Comparitive Study of Portland Pozzolana Cement with Ordinary Portland Cement

PROJECT REPORT

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SYNOPSIS

In the context of cement although it is to be admitted that anything has the binding character can be called cement. It is only ordinary Portland cement (OPC) that has established credentials in the construction market. Though there are other varieties of binding materials such as, Portland Pozzolana Cement (PPC). Which are economical and ensuring good strength with time when compared with ordinary Portland cement.

The constituents of PPC are fly ash, lime and gypsum. Fly ash is a fine residue come out as a waste material in large quantities at thermal power plants. This is produced when pulverised coal is used for producing steam in boilers. This fly ash requires large area of land for disposal and may cause serious pollution problems. IS: 3812-1981 part I, part II and part III gives the specification of fly ash.

In this work Load corrected out different types of test such as initial setting, final setting, compressive strength, workability, compaction factor, standard consistency, etc., Cube are casted for different water cement factors. The proportion adopted for concrete cube is 1 : 2 : 4.

The strength development was studied 7 days, 28 days, 36 days and result were compared and goes in graphical and tabular form. However the gains of strength after 36 days could not be studied because of the constraints in time.

1. INTRODUCTION

With the growth of construction industry, the use of cement has been increased. The introduction of graded ordinary Portland cement, pozzolana Portland cement and various other blended cements, have really brought a choice for cement.

Cement is manufactured from the following class of materials.

Argillaceous,

Calcareous,

Silicious.

In this context some of the materials are naturally available and which will get exhausted at one time. So how it can be substituted? There comes the introduction of pozzolana Portland cement were lime is partially replaced by "FLY ASH" (Pozzolonic material).

To make a right selection of cement according to the need, a technical study has been conducted on OPC & PPC. The strength of concrete made from both the cements are compared in this project work.

Due to the limitation in time an exhaustive study was not possible.

2. OBJECTIVE AND SCOPE OF THE PRESENT INVESTIGATION

2.1 OBJECTIVE OF THE PRESENT INVESTIGATION:-

The objective of this investigation is to find the following.

1) Strength comparison of OPC and PPC.

2) Setting time comparison of OPC and PPC.

3) Utilisation of fly ash towards the environmental protection.

There is a limitation in the availability of natural resources which used for manufacture of cement. Also the quality of line from quarry to quarry will vary. Under this circumstances it becomes difficult is get a unique character for cement.

2.2 SCOPE OF THE PRESENT INVESTIGATION: -

This study clearly shows the comparison of OPC and PPC. It is very common that to use OPC as binding material. But as strength wise this study shows that PPC have more strength and it is interesting to see that the strength is increasing after 28 days.

The raw material of PPC have fly ash which is an industrial waste. By using this waste regularly has been achieved.

3. REVIEW OF EARLIER LITERATURE

3.1 PORTLAND POZZOLANA CEMENT (PPC) : -

The addition of a pozzolana to improve the preparation of cementing material is a time-tested practice since the Roman times. The many buildings viaducts and sewers which have with stood the ravages of time for over 2000 years is indeed a testimony to the acumen of Roman engineers. Even today Italy and USA are pozzolana cement on a fairly large scale for building construction because of the many positive advantages of concrete based on this kind of cement.

PPC differs from OPC mainly in that it incorporates an active constituent called pozzolana. Which is either interground with clinker and gypsum or intimately blended with OPC. In either case the pozzolana content is limited by Indian standard K89-1991 (Part I Fly-ash based and Part II calcined day based) to maximum of 25 percent and minimum of 10 percent by 10 eight of cement.

The form "Pozzolana" is employed to describe a siliceous or siliceous and aluminious material which in itself posses little or no cementitious value. But, which will in finely divided from and in the presence of moisture. Chemically react with calcium hydroxide at ordinary temperature liberated during the hydration of Portland cement to produce stable, cementitious compounds which contribute to strength and water tightness. It is generally agreed that the siliceous ingredient of a pozzolana should be in an amorphous or non-crystalline state such as glass opal or thermally altered day for the best reactivity.

The pozzolanas used in the manufacture of PPC are of two types. Calcined day pozzolanas conforming to IS: 1344-1981 and fly ash conforming to IS: 3812-1981. The farmer are produced by controller calcination of specially selected days or shales at a temperature which varies from 600°C to over 900°C according to the nature of day. Fly ashes are by product of thermal power station equipped with electrostatic precipitators. Even so not all fly ashes from this source are suitable as pozzolana and their selection for use in PPC is invariably preceded by exhaustive chemical and physical tests. The stringent controls during manufacture of PPC and known benefits accruing from its use in concrete makes PPC an eminently suitable cement for an engineering construction.

ADVANTAGES:

Advantages in the use of PPC are:

- the plasticity of concrete, its freedom from segregation, and bleeding at a given slump are much improved, particularly with leaner mixes.
- The heat evolved during hardening is reduced thereby reducing cracking in mass concrete structures.
- Reduced alkali-aggregate reaction
- Improved resistance to sulphate attack particularly if the alumina content of both the clinker and pozzolana are low.
- Water tightness is increased.
- Improved extensibility or resistance to cracking
- Lower susceptibility to dissolution and leaching.

APPLICATIONS:

- In lean mixes of mass concrete, such as used for dams and bridge piers where freedom from segregation and low heat of hydration are desirable.
- In hydraulic structures and mortars and plasters where water tightness is desired.
- In concrete made with reactive aggregates.

- In marine structures where impermeability and resistance to attack by sea water are important.
- In sewers and other structures subject to weak acidic or sulphate attack.

Portland Pozzolana Cement (PPC) is a known blend practiced in the world for the last several decades. Though the Indian market has not received the product well nor acknowledged its technical virtues, the chemistry of PPC is well known to the cement chemists but mostly confined to laboratories in Indian without finding its in roads into extensive application commensurating to its factors of durability over Ordinary Portland Cement (OPC).

It is to counteract this malady, that PPC has been developed wherein, the lime pozzolana interacts with the free lime released in OPC after hydration, to render parallel mineralogy without effecting the ultimate strength. It is because of this phenomenon, the free lime of hydrated OPC portion gets drastically engaged, minimizing its chances of availability for deleterious reactions. Hence, PPC is recommended towards sulphate resistant applications particularly in coastal areas in preference to OPC.

3.2 ORDINARY PORTLAND CEMENT [OPC]

Ordinary Portland Cement is a product principally consisting of for mineralogical phases which formulate during the process of sintering. It is for this purpose, that raw meal design is carefully monitored at production stage in order to allow the desirable constituent percentage of these mineralogical phases. Lime, which is the common constituent of all these mineralogical phases, is determined for its quantitative input based on this mineralogical synthesis. But, in the process, the studies have revealed that undue quantities of lime are released during hydration, leaving opportunities for detrimental chemical reactions with atmosphere pollutants which are increasing everyday with rapid industrialization. This aspect has further substantiated the manifestation of distress in concrete structures constructed for the last fifty years over the structures that are centuries old.

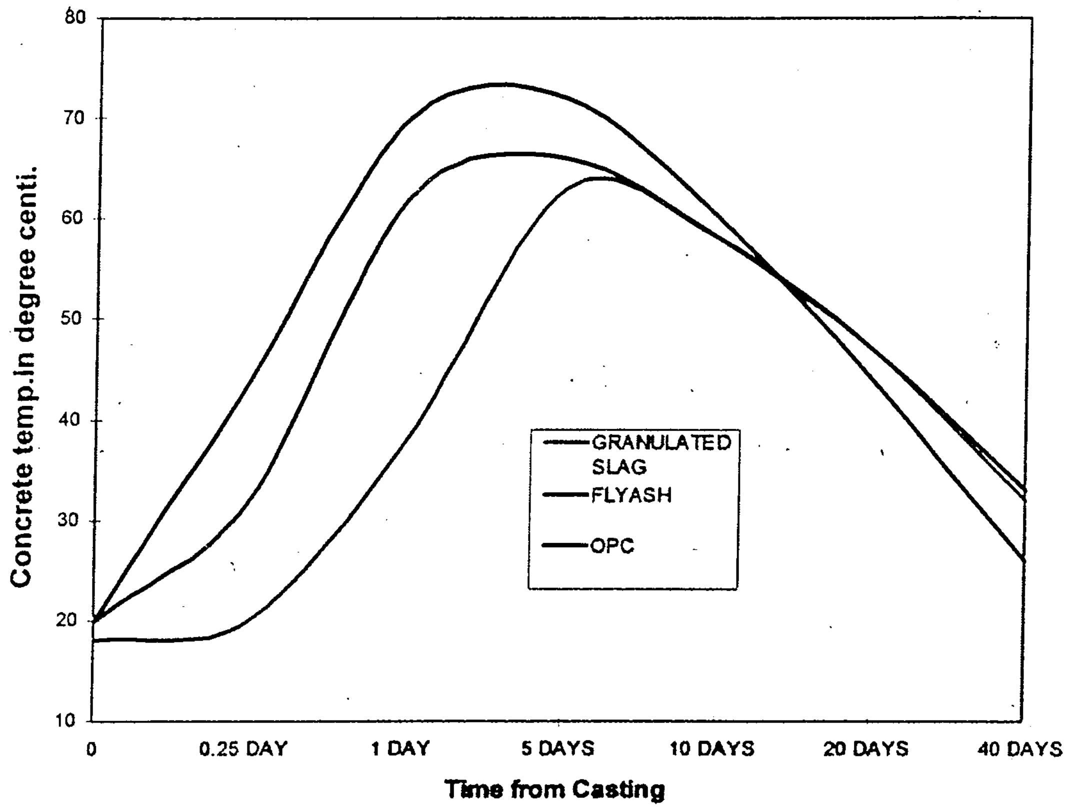
Cement obtained by directly grinding Clinker – Gypsum mixture is called OPC. There are three different grades of OPC, viz. 33 G, 43 G and 53 G. Grade indicates that the strength of cement mortar cubes (cement : sand – 1:3) tested under specified standard conditions should give a strength of minimum 33 N / sq.mm after 28 days. Similarly 43 Grade indicates 43 N/sq.mm and 53 grade indicates 53 N/sq.mm.

