# RUBBERISED FIBRE REINFORCED CONCRETE

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## ABSTRACT

The compressive, split tensile and flexural strengths of concrete have been observed to decrease with the increase of rubber quantity.

The present experiment is carried out to investigate the fresh and hardened properties of binary blended concrete with 20% of Fly ash, by weight of cement, as partial replacement of cement and replacement of 0%, 5%, 10%, 15% and 20% of sand with Crumb rubber, by volume and addition of Coconut fibres at 0.1%, 0.2% and 0.3%, by weight of cement. Compressive strength of concrete is measured by testing standard cubes (150mm x 150mm x 150mm) at the age of 28 days, split tensile strength of concrete is measured by testing standard cylinders (150mm Ø, 300mm height) at the age of 28 days and impact resistance of concrete is measured by testing beams (100mm x 100mm x 500mm) at the age of 28 days

**Keywords:** Crumb Rubber, Coconut Fibre, fly ash, Compressive Strength, Split Tensile Strength, M30 grade concrete.

## 1. NTRODUCTION

### 1.1 General

Concrete is the most widely used construction material all over the world. The importance of concrete in modern society cannot be underestimated. Typical concrete is a mixture of fine aggregate (sand), coarse aggregate (rock), cement, and water. The aggregates, both fine and coarse, are bound together by cement when mixed with water. Since the late 1800s onwards, when consistent mass produce Portland cement became readily available, the world has been transformed by the design and construction of all sorts of concrete structures.

### Admixtures

A material other than the primary ingredients of concrete viz-a-viz water, cement and aggregates that is added to the mixture immediately before or during mixing to modify the properties of fresh or hardened concrete is defined as admixture. Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry.

### 1.2 Types of Pozzolanas

The Pozzolanic materials can be divided in to two types 1. Natural pozzolanas 2. Artificial pozzolanas

**Natural pozzolanas** such as Clay and Shale, Diatomaceous earth, Opaline shales, Volcanic tuffs and Humilities etc., are processed involving crushing, grinding and size preparation, including thermal activation if necessary. The natural pozzolanas have lost their popularity in view of the availability of more active pozzolanas available as industrial by-products

**Artificial pozzolanas** such as Fly ash, Blast furnace slag, Micro silica, Silica fume, Rice husk ash, Metakaolin are major industrial by products. Practical experience has revealed that addition of mineral The reaction can be shown as

Pozzolana + Calcium Hydroxide + Water → C – S – H (Gel)

### Alkalis

a) Sodium oxide ($Na_2O$) 0.58

b) Potassium oxide ($K_2O$)

### FLY ASH:

Fly ash, an artificial Pozzolana, is the unburnt residue resulting from combustion of pulverized coal or lignite, mechanical or electrostatic separators called hoppers collect it from flue gases of power plants where powdered coal is used as fuel. India is a resourceful country for fly ash generation with an annual output of over 110 million tones, but utilization is still below 20% in spite of quantum jump in last three to four years.

1. Type F, low calcium, 8% CaO
2. Type CI, intermediate calcium, 8–20% CaO
3. Type CH, high calcium, 20% CaO

### 1.3 Physical properties of Fly ash:

| S.No. | Physical properties | Test results |
|---|---|---|
| 1 | Colour | Grey (blackish) |
| 2 | Specific gravity | 1.93 |
| 3 | Lime reactivity- Average compressive strength 4.90 MPa After 28 days of mixture | 1.90 Pa |

### 1.3.1. Chemical properties of Fly ash

1.1 Indian standard Institution defines Bitumen

| S.NO | CONSTITUENTS | % BY WEIGHT |
|---|---|---|
| 1 | Loss of ignition | 4.17 |
| 2 | Silica (SiO2) | 58.55 |
| 3 | Iron oxide (Fe2O3) | 3.44 |
| 4 | Alumina (Al2O3) | 28.20 |
| 5 | Calcium oxide (CaO) | 2.23 |
| 6 | Magnesium oxide (MgO) | 0.32 |
| 7 | Alkalis<br>a) Sodium oxide (Na2O)<br>b) Potassium oxide (K2O) | <br>0.58<br>1.26 |

