Nile Higher Institute for Engineering & Technology

Department of Civil Engineering

"Properties and Strength of Materials Project"

"Strengthening of Various Concrete Specimens with different configuration using G/C FRP Sheets"

Supervisor

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“Strengthening of Concrete Specimens with FRP Sheets”

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ABSTRACT

Many efforts have been conducted on the strengthening of existing structures due to load increase, under-designing, or poor construction. Therefore, strengthening methods have become a necessity to increase the capacity of the existing structures and meet the various serviceability requirements.

This study presents an elaborated characterization of the utilized specimens, the material properties, the testing setup, instrumentation, and the testing procedure. The experimental program included six cylinder specimens 15Ǿ30 and and seven of 10Ǿ20 , eight cube specimens, and nine PC beam specimens. The cylinder specimen was with a side length of 200 mm and a diameter of 100 mm and other was with a side length of 300 mm and a diameter of 150 mm. The cube specimen was with length sides of 150*150*150 mm. The beam specimens were with a length of 500 mm and a cross section of 100*100 mm. Specimens were loaded up to failure under increasing static loads. For the cylinder, cube, and beam specimens, cylinder and cube specimens were tested in terms of compressive strength, and beams specimens were tested in terms of flexure strength. The compressive and bending strength tests were carried out according to the Egyptian Code for Design and Construction of Reinforced Concrete Structures, **ECP 203-2018**.

All experiments were carried out in the Material Lab. of the Faculty of Engineering, Nile higher institute, Mansoura city.

The test results demonstrate that the investigated strengthening techniques can be used to for enhancing both the compressive and flexural behavior of concrete specimens with GFRP sheets and even that load capacity can be increased compared to the control un-strengthened specimens.

Chapter 1

INITIAL REPORT

1.1 Project Definition

The field of strengthing 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. Cracking is a common occurrence in concrete bridge decks and barrier or parapet walls. The presence of cracks leads to poor durability and shorter service life of the structure. The successful repair of cracks would reduce the deterioration effects resulting in longer service life. Prolonging the service life defers the rehabilitation or replacement of the bridge and the government sectors responsible for the management of multiple bridges would experience economic benefits. The result of longer service life is also indicative of sustainable practice.

- Literature review: The aim is to get knowledge about the current state of the art -to gain awareness of the state-of-the-art techniques in strengthening concrete structures, in general.
- General information: The aim is to understand the failure mechanisms to develop methods for strengthening that are more efficient.
- Experimental investigations: The aim is to perform experiments in laboratory-controlled environments to obtain a better understanding of the properties of concrete strengthened with FRP.

1.2 The Problem

Find properties of concrete strengthened with FRP with a different configuration of strip widths as well as lengths.

1.3 Study Objectives

In this research, the main objectives were mainly concentrated on:

- Conclude the best properties of FRP material.
- Conduct tests on both fresh and hardened concrete.
- Increase the load-carrying capacity of concrete without reinforcement.

- Compare the different test results to find the best/optimum strengthening configuration.

1.4 Existing Solutions

Using FRP, the current research test results were compared with other similar research results that carried out in the previous work to reach a better judgment of such material.

To understand the effect of using such materials in different fields, the following study has been investigated.

1.5 Design Constraints

The primary constraints faced during our research work are classified into the following categories:

1.5.1 Economic

There is a need to search for financial support sources for students, or full and/or partial grants to contribute for solving some of the problems that may be faced.

1.5.2 Environmental

No direct environmental constraints, but the process of concrete technology in general such as its production initiating from the process of cement manufacturing ending with a partial/total replacement of the defected/deteriorated concrete is significantly affecting the environment.

1.5.3 Sustainability

For the time being, there is nothing can constrain the sustainability as well as terminate it.

1.5.4 Ethical

During the different project stages, no ethical constraints were faced.

1.5.5 Health and Safety

There was some concern about the safety of students when dealing with concrete materials and saturated materials, especially the strengthening FRP materials as well as the application of its different techniques. Therefore, cares and the necessary precautions should be followed.

1.5.6 Social and Political

The establishment of several seminars and meetings involving both students and professors, which pose academic and administrative problems, and everyone, is working to provide appropriate solutions, which increase the social bond between students and their tutors.

It is necessary to mention that *all the experimental work starting from design stage, followed by production stage ending with testing stage for the specimens examined in this project is conducted according to both the Egyptian Code for Design and Construction of Reinforced Concrete Structures, ECP 203-2018, and Egyptian Code of Practice for The Use of Fiber Reinforced Polymer (FRP) in the Construction Fields, ECP 208-2005 requirements. Moreover, all Egyptian standards in the field of construction products are nearly harmonized with the international, European, or foreign standards.*

1.6 Concrete mix

The concrete mixture produced at the concrete laboratory by mix design using the absolute volume method. This method assumes that the absolute volume of concrete is the sum of the absolute volumes of the constituent materials. For concrete i.e., the absolute volume of cement, sand, gravel, and water is as follows:

C = 450 kg ***S*** = 550 kg ***G*** = 1065 kg ***W*** = 250 lit

"This amount for 1 Cubic meter"

Where:

C*: weight of cement in kilograms needed per cubic meter of concrete.*
S: *weight of sand in kilograms needed per cubic meter of concrete.*
G: *weight of gravel in kilograms needed per cubic meter of concrete.*
W: *weight of water in kilograms needed per cubic meter of concrete.*

This concrete mixture was designed to develop (35 MPa) for cube strength. The concrete mixing was done mechanically by mixing materials in a dry condition for two minutes, then gradually adding water and continuing the mixing for another two minutes. Table (3-3) gives the mass of the ingredients for a cubic meter of concrete. Figure (3-3) shows the components of the concrete mixture batch used in this study.

Chapter 02

Engineering Standards

02.1 Slump

02.1.1 test steps

Before starting the test, it is necessary to ensure that the inner surface of the mold is clean, moist and without any excess moisture. The mold is placed on a smooth, rigid, impermeable surface, in a completely horizontal position, and is not subject to vibrations and shocks.

The mold is well fixed above the horizontal surface and it contains the oppression if used, then it is filled with three layers of concrete, each of which represents one-third of the height of the mold after compaction, then compacting each layer 25 times with the standard compaction rod, provided that the times of compaction are evenly distributed over the cross-section of the layer, and compaction is for each layer. up to its full depth, taking into account making sure that the compaction rod did not hit the bottom surface hard when compacting the first layer, provided that the compacting rod passes slightly

Engineering Standards

when compacting the second and last layer to the layer directly below it, then the concrete is piled over the mold before compacting
the upper layer.
An additional amount of concrete should be placed on top of the mold during the compaction process. The
concrete surface is leveled by pricking and rotating the compactor bar. Then, while the mold is still installed, the bottom
surface is cleaned of any concrete that may have fallen on it or leaked from the bottom edge of the mold, and then the mold is removed
from the concrete by lifting it vertically slowly and carefully for a period of 5 to 10 seconds with the slightest movement.
lateral or torsional of the concrete, and the whole process must be carried out from initiation of filling to lifting of the formwork Non-stop and completed within 150 seconds.
Then the slump is measured immediately after the mold is lifted nearest 5 with using a ruler by setting the difference between

Engineering Standards

The mold height is between the highest point in the tested sample, and the following should be noted:

1- It is possible to find out some indications about the cohesion and operability of the mixture after the completion of the slump measurement by lightly tapping on the sides of the concrete with a compaction rod, where concrete with good proportions of its components and with noticeable slumping occurs another gradual slump, but it happens to the concrete Poorly proportioned ingredients can fall flat.

2- The workability of the concrete mix changes with time as a result of cement sedimentation (cement interaction with water) and also as a result of moisture loss. Therefore, tests must be carried out on different samples at standard intervals after adding the mixing water if completely comparable results are to be obtained.

02.2 Density

02.2.1 steps of the test

1-Determine the mass of the sample

- The mass of the sample as it was received in the laboratory (W): it is determined by its weight on the scale, then the reading (W) is

recorded. - The mass of the sample saturated with water (W): It is determined when weighing it after immersing it in water at a temperature of 20 ° C until two successive weights prove the time difference between them is 24 hours (the weight is considered constant

if the change in it does not exceed 0.2% before weighing the sample and drying its surface with a damp cloth

Oven-dry mass (W2): It is determined after drying the sample in a ventilated oven at a temperature of 100 °C until two successive weights are fixed, the time difference between them is 24 hours (the weight is considered constant if

The change in it did not exceed 0.2%.

1-6-2- Determine the sample size

Determining the size by displacement method is used for samples with irregular shapes, and this method is not

suitable for samples whose nature requires not to change their moisture content, or light concrete containing large voids, or concrete that does not contain small aggregates and has large voids. - The sample is saturated with water, then weighed and its weight (W) is determined in kilograms as in item (1-6-1-7)

- The sample is placed on the stand, then immersed in water, and its weight is determined while it is immersed in water, after getting rid of any air bubbles that are attached to the surface of the sample, and let it be (W) kg.
- The weight is corrected after subtracting the weight of the carrier empty while it is immersed in water to the same depth at which the weight of the sample was measured, and the corrected weight is (W) kg. The volume of the sample in cubic meters is determined by the relationship:

- Determining the size of the sample by direct measurement. In the event that the sample has a regular shape, its dimensions can be measured and the volume can be calculated from it, then the vernier caliper can be used for this purpose, with the dimensions recorded to the nearest mm.

02.3 Comp

02.3.1 test steps

The surface of the machine loading plate and the sample loading surface shall be cleaned.

- The sample is placed on the lower plate of the machine and its axis is adjusted to match the load axis of the machine - The error in adjusting the axiality should not exceed 1/100 of the length or diameter of the sample. - When the contact between the upper machine plate and the sample begins, the spherical support is adjusted to ensure an even distribution

To load onto the sample loading surface.

- The load is increased regularly at a constant rate between 0.6 - 0.4 N/mm/sec.

The slow loading rate is used for low strength concrete samples, while the slow loading rate is used for low strength concrete samples

Rapid loading of high strength concrete samples.

- When the sample formation begins to increase rapidly before it completely collapses, the tester must stop any modification in the loading rate and leave the sample forming under the influence of the load without changing the loading rate.

- The load is increased until complete collapse of the sample occurs and the collapse load is determined.

02.4 Flexure

02.4.1 test steps

The dimensions of the sample are measured and each dimension is calculated as an average

of three measurements. - The sample is placed in the testing machine on the two support pillars, so that the support or loading is not on a surface

Casting.

Loading does not begin until all supports are in uniform contact with the sample. Bearing

the sample at a rate of 0.06 - 0.04 N/mm/sec regularly until fracture. The fracture load shall be

specified for samples whose fracture surface is located in the middle third of the sample sea. The results in which the fracture appears outside the

middle third of the sea must be excluded. - In the case of using gaskets between the abutments and the beam, this must be taken into account when calculating the stresses by increasing the depth of the beam by the amount of gaskets, if the fracture occurred under the abutment.

Chapter 2

(Introduction to Concrete Technology)

2.1 Definition of concrete:

Concrete is the most commonly used man-made material on earth. It is an important construction material used extensively in buildings, bridges, roads and dams. Its uses range from structural applications, to kerbs, pipes and drains. Concrete is a mixture of binding material, aggregates and water in a definate proportion.

2.2 Types of concrete:

1. Cement concrete:

It is a mixture of cement, fine aggregates, coarse aggregates and water in a definite proportion.

2. Lime concrete: Here binding material is lime (CaO)

3. RCC: Steel reinforcing is done in the CementConcrete.

4. Prestressed cement concrete:This concrete is a form of concrete used in construction which is "pre-stressed" by being placed under compression prior to supporting any loads beyond its own dead weight. This compression is produced by the tensioning of high-strength "tendons" located within or adjacent to the concrete volume, and is done to improve the performance of the concrete in service.

2.3 Uses of concrete:

Many structural elements like footings, columns, beams, chejjas, lintels, roofs are made with R.C.C. Cement concrete is used for making storage structures like water tanks, bins, silos, bunkers etc. Bridges, dams, retaining walls are R.C.C. structures in which concrete is the major ingradienting storage structures like water tanks, bins, silos, bunkers etc.

2.4 Benefits of concrete:

There are numerous positive aspects of concrete:

1. It is a relatively cheap material and has a relatively long life with few. maintenance requirements
2. It is strong in compression.
3. Before it hardens it is a very pliable substance that can easily be shaped
4. It is non-combustible.

2.5 Limitations of concrete:

The limitations of concrete include:

1. Relatively low tensile strength when compared to other building materials.
2. Low ductility.
3. Low strength-to-weight ratio.
4. It is susceptible to cracking.

2.6 Ingredients of concrete

2.6.1 Cement:

cement is a binding material used in the masonry.

2.6.1.1 Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cementare based on:

1) Fineness of cement

2) Soundness

3) Consistency

4) Strength

Setting time Heat of hydration Loss of ignition

Bulk density

Specific gravity (Relative density)

These physical properties are discussed in details in the following segment.

Also, you will find the test names associated with these physical properties.

2.6.1.1.1 Fineness of Cement

The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last step of cement production process. As hydration rate of cement is directly related to

the cement particle size, fineness of cement is very important.

2.6.1.1.2 Soundness of Cement

refers to the ability of cement to not shrink upon hardening. Good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia. Tests: Unsoundness of cement may appear after several years, so tests for ensuring soundness must be able to determine that potential.

2.6.1.1.2.1 Le Chatelier Test

This method, done by using Le Chatelier Apparatus, tests the expansion of cement due to lime. Cement paste (normal consistency) is taken between glass slides and submerged in water for 24 hours at 20+1°C. It is taken out to measure the distance between the indicators and then returned under water, brought to boil in 25-30 mins and boiled for an hour. After cooling the device, the distance between indicator points is measured again. In a good quality cement, the distance should not exceed 10 mm.

2.6.1.1.3 Consistency of Cement

The ability of cement paste to flow is consistency. It is measured by Vicat Test. In Vicat Test Cement paste of normal consistency is taken in the Vicat Apparatus. The plunger of the apparatus is brought down to touch the top surface of the cement. The plunger will penetrate the cement up to a certain depth depending on the consistency. A cement is said to have a normal consistency when the plunger penetrates 10±1 mm.

2.6.1.1.4 Strength of cement

Three types of strength of cement are measured - compressive, tensile and flexural. Various factors affect the strength, such as water-cement ratio, cement- fine aggregate ratio, curing conditions, size and shape of a specimen, the manner of molding and mixing, loading conditions and age. While testing the strength, the following should be considered: Cement mortar strength and cement concrete strength are not directly related. Cement strength is merely a quality control measure. The tests of strength are performed on cement mortar mix, not on cement paste.

Cement gains strength over time, so the specific time of performing the test should be mentioned.

2.6.1.1.4.1 Compressive Strength

It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be

within 20 seconds and 80 seconds.

2.6.1.1.4.2 Tensile strength

Though this test used to be common during the early years of cement production, now it does not offer any useful information about the properties of cement.

2.6.1.1.4.3 Flexural strength

This is actually a measure of tensile strength in bending. The test is performed in a 40 x40 x 160 mm cement mortar beam, which is loaded at its center point until failure. Standard test: ASTM C 348: Flexural Strength of Hydraulic Cement Mortars.

2.6.1.1.5 Setting Time of Cement

Cement sets and hardens when water is added. This setting time can vary depending on multiple factors, such as fineness of cement, cement-water ratio, chemical content, and admixtures. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured: Initial set: When the paste begins to stiffen noticeably (typically occurs within 30-45 minutes) Final set: When the cement hardens, being able to sustain some load (occurs below 10 hours) Again, setting time can also be an indicator of hydration rate.

Standard Tests:

AASHTO T 131 and ASTM C 191: Time of Setting of Hydraulic Cement by Vicat Needle AASHTO T 154: Time of Setting of Hydraulic Cement by Gillmore Needles.

ASTM C 266: Time of Setting of Hydraulic-Cement Paste by Gillmore Needles.

2.6.1.1.6 Heat of Hydration

When water is added to cement, the reaction that takes place is called hydration. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress. The heat of hydration is affected most by C3S and C3A present in cement, and also by water-cement ratio, fineness and curing temperature. The heat of hydration of Portland cement is calculated by determining the difference between the dry and the partially hydrated cement (obtained by comparing these at 7th and 28th days). Standard Test: ASTM C 186: Heat of Hydration of Hydraulic Cement

2.6.1.1.7 Loss of Ignition

Heating a cement sample at 900 - 1000°C (that is, until a constant weight is obtained) causes weight loss. This loss of weight upon heating is calculated as loss of ignition. Improper and prolonged storage or adulteration during transport or transfer may lead to pre-hydration and carbonation, both of which might be indicated by increased loss of ignition. Standard Test: AASHTO T 105 and ASTM C 114: Chemical Analysis of Hydraulic Cement

2.6.1.1.8 Bulk density

When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from 62 to 78 pounds per cubic foot.

2.6.1.1.9 Specific Gravity (Relative Density)

Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of 3.15, but other types of cement (for example, portland-blast-furnace-slag and portlandpozzolan cement) may have specific gravities of about 2.90. Standard Test: AASHTO T 133 and ASTM C 188: Density of Hydraulic Cement

2.6.1.2 Chemical Properties of Cement

The raw materials for cement production are limestone (calcium), sand or clay (silicon), bauxite (aluminum) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. Chemical analysis of cement raw

materials provides insight into the chemical properties of cement.

2.6.1.2.1 Tricalcium aluminate (C3A)

Low content of C3A makes the cement sulfate-resistant. Gypsum reduces the hydration of C3A, which liberates a lot of heat in the early stages of hydration. C3A does not provide any more than a little amount of strength. Type I cement: contains up to 3.5% SO3 (in cement having more than 8% C3A) Type II cement: contains up to 3% SO3 (in cement having less than 8% C3A).

2.6.1.2.2Tricalcium silicate (C3S)

C3S causes rapid hydration as well as hardening and is responsible for the cement's early strength gain an initial setting.

2.6.1.2.3 Dicalcium silicate (C2S)

As opposed to tricalcium silicate, which helps early strength gain, dicalcium silicate in cement helps the strength gain after one week.

2.6.1.2.4 Ferrite (C4AF)

Ferrite is a fluxing agent. It reduces the melting temperature of the raw materials in the kiln from 3,000°F to 2,600°F. Though it hydrates rapidly, it does not contribute much to the strength of the cement.

2.6.1.2.5 Magnesia (MgO)

The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO-based cement also causes less CO2 emission. Allcement is limited to a content of 6% MgO.

2.6.1.2.6 Sulphur trioxide

Sulfur trioxide in excess amount can make cement unsound.

2.6.1.2.7 Iron oxide/ Ferric oxide

Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the color of the cement.

2.6.1.2.8 Alkalis

The amounts of potassium oxide (K_2O) and sodium oxide (Na_2O) determine the alkali content of the cement. Cement containing large amounts of alkali can cause some difficulty in regulating the setting time of cement. Low alkali cement, when used with calcium chloride in concrete, can cause discoloration. In slag-lime cement, ground granulated blast furnace slag is not hydraulic on its own but is "activated" by addition of alkalis. There is an optional limit in total alkali content of 0.60%, calculated by the equation Na20 +0.658 K_2O.

2.6.1.2.9 Free lime

Free lime, which is sometimes present in cement, may cause expansion. 2.6.1.2.10 Silica fumes

Silica fume is added to cement concrete in order to improve a variety of properties, especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume, it can grant exceptionally high strength. Hence, Portland cement containing 5-20% silica fume is usually produced for Portland cement projects that require high strength.

2.6.1.2.11 Allumina

Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical-resistant. It also quickens the setting but weakens the cement.

2.6.2 Aggregates:

What is an Aggregate?

Aggregates are the important constituents of the concrete which give body to the concrete and alsoreduce shrinkage. Aggregates occupy 70 to 80 % of total volume of concrete. So, we can say that one should know definitely about the aggregates in depth to study more about concrete.

2.6.2.1 Classification of Aggregates as per Size and Shape

Aggregates are classified based on so many considerations, but here we are going to discuss about their shape and size classifications in detail. 2.6.2.1.1

Classification of Aggregates Based on Shape

We know that aggregate is derived from naturally occurring rocks by blasting or crushing etc., so, it is difficult to attain required shape of aggregate. But, the shape of aggregate will affect the workability of concrete. So, we should take care about the shape of aggregate. This care is not only applicable to parent rock but also to the crushing machine used.

care is not only applicable to parent rock but also to the crushing machine used.

Aggregates are classified according to shape into the following types

- Rounded aggregates
- Irregular or partly rounded aggregate

- Angular aggregate
- Flaky aggregates
- Elongated aggregates
- Flaky and elongated aggregates

2.6.2.1.1.1 Rounded Aggregate

The rounded aggregates are completely shaped by attrition and available in the form of seashore gravel. Rounded aggregates result the minimum percentage of voids (32-33%) hence gives more workability. They require lesser amount of water-cement ratio. They are not considered for high strength concrete because of poor interlocking behavior and weak bond strength.

Figure 2-1 rounded aggregate

2.6.2.1.1.2 Irregular Aggregates

The irregular or partly rounded aggregates are partly shaped by attrition and these are available in the form of pit sands and gravel. Irregular aggregates may result 35-37% of voids. These will give lesser workability when compared to rounded

aggregates. The bond strength is slightly higher than rounded aggregates but not as required for high strength concrete.

Figure 2-2 irregular aggregates

2.6.2.1.1.3 Angular Aggregates

The angular aggregates consist well defined edges formed at the intersection of roughly planar surfaces and these are obtained by crushing the rocks. Angular aggregates result maximum percentage of voids (38-45%) hence gives less workability. They give 10-20% more compressive strength due to development of stronger aggregate-mortar bond. So, these are useful in high strength concrete manufacturing.

Figure 2-3 angular aggregates

2.6.2.1.1.4 Flaky Aggregates

When the aggregate thickness is small when compared with width and length of that aggregate it is said to be flaky aggregate. Or in the other, when the least dimension of aggregate is less than the 60% of its mean dimension then it is said to be flaky aggregate.

Figure 2-4 Flaky Aggregates

2.6.2.1.1.5 Elongated Aggregates

When the length of aggregate is larger than the other two dimensions then it is called elongated aggregate or the length of aggregate is greater than 180% of its mean dimension .

Figure 2-5 Elongated Aggregates

2.6.2.1.1.6 Flaky and Elongated Aggregates

When the aggregate length is larger than its width and width is larger than its thickness then it is said to be flaky and elongated aggregates. The above 3 types of aggregates are not suitable for concrete

Figure 2-6 Flaky and Elongated Aggregates

mixing. These are generally obtained from the poorly crushed rocks

2.6.2.1.2 Classification of Aggregates Based on Size

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

Aggregates are classified into 2 types according to size

- Fine aggregate
- Coarse aggregate

2.6.2.1.2.1 Fine Aggregate

When the aggregate is sieved through 4.75mm sieve, the aggregate passed through it called as fine aggregate. Natural sand is generally used as fine aggregate, silt and clay are also come under this category. The soft deposit consisting of sand, silt and clay is termed as loam. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Table 2-1 Fine Aggregate

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

Figure 2-7 Fine Aggregate

2.6.2.1.2.2 Coarse Aggregate

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

Table 2-2 Coarse Aggregate

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

2.6.2.1.2.3 Bulking of Sand

The increase in moisture of sand increases the volume of sand. The reason is that moisture causes film of water around sand particles which results in the increase of volume of sand. For a moisture content percentage of 5 to 8 there will be an increase in volume up to 20 to 40 percent depending upon sand. If the sand is finer there will be more increase in volume. This is known as bulking of sand.