Higher strength levels (initial and final) are obtained by altering the chemical composition of C3A and C3S contents in clinker.

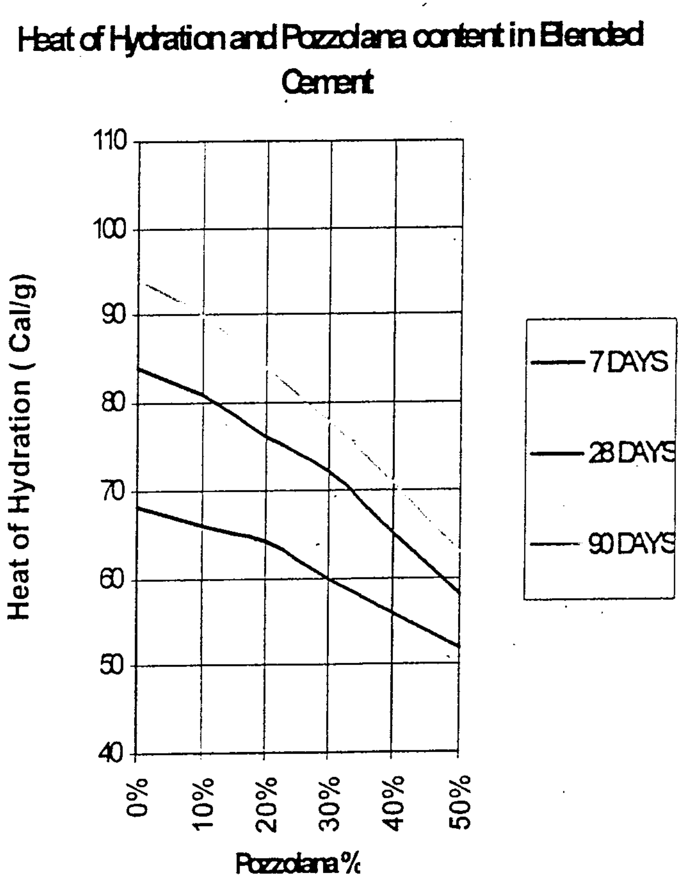
Heat of hydration increases with the increase in grade of cement due to the increase in C3A content. The concrete near the exposed side cools faster than the inside. The thermal strain because of differences in external and internal temperatures, brings in the problem of cracks. Moreover, the quantity of lime liberated is also higher in high-grade cements leading to leaching, porosity and chemical attach. A higher C3A content also makes the concrete more vulnerable to the attack of Sulphates. Therefore, use of high grade should be made selectively for concrete, with very good quality control measures.

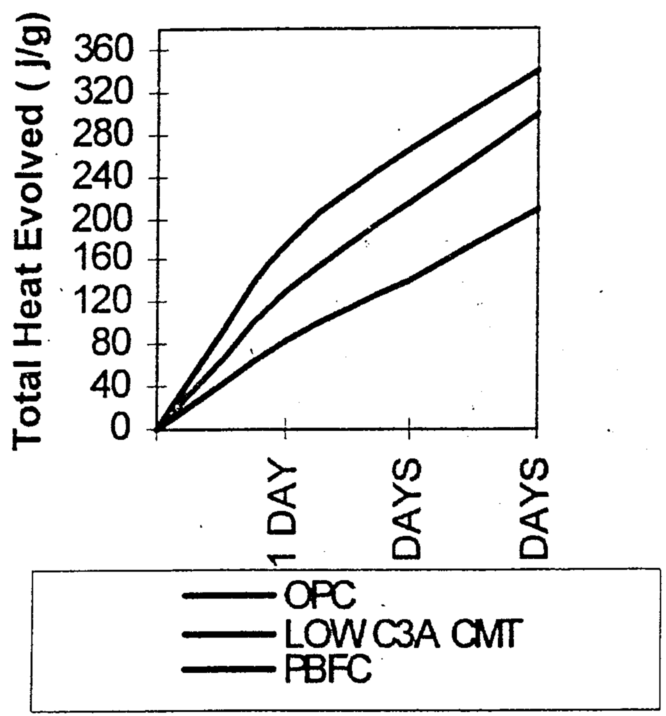
Blended Cements
Ideal for Mass Concreting

