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EFFECT OF FLY ASH ON STRENGTH OF PAVEMENT QUALITY CONCRETE

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Abstract

Now-a-days with the growing industries large amount of waste products are produced. Disposal of these waste materials are required as they cause harm to human and other life.For its disposal large area is covered. As the production of waste is increasing day by day, we need to find a substitute to overcome this problem. Fly ash is a waste product produceddue to burning of coal in power generating plants.

Concrete consists of cement, sand, fine and coarse aggregate. Production of cement emits large quantity of greenhouse gases. Due to increase in construction work, demand for cement will also increase. So, to avoid production of greenhouse gases and to produce environment friendly concrete, cement is replaced with certain percentage of fly ash. Replacement of cement with certain percentage of fly ash is to improve the strength of pavement concrete. The fly ash used in this study is from NTPC, Badarpur, Delhi and is of Class B.

In the experimental study the replacement of OPC (Ordinary Portland Cement) with fly ashis done and to get the desired workability and strength. Polymer based superplasticizer is used for all grades of concrete. The compressive and flexural strength of PQC (Pavement Quality Concrete) with different percentage of fly ash has been studied for 3, 14 and 28 days.From the experimental results it has been noted that without superplasticizer the compressive strength of Pavement Concrete is less for both 7days and 28 days. With the useof superplasticizer, the desired compressive strength is achieved. But in case of flexural strength even without superplasticizer concrete attains the required strength and with superplasticizer the flexural strength of PQC achieve higher strength.

Notations & Abbreviations

ASTM	: American Society for Testing and Materials
CA	: Coarse Aggregate
FA	: Fly Ash
S	: Sand (Fine Aggregate)
C	: Cement
OPC	: Ordinary Portland Cement
OPCC	: Ordinary Portland Cement Concrete
NTPC	: National Thermal Power Corp.
HVFAC	: High Volume Fly Ash Concrete
PQC	: Pavement Quality Concrete
IS	: Indian Standard
IRC	: Indian Road Congress
m	: Meter
cm	: Centimeter
mm	: Millimeter
KN	: Kilo Newton
MPa	: Mega Pascal
min	: Minute
G	: Specific Gravity
rpm	: Rotation per minute

Chapter 1 Introduction

1.1. General

Fly ash concrete is extensively used among various industries. Use of such concrete is increasing because of higher performance, environment friendly and conserves natural resources. By adding admixture to concrete makes the concrete mix workable with lower water cement ratio and improves the strength of concrete.

1.2. Fly Ash

It is a fine grey powder produced by burning coal in power generating industries. It consistsof iron, silica, calcium and alumina. It is a pozzolanic material which has almost negligible cementitious property. It shows cementitious property when react with cement in the presence of moisture. Only because of this reason it can be used as a substitute of cement in concrete mix with many advantages.

Ash generation from Thermal power plants is increasing day by day. In the year 1993-1994 the production of ash was 40 million ton which increased to 110 million ton during 2005- 2006 and expected to increase further in the coming years as the need of power generationincreases in India. Disposal of fly ash is required as it pollutes environment and causes serious health issues. As maximum number of powers generating plant uses coal, they ultimately produces large amount of fly ash. So, for disposal of fly ash many acres of land are occupied by ash ponds.

ASTM categorizes fly ash into two types, and they are: Class C & Class F. Composition of bothfly ashes differentiates them from each other which mainly include content of silica, calcium,iron, and alumina. The chemical property of fly ash mainly depends on burned coal.

Class F Fly ash:

It is produced from burning anthracite and bituminous coal. It has little or no cementitious property. It has pozzolanic property with lime content less than 20%. As it is pozzolanic material produces cementitious material when react with lime with certain moisture content.

Class C Fly ash:

Burning of lignite or sub-bituminous coal produces Class C fly ash. Being a pozzolanic material it has Cementious property. It can gain strength in the presence of moisture. In thisfly ash lime content is more than 20%. It also has higher content of sulfate and alkali. Class C fly ash can replace higher percentage of cement than Class F fly ash.

The chemical property of fly ash mainly depends upon the property of coal being burnt anddepends upon storage and handling of coal. There are four types of coal with varying chemical composition, heating value, geological properties, and percentage of ash. They arelignite, anthracite, bituminous and sub-bituminous. The calcium content in Class F fly ash varies from 1% to 12% whereas in Class C fly ash it varies between 30%-40%. The sulphate content and alkalis content in Class C fly ash is higher than in Class F fly ash.

1.3. High Volume Fly Ash Concrete

Many research show that partial replacement of cement with fly ash improves the propertyof fresh as well as hardened concrete. So, it helps in recycling the waste from power generating industries instead of filling in ash ponds. Earlier the replacement was limited to 20- 30% but now it is being replaced with higher percentage of fly ash. Using fly ash in sucha higher percentage creates green concrete and environment friendly. Studies show that during manufacture of cement 7% of greenhouse gases are emitted to the atmosphere. Flyash being a byproduct of burning coal doesn't produce greenhouse gases. So, replacement with a higher percentage reduces the emission of greenhouse gases from cement production as demand for cement reduces. Fly ash delays the setting time of concrete. Admixture can accelerate the setting time of concrete having fly ash. There are many typesof admixtures like water reducing, air entraining, plasticizer, superplasticizer etc.

1.4. Aim of the Research

Fly ash is generally produced in large quantities due to increase in power generation capacity. Its production is going to increase further in near future. As its disposal will createproblem, we need to utilize large amount of fly ash, so it is used in cement concrete. A lot of research show that earlier its replacement was limited to 20-30% but now it is increasedto more than 50% 4 replacements. Here focus is mainly on producing concrete with high flyash replacement and determining various physical properties of material used, flexural andcompressive strength of cube and prism.