Advantages of Fly ash in concrete the technical benefits of using fly ash in concrete are numerous. The various advantages found by different investigators in India are summarized below:

•Superior Pozzolanic action • Reduced water demand (for fly ash low carbon content and high fineness) • Improved workability • More effective action of water reducing admixtures • Reduced segregation and bleeding

**1.4 BINARY BLENDED CONCRETE**:

Cement mixtures containing Ordinary Portland Cement (OPC) and at least one supplementary cementitious material (SCM) is called blended cements. Binary cements contain OPC and one SCM. Concrete made with such binary cement is called Binary Blended Concrete. 9 In this study, the term Binary Blended Concrete is used to refer to concrete made with binary blended cement containing Ordinary Portland Cement (OPC) and 20% Class F Fly ash.

**1.5 CRUMB RUBBER**: Sand has by now become the most widely consumed natural resource on the planet, next only to fresh water. Especially in Asia and Arab states the hunger of the construction industry is ever growing. Once sand is used in concrete, the components are bound forever and are no longer available as resources. On the other hand, large quantities of scrap tyres are being generated every year globally.

1.2 **1.5 Classification of Rubber based on size:** In most of the researches performed, usually three broad categories of rubber have been considered: Chipped rubber, Crumb rubber and Ground rubber.

a. Shredded or chipped rubber to replace the gravel. To produce this rubber, it is needed to shred the Tyres in two stages. By the end of the stage one, the rubber has length of 300-430 mm and width of 100-230 mm. in the second stage its dimension changes to 100-150 mm by cutting. If shredding is further continued, particles of about 130-75 mm dimensions are produced and are called "shredded particles".

b. Crumb rubber that replaces sand, is manufactured by special mills in which big rubbers change into smaller torn particles. In this procedure, different sizes of rubber particles may be produced depending on the kind of mills used and the temperature generated. In a simple method, particles are made with a higher irregularity in the range of 0.425-4.75 mm.

**1.5.**1 Effect on physical properties One of the main issues relating to the use of chipped or crumb rubber aggregate is the increased tendency towards segregation and bleeding.

**1.5.**2 Effect on strength properties as rubber has lower stiffness compared to aggregates, presence of rubber particles in concrete reduces concrete massstiffness and lowers its load bearing capacity.

**1.6 FIBRES:** Fibre is a small piece of reinforcing

Material possessing certain characteristic properties.

Fibres can be of any shape and size. Fibres are often described by a convenient parameter called aspect ratio. The aspect ratio of a fibre is the ratio of its length to its diameter

- **Natural fibres**: Natural fibres are fibres made or extracted from plant, animal and mineral sources. Natural fibres such as cellulose, jute, sisal and coir are used in concrete. Natural fibres are a resource that can be utilized in concrete to enhance its strength and are abundantly available in tropical regions.

- **Artificial fibres:** Artificial fibres are man-made fibres. Artificial fibres such as steel, glass, carbon, nylon asbestos and polypropylene fibres are used in concrete. The most commonly used artificial fibres are steel fibres.

### 1.7 COCONUT FIBRES:

Coconut fibres are agricultural waste products obtained in the processing of coconut oil and are available in large quantities in the tropical regions of the world, especially in Africa, Asia and America. Coconut fibres are not commonly used in the construction industry but are often dumped as agricultural wastes.

### 1.8 FIBRE REINFORCED CONCRETE:

Fibre reinforced concrete is a concrete mix containing water, cement, aggregate and discontinuous fibres of various shapes and sizes. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro-cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro-cracks, eventually leading to brittle fracture of the concrete.