Temperature Rise In Large Foundation Units

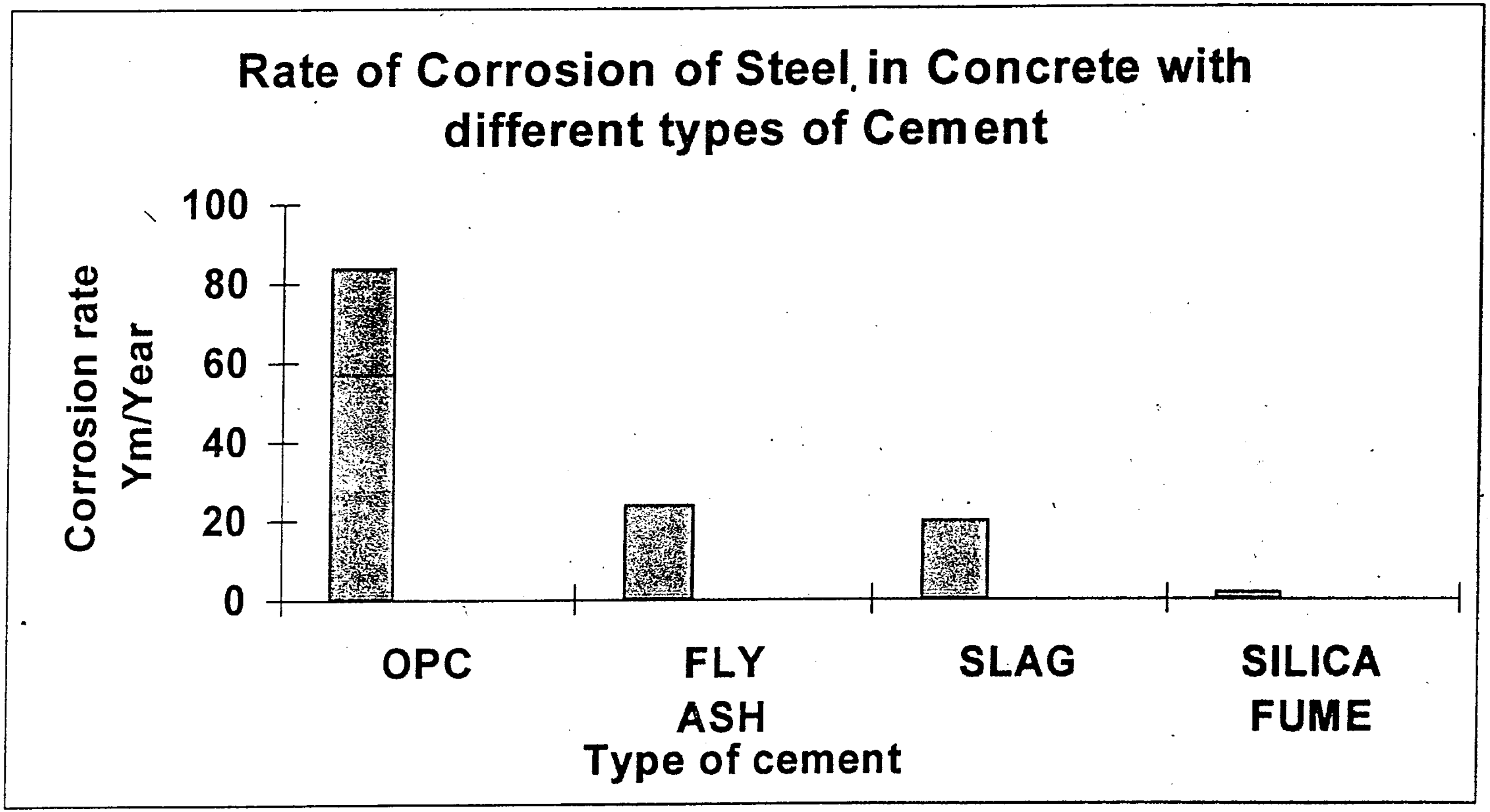


Blended Cements
Minimise Risk of Thermal Cracking

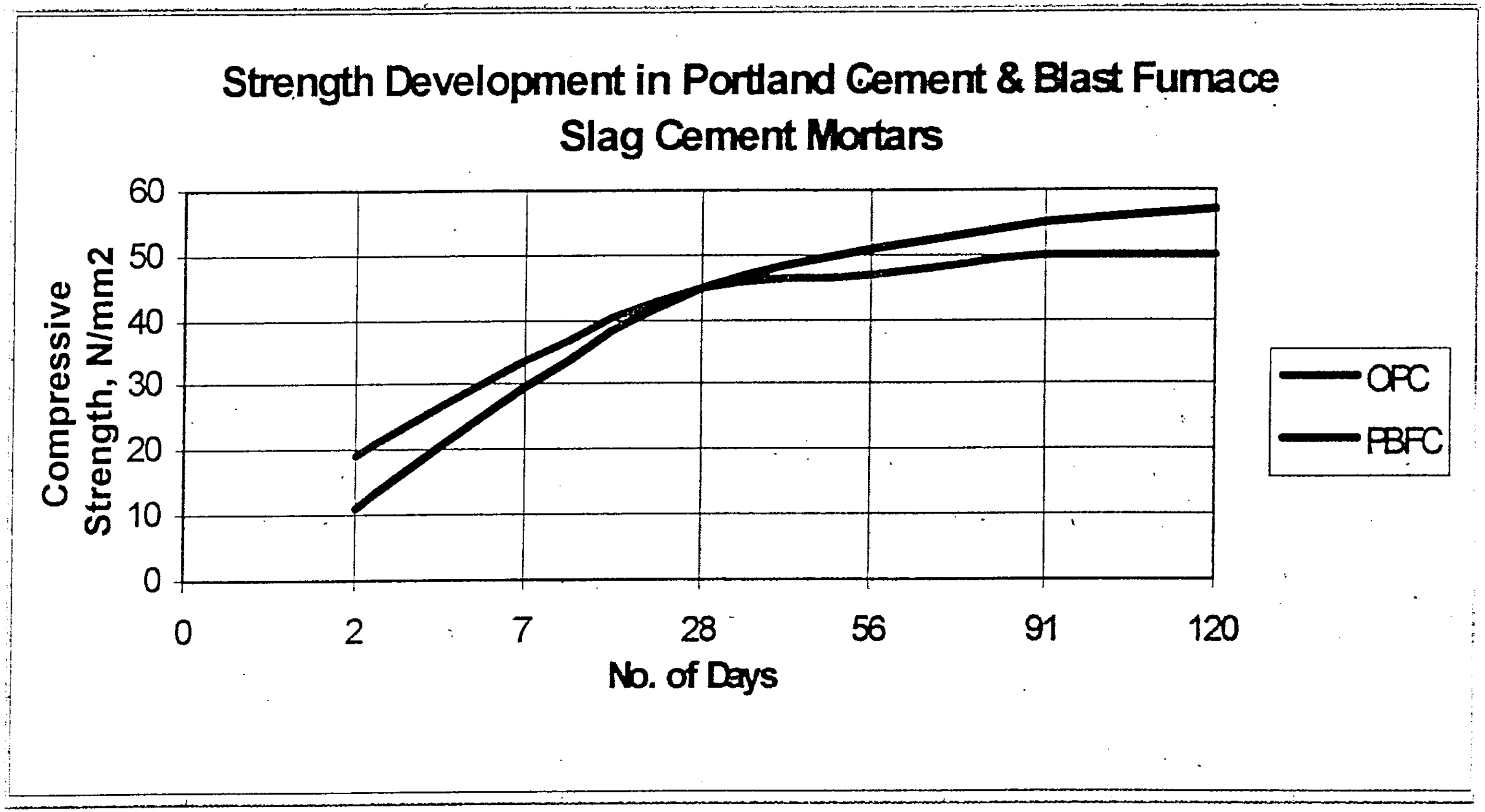




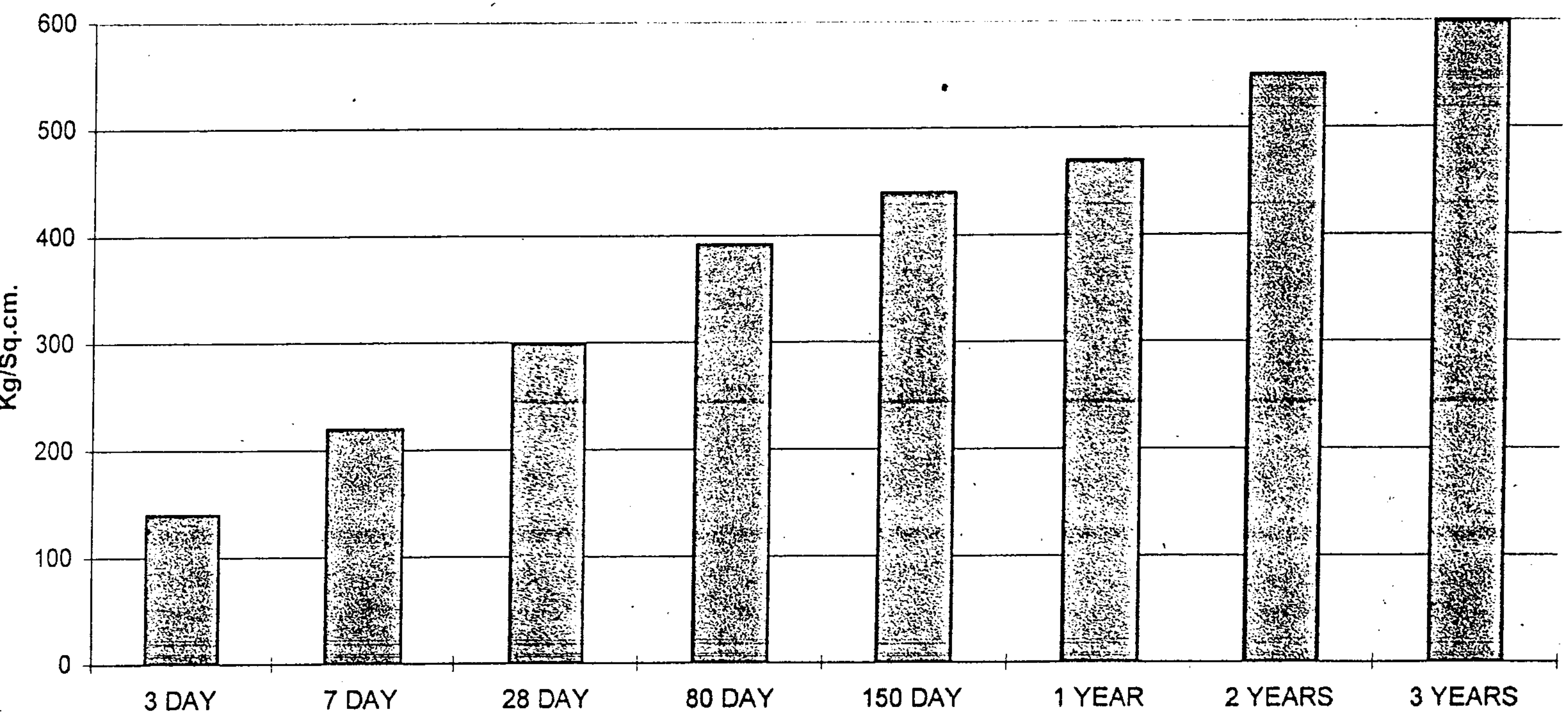
Blended Cements
Reduces corrosion of Reinforcement



Blended Cements
The Ultimate Winners



Blended Cements
Gaining Strength with Time



Cement content in concrete : 410 kg/m3 for M-30 grade concrete

Water Cement Ratio : 0.45

With proper mix design, using good aggregates and lower water content, higher grades of concrete may also be obtained.

Environment V/s Concrete

Hot -humid environment, salt -bearing ground water and reactive soil conditions cause :

- Thermal cracking
- Deleterious chemical reactions are activated
- Corrosion of steel in concrete
- Sulphate attack
- Leaching
- Carbonation
- Alkali -aggregate reaction

4. DETAILS OF MATERIALS USED

4.1 FLY ASH

Fly ash is a hasardous industrial works. It posses a formidable challenge to human ingenuity in regard to its satisfactory utilisation and or disposal. Its generation is highest at the thermal power plants. Currently India's thermal power generation capacities stands at 48,722Mw as year. (30.3.93) Which is stated to double during the next one-decade or so. Besides thermal power plants coal ash is also produced by other coal assuming industries such as cement, fertilizer, sugar, rubber, Iron and steels and all other requiring heat or steam for their operation. Until recently dumping of ash in rivers, lakes, ponds or other similar generated by the industry. When such sites were not conveniently located, coal and ash was merely allowed to accumulated on the near by available land. These disposal practices caused wide spread pollution of land, air and water. But only recently measures have been adopted to check on these practices making it all the more elegant for coal users to look for, suitable means of coal ash utilisation. Currently total ash generators by thermal power utilises is estimates out about 40 million tone, which may mount to 90MT by the year 2000.

