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Use of Cement in Road Construction: A Review

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I. ABSTRACT AND INTRODUCTION

Urban planning, motor vehicles, or even wheel, first roads that were appeared on landscape thousands of years before. First roads were impulsively formed by humans walking common paths over & over to find water & food like molecules coalesced into cells & cells into more complicated organisms

The transportation of larger, heavier loads showed many limitations of dirt paths which turned into muddy bogs on the time of raining and followed introduction of wheel 7,000 years ago. The ancient stone paved roads was found about 4,000 B.C. in Indian subcontinent & Mesopotamia.

Recent road-construction techniques might be traced into a process developed by Scottish engineer John McAdam in early 19th century. McAdam excelled multi-layer roadbeds with soil & crushed stone that was then settled down with heavy rollers. Modern day asphalt roads are able to support vehicles that emerged in 20th century. It was built upon McAdams' methods with adding tar as a binder.

A. Role Of Concrete In Road Construction

The role of cement & concrete in transportations & especially in road construction is important. Bridges, concrete roads tunnels, safety barriers, & sound barriers are several examples of successful cement application. The use of cement in above mentioned applications elongates the service life of structure together with small maintenance cost.

B. Pavements

A Highway pavement is powerful outside material which is laid down on pasture with intention of sustained vehicular or base traffic, like a road or path in past, gravel road surfaces, cobblestone & granite sets were importantly used, but these surfaces have been replaced by asphalt or concrete due to compacted base course. Road surface are often marked to lead traffic. Present permeable paving method is beginning to be used for low down -impact roadways & walkways.

C. Material Used In Pavements System

1) *Concrete:* Concrete is made of three basic components: water, aggregate & Portland cement. Cement which is usually in powder form, acts as a binding agent when it is mixed with water & aggregates.

There are three basic ingredients in concrete mix:

a) *Portland Cement:* The cement & water makes a paste which coats aggregate & sand in mix. The paste hardens & binds aggregates & sand.
b) *Water:* Water is essential for reacting chemically with cement & also provides workability with concrete. The amount of water mix in pounds compared with amount of cement is called water/cement ratio. The lesser will be the water cement ratio leads to stronger concrete.
c) *Aggregates:* Sand is a fine aggregate. Gravel or crushed stone is used as a coarse aggregate in most mixes.

2) *Bottom Ash:* Bottom ash is part of non-combustible residue of combustion in a furnace or incinerator. In an industrial context, it usually refers to coal combustion & comprises traces of combustibles embedded in forming clinkers & sticking to hot side walls of a coal-burning furnace during its operation. The portion of ash that escapes up chimney or stack is, however, referred to as fly ash. The clinkers fall themselves into bottom hopper of a coal-burning furnace & cooled down.

Fig 1.5 Bottom ash

3) *Fly Ash:* Fly ash is finaly a divided residue arises from combustion of powdered coal & transported by flue gases & collected by electrostatic precipitator. ASTM broadly classify fly ash into two classes Class F: Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only. Class C: Fly ash normally produced by burning lignite or sub bituminous coal. Some class C fly ash may have CaO content in excess of 10%. In addition to pozzolanic properties, class C fly ash also contains cementious properties for improving engineering properties like strength, workability, plasticity, water absorption tightness.

D. Objective Of Research

1) To evaluate properties of fly ash & bottom ash mixtures.
2) To identify workability & durability of Highway pavement.
3) To investigate optimal use of bottom ash & fly ash for pavement.
4) To check compressive strength by replacing aggregate with bottom ash & fly ash at different percentage i.e. 0%, 5%, 10%, 15%, 20%.
5) To check suitability of reuse of bottom ash & fly ash in a useful manner.
6) To minimize overall environmental effects of production using these materials as partial replacement.
7) To perform Following tests

a) Water Absorption of Bottom ash/ fly ash
b) Abrasion Test of Bottom ash / Fly ash
c) Impact Test Bottom ash / Fly ash
d) Crushing strength Test Bottom ash / Fly ash
e) Soundness test of Bottom ash / Fly ash
f) Compressive strength after using Bottom ash /fly ash

II. LITERATURE REVIEW

With view to carry out this study in a successful way, literature/reports from national & international journals have been referred to understand present status, identify gap areas & emerging issues to make this study more fruitful. Much research has already been undertaken by research scholars Doughnut world. Abstract of most of related & latest literatures are summarized here. Hence an attempt is made to review literature to know latest development in this study area.