1.5. Objective and Scope of Work

Fly ash has been used to certain extend to replace cement in preparation of concrete for various applications. An attempt has been made in this study to utilize fly ash in varying quantities for preparation pavement quality concrete and study the effect of fly ash on strength properties of this type of concrete. In this study fly ash obtained from the nearby thermal power station belonging to NTPC, Badarpur. To achieve the above objective the following scope of work has been planned.

- To determine the physical properties of ingredient materials such as Ordinary Portland Cement (OPC) grade-43, NTPC fly ash, aggregate, and sand.
- To develop mix design for concrete with and without fly ash in varying percentage.
- To perform compressive strength and flexural strength test on both cube and prism specimen for all type of concrete mix samples.
- To study the effect of fly ash replacement on strength characteristics of concrete.

1.6. Organization of the Thesis

The thesis consists of five chapters. Information regarding each chapter can be found below.Chapter 1 is the introduction to the thesis. It contains brief background of fly ash as a material used as substitute to cement. It also contains objective and scope of work and aimof research work. Chapter 2 is the literature review which contains brief review on HVFAC of recent past studies carried out in laboratory on concrete mixes with varying fly ash content. 5 Chapter 3 is the experimental methodology which is carried out to determine theproperties of varies materials used in PQC using fly ash, compressive strength, and flexural strength of fly ash concrete mix. Chapter 4 is the analysis of the test results and discussion carried out for compressive and flexural strength on PQC using fly ash. Chapter 5 gives the summary of present work with conclusion and contains suggestion for future work.

Chapter 2 Literature Review

2.1. Introduction

This chapter focuses on a vast literature study on both field and laboratory works which are conducted in the recent past to observe the compressive and flexural strength of pavement quality concrete using fly ash and HVFAC for higher percentage of fly ash.

2.2. Past Studies on High Volume Fly Ash Concrete

P. Vipul Naidu and Pawan Kumar Pandey (2014) presented that using fly ash reduces thecost of construction and heat of hydration. It improves the durability of concrete and forms green concrete. Use of admixture improves the property of concrete like higher workability,early age strength and reduces water content. With the use of other binding materials it reduces water cement ratio. From various trials he concluded that fly ash can be replaced upto 65% and with this much of replacement the workability also get improved and reduces the cost of construction.

Mini Soman and Sobha.K (2014) they presented that workability of concrete improves by using fly ash and contributing to a sustainable development. The tests are performed on concrete beams. The strength of concrete with 50% fly ash shows reduction in strength of about 20% at an age of 7 days but at 28 days it acquire the required strength. HVFA concretecan carry larger load than Portland cement concrete. From the various studies it is found thatHVFAC are more crack free than OPCC. It helps in reducing the cost of construction about 24% with a replacement of 50%.

Jino John and M. Ashok (2014) they presented the mechanical properties of HVFAC. The mechanical properties of HVFAC are studied with replacement of cement about 50%, 60% and 70% of fly ash. The HVFAC attains less compressive and tensile strength as compared to the ordinary Portland cement concrete. The various other mechanical properties of HVFACshows lesser value than that of OPCC.

Claudia Ostertag (2005) presented that Fly Ash Concrete produce sustainable concrete as well as reduces negative effect on environment. Class F and Class C fly ash is being used. The need of cement is increasing as the development increases so by using fly ash in place ofcement will reduce the cost of construction. Researches show that HVFAC with a replacement of approx. 50% can be used in places where strength at initial days is less required. Even strength at initial age can be obtained by adding superplasticizer to concrete mix having lower water to cementitious material ratio. HVFAC reduces the cost of construction and give better surface finish. Fly ash can be used even in a higher percentage of about 60%-80% with proper mix design. In such cases Class C fly ash is used as it containhigh lime and have high cementitious property than Class F.

Pattanaik and Saba (2010) presented that fly ash can be used as a cementitious material in concrete. In this study fly ash produced by NALCO, angul, Odisha with varying percentage of superplasticizer is used and it can replace cement about 30-35%. The target strength at 28days can be achieved by 30% replacement of fly ash. As fly ash concrete has low early age strength it can be improved by adding superplasticizer to concrete mix. It even helps in reducing water to cementitious ratio and improves workability of mix.

Ramakrishnan et al. they studied on both plain concrete as well as on HVFA concrete. In case of HVFA concrete superplasticizer is used. In case of air entrained HVFA concrete flexural strength and endurance limit are studied and same for plain concrete. Fly ash concreteis formed with cement replacement of 58% with low Class F. W/C ratio was 0.32 and workable concrete mix is formed by adding naphthalene based superplasticizer. Total 40 beams are prepared, 20 beams of 75mm X 100mm X 400mm for each test are subjected to third point loading for flexure. Test on beam was performed with a non reversal fluctuating load. The constant lower limit was taken as 10% of the flexural static strength, and the upperlimit varied from about 90% of the static strength down to the fatigue limit. The fatigue test was run between lower load limit (10%). The test result reveals that endurance limit of high volume fly ash concrete is higher (7%) than that of plain concrete. But flexural strength and modulus of rupture of plain concrete is higher than high volume fly ash concrete. It also showsthat static flexural strength of both plain and fly ash concrete increases by 15% - 30%.

Sarang Shashikant Pawar and Shubhankar Anant Bujone (2017), thoroughly explains all the aspects of "Use of Fly ash and Plastic in Paver Block". Paver blocks are constructed by using waste like fly ash, plastic sag strip and wire plastic. In this research work the paver block made with the help of some percentage of plastic and flyash by weight of cement and aggregate added in concrete help to reduce plastic bag and also improve the properties of the paver block. The plastic and fly ash use in paver block will reduce the cost.

