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AN EXPERIMENTAL INVESTIGATION ON MIX DESIGN AND THE PROPERTIES OF FLY-ASH WASTE LIGHT WEIGHT AGGREGATES IN CONCRETE

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ABSTRACT

Concrete is one of the most widely used construction materials and has the ability to consume industrial wastes in high volume. As the demand for concrete is increasing, one of the effective ways to reduce the undesirable environmental impact of the concrete is by the use of waste and by-product materials as cement and aggregate substitutes in concrete. One such waste materials fly ash, which is produced in large quantities from thermal power plants as a by-product. A substantial amount of fly ash is left unused posing environmental and storage problems. The production of sintered lightweight aggregate with fly ash is an effective method to dispose of fly ash in large quantities. Due to lack of a proper mix design procedure, the production and application of lightweight aggregate in structural concrete are not much entertained. The absorption characteristic of lightweight aggregate is a major concern, while developing the mix proportioning of light weight concretes. The present study is an attempt to establish a new mix design procedure for the development of sintered fly ash lightweight aggregate concretes, which is simple and more reliable than the existing procedures. Also, the proposed methodology has been validated by developing a spectrum of concretes having water cement ratios varying from 0.25 to 0.75. From the study, it is obvious that the development of 70MPa concrete is possible by using cement alone without any additives. Also, it is ensured that all the concretes have densities less than 2000kg/m^3.Concrete specimens were casted using 10%, 20%, 30%, 40% replacement of coarse aggregates with fly ash waste light weight aggregate. Cubes of standard size 150x150X150mm were casted for 7,14 and 28 days and tested for compressive strength, split tensile strength, flexural strength.

KEYWORDS: Compressive Strength, Conplast WL, Flexural strength, Split tensile strength, Cube specimens.

CHAPTER-1

INTRODUCTION

1.1 GENERAL

Concrete is one of the most common construction materials in the world, mainly due to its low cost, availability, versatility, sustainability, its long durability, and ability to sustain extreme weather conditions. The worldwide production of concrete is10 times that of steel by tonnage. When aggregate is mixed with dry Portland cement and water, the mixture forms a fluid slurry that is easily poured and molded into shape. The cement reacts with the water through a process called concrete hydration that hardens over several hours to form a hard matrix that binds the materials together into a durable stone-like material that has many uses. This time allows concrete to not only be cast in forms but also to have a variety of tooled processes preformed. The hydration process is exothermic, which means ambient temperature plays a significant role in how long it takes concrete to set. Often, additives (such as pozzolans or superplasticizers) are included in the mixture to improve the physical properties of the wet mix, delay or accelerate the curing time, or otherwise change the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete.

The productive use of waste materials is one of the ways to ease some of the problems of solid waste management. There are several benefits of using waste materials. The use of fly ash increases the strength of the concrete. Many researchers are finding difficulty in replacing the coarse aggregate with lightweight aggregates such that the cost and usage of the aggregates will be less and also economical.

According to some authors SLWAC can be formulated with the same basic principles adopted for normal weight concretes (NWC), just with some specific aspects of its behavior and nature being taken into report that the water absorbed by LWA and the increased risk of segregation due to the lower density of aggregates are the main additional factors that must be considered. Density is an additional requirement for the SLWAC design that must be also taken into consideration.

Lightweight concrete design optimization is therefore more difficult since it must respect different properties that are partially conflicting such as durability, strength, workability, density and thermal properties. For example, a concrete with higher strength and durability is usually associated with higher density and lower insulation properties

1.2 FLYASH:

Fly ash is a by-product of coal-fired power generating plants consists off in particles that rise with flue gases. In industry, it usually refers to the ash produced during coal combustion, India produces about 75 million tonnes of fly-ash per year. one method for integrating some percentage of fly ash with cement clinker for the production of PPC

Component	Bituminous Coal	Sub bituminous Coal	Lignite Coal
SiO2 (%)	20-60	40-60	15-45
Al2O3 (%)	5-35	20-30	20-25
Fe2O3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

Table no-1 Chemical composition of fly ash

1.2.1 TYPES OF FLYASH:

- **Class F:**

Fly ash generally produced by burning anthracite or bituminous coal is classified as class ‘F’ fly ash. Commonly produced fly ash by burning anthracite or bituminous coal usually has less than 5% lime. This fly ash is pozzolanic in nature and contains less than 20%lime (CaO).

- **Class C:**

Fly ash normally manufactured by burning lignite or sub-bituminous coal is classified as Class ‘C’ fly ash. It comes with pozzolanic and cementation properties. It is usually made by burning lignite or sub-bituminous coal usually contains more than 20%lime. The content of alkali and sulfate (SO4) is generally higher in Class C fly ash.

1.2.2 FLYASH PROPERTIES:

- **Fineness:**

According to ASTM, the beauty of fly ash is to be tested in both dry and wet seasons. The fly ash sample is sieved in a 45-µm strainer and the proportion of retaining on the 45-µm strainer is calculated. In addition, beauty is also measured by the Lachelier method and the plain specification

- **Specific gravity:**

The specific gravity of fly ash varies from a low value of 1.90 for sub-bituminous ash to a high value of 2.96 for iron-rich bituminous ash. The specific gravity of fly ash varies from a low value of 1.90 for sub-bituminous ash to a high value of 2.96 for iron-rich bituminous ash.

- **Size and shape:**

Since fly ash is a really fine material, the particle dimension is between 10 and 100μm.Theflyash is usually shaped like a circular glass.

- **Colour:**

The colour of fly ash is determined by the chemical and mineral elements. The materials of lime in fly ash provide tan and light-weight colour whereas brown colour is applied by the presence of iron content material. A dark brown to black colour is usually attributed to an enhance dun-burn material.

Fig:1 Fly ash

1.2.3 ADVANTAGES OF FLY ASH:

- The heat of hydration can be reduced by replacing fly ash.
- Bleeding rate decreases as work efficiency increases.
- Superior long time strength and durability performance.
- Lower water content results in less shrinkage and perforation.
- Low permeability and improved resistance to sulfate attack.

1.2.4 DISADVANTAGES OF FLY ASH:

- A few hours after pouring it changes from liquid to solid but the curing process may take longer.

- It can prolong the time as concrete takes more time to set.
- It reduces the amount of air ingress, and high concrete admixture, often requires more air-entraining penetration.
- The colour of concrete is more difficult to control with fly ash than blends with only Portland cement.

1.2.5 USES OF FLYASH:

- Mass solid block.
- Ready-mix concrete and precast applications.
- Includes marine environment.
- For use with alkali-reactive aggregates.
- Water retaining structure.
- Self-compacting concrete.
- Tunneling work.
- Road Stabilization.

1.3 LIGHT WEIGHT AGGREGATES

Lightweight aggregate is a widely used construction material owing to its versatile properties. The lightweight aggregate, its properties, applications and manufacturing process. Lightweight aggregate is a coarse aggregate used to make light weight concrete for structural as well as non-structural applications.

- The Compressive design strength of normal concrete for cast-in situ, precast and prestressed concrete ranges between 20 N/mm^2 to 35 N/mm^2. On the other hand, the minimum compressive design strength of concrete which uses lightweight aggregate will be around17-18N/mm^2.