A. Literature Survey

Li Yijin, Zhou Shiqiong(2002) “The effect of fly ash on the fluidity of Cement paste, mortar, and concrete”, International Workshop on Sustainable Development and Concrete Technology[1]

The addition of ultra-fine fly ash to cement paste, mortar and concrete can improve their fluidity, but some coarse fly ash can’t reduce water. This paper investigates the effect of fineness and replacement levels of fly ash on the fluidity of cement paste, mortar, and concrete. The fly ash is collected by electro-static precipitators and airflow classing technology. Three different finenesses were chosen, and their replacement levels were 20%, 30%, and 40%, respectively. The experiment results show that particle size distribution, Zeta potential, density and particle morphologies of fly ash are the major factors affecting their fluidity.

Syed Afzal Basha, P.Pavithra, B.Sudharshan Reddy “Compressive Strength of Fly Ash Based Cement Concrete” [2014][12]

In this paper an attempt is made for assessment of compressive strength of Fly ash based cement concrete. Concrete mixes M25, M30, are designed as per the Indian standard code (IS-10262-82) by adding, 0%, 10%, 20%, 30% and 40% of fly ash. Concrete cubes of size 150mm X 150mm X 150 mm are casted and tested for compressive strength at 7 days, 14 days, 21 days and 28 days curing for all mixes and the results are compared with that of conventional concrete.

The compressive strength of all mixes is tabulated. Concrete is a vital ingredient in infrastructure development with its versatile and extensive applications. It is the most widely used construction material because of its mouldability into any required structural form and shape due to its fluid behavior at early ages. However, there is a limit to the fluid behavior of normal fresh concrete. Thorough compaction, using vibration, is normally essential for achieving workability, the required strength and durability of concrete. Inadequate compaction of concrete results in large number of voids, affecting performance and long-term durability of structures. Since due to the vast construction in the urban development programs there is a high demand of concrete in bulk and for achieving the requirement of concrete in bulk, fly ash is being used as a mineral admixture in concrete.

S. Sivakumar1 and B. Kameshwari (2014) “Influence of Fly Ash, Bottom Ash, and Light Expanded Clay Aggregate on Concrete”,[14]

The paper attains the highest possible strength for LECA concrete while noting the advanced technology in producing light weight concrete. The results show that 5% replacement of cement with fly ash, fine aggregate with bottom ash, and coarse aggregate with light expanded clay aggregate (LECA) was found to be good performance in compressive strength, split tensile strength, and flexural strength of beamin 56 days when compared with 28 days strength. At the same time 28 days strength also approximately equals normal conventional concrete; that is, 0% replacement and dry weight of specimen have been reduced. In future, soft computing techniques will lead with core areas us to attain better performance in short interval of time as the time is the major factor involved in this research work.

A. Sumathi*1, K. Saravana Raja Mohan (2015) “ Compressive Strength of Fly Ash Brick with Addition of Lime, Gypsum and Quarry Dust”, International Journal of ChemTech Research, Vol.7, No.01, pp 28-36,[13]

Based on the experimental study, following conclusions can be drawn regarding the strength behavior of flyash brick; The study was conducted to find the optimum mix percentage of flyash brick. However the brick specimen of size 230mm x 110mm x 90mm were cast for different mix percentage of Flyash (15 to 50%), Gypsum (2%), Lime (5 to 30%) and Quarry dust (45 to 55%). However the specimens have been tested for seven mix proportions. The mechanical properties such as compressive strength were studied for different mix proportions, at different curing ages. From the results it was inferred that, among the seven proportions the maximum optimized compressive strength is obtained for optimal mix percentage of Flyash-15% Lime-30% Gypsum-2% Quarry dust-53% as 7.91 N/mm².

Vikas R Nadig, Sanjith J , Ranjith A (2015) “Bottom Ash as Partial Sand Replacement in Concrete- A Review”,[15]

This study reviews the characteristics of Concrete incorporated with Bottom Ash as partial replacement for fine aggregates, with a main focus on the mechanical properties such as Compressive strength, splitting tensile strength, flexural strength etc. Ten different research papers are reviewed. The practical use of Bottom ash shows a great contribution to waste minimization as well as resources conservation.

K. SathyaPrabha1, J. Rajasekar (2015) “Experimental Study on Properties of Concrete Using Bottom Ash with Addition of Polypropylene Fibre”,[16]

Bottom ash is a hazardous by-product from coal based thermal power plants. In this study fine aggregate in concrete mix has been replaced with bottom ash and Polypropylene fibre is additionally used to enhance the strength characteristics of concrete. The concrete mix design is done for M25 grade concrete. The mix is prepared for different combinations of 0%, 10%, 20% and 30% of replacement of sand by bottom ash with 0.5% of polypropylene fibre by total weight of the Cube. The mechanical properties were compared with control mix and it was found that the optimal combination as 30% bottom ash and 1.0% polypropylene fibre. Flexural strength was compared by testing beams of size 1.5 x 0.25 x 0.15m under two point loading. Results showed that there was no degradation of strength for beams with bottom ash as replacement for fine aggregates.