B. Shanmugavalli, K.Gowtham, P. Jeba Nalwin2 and B. Eswara Moorthy (2017) the research paper is about "Reuse of Plastic Waste in Paver Blocks". They give concepts about disposal of waste materials including waste plastic bags has become a thoughtful problem. Here the strength properties of pavement blocks including of waste plastics and the design considerations for pavement block incorporating waste plastic bags is presented. It will be a bonus to modern society and environment. The main aim is to use the plastic nature in construction fields with limited additions and the replacement of cement with plastic waste in paver block will reduce the cost of paver block when compared to that of convention concrete paver blocks. It will be absolutely a cost economical and can be applied in different practices.

Mohan D.M.S, Vignesh.J, Iyyappan.P and C.Suresh (2018) conducted a study on "Utilization of plastic bags in pavement blocks". He introduces the concept of addition of waste plastic bags with cement concrete to improve the properties of paver block. In this research work he conclude that if we are using 20% plastic by the weight of aggregate which does not affect the properties of paver block as well as the compressive strength of this block is equal to conventional block. He also conclude that the weight of plastic paver block is reduces up to 15% of conventional block and reduces the cost of construction and also helps to avoid disposal problem of plastic. Lastly he strongly conclude that the use of plastic in paver block is the best option for the disposal of plastic and ultimately reduces plastic pollution in the environment. Hence the use of plastic in paver block constituent is helpful in reducing plastic waste in a useful way.

Koli Nishikant, Aiwale Nachiket, Inamdar Avadhut and Abhishek Sangar (2016) proposes a "Manufacturing of concrete paving block by using waste glass material". This technology has been introduced in in construction for specific requirement namely footpaths, parking areas etc. In this research work he added different proportions of waste glass fine aggregate and fly ash, In this research work he conclude that the use of waste glass as fine aggregate decreases the unit weight of concrete, workability of concrete mix increases with the increase in fly ash and waste glass content. Also he conclude that bending strength decreases with the increase in waste glass content as well as cost of the paver block reduces. For all above conclusion it is conclude that the best ratio of fine crushed glass which leads to higher strength of concrete in order to produce concrete blocks, and the effect of waste glass replacement on the expansion caused by Alkali-silica reaction (ASR).

Dinesh.S, Dinesh.A and Kirubakaran.K (2016) presented an "Utilization of waste plastic in manufacturing of bricks and paver blocks". In this paper he said that the large amount of plastic is being brought into the tourist trekking areas are discarded or burned which leads to the pollution of environment and air. These waste plastics are to be effectively utilized. High-density polyethylene (HDPE) and polyethylene (PE) bags are cleaned and added with sand and aggregate at various percentages to obtain high strength bricks that possess thermal and sound insulation properties to control pollution and to reduce the overall cost of construction; this is one of the greatest ways to avoid the gathering of plastic waste which is an undegradable pollutant.

A.Panimayam, P.Chinnadurai, Anuradha and K.Pradeesh, A.Umar Jaffer (2017) he studied on "Utilisation of Waste Plastics as a Replacement of Coarse Aggregate in Paver Blocks". This Paper suggests reuse of plastics as partial replacement of coarse aggregate in M20 concrete. Usually, M20 concrete is used for most constructional works. Waste Plastics were progressively rises in 0%, 2%, 4%, 6%, 8% and 10% to replace the same quantity of Aggregate. Tests were conducted on coarse aggregates, fine aggregates, cement, and waste plastics to determine their physical properties. Paver Blocks of I section of casted and tested for 7, 14 and 28-days strength and the result shows that the compressive strength of M20 concrete with waste plastics is 4% for Paver Blocks.

Mohammad Jalaluddin (2017) researched on "Use of Plastic Waste in Civil Constructions and Innovative Decorative Material (Eco- Friendly)" presented a alteration to the use of plastic in civil construction, the mechanisms used include everything from plastic screws and hangers to bigger plastic parts that are used in decoration, electric wiring, flooring, wall covering and waterproofing. Plastic use in road construction that have shown same confidence in terms of using plastic waste in road construction, i.e., plastic roads and paver block. He said that Plastic will increase the melting point of the bitumen. Rainwater will not seep through because of the plastic in the tar. So, this technology will result in lesser road repairs.

A.I. Essawy a, A.M.M. Saleh b, Magdy T. Zaky c, Reem K. Farag b, A.A. Ragab b (2013) researched on "Environmentally friendly road construction" this Paper proposes a reuse of waste polymers is considered an good looking solution for environmental white pollution and reducing of the costs of road pavement and maintenance. The environmentally friendly hot mix asphalt (HMA) for paving can be prepared using some industrial wastes as polypropylene and polyester fibres.

Ghassan Abood Habeeb*; Hilmi Bin Mahmud (2010) conducted a study on “Properties of rice husk ash and its use as cement replacement material”. This paper investigates the properties of rice husk ash (RHA) produced by using a ferro-cement furnace. The effect of grinding on the particle size and the surface area was first investigated, then the XRD analysis was conducted to verify the presence of amorphous silica in the ash. Furthermore, the effect of RHA average particle size and percentage on concrete workability, fresh density, superplasticizer (SP) content and the compressive strength were also investigated. Although grinding RHA would reduce its average particle size (APS), it was not the main factor controlling the surface area and it is thus resulted from RHA's multilayered, angular and microporous surface. Incorporation of RHA in concrete increased water demand. RHA concrete gave excellent improvement in strength for 10% replacement (30.8% increment compared to the control mix), and up to 20% of cement could be valuably replaced with RHA without adversely affecting the strength. Increasing RHA fineness enhanced the strength of blended concrete compared to coarser RHA and control OPC mixtures.