COAL ASH AND ITS COMPOSITION: -

Coal ash forms about 3 –30% to about coal and gets separated into two parts bottom ash and fly ash. The chemical composition of coal ash depends on several factors. Geological and Geographic, as well as those creating to the compression condition and the efficiency of the air pollution control equipment. The oxides of Si, Al, Fe and Ce constitute 95% to 99% of the ash and the crest is made up of small amount Mg, Ti, S, Na, N and the traces of about 20 to 50 other elements.

By and large the distributions of major elements is found to be dust about the some in fly ash and bottom ash but in the case of trace elements concentration new vary in two types. The chemical and physical properties of Indians as shows marked variation depending largely on the coal quality which usually varies from mine to mine. Some thermal plants burn lignite also. Indian coal ash can therefore be classified into two difficult groups are bituminous and lignite. Lignite ash contains were CaO, MgO and Fe_2O_3 where bituminous coal as a higher % of Fe_2O_3 than CaO. Despite such variation most fly ashes meet the requirement of IS 3612-1931. Mineralogical composition of fly ash shows the preserve of trace elements units a fairly high concentration in some cases.

Concentration of trace elements in fly elements.

Element	Symbol	Concentration (ppm)
Sodium	Na	1299.00
Potassium	K	18275.00
Lanthanum	La	238.00
Cerium	Ca	145.00
Mercury	Hg	48.00
Terbium	Tb	887.00
Thorium	Th	25.00
Chromium	Cr	404.00
Hafnium	Hf	32.60
Scandium	Sc	106.00
Zinc	Zn	2027.00
Iron	Fe	106667.00
Tantalum	Ta	5.05
Cobalt	Co	128.00
Europium	Eu	5.6
Smarium	Sm	1.99
Gold	Au	0.69

Coal ash and Pollution:-

The presence of trace metals like arsenic, Cadmium, Vanadium etc., are even though is very small quantity can very harmful to human population, plants and animals. Inhalation of metals be more harmful ingestion by way of flood. Being highly toxic, the metals causes severe poisons and other helps hazards to human habitation located near the thermal plant, burning coal. Pumping of fly ash in and with sources caused severe water pollution through each action or as valuable contents from fly ash. At higher PH value Fe and Si also becomes soluble, then presence of these elements in water. Ca prove to be extremely harmful to aquatic life too. Similarly led pollution can become and serious problem as to study done by EDF in some areas has shown uncontrolled accumulate of coal ash thus carries with it the danger of a severe ecological disturbance in its immediate neighbour load.

Engineering properties of fly ash.

Sl. No.	Properties	Value
1.	Consistency	Non-plastic
2.	OMC	45%
3.	MOD	0-8 gm/cc
4.	Fire	7.7%

4.2 LIME:-

Lime is a simple cementing material produced by drinking off water from natural materials, its cementing properties are caused by the reabsorption of the expelled water and the formation of the same chemical compounds of which the original raw material was composed.

Due to calcination of lime stone, moisture and CO_2 are removed from it. Product which remains thereafter is known as lime. Its chemical composition is calcium oxide (CaO). The chemical reaction is as follows.

$$\underset{\text{(Lime stone)}}{CaCO_3} \longrightarrow \underset{\text{Lime}}{CaO} + \underset{\text{(Carbon dioxide)}}{CO_2}$$

Classification of lime:-

Building limes according to IS 712-1973 are classified under five categories, namely Class A, Class B, Class C, Class D and Class E.

Class A lime is the eminently hydraulic lime which is used for structural purpose and it is to be supplied in the hydrated form only. Its minimum compressive strength with lime sand mortar of proportion (1:3) by weight at the end of 14 days and 28 days should be respectively 17.5 kg/cm^2 and 28.00 kg/cm^2.

Class B lime is semi-hydraulic lime which is used for mortars for masonry work and it can be supplied either as quicklime or as hydrated lime. Its minimum compressive strength with lime sand mortar to proportion (1:3) by weight at the end of 14 days and 28 days should be 12.5 kg/cm^2 and 17.5 kg/cm^2 respectively.

Class C lime is the fat lime which is used mainly for finishing coat in plastering, white washing and with suitable admixture such as or any other Pozzolanic materials, to produce artificial hydraulic mortars.

Class D lime is the magnesium lime which is used for finishing coat in plastering, white washing etc.,

Class E lime is the kankar lime which is used for masonry mortar.

Engineering properties of lime:

Sl. No.	Properties	Value
1.	Unslaked weight	1080 kg/m^3
2.	Slaked weight	650 kg/m^3
3.	Optimum moisture constant	42.5%
4.	Man dry density	1.08 gm/cc
5.	Residue on slaking (on the basis of quick limes taken) maximum % by weight	IS sieve, the fraction passing through this sieve when pass through 300 micro sieve leaves residues.

4.3 GYPSUM:-

Definition:

Calcium sulphate combined with two molecules of water or crystalline form having the approximate formula $CaSO_4\ 2H_2O$.

Calcined Gypsum:

Gypsum partially dehydrated by means of heat having the approximate chemical formula $CaSO_4 \frac{1}{2} H_2O$.

4.4 AGGREGATES:

Aggregates comprise about 75% by volume of a typical concrete mix. The term aggregates includes the natural sands, gravels and crushed stone used for making mortars and concrete and also is approved to special materials used in producing light and heavy weight concrete. In casting cubes normal river sand and locally available coarse aggregates were used.

5. COMPARATIVE STUDY OF PORTLAND POZZOLANA CEMENT WITH ORDINARY POZZOLANA CEMENT

5.1 THEORETICAL BACKGROUND

MANUFACTURE OF PORTLAND CEMENT:

The raw materials required for manufacture of Portland cement are calcareous materials, such as lime stone or chalk, and argillaceous materials such as shale or clay. Cement factories are established where these raw materials are available in plenty.

The process of manufacture of cement consists of grinding the raw materials, mixing them infinitely in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 to 1500°C, at which temperature, the material sinters and partially fuses to form modular shaped clinker. The clinker is cooled and ground to a fine powder with addition of about 2 to 3% of gypsum. The product formed by using this procedure is Portland Cement.

There are three processes of burning: (a) Dry Process, (b) Wet Process, and (c) Semi-dry Process:

(a) In the dry-process, we have the following three variations:

(i) Long Rotary Kilns fitted with integral heat exchangers.

(ii) Short Rotary Kilns with suspension pre-heaters or cyclones.

(iii) Fluidised Bed Reactors. This is still in the experimental stage.

b) In the wet-process, there are the following three variations:

(i) Long Rotary Kilns fitted with integral heat exchangers, like pre-heaters, chains and crosses.

(ii) Short Rotary Kilns with external rotary or stationary heat exchangers (calcinators).

(iii) Shorter Rotary Kilns using filtered, low-moisture slurry cake as feed.

c) In the semi-dry process, there are two variations:

(i) Short rotary Kilns with moving grate heat exchangers at the feed end.

(ii) Vertical Shaft Kilns in which nodules of ground slurry and coal are fed.

CHEMICAL COMPOSITION OF CEMENT

The main raw materials for manufacturing cement are lime, silica, alumina and iron oxide. Depending upon the wide variety of raw materials used in the manufacture of cement, its oxide components vary widely.

Oxide	Content(%)
CaO	59-64
S_iO_2	19-24
Al_2O_3	3-6
Fe_2O_3	1-4
SO_3	1-3
MgO	0.5-4
Alkalis	0.2-1.3

The calcium oxide reacts with silica, alumina and iron oxide to form tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetracalcium alumino-ferrite. It also contains some other compounds in small quantities. The composition limits of these compounds are given below:

Compounds	Composition	Abbreviation	Content (%)
Tricalcium silicate	$3CaO\ SiO_2$	C_3S	30-50
Dicalcium silicate	$2CaO\ SiO_2$	C_2S	20-45
Tricalcium aluminate	$3CaO\ Al_2O_3$	C_3A	8-12
Tetracalcium alumino-ferrite	$CaO\ Al_2O_3\ Fe_2O_2$	C_4AF	6-10
Other compounds	MgO, K_2O, Na_2O	--	2-3

TYPES OF CEMENT:-

A wide variety of cements are available which are suitable for use under certain conditions due to its special properties. they are

1. Ordinary Portland cement.
2. Rapid hardening Portland cement.
3. Extra rapid hardening Portland cement.
4. Low heat Portland cement.
5. Sulphate-resisting Portland cement.
6. Super sulphated cement.
7. High alumina cement.
8. Portland blast furnace cement.
9. Pozzolanic cement.
10. White Portland cement.
11. Air entrainig cement.
12. Hydrophobic cement.

PHYSICAL PROPERTIES OF CEMENT:

Following are the important physical properties of cement.

1. Chemical composition.
    a. Loss on ignition.
    b. Insoluble residues.
    c. Lime and alumina content.
    d. Magnesia content.
    e. Sulpher content.
2. Fineness
3. Normal consistency
4. Setting time.
5. Soundness
6. Heat of hydration
7. Strength of cement.

5.2 PRACTICAL BACKGROUND

AGGREGATE:

A mixture of only cement and water is costly and processes low strength and shrinks unacceptably on drying. In order to reduce the cost and modify such properties as the strength and drying shrinkage of the hardened mass, it is usual to introduce insoluble non-cementations particles described as aggregates.