Mamta Mishra (2016) “Use of Industrial Waste Materials in Road Construction”[17]

The proposed has developed of Industrial Waste Materials in Road Construction. There are many types of waste material found in India like industrial, building, household, agricultural etc. it includes coal ash, stone quarry, plastics, glass, recycled aggregate, geo-naturals, fibers & polythene bags etc. One of best solutions to use waste material to improve strength of sub grade soils is by using any one or composite material of lime, fly ash, coir fiber etc. In this paper we describe use of industrial waste material in road construction.

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A waste material is not good for society & environments then produce minimum waste produce society. A maximum use of waste materials may be applied to businesses, communities, industrial sectors, schools, homes & road constructions. Also utilization of waste materials like solid waste, hazardous waste would protect environment & lead to a much more productive, efficient, & sustainable future. Objective of road constructions & others structure is to contain waste material in a manner that is protective to human health & environment. On basis of above discussion we also observed that Blast furnace slag could be used in soil stabilization due to its hardening property when exposed to moisture, Blast furnace slag provides a great potential for profitable use of this waste material & produces alternate binder to cement, Coal fly ash Light weight, could be used as binder in base course in stabilization to pozzolanic property, Fly ash is an effective agent for chemical and/or mechanical stabilization of soils & Recycling & reuse of waste materials are found to be an appropriate solution to problems of dumping hundreds of thousand tons of waste on natural soil, which would result in consumptions natural materials required for all construction activities.

Sabelo N.F Zulu(2017) "optimizing the usage of fly ash in concrete mixes"[22]

After evaluating the performance of FA concrete, by performing various tests on fresh and hardened concrete of different grades and varying levels of FA content, it was noted that FA affects the properties and characteristics of concrete.

The results from the slump tests for the 35 MPa FA mixes showed that the mixes with higher FA content had higher slump than the control, 30% FA, mix. The 40% and the 50% mixes attained equal slumps of 85 mm, compared to the 70 mm achieved by the 30% FA mix. This proves that the addition of FA does improve the workability and consistency of the concrete mixes. This would be due to the spherical shape of FA particles, which creates a ball-bearing effect thus making the concrete more workable. Concrete with high FA volume can be beneficial for pump mixes as the desired slumps can be achieved with lesser water and plasticizers.

Shivasheesh Kaushik, Nimisha Raj (2017) "Optimization of Compressive Strength for Fly Ash Building Bricks Using Taguchi Method", [19]

In our present research paper we are investigating to determine the optimum mixture percentage of fly ash building bricks for varying material composition with three different particle sizes of fly ash and coarse aggregate dust i.e. 425 micron, 600micron, and 825micron, which prepared at three different curing time under solar radiation i.e. 7 Days, 14 Days, and 21 Days, so that we achieve the optimum mixture percentage for fly ash building bricks of high compressive strength, which we will further use for the different applications also.

Saurabh Kajal1, Er. Vedpal (2017) "Strength performance of concrete Using bottom ash as fine aggregate", [21]

The challenge for civil engineers in the future is to design the project using high performance materials within reasonable cost and lower impact on environment. Large quantities of waste materials are produced from the manufacturing industry, service industry and municipal solid waste incinerators. The sense of using waste materials not only helps in getting them utilized in cement, concrete, and other construction materials, it helps in reducing the cost of cement and concrete manufacturing, but also has numerous indirect benefits such as reduction in land-fill cost, saving in energy, and protecting the environment from possible pollution effects. Coal is primarily used as a solid fuel to produce electricity and heat through combustion. It is one of the world's most important sources of energy, fuelling almost 41% of electricity worldwide. In India, over 70% of electricity generated is by combustion of fossil fuels, out of which nearly 61% is produced by coal-fired plants.

III. MATERIALS AND METHODOLOGY

A. Material Used

Bottom Ash, Fly ash is a variable material. It is not practical to expect that characteristics of a concrete pavement mix could be identically replicated on a consistent basis. One of main reasons for variability in concrete pavement is because of variability in materials used to make concrete pavement

1) Cement
2) Bottom Ash
3) Fly Ash
4) Water

B. Chosen Tests

Each mix underwent a series of tests. These tests were chosen to assess individual characteristic of aggregates as well as strength testing, baby & durability indicators of Pavement A complete list of tests is given below

1) Strength Test
2) Particle Size Distribution

3) Specific Gravity
4) Water Absorption
5) Abrasion Resistance Test
6) Impact Value Test
7) Soundness Test
8) Workability Test
9) Compressive Strength