Nitesh kushwah and Sandeep K. Shrivastav (2019) researched on “Comparative Study on Impact of Rice Husk Ash and Fly Ash in Concrete Mix Design for Different Grades of Concrete.” This study is about the addition of furnace incinerated Rice Husk Ash into concrete with fly ash. The primary objective of this research work is to investigate the mechanical properties like compressive strength and to reduce the overall cost of construction. RHA and fly ash was used to replace cement partially at different rates, fly ash is used at the rate of 0%, 5% and 10% and RHA at the rate of 5% and 10%. The physical properties of RHA were determined by particle size analyzer. Pozzolanic reactivity of RHA is dependent on silica form. The silica form in RHA is determined by incineration process. To decide it is in crystalline form optimum cement replacement ratio of RHA and fly ash found at 5%+5%. In this investigation firstly two lower grades concrete M-15 and M-20 were prepared and the best result was found with M--15 grade of concrete, then experiment were done with higher grades i.e. M-30 and M35 grades and there is slight increase in compressive strength in higher grades.

MOHAMED AMIN AND BASSAM ABBDELSALAM ABBDEL SALAM (2019) conducted a study on “Efficiency of rice husk ash and fly ash as reactivity materials in sustainable concrete.” This paper presents the recycling of rice husk ash (RHA) and fly ash (FA) from power plants as reactivity materials for producing sustainable (green) concrete. This research aims to investigate the efficiency of RHA and FA replacement ratios on fresh and hardened properties of concrete mixtures. The experimental program consisted of 21 concrete mixtures, which were divided into three groups. The cementitious material contents were 350, 450 and 550 kg m^{-3} for groups one, two and three, respectively. The replacement ratios from the cement content were 10, 20 and 30% respectively, for each recycle material (RHA and FA). The slump and air contents of fresh concrete were measured. The compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity and bond strength of hardened concrete as mechanical properties were also analyzed. The compressive strength was monitored at different ages: 3, 7, 28, 60 and 90 d. The water permeability test of hardened concrete as physical properties was conducted. Test results showed that the RHA and FA enhanced the mechanical and physical properties compared with the control mixture. The cementitious content of 450 kg m^{-3} exhibited better results than other utilized contents. In particular, the replacement ratios of 10 and 30% of RHA presented higher mechanical properties than those of FA for each group. The water permeability decreased as the cementitious content increased due to the decrease in air content for all mixtures. The water permeability loss ratios increased as the cementitious content decreased.

Satish H. Sathawanea, Vikrant S. Vairagadeb and Kavita S Kene (2013) presented a "Combine Effect of Rice Husk Ash and Fly Ash on Concrete by 30% Cement Replacement". The work presented in this paper reports the effects on the behavior of concrete produced from cement with combination of FA and RHA at different proportions on the mechanical properties of concrete such as compressive strength, flexural strength, and split tensile strength. Investigation reported that compressive strength increases by 30.15% in compared with targeted strength and reduces by 8.73% compared with control concrete at 28 days, flexural strength increases by 4.57% compared with control concrete at 28 days, split tensile strength decreases by 9.58% compared with control concrete at 28 days, were obtained at combination of 22.5% FA and 7.5% RHA. Partial replacement of FA and RHA reduces the environmental effects, produces economical and eco-friendly concrete.

Chapter - 3

Materials required for experimental work

The ordinary concrete used in the test program consisted of cementing materials, mineralaggregates and corrosion inhibitor with the following specifications:

- Portland Pozzolana cement
- Graded fine aggregates.
- Graded coarse aggregates.
- Water.
- Flyash

a. Portland Pozzolana Cement

The cement is a binding material. It conforming to IS456-2000-53 grade. It consists of grinding the raw materials, mixing them intimately in certain proportion depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 – 1500 degree centigrade at which temperature, the material Clinker and partially fuses to form modular chapped clinker. The clinker is cooled and ground to a fine powder with addition of 2 to 3% of gypsum the product formed by using this procedure Portland cement.Of all the materials that influence the behavior of concrete, cement is the most important constituent, because it is 11 used to bind sand and aggregate and it resists atmospheric action. Portland cement is a general term used to describe hydraulic cement.

b. Graded Fine Aggregates

The materials smaller than 4.75 mm size is called fine aggregates. Natural sand is generallyused as fine aggregate. In this experimental work replacement of river sand by quarry waste(fineness modulus of crushed sand equal to 3.2) conforming to grading Zone III of IS – 383
– 2019 was used as fine aggregates.

c. Graded Coarse Aggregate

Locally available well graded granite aggregates of normal size greater than 4.75 mm andit should be free from disintegrated stones, soft, flaky, elongated particles, salt, alkali and vegetable matter.

d. Water

Potable water has been used for casting concrete specimens. The water is free from oils, acids, and alkalis and has a water-soluble Chloride content of 140 mg/lit. As per IS 456 –2000, the permissible limit for chloride is 500 mg/lit for reinforced concrete; hence theamount of chloride present is very less than the permissible limit.

e. Fly Ash

Fly ash to be used as cementitious material in PQC shall conform to the requirements of Grade-I of IS 3812 – 2003 ensuring uniform blending as PPC meeting IS 1489 subject to strict control of the fly ash content.