Classification of Aggregates:-

Aggregates are classified as coarse aggregate and fine aggregate base upon their sizes.

a. Coarse aggregate: It passes through an 80mm sieve and retained on a 4.75mm sieve.

b. Fine aggregate: It passes through a 4.75mm sieve and retained on a 75 micron sieve.

PHYSICAL PROPERTIES OF AGGREGATES:

Following are the important properties of aggregates.

1. Size of aggregates
2. Shape of particles
3. Surface texture
4. Strength of coarse aggregates
5. Specific gravity

6. Bulk density
7. Water absorption and surface moisture
8. Bulking of sand
9. Deleterious substance
10. Soundness
11. Durability

CONCRETE:

Concrete is a freshly mixed material which can be moulded into any shape. The relative quantities of cement, aggregates and water mixed together control the properties in the wet state as well as in the hardened state.

PROPERTIES OF CONCRETE:

The characteristics or qualities which generally affect the behaviour and nature of concrete are known as properties of concrete.

The properties of concrete are studied in two stages.

1. Properties in plastic stage.
2. Properties in hardened stage.

The properties of concrete in plastic stage are

a. Workability
b. Freedom from segregation.
c. Freedom from bleeding.

The important properties of hardened concrete are

a. Strength
b. Elasticity
c. Shrinkage
d. Creep
e. Thermal expansion

TESTS ON CONCRETE:

Test for fresh concrete:

It is desirable that fresh concrete be relatively easy to mix, transport, deposit, compact and finish and that it remains free from segregation during these operations . The composite quality involving ease of placement and resistance to segregation is termed "Workability".

The essential properties which make up workability are

a. Compactability
b. Mobility and
c. Stability

6. I.S. CODE PROVISION

6.1 I.S. CODE PROVISION : LIME POZZOLANA MIXTURE: (I.S.: 4098 – 1983)

Lime pozzolana mixture which is essentially a mixture of lime and pozzolana, which alternates ordinary portland cement for certain categories of work likes masonry and concreting in various construction activities. This lime pozzolana mixture is also used in the manufacture of precast blocks and is also used for soil stabilization and in construction of water bound macadam road.

The lime pozzolana mixture contains namely class C hydrated lime **(IS:712-1973)** and Pozzolana such as burnt clay **(IS:1344-1981)** or fly ash **(IS:3812-1981)** and TYPE-IV mineral gypsum **(IS:1290-1973)** not exceeding 5%.

6.2 IS CODE PROVISION FOR LIME POZZOLANA CONCRETE: (IS – 5818 – 1970)

Lime pozzolana concrete is found to have many desirable properties advantages for use in road and building construction. The value of drying shrinkage of lime pozzolana concrete have been observed to vary from 0.019 to 0.04% which compares favourably, with values of 0.027 to 0.038% and 0.043 to 0.058% respectively for plain cement and pozzolana cement concrete of 1:5 and 1:6 nominal mix proportion. There is only negligible volume change after setting and initial shrinkage in pozzolana.

Well compacted lime pozzolana concrete is also found to be less permeable due to lime pozzolana concrete being more cohesive and plastic in nature than cement concrete of equivalent strength. The bond strength between lime – pozzolana concrete is found to be of the order 1.5 to 2 N/mm^2.

Details Of Experimental Work

7. DETAILS OF EXPERIMENTAL WORK

7.1 MIX DESIGN OF CONCRETE:

Minimum strength of concrete required at 28 days – 15 N/mm^2.

Fair control

Degree of workability required is good.

FM of Coarse Aggregate = 6.5

FM of Fine Aggregate = 2.5

Concrete is not vibrated.

Maximum aggregate size is 20mm (Angular)

$$\text{Design strength} = \frac{15}{0.6} = 25\ \text{N/mm}^2$$

Water cement ratio : 0.65

Slump in mm for medium degree of workability is taken as 75 mm.

For maximum size of 20mm coarse aggregate for 75 mm slump water required for angular coarse aggregate is 200 kg/m^3

Water Cement Ratio is : 0.65

$$\text{Cement/mm}^3 \text{ of concrete} = \frac{200}{0.65} = 333.33\ \text{kg}$$

Minimum value of fineness modulus of mixed aggregate F_m = 4.8

$$\% \text{ of fine aggregate} = \frac{F_c - F_m}{F_c - F_f} \times 100$$

$$= \frac{6.5 - 4.8}{6.5 - 2.5} \times 100 = 42.5\%$$

Percentage of coarse aggregate = 100 – 42.5

= 57.5%

$$\text{Absolute volume of water} = \frac{200}{1000} = 0.2 \text{ m}^3$$

$$\text{Absolute volume of cement} = \frac{333.33}{3.15 \times 10^3} = 0.106 \text{ m}^3$$

Absolute volume of mixed aggregate = 1 – (0.2 + 0.106)

= 0.694 m^3

$$\text{Absolute volume of FA} = 0.694 \times \frac{42.5}{100} = 0.295 \text{ m}^3$$

$$\text{Absolute volume of CA} = 0.694 \times \frac{57.5}{100} = 0.399 \text{ m}^3$$

Weight of FA/m^3 of concrete = $0.295 \times 2.65 \times 10^3$

= 681.75 kg.

Weight of CA/m^3 of concrete = $0.395 \times 2.8 \times 10^3$

= 1117.2 kg.

Proportion by weight = 333.33 : 681.75 : 1117.2

Mix ratio by weight = 1 : 2.04 : 3.85

7.2 FINENESS TEST:

Fineness of cement may be defined by

1. The relative proportion of particles coarser than a prescribed size (90 microns as per IS specifications).
2. Specific surface area of particles in 1g of cement.

Object:

To determine the fineness of cement by dry sieving as represented by the weight of the residue left on a standard 90 micron IS sieve.

Apparatus required:

IS sieve – 90 micron size, stop clock, balance to weight to an accuracy of 0.01g.

Procedure:

1. Break down the air-set lumps. If any in the cement sample with fingers.
2. Weigh accurately 100g of the cement and place it on a standard 90 micron IS sieve.

3. Sift the sample continuously for 15 minutes by holding the sieve in both hands and giving a gentle wrist motion. More or less continuous rotation of the sieve shall be carried out throughout the sieving. The underside of the sieve shall be lightly brushed with a 25 or 40mm bristle brush after every five minutes of sieving.

4. Weigh the residue left after sieving and report the value as percentage weight of the original sample taken.

Table 1. Fineness of OPC and PPC.

Grade	Weight of cement	Weight of residue	Fineness
43	100	8.5	8.5
53	100	6.0	6.0
PPC	100	3.5	3.5

Result:

Fineness of 43 Grade = 8.5

Fineness of 53 Grade = 6

Fineness of PPC = 3.5

7.3 STANDARD CONSISTENCY TEST:

Consistency of cement paste is its property by virtue of which it flows without segregation. It is defined by the degree of wetness. The standard consistency of cement is defined as the percentage water required, by weight, to produce a paste which permits the Vicat Plunge to penetrate to a point 5 to 7 mm from the bottom of the Vicat mould. The Vicat apparatus consists of a frame bearing a movable rod with a cap at one end and at the other end having provisions for fixing a brass plunger or setting time needles. This moving rod carries an indicator which moves over a graduated scale attached to the frame.

The total weight of moving rod with the cap and plunger is 300 g. The plunger used for consistency test is of polished brass 10 mm diameter and 50 mm long with a projection at the upper end for insertion into the movable rod. The bottom is flat. The mould for the cement paste consists of a split ring 80 mm internal diameter and 40mm high, resting on a non-porous plate.

Procedure:

1. Weight out 400 gm of sample of cement on a non-porous plat form and make it into a heap with a depression in the centre to hold the mixing water.

2. Take 30 percent water by weight of dry cement and add this to the cement.

3. Mix the cement and water carefully together thoroughly. The process of mixing shall include kneading and threading. The total time elapsed from the moment of adding water to the moment when mixing is completed shall not be less than 4 minutes and not more than 5 minutes.

4. Fill the mould completely with the cement paste and smooth off the surface of the paste making it level with the top of the mould. The mould may be slightly shaken to expel the air.

5. Keep the mould under the plunger, lower the plunger gently touch the surface of the paste and release the rod quickly.

6. After the plunger has come to rest, note the reading against the scale.

7. Repeat the experiment with trial pastes of varying percentages of water till the plunger comes to rest between 5 to 7 mm from the bottom.

Table 2. Test for consistency of Cement 53 Grade

Weight of cement = 300g

S.No.	Water cement ratio	Amount of water added	Non penetrated distance
1.	0.25	75	8
2.	0.26	78	15
3.	0.27	81	10
4.	0.28	84	8
5.	0.29	87	4
6.	0.285	85.5	5

Table 3. Consistency for PPC

S.No.	Water cement ratio	Amount of water added	Non penetrated distance
1.	0.26	78	14
2.	0.27	81	10
3.	0.28	84	8
4.	0.29	87	6

Table 4. Consistency for 43 Grade

S.No.	Water cement ratio	Amount of water added	Non penetrated distance
1.	0.26	78	9
2.	0.27	81	3
3.	0.265	79.5	8
4.	0.27	81	15
5.	0.28	84	6
6.	0.29	87	5

Result:

Consistency of 53 Grade = 0.28

Consistency of 43 Grade = 0.285

Consistency of PPC = 0.29

7.4 SETTING TIME:

Object:

To determine the initial and final setting times of the given cement.

