amount of cement becomes 400 kg instead of 500 kg in the components of the concrete mixture, adding brick powder at 20% of the original cement quantity, and replacing 100% of the amount of sand in the mixture with 100% of the main amount of sand in the mixture in marble powder.

 In this case, sand was completely excluded from the components

8.4.11 Testing of cylinders mixers S

Table 8.4.11.1 : Shows the Brazilian tensile test date, weight and durability of the cylinders

Mix	Test Date	Cylinders		
		Weight (kg)	Load (KN)	Strenght (Mpa)
S1	5/26/2024	12.56	306	4.3
S2	5/26/2024	12.24	284	3.89
S3	5/26/2024	12.53	252	3.5
S4	5/26/2024	12.667	270	3.75
S5	5/26/2024	12.475	235.5	3.25
S6	5/26/2024	12.115	207	2.85
S7	5/26/2024	11.95	180	2.5

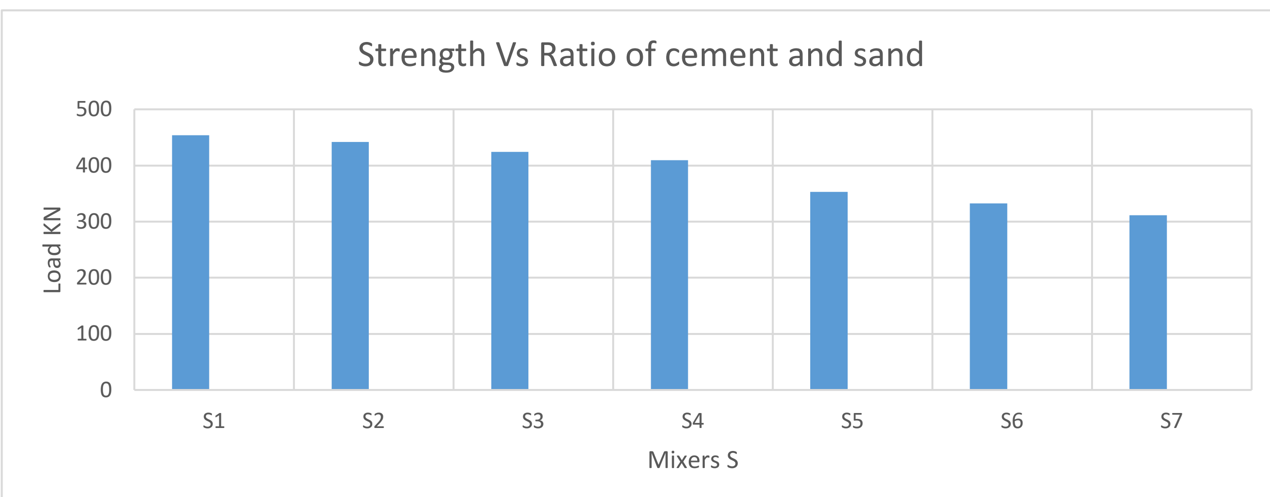


Figure 8.4.11.1 : The relationship between Brazilian tension and the change in the proportions of cement and sand