CHAPTER – 4

Experimental study

4.1 Process of manufacture of concrete

Production of quality concrete requires meticulous care exercised at every stage of manufacture of concrete. If meticulous care is not exercised, and good rules are not observed, the resultant concrete is going to be of bad concrete. Therefore, it is necessary forus to know what the good rules are to be followed in each stage of manufacture of concretefor producing good quality concrete. The various stages of manufacture of concrete are:

1. Batching
2. Mixing
3. Placing
4. Compacting
5. Curing

4.2. Tests on Material

4.2.1. Specific Gravity and Water Absorption

Specific Gravity helps in measuring the quality of aggregate used. It is defined as the ratio of mass of any substance to the mass of equivalent volume of water. Aggregates having lower specific gravity are considered as weak than the aggregates having higher specific gravity. If the water absorption value of aggregates is high then they are weak and porous. It is determined as per IS: 2386 (Part III) –1963.

In case of coarse aggregates the specific gravity is obtained by using wire basket. About 2kg of coarse aggregates are tested. The aggregates are kept in the wire basket and submerged in water. Air entrapped on the surface of aggregate shall be expelled by gentle disturbance or by rapid clockwise and anti-clockwise movement of wire basket. The basket and aggregate remain submerged in water for 24 hrs. Then the aggregates are surface dried and weighed. After that the aggregates are oven dried.

Specific gravity = W4 W3−(W1−W2)

Apparent Specific gravity = W4 W4−(W1−W2)

Water absorption = W3−W4 W4 × 100

Where,

W1 = weight of wire basket containing sample and filled with distilled water, gm

W2 = weight of wire basket filled with distilled water only, gm

W3 = weight of saturated and surface-dry aggregate, gm

W4 = weight of oven-dry aggregate, gm

In case of fine aggregate pycnometer is used for determination specific gravity as per IS: 2386 (Part III) –1963. Sample of weight 500gm is taken for test. Saturated surface dry aggregates are used for the testing. These aggregates are then deposited in pycnometer and distilled water is filled to the top so that water in the hole is flat and its weight is taken. Weight of pycnometer is taken when it is filled with water. Then fine aggregate is oven dried.

Specific gravity = W4 W1−(W2−W3)
Apparent specific gravity = W4 W4−(W2−W3)
Water absorption = (W1−W4) W4 × 100

Where,
W1 = weight of saturated and surface-dry fine aggregate, gm
W2 = weight of pycnometer containing fine aggregate and filled with distilled water, gm
W3 = weight of pycnometer filled with distilled water, gm
W4 = weight of oven-dried fine aggregate, gm

In case of cementitious material specific gravity is obtained by using Le-chatelier flask. Kerosene oil or Naptha is filled in the flask in between 0 and 1 ml. Specific gravity of cementitious material is determined as per IS: 4031 (part XI)- 1988.

Le-chatelier Flask Initial reading is noted down. Using funnel cementitious material is filled in the flask of about 60 gm.
The final reading is taken. Specific gravity is given by, G = Mass of cement, gm Displaced volume ,cm 3

4.2.2. Aggregate Crushing Test

Aggregate crushing test is carried out to determine the strength of aggregate. It is determined as per the IS: 2386 (Part IV) -1963. Surface dry aggregate is used which passes through 12.5 mm IS sieve and retain on IS sieve 10 mm is filled in three equal layers in a mould of cylindrical shape, each layer being ramped 25 times by the tamper. The plunger is placed on the top of specimen and a load of 40 tones is applied at certain rate by the compression machine. The crushed aggregates are sieved through 2.36 mm IS sieve. Strong aggregate give low aggregate crushing value.

Aggregate crushing value = W2 W1 × 100 percent (3.8)
Where W1 = weight of surface dry aggregate
W2 = weight of crushed aggregate passing 2.36 mm IS sieve.

4.2.3. Aggregate Impact Test

This test carried out to determine the toughness or resistance of aggregate to fracture under repeated impacts. It is determined as per IS: 2386 (Part IV) -1963.

(Source: www.civilblog.org) Figure 3.2:

Impact Testing Machine

The aggregates which passes 12.5mm sieve and retain on 10mm sieve is filled in a mould of inner diameter 10.2cm and depth 5cm in three layers and giving each layer 25 blows. The hammer of weight 13.5-14 kg is lifted to a ht. of 380mm above the top surface of mould in which aggregates are placed and allowed to drop on the specimen. The aggregates are subjected to 15 blows with 1 sec interval. The crushed aggregates are sieved through 2.36mm.

Impact value = W2 W1 × 100 percent (3.9)
Where W1 = weight of surface dry aggregate
W2 = weight of crushed aggregate passing 2.36 mm sieve.

4.2.4. Aggregate Abrasion Test

This test is carried out to determine the hardness of aggregates. The test is carried out as per IS: 2386 (Part IV) -1963. Los Angeles abrasion testing machine is used for the testing which is a hollow steel cylinder closed at both ends and having internal diameter of 700mm and length of 500mm. A steel shelf is radially projected 88mm for the full length of cylinder. Specified weight of aggregate depending upon the gradation is placed in the machine. The machine rotates at a speed of 33rpm for specified number of rotation as per grading. Then the aggregates are taken and sieved through 1.7mm sieve.

Los Angeles Abrasion Testing Machine Abrasion value = W2 W1 × 100 (3.10)

Where W1 = weight of surface dry aggregate
W2 = weight of crushed aggregate passing 1.7 mm sieve.