Fig:1.1 Fly ash light weight aggregate

Fig:1.2 Fly ash light weight aggregate

- Normal concrete has a density between 2300 and 2500 kg/m^3. However, when it comes to LWC the density ranges between 500 kg/m^3 to 1800 kg/m^3 depending on the type of aggregate used.
- Lightweight concrete with densities lower than 17 N/mm^2 falls under the category of LWC. And, those with densities above 17 N/mm^2 are referred to as structural light weight concrete (SLWC).
- LWC can also be designed for the minimum compressive strength as normal concrete by varying the proportions of mineral admixtures used.
- SLWC is used for structural applications. They can be used along with reinforcement steel just like normal concrete.

1.3.1 FEATURES OF FLY ASH WASTE LIGHT WEIGHT AGGREGATES

- The light weight aggregate used in concrete may have any form, including cubical, rounded, angular, and other shapes. Its workability is directly influenced by its form and texture.
- These aggregates are known for absorbing little water and maintaining their low density.
- A high saturation level makes it an attractive option.
- FLWA can reduce the deadloads on the structure and make it more economical.
- Has relatively low thermal conductivity.
- Helps in consuming industrial wastes like blast furnace slag, fly ash, clinkers etc.
- Possess good a caustic properties.

CHAPTER-2

LITERATURE REVIEW

S. Syed Abdul Rahman (2016)

In recent development scenario, the lightweight concrete is a versatile material, which offers arrange of technical, economic and environmental–enhancing and preserving advantage and is designed to become a dominant material in the millennium. For structural application of light weight concrete, the density is often more important than the strength. A decreased density of the same strength level reduces the self weight, foundation size and construction cost. Structural light weight aggregate concrete is generally used to reduce dead weight of the structure as well as to reduce the risk of seismic damage to a structure because the seismic forces that will influence the civil engineering structures are proportional to the mass of those structures. In this study, structural light weight aggregate concrete was designed with the use of natural vermiculite aggregate that will provide an advantage of reducing dead weight of structure and to obtain a more economical structural light weight concrete by the use of vermiculite power as a partial replacement of sand. Three mixes were produced with the cement content of 479 kg/m^3 in M30 grade and water cement ratio is 0.40. More over the group had proportion of 0%, 5%, 10%, as vermiculite replacement.

In their study, structural lightweight aggregate concrete was designed with the use of natural vermiculite aggregate that will provide an advantage of reducing dead weight of structure and to obtain a more reasonable structural light weight concrete by the use of vermiculite power as a partial replacement of fine aggregate. Three mixes were created with the cement content of 479 kg/m3 in M30 grade and water cement ratio is 0.40. The proportion of 0% ,5% and 10%, as vermiculite replacement to fine aggregate. And lastly they concluded that the 10% replacement of vermiculite to fine aggregate well compared to control mix.

Chandra and Berntsson (2017)

They proposed a semi empirical method for SLWAC mix design which makes it clear that the concrete strength depends on the strength and volume of its constituents. Based on a biphasic model, the authors proposed the expression estimate the strength of SLWAC, which is a function of the volume and strength of the mortar and the LWA. This expression considers that the density of the concrete corresponds to the addition of its constituents' densities and assumes that the strength of each constituent is exponentially related to its density. In the mean compressive strength of the concrete is the mean compressive strength of the mortar, whose composition is the same as that of the mortar in the concrete and LWA are the relative volumes of cement and lightweight aggregate in the mix.

The following less positive aspects of this method should be noted: it does not directly consider the concrete density the compressive behavior of SLWAC does not depend on the stiffness ratio between LWA and mortar; the mix design depends on determinable empirical parameters.

The compressive behavior of LWAC is strongly dependent on the 1Þ limit strength, fL, and the ceiling strength, fcs. fL corresponds to the strength for which the modulus of elasticity is similar to that of the aggregate [6, 10, 21]. Above fL the strength of concrete is also affected by LWA and is lower than the mortar strength. fcs correspond to the highest bearing strength of LWAC, beyond which an increment of the mortar strength has little influence on the concrete

N. Siva Linga Rao (2013)

Has studied an investigation has been made to understand the behavior of conventional aggregate concrete in which normal aggregate is replaced with cinder in volume percentages of 20, 40, 60, 80 and 100 and cement is replaced with silica fume in weight percentages of 0,5,8,10,15 and 20. From the study it is concluded that 60 percent replacement of conventional aggregate with cinder by volume along with cement replaced by 10 percent of silica fume by weight yields the target mean strength. The unit weight of the cinder concrete is varying from 1980Kg/m^3 to 2000Kg/ m^3 with different percentages of cinder

From the study it is concluded that 5 % silica fume is giving the best results when compare to 10% and 15% silica fume. and also, from fly ash 20% is giving best results when compare to 10% and 30%.

From the study it may concluded that the usage of light weight cinder aggregate to some extent (60%) and granite aggregate (40%) using admixture as silica fume and fly ash has proved to be quite satisfactory strength when compare to various strengths studied. It can be concluded that due to porous nature Cinder aggregate's quality is low in comparison with normal aggregate

The results indicate that the compressive strength is decreases with the increase in percentage of cinder. The results indicate that the split tensile strength is decreases with increase in percentage of cinder. Compressive strength of 5% silica fume concrete is more than the 10% and 15fume concrete at 28 days Similarly tensile strength of 5% silica fume is greater than the 10% and 15% silica fume concrete at 28 days. Compressive strength of 10% fly ash concrete is more than the 20% and 30% fly ash concrete at 28 days Similarly tensile strength of 10% fly ash concrete is greater than the 20% and 30% fly ash concrete.

P. Rathish Kumar (2018)

He studied the strength and sorptivity attributes of concrete made with cinder based on lightweight aggregates. Before this the span of cinder based light weight aggregate was enhanced. The mechanical properties, compressive strength and split tensile strength were learned at the end what's more 28 days for mid-range evaluation concrete with sizes of total. It was noted that with 12.5mm size total and 30% fly ash the mechanical properties were predominant in 20MPa Lightweight Concrete, while 10 mm size total with 30% fly powder substitution properties of 30MPaconcrete.

According to his study he concluded that 12.5mm size of aggregate was helpful in increasing the strength of the concrete.

Euro Light Con (2000)

A rational mix design method for the development of lightweight aggregate concrete

- A detailed study was conducted on the absorption characteristics of the commercially available aggregates known as liapor (expanded shale) and lytag (sintered fly ash)
- Thirty minutes' water absorption was considered as the amount of water absorbed during mixing and casting
- In this procedure, for a desired slump, the volume percentage of the matrix content was determined from s-curve
- Was observed that 30% of matrix content provided good workability. The volume of sand was fixed as 40% of the total aggregate volume. This procedure is limited to W/C ratios varying between 0.25 and 0.35.

SUMMARY:

By reviewing above literature reviews, we came to know that strength of concrete increases until 50 % replacement of coarse aggregate with fly ash waste light weight aggregate. In this present project we are going to to calculate the specified mix design (M30) and to determine the percentage of increase in compressive strength of M30 grade concrete with partial replacement of coarse aggregate with fly ash waste light weight aggregates by (0%,10%,20%,30%,40%) percentages. To determine the percentage of increase in tensile strength and flexural strength of M30 grade concrete with replacement of coarse aggregate with fly ash waste light weight aggregates. To know the different characteristics and performance between normal concrete and lightweight aggregate concrete

CHAPTER-3

METHODOLOGY

3.1 TYPES OF MIXES

Nominal mixes:

In the nominal mix concrete, all the ingredients and their proportions are prescribed in the standard specifications. These proportions are specified in the ratio of cement to aggregates for certain strength achievement .

