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# A STUDY ON STRENGTH AND DURABILITY PROPERTIES OF CONCRETE USING FLYASH AS CEMENT REPLACEMENT

*[1]C.Pooja,[2] B Fayaz*
*[1]Student,[2]Assistant Professor*
*Department Of Civil Engineering*
*PVVKIT*

## ABSTRACT

Fly ash is a by-product from the coal industry, which is widely available in the world. the use of fly ash in concrete as partial replacement of cement is gaining immense importance today. mainly on account of the improvement in the long-term durability of concrete combined with environmental benefits. The replacement of fly ash as a cementations component in concrete depends upon the design strength, water demand and relative cost of ash compared to cement. This paper reports the results of an experimental investigation carried out to study the effects of fly ash on strength development of concrete and the optimum use of fly ash in concrete. The concrete grade of M15 has been selected and designed as per IS 456-2000 Standard method.Cement was replaced by 10%, 20% and 30% of class F fly ash by the weight. After each mix preparation, nine cubes specimens are cast and cured. Necessary tests were carried out in fresh and hardened concrete. Workability was found from slump test. Tests for compressive strength were carried out on specimens at age 7,14 and 28 days.The test results were compared with the results of specimen prepared after control mix. Test results shows that, inclusion of fly ash generally improves the compressive strength up to certain percent of replacement.

**Keywords:** fly ash, cement, compressive strength, workability.

## I. INTRODUCTION

The demand for building materials like cement, sand and coarse aggregate is increasing in the country due to the growth of population, economy, and living standards of the people. Cement production in the country is assessed to be 347 metric tons per annum. Cement production grew by 5% every year.

Cement concrete is the most chosen construction material for its wide variety of skills, ease in production, and use. There are three aspects in the use of concrete. The first one is the durability aspect. The second aspect is the economy in construction by improved design and cost reduction in cost of materials. The third aspect is energy preservation and environmental protection. We can satisfy these three aspects by using fly ash in concrete.

Fly ash, also known as flue-ash, is one of the remains generated in combustion and contains the fine particles that rise with the flue gases. Ash that does not rise is named bottom ash. In an industrial context, fly ash generally refers to ash produced during the combustion of coal. Fly ash is generally caught by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash comprises substantial amounts of silicon dioxide ($SiO_2$) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.

Currently about 250 million tons per annum of fly ash is generated in India as a by-product of coal consumed in the thermal power plants. The thermal power plant is the only source to produce about 65% of the total electricity produced in our country. Investigation on the utilization of fly ash in cement mortar is carried out by many authors reported in the literature. Several million tons of coal for generating electricity is being spent in India out of which 40% of coal is accounted for generating of fly ash as a by-product. By the year 2010 more than 180 million tons of flyash would be produced every year . The type of flyash collected at the bottom of boiler furnace having lesser fineness and high carbon content is called bottom flyash. The finest flyash is called dry flyash, collected from different electrostatic precipitators (ESP) in dry form. While the ash mixed with water, slurry and drained out in ponds is referred as pond flyash.

The mineralogical studies of fly ash discloses that silica is present in crystalline forms of quartz (sio3) and partially it is associated with alumina as mullite (2AL2O32Sio2), the rest being mostly in the glassy phase. The huge amount of flyash imposes challenges for its disposal and managing. At present flyash is disposed in slurry form in large ponds accomplished by Thermal power corporation plant units. A small percentage that is 3% to 5% of flyash is being used in India while in other countries the percentage of utilization is 30% to 80%, whatever be the type of flyash, it causes some of the types of pollution and air born diseases such as silicoses, fibrosis of lungs, bronchitis etc. Due to the existence of toxic metals in flyash, it causes water pollution through percolation. Its disposition on agricultural land affects the horticulture and also made the soil uncultivable. It also adversely affects the civil and mechanical structures. It also causes silting and other problems for human and aquatic life, therefore, it cannot be disposed in sea or river . Flyash is being consumed (tones/day) by several establishments in production of cement,bricks, cellular blocks, asbestos sheets, filling low lying areas and construction of roads .