### 1.9 NEED FOR THE PROJECT:

The replacement of sand with crumb rubber may tend to mar the fresh properties of concrete as indicated by some researchers. Therefore, significant quantity of cement is often replaced with admixtures to enhance the fresh properties of concrete and reduce heat generation. The use of Fly ash in concrete is well established and widespread; it is not only economical but also improves the fresh and hardened properties of concrete. It also helps to solve the problem of storage and disposal of the ash.

### 1.10 OBJECTIVES OF THE PRESENT STUDY

- To study the influence of addition of coconut fibres as reinforcement, by weight of cement, on strength properties of binary blended concrete. • To study the influence of crumb rubber in various percentages of sand replacement, by volume, on strength properties of coconut fibre reinforced binary blended concrete.

- To form a comparative study of the properties of coconut fibre reinforced binary blended concrete and rubberized coconut fibre reinforced binary blended concrete.

### 1.11 SCOPE OF THE PRESENT STUDY:

The present investigation is carried out to study the strength properties of binary blended concrete of M30 grade with 20% replacement of cement with Fly ash (by weight), 0%, 5%, 10%, 15% and 20% replacement of sand with Crumb rubber (by volume) and addition of 0.1%, 0.2% and 0.3% Coconut fibre by weight of cement.

### 1.12 SUMMARY:

In this chapter, use of admixtures in concrete, Pozzolanic materials, Fly ash and its advantages on addition to concrete, Crumb rubber and its benefits in concrete, use of fibres in concrete, Coconut fibres, Fibre reinforced concrete are discussed.

## 2. LITERATURE REVIEW

**2.1 GENERAL:** This chapter deals with the review of literature related to the properties of concrete made with Crumb rubber as sand replacement, effect of Fly ash and Coconut fibre on properties of concrete.

### 2.1.1 LITERATURE REVIEW

**Literature Review on Coconut Fibre**

- **Noor Md. Sadiqul Hasan et al. (2012):** Studied the physical and mechanical properties of concrete produced using chopped coconut fibres incorporating different volume percentage of fibres 1.0, 3.0, 5.0 and 7.0 subjected to static loading. The mix proportion of 1:2:3 was adopted with water cement ratio of 0.4.

- **Pravin V Domke (2012**): studied the effect of partial replacement of cement by rice husk ash (RHA) and addition of coconut fibre (COIR) on the compressive, split tensile and flexural strengths of concrete. It was observed that 12.5%RHA+2%COIR gives maximum compressive strength which was close to that of normal concrete. Maximum flexural strength was observed at 20%RHA+2%COIR which was 21.11% more than that of normal concrete. Maximum split tensile strength was observed from the mix of 15%RHA+3%COIR.

- **Olonade et al. (2013): S**tudied the development of compressive strength and modulus of rupture of coconut fibre reinforced concrete at different curing ages. Concrete of mix ratio 1:2:4 was used containing coconut fibre of 0, 1, 2, 3 and 4% 16 by weight of cement. Compressive strength and modulus of rupture of CFRC specimens were determined at curing ages of 7, 21, 28 and 56 days.

- **J. Sahaya Ruben et al. (2014):** Investigated the compressive strength of coconut fibre reinforced concrete. In this experiment M25 grade concrete was used. Coir fibres were chopped to lengths of 20mm, 25mm and 30mm and subjected to chemical treatments. Compressive strength test was carried out on concrete containing different percentages of fibres (0.5%, 0.75% and 1.0%) by weight of cement. The results showed that the maximum compressive strength is achieved using 25mm length coconut fibres with 0.75% addition of fibres.

- **Bhupendra Kumar et al. (2015):** Compared the workability and compressive strength of flyash based coconut fibre reinforced concrete and plain cement concrete of M40 grade. The fly ash was replaced with the cement as 10, 20, and 30% and coconut fibres are added additionally by weight of cement in the proportions of 0, 1, 1.5, 2, 2.5 and 3%. The diameter of coconut fibre varied between 0.25 to 1.0 cm and length taken was 4 cm.