The mix proportions like 1:1.5:3, 1:2:4, 1:3:6 etc. are adopted in nominal mix of concrete without any scientific base, only on the basis on past empirical studies. Thus, it is adopted for ordinary concrete or you can say, the nominal mix is preferred for simpler, relatively unimportant and small concrete works.

As per the 'Indian Standard- IS 456:2000', nominal mix concrete may be used for concrete of M20 grade or lower grade such as M5, M7.5, M10, M15.

Design mix:

It can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

Designated mix:

Designated Concrete Mixes are recipes used to prepare concretes that can be used to perform particular functions within the civil engineering industry.

3.1.1 FACTORS EFFECTING THE CHOICES OF MIX DESIGNS:

Compressive Strength:

It is one of the most important Properties of concrete and influences many other desirable properties of the hardened concrete. The mean compressive strength that is required at a specific age usually 28 days, will determine the nominal water-cement ratio of the mix. The other factor affecting the strength of the concrete at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham's law, the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

Workability:

The degree of workability required depends on the below mentioned three factors:

i. Size of the section to be concreted

ii. Amount of reinforcement

iii. Method of compaction that is used

Durability:

The durability of concrete is its resistance to the aggressive environmental conditions. The high strength concrete is generally more durable than the low strength concrete.

Maximum Nominal Size of Aggregate:

Larger the maximum size aggregate, smaller is the cement requirement for a particular water-cement ratio. This is because the workability of the concrete increases with the increase in the maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in the size of the aggregate.

IS 456:2000, Indian Code for Concrete Design, recommend that the nominal size of the aggregate should be as large as possible.

Grading and Type of Aggregate:

Coarser the grading, leaner will be the mix. A very clean mix is not desirable since it does not contain enough finer material to make the concrete cohesive. The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water-cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which is achieved by mixing different size fractions.

Quality Control:

The degree of control can be estimated statistically by the variations in the test results. The variation in the strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing.

3.2 MATERIALS USED:

3.2.1 Portland cement

Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and non-specialty grout. It was developed from other types of hydraulic lime in England in the early 19th century by Joseph Aspdin, and is usually made from limestone. It is a fine powder, produced by heating limestone and clay minerals in a klint of or clinker, grinding the clinker, and adding 2 to 3 percent of gypsum. 53 grade of cement is adopted

Fig:3.2.1 Portland cement

3.2.2 Fine aggregate

Fine aggregates are essentially any natural sand particles won from the land through the mining process. Fine aggregates consist of natural sand or any crushed stone particles that are ¼" or smaller. This product is often referred to as 1/4"' minus as it refers to the size, or grading, of this particular aggregate. Less than 4.75 mm size aggregates are adopted.

Fig:3.2.2 Fine aggregate

3.2.3 Fly ash Lightweight aggregates

The lightweight aggregate is a kind of coarse aggregate which is used in the production of lightweight concrete products like concrete block, structural concrete, and pavement. The shape of the lightweight aggregate used in concrete can be cubical, rounded, angular, or of any other shape. these are made up of fly ash waste where the weight of the aggregates are lighter than coarse aggregates

Fig:3.2.3 Fly ash light weight aggregate

3.2.4 Coarse aggregates

Materials that are larger to be retained on 4.75 mm sieve size are called coarse aggregate, and their maximum size can be up to 63 mm. In coarse aggregate, foreign materials like coal, lignite, soft fragments, and clay lumps should not exceed 5 percent of their actual weight.

Fig:3.2.4 Coarse aggregate

3.2.5 conplast WL xtra

Conplast WL Xtra is a dark brown liquid based on cement dispersion polymers which mixes readily with water and therefore disperses evenly. Conplast WL Xtra waterproofs by improving the quality of the concrete or mortar. It reduces the water demand for required workability and minimizes segregation and bleeding. Thus it is more efficient compared to traditional powder and conventional integral waterproofing compounds as its use results in two fold improvement of concrete or mortar.

Uses

To minimise permeability and increase the waterproofing properties of concrete, plaster and cement sand mortars for critical applications like roof slabs, screeds, basements, external plastering, bathroom floors, water tanks, sumps, drains etc.

High Strength: Due to better dispersion of cement particles and helps in the better degree of hydration yielding high strength compared to control.

Cohesive Mix: Improves workability and cohesiveness of the concrete.

Durability: Improves durability due to reduction in permeability of concrete and corrosion resistance of steel.

Fig: 3.2.5 conplast WL xtra

3.3 TEST PERFORMED:

Tests Performed on Portland cement

3.3.1 Specific gravity test:

- Initially empty weight of density bottle is taken as W_1.
- Then 1/3rd of cement is weighed with the density bottle and is taken as W_2.
- For W2 water is added up to the neck of density bottle and weighed as W_3.
- Density bottle is cleaned and only kerosene is filled up to the neck, the weight istaken as W4.
- Cleaned the density bottle again, and filled it up to the neck with water and the weight is taken as W5.

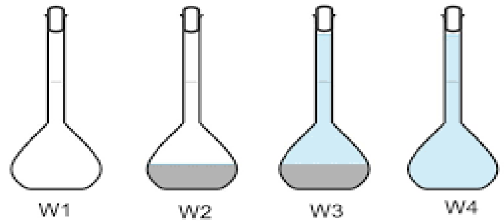


Fig:3.3.1 pycnometer

Description	**Observations (grams)**
Weight of bottle (W_1)	34
Weight of bottle+1/3 Cement (W_2)	69
Weight of bottle + Cement +Kerosene(W_3)	103
Weight of bottle + Kerosene (W_4)	78
Weight of bottle filled with water (W_5)	88
Specific gravity of Cement G = $[(W_2-W_1)G_K]/[(W_4-W_1)-(W_3W_2)]$	3.15

Table-3.3.1 Specific gravity of cement

3.3.2 Standard consistency of cement

- Weighed about 400 grams of cement (C) accurately and placed it in the enamel trough.
- Starting with 23% of water by weight, mixed it with cement by means of a spatula. Care is taken that that the time of gauging is not less than 3 minutes and not more than 5 minutes. The gauging time is counted from the time of adding water to the dry cement until commencing to fill the mould.
- Filled the Vicat's mould with the cement paste, which is resting on a non-porous plate.
- The top surface of the cement paste is levelled with the trowel. The mould is slightly shaken to expel the air.
- The mould is placed together with a nonporous plate under the rod bearing the plunger. Adjusted the indicator to show the 0-0 reading when it touches the test block.
- Released the plunger quickly, allowing it to sink into the paste.
- Prepared the trail pastes with varying percentages of water and tested as described above until the needle penetrates 5mm to 7mm above the bottom of the mould.
- Expressed the amount of water as a percentage (P) by weight of the dry cement which is determined as the consistency of cement.