The impacts of flyash usage in road works including embankments are wind erosion, surface water erosion and leaching of toxic heavy metals into water bodies including underground aquifers. The sub base/base layers of roadways constructed using flash need to be covered with black top to prevent percolation of rain water to avoid ground water interference and to keep sub grade dry as per standard road construction practices. It is to be ensured that leaching of heavy metals is minimized. Flyash may sometimes accidentally comes in contact with running water and ground water and the flyash water mixture is basic in nature ($8<PH<10$) which tends to limit the heavy metal leaching.

Pozzolanic concretes are used expansively throughout the world where oil, gas, nuclear and power industries are among the major users.The applications of such concretes are increasing day by day due to their superior structural performance, environmental friendliness, and energy conserving consequences. Research has been conducted on the use of fly ash, volcanic ash, volcanic pumice, pulverized-fuel ash, blast slag and silica fume as cement replacement material. Fly ash and others are pozzolanic materials because of their reaction with lime liberated during the hydration of cement. These materials can also improve the strength of concrete
and the rate of gain in strength and can also reduce the rate of release of heat, which is beneficial for mass concrete. Concretes containing mineral admixtures are used widely throughout the world for their good performance and for ecological and economic reason.

In the past few years, many research and alteration has been done to produce concrete with higher strength and durability.

Toxic ingredients depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic , beryllium , boron , cadmium, chromium , chromiumVI , cobalt , lead , manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds.

In the past, fly ash was usually released into the atmosphere, but pollution control equipment mandated in recent decades now require that it be caught prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, regularly used to supplement Portland cement in concrete production. Some have expressed health concerns about this.

## II. LITERATURE REVIEW

### 2.1 FLY ASH – SOURCE AND TERMINOLOGY

#### 2.1.1 Source

Fly ash is a by-product of the combustion of pulverized coal in thermal power plants.

Bree different processes, namely, high-temperature combustion (1 500 - 1700"C) ; dry combustion (1 100 - 1400" C) and fluidized-bed combustion (<900° C) are employed for the combustion of pulverized coal. Ashes obtained from fluidized-bed combustion (FBC), are not genuine fly ashes, and are of little interest for building material applications (Wesche, 1991). The dust-collection system (mechanical / electrostatic precipitator - ESP) removes the fly ash , as a fine particulate system from the combustion gases, before they are discharged into the atmosphere. The term 'fly ash' is not applied to the residue extracted from the bottom of boilers.

### 2.2 PARTIAL REPLACEMENT OF SAND WITH FLY ASH

Hwang, Noguchi & Tomosawa, 2004 based on their experimental results concerning the compressive strength development of concrete containing fly ash, the authors concluded that the pores in concrete reduce by addition of fly ash as replacement of sand. (Siddique, 2003) carried out experimental investigation to evaluate mechanical properties of concrete mixes in which fine aggregate (sand) was partially replaced with class F fly ash. Fine aggregate was replaced with five percentages (10%,20%, 30%, 40% and 50 %) of class F fly ash by weight. The test result showed that the compressive strength of fly ash concrete mixes with 10% to 50% fine aggregate replacement with fly ash were higher than control mix at all ages. Also the compressive strength of concrete mixes was increasing with increase in fly ash percentages. This increase in strength due to replacement of fine aggregate with fly ash was attributed to pozzolanic action of fly ash. The splitting tensile strength also increased with increase in percentage of fly ash as replacement of fine aggregate. The tests on flexural strength and modulus of elasticity also showed improvement in the results as compared to control concrete. (Namagg & Atadero, 2009) described early stages of a project to study the use of large volumes of high lime fly ash in concrete. Authors used fly ash for partial replacement of cement and fine aggregates. Replacement percent from 0% to 50% was tested in their study. They reported that concrete with 25% to 35% fly ash provided the most optimal results for its compressive strength. They concluded that this was due to the pozzolanic action of high lime fly ash. (Jones & McCarthy, 2005) made an extensive laboratory based investigation in to unprocessed low lime fly ash in foamed concrete, as a replacement for sand. For a given plastic density, the spread obtained on fly ash concretes were up to 2.5 times greater than those noted on sand mixes. The early age strengths were found to be similar for both sand and fly ash concrete, the 28-day values varied significantly with density. The strength of fly ash concrete was more than 3 times higher than sand concrete. More significantly while the strength of sand mixes remained fairly constant beyond 28 days, those of fly ash foamed concrete at 56 and 180 days were up to 1.7 to 2.5 times higher than 28 days values respectively.