Theory: Setting is the process in which the plastic paste changes into a solid mass. The time taken for setting depends on the amount of gypsum present in the cement. The initial set is that stage at which any cracks that appear on the surface will not reunite. A square needle of 1mm size is used to determine the initial setting time of cement.

The period that elapses between the time of adding water to the cement and the time at which the Vicat needle fails to penetrate the standard paste completely (beyond 35mm from top) is taken as the initial setting time of the cement.

The final set relates to the completion of the setting process. A separate needle fitted with an annular ring is used to determine the final setting time. The period that elapses between the time of adding water and the time at which the needle makes an impression on the surface of paste while the attachment fails to do so is taken as the final setting time of the cement.

Procedure:

1. Weigh out 250g of the sample of cement on to a non-porous platform and stack it into a heap with a depression in the centre.

2. Calculate the amount of water to be added as 0.85 time the amount of water required to produce a paste of standard consistency. Add this calculated quantity of water to the cement and simultaneously start a stop clock.

3. Mix the cement and water thoroughly and fill the mould completely with the paste. Smooth of the surface of the paste making it level with the top of the mould. Slightly jar the mould to drive-out all the entrapped air.

4. Place the mould under the Vicat needle, lower the needle gently to touch the surface of the paste and release it quickly. Note down the depth of penetration of the needle. Raise the moving rod and wipe the needle clear.

5. Repeat step No. 4 at regular of time (at various locations) till the needle stops at a height of 5mm above the base.

6. See the clock and note down the time elapsed as the initial setting time.

7. Replace the needle by the needle with annular attachment.

8. Release the moving rod at regular interval of time and observe the impression made by the needle. Note the time elapsed when the needle makes a mark but the metal attachment fails to do so as the final setting time of the cement.

Table 5. Initial setting for 53 Grade cement.

S.No	Time	Time for penetration (Sec)	Non penetrated distance
1.	30-30.20	20	0
2.	60-6.28	28	0
3.	90-90.35	35	1
4.	95-95.35	35	1
5.	101-101.35	35	1
6.	105-105.37	37	2
7.	120-120.39	39	2
8.	120-120.39	41	3
9.	165-165.43	43	5
10.	170-170.45	45	6

Table 6. Initial setting time for PPC.

S.No.	Time	Time for penetration (Sec)	Non penetrated distance
1.	30-25	25	0
2.	60-27	27	0
3.	70-37	37	1
4.	75-35	35	1
5.	81-36	36	3
6.	85-38	38	3.5
7.	100-38	38	4.0
8.	120-39	39	4.5
9.	130-41	41	5
10.	140-41	43	6

Table 7. Initial setting time for 43 Grade.

S.No.	Time	Time for penetration (Sec)	Non penetrated distance
1.	30-30.20	20	0
2.	60-6.26	26	1
3.	90-90.32	32	2
4.	95-95.35	35	3
5.	105-105.37	37	4.5
6.	110-110.38	38	5
7.	120-120.39	39	5.5

Result:

Initial setting time for 53 Grade = 170

Initial setting time for 43 Grade = 110

Initial setting time for PPC = 140

Final setting time for 53 Grade = 228

Final setting time for 43 Grade = 192

Final setting time for PPC = 215

7.5 WORKABILITY

Object:

This test is intended for determining the consistency of freshly mixed concrete and for defining ranges of consistency of concrete based on the slump values.

Apparatus required:

1. Slump cone, 300mm high, 200mm diameter of base and 100mm diameter of top.
2. Trowel
3. Tamping rod – 600mm long, 16mm diameter round nosed.
4. Scale
5. Straight edge
6. Measuring cylinder
7. Mixing pan and
8. Balance.

Procedure:-

1. Mix the materials – cement and aggregates in their proper proportions – in the dry state to have a uniform mixture (For 1:2:4 concrete take 9kg of coarse aggregate, 4.5kg of fine aggregate and 2.25kg of cement.

2. Calculate the required quantity of water for a particular water-cement ratio. Add this amount of water to the mixture and mix it thoroughly.
3. Keep the slump on a smooth rigid platform add fill it with the concrete prepared in four equal layers, tamping each layer 25 times with the standard tamping rod. The strokes shall be distributed uniformly over the surface and shall just penetrate into the layer beneath.
4. When the top layer has been tamped, strike off the concrete with a trowel, leaving the mould exactly filled.
5. Remove all excess concrete lying around the cone and remove the slump cone by a steady upward pull.
6. Measure the slump immediately by determining the difference between the height of the mould and the height of vertical axis of the specimen.
7. Repeat the experiment with different water-cement ratio and record the corresponding slump values.

Table 8. Slump value for OPC and PPC

Grade of cement	Water cement ratio	Volume of water added	Slump (mm)
43	0.65	1950	75
53	0.65	1950	78
PPC	0.65	1950	85
43	0.6	1800	68
53	0.6	1800	72
PPC	0.6	1800	76
43	0.7	2100	78
53	0.7	2100	82
PPC	0.7	2100	91

7.6 COMPACTION FACTOR TEST:-

Object:

This test is for determining the compactability of concrete. It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration.

APPARATUS REQUIRED:-

1. Compacting factor apparatus.
2. Trowel, tray, measuring jars etc.,
3. Balance
4. Tamping rod.

Procedure:

1. Mix the materials-cement and aggregated in their proportions – in the dry state to have a uniform mixture.

2. Calculate the required quantity of water for a particular water cement ratio. Add this amount of water to the mixture and mix it thoroughly.

3. Fill the upper hopper with the prepared concrete using a land scoop.

4. Open the trap door of the upper hopper and allow the concrete to fall into the lower hopper.

5. Immediately after the concrete has come to rest, open the trap door of the lower hopper and allow the concrete to fall into the cylinder.

6. Cut off the excess of concrete remaining above the level of the top of the cylinder. wipe the outside of the cylinder clean.

7. Determine the height of the concrete in the cylinder. This height is known as the height of partially compacted concrete.

8. Remove the concrete from the cylinder and refill the cylinder to top with the same concrete in layers of 50mm depth, each layer being rammed heavily to obtain full compaction.

9. Determine the height of the fully compacted concrete and find out the compacting factor.

10. Repeat the experiment with different water-cement ratios.

Table 9. Compaction factor for OPC and PPC.

Grade	Water cement ratio	Amount of water taken (ml)	Weight of empty cylinder (W1)g	Weight of cylinder + Partially compacted concrete (W2) g	Weight of partially compacted concrete Wp=W2-W1 g	Weight of cylinder + fully compacted concrete (W3) g	Weight of fully compacted concrete Wf=W3-W1 (g)	Compacting factor = Wp/Wf
43	0.65	1950	10850	22025	11175	22997	12147	0.92
53	0.65	1950	10850	22317	11467	23049	12199	0.94
PPC	0.65	1950	10850	22869	12019	23114	12264	0.98

Result:

Compaction factor for 43 Grade = 0.92
Compaction factor for 53 Grade = 0.94
Compaction factor for PPC = 0.98

7.7 COMPRESSIVE STRENGTH

(I) COMPRESSION TEST ON CEMENT MORTAR CUBES

Object:

The cement mortars and concrete are usually subjected to compressive forces in structures. The object of this test is to determine the suitability of the given cement for developing the required compressive strength of concrete. The compressive strength of cement is determined by testing cement mortar cubes compacted by means of a standard vibrating machine or poking rod.

Apparatus required

1. Compression Testing machine (or) U.T.M.
2. Cube moulds of face area 50 cm^2
3. Mixing pan
4. Measuring jar
5. Gauging trowel
6. Standard vibrating machine or poking rod.

Procedure: (a) Preparation of cubes:

1. Assemble the mould after coating all joints with a light film of paraffin of petroleum jelly. Give a light coating of mould oil to the inner faces of the mould. Mount the mould under the hopper of the vibrating machine and tighten the holding nuts firmly. If vibrating machine is not available, a poking rod as described below can be made use of. The poking rod shall be made on non absorptive, non abrasive, non brittle material such as rubber compound having shore A durometer hardness of 80 $\pm$ 10, or seasoned teakwood rendered non absorptive by immersion for 15 minutes in paraffin at approximately 200° C. This rod shall be 150 to 175 mm long and shall have cross section of 12 mm x 25 mm with tamping face in the form of a blunt torpedo.

2. Place on a non-porous plate the mixture of cement and standard sand in the proportion of 1:3 by weight. Mix it dry with a trowel for one minute and then with the required amount of water until the mixture is of uniform colour. The time of gauging shall not be less than 3 minutes and not more than 4 minutes.

4. Cover the mould with a damp cloth and leave it undisturbed for 24 hours. The cloth may be moistened periodically if necessary.

5. Remove the cube from the mould and submerge it is fresh water for curing. Six such cubes shall be made, three for testing of the end of 3 days and the rest for testing at the end of 7 days.