Fig:3.3.2 vicats apparatus

S. No	Quantity of water added 'W'(ml)	Time of gauging (min)	Penetration from thebottom of the mould
1	92	5	42
2	100	5	39
3	108	5	36
4	116	5	24
5	124	5	13
6	132	5	6
P = (W/C) × 100 = 33%			

Table-3.3.2 consistency of cement

3.3.3 Initial setting time of cement:

- Weighed about 300 grams of cement and is taken to make a paste.
- Prepared a neat cement paste by adding water of 0.85 times the percentage of water required for standard consistency and weight of cement.
- Started the stop watch at the instant when the water is added to the cement.
- Filled the Vicat's mould with the cement paste prepared with the mould resting on the non-porous plate. Care is taken that the gauging time is not less than 3 minutes and not more than 5 minutes.
- Filled the mould completely and levelled the surface with the top of the mould to give a test block.
- Placed the test block confined in the mould and rested on a non-porous plate under the rod, bearing the needle.
- Lowered the needle gently till it comes in contact with the surface of the test block and quickly released, allowing it to penetrate into the test block and penetrations for every two minutes is noted.
- Repeated this procedure until the needle failed to piece the block for about 5mm measured from the bottom of the mould. Switched off the stop watch and notedthe time, which is determined as the initial setting time.

Fig:3.3.3 Vicats apparatus for initial setting time

S. No	Time in minutes afteradding water	Penetration reading (mm)
1	5	16
2	10	19
3	15	21
4	20	23
5	25	24
6	30	24
7	35	24
8	40	28
9	45	30
10	50	31
11	55	36

Table 3.3.3 Initial setting time of cement

3.3.4 Final setting time of cement

- Replaced the needle of the Vicat's apparatus by the needle with an annular attachment.
- Started releasing the needle as described earlier till the needle makes an impression thereon, while the attachment fails to do so.
- The time that elapsed between the moment of water which is added to the cement and the needle which makes an impression is taken as the final setting time.
- We got the final setting time = 455 minutes.

3.4 TESTS ON FINE AGGREGATE

3.4.1 Sieve analysis

- Take 1000 grams of fine aggregates sample.
- Arrange the sieve set from top to bottom as follows 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron, 150 micron, 75 micron and Pan.
- After weighing the sample, transfer the sample to 4.75 mm sieve and cover it with lid.
- Place the assembly of sieve set on mechanical sieve shaker and sieve it for five to ten minutes.
- Remove the assembly from mechanical sieve shaker and weigh the sample retained on each sieve, simultaneously note down in observation sheet.

Fig:3.4.1 set of sieves

Sieve no	Percent of individual fraction by mass (gm)	Percent passing by mass (gm)	Cumulative percent retained by mass (gm)
20mm	0	100	0
4.75mm	0	100	0
2.36mm	12	33	12
1.18mm	13	75	25
600 microns	39	36	64
300 microns	20	16	84
150 microns	9	7	93
pan	7	0	-

Table-3.4.1 specific gravity of fine aggregate

3.4.2 Specific gravity and water absorption test

- Initially, a sample of 500 grams finer than 4.75mm is placed in the tray and covered with distilled water at a temperature of 22°C and 32° C.
- Soon after immersion air entrapped in or bubbles on the surface of aggregates are removed by gentle agitation with a rod. The sample is kept immersed for 24 hours.
- The water is then carefully drained off from the sample by decantation through a filter paper and the material retained on the filter paper is returned to the sample.
- The aggregate is exposed to a warm air to evaporate surface moisture and is stirred atfrequent intervals to ensure uniform drying till no free moisture is seen.
- The saturated and surface dry sample is weighed. The aggregate is then placed in pycnometer and is filled with distilled water.

- Any air entrapped is eliminated by rotating the pycnometer on its side, the hole of the apex of the cone is covered with a finger.

- The pycnometer is then dried on the outside and weighed. The contents of the pycnometer are transferred into a tray, care is taken such that all the aggregates are transferred.

- The pycnometer is then refilled with distilled water to the same level as before, dried on the outside and weighed. The water from the sample is removed by decantation and the sample is dried in the oven at 100° C for 24 hours, cooled and weighed.

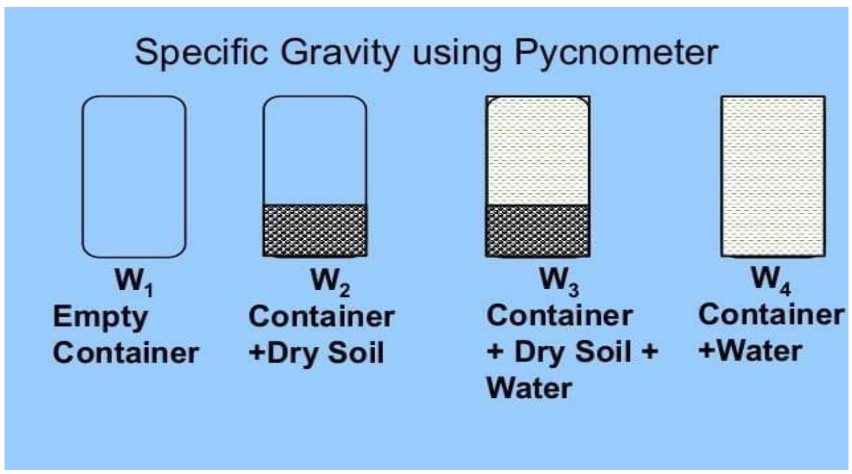


Fig:3.4.2 pycnometer measuring SG of fine aggregates

Description	**Observations (grams)**
Weight of empty pycnometer (W_1)	610
Weight of pycnometer with sample (W_2)	1220
Weight of pycnometer with sample and filled with water C (W_3)	1950
o Weight of pycnometer filled with water (W_4)	1640
m Specific gravity = $W_2 - W_1 / (W_4 - W_1) - (W_3 - W_2)$ p	2.62
r Water absorption = 100	0.40

Table-3.4.2 specific gravity and water absorption of fine aggregate

3.5 TESTS ON COARSE AGGREGATE

3.5.1 Specific gravity and water absorption test

- Initially taken required amount of sample for sieving.
- The sample is screened on a 20mm, 10mm IS sieves, to get 1kg of 20mm, 10mm aggregates respectively.
- The aggregates are thoroughly washed to remove the fine particles of dust, drained, and then the aggregates are immersed in water jar and allowed to remain immersed at a temperature of 22 to 32° C for 24 hours.
- Soon after immersion and again at the end of soaking period air entrapped in or bubbles on the surface of the aggregates is removed by gentle agitation. This is achieved by rapid clock-wise and anti- clockwise rotation of vessel between the hands.
- The vessel is over filled by adding distilled water and a slid is placed on the top of the jar to ensure that no air is trapped in the vessel. The vessel is dried on the outside and weighed.
- The vessel is emptied and the aggregate is allowed to drain out. Again, refilled the vessel with distilled water, the top of the jar is covered with a slid, the vessel is dried and weighed.
- The aggregate is placed on a dry cloth, gently surface dried with the cloth.
- The aggregate is then spread out not more than one stone deep on a separate cloth, and left exposed to atmosphere away from sunlight or any other source of heat, until it appears to be completely surface dry.
- The aggregate is weighed. The aggregate is then placed in the oven in the circular tray, at a temperature of 100° C for 24 hours.
- It is then cooled in air tight container and weighed.