C. Mix Design Methodology

1) *Mix Design:* Pavement is an extremely versatile road material because; it could be designed for strength is ranging from M25 & workability ranging from 0 mm slump to 160mm slump. In all these cases basic ingredients of Pavement are same, but it is their relative proportioning that makes difference.
2) *Basic Ingredients of Pavement*
a) *Cement:* It is basic road material in Pavement
b) *Fly Ash:* It is basic road component of Pavement
c) *Bottom Ash:* Along with cement paste it forms mortar grout.
d) *Water:* Water from such sources should be avoided since quality of water could change due to low water or by intermittent tap water is used for casting.
3) *Properties Desired From Pavement In Plastic Stage*
a) Workability
b) Cohesiveness
c) Initial set retardation
4) *Mix Design Of Concrete Pavement For Present Research:* To ensure repeatability of concrete pavement detailed steps on mix design procedure have been included. The mix design was based on method concrete pavement mix proportioning – guidelines (10262:2009). For using this method, certain data is necessary, water absorption rates of bottom ash & percentage passes 600 micron sieve. The mix design based on this method has following stages:
a) Target mean strength for mix proportioning
b) Selection of water cement ratio
c) Selection of water content
d) Calculation of cementation material content
e) Estimation of Fly Ash proportion
f) Combination of different Fly Ash fraction
g) Estimation of Bottom Ash proportion
h) Combination of Different Bottom Ash fraction

D. Test Procedures And Methodology

This testing was done according to applicable Indian Standards. Due to equipment, resources & other restrictions, Indian Standards could not be followed. There are also several tests that are not represented by an Indian Standard. This chapter presents, in detail, procedures for each test to ensure repeatability

1) *Particle Size Distribution:* In this project Particle size distributions were carried out for all fine & Fly ash in accordance with IS 383-1970 with Specification for Coarse & Bottom Ash from Natural Sources for Pavement. This section has methodology for conducting a sieve analysis.
2) *Procedure for Bottom Ash Sieving:* For sieve analysis about 2 kg of oven dried Bottom Ash is required. Eight sieves of 20 cm in diameter were stacked in order, from largest to smallest with smallest sitting on bottom. The sieves aperture sizes used were 4.75mm, 2.36 mm, 1.18mm, 600 µm, 300 µm, 150 µm. The sand sample was then kept in top sieve & it is shaked by hand until less than 1% of particles left on each sieve were able to fall. Then sand left on sieves having extra material o must be divided into smaller allowable portions & re-sieved by hands.

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Fig 3.1 Sieve analysis of bottom Ash
(B.K. Satish & Ganesh 2014)

Then the volume retained on each sieve was measured & shown as a percentage of total samples. The total percentage was then compared with grading requirements given in IS 383-1970, Specification for Coarse & Bottom Ash from Natural Sources for Pavement.

3) *Procedure for Fly Ash Sieving:* The procedure for Fly Ash sieving is same as for Bottom Ash. There is only one exception that it is done on a larger scale. The measures of the sieves used for Fly Ash sieving are 30 cm in diameter & sieve aperture sizes used are 40mm, 20mm, 10mm, 4.75 mm .The pan are shown in (Figure 3.4). A bigger mechanical shaker was operated for 10-15minutes, a little longer than for Bottom Ash sieving; and same methodology is followed as for Bottom Ash sieving.

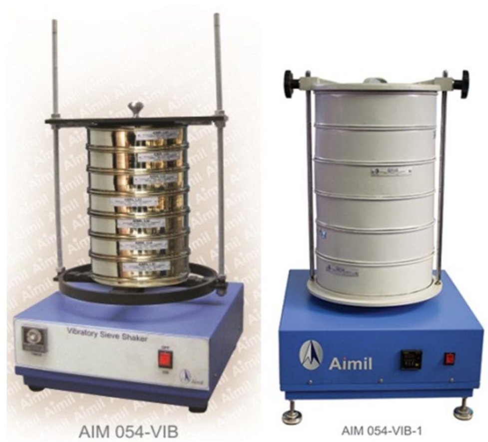

Fig 3.2 Sieve analysis of Fly Ash
(encrypted-tbn0.gstatic.com/images)

4) *Gravity*

a) *Specific gravity of Bottom Ash:* These types of tests have been made in order to find specific gravity**.** Determined & recorded weight of empty clean & dry pycnometer is W_1. One third of a Bottom ash sample has been placed in pycnometer. Determine & record weight of pycnometer containing bottom ash, W_2. Then distilled water is added to fill about full of pycnometer. After that sample has been soaked for ten minutes & partial vacuum has been applied to contents for ten minutes, in order to remove entrapped air. Vacuum has been stopped after that. CA vacuum line has been removed from pycnometer.