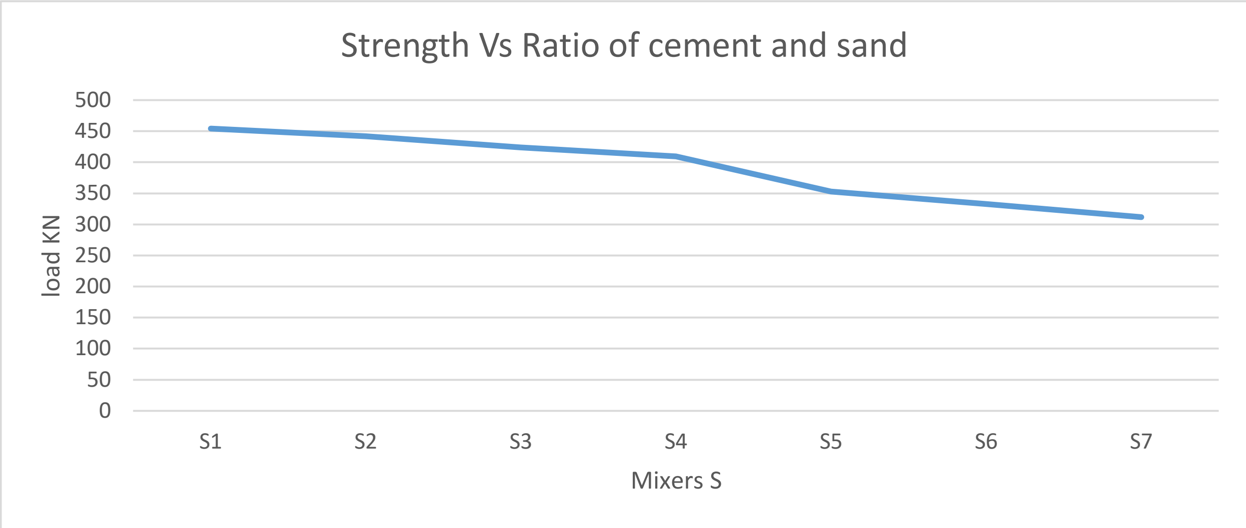


Figure 8.4.11.2 : The relationship between Brazilian tension and the change in the proportions of cement and sand

The effect of the Brazilian compression test on cylinders

Table 8.4.11.1 and Figure 8.4.11.1 and 8.4.11.2 show the effect of the purpose of conducting the Brazilian tensileor indirect tensile test is to determine the total tensile strength of the concrete, so this test was conducted on all M! mixtures. S1. S2. S3. S4. S5. S6. S7. Comparison between the tensile strength of the mixture and the type of mixture according to the components and their proportions of quantities

This test can be performed using devices such as VTS or VICTORY TEST or GCTS device

We notice in this curve that mixture S1 has the largest value, meaning that it has the highest ability to withstand tensile stress. The stress decreases as the ratio of cement and sand changes, then increases again in S4 and then decreases again.

8.4.12 Testing of concrete Beams for S mixers

Table 8.4.12.1 : Shows the test date, weight and pressure of the Beams.

Mix	Test Date	Beams		
		Load (KN)	Strenght (Mpa)	Deflection (mm)
S1	5/26/2024	6.218	0.176	0.7
S2	5/26/2024	2.84	0.122	0.27
S3	5/26/2024	5.683	0.161	0.5
S4	5/26/2024	6.23	0.176	0.375
S5	5/26/2024	5.558	0.157	0.43
S6	5/26/2024	4.213	0.119	0.31
S7	5/26/2024	4.648	0.132	0.375

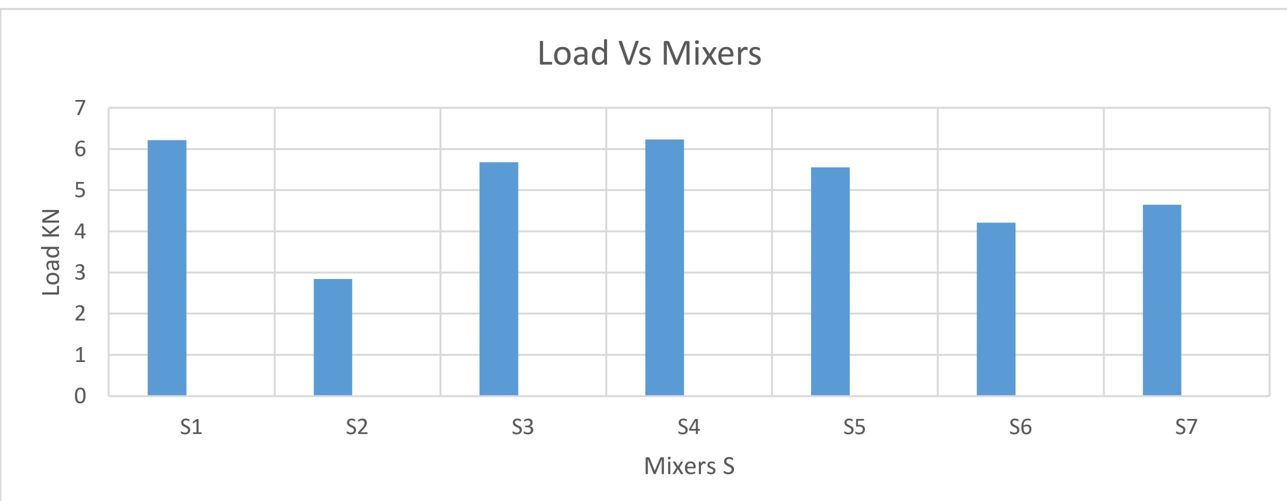


Figure 8.4.12.1 : The relationship between the bending strength of the Beams and the change in the proportions of cement and sand