Rebeiz, Serhal & Craft, 2004 reported investigation on the use of fly ash as replacement of sand in polymer concrete. In the weight mix design 15% sand was replaced by fly ash. This replacement of 15% sand with fly ash by weight increased compressive strength by about 30%. Also there was improvement in the stress strain curve. They also reported good surface finish due to addition of fly ash as replacement of sand which also reduce permeability and have an attractive dark colour. Flexural strength of steel reinforced polymer concrete beams was increased by 15%.When subjected to 80 thermal cycles polymer concrete with fly ash exhibits slightly better thermal cycling resistance (about 7% improvement) than polymer concrete without fly ash. (Rao, 2004) discussed the need to use about 650 kg/cu.m of fine material to make self compacting concrete. This also requires fine aggregates more than 50% of total aggregate so that coarse aggregate can float in the fine material. This requirement of fine materials can be easily fulfilled by use of fly ash. (Papadakis, 1999) used a typical low calcium fly ash as additive in mortar replacing, part of volume either of Portland cement or aggregate. In both cases 10, 20 and 30% addition to the cement weight was done. A very important finding was that when the compressive strength of mix in which aggregate was replaced by fly ash were similar to that of control mix at 3 and 14 days, but were higher from 28 days and later. The strength increase is due to higher content of calcium silicate hydrate. There is reasonable distribution of the strength increase according to fly ash content but after 91 days there is no difference between 20% and 30% replacement. When fly ash replaces cement the strength is reduced, at first due to lower activity of the fly ash, but as time precedes this gap is gradually eliminated. (Neville, 2009) In general, the aggregate cement ratio is only a secondary factor in the strength of concrete but it is found that, for a constant water cement ratio, a leaner mix leads to higher strength for higher aggregate cement ratio. A large amount of aggregate absorbs a greater quantity of water. It reduces the effective water cement ratio increasing the strength. The most likely explanation, however, lies in the fact that the total water content per cubic meter of concrete is lower in a leaner concrete. As a result, in a leaner mix, voids form a smaller fraction of total volume of concrete, and it is these voids that have an adverse effect on strength. (Pofale, & Deo, 2010) with their study indicated about 20% increase in compressive strength and about 15% increase in flexural strength of concrete over control concrete by replacing 27% of sand with low lime fly ash. In study fly ash based Portland pozzolana cement was used. They had also reported about 25% increase in workability of the fly ash based concrete over control concrete.

## III. MATERIALS AND METHODS

The concrete manufacturers and construction industry have realized that they need to use available alternative instead of search for the perfect aggregate to make the concrete suitable for all purpose. At the same time, importance increases in concrete reusing result in hundreds of tones of Fly Ash to fine aggregate that can be used in the production of concrete for the particular purposes.

It have been well established that flyash can be used for all structural elements in civil engineering technology. Based on literature review it is clear that very small research so far has been carried out on the modulus of elasticity of fly ash. Accordingly, the present investigation point to study on the Impact behavior Fly Ash Concrete.

### 3.1 MATERIALS

**Ordinary Portland Cement (53 grade)**

Ordinary Portland Cement (OPC) is one of several types of cement being manufactured throughout the world, are some of the more commonly used. OPC is the common purpose cement used in concrete constructions. OPC is a compound of lime (CaO), silica ($SiO_2$), alumina ($AL_2O_3$), iron ($Fe_2O_3$) and sulphur trioxide ($SO_3$), Magnesium (MgO) is present in small quantities as an impurity related with limestone. $SO_3$ is added at the grinding step to retard the setting time of the finished cement. When cement raw materials containing the proper proportions of the essential oxides are ground to a suitable fineness and then burnt to incipient.