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Fig 3.3 Specific gravity of Bottom Ash pycnometer

Pycnometer would be filled with distilled water and clean the exterior surface of pycnometer with a dry and clean cloth. Weight of pycnometer & contents that is W3 would be determined. Make the pycnometer empty to clean it. It would be filled with distilled water to mark. Clean exterior surface of pycnometer would be cleaned with dry and clean cloth. Weight of pycnometer & distilled water, W4 would be determined. Empty the pycnometer & clean it. This test is conduct under specification of IS: 2720 (part IV) – 1985.

Where
W1= Weight of empty clean & dry pycnometer
W2= Weight of pycnometer containing dry soil
W3= Weight of pycnometer, soil & water
W4= Weight of pycnometer & distilled water

Formula used in specific gravity = $\frac{W2 - W1}{(W2 - W1) - (W3 - W4)}$

b) *Specific Gravity Of Fly Ash:* Such types of tests have been made in order to find specific gravity of fly ash**.** Determined & recorded weight of empty clean & dry pycnometer is W_1. One third of a fly ash soil sample has been placed in pycnometer. Determine & record weight of pycnometer containing fly ash , W_2. Then distilled water is added to fill about full of pycnometer. After that sample has been soaked for ten minutes & partial vacuum has been applied to contents for ten minutes, in order to remove entrapped air. Vacuum has been stopped after that. CA vacuum line has been removed from pycnometer.
c) *Specific Gravity and Water Absorption Of Coarse Aggregate:* The test is significant to determine the porosity of road aggregates. It is indirect measure to check strength and stones quality. Road stones that are absorbing more water have been considered unsuitable in case of road making. Water absorption has been expressed as percent water absorbed by aggregate in terms of oven dried weight of aggregate.

Fig 3.4 Specific gravity of Fly Ash pycnometer

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d) *Procedure:* Sample of approximately 2000 gram of the aggregate would be washed in order to remove dust and finer particles, drained and then located in wire basket and immersed in distilled water at a temperature between 22°C to32°C with a cover of at least 5 centimeter of water above top of basket. Immediately after immersion entrapped air would be removed from sample by lifting basket containing it 25 mm above base of tank and allowing it to drop 25 times at rate of about one drop per second. Basket and aggregate would stay completely immersed at the time of operation and for a period of 24 ± l/2 hours afterwards. The basket and the sample shall then be jolted and weighed in water at a temperature of 22°C to32°C (weight A_1). The basket and the aggregate would be removed from water and allowed to drain for a few minutes, after which the aggregate would be emptied from basket on to one of dry clothes, and empty basket would be returned to water and weighed in water (weight A_2). Aggregate placed on dry cloth would be surface dried with help of cloth, transferring it to second dry cloth when first would eliminate no further moisture. Aggregate would then be weighed (weight B). Aggregate would be placed in oven in shallow tray, at a temperature of hundred to hundred and ten °C and maintained at this temperature for 24 ± l/2 hours. It will be removed from oven, cooled in airtight container and weighed (weight C). Such test is performed under the specification of IS: 2386 (part V) – 1963.

e) *Calculations:* Specific gravity and water & absorption shall be calculated as

Specific gravity = $\frac{C}{A-B}$

Water absorption = $\frac{100\,(B-C)}{C}$

A = Weight of saturated aggregate in water = (A_1-A_2)
B = Weight of saturated surface dry aggregate in air.
C = Weight of oven dried aggregate in air.

Fig 3.5 Wire Bucket Method

5) *Hardened Concrete Tests*

a) *Compressive Strength Test (IS: 516 – 1959):* This test is conducted on cube specimens (150mm x 150mm x 150mm) for determining compressive strength at various ages:-

Apparatus

i) Testing Machine: A reliable type testing machine should be used or it should have sufficient capacity for tests & should be capable of applying load at specified rate. Only ± 2% of Maximum load error is permissible The testing machine will be equipped with two steel bearing platens which have hardened faces. A platen would be fitted with a ball seating in form of a portion of a sphere, its centre coincides with central point of face of platen. other compression platen would be plain rigid bearing block. The bearing faces of both of the platens should be as large at least & larger than nominal size of specimen to which load is applied. Age at Test Tests would be made at recognized ages of specimens, usually being 7 & 28 days. A test at an age of 56 days may also be performed. if tests are required at greater ages, then ages of 13 weeks & one year are done. If it is necessary to obtain early strengths, tests should be done at ages of 24 hours ± ½ hour & 72 hours ± 2 hours. Ages are calculated on the basis of time of addition of water to dry ingredients.