Graphical representation of bulking of sand is shown below.

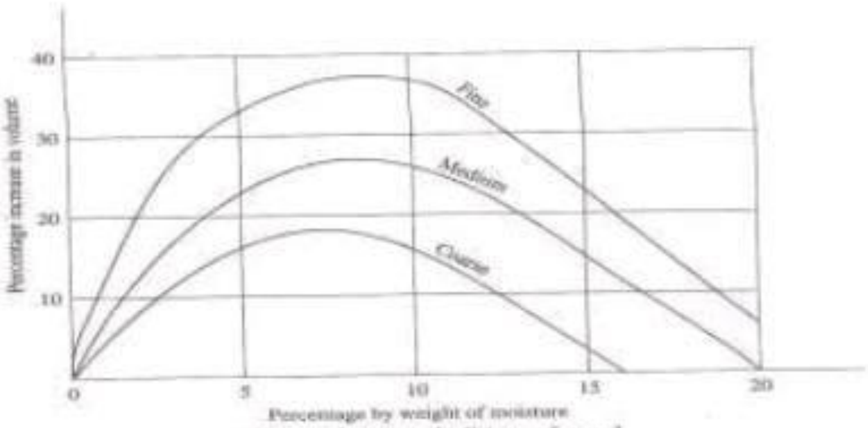

Chart showing bulking of sand

Figure 2-8 Bulking of Sand

When the moisture content of sand is increased by adding more water, the sand particles pack near each other and the amount of bulking of sand is decreased.

Thus, it helps in determining the actual volume of sand, the dry sand and the sand completely filled with water will have the exact volume. The volumetric proportioning of sand is greatly affected by bulking of sand to a greater extent. The affected volume will be great for fine sand and will be less for coarse sand. If proper allowance is not made for the bulking of sand, the cost of concrete and mortar increases and it results into under-sanded mixes which are harsh and difficult for working and placing.

2.6.2.2 SPECIFIC GRAVITY AND WATER ABSORPTIO TEST

AIM:

- To measure the strength or quality of the material
- To determine the water absorption of aggregates

APPARATUS:

The apparatus consists of the following

(a) A balance of capacity about 3kg, to weigh accurate 0.5g, and of such a type and shape as to permit weighing of the sample container when suspended in water.

(b) A thermostatically controlled oven to maintain temperature at 100-110°C.

(c) A wire basket of not more than 6.3 mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.

(d) A container for filling water and suspending the basket. (e) An air tight container of capacity similar to that of the basket.

(f) A shallow tray and two absorbent clothes, each not less than 75x45cm

THEORY: The specific gravity of an aggregate is considered to be a measure of strength or quality of the material.

Stones having low specific gravity are generally weaker than those with higher specific gravity values.

> PROCEDURE:

(i) About 2 kg of aggregate sample is washed thoroughly to remove fines, drained and placed in wire basket and immersed in distilled water at a temperature between 22-32° C and a cover of at least 5cm of water above the top of basket.

(ii) Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop at the rate of about one drop per second. The basket and aggregate should remain completely immersed in water for a period of 24 hour afterwards.

(iii) The basket and the sample are weighed while suspended in water at a temperature of 22° -32°C. The weight while suspended in water is noted =W1g,

(iv) The basket and aggregates are removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to the dry absorbent clothes. The empty basket is then returned to the tank of water jolted 25 times and weighed in water-W2g.

(v) The aggregates placed on the absorbent clothes are surface dried till no further moisture could be removed by this cloth. Then the aggregates are transferred to the second dry cloth spread in single layer and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. The surface dried aggregate is then weighed =W3 g

(vi) The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110° C for 24 hrs. It is then removed from the oven, cooled in an air tight container and weighted-W4 g. -Specific gravity = (dry weight of the aggregate /Weight of equal volume of water)

-Apparent specific gravity= (dry weight of the aggregate/Weight of equal volume of water excluding air voids in aggregate)

> OBSERVATIONS

- Weight of saturated aggregate suspended in water with basket =W1 g Weight of basket

suspended in water- W2g

- Weight of saturated aggregate in water = W1 - W2 g Weight of saturated surface dry aggregate in air = W3 g

- Weight of water equal to the volume of the aggregate = W3-(WI- W2)g Weight of oven dryaggregate = W4 g
- Specific gravity = W3/(W3-(W1-W2))

Apparent specific gravity W4/(W4-(W1- W2)) (3) Water Absorption =

((W3 W4)/W4) X 100

> RESULT: (1) Specific gravity=

(2) Apparent specific gravity =

(3) Water Absorption =

> RECOMMENDED VALUE:

The size of the aggregate and whether it has been artificially heated should be indicated, ISI specifies three methods of testing for the determination of the specific gravity of aggregates, according to the size of the aggregates. The three size ranges used are aggregates larger than 10 mm, 40 mm and smaller than 10 mm. The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68. Though high specific gravity is considered as an indication of high strength, it is not possible to judge the suitability of a sample road aggregate without finding the mechanical properties such as aggregate crushing, impact and abrasion values. Water absorption shall not be more than 0.6 per unit by weight.

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2.6.3 Water Cement Ratio

2.6.3.1 Hydration of Cement Introduction

Portland cement is a hydraulic cement; hence it derives its strength from chemical reactions between the cement and water. The process is known as hydration.

Cement consists of the following major compounds (see the composition of cement in table):

- Tricalcium silicate, C3S
- Dicalcium silicate, C2S
- Tricalcium aluminate, C3A
- Tetra calcium aluminoferrite, C4AF

Gypsum, CSH2

Table 2-3 composition of cemen

Compound	Formula	Shorthand form	% by weight'
Tricalcium aluminate	$Ca_3Al_2O_6$	C_3A	10
Tetracalcium aluminoferrite	$Ca_4Al_2Fe_2O_{10}$	C4AF	8
Belite or dicalcium silicate	Ca_2SiO_4	C_2S	20
Alite or tricalcium silicate	Ca_3SiO_4	C_3S	55
Sodium oxide	Na_2O	N	Up to 2
Potassium oxide	K_2O	K	
Gypsum	$CaSO_4.2H_2O$	CSH_2	5

2.6.3.2 Water-cement ratio

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

refers to the ratio of water to cement plus pozzolan ratio, w/(c+p). The pozzolan is typically fly ash or blast furnace slag. It can include several other materials, such as silica fume, rice husk ash, or natural pozzolans. Pozzolans can be added to strengthen concrete.

• Duff Abrams' law

The notion of the water-cement ratio was first developed by Duff A. Abrams and published in 1918. Concrete hardens as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every pound (or kilogram or any unit of weight) of cement, about 0.35

pounds (or 0.35 kg or corresponding unit) of water is needed to fully complete hydration reactions. Ilowever, a mix with a ratio of 0.35 may not mix thoroughly, and may not flow well enough to be placed. More water is therefore used than I technically necessary to react with cement. Water-cement ratios of 0.45 to 0.60 are more typically used. For higher-strength concrete, lower ratios are used, along with a plasticizer to increase flowability. Too much water will result in segregation of the sand and aggregate components from the cementpaste

2.6.3.3 Effect of Water Cement Ratio on Strength of Concrete:

The water-cement ratio is one of the most important aspects when it comes to maintaining the strength of Concrete. The ratio depends on the grade of concrete and the structure size. We generally prefer a W/C ratio of 0.4 to 0.6, but it can be decreased in the case of high-grade concrete, we reduce the amount of water and use plasticizers instead. W/C ratio affects the workability of concrete and thus should be taken into careful consideration. Also, if the ratio exceeds the normal value, segregation of concrete occurs and the coarse aggregate settles atthe bottom, thus affecting the strength of concrete greatly.

2.6.3.4 Limitation of Water Cement Law

1. The internal moisture condition of hydration of cement continues till the concrete gain fullstrength.
2. The concrete specimen is cured under standard

3. temperatures.
4. The concrete specimens should be of the same size.
5. The concrete specimens should be of the same age

1.6.1.1 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.

Factors Affecting Workability

-Cement content of concrete

1.6.1.2 Following are the general factors affecting concrete workability:

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 also 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.

2. Type and Composition of Cement

There are also affect 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 Al2O3 or C2S contents.

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 method 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/cement

ratio so that desired strength and durability of concrete can be achieved.

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.

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.

1. 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 elongated 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.

2. Grading of Aggregates

Grading of aggregates have the maximum effect on the workability of concrete.

A 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.

6. 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.

7. 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 superplasticizers 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.

Air 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.

Measurement of Workability:

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 IS 456: 2000

Generally concrete slump value is used to find the workability, which indicates water-cement

ratio, but there are various factors including

properties of materials, mixing methods, dosage, admixtures etc. also affect the concrete slump value.

1.6.1.3 Factors which 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,

in the form of the frustum of a cone having height 30 cm, bottom diameter 20 cm and top diameter 10

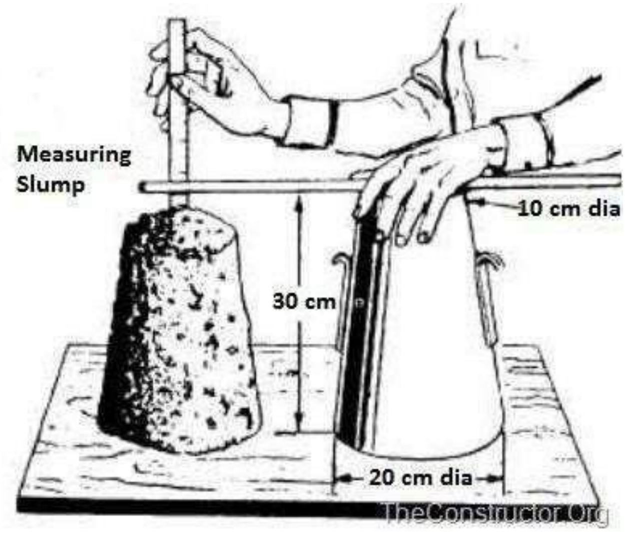
Mould for slump test, non-porous base plate, measuring scale, temping rod. The mould for the test is

cm. The tamping rod is of steel 16 mm diameter and 60cm long and rounded at one end.

1.6.1.4 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 6 cubes after conducting Slump test.



1. 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.

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 balance. Sampling

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

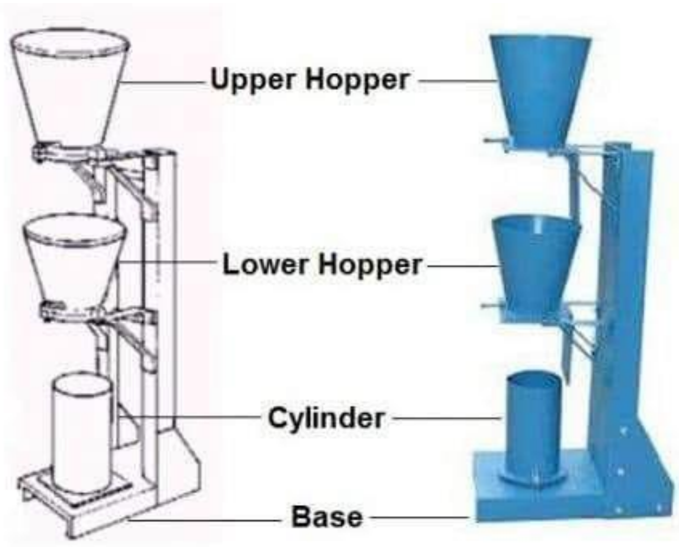


Figure 2-10 Compaction Factor Test On Concrete

1.6.1.5 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 fall 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).

2.VEE-BEE CONSISTOMETER TEST

Figure 2-11 VEE-BEE CONSISTOMETER TEST

1.6.1.6 SUITABILITY

This method is suitable for dry concrete having very low workability

1.6.1.7 PROCEDURE

The test is performed as given described below

1. Mix the dry ingredients of the concrete thoroughly till a uniform colour is obtained and then add the required quantity of water.
2. Pour the concrete into the slump cone with the help of the funnel fitted to the stand.
3. Remove the slump mould and rotate the stand so that transparent disc touches the top of the concrete.
4. Start the vibrator on which cylindrical container is placed.
5. Due to vibrating action, the concrete starts remoulding and occupying the cylindrical container. Continue vibrating the cylinder till concrete surface becomes horizontal.

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

Table 2-4COMPARISON OF WORKABILITY MEASUREMENTS BY VARIOUS METHODS

Workability	Slump in mm	Vee-bee Time in Seconds	Compacting Factor
Extremely dry	-	32-18	-
Very stiff	-	18-10	0.7
Stiff	0-25	10-5	0.75
Stiff plastic	25-50	5-3	0.85
Plastic	75-100	3-0	0.9
Flowing	150-175	-	0.95

Chapter 3: Special Concretes

3.1 Introduction

• Special concretes are the concrete prepared for specific purpose like light weight, high density, fire protection, radiation shielding etc. concrete is a versatile material possessing good compressive strength. But it suffers from many drawbacks like low tensile strength, permeability to liquids, corrosion ofreinforcement, susceptibility to chemical attack and low durability.

• Modification have been made from time to time to overcome the deficienciesof cement concrete. The recent developments in the material and construction technology have led to signific changes resulting in improved performance, wider and more economical use.

• Research work is going on in various concrete research laboratories to getimprovement in the performance of concrete.

• Attempts are being made for improvements in the following areas.

• Improvement in mechanical properties like compressive strength, tensilestrength, impact resistance.

• Improvement in durability in terms of increased chemical and freezingresistances.

• Improvements in impermeability, thermal insulation, abrasion, skid resistanceetc.

3.2 Different Types of Special Concrete are:

• Lightweight concrete

• High strength concrete

• Fibre reinforced concrete

• Ferrocement

• Ready mix concrete

• Shotcrete

• Polymer concrete

• High performance concrete

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• Lightweight concrete

• High strength concrete

• Fibre reinforced concrete

• Ferrocement

• Ready mix concrete

• Shotcrete

• Polymer concrete

• High performance concrete

3.3 Difference Between Ordinary and Special Concrete

Table 3-1 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^3 and that of heavy weight concrete is about 3000 to 5000 kg.m ^{3}
It is economical	It is costly

3.4 Light Weight Concrete

• The density of conventional concrete is in order of 2200 to 2600 kg/m 3.

Thisheavy 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 concreteto increase the efficiency of concrete as a structural material.

The light weight concrete with density in the range of 300 to 1900 kg/ m3

have been successfully developed.

3.4.1 The Light Weight Concrete Offers the FollowingAdvantage:

• Reduction of Dead Load

• Smaller section of structural members can be adopted. • Lower haulage andhandling costs.

- Increase in the progress of work.
- Reduction of foundation costs, particularly in the case of weak soil and tallstructures.
- Light weight concrete has a lower thermal conductivity. In case of buildings where air conditioning is to be installed, the use of light weight concrete will result in better thermal comforts and lower power consumption.
- The use of light weight concrete gives an outlet for industrial wastes such asfly ash, clinkers, slag etc. which otherwise create problem for disposal. • It offers great fire resistance.
- Light weight concrete gives overall economy.
- The lower modulus of elasticity and adequate ductility of light weight concretemay be advantageous in the seismic design of structures.

3.4.2 The Light Weight Concrete Is Achieved by Three DifferentWays:

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

- **Table 3-2 Different Between Natural and Artificial Lightweight aggregate**

Natural lightweight aggregate	Artificial lightweight aggregate
(i) Pumice	(i) Artificial cinder
(ii) Diatomite	(ii) Coke breeze
(iii)Scoria	(iii)Foamed slag
(iv)Volcanic cinder	(iv)Bloated clay
(v) Sawdust	(v) Expanded shales and slate
(vi)Rice husk	(vi)Sintered fly ash
	(vii)Expanded perlite

3.4.3 Light Weight Aggregates

3.4.3.1 Natural light weight aggregate:

• Pumice: These are rocks of volcanic origin. They are light coloured or 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.

Table 3-3 Natural Lightweight aggregate

• Sintered flash (Pulverized fuel ash): The fly ash collected from modern thermal power plants burning pulverized fuel, is mixed with water andcoal slurry in screw mixers and then fed on to rotating pans, known a pelletizers, toform spherical pellets. The pellets are then fed on to a sinster strand at a temperature of 1000 0C to 1200 0C. 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 ofpig iron. It is a porous, honeycombed material which resembles pumice.

Table 3-4 Foamed Slag

• **Bloated Clay:** When special grade of clay and shales are heated to the point ofincipient 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.

• **Exfoliated vermiculite:** The raw vermiculite material resembles mica inappearance and consists of thin flat flakes containing microscopic particles ofwater. 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 with vermiculate as aggregate will have very low density and very low strength.

• Ciders, clinkers, breeze: The partly fused or sintered particles arising from thecombustion of coal, is termed as cinder or clinker or breeze.Cinder aggregate undergo high drying shrinkage and moisture movement. These are used for making building blocks for partition walls,

for making screening over flat roofs and for plastering purposes.

Figure 3-2 Exfoliated vermiculite

3.4.4 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 singlesized 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 varybetween 0.38 to 0.50. The strength of no fines concrete is dependent on the water/ cement ratio, aggregate/ cement ratio and unit weight of concrete

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 wallin 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 nofines concrete, it is advisable to smear the reinforcement with cement paste to improve the bond strength and to protect it from rusting.

Figure 3-3 No Fines Concrete

3.4.5 Advantages of Lightweight Concrete:

a) Reduced dead load of the concrete allows longer span. This saves both labourand 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 a coveringfor 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 or domestictype construction.

h) General insulation of walls.

I) It is also being used for reinforced concrete.

3.5 HIGH STRENGTH CONCRETE

• High strength concrete can be defined by compressive strength of concrete at28 days of water curing.

• When the grade of concrete exceeds M35, then the concrete may be called ashigh 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 achieved by 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 Portlandcement 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 strengthof concrete.

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

(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 (polythene of 0.025 mm thick and 3 to 4 mm in diameter).

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

(f) Sulphur Impregnation:

• Satisfactory high strength concrete has been produced by impregnating lowstrength 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 calledcementitious aggregate (E.g. ALAG).

• It gives high strength to the concrete up to 125 MPa with very low watercement ratio of 0.32.

3.6 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 and amount of improvement is dependent upon the fibre type,size, strength and configuration and amount of fibre

3.6.1 Types of fibre:

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

1. Steel Fibre
2. Polypropylene Fibre
3. GFRC Glass Fibre
4. Asbestos Fibres
5. Carbon Fibres
6. Organic Fibres
7. Natural fibre (Coir fibre, Cotton fibre, Sisal fibre, Jute fibre andWool fibre)

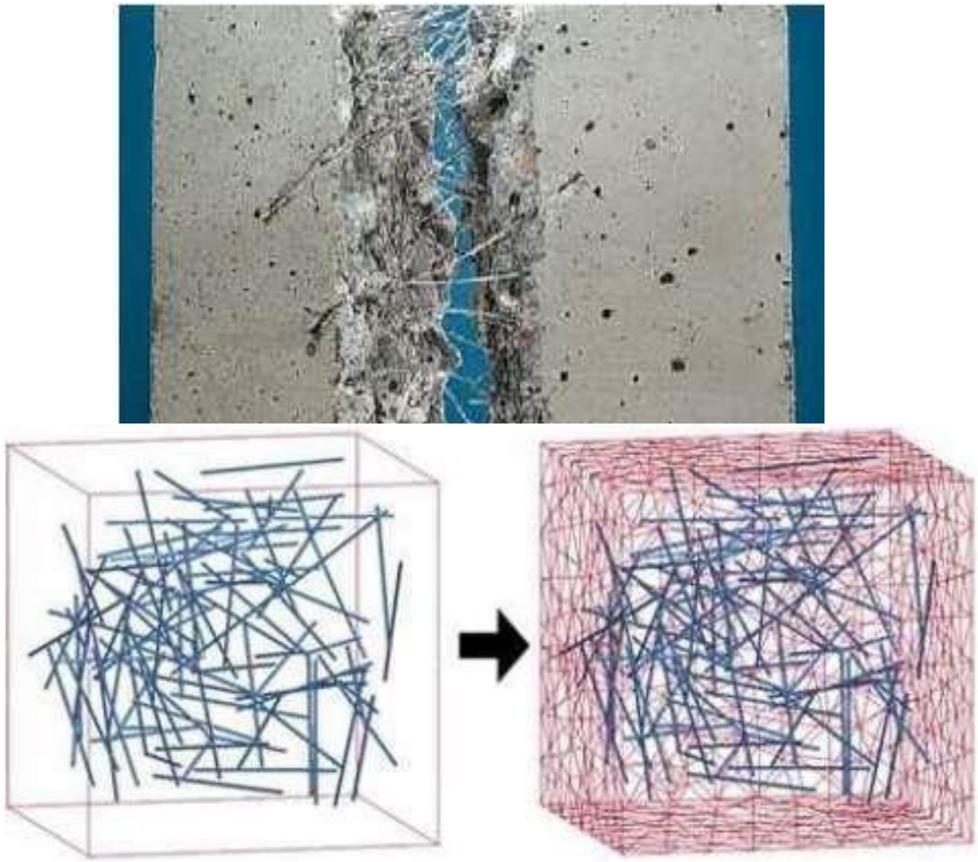

Figure 3-4 Fibre Reinforced Concrete (FRC)

• 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. They are 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 itsstrength. 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, airfields, bridge decks, thin shells and floorings subjected to wear and tear and chemical attack.

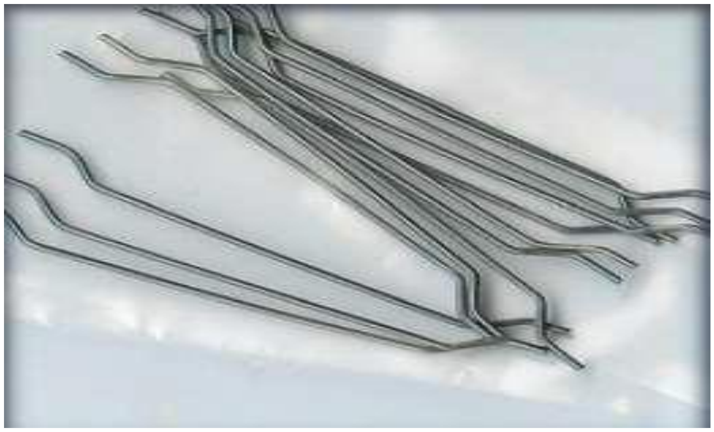

Figure 3-5 Steel Fibres

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 degradationof 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. Withthe addition of 2 % fibers the flexural strength is almost doubled.