Description	20mm (g)
Weight of the sample	1000
Weight of the vessel containing sample and filled with water (A)	1997
Weight of vessel filled with water (B)	1344
Weight of saturated surface dry sample (C)	1001
Weight of oven-dry sample (D)	996
Specific gravity = D / C−(A−B)	2.86
Water absorption = 100 x C – D / D	0.81

Table3.5.1 Specific gravity and water absorption of coarse aggregate

3.5.2 Flakiness Index:

- Initially, 200 pieces of 20mm size aggregates are taken for testing.
- The sample is sieved through the IS sieves of 20mm, 16mm, 12.5mm, 10mm, 6.3mm. Separated the aggregates which are retained on the sieves.
- Tried to pass each aggregate through the corresponding slot in the thickness gauge. e.g. the material passing through 20mm and retained on 16mm sieves should be made pass only through 10.9 thickness slot.
- Weighed all the pieces which pass through the slot, since they are considered flaky.

Fig:3.5.2 Flakiness index

Size of aggregate = 20mm			
Passing & retained throughIS sieve (mm)	Weight of 200 pieces of aggregates (W) grams	Corresponding thickness gauge size mm	Weight of aggregates passing the thickness gauge (w) grams
20-16	1530	10.9	196
	$\sum W = 1530$		$\sum w = 196$

Table-3.5.2 flakiness index

$$\text{Flakiness index } \frac{\sum w}{\sum W} \times 100 = 196 / 1530 \text{ X } 100 = 12.81\%$$

3.5.3 Elongation Index:

- Sieved the aggregates on 20mm, 16mm, 12.5mm, 10mm and 6.3mm and separated theaggregates retained on the sieves.
- Tried to pass each aggregate piece through the corresponding gauge size. If the length of the particle is such that it does not pass through the length gauge, it is said to have been retained by the length gauge.
- Weighed all the materials retained on the length gauge.

Fig:3.5.3 Elongation index

Size of aggregate = 20mm			
Passing & retained through IS sieve (mm)	Weight of 200 pieces of aggregates (W)grams	Corresponding length gauge size mm	Weight of aggregates retained on the thickness gauge (w) grams
20-16	1530	32.4	314
	$\sum W = 1530$		$\sum w = 314$

Table-3.5.3 Elongation index

$$\text{Flakiness index } \frac{\sum w}{\sum W} \times 100 = 314 / 1530 \text{ X}100 = 20.52\%$$

3.6 EXPERIMENTS ON FLY ASH LIGHT WEIGHT AGGREGATE

3.6.1 Specific gravity and water absorption of fly ash light weight aggregate

- Initially taken required amount of sample for sieving.
- The sample is screened on a 20mm, 10mm IS sieves, to get 2 kg of 20mm, 10mm aggregates respectively.
- The aggregates are thoroughly washed to remove the fine particles of dust, drained, and then the aggregates are immersed in water jar and allowed to remain immersed at a temperature of 22 to 32° C for 24 hours.
- Soon after immersion and again at the end of soaking period air entrapped in or bubbles on the surface of the aggregates is removed by gentle agitation. This is achieved by rapid clock-wise and anti- clockwise rotation of vessel between the hands.
- The vessel is over filled by adding distilled water and a slid is placed on the top of the jar to ensure that no air is trapped in the vessel. The vessel is dried on the outside and weighed.
- The vessel is emptied and the aggregate is allowed to drain out. Again, refilled the vessel with distilled water, the top of the jar is covered with a slid, the vessel is dried and weighed.

- The aggregate is placed on a dry cloth, gently surface dried with the cloth.
- The aggregate is then spread out not more than one stone deep on a separate cloth, and left exposed to atmosphere away from sunlight or any other source of heat, until it appears to be completely surface dry.
- The aggregate is weighed. The aggregate is then placed in the oven in the circular tray, at a temperature of 100° C for 24 hours.
- It is then cooled in air tight container and weighed.

Description	20mm (g)
Weight of the sample	2000
Weight of the vessel containing sample and filled with water (A)	1997
Weight of vessel filled with water (B)	2344
Weight of saturated surface dry sample (C)	2001
Weight of oven-dry sample (D)	996
Specific gravity = D/ (A−B)	2.35
Water absorption = 100 x (B - C) / D	0.39

Table no-3.6.1 Specific gravity and water absorption of fly ash light weight aggregate

3.7 TESTS ON FRESH CONCRETE:

3.7.1 Slump cone test

- Clean the internal surface of the mould and apply oil.
- Place the mould on a smooth horizontal non- porous base plate.
- Fill the mould with the prepared concrete mix in 4 approximately equal layers.
- Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should

penetrate into the underlying layer.

- Remove the excess concrete and level the surface with a trowel.
- Clean away the mortar or water leaked out between the mould and the base plate.
- Raise the mould from the concrete immediately and slowly in vertical direction.
- Measure the slump as the difference between the height of the mould and that of height point of the specimen being test.

Fig: 3.7 Slump cone

Mix M30	Slump(mm)
Trial 1(0%)	80
Trail 2 (10%)	78
Trail 3 (20%)	83
Trail 4 (30%)	80
Trail 5 (40%)	79

Table -3.7.1 trails of slump cone

3.8 TESTS ON HARDENED CONCRETE

3.8.1 Compressive strength of concrete

Mixing

- Mix the cement and fine aggregate on a watertight none-absorbent platform until the mixture is thoroughly blended and is of uniform color.
- Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
- Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

Fig: 3.8.1 Materials

Fig: 3.8.2 Mixing of materials

Fig: 3.8.3 Preparation of Cubes

Sampling of Cubes for Test

- Clean the mounds and apply oil.
- Fill the concrete in the molds in layers approximately 5 cm thick.
- Compact each layer with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet-pointed at lower end).
- Level the top surface and smoothen it with a trowel.

Curing of Cubes

- The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the moulds and kept submerged in clear freshwater until taken out prior to the test.
- The compressive strength is determined using 200T compression testing machine in accordance with BIS (IS:516-1959). A typical arrangement for compression testing of cubesis presented in the figure below.
- The compressive strength test is conducted on 150mm×150mm×150mm cubes at 7, 28 daysadopting wet curing process (IS: 516-1959). Three cube specimens were tested for each curing period. A total of 6 cube specimens were tested for compressive strength for each grade of concrete. The rate of loading was maintained at 5N/mm^2/min throughout the test.
- Based on the abovementioned mix design, casting and curing process, in total 126 cubes were casted for trail mixes to obtain the specific target strengths for the respective grades of parent concrete and the final mix designs are tabulated below.

Fig:3.8.4 Compression testing machine

Fig: 3.8.5 cube in compression testing machine

Fig: 3.8.6 cube under compression

3.8.2 Split tensile strength

Preparation of Samples

The sample size is cylinder of diameter 15 cm and height of 30 cm. The mould used is metal with mean internal diameter of the mould is 15 cm ± 0.2 mm and the height is 30 +/- 0.1 cm. The mould should be coated with a thin film of mould oil before use to prevent adhesion of concrete.