### 2.1.2 Literature Review on Crumb Rubber

- **Piti Sukontasukkul (2008):** Investigated the thermal and sound properties of crumb rubber concrete panels. The mix proportion for the control specimen (no crumb rubber) was set at 1:1.64:1.55 and crumb rubber was used to replace fine aggregate at 10%, 20% and 30%. The results showed that by replacing fine aggregate with 17 crumb rubber at 10 to 30%, the unit weight of concrete can be reduced from 14 % up to 28%. Also, rubberized concrete exhibited superior thermal and sound properties than plain concrete.

- **Piti Sukontasukkul et al. (2009):** studied the mechanical and physical properties of lightweight concrete obtained by replacing fine aggregate partially with crumb rubber. The mix proportion for the control specimen (no crumb rubber) was set at 1:1.64:1.55 and crumb rubber was used to replace fine aggregate at 10%, 20% and 30%

- **Yogender Antil et al. (2012):** Studied the use of crumb rubber in concrete to replace sand partially. The study was conducted on M30 grade concrete mix with crumb rubber replacing sand by volume at 5%, 10%, 15% and 20%. Specimens were cast for compressive strength and tested at 7 days and 28 days curing periods for plain concrete and rubberized concrete.

**Parveen et al. (2013):** Studied the use of rubber waste as partial replacement of fine aggregate to produce rubberized concrete in M30 mix. Specimens with different partial replacements of crumb rubber (0, 5, 10, 15 and 20%) by volume of fine aggregate were cast and tested for compressive strength, flexural strength, split tensile strength and stress strain bahavaiour.

- **S. Selvakumar et al. (2015):** Studied the effectiveness of rubber as substitute for fine aggregate. Concrete mix design in this experiment was designed as per the guidelines in IS 10262-2009. All the samples were prepared using design mix. M30 grade of concrete was used for the investigation.

### 2.3 CRITICAL APPRAISAL OF LITERATURE REVIEW

- The increase in cement replacement by Fly ash produces a better workable concrete. The optimum usage of Fly ash content replacing cement in concrete is 20%.

- Addition of coconut fibre to concrete increases the compressive strength to a certain amount of fibres. Higher amount of coconut fibres in concrete decreases the compressive strength of concrete.

### 2.4 SUMMARY:

In this chapter, the literature review of papers on properties of Coconut Fibre Reinforced Concrete and Rubberized Concrete was done. The reviews of the above papers suggest that Crumb rubber, Coconut fibre and Fly ash have significant effect on the properties of fresh and hardened concrete.

## 3. EXPERIMENTAL PROGRAM

### 3.1 GENERAL:

In the present experimental program, standard cubes (150mm x 150mm x 150mm), standard beams (100mm x 100mm x 500mm), standard cylinders (150mm Ø, height 300mm) were casted and tested for finding the Compressive strength, Impact resistance and Split Tensile strength properties of Plain Concrete, Plain Coconut Fibre Reinforced Binary Blended Concrete and Rubberized Coconut Fibre Reinforced Binary Blended Concrete. Before casting of specimens, the mixes were tested for properties of fresh concrete.

### 3.2 MATERIALS:

The materials used in this experimental study are Cement, Fine aggregate, Coarse aggregate, Water, Fly ash, Crumb rubber and Coconut fiber.

**3.2.1 Cement:**

Ordinary Portland cement (Ultratech cement) of 53 grades confirming to IS: 12269-1987 was used. It was tested for its physical properties as per IS 4031 (part II)- 1988 and chemical properties as per IS: 12269. The details of the test results are given in Table 3.1 and Table 3.2.