Figure 3-6 Glass Fibers

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.

Figure 3-7 Polypropylene Fiber

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.

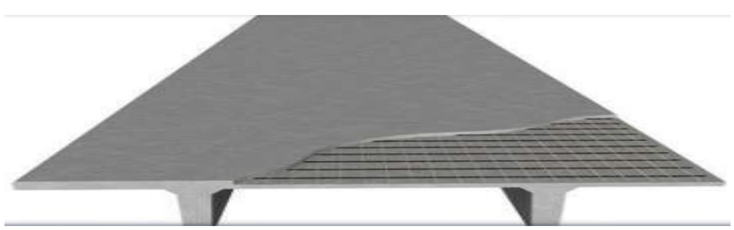

Figure 3-8 Carbon Fiber

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

3.6.2 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

3.6.3 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 spaced and uniformly dispersed fibers to concrete would act as crack arrester

g) It substantially improves its static and dynamic properties.

3.7 FERROCEMENT

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

3.7.1 Materials for ferrocement

a) Cement mortar mix

b) Skeleton steel

c) Steel mesh reinforcement

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• 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

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• 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

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"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." Advantages of Ready Mixed Concrete:

• Concrete is produced under controlled conditions using consistent quality ofraw material.

• Speed of construction can be very fast in case RMC is used.

• Reduction in cement consumption by 10 – 12 % due to better handling andproper mixing.

• The mix design of the concrete can be tailor made to suit the placing methodsof the contractor.

• Since ready mixed concrete (RMC) uses bulk cement instead of baggedcement, 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 petroland diesel and less time loss to business.

3.7 SHOTCRETE or GUNITE

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

3.7.1 Methods:

• Dry mix - In this dry mix the cement and sand is mixed thoroughly indry state

• Wet mix - Concrete is mixed with water before conveying through

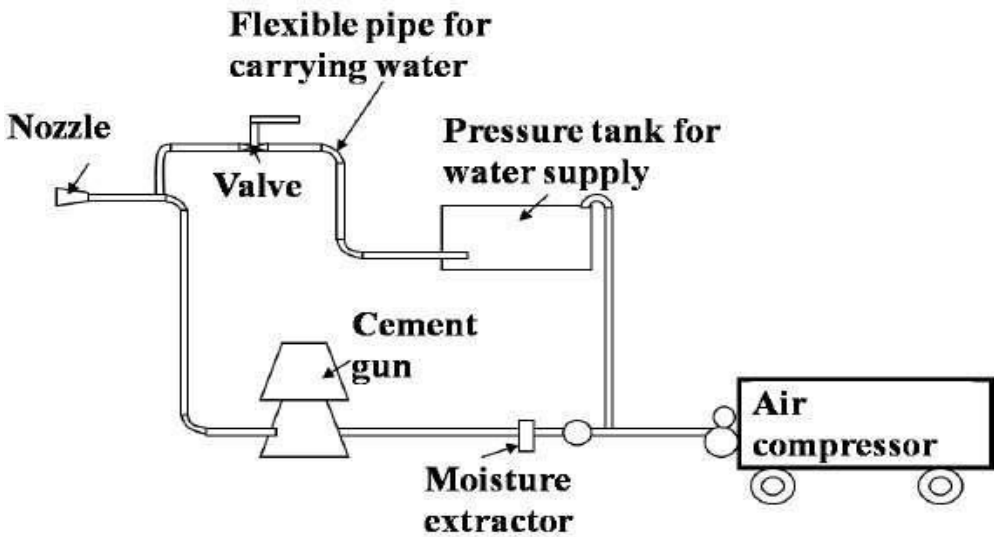

Figure 3-12 SHOTCRETE

3.7.2 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 asaturated surface dry condition.

• Fix wire mesh to the concrete surface. The steel wire mesh has to be placed inposition keeping the mesh within 10-15 mm from the surface. Suitable fixing pins are to be inserted to keep the mesh in proper position and to ensure that theweld mesh is not disturbed during shotcreting.

• Prepare a cement-sand / water mix and pour this mix into Pump

• hose for lubrication before starting to pump the production mixture

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• thickness of shotcrete in layers of about 30 mm thick each. The

• presence of voids can be found by hollow hammering sound after

• the shotcrete has attained strength after around 3 days.

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• Shotcrete repair can be used for bridge deck rehabilitation

• repair of fire and earthquake damage and deterioration, strengthening walls.

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3.8 POLYMER CONCRETE

Polymer concrete is nothing but impregnations of monomer into the pores ofharden concrete and then getting it polymerized by thermal process is called polymer concrete.

By this polymerization, the strength of the concrete is much improved.

3.8.1 Types of polymer concrete:

– Polymer Impregnated concrete

– Polymer cement concrete

– Polymer concrete

– Partially impregnated and surface coated polymer concrete

3.8.2 Types of monomer:

• Methyl methacrylate

• Styrene

• Acrylonitrile

• T-butyl styrene

• Thermoplastic monomer

3.8.3 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.

3.8.4 Application of polymer concrete:

• Nuclear power plants.

• Kerbstones.

• Prefabricated structural element.

• Precast slabs for bridge decks.

• Roads.

• Marine Works.

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• Irrigation works.

• Sewage works.

• Waterproofing of buildings.

• Food processing buildings

etc.Questions

• State different types of special concrete and describe light

weightconcrete. (May 2011)

2 Chapter 3: Special Concretes

3.1 Introduction

• Special concretes are the concrete prepared for specific purpose like light weight, high density, fire protection, radiation shielding etc. concrete is a versatile material possessing good compressive strength. But it suffers from many drawbacks like low tensile strength, permeability to liquids, corrosion ofreinforcement, susceptibility to chemical attack and low durability.

• Modification have been made from time to time to overcome the deficienciesof cement concrete. The recent developments in the material and construction technology have led to signific changes resulting in improved performance, wider and more economical use.

• Research work is going on in various concrete research laboratories to getimprovement in the performance of concrete.

• Attempts are being made for improvements in the following areas.

• Improvement in mechanical properties like compressive strength, tensilestrength, impact resistance.

• Improvement in durability in terms of increased chemical and freezingresistances.

• Improvements in impermeability, thermal insulation, abrasion, skid resistanceetc.

3.2 Different Types of Special Concrete are:

• Lightweight concrete

• High strength concrete

• Fibre reinforced concrete

• Ferrocement

• Ready mix concrete

• Shotcrete

• Polymer concrete

• High performance concrete

3.3 Difference Between Ordinary and Special Concrete

Table 3-1 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^3 and that of heavy weight concrete is about 3000 to 5000 $kg.m^3$
It is economical	It is costly

3.7 Light Weight Concrete

• The density of conventional concrete is in order of 2200 to 2600 kg/m 3. Thisheavy 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 concreteto increase the efficiency of concrete as a structural material.

The light weight concrete with densityin the range of 300 to 1900 kg/ m3

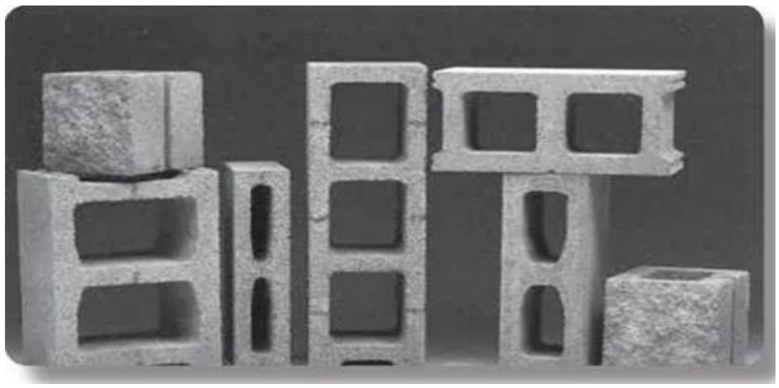


Figure 3-1 Light weight concrete

3.4.1 The Light Weight Concrete Offers the FollowingAdvantage:

• Reduction of Dead Load

• Smaller section of structural members can be adopted. • Lower haulage andhandling costs.

• Increase in the progress of work.

• Reduction of foundation costs, particularly in the case of weak soil and tallstructures.

• Light weight concrete has a lower thermal conductivity. In case of buildingswhere air conditioning is to be installed, the use of light weight concrete will result in better thermal comforts and lower power consumption.

• The use of light weight concrete gives an outlet for industrial wastes such asfly ash, clinkers, slag etc. which otherwise create problem for disposal. • It offers great fire resistance.

• Light weight concrete gives overall economy.

• The lower modulus of elasticity and adequate ductility of light weight concretemay be advantageous in the seismic design of structures.

3.4.2 The Light Weight Concrete Is Achieved by Three DifferentWays:

• By replacing the normal mineral aggregate, by cellular porous or light weightaggregate.

• By introducing air bubble in mortar this is known as 'aerated concrete'.

• By omitting sand fraction from the aggregate This is known as 'no fines concrete'.

Table 3-2 Different Between Natural and Artificial Lightweight aggregate

Natural lightweight aggregate	Artificial lightweight aggregate
(i) Pumice	(i) Artificial cinder
(ii) Diatomite	(ii) Coke breeze
(iii)Scoria	(iii)Foamed slag
(iv) Volcanic cinder	(iv) Bloated clay
(v) Sawdust	(v) Expanded shales and slate
(vi) Rice husk	(vi) Sintered fly ash
	(vii)Expanded perlite

3.4.3 Light Weight Aggregates

3.4.3.1 Natural light weight aggregate:

• Pumice: These are rocks of volcanic origin. They are light coloured or nearlywhite 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 incolour It is slightly weaker than pumice.

•Rice Husk: Use of rice husk or groundnut husk has been reported as lightweight aggregate.

•Saw dust: Saw dust is used as light weight aggregate in the flooring and in themanufacture 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.

Table 3-3 Natural Lightweight aggregate

• Sintered flash (Pulverized fuel ash): The fly ash collected from modern thermal power plants burning pulverized fuel, is mixed with water andcoal slurry in screw mixers and then fed on to rotating pans, known a pelletizers, toform spherical pellets. The pellets are then fed on to a sinster strand at a temperature of 1000 0C to 1200 0C. 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 ofpig iron. It is a porous, honeycombed material which resembles pumice.

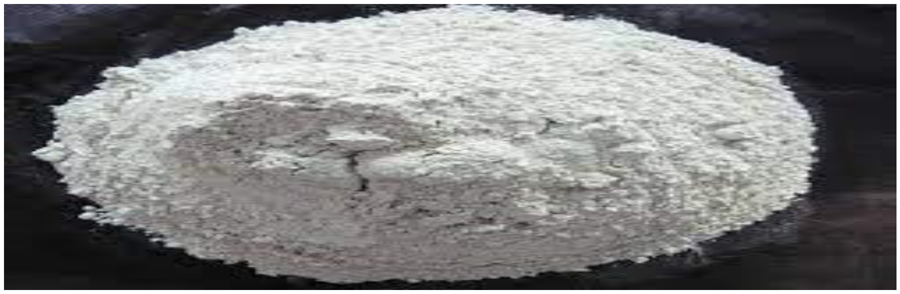


Table 3-4 Foamed Slag

• **Bloated Clay:** When special grade of clay and shales are heated to the point ofincipient 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.

• **Exfoliated vermiculite:** The raw vermiculite material resembles mica inappearance and consists of thin flat flakes containing microscopic particles ofwater. 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 with vermiculate as aggregate will have very low density and very low strength.

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

Figure 3-2 Exfoliated vermiculite

3.4.4 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 singlesized 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 varybetween 0.38 to 0.50. The strength of no fines concrete is dependent on the water/ cement ratio, aggregate/ cement ratio and unit weight of concrete

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 wallin 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 nofines concrete, it is advisable to smear the reinforcement with cement paste to improve the bond strength and to protect it from rusting.

Figure 3-3 No Fines Concrete

3.4.5 Advantages of Lightweight Concrete:

a) Reduced dead load of the concrete allows longer span. This saves both labourand 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 a coveringfor 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 or domestictype construction.

h) General insulation of walls.

I) It is also being used for reinforced concrete.

3.5 HIGH STRENGTH CONCRETE

• High strength concrete can be defined by compressive strength of concrete at28 days of water curing.

• When the grade of concrete exceeds M35, then the concrete may be called ashigh 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 achieved by 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 Portlandcement 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 strengthof concrete.

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

• This process involves advanced preparation of cement water mixture which isthen blended with aggregate to produce HSC d.Use of admixtures:

The high strength can be achieved by adding chemical admixtures such as superplasticizer 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 (polythene of 0.025 mm thick and 3 to 4 mm in diameter).

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

(f) Sulphur Impregnation:

• Satisfactory high strength concrete has been produced by impregnating lowstrength 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.

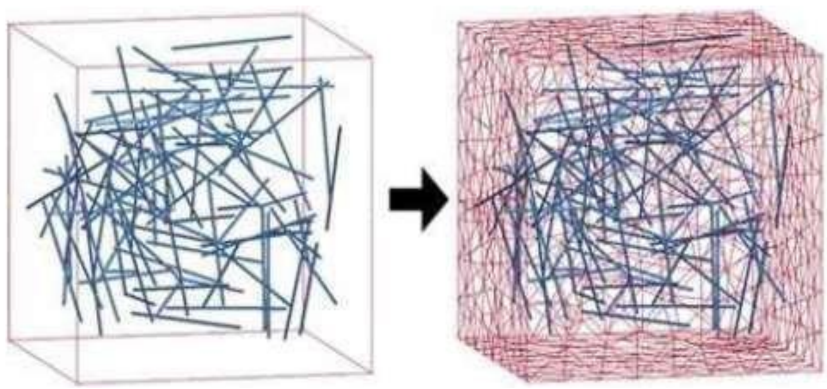
(g) Use of cementitious aggregates:

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

• It gives high strength to the concrete up to 125 MPa with very low watercement ratio of 0.32.

3.6 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 and amount of improvement is dependent upon the fibre type,size, strength and configuration and amount of fibre.



3.6.1 Types of fibre:

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

1. Steel Fibre
2. Polypropylene Fibre
3. GFRC Glass Fibre
4. Asbestos Fibres
5. Carbon Fibres

6. Organic Fibres

7. Natural fibre (Coir fibre, Cotton fibre, Sisal fibre, Jute fibre andWool 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. They are 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 itsstrength. 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, airfields, bridge decks, thin shells and floorings subjected to wear and tear and chemical attack.

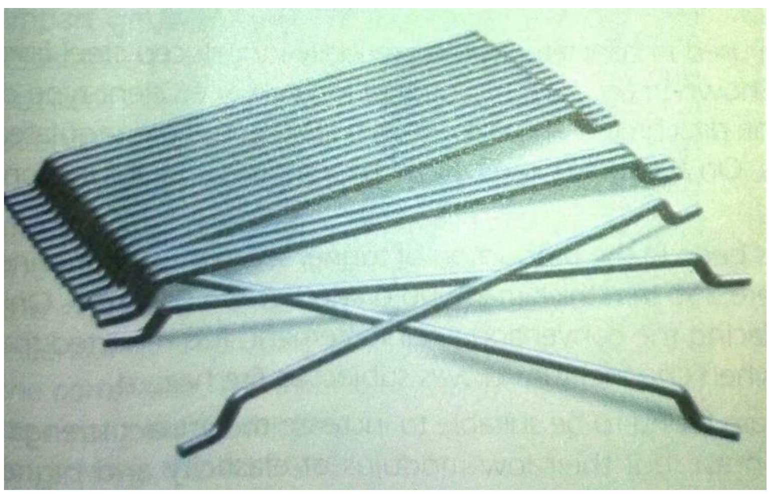


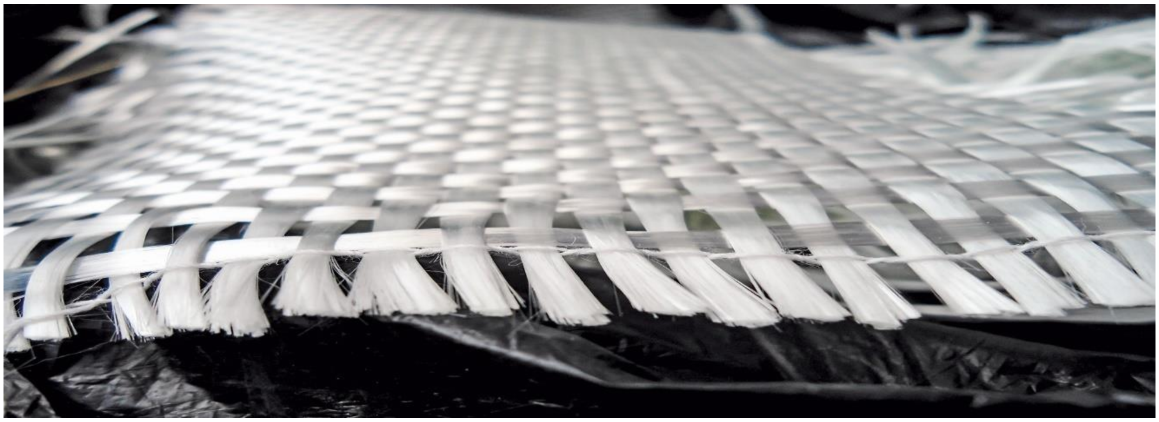
Figure 3-5 Steel Fibres

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 degradationof 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. Withthe addition of 2 % fibers the flexural strength is almost doubled.



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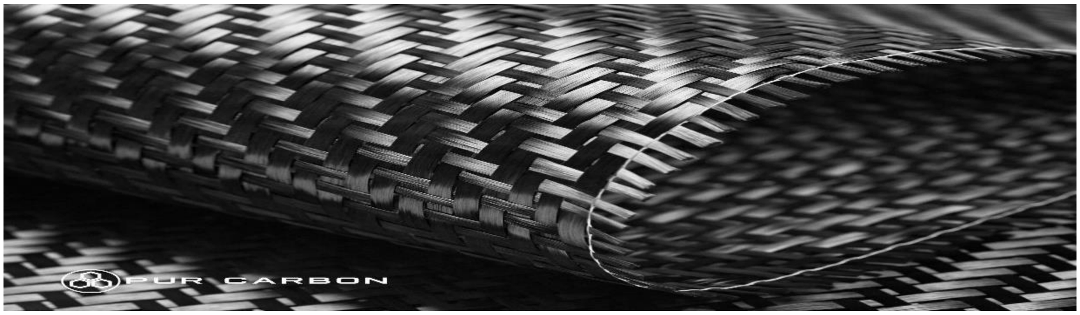

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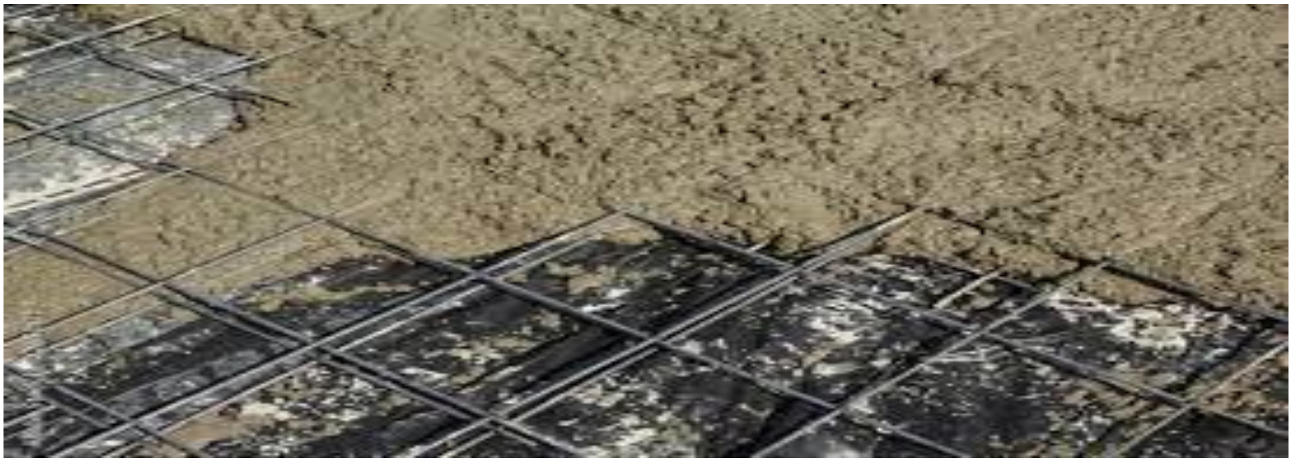

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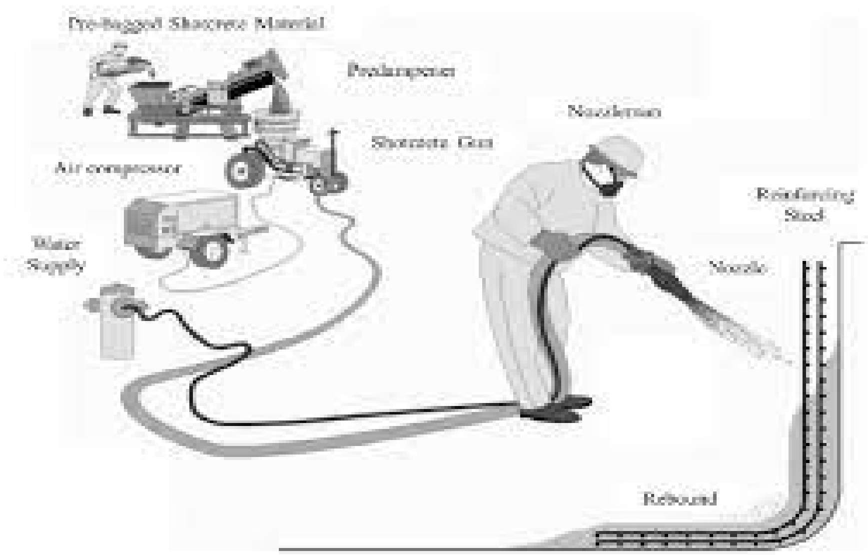

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- Describe polymer concrete and its application

(March2010)High Strength Concrete.