6. Just prior to testing, remove the cubes from water, wipe the surface clean and record the weight.

(b) Testing:-

The cubes are to be tested on their sides without any packing between the cube and the steel patterns of the testing machine.

Apply the load gradually at a rate of 3.5 N/mm^2/minute and rate the ultimate counting rate.

(II) COMPRESSIVE STRENGTH:-

The test specimens cubical in shape 150 x 150 x 150 mm are cast in cube moulds by filling the concrete in the mould in layers of approximately 500mm deep, and compacted by means of a tamping bar of 16mm diameter, 0.6m long and bullet pointed and the lower end. Each layer of concrete is given 35 strokes. After curing the specimen for 24 hours ± ½ hours and 72 hours ± 2 hours or 7 days or 14 days or 28 days according to the age of test. They are tested in the testing machine. The specimen shall be placed in the machine in such a manner that the load shall be applied to the opposite sides of the cubes as cast, and not to the top and bottom as cast. The load shall be applied without shock and increased at a rate of approximately 14 N/mm^2/minute until the resistance of the specimen to the increasing load breaks down and no grater load can be sustained.

The ultimate compressive strength of specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area.

Table 10. COMPRESSION STRENGTH OF CONCRETE CUBE

Water Cement Ratio = 0.65

43 Grade			
3 days N/mm^2	7 days N/mm^2	28 days N/mm^2	36 days N/mm^2
10.96	17.82	26.60	28.73
11.02	17.97	26.42	28.53
10.99	17.90	26.51	28.63

53 Grade			
3 days N/mm^2	7 days N/mm^2	28 days N/mm^2	36 days N/mm^2
12.96	21.71	32.4	34.99
11.78	21.70	31.1	35.2
12.37	21.71	32.25	35.01

PPC			
3 days N/mm^2	7 days N/mm^2	28 days N/mm^2	36 days N/mm^2
8.68	14.54	21.7	23.44
9.12	14.63	20.9	24.01
8.9	14.59	21.3	23.73

Table 11. Compressive strength for mortar cube.

43 GRADE				
% of water	3 days N/mm^2	7 days N/mm^2	28 days N/mm^2	36 days N/mm^2
11	21.5	31.5	52.1	56.9
11	20.8	32.7	54.7	59.6
	21.17	32.1	53.4	58.3

53 GRADE				
% of water	3 days N/mm^2	7 days N/mm^2	28 days N/mm^2	36 days N/mm^2
10.6	30.0	46.7	66.7	74.7
10.6	31.2	46.6	68.2	75.2
	30.6	46.7	67.5	74.9

PPC				
% of water	3 days N/mm^2	7 days N/mm^2	28 days N/mm^2	36 days N/mm^2
10.75	9.2	20.2	39.2	46.3
10.75	10.7	21.4	38.8	45.9
	9.95	20.8	39.0	46.1

7.8. SIEVE ANALYSIS OF AGGREGATES:

Object:

To draw the grading curves for the aggregates and to determine their fineness values.

Theory:

Aggregates are termed as well graded when they contain particles of different sizes in the required proportion to produce the required qualities such as workability, density uniformity etc., to the concrete. When they contain particles of more or less same size they are termed as uniformly graded aggregates.

- The grading limits specified by I.S. codes for fine, coarse and all-in aggregates of different nominal sizes are given.

The average size of particles in the aggregate is roughly expressed by the fineness modulus number.

Apparatus required:

1. I.S. Sieve set
2. Balance

Procedure:

1. For testing fine aggregates take seives of sizes 4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron and 150 micron. For coarse aggregates take sieves of sizes 80 mm, 40mm, 20 mm and 10 mm also in addition to the above sieves.

2. Take about 1000 g of given aggregate.

3. Arrange the sieves in the order of sizes and sift the sample successively in each sieve, starting from the sieve of larger size and find the weight of residue in each sieves.

4. Tabulate the results in a Tabular column and calculate the percentage weight of residue, cumulative percentage of residue and percentage weight of particles passing in each sieve.

Table 12. Fineness modulus of Coarse aggregate.

S.No.	Sieve size	Weight of materials retained	% of weight retained	Cumulative weight retained	Cumulative % passing
1.	80	0	0	0	100
2.	40	85	1.7	1.7	98.3
3.	20	656	13.12	14.82	85.18
4.	10	446.5	8.93	23.75	76.25
5.	4.75	550	11.0	34.75	65.25
6.	2.36	982.5	19.65	544	45.6
7.	1.18	267.5	5.35	59.75	40.25
8.	600	200	4.00	63.75	36.25
9.	300	40	0.8	64.55	35.45
10.	150	168	3.36	67.91	32.09
11.	75	95.5	1.91	69.82	30.18
12.	Receiver	1249	24.98	94.8	5.2
					650

Table 13. Fineness modulus of fine aggregate.

S.No.	Sieve size	Weight of materials retained	% of weight retained	Cumulative weight retained	Cumulative % passing
1.	4.75	40	0.8	0.8	99.2
2.	2.36	2185	43.7	44.5	55.5
3.	1.18	1269	25.38	69.88	30.12
4.	600	2623	7.87	77.75	22.25
5.	300	345	6.89	84.64	15.36
6.	150	191	3.82	88.46	11.54
7.	75	43	0.86	89.32	10.68
8.	Receiver	266.5	5.33	94.65	5.35
					250

Result:

Fineness modulus of Coarse Aggregate = 6.5

Fineness modulus of Fine Aggregate = 2.5

8. DISCUSSION OF TEST RESULTS

8.1 Setting Time:

Setting time test is conducted for OPC(43 and 53 grade) and for PPC, standard consistency for each grade is used from the test results. The result conclude that PPC takes more time to set when compare to 43 grade and take less time when compare to 53 grade.

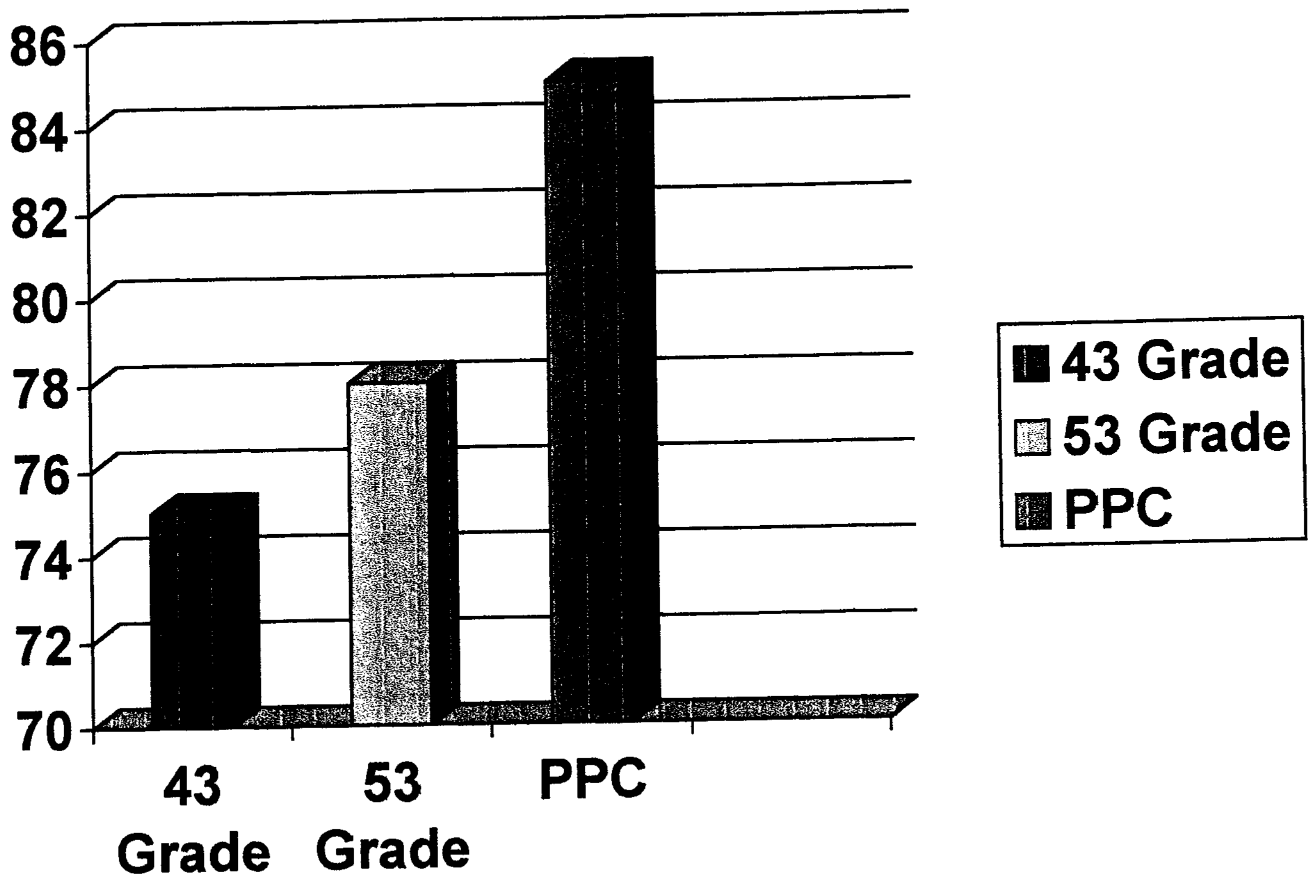
8.2 Workability:

Pozzolana is a finely divided material PPC tends to have a higher specific surface than other types of cement, and the minimum requirement for specific surface is 300 m^2/kg as compared to only 225 m^2/kg for OPC. Obviously using the same aggregate and water for mixing concrete made with PPC will be more cohesive than that made with OPC. Usually, the concrete made with PPC appears to be sticky and less workable. In natural fact, this appearance is misleading for under vibration but this study conclude that PPC have good workability.