**3.2.2 Fine Aggregate:**

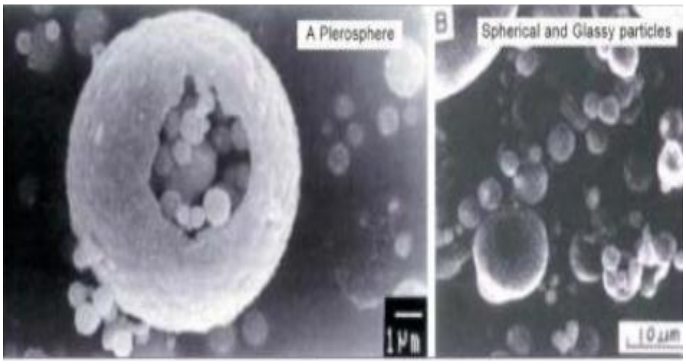
Locally available sand is used as fine aggregate in the present investigation. The sand is free from clayey matter, salt and organic impurities. The sand is tested for various properties like specific gravity, sieve analysis, bulk density etc., and in accordance with IS 2386-1963.

**3.2.3 Coarse Aggregate:** Machine crushed angular granite of 20mm nominal size from the local source is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc. The physical properties of coarse aggregate were investigated in accordance with IS 2386 -1963. The details of test results are given in Table 3.5 and Table 3.6.

**3.2.4 Water:** Locally available water is used for mixing and curing which is potable and is free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

**3.2.5 Fly Ash:** The fly ash obtained from a local fly ash brick manufacturing plant in Hyderabad,T elangana is used in the present experimental work.

**3.2.6 Crumb Rubber:** Crumb rubber used in the study was procured from a local workshop that recycles waste tyre rubber by grinding it mechanically to make crumb rubber. It is free from impurities such as dust, clay particles and organic matter etc.




The chemical composition of Fly ash is rich in silica

$$\text{compaction factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

content which reacts with calcium hydroxide to form C-S-H gel. This gel is responsible for the strength of mortar or concrete.

**3.2.7 Coconut fibres:** Coconut fibres were obtained from a local coir factory that extracts coir from coconut husks. The coconut fibres were cleaned and chopped to maintain a uniform length of 40 mm.

**3.3 CONCRETE MIX DESIGN:** The concrete mix of M30 grade was designed as per IS 10262-2009 using the properties of cement and aggregate. For each mix of Rubberized concrete, the concrete mix was modified by replacing the amount of sand to be replaced by crumb rubber for the mix.

| Water ($kg/m^3$) | Cement ($kg/m^3$) | Fine Aggregate ($kg/m^3$) | Coarse Aggregate ($kg/m^3$) |
|---|---|---|---|
| 197 | 438 | 651 | 1130 |
| 0.45 | 1 | 1.486 | 2.58 |

### 3.4 PREPARATION OF TEST SPECIMENS

**3.4.1 Mixing:** Mixing of ingredients is done manually. Thorough mixing by hand, using spades is adopted. Initially, Ordinary Portland Cement and Fly ash was mixed thoroughly and then added to the mix of fine aggregate and coarse aggregate. Crumb rubber and river sand were weighed accurately and mixed well before mixing with the coarse aggregate.

**3.4.2 Testing of fresh properties of concrete**

**3.4.3 Slump Cone Test:** Slump test is used to determine the workability of fresh concrete. Slump test as per IS 1199-1959 is followed. The apparatus used for doing slump test are slump cone and tamping rod.

**Methodology:** About 6 liter of concrete is needed to perform the test, sampled normally. The base plate and inside of mould is thoroughly cleaned and oiled. The base plate is placed on level stable ground and the slump cone centrally on the base plate and hold down firmly. The mould is then filled in four layers with freshly mixed concrete, each approximately to one-fourth of the height of the mould.

**3.4.4 Compaction factor test:** Compaction factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS 1199-1959. The apparatus used is Compaction factor apparatus.

**Methodology:** Both the hoppers and the cylinder of Compaction factor apparatus are cleaned thoroughly the oiled inside.