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Fig 3.6 Compression Testing Machine

ii) *Number of Specimens:* At each selected age, at least three specimens should be taken for testing which are from different batches.

iii) *Procedure:* Specimens stored in water would be tested immediately after removing from water & still in wet condition. Surface water & grit would be wiped off of specimens & any projecting fins removed. After drying specimens shall be kept in water for 24 hours before they are taken for testing. Specimens dimensions should be nearest 0.2mm & their weight should be noted before testing.

iv) *Calculation:* The compressive strength of specimen which was measured earlier would be calculated by dividing maximum load applied to specimen by cross-sectional area calculated from mean dimension during test. As representative of batch provided individual average of three values shall be taken and variation is not more than ±15 percent of average.

v) *Report:* On each test specimen following information shall be included in report:-

a. Date of test ,identification mark, & age of specimen.

b. Curing conditions, including date of manufacture of specimen in field.

c. Weight and dimensions of specimen, cross-sectional area, maximum load, compressive strength, & appearance of fractured faces of concrete & type of fracture, if these are unusual.

Fig. 3.7 Compression Testing

b) *Flexure Strength Test (IS: 9399-1979):* This test is performed on beam specimen (100mm x 100mm x 500mm) to measure its flexure strength at various ages.

Apparatus:

i) Testing machine: The testing machine may be of any dependable type of sufficient capacity for tests .it is capable of applying load at specified rate. Permissible errors should not be more than ± 0.5 % of applied load because it requuires a high degree of accuracy. It should not be greater than ±1.5% of applied load for commercial type of use. The bed of testing machine is provided with two steel rollers which are 38 mm in diameter, for which specimen is to be supported, & these rollers would be so mounted that distance from centre to centre is 60 cm for 15 cm specimens or 40 cm for 10cm specimens. The load would be applied through two similar roller, placed at third points of supporting span, that is, spaced at 20 or 13·3 cm centre to centre. This load would be divided equally between two loading rollers, & all rollers would be placed in such a way that load is applied axially & without giving the specimen any torsional stresses or restraints.

ii) Procedure: Before testing, test specimens are stored in water at a temperature of 24º to 30ºC for 48 hours If the specimen are still in a wet condition, it would be tested immediately on removal from water. The dimensions of each specimen would be noted before testing of surfaces, no preparation is required.

Fig 3.8 Flexural Testing Machine

c) *Placing The Specimen In Testing Machine:* The bearing surfaces of supporting & loading rollers will be wiped off to clean. If there is any loose sand or other material, it is removed from specimen surfaces for contacting with rollers. Then specimen would be so placed in machine to apply the load to uppermost surface. Casted in mould, along two lines spaced 20 or 13·3 cm apart. The specimen axis would be aligned with loading device axis. No packing shall be used between bearing surfaces of specimen & rollers, load would be applied without shock & increased continuously at such a rate that extreme fibre stress increases at approximately 7kg/cm^2/min, that is, at a rate of loading of 400 kg/min for 15·0 cm specimens & at a rate of 180 kg/min for 10·0 cm specimens, load would be in increasing process until specimen fails, & it is re corded what is the maximum load applied to specimen during test. The appearance of fractured faces of concrete & any unusual features in type of failure would be noted.

i) *Calculation:* The calculation of equivalent cube strength of specimen would be calculated by dividing maximum load by area of contact of bearing plates.

ii) *Report:* On each specimen following information shall be included in report:-

a) Date of test, Identification mark, age of specimen & curing conditions.

b) Also span length, maximum load, size of specimen, position of fracture, modulus of rupture & appearance of concrete & type of fracture in case of their unusuality.

Fig. 3.9 Flexural Testing

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d) *Testing For Concrete Workability (Slump Test):* The workability of concrete could be measured by using various methods like Vebe test, Compaction factor test, Ball-penetration test & Slump test. In this study the slump test was performed to determine workability of concrete mixes. It determines consistency of freshly mixed concrete in accordance with ASTM C 143/C 143M-15a (2015) & SANS 5862-1:2006 (2006) specifications.

Fig 3.10 Testing for concrete workability

The procedure for slump test is as follows

i) Wet slump test mould & it has to be placed on a flat, moist, non absorbent, rigid surface, like a steel plate.
ii) Fill mould to ⅓ full by volume & rod bottom layer with 25 evenly spaced strokes.
iii) Fill mould to ⅔ full & rod second layer with 25 strokes penetrating top of bottom layer.
iv) Heap concrete on top of mould, & rod top layer with 25 strokes penetrating top of second layer.
v) Strike off top surface of concrete even to top of mould.
vi) Remove mould in vertical direction .
vii) Immediately invert & place mould beside slumped concrete & place rod horizontally across mould, & measure slump, in mm, to nearest 5 mm.