4.2.5. Consistency of Cementitious Material

Consistency is the percentage of water required for cement paste at which viscosity of the paste becomes such that the plunger in a Vicat's apparatus penetrates a depth of 5 to 7mm, measured 21 from the bottom of Vicat mould. Consistency of cementious material is determined as per IS: 4031 (Part IV) – 1988. In this test measured quantity of cementitious material is mixed with measured quantity of potable or distilled water, care should be taken such that the gauging time should not be less than 3 minutes and not more than 5 minutes. The gauging time is the time of mixing water to dry cemetitious material up to the commencing of filling the mould. The Vicat mould is kept on non porous plate. Mould is filled with cement paste and leveled using trowel.

Vicat's Apparatus Mould is slightly shaken to expel air. Plunger is attached to the apparatus and allowed to rest on the surface of the test mould. Then the plunger is quickly released to sink into the mould. This procedure is repeated until plunger penetrates 5 to 7 mm from the bottom by adjusting the quantity of water added.

Consistency = A B × 100 = P (3.11)
Where A = quantity of water added
B = quantity of cementitious material used

4.2.6. Soundness

Test is carried out to detect the presence of uncombined lime in cement. It is the property by virtue of which the cement does not undergo any appreciable expansion (or change in volume) after it has set, thus eliminating any chances of disrupting the mortar or concrete. The apparatus used for soundness test is Le-chatelier apparatus. Soundness test is carried out as per IS: 4031 (Part III) - 1988. The mould and glass sheets are lightly oiled and cement paste formed by adding cement with 0.78 times the water required to form paste of standard consistency is placed in the Le chatelier's mould by placing a glass sheet below and holding the two edges together.

Le-chatelier Apparatus
The Le-chatelier mould is covered with other glass sheet and a weight is placed over the whole assembly. Immediately submerge the whole assembly in water for 24 hours. The distance between the two indicators is measured. Again immerse the sample in water and boil for 3 hours and distance between both indicators are noted. The difference of both the reading indicates the expansion of cement.

4.2.7. Initial and Final Setting Time

Initial setting time is the time period that elapses from the time when water is added to the cementitious material and the needle for initial setting time ceases to penetrate 5 to 7 mm from bottom of the Vicat's mould.

Vicat's Apparatus Final setting time is the time period that elapses from the moment water is added to the cementitious material and the needle for final setting time with annular collar at the tip of needle just makes an impression on the paste. Initial and final setting time of cementitious material is determined as per IS: 4031(PART V) – 1988. For this test measured quantity of cementitious material is taken and mixed with 0.85times the water required to form standard consistency paste. Gauging time is maintained. Needle is used for initial setting time and for final setting time needle with annular attachment is used.

4.2.8. Fineness

The degree to which cementious material is drawn to smaller and smaller particles is called fineness. Finer the material higher the rate of radiation and do faster the development of strain. It is because finer material offers greater surface area of particles for hydration. Fineness is determined by Blaine's Air Permeability method as per IS: 4031 (Part II) – 1988. Blaine's air permeability apparatus consists essentially of a means of drawing a definite quantity of air through a prepared bed of cement of definite porosity. The fineness is expressed as a total surface area in square centimeters per gram. In this method density of cementitious material, bed volume and apparatus constant are determined first.

Blaine's Air Permeability Apparatus

Fineness of cementious material is obtained by using the formula

$S = 521.08K\sqrt{t}\ \rho$ cm2 /gm (3.12)

Where, S = Specific surface area
K = Apparatus constant
ρ = Density of cement
t = Time

4.2.9. Flakiness and Elongation Index

The flakiness and elongation index is determined as per IS: 2386 (Part IV) -1963. The flakiness index of an aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three-fifths of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm. The thickness gauge is used for flakiness of aggregate.

The measured quantity of material is sieved through the sieve size mentioned in the metal gauge and collected separately as per range. Then the fraction of material is gauged through thickness in metal gauge. The total mass of each size fraction of the sample also shall be determined. The mass of material passing the respective gauge to the total mass of aggregate retained on 6.3mm sieve gives the flakiness index of aggregate which is expressed in percentage. Elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than one and four-fifths times their mean dimension. Normally, the properties of interest to the engineer are sufficiently covered by the flakiness or angularity tests. The elongation test is not applicable to sizes smaller than 6.3 mm. The fraction of material is gauged through length in metal gauge. The total weight of material retained in every range to the total weight of material retained.

4.2.10. Sieve Analysis of Aggregates

This method is adopted to determine the particle size distribution of fine and coarse aggregate. It is carried out as per IS: 2386 (Part I) – 1963. Set of sieves are used for analysis of both fine and coarse aggregates which are arranged in descending order. Measured quantity of air dry 26 aggregates are used. Aggregates are passed through the set of sieves and material retained on each sieve is weighed. The result is calculated as cumulative percentage by weight of the total sample passing each of the sieves, to the nearest whole number. The result is represented graphically.

4.2.11. Compression Test

Compression test is performed on concrete cube to determine the compressive strength. The test is performed on Compression testing machine. The test is performed as per IS: 516 – 1959. The prepared concrete mix should be workable and poured in layers in the cube and compacted by hand using tamping rod. The cubical mould is of cast iron or steel of 15 X 15 X 15 cm size. After filling to the mould is kept on vibratory table for 2 min for full compaction so that no air voids will be there. Compression Testing Machine Then the mould is kept for 24 ± 1 2 hr. without any disturbance. After this period specimen is removed from the mould and submerged in water and kept there until taken out just prior to test. The testing is done after 7, 14, and 28 days curing period. 27 Compressive Strength = Load (KN) Cross sectional area (mm 2)

4.2.12. Flexure Test

The flexure test is performed to determine the flexural strength as per IS: 516 - 1959. Flexural strength is defined as the maximum stress developed at the outermost fiber on either the compression or tension side of the specimen. This test is performed on prism specimen submerged in water and kept until test is performed. The size of prism mould is 10 X 10 X 50 cm. The specimen is placed in the testing machine such that the load acts on the upper surface of prism along two lines at a spacing of 13.3cm center to center. The specimen is placed on rollers at a distance of 40cm. 3 point load is done for flexure test. The testing is done after 7, 14, and 28 days curing period. The load is applied at a rate of 180 kg/min for the 10.0 cm specimens.