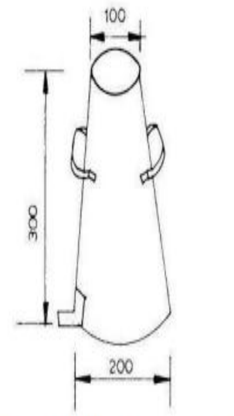



Figure 3.2 Slump Cone Apparatus

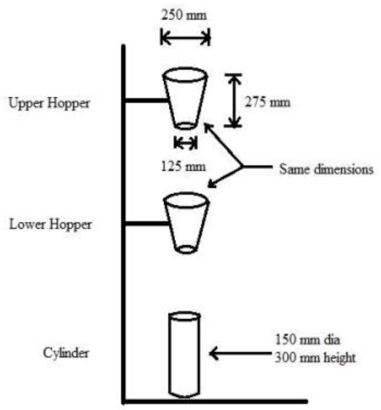



Figure 3.4 Compaction Factor Apparatus

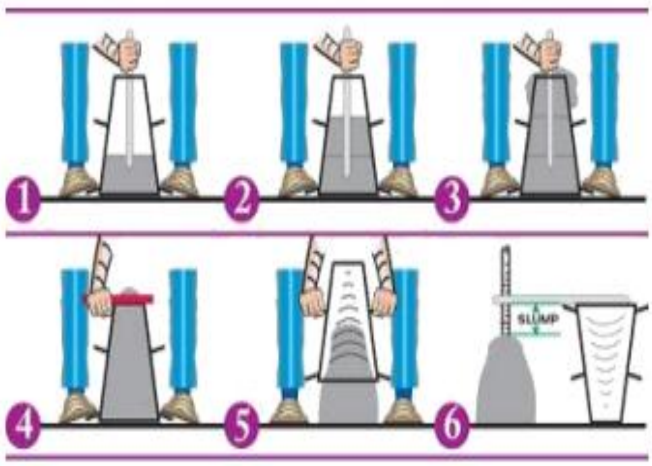



**Figure 3.3 Slump Cone Test**

**Methodology:** Both the hoppers and the cylinder of Compaction factor apparatus are cleaned thoroughly and oiled inside. The trap doors of both the hoppers are closed and the cylinder is placed in position. The sample of concrete is placed in the upper hopper up to the brim. The trap door is opened so that the concrete falls into the lower hopper.

**3.4.5 Casting of Specimens:** The cast iron Moulds are cleaned of dust particles and applied with oil on all sides before concrete are poured in the moulds. The mould of size 150mm x 150mm for cubes, 100mm x 100mm x 500mm for beam specimens, mould of diameter 150mm and height 300mm for the cylinder specimens.

**3.4.4 Curing of Specimens:** The specimens are left in the mould is undisturbed at room temperature for about 24 hours after casting. The specimens are then removed from the moulds and immediately transferred to the curing pond containing clean and fresh water.

**3.4.5 Testing of Specimens:** A time schedule for testing of specimens is maintained to ensure that proper testing on the due date and time. The cast specimens are tested as per standard procedures, immediately after they are removed from curing pond and wiped off the surface water. The test results are tabulated carefully.

**3.4.6 Description of Compression Testing Machine:** The Compression Testing Machine used for testing the cube specimens is of standard make. The capacity of the testing machine is 200 Tones or 2000 KN. The machine has a facility to control the rate of loading with a control valve. The machine has an ideal gauge on which the load applied can be read directly.

**Methodology:** The specimens are removed from the curing pond just before testing on the specified due date and time and cleaned to wipe off the surface water. The cube specimen is placed on the lower platen such that the load is applied centrally on the faces other than top and bottom faces of casting.

**3.4.7 Test arrangement for determination of Split Tensile Strength:** Though concrete is not expected to resist direct tension, the determination of Tensile strength of concrete is necessary to determine the load at which the concrete member may crack, since cracking is a tensile failure.

**Figure 3.5 Cube compression strength test**

**Methodology:** Before testing, diameter, length of specimen is determined to nearest 0.2mm. Center one of the plywood strips along the center of lower platen. The specimen is placed on the plywood strip.