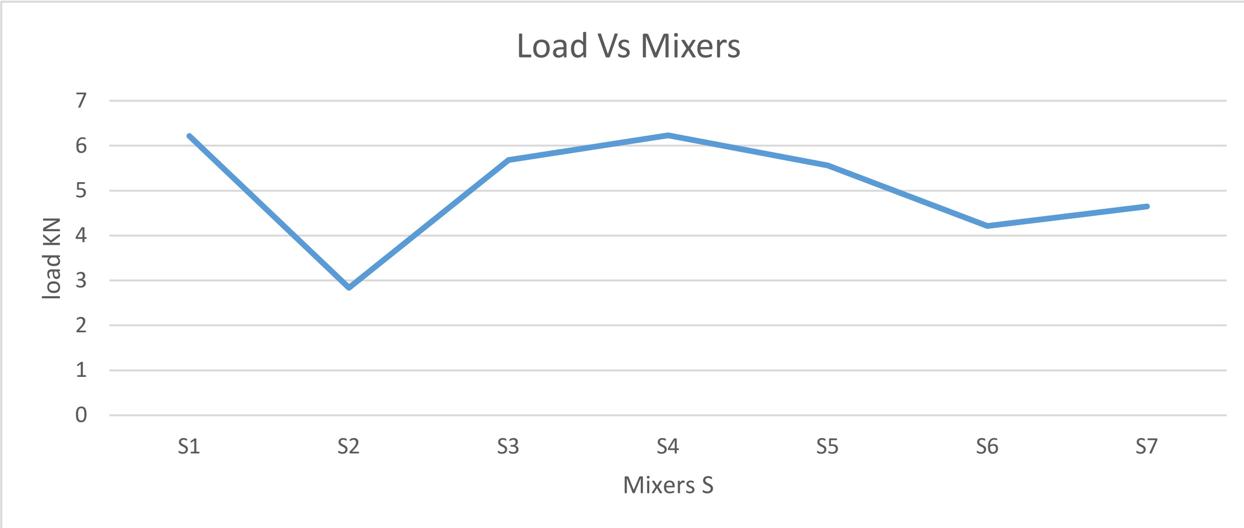


Figure 8.4.12.2 : The relationship between the bending strength of the cameras and the change in the proportions of cement and sand

Table 8.4.12.2 and Figure 8.4.12.1 and 8.4.12.2 show the effect of the bending or marbling test determines the extent of resistance to the resulting bending force and the shape of cracks and fractures, including that it appears that the resistance of the concrete mixture when bending is higher than its resistance when tensile the refore, it is determined the extent to which the mixture can resist its highest stress, and the comparison is based on that. Between each mixture the bending resistance to determine the change in the components of the concrete the mixture and adding other quantities causes a change in marbling the resistance between each of the mixtures is S1. S2. S3. S4. S5. S6. S7.

8.7 Conclusion

In this study, it was proved that the temperature effects on the concrete mixture, such as (Coarse aggregate, fine aggregateand water) and affects additions added on Concrete mixture such as (marble powder, brick powder, and Sikament R2004).Additives such as marble powder, brick powder and sikamant 2004 to see How does it affect the concrete mix after 7 days and 28 days and see how the behavior of the Concrete after testing under pressure.

After testing the concrete after 7 days period we reached the following:

1- For the normal mixture the comp. strength was 214 kg/Cm^2.

2-After adding 20 % of CBP the comp .strength increased to 251 kg/Cm^2.

3- After adding 20 % of MP instead of sand the comp .strenght increased to be 395 kg/Cm^2, and increased by 57.3 % compared to S2

4- After adding 40 % of MP the comp. strength increased to be 434 kg/cm^2, and increased by 72.9 % compared to S2

5-After adding 60 % of MP the comp. Strength decreased to be 313 kg/cm^2, and increased by 24.7 % compared to S2

6- After adding 80 % of MP the comp. strength decreased to be 315.33 kg/cm^2, and decreased by 25.6 % compared to S2

7-After adding 100 % of MP the comp. strength decreased to be 217 kg/cm^2, and decreased by 12 % compared to S2

After 28 days period and testing after raising the temperature by (150,300,450 degree) we also reached the following

1-for the normal mixture the comp. strength was (000, 226, 259 and 284 kg/cm^2) for lab degree, 150, 300, 450 degree.

2-After adding 20% of CBP the comp. strength was (442, 368, 387 and 425 kg/cm^2) for each degree.

3 - After adding 20% of MP the comp. strength was (424, 440, 447 and 530 kg/cm^2) And increased by (4%, 19%, 15%) for (lab degree,150 and 300) and increased by 20% at 450 degree all compared to S2 at each degree.

4 - After adding 40% of MP the comp. strength was (441, 372, 376 and 484 kg/cm^2), And decreased by 0.22% at lab degree, increased by (0.01% at 150, and decreased by 0.2% at 300, And 13.8% compared to S2 at each degree.