Fig: 3.8.7 Cylinder sample

- Concrete is placed into the mould in layers of approximately 5 cm thickness. Each layer is compacted either by hand or by vibration. When compacting by hand, the tamping bar is utilized and the stroke of the bar shall be distributed in a uniform way.The number of strokes for each layer should not at least 30. The stroke should penetrate in to the underlying layer and the bottom layer should be rodded throughout its depth.
- After compacting the top layer, the surface of the concrete should be finished level with the top of the mould, using a trowel and covered with a glass or metal plate to prevent evaporation of water.
- Curing: The test specimen should be stored in a place at a temperature of 27° +/- 2°C for 24 hrs. After this period, specimens are removed from the moulds to be

submerged in clean fresh water for the specified period(such as 7 or 28 days).

Procedure of Splitting Tensile Test:

- After curing, wipe out water from the surface of specimen
- Using a marker, draw diametrical lines on the two ends of the specimen to verify thatthey are on the same axial place.
- Measure the dimensions of the specimen.
- Keep the plywood strip on the lower plate and place the specimen.
- Align the specimen so that the lines marked on the ends are vertical and centeredover the bottom plate.
- Place the other plywood strip above the specimen and bring down the upper plate to touch the plywood strip.
- Apply the load continuously without shock at a rate of approximately 14-21 kg/cm2/minute (Which corresponds to a total load of 9.9 ton/minute to 14.85 ton/minute)
- Write the breaking load (P)

Fig: 3.8.8 cylinder in compression machine

3.8.3 FLEXURAL STRENGTH

Sample Preparation of Concrete

- Determine proportions of materials including cement, sand, aggregate and water.
- Mix the materials using either by hand or using suitable mixing machine in batches with size of 10 percent greater than molding test specimen.
- Measure the slump of each concrete batch after blending.
- Place molds on horizontal surface and lubricate inside surface with proper lubricant material and excessive lubrication should be prevented.
- Pour fresh concrete into the molds in three layers.

Fig:3.8.10 Preparation of sample

- Compact each layer with 16mm rode and apply 25 strokes for each layer or fill the mold completely and compact concrete using vibration table.
- Remove excess concrete from the top of the mold and smoothen it without imposing pressure on it.
- Cover top of specimens in the molds and store them in a temperature room for 24 hours.
- Remove the molds and moist cure specimens at 23+/-2 ^{o} C till the time of testing.

- The age of the test is 14 days and 28 days and three specimens for each test shouldbe prepared (according to Indian Code, the specimen is stored in water at 24-30^{o}C for48hours and then tested)

Procedure of Flexural Test on Concrete

- The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength.
- Place the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points.
- Center the loading system in relation to the applied force.
- Bring the block applying force in contact with the specimen surface at the loading points.
- Applying loads between 2 to 6 percent of the computed ultimate load.
- Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 25 mm or more.
- Eliminate any gap greater than 0.10mm using leather shims (6.4mm thick and 25 to 50mm long) and it should extend the full width of the specimen.
- Capping or grinding should be considered to remove gaps in excess of 0.38mm.
- Load the specimen continuously without shock till the point of failure at a constant rate (Indian standard specified loading rate of 400 Kg/min for 150mm specimen and 180kg/min for 100mm specimen, stress increase rate 0.06+/-0.04N/mm^2.s according to British standard).

.

Fig :3.8.11 beam under point load

Fig :3.8.12 failure of beam

CHAPTER-4
MIX DESIGN

4.1 TARGET STRENGTH OF MIX PROPORTIONING

f'ck = f ck+1.65 S

or

f'ck = f ck + X

S.no	Grade of concrete	Value of X
1	M10-15	5.0
2	M 20-25	5.5
3	M 30-60	6.5
4	Above 65	8.0

Table no -4.1 value of X

S,no	Grade of concrete	Assumed standard deviation
1	M 10-15	3.5
2	M 20-25	4.0
3	M 30-60	5.0
4	M 65-80	6.0

Table no 4.2 standard deviation

Which ever is higher.Where,

f'ck = target average compressive strength at 28 days,

fck = characteristic compressive strength at 28 days,

S = standard deviation, and

X = factor based on grade of concrete.

From Table 4.2, standard deviation, S = 5 N/mm^2

From Table 4.1, X = 6.5.

Therefore, target strength using both equations, that is,

a) f'ck = fck+1.65 S =340+1.65 × 5 = 38.25 N/mm^2

b) f'ck = fck + 6.5 = 30 + 6.5 = 36.5 N/mm^2 The higher value is to be adopted.

Therefore, target strength will be 48.25 N/mm^2 as 48.25 N/mm^2 > 46.5 N/mm^2.

4.2 Approximate air content

From Table 3, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1.0 percent for 20 mm nominal maximum size of aggregate. SELECTION OF WATER-CEMENT RATIO From Fig. 1, the free water-cement ratio required for the target strength of 48.25 N/mm2 is 0.36 for OPC 43 grade curve. (For PPC, the strength corresponding to OPC 43 grade curve is assumed for the trial). This is lower than the maximum value of 0.45 prescribed for 'severe' exposure for reinforced concrete as per Table 5 of IS 456. 0.36< 0.45, hence O.K

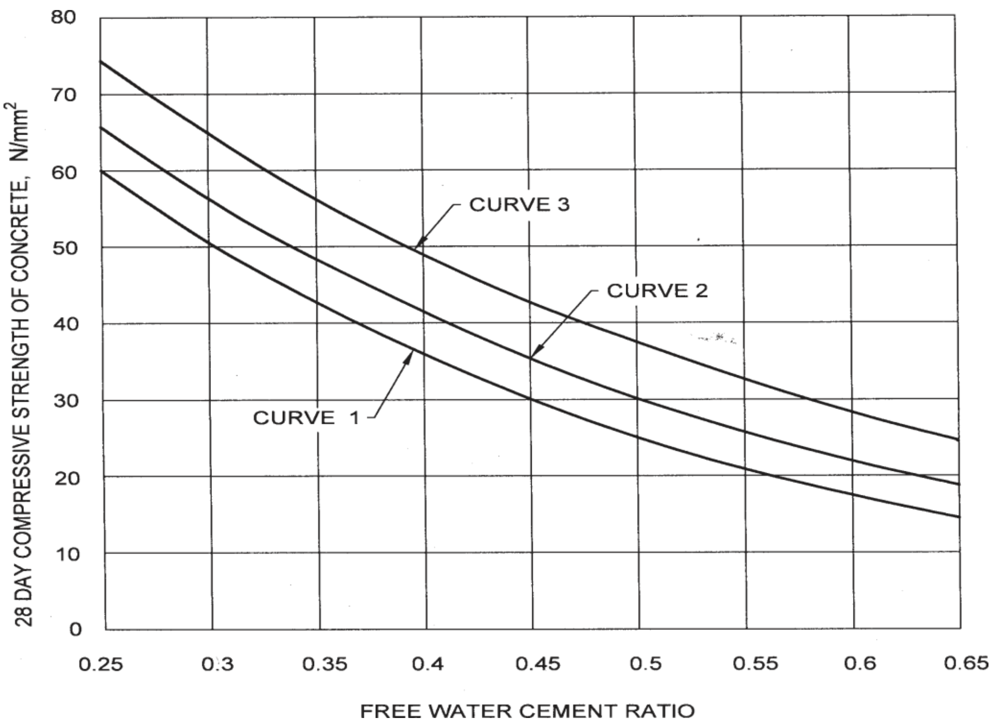
Si no	Nominal maximum size of aggregate	Entrapped air as percentage of volume of concrete
1	10	1.5
2	20	1.0
3	40	0.8

Table-4.3 Approximate air content

4.3 Selection of water cement ratio

From Fig. 1, the free water-cement ratio required for the target strength of 48.25 N/mm2 is 0.36 for OPC 43 grade curve. (For PPC, the strength corresponding to OPC 43 grade curve is assumed for the trial). This is lower than the maximum value of 0.45 prescribed for 'severe' exposure for reinforced concrete as per Table 5 of IS 456. 0.36< 0.45, hence O.K.