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- concrete . Fiber
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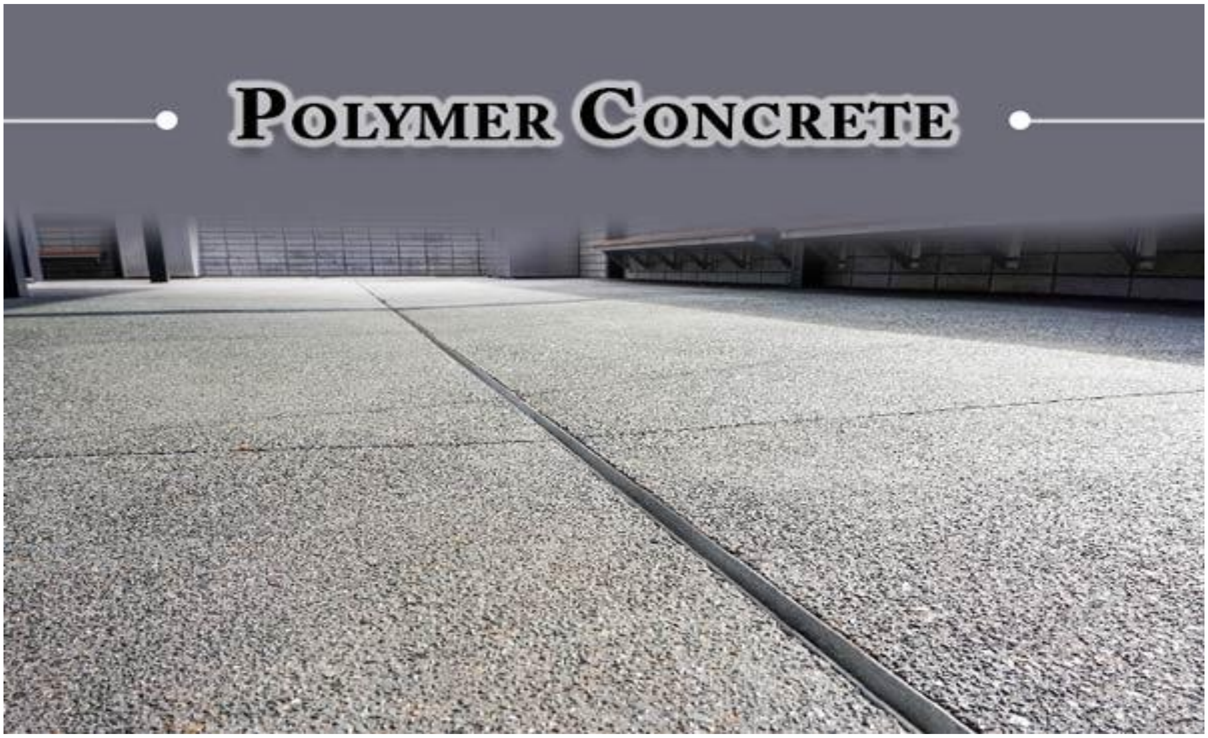
- Mass Concrete.
- Plum Concrete .
- Aerated Concrete .

• Ferro cement.



Defects reinforced concrete

Introduction

Chapter 4 :Defects reinforced concrete

Concrete is known to be a very versatile and reliable material, but some construction errors and construction negligence can lead to the development of defects in a concrete structure. These defects in concrete structures can be due to poor construction practices, poor quality control or due to poor structural design and detailing.

Common types of defects in concrete structures

1. Honeycomb

Honeycomb is mainly manifested by local loosening of concrete,less mortar, more gravel, and voids between gravel, forming honeycomb-like holes.

Causes of Honeycomb

- The small slump of concrete, improper mix ratio or inaccurate measurement of raw materials result in less mortar, more stones and insufficient vibration time or vibration leakage.
- Poor homogeneity and insufficient mixing of concrete.
- Framework leakage.
- Free dumping height exceeding the stipulation, concrete segregation, stones piled up.
- The vibration time is insufficient and the bubbles are not

eliminated.

2.1 How To Prevent Honeycomb

- Concrete mixing ratio and measurement should be strictly, inspection regularly.
- Concrete mixing should be full and even.
- Chutes should be used when the feeding height > 2m.
- Layered feeding, layered tamping and preventing vibration missing.
- Blocking the formwork gaps and check the leakage of grouting during pouring.
- How To Repair Honeycomb
- For minor honeycombs, wash and repair with 1:2 cement mortar.
- Larger honeycombs, chiseled away weak and loose particles, washed andmolded, carefully tampered with high-strength fine stone concrete.
- Deep honeycombs can be grouted with cement after burying grouting pipes andexhaust pipes, plastering the surface with mortar.

1. Pitting

Pitting is caused by incomplete air removal after concrete pouring or by leakage ofconcrete grout. The surface of concrete is not smooth and uneven, and there are holes in it. There are numerous holes on the surface of structural components andthere is no exposure of reinfor

Causes of Pitting

- The surface of the formwork is rough or adheres to debris, and the concrete surface is damaged when the formwork is removed.
- The formwork is not watered or watered enough, and concrete loose too much water, form pits.
- Formwork isolation reagent is unevenly painted, and the surface of concrete bonds with the formwork, resulting in pitting.
- There are gaps between the formworks.
- The concrete is loosed, and the bubbles are stop on the surface of the formwork to form pits.

How To Prevent Pitting

- Clean the surface of the formworks.
- Formwork joints should be fully watered before grouting concrete.
- Formwork isolation reagents should be painted evenly.
- Formwork joints should be sealed by packing paper or putty.
- Vibro-compaction of concrete, ful discharge of air bubbles.
-

How To Repair Pitting

- Prepareing concrete with original concrete mixing ratio, repairing the pitting after the pitting is well watered. If whitewash walls, don’t do anythings.

3. Holes

Holes refer to the concrete structure with large internal voids, no concrete or honeycomb in part is particularly large, and the reinforcement is partly or completely exposed.

Causes of Holes

- Where the reinforcement is densely or the reserved holes and buried parts are located, the concrete grouting is not smooth, and the concrete not be compacted by vibration.
- Concrete segregation, mortar separation, stones piled up, serious slurry running.
- The concrete is blocked by tools, blocks, mud and other debris.

How To Prevent Holes

- Use high-strength fine stone concrete in steel bar dense areas, conscientiously layered tamping or with manual tamping.
- If reserved holes, should feeding from both sides at the same time.
- Remove debris from concrete in time.

How To Repair Holes

- Remove loose concrete and soft grouting mould around the hole and grout it with 8% expansion agent mixed with high strength fine stone concrete after full watering.

- Concrete surface treatment, remove floating stones, check whether the concrete surface is dense after chipping, and then coat a layer of cement mortaron the interface between new and old concrete.
- When the depth of repaired wall is more than 5cm, formwork shall be erected.
- Check the concrete strength of the repairing wall. A higher grade concrete mixed with expansion reagent is used to repair the holes.
- After 12 hours of repairing, watered the parts, and the curing time > 5 days.

Exposed Steel Reinforcement

In the process of concrete grouting, the vibration is not in place, the protective cushion is not set or fixed firmly, the concrete slump is small, the demolition of formwork is too early, the external force is destroyed before hardening, and the steel bars are exposed after concrete forming.

Causes of Exposed Steel Reinforcement

- Displacement of reinforced protective cushion block or too little or leakage of cushion block during concrete grouting.
- Small cross-section of structural members, too dense reinforcing bars, cement mortar can not be filled around reinforcing bars.
- Improper mixing ratio of concrete results in break-off.
- The concrete cover is too small
- Formwork isn't watered well, bonding or remove prematurely

How To Prevent Exposed Steel Reinforcement

- The position of reinforcing bar and the thickness of protective layer should be ensured correctly when grouting.
- Guarantee the accuracy and workability of concrete mixing ratio.
- Formwork should be fully watered and carefully sealed.
- Avoid trampling steel bar, remove formworks correctly.

How To Repair Exposed Steel Reinforcement

- After cleaning, 1:2 cement mortar is applied on the surface. If the exposed steel reinforcement part is deep, the interface should be treated well and compacted with high-grade fine stone concr

5 .Cracking

Concrete cracks are the physical structural changes caused by the internal and external factors of the concrete structure, and the cracks are the main reason forthe reduction of the bearing capacity, durability and waterproof of the concrete structure.

Causes of Cracking

- The water cement ratio is too large, the surface produces air holes and cracks.
- Excessive cement consumption leads to shrinkage cracks.
- Poor or untimely curing, surface dehydration, shrinkage cracks.
- The slump is too big, the grouting is too high and too thick.

- The steel protective layer is too thin and cracks along the reinforcement.

How To Prevent Cracking

- Curing begins 6 hours after concrete is grouted, and the curing age is 7 days.
- Vibrating and compacting without segregation, plastering the surface twice to reduce the shrinkage.

How To Repair Cracking

For fine cracks, pour pure cement slurry into the cracks, embedding, covering and curing, clean the cracks, brush epoxy cement twice after drying or paste epoxy glass cloth to seal the surface.

For deep or penetrating cracks, epoxy resin grouting is applied and epoxy cement is applied to seal the surface.

Defects of reinforced concrete in concrete ceilings

Ceiling cracks are the occurrence of cracks and cracks that appear on the roof surfaces as a result of poor construction and the failure to use high-quality materials during construction, or a violation of the worker's conscience, and sometimes they occur due to the direct exposure of the roof to the high temperature of the sun, the lack of insulation to isolate the extreme heat, or the occurrence of water leaks that cause Ceiling erosion and cracking .

Ceiling cracks after casting:

It often happens that cracks and cracks appear in the ceilings immediately after the ceiling is poured, which raises great anxiety and surprise in the hearts of the residents and makes them feel that their time and money are being wasted.

There is no doubt that the appearance of cracks and cracks in the ceilings immediately after they are poured is due to the lack of professionalism of thebuilder or the person responsible for the repair, because some of the problems are attributed to people who are not specialized in construction work and do not have the experience required for work.

Ceiling crack repair:

If cracks or cracks are observed in the ceilings, a specialist in the field of .buildings and ceiling treatment must be contacted

immediately, in order to conduct a comprehensive examination of the causes ofthese cracks and clarify treatment methods.

The expert or specialist performs the correct examination of the roof, indicating the causes of its cracking, and clarifying whether it can be treated or if it has reached the last stage and must be

rebuilt, and a solid plan is drawn up that works to repair the roof and enable it again.

Ceilings are repaired in many and varied ways, depending on the depth of the problem, the types of cracks, and the factorsthat caused their appearance. Accuracy must also be

investigated in the treatment, and care must be taken to fullyaddress the problem and ensure that it does not appear again the treatment.

Causes of cracking of concrete ceilings:

Concrete ceilings can crack quite easily so it is essential to repair them immediately to prevent further damage that could endanger the public if it collapses

- **High temperature, direct sun exposure to the roof, lack of solid insulation to protect it, and sometimes water leakage are the causes of concrete cracking**
- **You should visit a specialist and expert as soon as**
- **you become aware of the cracks in order to make a basic diagnosis and establish a sound treatment strategy.**
- **Depending on the nature and depth of the crack, the task is to treat it in several ways, such as applying several coats of paint or using a chemical to help hide the crack.**
- **Insulating the roof to protect it from high roof temperature and potential water leaks is one way to repair cracks**

Concrete defects of piles

Concrete defects

Problems with pile construction due to concrete defects include:

1. Insufficient strength and grade of concrete

Insufficient strength due to poor mix design or casting processes. Generally, cylindrical or cubic concrete is sampled from each mixture and tested for concrete strength. This problem is solved by designing the right mix while ensuring proper workability and practicing good quality control during concrete pouring.

2. Voids in piling concrete

Voids may form due to improper compaction of concrete in piles without a casing or with casings that are not pulled out after the completion of pouring. In this case, the construction must be properly monitored to ensure sufficient compaction of the concrete using appropriate technologies.

Furthermore, if the casing is pulled, pulling the casing may lead to the formation of voids in the concrete. Voids in this case can be prevented by cleaning the casings and ensuring that a sufficient amount of concrete is poured.

Rebar problems

Reinforcing bars are more likely to move sideways or be pulled down while pressing and compacting. There are a number of reasons that lead to the movement of the reinforcement, for example, the incorrect placement of spacers or tires, negligence, and defective fixation of the reinforcement in some types of piles.

The iron cage during manufacturing should be inspected to specifications and monitorthe installation and unloading process to prevent such problems. Finally, piling iron cages should be securely supported at the bottom and spacers and covers should be provided according to establishe.

Errors in operating loads Piles may suffer damage due to load testing or permanent operating loads. In thefollowing sections, loading errors will be classified by type and methods of incorporation used.

1. **Loading errors in piles driven**

There are a number of factors that make driven piles suffer deterioration and damage under operating loads. For example, the wrong formwork method used to cast the core of the driven drill shaft, the lifting of piles due to soil problems, insufficient concrete at the ends of piles with enlarged piles whether in driven or dug piles, wrongpushing and hammering space used, and insufficient thrust resistance.

These harmful factors can be eliminated by checking the volume of poured concrete, adjusting hammer hammer strokes on the pile head, adjusting the links in the assembled sections, and adjusting the clear and correct construction method.

2. **Loading errors in drilling piles**

Factors leading to damage to drilling piles under operating loads include poor ground around the pile due to faulty pile drilling technique ,insufficient concrete cover due to the displacement of the reinforcing cage, poor execution of formwork, insufficient depth in relation to soil or the characteristics of the rocks encountered.

To ensure sufficient depth, the digging depth needs to be checked by weight. In addition, extreme caution is necessary during drilling and pouring of concrete to prevent undesirable results.

3. Loading errors in mechanically stacked piles CFA

Factors that may cause mechanically established piles to fail under operating loads include:

Malfunction of drilling and displacement equipment where the diameter of the pipe bump can be insufficient. This can be prevented by constant observation of the drilling tools and the base of the main displacement pipe.

Insufficient depth in relation to the characteristics of the encountered soil. It is advisable to monitor the drilling outputs during the drilling process.

The use of unsuitable technology for pouring concrete.Insufficient

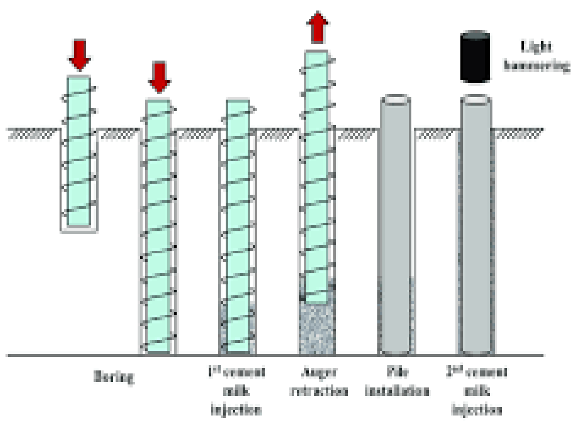
concrete cover.

The ground around the drill shaft or under the base is weakened due to an improper drilling technique.

Types of piles according to the materials from which the pile is made .

1. **timber piles**

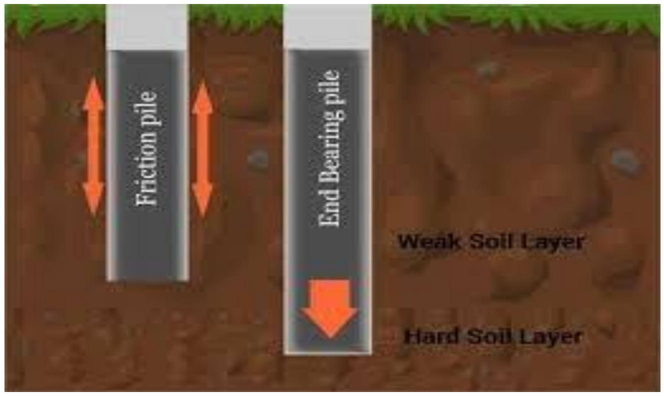
2. concrete precast piles



3 cast in site piles

4 steel piles

- Load bearing pile



The main problems during the construction and treatment of piling foundations

There are many problems that can be encountered during the construction of pile foundations. These problems will result in a shortage in the capacity and capacity of the pile unless properly addressed.

We discuss these problems of piling construction, their causes and measures required to prevent them in the following lines.

The main problems during the construction of piling foundations

Possible piling problems are classified as follows:

1. Problems during the preparation of piling foundation
2. Concrete defects
3. Armament problems
4. Errors in operating loads

1 Problems during the preparation of piling foundations

1.1 Deterioration and damage to the hard casing or permanent concrete casing

Permanent concrete or steel casing (caisson or casing pipe into which the pile is poured) due to lowering and pushing the piles strongly on the obstacle or pushing the drilling tool non-vertically. Another problem that a hard casing or permanent concrete may suffer from is its initial cleavage

This problem can be prevented by supervising the installation of the casing and checking the work before laying concrete. Finally, if this problem occurs, the pile must be pulled out and reinstalled properly.

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1.2 Collapse of the sides of the pile pit

If the appropriate casing or frame is not provided to support the sides of the piling piles, the sides of the excavation will collapse in the case of loose, soft or loose soil. This problem can be observed and solved by the supervisor. The solution is to install or hammer a casing or use bentonite.

1.3 Excess water in the piling pit

The flow of groundwater to the construction site is the cause of excess water in piling piles. Using a steel or bentonite casing will eliminate and prevent this problem.

1.4 Lateral movement and lifting of adjacent piles when hammering casing pipes

While pile casings are pushed and hammered, lateral movements and lifting forces may occur to nearby piles or affect the soil adjacent to the work site and is caused by displacement and drag around the piling installation site. These movements can be observed by checking the location, level and level of the adjacent piles.

The engineer decides on the appropriate method and technique used to solve the problem of lateral movement and lifting adjacent piles.

1.5 Subsidence of adjacent structures or land

Subsidence in neighboring buildings and territory occurs due to vibrations in sandy soils during hammering of piles and casings. Also sinking piles in soft clay soil due to water loaded with soil grains or leaking water into the neighborhood is another reason for subsidence of neighboring buildings. This problem can be observed by checking the level of buildings or ground before and during the foundation of piles.

Finally, subsidence of adjacent floor or buildings may be prevented or reduced by holding the water column in the casing while drilling piles. Vibration force dispersion excavations can be made. Support the sides of adjacent buildings. Reduce the use of hammering in the foundation of piles. In addition, the site engineer may choose the appropriate solution to the problem.

Problems with the construction of piles due to concrete defects include:

2.1 Insufficient strength and grade of concrete

Insufficient strength due to poor mix design or casting processes. Generally, cylindrical or cubic concrete samples are taken from each mixture and tested for concrete strength. This problem is solved by designing the right mix while ensuring proper workability and good quality control practice during formwork.

2.2 Voids in piling concrete

Voids may form due to improper compaction of concrete in piles without a casing or with casings that are not pulled out after the completion of pouring. In this case, the masonry must be properly monitored to ensure sufficient compaction of the concrete using appropriate technologies.

Furthermore, if the casings are pulled, pulling the casing may lead to the formation of voids in the concrete. Voids in this case can be prevented by cleaning the casings and ensuring that a sufficient amount of concrete is poured.

3- Problems related to rebar

Reinforcing rods are more likely to move sideways or be pulled down during compression and tamping. There are a number of reasons why reinforcement moves, for example, improper placement of spacers or covers or covers, negligence, and defective installation of reinforcement in some types of piles.

The iron cage during manufacturing should be inspected in accordance with the specifications and monitor the installation and unloading process to prevent such problems. Finally, pile iron cages should be tightly supported at the bottom and spacers and tires should be provided in accordance with the applicable codes.

4. Errors in operating loads

Piles may be damaged due to load testing or permanent operating loads. In the following sections, loading errors will be classified by the type and methods of foundation used.

1. Loading errors in hammer piles or paid
1. Loading errors in drilling piles
2. Loading errors in CFA mechanically stacked piles

4.1 Loading errors in piles driven

There are a number of factors that make driven piles suffer deterioration and damage under operating loads. For example, the wrong formwork method used to cast the core of the driven drillshaft, pile lifting due to soil problems, insufficient concrete at the ends of piles with magnifying piles whether in driven or drilled piles, wrong push and hammer area used, and insufficient thrust resistance.

These harmful factors can be eliminated by checking the size of the poured concrete, adjusting the hammer knock blows on the pile head, adjusting the links in the assembled sections, and adjusting the clear and correct construction method.

4.2 Loading errors in drilling piles

Factors leading to damage to piles under operating loads include poor ground around the pile due to faulty piling technology, insufficient concrete cover due to displacement of the reinforcing cage, poor execution of formwork, insufficient depth in relation to the soil or rock properties encountered.

To ensure sufficient depth, it is required to check the depth of the drill by weighting. In addition, extreme caution is necessary during drilling and pouring operations for concrete to prevent undesirable results.

Concrete defects of beams

Deformities and cracks

Types of cracks of concrete beams and their causes

Several types of cracks in concrete beams occur due to shear stress called shear crack, corrosion and rust of the reinforcement, insufficient rebar cover, bending stress, overtension and pressure breakdown.

Cracks of concrete beams - causes - shapes and locations

In the following lines, we will discuss a set of details about the causes of these cracks in reinforced concrete beams, their positions and ways to avoid them.

1. Cracks in the beams due to increased shear stress

Cracks in concrete beams appear due to increased shear stress near supports such as a wall or column. These cracks are also called shear cracks and are inclined at a 45° angle to the horizontal.

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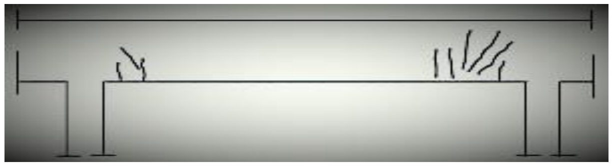


(Cracks in beams due to increased shear stress)   (Cracks in beams due to increased shear stress)

These cracks in the beams can be avoided by providing additional shear reinforcement (cans, sweeping iron) near the supports where the maximum shear stress is present. The maximum shear stress is at a distance of d/ 2 from the support where d is the effective depth of the beam.

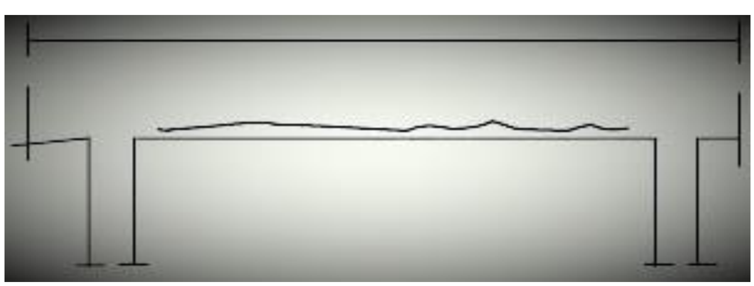
2. Cracks in the beams as a result of twisting

They are similar to shear cracks (diagonal at an angle of 45 near the substrates) but the difference between them is that the torsion cracks are different in the direction of the inclination of the crack on the sides or sides of the beam.

It can be avoided by providing special reinforcement to withstand twisting and twisting stresses such as closed cans and longitudinal reinforcement on both sides of the beam.

3. Cracks in the beams due to rust or insufficient concrete cover

In general, beams are poured with a roof slab on top, so the top of the beam is not exposed to environmental factors. The bottom of the beam is exposed to the environment and if the concrete cover around the reinforcement is insufficient, iron rust will occur. Therefore, cracks due to reinforcement rust appear at the bottom of the beam.



(cracks in the beams due to rust or insufficient concrete cover)

These cracks generally appear near the side face of the beam near the lower reinforcement along its length as shown in the figure below. Cracks caused by iron rust can cause concrete to swell and fall in severe cases and this can be prevented by good quality control during implementation and provision of appropriate rebar cover according to environmental conditions.