5 - After adding 60% of MP the comp. strength was (353, 340, 331 and 478 kg/cm^2), And decreased by (20 %, 7%, 14.4%), Then increased by 11% at 450 degree all compared with S2

6 - After adding 80% of MP the comp. strength was (332, 312, 315 and 385 kg/cm^2), And decreased by (24.8%, 15.2%, 18.6%, 9.4%) and all compared to S2 at each degree.

7- After adding 100 % of MP the comp. strength was (311, 315, 426 and 358 kg/cm^2), And decreased by (29.6% and 14.4%) for lab degree and 150, then increased by 10% at 300, And decreased by 15.7% at 450 all compared to S2 at each degree.

After testing Beams and Cylinders we reached the following:

For the beams after adding 20% of CPB and (20,40,60,80 and 100%) of GP on each mix It was clear that 40 % of MP was the best mixture (6.23 KN) for the load, (0.375 Mpa) for the strength and least deflection which was (0.27 mm), And the load increased by (100.1% for S3, 119.3% for S4, 95.7% for S5, 48.3% for S6 and 63.6% for S7), all compared to S2.

For the Cylinders after adding 20 % of CPB and (20, 40, 60, 80 and 100 %) of MP on each mixture it was clear that 40 % of MP was the best mixture (270 KN) for the load and (3.75 Mpa) for the strength, And the load decreased by (11.2% for S3, 4.9% for S4, 17% for S5, 27.1% for S6, 36.6% for S7) all compared to S2.

References

- Concrete Technology by: R.P. Rethaliya - Atul Prakashan Concrete Technology by M.S. Shetty Intemet websites
- Nawy, E.G., (2008). Concrete Construction Engineering Handbook: Chapter 3- Chemical Admixtures. by David P. Whitney, DOI: 10.1201/9781420007657.ch3
- Graybeal, Ben. 2014. Design and Construction of Field-Cast UHPC Connections. Publication No. FHWA-HRT-14-084. National Technical Information Service, McLean, Virginia, USA.11-16.
- Richard, P., and Cheyrezy, M.H. 1994. Reactive Powder Concretes with High Ductility and 200-800 MPa Compressive Strength, ACI, SP-144(24),San Francisco, California, USA, 507-518.
- Tadros, M. K., and Morcous, G. 2009. Application of Ultra-High Performance Concrete to Bridge Girders. Nebraska Department of Roads (NDOR) Project Number P310, Lincoln, NE, USA, 72.
- Voo, Y. L., Foster, S. J., and Hassan, M. F. 2014. The Current State of Art of Ultra-High Performance Concrete Bridge Construction in Malaysia, Proceedings of the 12th International Conference on Concrete Engineering and Technology. 12-14 Aug, Selangor, Malaysia, 95-102.
- Wille, K., Naaman, A.E., and El-Tawil, S. 2011. Optimizing Ultra-High Performance Fiber- Reinforced Concrete. Concrete International, 33(9): 35-41.
- Caijun Shi, Zemei Wu, Jianfan Xiao, Dehui Wang, Zhengyu Huang, Zhi FangA review on ultra high performance concrete: Part I. Raw materials and mixture design Construction and Building Materials 101 (2015) 741 751
- Ultra-High Performance Concrete:A State-of-the-Art Report for the Bridge Community, Research, Development, and Technology Turner-Fairbank Highway Research Center, Publication No. FHWA-HRT-13-060, JUNEv2013.

- N.M.Azmee, N. Shafiq, Ultra-high performance concrete: From fundamental to applications, Case Studies in Construction Materials.9, 2018
- EFNARC, the European federation dedicated to specialist construction chemicals and concrete systems.
- ACI (American Concrete Institute). (2014). Building code requirements for reinforced concrete. ACI 318-14.
- JSCE Guidelines for Concrete, Standard specifications for concrete structures-2007, Japan.
- NZS 3101. (2006), the design of concrete structures.
- Australian code AS 3600. (2009). Australian standard for concrete structures (p. 213). North Sydney: Standards Australia.
- Subhan Ahmad, Qazi Inaam, "Shear strength of self-compacting concrete and recycled aggregate concrete beams"an appraisal of design codes Asian Journal of Civil Engineering, 2018.
- European Committee for! Standardization: EN 1992-1- 1:2004: Design of concrete structures- Part 1-1: General rules and rules for buildings, Brussels, 2004
- International Federation for Structural Concrete: fib Model Code for Concrete Structures 2010, Wilhelm Ernst & Sohn, Berlin, 2013
- Associação Brasileira de Normas Técnicas: ABNT NBR 6118:2014: Design of concrete structures Procedures, Rio de Janeiro, 2014 (in Portuguese).