SELECTION OF WATER CONTENT From Table 4, water content = 186 kg (for 50 mm slump) for 20 mm aggregate. Estimated water content for 75 mm slump = 186 + 3 186 100 × = 191.58 kg As superplasticizer is used, the water content may be reduced. Based on trial data, the water content reduction of 23 percent is considered while using superplasticizer at the rate 1.0 percent by weight of cement. Hence the water content = 191.58 × 0.77 = 147.52 kg ≈ 148 kg



Graph:1 showing water cement ratio

4.4 Calculation of cement content

Water-cement ratio = 0.40

Cement content = 1157 / 0.40 = 394 kg/ m^3

From Table 5 of IS 456, minimum cement content for 'severe' exposure condition = 320 kg/m3 394 kg/m^3 > 320 kg/ m^3, hence, O.K.

Proportion of volume of coarse aggregate and fine aggregate content f, the proportionate volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 = 0.62. In the present case water-cement ratio is 0.36.

Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.14, the proportion of volume of coarse, aggregate is increased by 0.028, 0.01 for every ± 0.05 change in water cement ratio).

Therefore, corrected proportion of (at the rate of volume of coarse aggregate for the water-cement ratio of 0.36 = 0.62 + 0.028 = 0.648. Volume of fine aggregate content = 1 – 0.648 = 0.352.

4.5 Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

a) Total volume = 1 m^3

b) Volume of entrapped air in wet concrete = 0.01 m^3

c) Volume of cement = 470 / (3.15X1000)= 0.149 m^3

d) Volume of water = 197 / (1 X 1000)=0.197 m^3

Total weight of other materials except coarse aggregate = 0.149+0.197 = 0.346 m^3 Volume of coarse and fine aggregate = 1-0.549 = 0.451 m^3 (Assuming 57% by volume Of total aggregate)

Volume of F.A.= 0.654x 1561.8 =1021.417 m^3

Weight of F.A. = 469 kg/m^3

Volume of C.A. = 0.654x 1178.2=770.543 m^3

Weight of C.A.= 1178.542 kg/m^3

Water: Cement: F.A: C.A = 0.4:1:2:2.61

4.6 Proportions of trail number

1 Cement = 412 kg/ m^3

Water = 148 kg/m^3

Fine aggregate (SSD) = 648 kg/ m^3

Coarse aggregate (SSD) = 1234 kg/ m^3

Chemical admixture = 4.12 kg/ m^3

Free water-cement ratio = 0.40

4.7 CALCULATION OF MATERIALS

M30 design. (1: 2.00: 2.61)

4.7.1 Cubes

volume = 0:15 X0.15 X 6·15 = 0·00337 m^3

weight of cement = 0.00337X1.54 / 5.61 X 1440 X 1 = 1.33 kg

weight of FA = 0.00337X1.54 / 5.61 X 1600 X 2 = 2.96 kg

weight of CA = 0.00337X1.54 / 5.61 X 1800X2.16 = 4.34 kg

calculation for 9 cubes

S no	Proportion Percentage (%)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Fly ash waste light weight aggregate (kg)
1	10	11.97	26.64	39.06	0
2	20	11.97	26.64	35.154	3.906
3	30	11.97	26.64	31.248	7.812
4	40	11.97	26.64	27.342	11.718
5	50	11.97	26.64	23.436	15.624

Table no-4.7.1 mix design calculation for cubes

4.7.2 Beams

volume = 0.1X0·1X0·5 = 0.005 cubic meter

weight of Cement = 0·005X1.54 / 5.61 X1440 = 1.97 kg

weight of FA = 0·605X1.54 / 5.61 X1600 X 2 = 4.39 kg

weight of CA = 0.005×1.54 / 5.61 X1800 X 2.61= 6.44 kg

S no	Proportion Percentage (%)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Fly ash waste light weight aggregate (kg)
1	0	1.97	4.39	6.44	0
2	10	1.97	4.39	5.796	0.644
3	20	1.97	4.39	5.152	1.288
4	30	1.97	4.39	4.508	1.932
5	40	1.97	4.39	3.864	2.576

Table no-4.7.2 Mix design calculations for beams

4.7.3 Cylinders

vol = $A = \frac{\pi D^2}{4} X\ h$ = 22/7 x $(0.75)^2$ x 0.3 =0.0053m^3

weight of Cement = 0·0053x1.54 5.61X1440=2.09 kg

weight of FA = 0.0053× 1.54 / 5.61 X1600X2= 4.65 kg

weight of CA = 0.0053X 1.54 / 5.61 X 1800 x 2.61 = 6.83kg

calculations for 4 cylinders

S no	Proportion Percentage (%)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate(kg)	Fly ash waste light weight aggregate (kg)
1	0	8.36	18.6	27.32	0
2	10	8.36	18.6	24.588	2.732
3	20	8.36	18.6	21.856	5.464
4	30	8.36	18.6	19.124	8.196
5	40	8.36	18.6	16.392	10.928

Table no-4.7.3 Mix design calculations for cylinder

CHAPTER-5

RESULTS

COMPRESSIVE STRENGTH

Mix Proportion	Avg. Compressive load (KN)	Avg. Compressive strength (N/mm^2)
0%	455	20.22
10%	470	20.83
20%	485	21.63
30%	505	22.44
40%	482	21.43

Table no-5.1 Compressive strength for 7 days

Mix Proportion	Avg. Compressive load (KN)	Avg. Compressive strength (N/mm^2)
0%	611	27.18
10%	630	27.99
20%	660	29.35
30%	685	30.48
40%	650	28.81

Table no-5.2 Compressive strength for 14 days

Mix Proportion	Avg. Compressive load (KN)	Avg. Compressive strength (N/mm^2)
0%	675	30
10%	695	30.9
20%	720	32.1
30%	750	33.3
40%	710	31.8

Table no-5.3 Compressive strength for 28 days

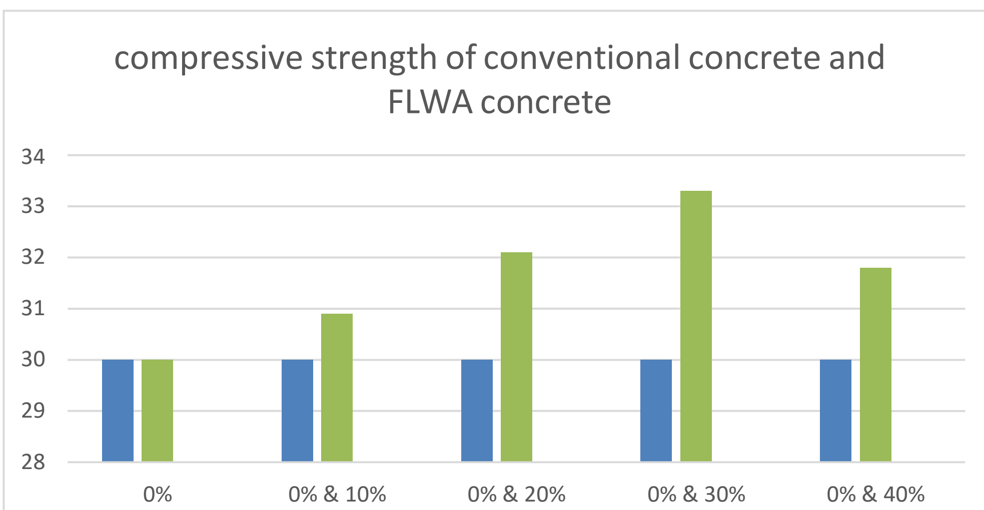


Fig 5.1 Graph comparison of compression strength between conventional concreteand FLWA concrete