Fusion in a kiln, chemical combination takes place, largely in the solid state resulting in a product aptly named clinker. This clinker, when ground to a proper fineness, together with a small amount of gypsum ($SO_3$) is Portland cement. In fact, cement powder is "nothing else" other than a combination of oxides of calcium, silicon, aluminium and iron. The cement used throughout the test programme was Ordinary Portland Cement (OPC) of 53 grade confirming to IS 4031:1988 was used in the present study. The specific gravity of cement is taken as 3.15. The chemical and physical properties of cement are presented in following tables.

**Chemical composition**

Although Portland cement consists essentially composed of four major oxides: lime (CaO), silica (SiO2), alumina (Al2O3), and iron (Fe2O3) and also Portland cement contains small amount of magnesia (MgO), alkalies (Na2O and K2O), and sulfuric anhydrite (SO3).

Chemical composition Limits of Oxides in Portland cement are given below

**Table: 3.1 Chemical composition of OPC**

| S.NO | Oxide Composition | Percent Content |
|---|---|---|
| 1 | Lime, CaO | 63 |
| 2 | Silica, $SiO_2$ | 20 |
| 3 | Alumina, $Al_2O_3$ | 6 |
| 4 | Iron oxide, $Fe_2O_3$ | 3 |
| 5 | Magnesia, MgO | 1.5 |
| 6 | Sulphur trioxide, $SO_3$ | 2 |
| 7 | Potassium oxide, $K_2O$ | 1 |
| 8 | Sodium oxide, $Na_2O$ | 1 |
| 9 | Tricalcium silicate, $C_3S$ | 54.1 |
| 10 | Dicalcium silicate, $C_2S$ | 16.6 |
| 11 | Tricalcium aluminate, $C_3A$ | 10.8 |
| 12 | Tetra calcium aluminoferrite, $C_4AF$ | 9.1 |

**Fine Aggregate**

Locally available natural sand is used as fine aggregate in the present work. The most common ingredient of sand is silica, usually in the form of quartz, which is chemical inert and hard. The sand is free from clayey matter, silt and organic impurities etc. therefore used as a fine aggregate in concrete. The size of sand is that passing through 4.75 and retained on 150 micron IS sieve. The specific gravity of Sand is taken as 2.7. Sand is tested for specific gravity, in accordance with IS: 2386-1963.

**Coarse Aggregate**

The coarse aggregates are basically granite origin, and it is free from clayey matter, silt and organic impurities etc. Coarse aggregate is tested for specific gravity, in accordance with IS: 2386-1963. The maximum size of 20 mm is used as a coarse aggregate in concrete. For most of building constructions, the coarse aggregate consists of gravel or crushed stone up to 20mm size. However, in massive structures, such as dams, the coarse aggregate may include natural stones or rock.

**Fly ash (FA)**

Fly ash is a by-product of the combustion of pulverized coal in power stations. It is a solid material extracted by electrostatic and mechanical means from the flue gases of furnaces fired with pulverized bituminous coal. During production of FA, the coal passes through the high temperature zone in the furnace and the carbon and volatile matter are burned off, whereas most of the mineral impurities, such as clays, quartz, and feldspar melt at high temperature. The fused matter is quickly transported to low-temperature zones, where it solidifies as spherical particles of glass. Some of the mineral substance agglomerates forming bottom ash, but most of it flies out with the flue gas stream and is called "fly ash". This ash is subsequently removed from the gas by mechanical separator, electrostatic precipitators. Its main constituents are SiO2, AL2O3 and Fe2O3 with smaller quantities of other metal oxides, the chemical composition of fly ash is shown in Table 3.13.

Due to its unique mineralogical and granulometric characteristics, fly ash generally does not need any processing before use as a mineral admixture. Bottom ash is much coarser, less reactive and therefore requires fine grinding to develop a pozzolanic property. Average worldwide utilization of fly ash is about 15%, whereas in India, its utilization is form 2 to 5% only. In the present study Fly ash is collected from RTPP. It is conformed to grade1 of IS: 3812-1981.