The appearance of concrete and any unusual features in the type of failure is carefully observed. Splitting strength of specimen is computed to nearest of 0.05 N/mm2.

Figure 3.6 Cylinder split tensile strength test

**3.4.8 Test arrangement for determination of Impact Resistance:** Test for Impact Resistance was carried out on plain concrete mix and optimum concrete mix. Three specimens of size 100mm x 100mm x 500mm were casted for each mix. These specimens were tested by Modified Chirpy Method. The length of the pendulum of Modified Chirpy apparatus is 1.65m and the striker is a steel cylinder of 15 kilograms attached to the end of the pendulum.

**Methodology:** The specimens are removed from the curing pond just before testing on the specified due date and time and cleaned to wipe off the surface water.

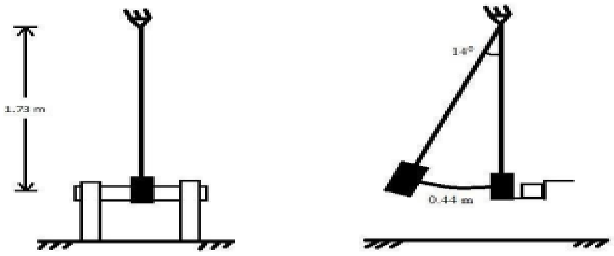



Figure 3.7 Impact resistance test

**3.5 TESTS CONDUCTE:** Tests are carried for control mix (Plain Concrete), Binary blended Coconut fibre Reinforced Concrete containing 20% Fly ash and with varying percentages of crumb rubber as sand replacement and varying coconut fibre as addition to cement mix.

**3.6 CEMENT PROPERTIES:** In the present investigation, Ordinary Portland Cement of 53 Grade (Ultra Tech) is used. Care is taken that it is freshly produced and from a single producer. The cement then produced was tested for physical properties in accordance with IS 4031.

**3.7 FINE AGGREGATE PROPERTIES:** Fine aggregate is natural sand obtained locally. The physical properties like specific gravity, bulk density, gradation and fineness modulus were determined in accordance with IS 2386. Fineness modulus was found based on sieve analysis results for fine aggregate. Weight of the sample taken was 1000 grams.

**3.8 COARSE AGGREGATE PROPERTIES:** The crushed coarse aggregate of 20 mm maximum size angular obtained from the local crushing plant at Hyderabad is used in the present study. The physical properties of the coarse aggregate like specific gravity, bulk density, gradation and fineness modulus was found in accordance with IS 2386.

**3.9 TYPICAL OXIDE COMPOSITION OF FLY ASH:** The following Table shown below gives the typical oxide composition of Fly ash which is used in the present investigation.

**3.10 CRUMB RUBBER PROPERTIES:** Crumb rubber is obtained from local tyre rubber recycling workshop. The physical properties like specific gravity, bulk density, gradation fineness modulus were determined in accordance with IS 2386.

**3.11 WATER IMPORTANCE:** This is the least expensive but most important ingredient in concrete. The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid etc. In general, the water fit for drinking should be used for making concrete.

**3.12 SUMMARY:** In this chapter, the study of materials used, their properties, mixing procedures of the concretes, the phases of experimental program and the procedures for testing of fresh and hardened concretes was discussed. The results of the experimental program discussed in this chapter is tabulated and studied in the next chapter.

## 4. CONCLUSIONS:

- The workability of fresh binary blended concrete decreased with the increase in sand replacement with crumb rubber and addition of coconut fibres.
- Replacement of river sand with crumb rubber ranging from 0% to 20% decreases the compressive strength of concrete.
- Split Tensile strength of concrete mix also decreases with increase in replacement of sand with crumb rubber.
- The impact resistance of optimum mix is 21% more the that of plain concrete for first crack and 24% for failure.
- The compressive strength and split tensile strength for all the fibre reinforced mixes increase upto 0.2%addition of coconut fibres and decreased thereafter.

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