It is possible that these cracks take on a vertical shape due to canate rust.

4. Cracks parallel to the main reinforcing skewers as a result of rust

(Cracks parallel to the main reinforcing skewers due to rust)

These cracks also appear due to corrosion and rust of the reinforcement but at the bottom of the camera. These look parallel to the main reinforcing skewers at the bottom. The cause of this rust is also due to the provision of insufficient concrete cover, which leads to corrosion and rust of the main reinforcement. Also upper iron rust.

They sometimes appear on the upper surface after pouring as a result of the proximity of the skewers to the concrete surface and the occurrence of plastic subsidence in the deep beams or the movement of intensity.

They can be avoided by reducing water loss, good blood and strengthening tensions.

These longitudinal cracks can occur as a result of the use of highly different diameter diameters or the use of two types of high-resistance iron and ordinary in the same sector.

This type of crack can be prevented by designing a suitable sector in which the compressive ability of the beam is able to withstand additional pressure stresses.

1. Cracks insufficient length of cohesion of the iron

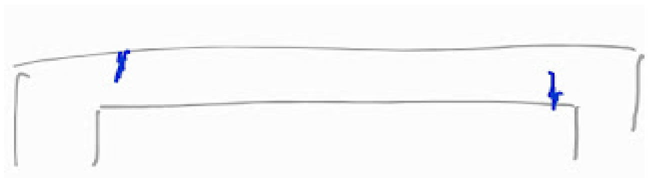
Some cracks next to the piles occur vertically in the upper or lower region when a good bonding length is not provided for the iron skewers inside the columns and pedestals.

These cracks can be avoided by following the reinforcement details and providing a good cohesion length for the iron inside the piles such as pillars, walls, or even secondary bearing main beams.

2. Landing cracks of one of the piles

It is possible to appear vertical cracks next to the pedestals starting from the bottom up and at the second pillar a vertical appears starting from top to bottom and is due to an excessive subsidence in one of the two pillars.

If they appear on the sides in the same shape widening from bottom to top after casting in early stages, it may be due to the movement of the intensity, the speed of its dismantling, or the insufficient length of bonding and cohesion of the skewers inside the substrate.



(Subsidence cracks of one of the pillars in the beams)

These cracks can be avoided by good design, following soil inspection reports, sound construction practices and providing proper cohesion length.

Random cracks on both sides of the beams

A group of random cracks appear on the surface of the sides of the beam, if it is accompanied by sunken fragmentation in wet places, it is due to the interaction of aggregates with alkali, but if it is not in wet places, it is caused by chemical reactions, the use of defective materials, and the analysis of a sample of concrete chemically determines the cause accurately.

They can be avoided with clean materials and avoid moisture

If the cancerous cracks appeared within a week of hardening, they are due to the use of water-impermeable intensity, and if they appear after that, they are due to the rapid removal of the sides of the beam and the weakness of the treatment, which led to a significant contraction, especially in hot climates.

They can be avoided by providing branding armament and good handling.

Cracks of thermal stresses in beams

Especially in the beams of the outer upper floors in hot regions, vertical and oblique cracks appear as a result of generating thermal stresses, extreme temperature change and contraction with restricted movement of the beams by the columns.

It can be avoided by providing sufficient reinforcement, using branding reinforcement on the sides, good strip design and using heat insulation.

Defects on Column

TYPES ARND EASONS OF CRACKS IN CONCRETE COLUMN

NON-STRUCTURAL CRACK AND STRUCTURAL CRACK

Building defects exist in various forms and it is inevitable. Crack is the most common

defect in the building, they are developed in building elements when the stress exceeds the material strength [1] .

The crack in a building can be classified as the non-structural crack and structural crack.

Non-structural crack is a fine crack that has little or negligible effect on the strength and integrity of the building. They are generally less than 2.00 mm in width, exist as a

thin hairline crack at any part of the building[2] .

They typically arise in the old building, created as internal stress forms in the building material due to varying humidity, surrounding temperature, and weather conditions[1][2] .

They may be caused by creep damage, vegetation or trees, shifting or moving foundations, settlement, and hydrostatic pressure. Non-structural cracks tend to develop as structural cracks if it is not well controlled. Water will seep through it,

generate internal pressure, and thereby force or expand the crack. Structural crack endangers the building structure and it will affect the building strength and stability.

Structural cracks are generally wider than 2.00 mm width, they may occur in the pattern of continuous horizontal cracks on walls, vertical cracks with relatively wider at the top or bottom, diagonal cracks, and stair-step cracks

Formation of structural crack may due to incorrect design, building material

deterioration due to chemical attack, overloading, soil settlement, and unbalanced soil pressure due to expansion of soil. They occcur at structural components such as foundation walls, beams, columns, slabs, etc. TYPES OF CRACKS IN CONCRETE COLUMN Column is an important element in the building framing structure and it transfers the load from the uppper floor towards the foundation. Cracks in the column can be categorized according to their crack pattern or propagation. The 4 types of cracks in the concrete column are listed below [3] [4]: a) Diagonal Crack: The crack propagation is

diagonal along the entire column face. This crack formed due to incorrect design causing the column to have inadequate load carrying capacity. Diagonal cracks in the column

indicate that the column may have not enough reinforcement area or inadequate cross section of the column. Figure 1 shows the diagonal crack in the concrete column.

TYPES OF CRACKS IN CONCRETE COLUMN

Column is an important element in the building framing structure and it transfers the load from the upper floor towards the foundation. Cracks in the column can be

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a) Diagonal Crack:

The crack propagation is diagonal along the entire column face. This crack formed due to incorrect design causing the column to have inadequate load carrying capacity.

Diagonal cracks in the column indicate that the column may have not enough reinforcement area or inadequate crosssection of the column. Figure 1 shows the diagonal crack in the concrete column

a) Horizontal Crack:

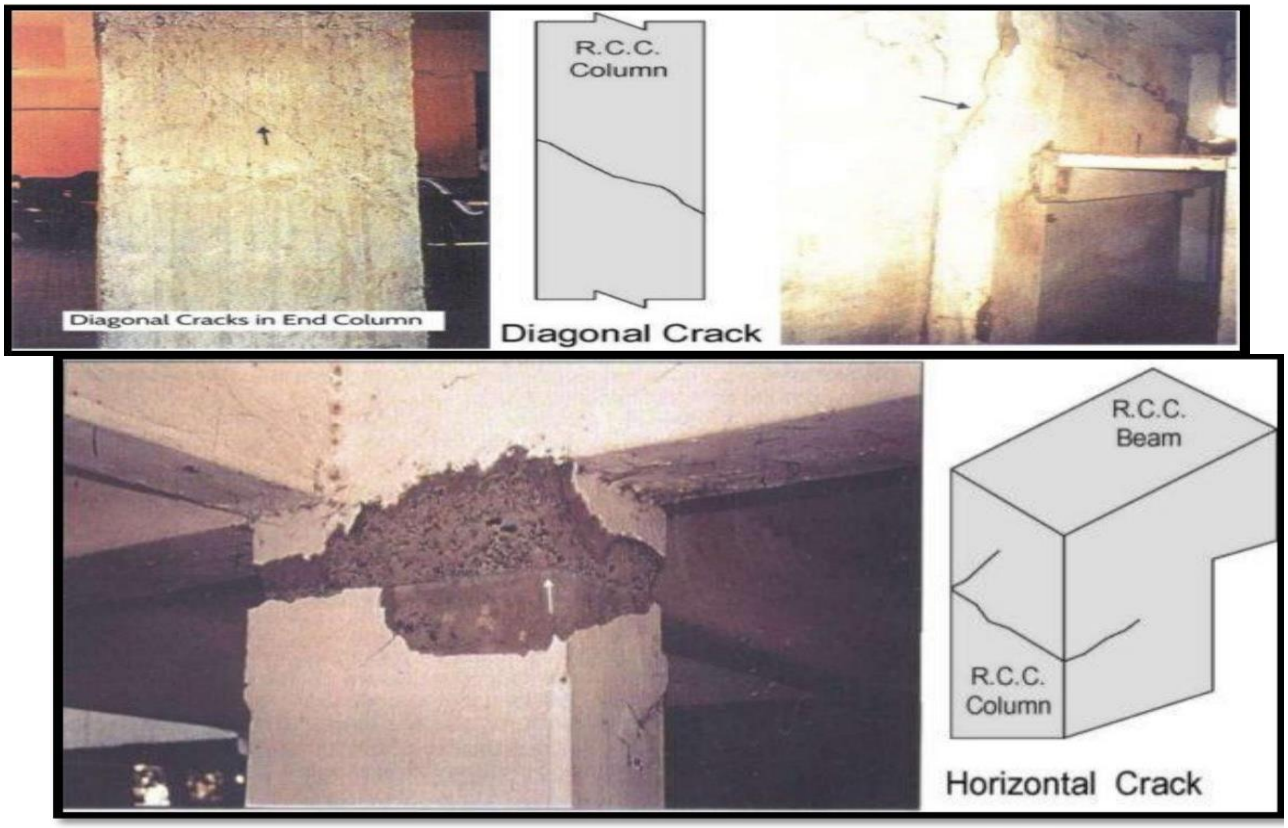


Figure 2: Horizontal Crack In The Concrete Column [3] [4]

Horizontal cracks within the concrete column are typically seen on the beam-column joint and on the column face where tensile stress is high. Columns with insufficient moment restrain, low reinforcement area or incorrect arrangement of reinforcement may result in horizontal cracking because of the impact of shear force, direct load, and uniaxial bending. Figure 2 is the horizontal cracks within the concrete column.

b) Splitting Crack:

Splitting cracks at the concrete columns are short and parallel vertical cracks of varying width. These types of cracks can occur in columns with insufficient steel bar reinforcement and low concrete strength. Splitting crack happens as the load acting on it reaches its ultimate load-bearing capacity. In other words, this is a compression failure of the concrete column. An example of the splitting crack in the concrete column is shown in Figure 3.

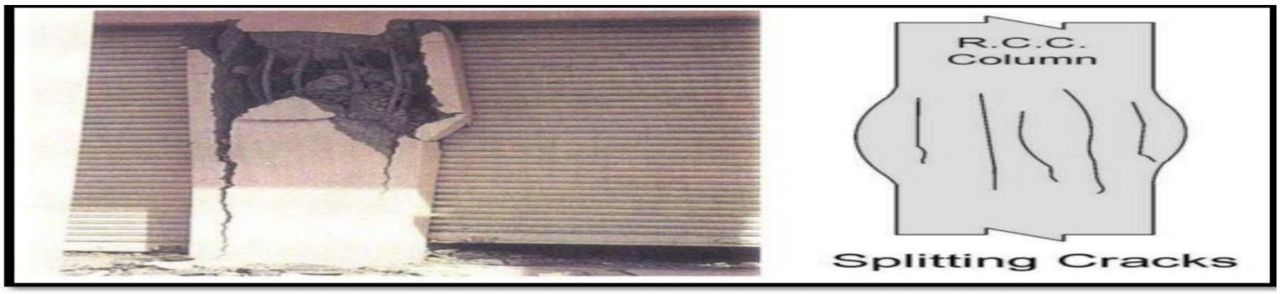


Figure 3: Splitting Crack In The Concrete Column [3] [4]

a) Corrosion Crack:

Corrosion crack is a crack formed by rusting the concrete reinforcement bar. The crack propagation follows the pattern or the line of the steel bar. The reinforcement bar normally corrodes due to

the inadequate concrete cover, hairline cracking on the concrete surface, and exposure to high humidity or chemical attack. If these types of cracks cannot be properly treated, the degradation of the steel reinforcement bars can worsen exponentially. Figure 4 shown the corrosion cracks in the concrete column.

Defects in Shear wall

Concrete wall palaces:

Types of damage to concrete walls are as follows:

Chapter 4 Defects reinforced concrete

X-shaped shear slits

Slide along structural breaks

Shortages resulting from bending moments

X-shaped shear notches:

The appearance of X-shaped cracks in concrete walls is the second most likely type of damage on concrete walls. These damages resulting from shear moments are considered a type of brittle failure. Because of the type of arrangement of the cracks, and the vertical loads of the equilateral triangles which are formed on both sides, they tend to separate from the structure and as a result the structure collapses.

1. Sliding along the structural joints :

The most common type of seismic damage to walls is the appearance of cracks along the structural joints. The occurrence of this kind of damage is mainly due to the fact that during implementation, the old concrete is not well connected with the new concrete. All new seismic regulations stress the need for concrete bonding when construction stops.

2. Shortcomings due to bending moments:

Damage due to bending moments of the walls is rare. This is generally due to the fact that the bending moments present are usually lower than the design values.

Methods of strengthening concrete walls:

If the bending, shear strength, ductility or stiffness of the shear wall is low for any reason, the wall can be reinforced in the following ways.

- Use a layer of concrete
- Use of steel sheets
- Use of FRP

fibers Usage

of concrete

shirt:

- One common method of strengthening concrete walls is to use a concretescreed.

Types of reinforcement methods using concrete layer are as follows:

- Increasing wall thickness by spraying concrete

- Building a new shear wall adjacent to the old wall

- Filling the openings with reinforced concrete

- In this method, it is possible to connect the old and new concrete by planting bolts. In this method, new fittings are also implanted on the inside of the lintel and column.

- Reinforcement using steel sheets:

Attaching steel sheets with a nail to the concrete wall on one or both sides increases the resistance and ductility of the walls. It should be noted that the reinforcement of the walls should not lead to brittle collapses as a result of shear stresses, but the fracture should be in the form of ductile bending.

Reinforcement using FRP fibers:

To provide the expected capacity and performance, reinforcement, restoration and rehabilitation of concrete walls and other walls, the FRP system can be used. The use of the shear wall reinforcement system using FRP, within increasing the flexural distributing the stress throughout the sheet instead of concentrating it on a specific point. Therefore, the wall must be protected against dynamic

lateral loads, earthquakes and corrosion-prone environments. In general, using FRP materials the following can be achieved:

Strengthening concrete walls using FRP to increase bending resistanceand shear resistance, results in Strengthening concrete shear walls using FRP to increase shear strength

Increase the stiffness of concrete walls with FRP Increased explosion resistance.

FRP sheets increases the yield strength, ultimate strength and ductility of the wall. The shearing capacity of FRP in this case is determined based on the shearing capacity of rectangular parts wrapped with FRP fibers.

Curvature Strengthening of FRP Reinforced Concrete Shear Wall:

To compensate for the weak curvature of the wall, FRP sheets and fibers are installed vertically, matching the wall height parallel to the

longitudinal rebar. The installation

method is usually such that the FRP fibers are installed on both sides of the wall. The way FRP fibers work together to bear bending on the wall, such as the role played by the main (vertical) steel reinforcement inside the wall, if FRP fibers are used to increase the bending resistance of the wall over its height, it is necessary to properly fix its end at the edge of the wall so that forces are transmitted within this sheets to the foundation of the wall. To constrain the ends of the bending sheets, a steel angle section can be used next to the wall support to which it is fixed, or an FRP

shearing plate perpendicular to the bending FRP layer, can be used at the end of the layer.

Chapter 4 Defects reinforced concrete

The method of breaking a wall that has a bending failure, begins with tensile cracks, which are formed horizontally at the edges of the wall near the edge of the wall, and then the external tensile bars are yielded.

Bending reinforcement of the wall with FRP sheets increases the crack strength, yield strength, and secondary stiffness during yield and increases the final strength of the wall.

Before the concrete cracking and the bars yielding inside the wall, the contribution of FRP fibers to the load bearing is low, but after the bending bars undergoing and the tensile concrete cracking, the

contribution of the FRP fibers to the bending tolerance increases significantly. The resulting fracture, if the fibers are not separated from the wall, is a ductile fracture, but a significant decrease in the load- bearing capacity of the members occurs. If both bending and shear

reinforcement are used horizontally and vertically on the wall, the

increase in yield load and the secondary toughness of the final strength and ductility are higher than before. In this FRP bracing system, the fibers are fixed horizontally, which results in the bending fibers being restricted.

Reinforcing the concrete wall with FRP slats

Increasing the ductility of the shear wall reinforced with FRP

The low ductility is the main weakness in the existing shear walls, to deal with the lateral force of an earthquake. Among the most important reasons for these shortcomings, the longitudinal reinforcing steel connections in areas prone to the formation of ductile joints, insufficient confinement in the border areas, and insufficient control of transverse

iron. Collapses in these cases are sudden and fragile, and lead to a sharp drop in load capacity.

Chapter 4 Defects reinforced concrete

In general, in order to achieve proper ductility, it is essential to avoid all cases of brittle breakdowns. On the other hand, the energy that enters the wall must be absorbed by the occurrence of a plastic joint at the height of the wall. In general, the shear resistance of the FRP reinforced wall should be such that a plastic joint can be formed along the wall without shear failure.

Repair the shear wall

5.1 Introduction

This chapter presents an elaborated characterization of the utilized specimens, the material properties, the testing setup, instrumentation, and the testing procedure. The experimental program included six-cylinder specimens were with a side length of 300 mm and a diameter of 150 mm , seven-cylinder specimens were with a side length of 200 mm and a diameter of 100 mm and five cube specimens were with length sides of 150*150*150 mm.

Specimens were loaded up to failure under increasing static loads. Both cylinder and cube specimens were tested in terms of compressive strength. The compressive and bending strength tests were carried out according to **ECP 203-2018**.

A set of two specimens of each type were considered as control specimens. The other specimens were strengthened with Externally Bonded (EB) Fiberglass sheets, with different strip widths for each specimen. All experiments were carried out in the Material Lab. of the Faculty of Engineering, Nile higher institute.

5.2Concrete materials

Materials of the specimens used in this research were procured from the available local materials. They include ordinary Portland cement, gravel, sand, and water.

5.2.1Coarse aggregate

Clean dry angular gravel free from impurities was utilized in the mixture. Two types of gravel were used according to the sieve analysis test. The first category of the nominal maximum size is not more than 30 mm and not smaller than 20 mm, while the second category of nominal maximum size does not exceed 15 mm. Table (3-1) and Figure (3-1) show the results of the sieve analysis test.

Table (3-1) Sieve analysis test results

Sieve number (mm)	Retained weight on every sieve(gm)	Cumulative retained weight (gm)	Cumulative Retained weight %	Passed weight %
40	100	100	1.00	99.00
20	3500	3600	36	64
10	3200	6800	68	32
5	600	7400	74	24
2.36	700	8100	81	19
1.18	700	8800	88	12
0.6	300	9100	91	9
0.3	300	9400	94	6
0.15	300	9700	97	3
pan	300	10000	100	0

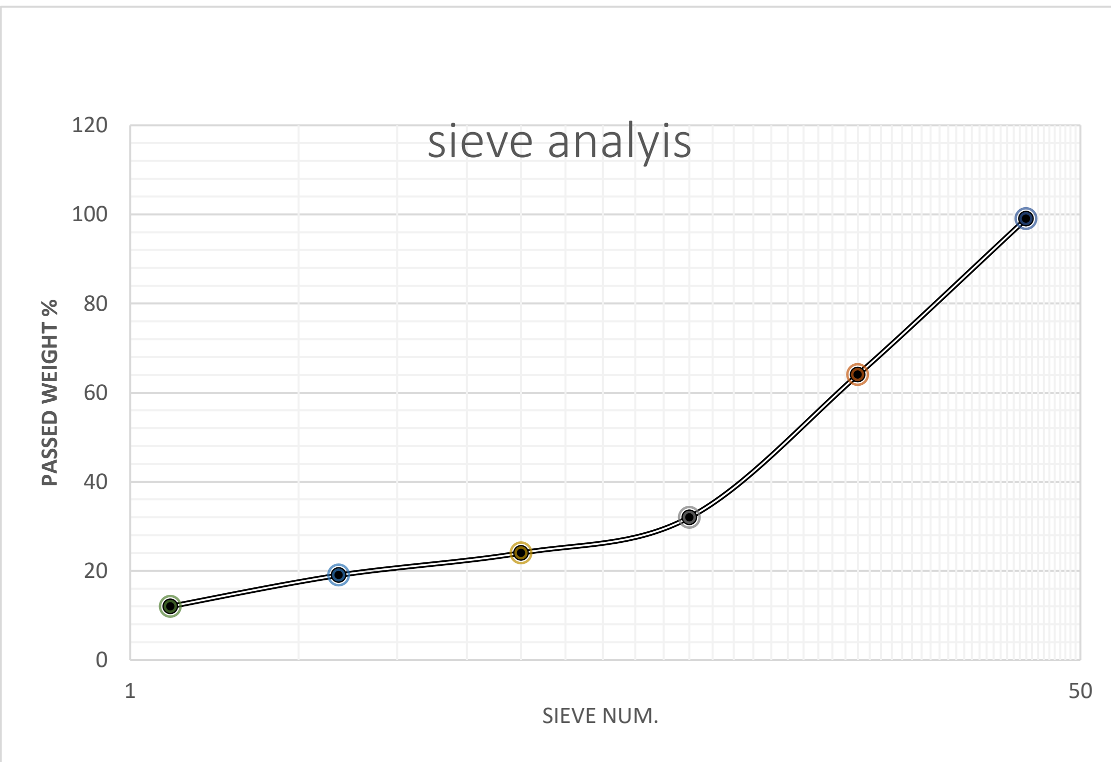


Figure (3-1)**:** Sieve analysis test for gravel

5.2.2 Fine aggregate

The fine aggregate used was natural sand. It was dry well-graded sand free from impurities.

5.2.3 Mixing water

Portable water free from compounds or impurities was utilized in the mixture. The water-cement ratio (w/c) equal to 0.5 by weight was used in the mix.

5.2.4 Cement

The cement used in the concrete mix was CEM I- N 42.5, Ordinary Portland cement, which complies with the Egyptian standard specifications.

5.3 Concrete mix

Figure (3-2) shows the concrete mixture produced at the concrete laboratory by mix design using the absolute volume method. This method assumes that the absolute volume of concrete is the sum of the absolute volumes of the constituent materials. For concrete i.e., the absolute volume of cement, sand, gravel, and water is as follows:

$$\text{Absolute volume} = \frac{C}{\gamma_C} + \frac{G}{\gamma_G} + \frac{S}{\gamma_S} + \frac{W}{\gamma_W} + \frac{SF}{\gamma_{sf}} = 1000 \text{ Lit}$$

C = 450 kg ***S*** = 550 kg ***G*** = 1065 kg ***W*** = 250 lit

"This amount for 1 Cubic meter"

<u>*Where:*</u>

C*: weight of cement in kilograms needed per cubic meter of concrete.*

S: *weight of sand in kilograms needed per cubic meter of concrete.*

G: *weight of gravel in kilograms needed per cubic meter of concrete.*

W: *weight of water in kilograms needed per cubic meter of concrete.*

SF *= weight of silica fumes in kilograms needed per cubic meter of concrete.*

Gc, Gs, Gg, Gsf: *the specific weight of cement, sand, and gravel, respectively, noting that* ***one cubic meter of concrete*** *= 1000 liters*

This concrete mixture was designed to develop (35 MPa) for cube strength. The concrete mixing was done mechanically by mixing materials in a dry.