**3.2 TESTS ON CEMENT**

Thoroughly mixed with fingers for one minute. The mould resting on a nonporous plate was filled completely with cement paste and the surface of filled paste was leveled smooth with the top of the mould. The test was conducted at room temperature of 27±20C at a relative humidity of 60%. The mould with the cement paste was placed in the Vicat's apparatus and the needle was lowered gently to make contact with the test block and was then quickly released. The needle thus penetrates the block and the reading on the graduated scale of Vicat's apparatus was recorded. The procedure was repeated until the needle fails to pierce the block by about 5 to 7 mm measured from the bottom of the mould. The stop button of stop watch was pushed down and the time was recorded which give the initial setting time. The cement paste was considered finally set when upon applying the needle gently to the surface of test block, the needle makes an immersion, but fails to penetrate and the time was noted which gives the final setting time. The needle was cleaned after every repetition and also care was taken such that there could not any vibrations.

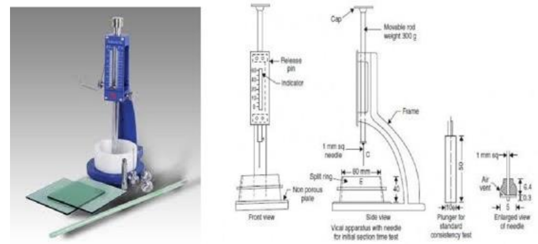


Figure: 3.1 Vicat apparatus with dimensions

**Soundness**

It consists of a small split cylinder of spring brass of 0.5mm thickness, forming a mould with 30mm internal diameter and 30mm high. On either side of the split are attached two indicators are attached with pointed ends AA, the distance from these ends to the Centre of Cylinder being 165mm. the mould was placed on a glass sheet and was filled with cement paste formed by gauging 100g of cement with 0.78 times the mixing water required to give a paste of standard consistency. The mould was covered with a glass sheet and a small weight was placed on its top. The mould was then submerged in the water at a temperature of 27 ± 20C. After 24hours, the mould was taken out and the distance separating the indicators points was measured. The mould was again submerged in water. Using the water heaters the water was brought to boiling point within 25 to35 minutes and the specimen was kept for 3 hours at a boiling point. The mould was removed from water and was allowed to cool down to 270C. The distance between the indicator points was measured again. The differentiation between the two measurements represents the unsoundness of cement. For each concentration of mixing water, three samples were tested and the mean value was taken as the unsoundness of cement sample.

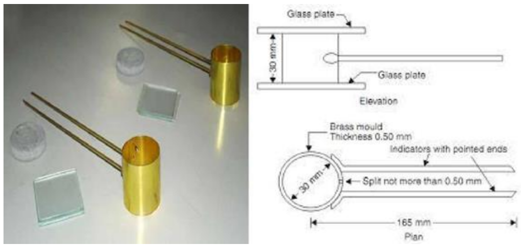



Figure: 3.2 Le Chatelier Apparatus with dimensions

## 3.3TESTS ON CONCRETE

**Compressive Strength Test**

Remove the specimen from water after specified curing time and wipe out excess water from the surface. Take the measurement of the specimen to the nearest 0.2m. Clean the bearing surface of the testing machine. Place the specimen in the machine in such a way that the load shall be applied to the opposite sides of the cube cast. Align the specimen centrally on the bottom plate of the machine. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply the load gradually without shock and constantly at the rate of 140kg/cm2/minute till the specimen fails. Record the maximum load and note any remarkable features in the type of failure.

Least three specimens should be tested at each selected age. If strength of any specimen varies by additional 15 per cent of average strength, results of such specimen should be rejected. Average of their specimens gives the crushing strength of concrete. The strength requirements of concrete.

Figure: 3.3 Compressive testing machine

Figure: 3.4 Concrete cube specimens

## IV. EXPERIMENTAL INVESTIGATION AND PRESENTATION OF TEST RESULTS

**Over view:**

The following materials were used for the experimental work so as to achieve the specified objectives, which are mentioned in the previous chapter.