The slump test should take approximately 2,5 min.

Fig 3.11 Slump Test Procedure

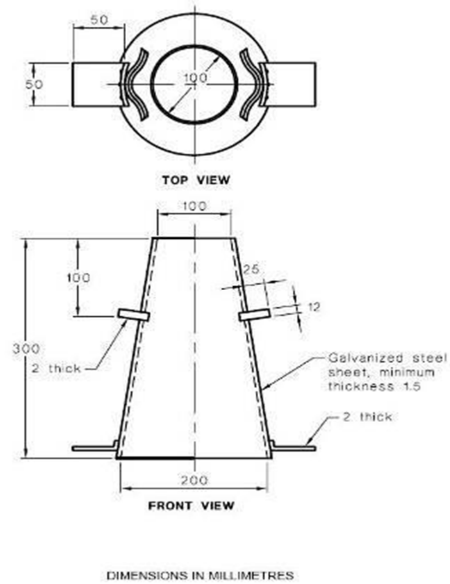

Fig 3.12 Model of Slump Test Device

E. Preparation of Material

Saturated surface dry (SSD) condition:

The most important aspect of casting concrete was to ensure that aggregates should be in suitable moisture condition named as saturated surface-dry (SSD). Its reason is that if aggregate is too wet it will add free water to mix, increasing free-water / cement ratio for mix and it would result in a reduced strength. The aggregate will absorb free-water in mix, If it is too dry .It resultes in a reduced free-water / cement ratio for mix and reduces workability. The SSD condition will be in a state when the aggregate will not give off any water & will not absorb any water. In this state the internal pores of aggregate are full of water but surface of aggregate is dry.

1) *Coarse Aggregate Preparation:* For bringing coarse aggregate to SSD condition aggregate is soaked for 24 hours & then it is allowed to air dry to SSD condition An alternative approach was taken due to difficulties in bringing aggregate to SSD condition in winter season. The amount of aggregate which is more than the required, was placed in a sealed container. A sample of approximately 1 kg was taken from sealed container for 24 hours prior to casting, accurately weighed & placed in an oven at105°C for 24 hours. Then again the sample is weighed & water content of aggregate is determined as a percentage. This value is subtracted from percentage of water contained in aggregate in SSD condition, which determines needed percentage of water that should be added aggregate in order for making it in SSD condition. The percentage was converted into a quantity for amount of aggregate to be used in batch & this was added or subtracted from free-water content of batch.

a) *Fine Aggregate Preparation:* The similar method is used for bringing fine aggregate to SSD condition as for coarse aggregate except that all of fine aggregate was dried & after this water was added to free-water content of mix. The oven is set at 105°C for at least 72 hours and the fine aggregate was completely dried. The ovens used for drying. Coarse aggregate water was added to free-water content of batch.

b) *Weighing Of Material:* Another critical element in casting of a batch of concrete is measuring out of materials. A weight batcher is used in this work, before starting work ,its level & calibration should be checked daily. The checking can be done by preparing sand bags of 25Kg & 5 Kg.

3.13 Weighting material

2) *Preparation of Concrete:* A 100 liters capacity tilting drum was used to mix mate rials. The mixing procedure was carried out as described in SP 23-1982 Hand Book on Concrete Mixes. Prior to first batch of each mix pan was moistened so that free-water was not lost to pan. The mixer was also thoroughly cleaned out between mixes.

All loading of mixer was done by hand & it will follow the following sequence:

a) All coarse aggregate was loaded and it will follow by fine aggregate;
b) The aggregates are mixed for a short period of time;
c) Then the cement is added ;
d) After this the cement is mixed in with aggregate;
e) Water is added while mixing for a period of 1-2 minute period;
f) The batch was then mixed for approximately 2 minutes, to thoroughly combine everything;
g) A slump measurement was taken in accordance with SP 23-1982 Hand Book on Concrete Mixes.

The concrete from slump test again added to mix & concrete was mixed for 2 minutes.

For concrete mixes, with exception of commercial mix, slump readings were in targeted range of 80-120 mm so there is no need of adjustments to water content.

3) *Casting & Compaction of Concrete Samples:* After mixing, concrete mix is casted into cube moulds of 15×15×15 cm for compressive strength. The cube is coated with a thin layer of a water-based release agent from inside to facilitate demoulding of samples after curing. The compaction of fresh concrete was carried out by using sixty hits per layer with a rod. Fresh concrete was placed in three layers in each cube & cylinder. Each layer was compacted by tamping rod for compaction. To prevent the loss of moisture, the moulds are covered in plastic sheets. The covered moulds are then transferred to curing room for 24 hours which was preset before start of curing at elevated temperatures.