The Flexural Strength or modulus of rupture (fb) is given by

fb = pl bd 2
(when a > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen) or (3.14)

fb = 3pa bd 2
(when a < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.) (3.15)
Where, a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen
b = width of specimen (cm)
d = failure point depth (cm)

l = supported length (cm)
p = max. Load (kg)

4.3. Concrete Mix Design

As per IRC 44: 2008 The process of selecting various ingredients and their amount for producing concrete of required strength, workability and durability as well as economical is termed as concrete mix design. The compressive strength of hardened concrete is one of the important properties it depends upon the quality and quantity of cement, water cement ratio, type of aggregate, batching, mixing, placing, compaction and curing. In PQC the cement is replaced by fly ash with a higher percentage and reducing the water cement ratio by adding admixture and making the mix in workable condition.

4.3.1. Procedure

• The mix design of concrete is done as per IRC 44.
• Determine the target mean strength f'ck using characteristic compressive strength at 28 days as per IS: 456 is as follows:
$f'ck = fck + 1.65S$
Where, f'ck = target mean compressive strength at 28 days, N/mm2
fck = characteristic compressive strength at 28 days, N/mm2
S = standard deviation, N/mm2 The standard deviation of various grades of concrete are assumed as per the table given below.

• Determine the flexural strength of concrete as per IS: 456 is as follows:

$fcr = 0.7 \times fck$
Where, fcr = flexural strength, N/mm2
fck = characteristic compressive strength at 28 days, N/mm2

• After determining the strength water cement ratio is obtained as per the grade of concrete the table given below.

Preliminary selection of w/c ratio for given grade of concrete

Sl.No.	Grade of Concrete	Approximate W/C Ratio
1	M25	0.5
2	M30	0.45
3	M35	0.42
4	M40	0.38
5	M50	0.34
6	M60	0.28

Sl. No.	Grade of Concrete	Assumed Standard Deviation (N/mm2)
1	M25	4
2	M30	5
3	M35	5
4	M40	5
5	M45	5
6	M50	5
7	M55	5
8	M60	5

Cementitious material is also considered in w/c ratio calculation and the w/c ratio is limited to 0.5 for all grades of concrete.

• The water content of concrete mix is influenced by many factors such as shape and size of aggregate, water cement ratio, texture of aggregate, type and content of cement and cementitious material. Use of admixture like plasticizer and superplasticizer also affects the water content. The water content is obtained depending upon the maximum nominal size of aggregate given in the table below:

Approximate Water Content for Nominal Maximum Size of Aggregate Nominal

Maximum Size of Aggregate (mm)	Suggestive Water Content (kg)
10	208
20	186
40	165

• The table above is for angular coarse aggregate and slump = 20mm ± 5mm and w/c ratio= 0.50.

• The cement content or cementitious material content can be calculated using water to cementitious ratio and water content. The obtained cementitious content should be less than the maximum cement content i.e 450 kg/cm3 and should be greater than minimum cement content of 310 kg/cm3 .

• The volume of coarse aggregate per unit volume of total aggregate is obtained using the table below for which nominal maximum size of aggregate and sand of different zones are required.

Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate as per IS: 383

The above table valid for water cement ratio of 0.50. With every decrease of 0.05 w/c ratio the ratio of coarse to total aggregate increases by 1 percent.

• All the ingredients are estimated except fine and coarse aggregate content. These two are obtained by determining the volume of water, admixture and cementitious material. Then dividing their mass by their respective specific gravity, multiplying by 1/1000 and subtracting the summation of result from unit volume.

- The mix proportion for concrete is formed for first trial mix.

- The concrete specimens are prepared for compressive strength test as well as for flexural test in the form of cube of 150 x 150 x 150mm and prism of 100 x 100 x 500mm size. The test is performed at 7, 14 and 28 days curing.

- The mix proportion is adjusted till the required strength is achieved from both cube and prism.

Chapter – 5

Result and Discussion

5.1. Introduction In this chapter all the results of experimental tests on various materials used in Pavement Quality Concrete for cube and prism specimen are presented to improve the mechanical properties. Replacement of cement with fly ash is being done with varying percentage. Polymer based superplasticizer is used in fly ash concrete. The results are discussed in details in the following section.

5.2. Tests Conducted on Cement various physical tests are performed on OPC Grade- 43. The results obtained from the tests are given in the following table and not presented for the publication purposes.

5.3. Tests Conducted on suratgarh thermal power plant Fly Ash The various tests on physical property of suratgarh thermal power plant Fly Ash are conducted. The results obtained are listed below.

Physical properties of suratgarh thermal power plant Fly Ash with standard values

5.3.1. Sieve Analysis on suratgarh thermal power plant Fly Ash, For Fly Ash it is performed by Hydrometer Analysis and Particle Distribution Curve is not presented for publication purposes.

5.4. Tests Conducted on Fine and Coarse Aggregate

5.4.1. Water Absorption and Specific Gravity of Aggregates

5.4.2. Tests carried out on Coarse Aggregate

Table 5.5: Physical test values of coarse aggregate

Tests on Coarse Aggregate	Obtained Value	Standard Value
Crushing Value	14.7%	Not more than 30%
Impact Value	14.9%	Not more than 30%
Abrasion Value	22.7%	Not more than 30%
Flakiness Index	9.1%	Not more than 15%
Elongation Index	18.7%	Not more than 15%

The sieve analysis of fine aggregate shows that it is well graded.