Figure (3-2): Concrete mixing in a batch drum mixer

5.4 Casting and compaction

The test molds were prepared for the concrete mix to be placed. After the concrete mixing had finished, it was cast in the molds and shaken for 0.5 minutes to compact the concrete. The top surface of concrete specimens was finished manually with a trowel, Figures (3-3) and (3-4).

Figure (3-3): Test molds

Figure (3-4): Casting and compaction of concrete mix

5.5 Curing

After 24 hours from the time the sample specimens were cast, they were left to cure for 28 days after wrapping with wet towel sheets and submerged in water tanks. Then they were taken from the molds and placed for testing, as shown in Figure (3-5).

Figure 3-5: Curing of samples

5.6Testing of fresh concrete

The slump test was carried out for the two batches of concrete mixes according to **ECP 203-2018**, and Egyptian Standard Specifications, **(E.S.S) 1658-1988 part 1** to achieve the consistency test. The measured slump was 24cm and 22cm , as shown in Figure (3-6).

Figure (3-6): Testing of fresh concrete(The slump test)

5.7Compressive strength of hardened concrete

8 cubes (150 × 150 × 150) mm were cast from each batch and cured with portable fresh water for 7 days to measure the concrete compressive strength. The average 28-day compressive strength values of batch cubes were 32, 36, and 34.4 MPa, respectively. The concrete characteristic compressive strength was taken as (f_{cu}) =/~ 34 N/mm^2. The compressive strength test was carried out according to **ECP 203-2018**, and **E.S.S 1658-1988 parts 4, 5**, Figure (3-7).

Figure (3-7): Compressive load test

5.8Strengthening materials

5.8.1 Glass Fiber sheets

The used Fiberglass (GFRP) sheets, known commercially as SikaWrap®-430 G of 600 mm width, were manufactured by **SIKA EGYPT** for construction chemicals,

Figure (3-8). Table (3-2) shows the GFRP system features following the datasheet of the manufacturer.

Table (3-2): Typical physical properties of the glass fiber sheet

Fiber Reinforcement	**White glass fiber– High tensile**
Fiber density	**2.56 g/cm^3**
Fiber tensile elastic modulus (E)	**70 kN/mm^2**
Fiber orientation	**0° (unidirectional)**
Sheet weight	**430 g/m^2**
Sheet thickness	**0.168 mm**
Sheet tensile strength	**1500 MPa**
Sheet tensile elongation at break, ultimate	**2.14 %**
Tensile Resistance	**252 kN/m**
Tensile Stiffness	**11.8 MN/m**

Figure (3-8): Glass Fiber Sheet

5.8.2 Saturants (Epoxy) sikadur-330 Epoxy

The saturant used was a two-component epoxy resin called Sikadur®-330 and manufactured by **SIKA EGYPT**. It was used as an impregnation resin for Sika

Wrap® fabric reinforcement for the dry application method. Table (3-3) and figure (3-9) shows the saturant specifications according to the manufacturer's datasheet.

Table (3-3): Saturant Sikadur®-330 specifications

Property	Saturant
Composition	Two-part 5 kg packs
Modulus of Elasticity in Flexure	3800 N/mm^2
Tensile Strength	30 N/mm^2
Modulus of Elasticity in Tension	4500 N/mm^2
Tensile Adhesion Strength	Concrete fracture (> 4 N/mm^2)
Density at 23° C	1.3 ± 0.1 kg/liter
Color	A: white, B: grey, A + B mixed: light grey
Viscosity at 23° C	~6000 MPa
Overall coverage	0.7: 1.5 kg/m^2
Theoretical consumption	0.7 kg/m2/coat (minimum 2 coats/ layer)
Workability period	30 min. at 23° c
Cure time	7 days at 23° c
Re-coat range max.	Within 24 hrs.

Figure (3-9): Saturants (Epoxy)

5.8.3 Carbon Fiber sheets

The used Fiberglass (CFRP) sheets, SikaWrap®-300 C is a unidirectional woven carbon fibre fabric with mid-range strengths, designed for installation using the dry or wet application process, were manufactured by **SIKA EGYPT** for construction chemicals, Figure (3-10). Table (3-4) shows the CFRP system features following the datasheet of the manufacturer.

Table (3-4): Typical physical properties of the glass fiber sheet

Fiber Reinforcement	**Black carbon fibre – High tensile**
Fiber density	**1.82 g/cm3**
Fiber tensile elastic modulus (E)	**230 KN/mm2**
Fiber orientation	**unidirectional**
Sheet weight	**304 g/m2**
Sheet thickness	**0.167 mm**
Sheet tensile strength	**3 500 Mpa**
Sheet tensile elongation at break, ultimate	**1.56 %**
Tensile Resistance	**585 N/mm**
Tensile Stiffness	**37.6 MN/m**

Figure (3-10): Carbon Fiber Sheet

5.9 Test program

The test program consisted of six-cylinder specimens were with a side length of 300 mm and a diameter of 150 mm , seven-cylinder specimens were with a side length of 200 mm and a diameter of 100 mm and five cube specimens were with length sides of 150*150*150 mm.

The first group was a set of two reference specimens without strengthening for each type. The strengthened specimens with externally bonded (EB) Fiberglass sheets, with different strip widths for each specimen, were shown in Table (3-11).

Table (3-1): Program details for tested specimens

Group	Spec. num.	Terminology	Properties	Strengthening method
I	S1	S1-CY	One control cylinder specimen (300*150)mm with no strengthening	–
	S2	S2- CU	One control cube (150*150*150)mm specimen with no strengthening	–
	S3	S3-CY	One control cylinder (200*100)mm specimen with no strengthening	–
II	S4	S4-CY- 2×5	Cylinder (300*150)mm strengthened with two strips of 50 mm width (one strip at the top and another at the bottom)	GFRP-(EB)
	S5	S5-CY-3×5	Cylinder (300*150)mm strengthened with three strips of 50 mm width(one strip at the top , one at middle and another at the bottom)	GFRP-(EB)
	S6	S6-CY-1×30	Cylinder strengthened with one strip of 300 mm width (F.H)	GFRP-(EB)
	S7	S7-CY-1×5	Cylinder(300*150)mm strengthened with one strips of 50 mm width (one at middle)	GFRP-(EB)
	S8	S8-CY-1×30	Cylinder(300*150)mm strengthened with one strips of 300 mm width (F.H)	CFRP-(EB)
	S9	S9- CU-1×5	Cubes(150*150*150)mm strengthened with one strips of 50 mm width(one at middle)	GFRP-(EB)

III	S10	S10- CU-2×5	Cubes(150*150*150)mm strengthened with two strips of 50 mm width(one strip at the top and another at the bottom)	GFRP-(EB)
	S11	S11- CU-1×10	Cubes(150*150*150)mm strengthened with one strips of 100 mm width(one at middle)	GFRP-(EB)
	S12	S12- CU-3×5	Cubes(150*150*150)mm strengthened with three strips of 50 mm width(one strip at the top , one at middle and another at the bottom)	GFRP-(EB)
	S13	S13-CY- 2×5	Cylinder(200*100)mm strengthened with two strips of 50 mm width (one strip at the top and another at the bottom)	GFRP-(EB)
	S14	S14-CY-3×5	Cylinder(200*100)mm strengthened with three strips of 50 mm width(one strip at the top , one at middle and another at the bottom)	GFRP-(EB)
IV	S15	S15-CY-1×20	Cylinder(200*100)mm strengthened with one strip of 200 mm width(F.H)	GFRP-(EB)
	S16	S16-CY-1×5	Cylinder(200*100)mm strengthened with one strips of 50 mm width (one at middle)	GFRP-(EB)
	S17	S17-CY-1×5	Cylinder(200*100)mm strengthened with one strips of 50 mm width	CFRP-(EB)
	S18	S17-CY-2×5	Cylinder(200*100)mm strengthened with two strips of 50 mm width(one strip at the top and another at the bottom)	CFRP-(EB)

5.10 Configuration of the tested specimens

5.10.1 Schematic detailing of the Specimens

Figure (3-11) and (3-12) show isometric 3D models of the main details for control and strengthened specimens.

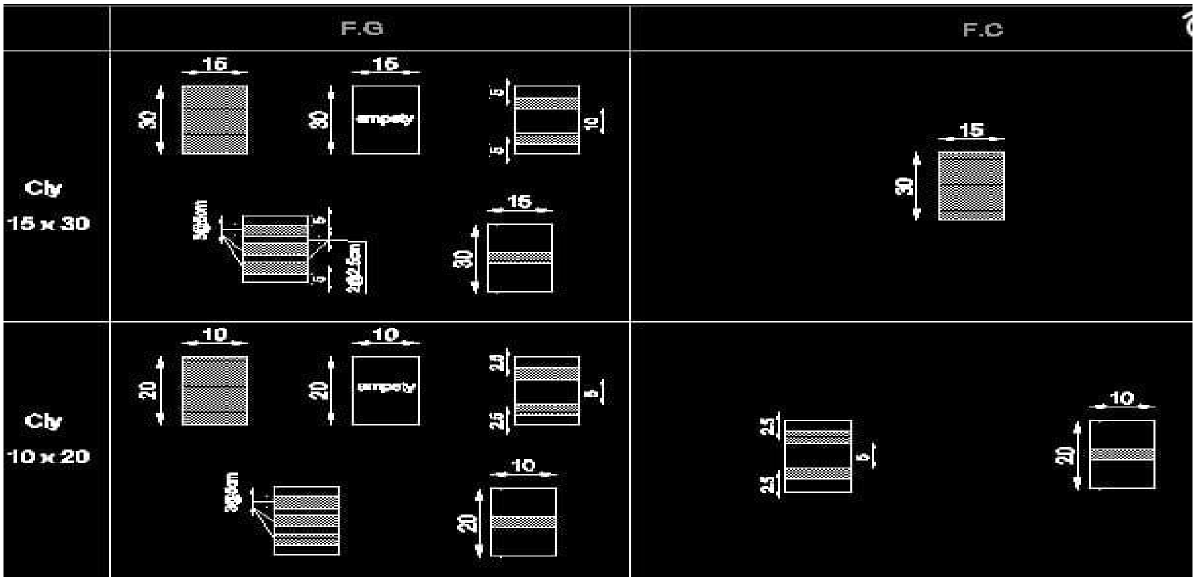


Figure (3-11) : Schematic details of the cylinder specimens

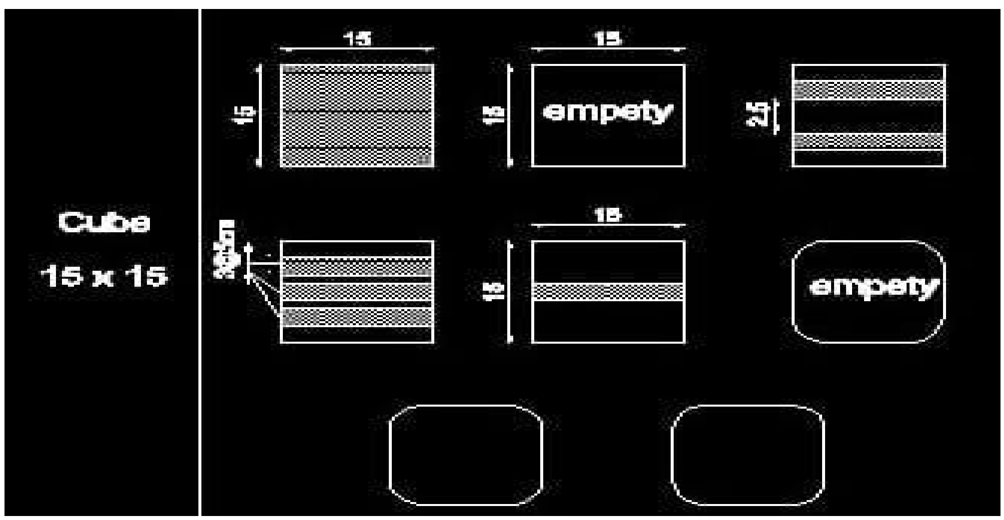
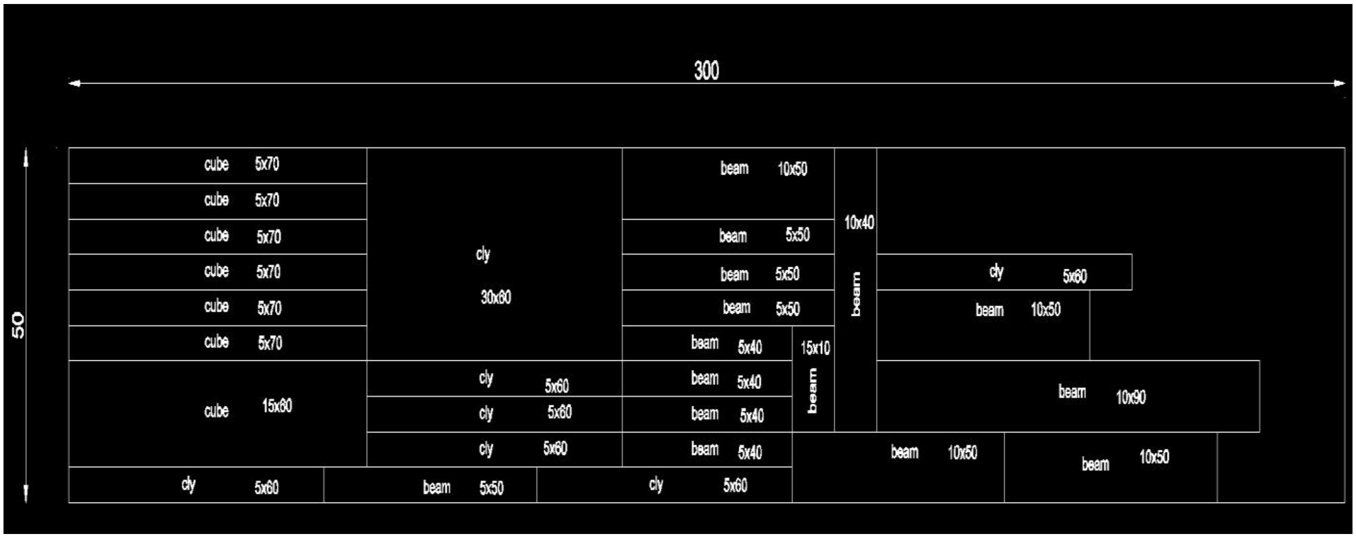
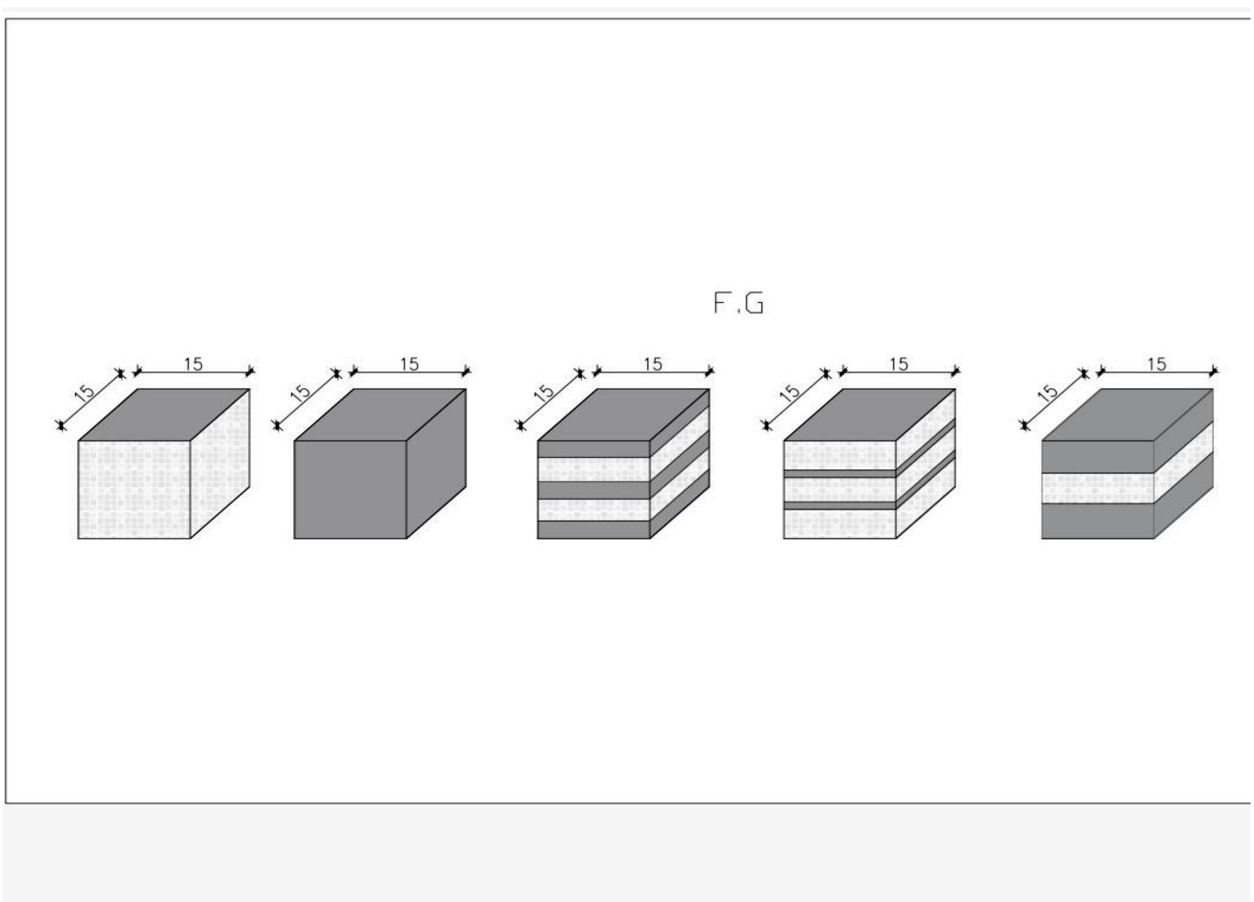
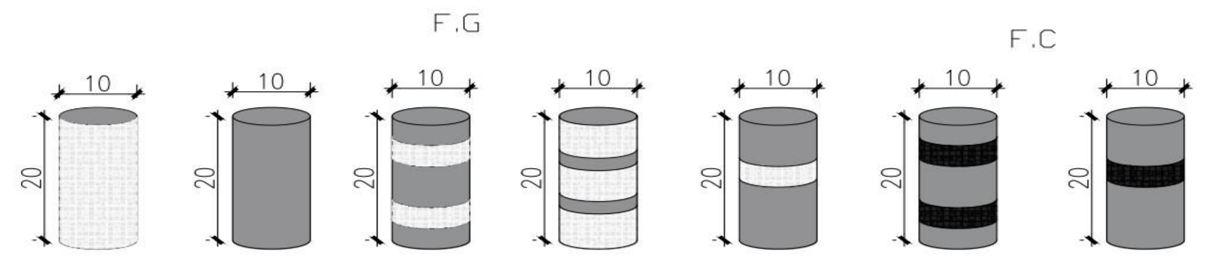


Figure (3-12): Schematic details of the cube specimens



igure (3-13): Divide the (GFRP) sheets and (CFRP) sheets




F.G
F.C
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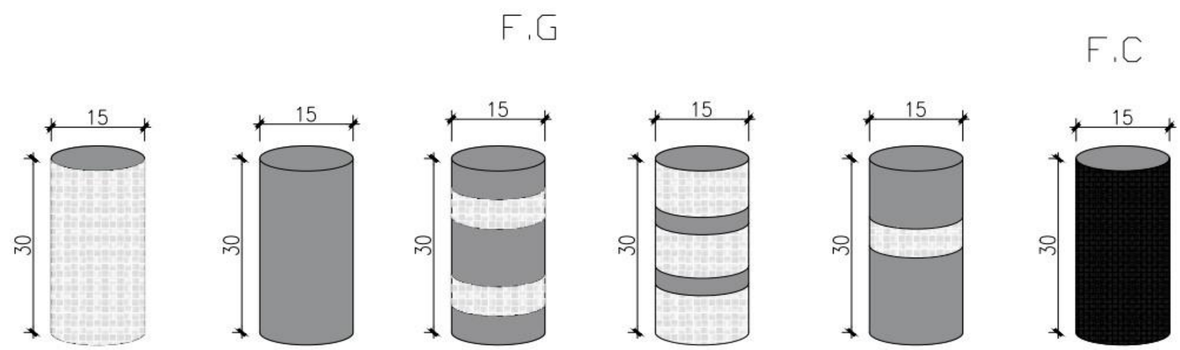
F.G
F.C
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15
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30

1.8.1.1 Specimen (S4-CY- 2×5)

Figure (3-14) : S4

1.8.1.2 Specimen (S5-CY-3×5)

Figure (3-15) : S5

1.8.1.3 Specimen (S6-CY-1×30)

Figure (3-16) : S6

1.1.1.4 Specimen (S7-CY-1×5)

Figure (3-17) : S7

1.1.1.5 Specimen (S8- CY1×30)

Figure (3-18) : S8

1.1.1.7 Specimen (S13- CY2×5)

Figure (3-19) : S13

1.1.1.8 Specimen (S14- CY3×5)

Figure (3-20) : S14

1.1.1.9 Specimen (S15- CY1×20)

Figure (3-21) : S15

1.1.1.10 Specimen (S16- CY1×5)

Figure (3-22) : S16

1.1.1.11 Specimen (S17- CY1×5)

Figure (3-23) : S17

1.1.1.11 Specimen (S18- CY2×5)

Figure (3-24) : S18

1.1.1.12 Specimen (S9- CY1×5)

Figure (3-25) : S9

1.1.1.13 Specimen (S10- CY2×5)

Figure (3-26) : S10

1.1.1.14 Specimen (S11- CY1×510)

Figure (3-27) : S11

1.1.1.15 Specimen (S12- CY3×5)

Figure (3-28) : S12

5.11 Specimens casting and strengthening

After being cleaned and sprayed with water, mold forms were used to cast the specimens. Then, the concrete mix was poured in. The side forms were removed after one day of casting. All specimens were cured for 12 days at the surrounding environmental ambient temperature. Strengthening materials were applied to specified specimens as mentioned earlier. This specimen was strengthened with GFRP sheets and CFRP sheets as discussed earlier. Figure (3-29) presents the steps of strengthening with EB-GFRP and EB-CFRP:

a) The concrete surface was made free from dust, oil, and an angle grinder was used to smooth the surface before applying GFRP sheets and CFRP sheets. In addition, a blower was used to remove the fine dust particles. Before applying the sheets, the surface was dried, as shown in Figure (3-29-a).
b) A GFRP sheet would be cut into pieces to be applied on a surface, as shown in Figure (3-29-b1) and CFRP sheets would be cut into pieces to be applied on a surface, as shown in Figure (3-29-b2)
c) GFRP strips and CFRP strips were then glued to the smooth surface using two layers of epoxy, as shown in Figures (3-29-c) to (3-29-e).
d) The full bond between the concrete surface and GFRP sheets was ensured, as the remaining air bubbles were removed using a soft card.
e) Figure (3-29-g) shows the final installation and finishing of GFRP sheets and CFRP sheets for the specimen (S5).