**Cement.**

Pozzolana Portland Pozzolana cement conforming to IS 8112: 1989 was used. The physical properties of cement is presented in table 4.1

Table 4.1 Physical properties of Cement

| S.NO | Property | Numerical value |
|---|---|---|
| 1 | Fineness of Cement | 225 $m^2$/kg |
| 2 | Specific Gravity | 3.1 |
| 3 | Normal Consistency | 33 % |
| 4 | Setting Time<br>i) Initial Setting time<br>ii) Final setting time | <br>45 min<br>6 hours |
| 5 | Compressive Strength<br>i) 3 days<br>ii) 7 days<br>iii) 28 days | <br>32 N/$mm^2$<br>46 N/$mm^2$<br>58 N/$mm^2$ |

**Fine Aggregate.**

Locally available river sand passing through 4.75 mm I.S .Sieve is used. The specific gravity of the sand is found to be 2.62. The physical properties and sieve analysis results are presented in table 4.2 and 4.3

Table 4.2: Physical properties of Fine Aggregate

| S.No | Property | Values |
|---|---|---|
| 1 | Specific Gravity | 2.62 |
| 2 | Fineness Modulus | 2.78 |
| 3 | Bulk Density<br>Loose State<br>Compacted State | <br>14.58 kN/$m^3$<br>15.99 kN/$m^3$ |
| 4 | Grading of Sand | Zone - II |

Table 4.3: Sieve Analysis of Fine Aggregate

| S.No | IS Sieve | Weight retained | % Weight retained | Cumulative % weight retained | % Passing |
|---|---|---|---|---|---|
| 1 | 4.75 mm | 18 | 1.8 | 1.8 | 98.2 |
| 2 | 2.36 mm | 38 | 3.8 | 5.6 | 94.4 |
| 3 | 1.18 µ | 216 | 21.6 | 27.2 | 72.8 |
| 4 | 600 µ | 334 | 33.4 | 60.6 | 39.4 |
| 5 | 300 µ | 258 | 25.8 | 86.4 | 13.6 |
| 6 | 150 µ | 100 | 10 | 96.4 | 3.6 |
| 7 | 75 µ | 20 | 2 | 98.4 | 4.2 |
| | | | | | Total =278.2 |
| | | | | | Fineness Modules = 2.78 |

### 4.1.3 Natural Coarse Aggregate.

Crushed granite aggregate available from local sources has been used. To obtain a reasonably good grading, 60% of the aggregate passing through 20 mm I.S. sieve and retained on 12.5mm I.S. Sieve and 40% of the aggregate passing through 12.5mm I.S. Sieve and retained on 10 mm I.S. Sieve is used in preparation of NAC and LSA. The specific gravity of the combined aggregate is 2.70. The granite aggregate is depicted in figure 4.0.The physical properties are presented in table 4.4

Table 4.4: Physical properties of granite Coarse Aggregate

| S.No. | Property | value |
|---|---|---|
| 1 | Specific Gravity | 2.75 |
| 2 | Bulk Density<br>Loose State<br>Compacted State | <br>14.13 kN/$m^3$<br>16.88 kN/$m^3$ |
| 3 | Water Absorption | 0.4% |
| 4 | Flakiness Index | 14.22% |
| 5 | Elongation Index | 21.33% |
| 6 | Crushing Value | 21.43% |
| 7 | Impact Value | 15.5% |
| 8 | Fineness Modulus | 3.4 |

Figure 4.0: Granite Aggregate

**Fly ash:**

Fig 4.1 Fly ash

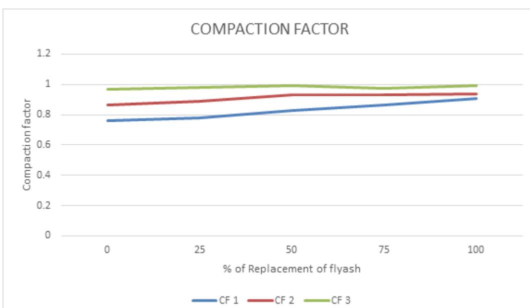
## V. DISCUSSION OF TEST RESULTS

### 5.1.1 Influence of fly ash on workability

The workability of mixes have been measured by Compaction factor test.The values of compaction factors results are presented in Table 5.1 and figure 51.From this it is observed that the compaction factor increase with increase in the % of fly ash in the concrete mix. Hankfi Binci et.al (2008) has been also reported same type of result for marble concrete. The decrease of workability may be due to higher water absorption .