SPLIT TENSILE STRENGTH

Mix Proportion	Avg. Compressive load (KN)	Avg. tensile strength (N/mm^2)
0%	105	1.52
10%	110	1.56
20%	115	1.62
30%	118	1.68
40%	112	1.59

Table no-5.4 Slit tensile strength for 7 days

Mix Proportion	Avg. Compressive load (KN)	Avg. tensile strength (N/mm^2)
0%	240	3.38
10%	250	3.51
20%	260	3.68
30%	280	3.92
40%	255	3.61

Table no-5.5 Split tensile strength for 28 days

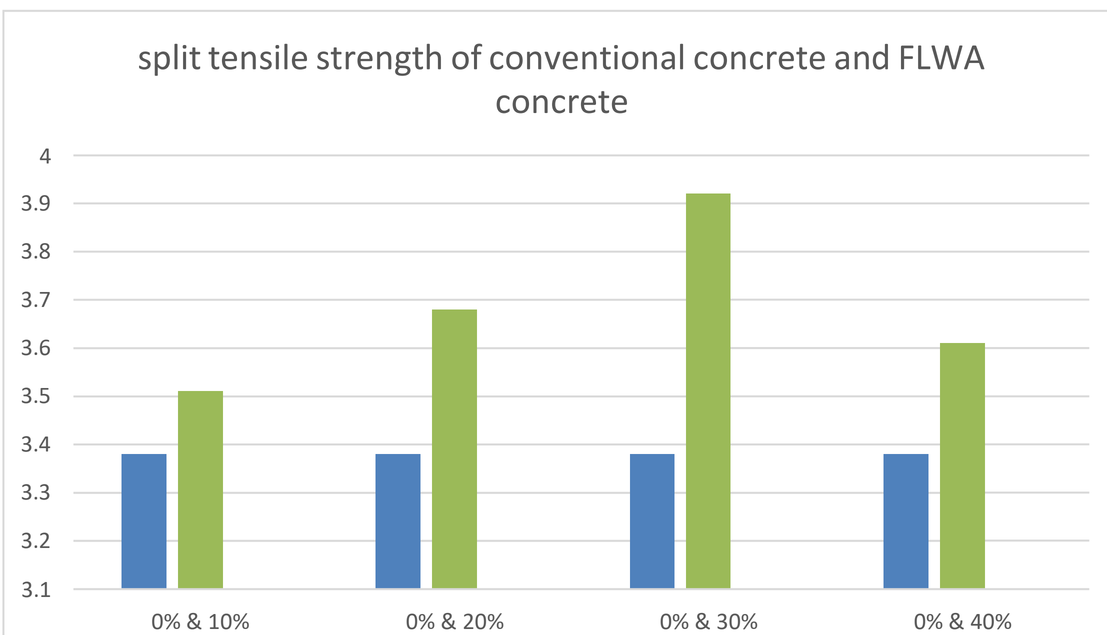


Fig 5.1.2 Graph comparison of tensile strength between conventional concrete

andFLWA concrete

FLEXURAL STRENGTH TEST

Mix Proportion	Avg. flexural strength (N/mm^2)
0%	4.12
10%	4.45
20%	4.80
30%	5.15
40%	5.06

Table no-5.6 Flexural tensile strength for 28 days

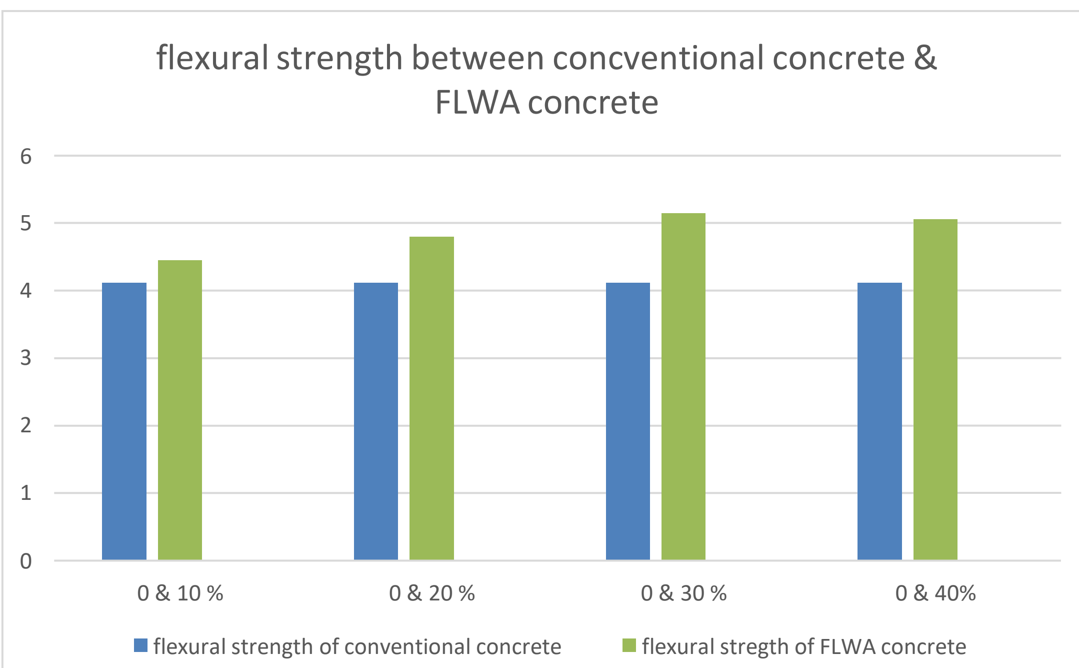


Fig 5.1.3 Graph comparison of flexural strength between conventional concrete and FLWA concrete

CONCLUSION

- As the Fly ash content increases there was increase as well as decrease in the strength of concrete.
- It was observed with replacement of 30% Fly ash concrete compressive strength was increased at 7,14 and 28-days period of curing.
- As percentage of fly ash waste lightweight aggregates increases workability also increases because the aggregate used is light in weight.
- It was observed that the compressive strength increased up to 30% replacement of the coarse aggregate with fly ash waste lightweight aggregates and it gradually decreased for 40%.
- The density of concrete decreased when lightweight aggregates are added. Because Lightweight concrete exhibited higher workability than the corresponding normal weight concrete mixtures.
- By using waste lightweight aggregates in concrete can reduce the environmental issues of wastage.
- This research concludes that aggregates made of Fly ash can be used as replacement up to a limited percentage.

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