Figure (3-29-a): Smoothing the concrete surface for the specimen

Figure (3-29-b1): Cutting of GFRP sheet to the required dimensions

Figure (3-29-b2): Cutting of CFRP sheet to the required dimensions

Figure (3-29-d): GFRP sheets and CFRP sheets installing and preparing the surface for the GFRP sheets and CFRP sheets

Figure (3-29-e): Applying the second layer of epoxy

Final installation and finishing of GFRP sheets and for CFRP sheets the specimens

5.12 Test setup

Every specimen was loaded up to failure under increasing static loads. For the Cylinder and cube , Cylinder and cube specimens were tested against compressive resistance. The compressive and bending strength tests were carried out according to ECP 203-2018.

To ensure the best results outcome throughout the overall test, the concentrated load was used to apply load gradually on tested specimens. As shown in Figure (3-26).

Figure (3-30): Test equipment

Chapter 6 TEST RESULTS AND DISCUSSIONS

TEST RESULTS AND DISCUSSIONS

6.1 Introduction

The laboratory studies tend to be the most effective and productive approach as they provide realistic comprehension and knowledge of the research program's behavior. For the calibration and evaluation of models, testing results are important. The outcomes and analysis of the test results of the specimens are presented in this chapter concerning their crack pattern propagation and failure loads.

A total of 5 cubes (150 × 150 × 150) mm, 6 concrete cylinders of (300 × 150) mm, and 7 concrete cylinders of (200 × 100) mm were cast and cured for 28 days then strengthened using GFRP and CFRP with different strips configurations, to measure the concrete compressive strength. The 28-day compressive test was carried out according to ECP 203-2018 and E.S.S 1658-1988, see Figures below.

Figure (4-1). Test Equipment

Chapter 6 TEST RESULTS AND DISCUSSIONS

6.2 Crack pattern propagation

6.2.1 Crack pattern for cylinder specimens (300*150)

6.2.1.1 S1 (S1-CY)

For the control cylinder specimen S1, the crack and failure shape of the specimen can be clearly seen for the photo illustrated in Figure 4.2-a. Effect of the friction between the tested cylinder specimen and the two chords of testing machine on the resulting failure as well as the compressive strength can de noticed as shown in Figure 4.2.b.

When loading the horizontal surfaces of the test sample, this sample is compressed vertically or deflated due to the pressure stresses on it, while the sides of the sample try to stretch horizontally, but this lateral expansion movement will be resisted by the friction that arises at this moment between the two metal plates and the two horizontal surfaces of the test sample. These friction forces are generated with a maximum value at the edges of the two surfaces of the sample and their value gradually decreases as we head inward until they vanish completely as shown in Figure 4.2-b.

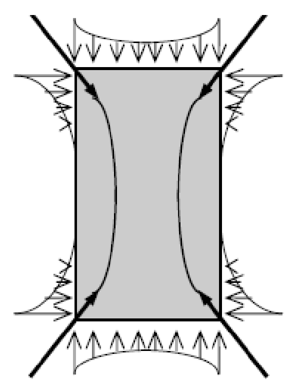

figure 4.2-b: Friction effect details

Chapter 6 TEST RESULTS AND DISCUSSIONS

Chapter 6 TEST RESULTS AND DISCUSSIONS

Figure 4.2-a Failure shape of S1

6.2.1.2 S4 (S4-CY- 2×5)

For the strengthened cylinder specimen S4 with two GFRP strips 50 mm wide as illustrated in Figure 4.3, the crack pattern and failure shape of the specimen can be clearly seen at the middle height of the specimen with no strengthening.

Chapter 6 TEST RESULTS AND DISCUSSIONS

Figure 4.3 Failure shape of S4

6.2.1.3 S5 (S5-CY- 3×5)

For the strengthened cylinder specimen S5 with 3 GFRP strips 50 mm wide, as described in photo in Figure 4.4, the crack pattern and failure shape of the specimen can be clearly seen at the middle height of the specimen S5 similar to S4.

Chapter 6 TEST RESULTS AND DISCUSSIONS

Figure 4.4 Failure shape of S5

5.2.1.4 S6 (S6-CY- 1×30)

For the strengthened cylinder specimens S6 with one GFRP middle strip 300 mm wide at the middle height of the specimen as described in photo in Figure 4.5, can be clearly seen at the weakest parts at the two ends of the S6-specimen that left without strengthening and extended to the whole specimen at its middle height of the specimen similar to both S4 and S5specimens.

Figure 4.5 Failure shape of S6

5.2.1.5 S7 (S7-CY- 1×5)

For the strengthened cylinder specimens S7 with one GFRP middle strip 50 mm wide at the middle height of the specimen as described in photo in Figure 4.6, can be clearly seen at the weakest parts at the two ends of the S7-specimen that left without strengthening and extended to the whole specimen at its middle height of the specimen similar to both S4, S5 and S6 specimens.

Chapter 6 TEST RESULTS AND DISCUSSIONS

Figure 4.6 Failure shape of S7

5.2.1.6 S8 (S8-CY- 1×30)

For the strengthened cylinder specimens S8 with one CFRP middle strip 300 mm wide at the middle height of the specimen as described in photo in Figure 4.7, can be clearly seen at the weakest parts at the two ends of the S8-specimen that left without strengthening and extended to the whole specimen at its middle height of the specimen similar to both S4, S5, S6 and S7 specimens.

Figure 4.7 Failure shape of S8

6.2.2 Crack pattern for Cube specimens

6.2.2.1 S2 (S2-CU)

Similarly, as previously illustrated for cylinder specimens, the crack and failure shape for the control cube specimen S2, is shown in Figure 4.8 photo.

Figure 4.8 Failure shape of S2

6.2.2.2 S9 (S9-CU-2×5)

For the strengthened cube specimen S9 with one GFRP strip 50 mm wide, its crack pattern and failure shape is shown in Figure 4.9

Figure 4.9 Failure shape of S9

6.2.2.3 S10 (S10-CU-2×5)

For the strengthened cube specimen S10 with two GFRP strips 50 mm wide, its crack pattern and failure shape is shown in Figure 4.10

Chapter 6 TEST RESULTS AND DISCUSSIONS

Figure 4.10 Failure shape of S10

6.2.2.4 S11 (S11-CU-1×10)

For the strengthened cube specimens S11 with one GFRP strip 100 mm wide, its crack pattern and failure shape is shown in Figure 4.11

Figure 4.11 Failure shape of S11

6.2.2.5 S12 (S12-CU-3×5)

For the strengthened cube specimen S12 with three GFRP strips 50 mm wide, its crack pattern and failure shape is shown in Figure 4.12

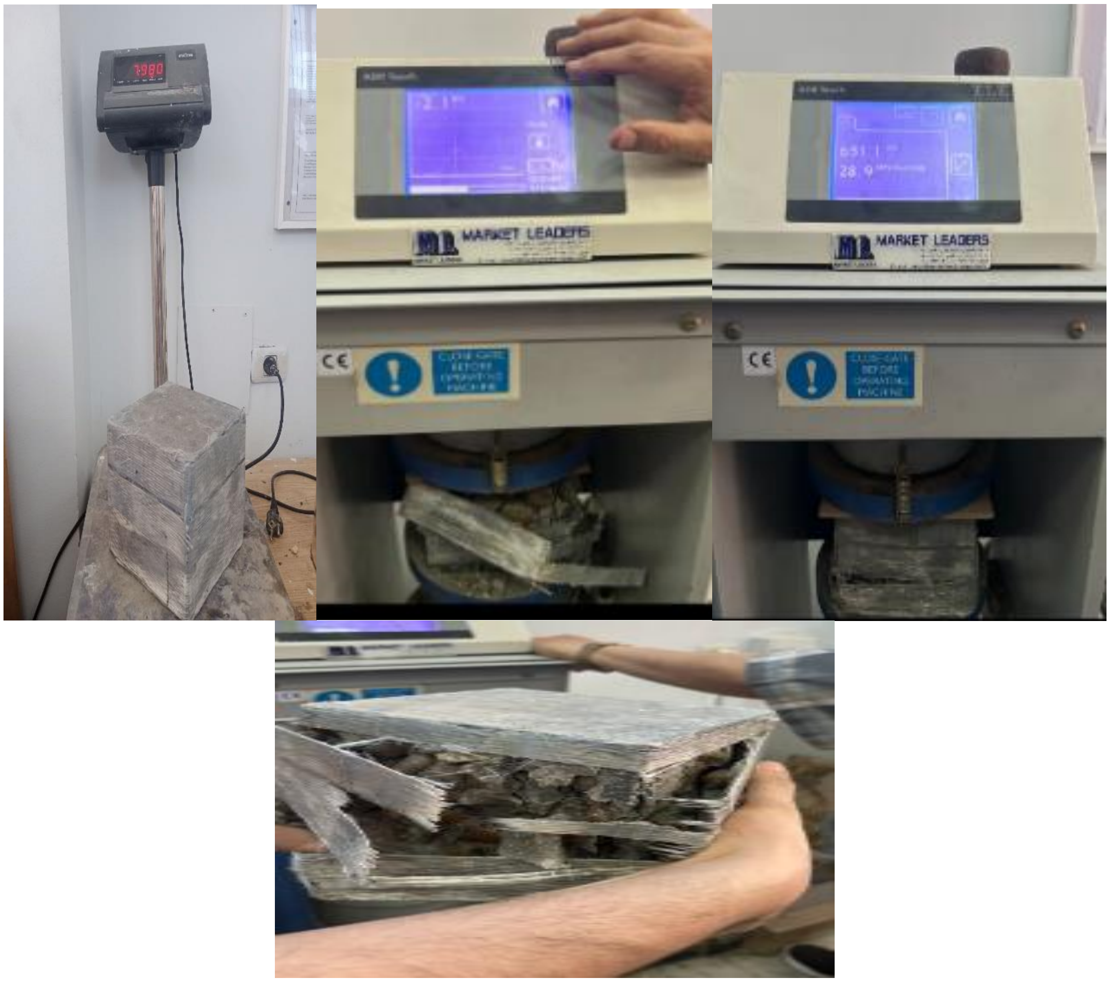

Figure 4.12 Failure shape of S12

6.2.3 Crack pattern for cylinder specimens (200*100)

6.2.3.1 S3 (S3-CY)

For the control cylinder specimen S3, the crack and failure shape of the specimen can be clearly seen for the photo illustrated in Figure 4.13. Effect of the friction between the tested cylinder specimen and the two chords of testing machine on the resulting failure as well as the compressive strength can de noticed as shown in Figure 4.2.b.

When loading the horizontal surfaces of the test sample, this sample is compressed vertically or deflated due to the pressure stresses on it, while the sides of the sample try to stretch horizontally, but this lateral expansion movement will be resisted by the friction that arises at this moment between the two metal plates and the two horizontal surfaces of the test sample. These friction forces are generated with a maximum value at the edges of the two surfaces of the sample and their value gradually decreases as we head inward until they vanish completely as shown in Figure 4.2-b.

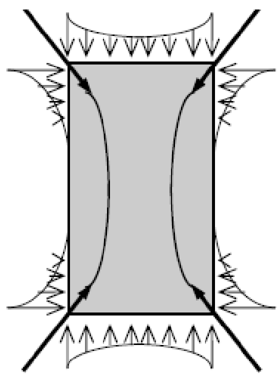

figure 4.2-b: Friction effect details

Figure 4.13 Failure shape of S3

6.2.3.2 S*13* (S*13*-CY- 2×5)

For the strengthened cylinder specimen S13 with two GFRP strips 50 mm wide as illustrated in Figure 4.14, the crack pattern and failure shape of the specimen can be clearly seen at the middle height of the specimen with no strengthening.

Figure 4.14 Failure shape of S13

5.2.3.3 S*14* (S*14*-CY- 3×5)

For the strengthened cylinder specimen S14 with 3 GFRP strips 50 mm wide, as described in photo in Figure 4.15, the crack pattern and failure shape of the specimen can be clearly seen at the middle height of the specimen S3 similar to S13.

Figure 4.15 Failure shape of S14

6.2.3.4 S*15* (S*15*-CY- 1×20)

For the strengthened cylinder specimens S15 with one GFRP middle strip 200 mm wide at the middle height of the specimen as described in photo in Figure 4.16, can be clearly seen at the weakest parts at the two ends of the S15-specimen that left without strengthening and extended to the whole specimen at its middle height of the specimen similar to S3 and S13specimens.

Figure 4.16 Failure shape of S15

6.2.3.5 S*16* (S*16*-CY- 1×5)

For the strengthened cylinder specimens S16 with one GFRP middle strip 50 mm wide at the middle height of the specimen as described in photo in Figure 4.17, can be clearly seen at the weakest parts at the two ends of the S16-specimen that left without strengthening and extended to the whole specimen at its middle height of the specimen similar to S3, S13 and S14 specimens.

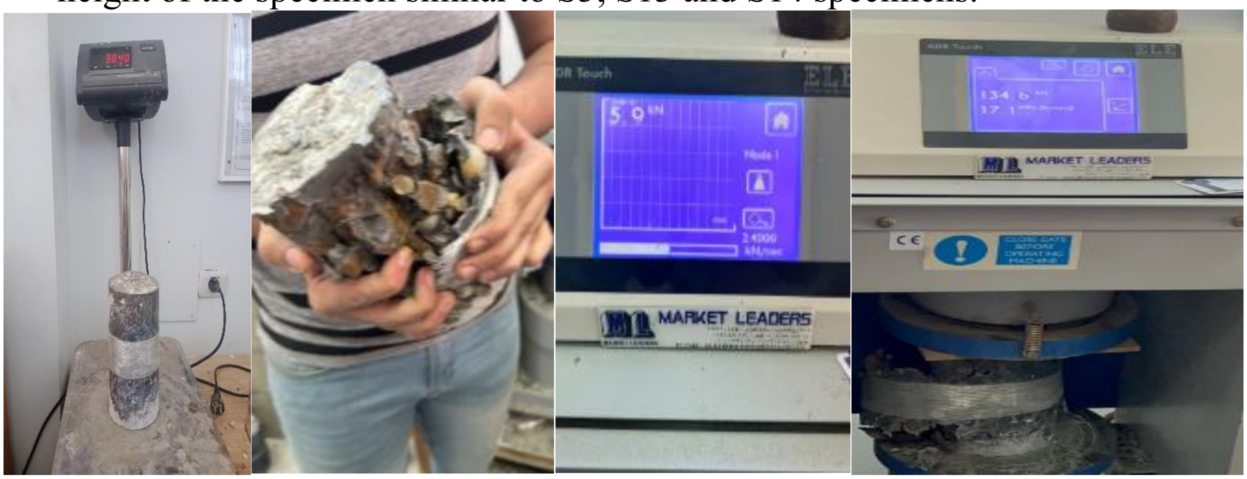

Figure 4.17 Failure shape of S16

6.2.3.6 S*1*7 (S*1*7-CY- 1×*5*)

For the strengthened cylinder specimens S17 with one CFRP middle strip 50 mm wide at the middle height of the specimen as described in photo in Figure 4.18, can be clearly seen at the weakest parts at the two ends of the S17-specimen that left without strengthening and extended to the whole specimen at its middle height of the specimen similar to S3, S13 and S14 specimens.

Figure 4.18 Failure shape of S17

6.2.3.7 S18 (S18-CY- 2×5)

For the strengthened cylinder specimen S18 with two CFRP strips 50 mm wide as illustrated in Figure 4.19, the crack pattern and failure shape of the specimen can be clearly seen at the middle height of the specimen with no strengthening.

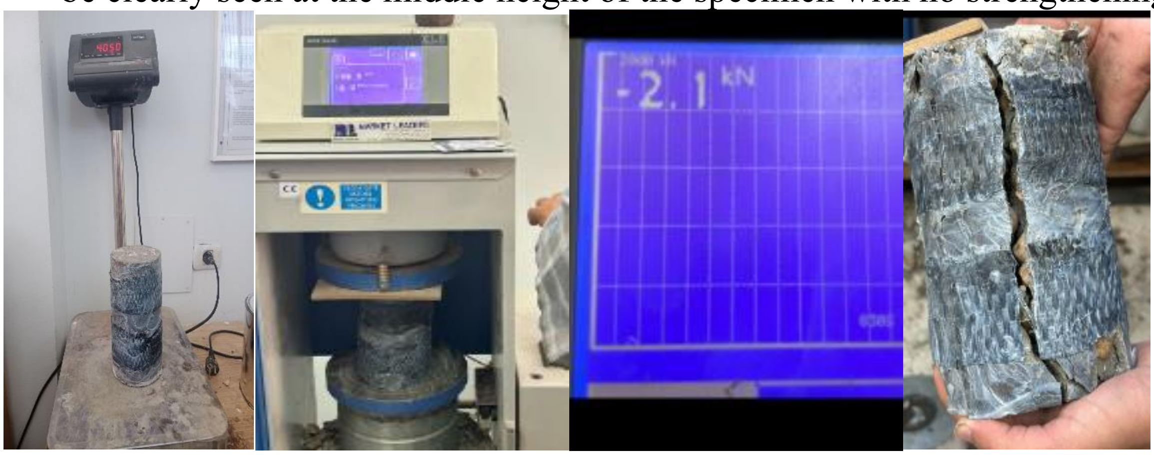

Figure 4.19 Failure shape of S18

Chapter 6 TEST RESULTS AND DISCUSSIONS

6.2.4 Test results

Results of cylinder specimens (300*150):

NAME	TYPE	DIM (mm)	PLACE	Results (MPA)	Ratio
S1	CLY	150*300	W/O	17	------
S4	CLY	150*300	T-B	18.4	8.24%
S5	CLY	150*300	T-B-M	18.8	10.6%
S6	CLY	150*300	FH	28.2	65.9%
S7	CLY	150*300	M	18.6	9.4%
S8 (Carbon)	CLY	150*300	FH	38.9	129%

Effect of fiber type:

NAME	TYPE	DIM (mm)	PLACE	Results (MPA)		F.T	Increase Ratio(C/G)
S1	CLY	150*300	FH	17	-	W/O	
S6	CLY	150*300	FH	28.2	65.9%	G	+38%
S8	CLY	150*300	FH	38.9	129%	C	

Effect of fiber type:

Chapter 6 TEST RESULTS AND DISCUSSIONS

NAME	TYPE	DIM (mm)	PLACE	Results (MPA)	F.T	Increase Ratio(C/G)
S6	CLY	150*300	FH	18.6	G	+109%
S8	CLY	150*300	FH	38.9	C	

Results of cylinder specimens (100*200)

NAME	TYPE	DIM (mm)	PLACE	Results (MPA)	Ratio
S3	CLY	100*200	W/O	16.2	-------
S13	CLY	100*200	T-B	25.3	56.2%
S14	CLY	100*200	T-B-M	34.4	113%
S15	CLY	100*200	FH	38.4	137%
S16	CLY	100*200	M	17.1	5.6%

Effect of Specimen Dimension (150*300) & (100*200), W/O

Symbol	TYPE	DIM (mm)	PLACE	Results (MPA)	Avg. Strength	Increase Ratio(C/G)	Comment
S1	CLY	150*300	W/O	17	16.6	+5%	Both results are more or less comparable
S3	CLY	100*200	W/O	16.2			

Chapter 6 TEST RESULTS AND DISCUSSIONS

Effect of Specimen Dimension (150*300) & (100*200), Str-FH

NAME	TYPE	DIM (mm)	PLACE	Results (MPA)	F.T	Increase Ratio (C/G)
S6	CLY	150*300	FH	28.2	G	+36%
S15	CLY	100*200	FH	38.4	G	

Results of cubes specimens (150*150*150):

NAME	TYPE	DIM (mm)	PLACE	Results (MPA)	Ratio
S2	CU	150*150*150	W/O	22	-----
S9	CU	150*150*150	M	23.9	8.6%
S10	CU	150*150*150	T-B	28.3	28.6%
S11	CU	150*150*150	M	30.5	38.6%
S12	CU	150*150*150	T-B-M	28.9	31.4%

Effect of fiber Width of glass fiber :

NAME	TYPE	DIM (mm)	PLACE	Results (MPA)	F.T	Increase Ratio(C/G)	Width OF FIBER
S9	CU	150*150*150	FH	23.9	G	+28%	50mm
S11	CU	150*150*150	FH	30.5	G		100mm

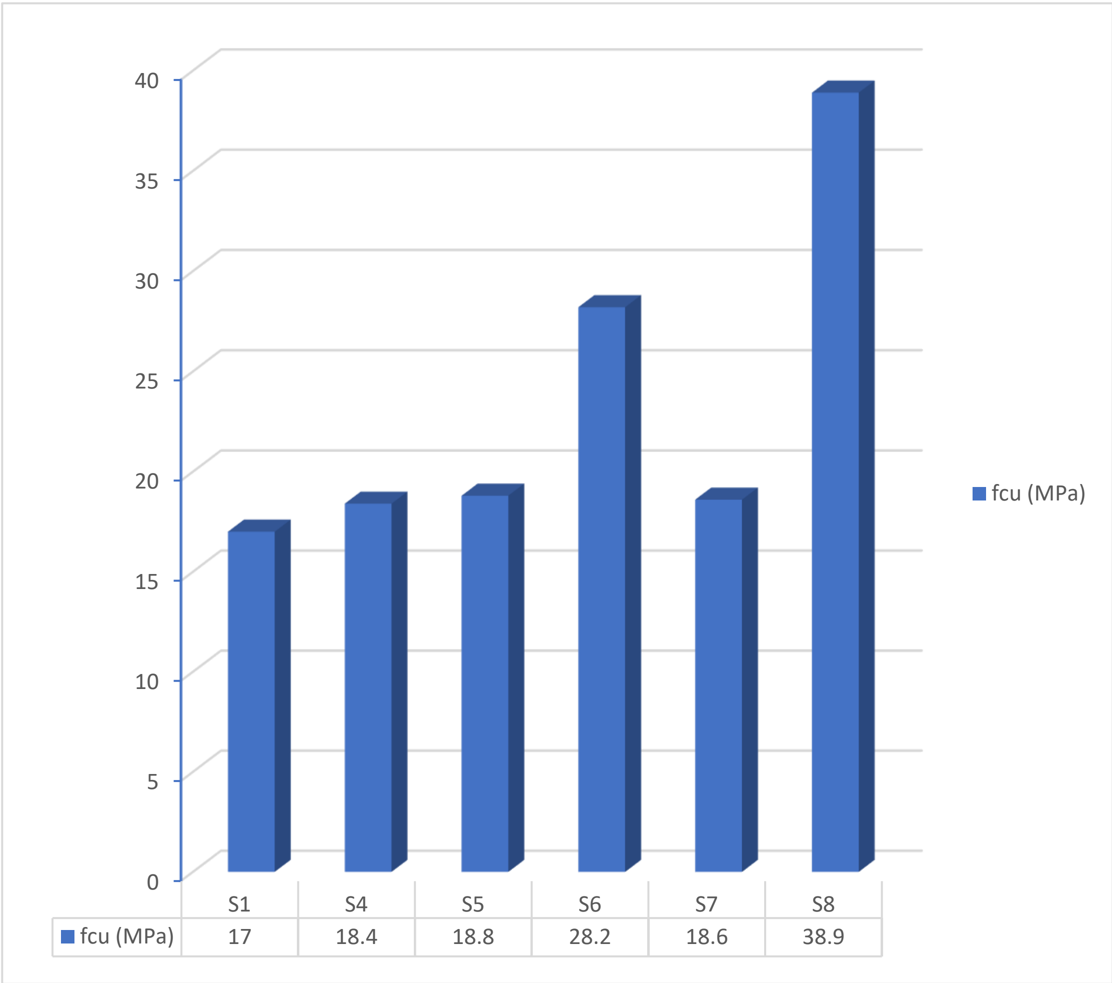

Figure 5.20 Results of cylinder specimens (300*150)