Table 5.1: Workability of concrete.

| S.No | Nomenclature | Compaction Factor(CF) | Compaction Factor(CF) | Compaction Factor(CF) |
|---|---|---|---|---|
| 1. | NC | 0.758 | 0.862 | 0.969 |
| 2. | FC 25 | 0.782 | 0.890 | 0.981 |
| 3. | FC 50 | 0.827 | 0.929 | 0.990 |
| 4. | FC 75 | 0.864 | 0.930 | 0.972 |
| 5. | FC 100 | 0.910 | 0.935 | 0.992 |




### 5.2 Compressive strength:

Table 5.2.1 Compressive Strength for fly ash concrete For 14 days with 0% fiber

| S.No | Nomenclature | Compressive strength(N/mm2) |
|---|---|---|
| 1. | NC | 15.10 |
| 2. | FC 25 | 15.50 |
| 3. | FC 50 | 17.20 |
| 4. | FC 75 | 16.41 |
| 5. | FC 100 | 15.80 |

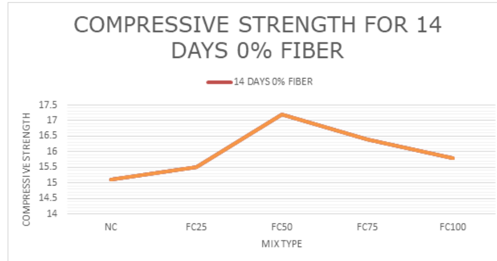



Figure 5.2.1 compressive strength versus % replacement for 14 days

Table 5.2.2 Compressive Strength for fly ash concrete For 14 days with 1% fiber

| S.No | Nomenclature | Ultimate Stress(N/mm2) |
|---|---|---|
| 1. | NC | 15.98 |
| 2. | FC 25 | 17.23 |
| 3. | FC 50 | 17.10 |
| 4. | FC 75 | 16.21 |
| 5. | FC 100 | 15.90 |

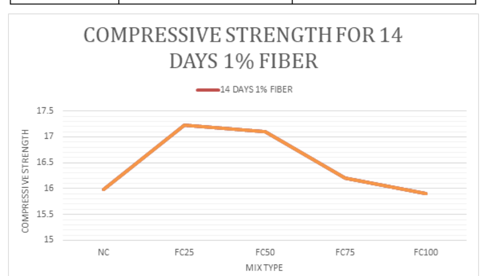



Figure 5.2.2 compressive strength versus % replacement for 14 days

## VI. CONCLUSIONS AND RECOMMENDATIONS

### CONCLUSIONS

The following conclusions may be drawn from the present experimental work

1. The workability of fly ash concrete decreases when compared to sand concrete.
2. The compressive and split tensile strengths increases with increase in fly ash concrete in the concrete mix up to 25% then decreases

3. It is economical , reduces cost and eco-friendly.
4. The incorporation of fly ash upto 25% is beneficial for the concrete works.
5. The use of fly ash for concrete works is demonstrated in compression and split strengths.
6. This study could enlighten the local peoples to use of fly ash to sand for concrete works.
7. we can save natural resources by using fly ash to sand as it is in scarce.

**RECOMMENDATIONS FOR FUTURE INVESTIGATIONS**

1. The studies can be conducted to know the performance under flexural loading and shrinkage effect.
2. Studies can be conducted by incorporation of steel fibres
3. Mathematical / Empirical models can be developed for the fly ash reinforced concrete.
4. Durability studies such as resistance to Sulphate attack, Acid resistance etc., can be carried out on lime flyash reinforced concrete.

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