The sieve analysis graph shows that coarse aggregate is well graded.

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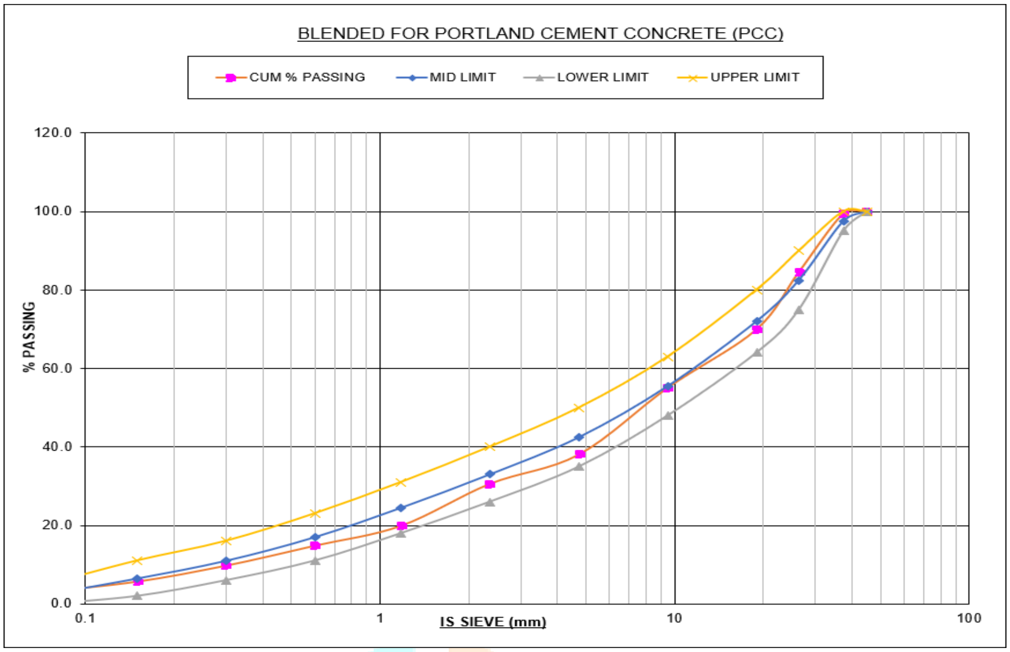


5.6. Mix Design of Concrete

Design of Pavement Quality Concrete

In the first trial mix of Pavement Quality Concrete is done. Six number of beams are casted. The Flexural strength of concrete in 7 and 28 days was obtained.

Test results of pavement quality grade concrete having Fly ash 20%, 23% 26% & 29% with superplasticizer. Test results have been presented for the publication purposes.

PQC TRIAL MIX SUMMARY

S.No.	Cement	Admixture	PROPORTIONS (40:20:10:M.SAND)	Cement + Flyash (%)	40 MM (kg)	20 MM (kg)	10 MM (kg)	M. Sand (kg)	W/C Ratio	Admixture Dosage (%)	Slump	
											Initial	90 min
1	Ultratech OPC -43	FOSROC AURAMIX 300	31:13:20:63 **(KOTPUTLI)**	362 Kg+91 kg (80 % + 20 %)	563	233	371	632	**0.33**	2.72 kg (0.6 %)	70 mm	30 mm
2	Ultratech OPC -43	FOSROC AURAMIX 300	31:13:20:63 **(KOTPUTLI)**	349 Kg+104 kg (77 % + 23 %)	562	233	371	631	**0.33**	2.72 kg (0.6%)	60 mm	15 mm
3	Ultratech OPC -43	FOSROC AURAMIX 300	31:13:20:63 **(KOTPUTLI)**	335 Kg+118 kg (74 % + 26 %)	560	232	271	630	**0.33**	2.72 Kg (0.6%)	85 mm	25 mm
4	Ultratech OPC -43	FOSROC AURAMIX 300	31:13:20:63 **(KOTPUTLI)**	322 Kg+131 kg (71 % + 29 %)	559	232	271	628	**0.33**	2.72 Kg (0.6%)	60 mm	25 mm

BEAM CASTING

BEAM CASTING

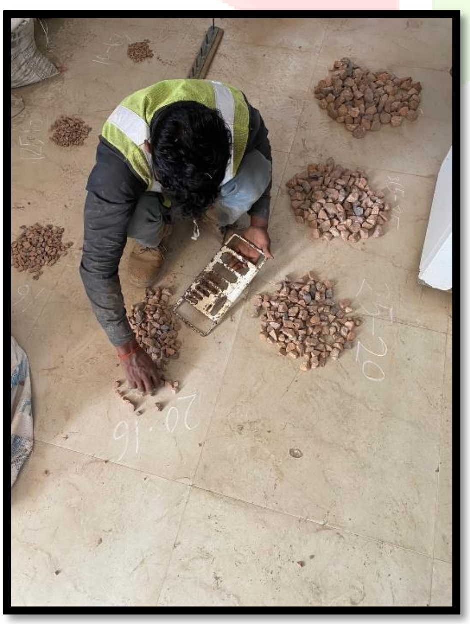
CUBE CASTING

FLEXURAL STRENGHT TESTING

AGGREGATE GRADATION

ELONGATION AND FLAKINESS TEST

ELONGATION TEST GRADATION

AGGREGATE IMPACT VALUE TEST

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