Chapter 6 TEST RESULTS AND DISCUSSIONS

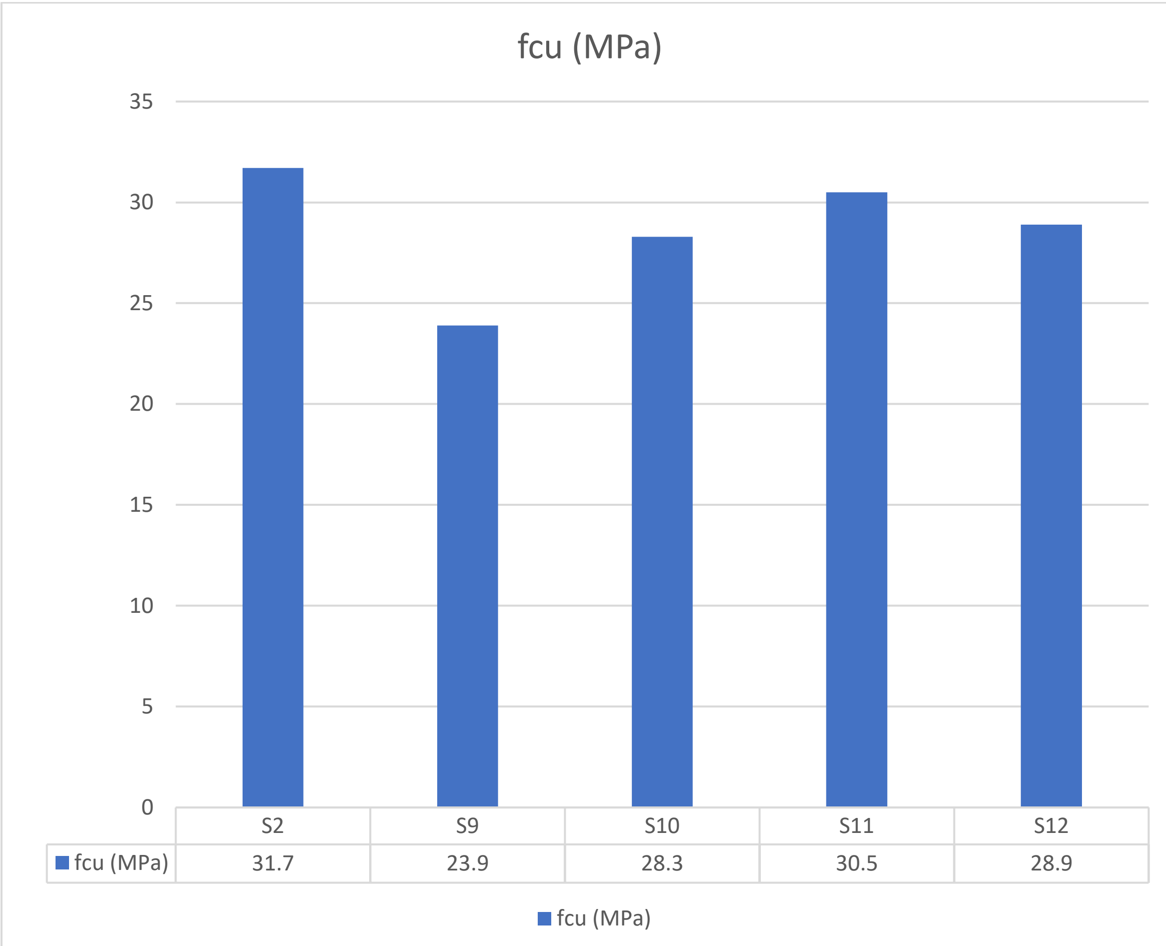

Figure 5.21 Results of cube specimens

Chapter 6 TEST RESULTS AND DISCUSSIONS

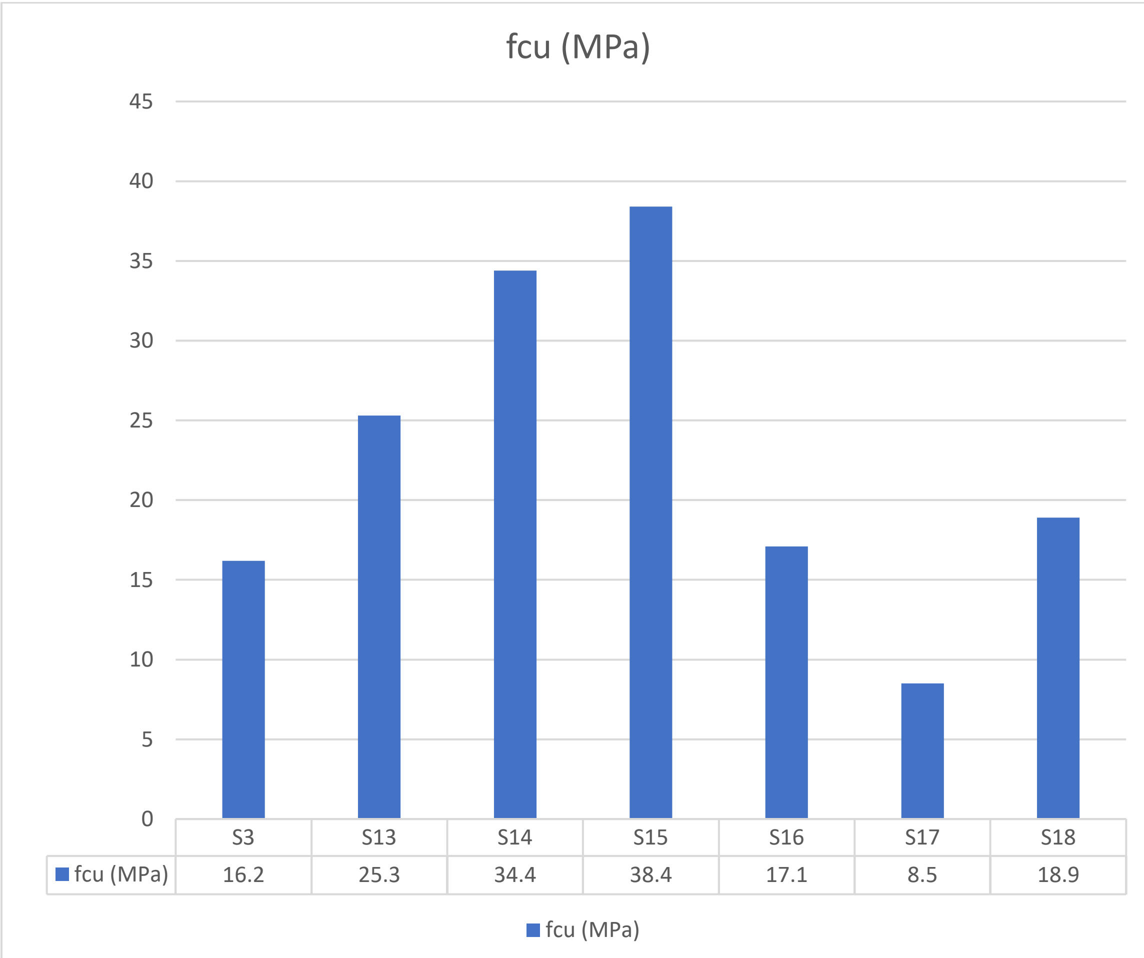

Figure 5.22 Results of cylinder specimens(200*100)

The following table (Table
1-4) shows the density, weight and volume of a sample.

(Table 1-4) : shows the density, weight and volume of a sample.

name	volume*10^{-3} (m^3)	Weight*10^{-3} (T)	Density (T/m^3)
cube (S2)	3.375	7.69	2.28
cube (S9)	3.375	7.95	2.36
cube (S10)	3.375	7.725	2.29
cube (S12)	3.375	7.98	2.36
cube (S11)	3.375	7.88	2.33
Cylinder 15*30 (S1)	5.3	12.22	2.31
Cylinder 15*30 (S7)	5.3	12.12	2.29
Cylinder 15*30 (S4)	5.3	12.27	2.32
Cylinder 15*30 (S5)	5.3	12.29	2.32
Cylinder 15*30 (S6)	5.3	12.34	2.33
Cylinder 15*30 (S8) C	5.3	12.415	2.34
Cylinder 10*20 (S3)	1.57	4.11	2.62
Cylinder 10*20 (S16)	1.57	3.84	2.45
Cylinder 10*20 (S13)	1.57	4.185	2.67
Cylinder 10*20 (S14)	1.57	4.2	2.68
Cylinder 10*20 (S15)	1.57	4.215	2.68

Cylinder 10*20 (S17) C	1.57	3.985	2.54
Cylinder 10*20 (S18) C	1.57	4.05	2.58
Beam	5	11.25	2.25
Beam	5	11.36	2.27
Beam	5	11.37	2.27
Beam	5	11.165	2.23
Beam	5	11.345	2.27
Beam	5	11.16	2.23
Beam	5	11.39	2.28
Beam	5	11.175	2.24
Beam	5	11.405	2.28

(Table 1-4) : shows the density, weight and volume of a sample.

SUMMARY AND CONCLUSION

6.1 Introduction

The main objective of this study is to investigate the behavior of concrete specimens strengthened with different configurations of G/C FRP sheets under monotonic loading using both compression and bending test. Primarily, the experimental study concentrates on the behavior of simple specimens with a focus on how the different strip width configurations affect such behavior. Through this investigation, it was possible to assess the best strengthening technique for different specimen types based on the compared results illustrated in details in the previous chapter. According to the aforementioned, the following sections provide detailed conclusions obtained from experimental evidence as well as recommendations for future research.

6.2 General Conclusion

The aim of this mechanism is to ensure that students are familiar with the latest and recent techniques and materials and to exchange local experience of each other. From the results and observations presented in this study, the following conclusions can be highlighted from each phase of the investigation:

1. Generally, the results of the test demonstrate that the strengthening systems can be used to strengthen concrete specimens with GFRP/CFRP sheet strips and even that load capacity can be increased compared to the control un-strengthened specimen.
2. Load-carrying capacities for Round-specimens (cylinders) strengthened with GFRP were increased by 8.24%, 10.6%, 65.9 and 9.4% whenever strengthening cylinder specimen of 150 mm*300mm with GFS-50 mm at both top and bottom ends, GFS-50 mm at top, middle and bottom, GFS-FH (Full height) and GFS-50 mm at middle only. Furthermore, about 129% increase is gained whenever strengthening the control specimen with CFS-FH (Full height).
3. Moreover, 56.2%, 113%, and 137% strength increase as a result of strengthening the control cylinder specimen of 100 mm*200mm with GFS-50mm at both top and bottom ends, GFS-50 mm at top, middle and bottom, GFS-FH (Full height). One can easily notice the effect of specimen dimensions (both x-sec and height).
4. For non-round compression specimens, (cubes 150*150*150mm) the strength increase of 8.6%, 28.6%, and 31.4% are gained after strengthening the cubes GFS-50 mm at middle, top and bottom, and GFS-FH (Full height). Furthermore, the ultimate load carrying capacity increases explicitly for the specimen by 38.6% whenever strengthening the cubes with GFS-100 mm at middle. Comparing the gained strength, 8.6% and 38.6% indicates the significant effect of GFS height.

5. • In the strengthened beam specimens, strips of 100mm width are used for all specimens. The flexural strength is increased by 38%, 129%, 220%, 393% are gained as a result of strengthening beams alongst its tension side with GFS of 150mm, 400mm, 500mm and 900mm length as a perfect anchor respectively. Moreover, 241% and 309% are gained as a result of strengthening the beams with both flexural strip alongst its full length and shear strengthening strip GFS-U shape-50*300mm for the first beam and GFS-50mm*500mm as a closed stirrup strips respectively.
6. On the other hand, 492% and 818% strength increase are gained as a result of strengthening beams alongst its tension side with CFS of 500mm and 900mm on the tension side as a perfect anchor respectively.

6.3 Future studies recommendations

Based on the findings of this work, the following areas are suggested for future investigation:

- Further experimental tests should be undertaken to investigate the behavior of strengthened RC beam and column specimens with both GFRP and CFRP strips under static loads.
- As the current study is conducted using Glass FRP strips, it is recommended to investigate the bond behavior between FRP and the concrete surface.
- Further researches are required to examine the structural behavior of RC specimens with different dimensions and strengthening techniques using different FFP materials.
- The empirical design equations for every investigated RC element should be derived taking into account the volume (both area and thickness) of strengthening materials.
- Exchange experience is urgently needed through establishing a mechanism for mutual attendance of some meetings for graduated students all over the world, especially for both in the European Union and in Egypt.

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Slump test:

Steps to perform a standard slump test for concrete:

1- Clean the mold 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 one-third of the total height of 30 cm. The mold is compacted 25 times using the applicator, provided that it penetrates the entire layer and the layer below it.

4- Leveling the final surface.

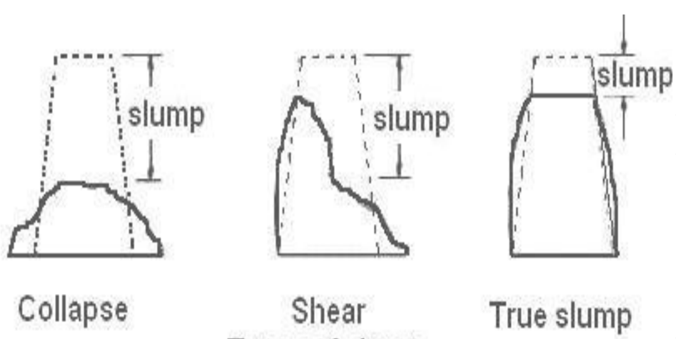
5- The mold is lifted immediately after leveling vertically upwards and very carefully.

6- The amount of slump is measured, which is the difference between the height of the mold and the height of the sample

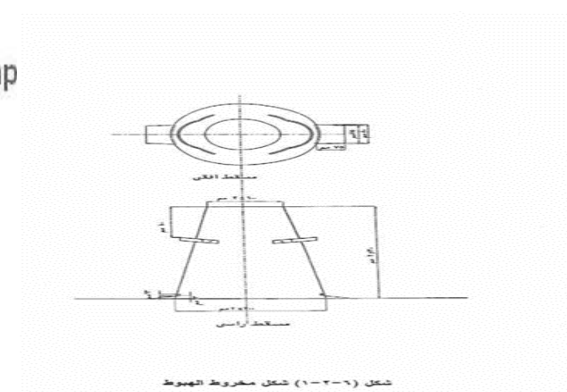
There are three forms of regression:

True collapse, shear or subsidence.

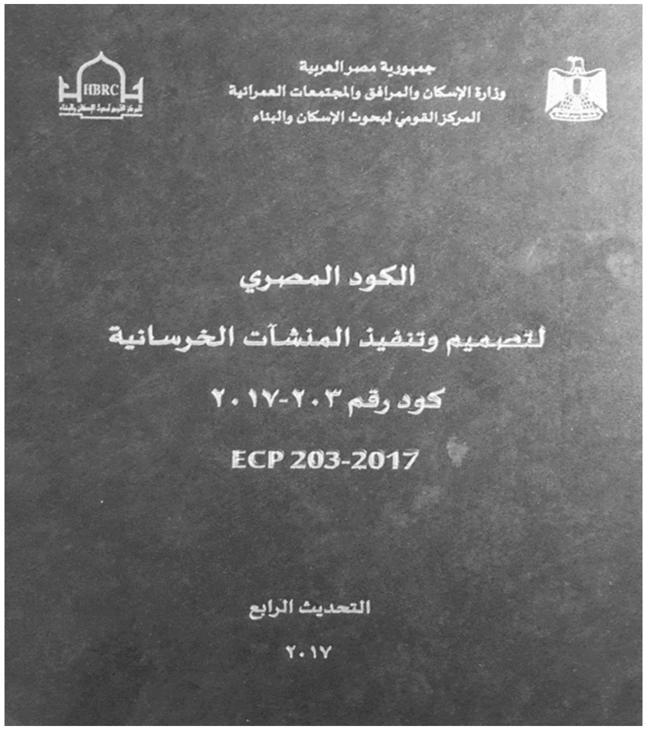
7- Comparing the slumping value with the slumping value recorded in the attached report with the concrete or the required slumping value in case of mixing on site



Types of slump



APPENDIX



The proportions of the concrete mixwere used according to the Egyptian code ECP203

جمهورية مصر العربية

وزارة الإسكان والمرافق والمجتمعات العمرانية

مركز بحوث الإسكان والبناء

الكود المصرى لتصميم وتنفيذ المنشآت الخرسانية

الملحق الثالث

دليل الاختبارات المعملية لمواد الخرسانة

اللجنة الدائمة للكود المصرى

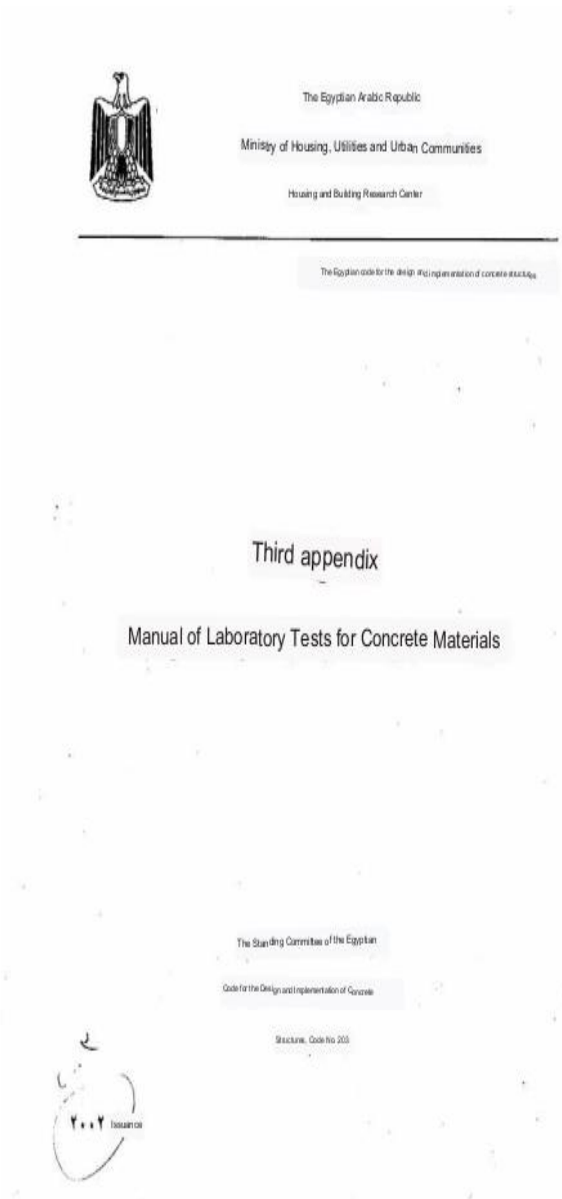
لتصميم وتنفيذ المنشآت الخرسانية

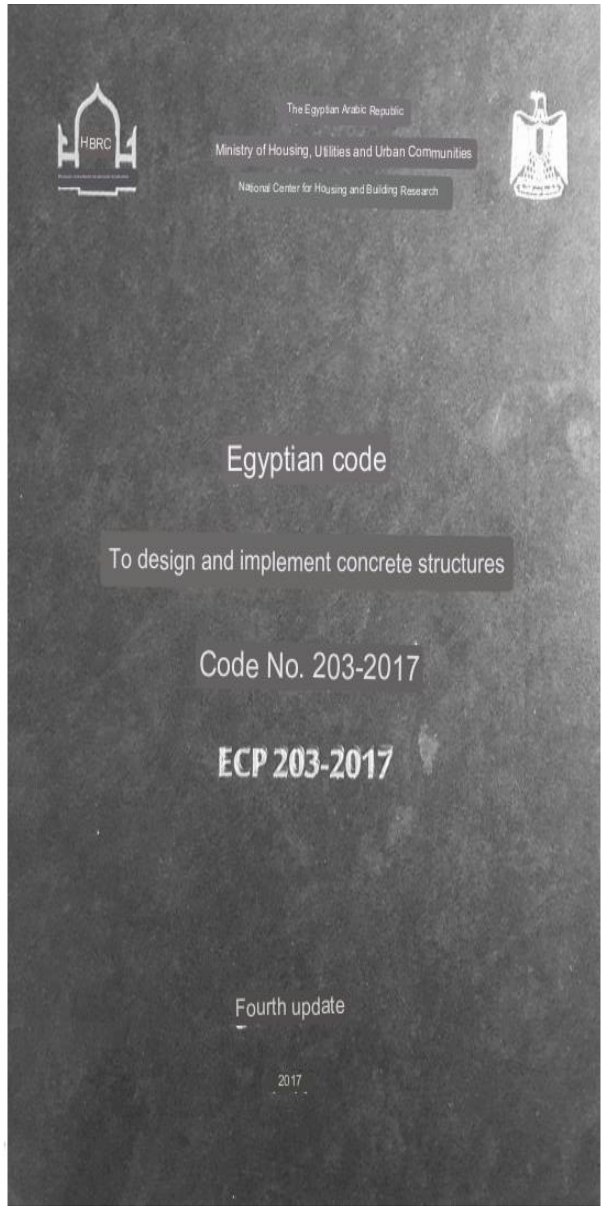
كود رقم ٢٠٣

إصدار ٢٠٠٢

All test steps were applied in accordance with the third appendix to the Egyptian code "ECP 203"

(laboratory test guide).


The Egyptian Arabic Republic
Ministry of Housing, Utilities and Urban Communities
Housing and Building Research Center
The Egyptian code for the design and implementation of concrete structures
Third appendix
Manual of Laboratory Tests for Concrete Materials
The Standing Committee of the Egyptian
Code for the Design and Implementation of Concrete
Structures, Code No 203
٢٠٠٢ Issuance


The Egyptian Arabic Republic
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Egyptian code
To design and implement concrete structures
Code No. 203-2017
ECP 203-2017
Fourth update
2017

Thank you