Fig 3.14 Ingredient mixing

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4) *Demoulding & Curing Details:* The time of demoulding was set between 18 to 24 hours from mixing. To prevent damage of specimen proper care was taken. Once samples had been demoulded they were placed in curing tanks filled with water. Curing means keeping concrete moist & warms enough so that hydration of cement could continue. The demand of Curing is increasing as demand for high quality concrete is increasing. In early period of hydration, if curing is neglected then quality of concrete will experience a sort of irreparable loss. Curing methods can be divided into four categories. They are water curing, membrane curing, application of heat & miscellaneous. Water curing was used like immersion. High temperature curing was started on day after casting. Moulds were taken to curing room & placed for curing.

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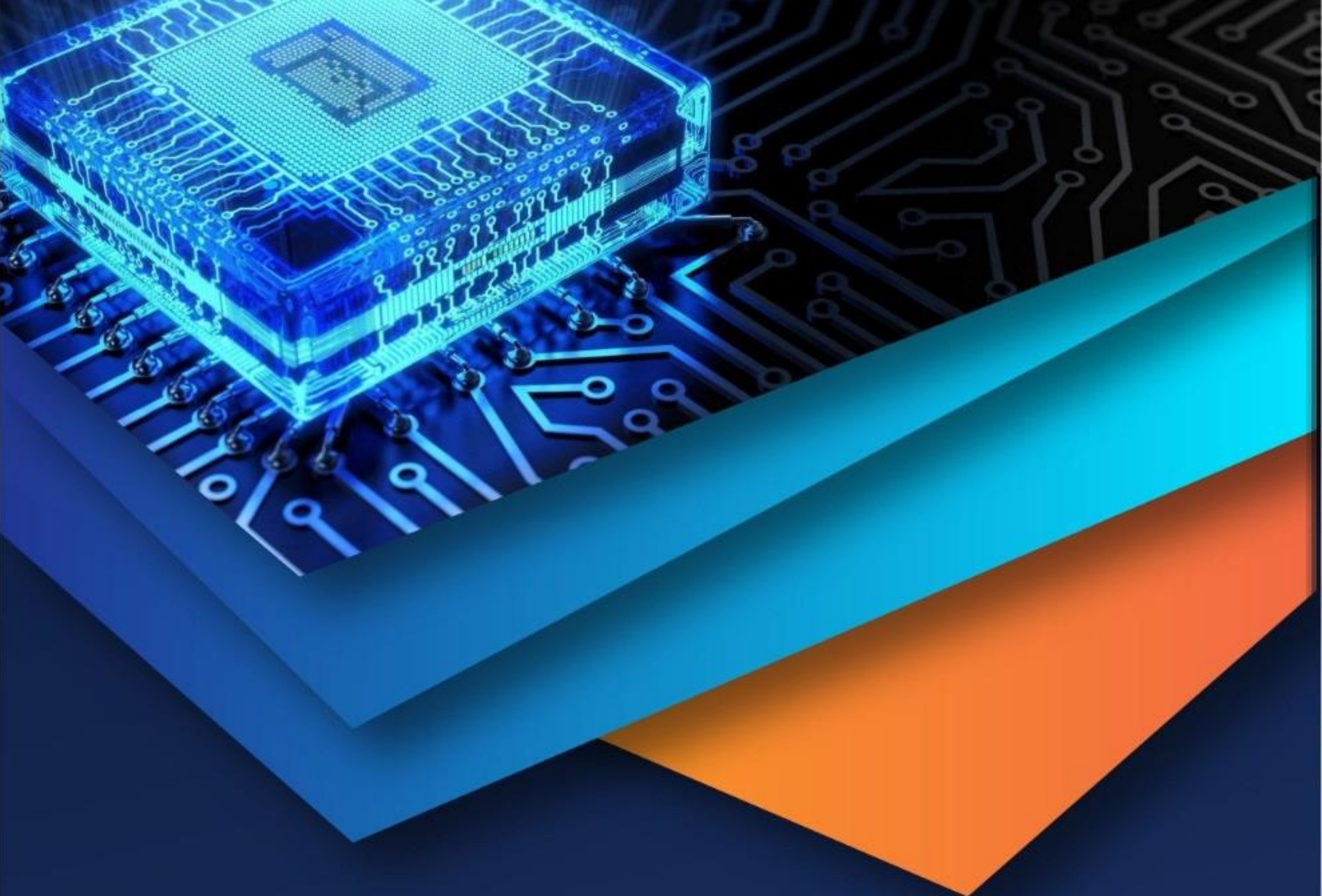

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