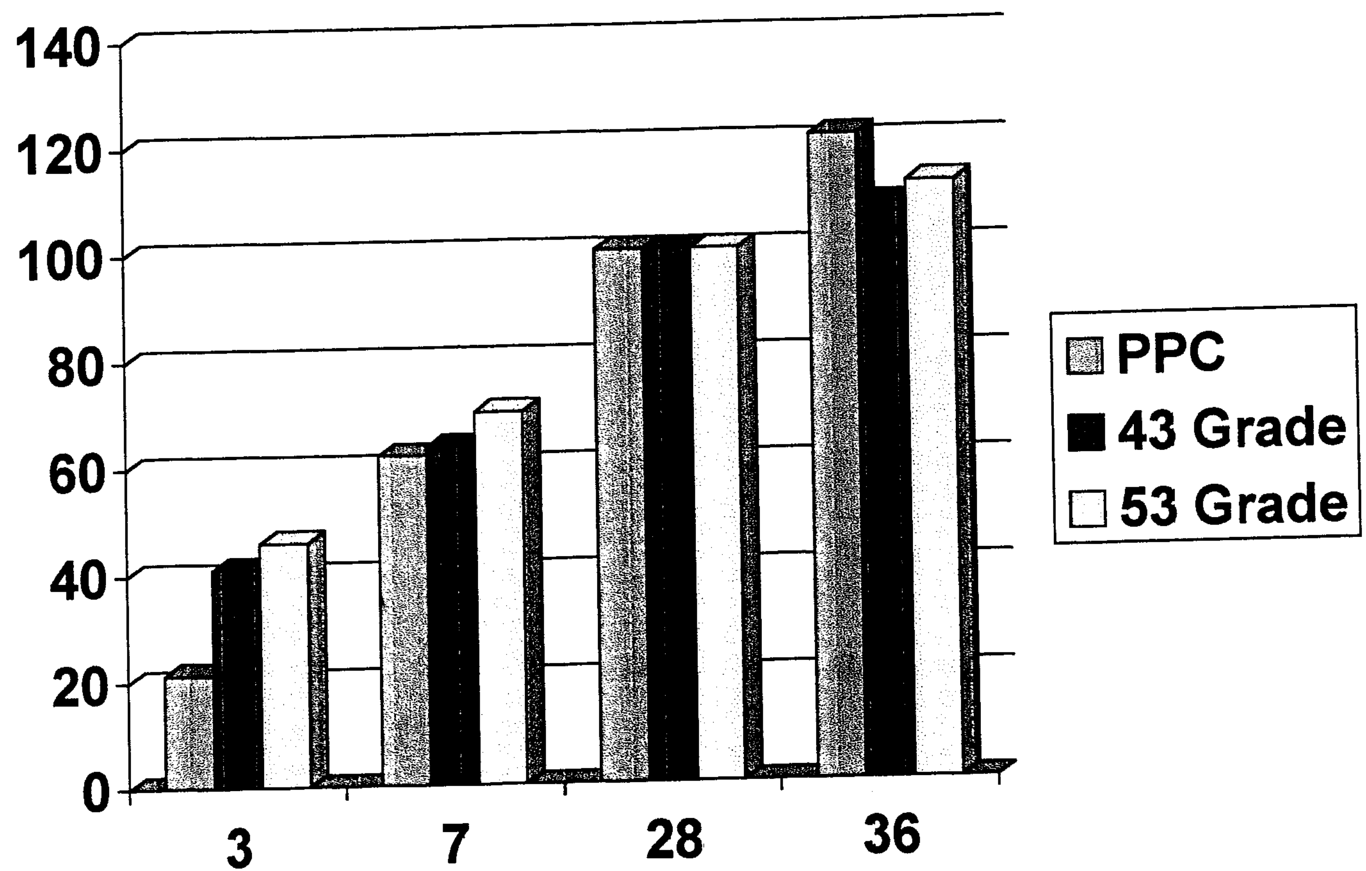
8.3 Compressive Strength:

This study concludes that strength gaining of PPC is slower in the earlier stage but increase in strength after 25 days, which is not possessed by OPC. The graph of percentage of strength gained clearly indicate the same.

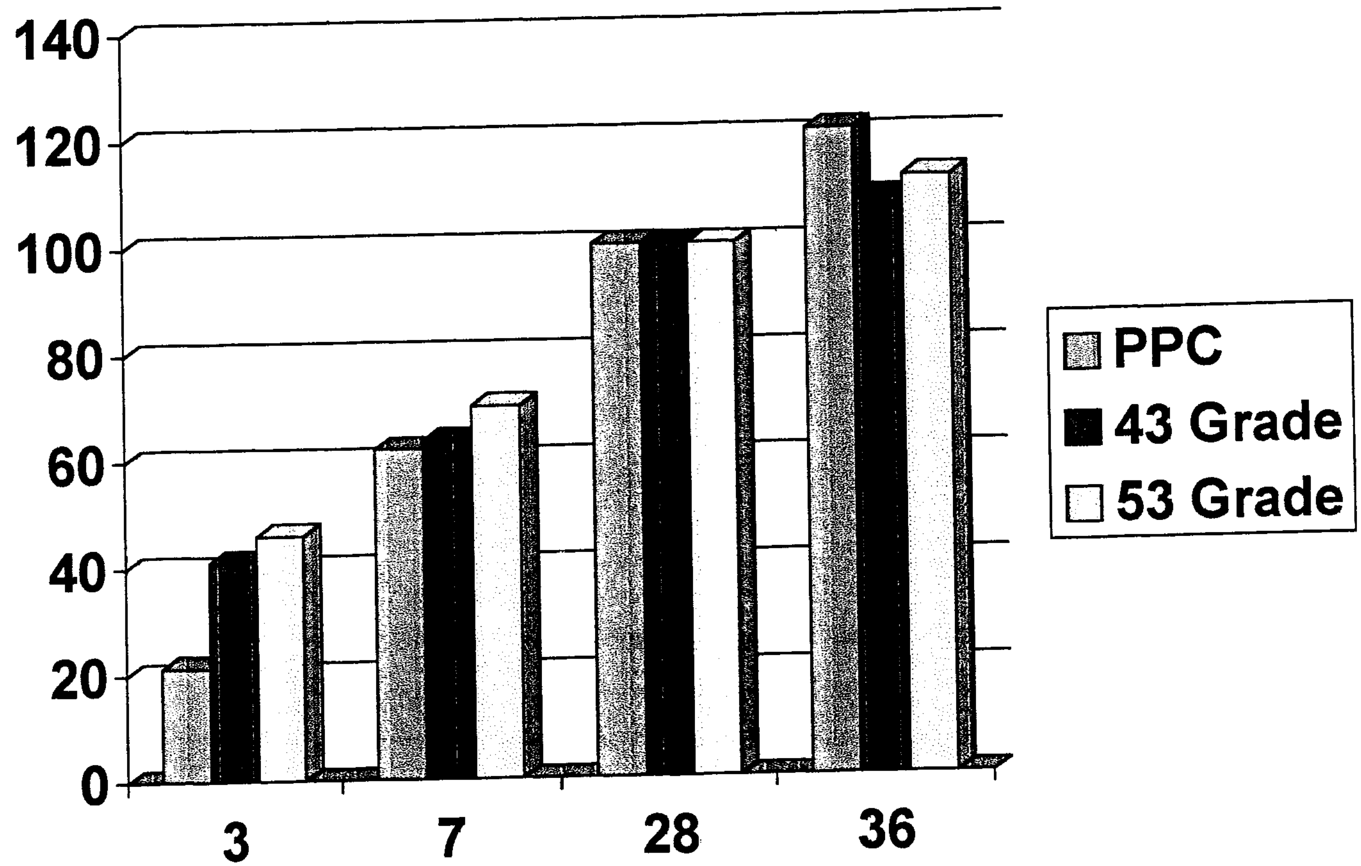
WORKABILITY CHART (WATER CEMENT RATIO 0.65)



PERCENTAGE OF STRENGTH GAINING IN CONCRETE CUBE



PERCENTAGE OF STRENGTH GAINING IN CEMENT MORTAR CUBE 1:3



9. CONCLUSION AND SUGGESTIONS FOR FUTURE WORK.

9.1. Conclusion:-

From this studies, it is concluded that the PPC having the following characters.

1. Standard consistency of 29% of water cement ratio.
2. It have good workability.
3. Setting time taken by PPC is greater than 43 grade OPC.
4. Strength gaining is slow in earlier stage but it posses a grade at increase in strength after 28 days. This character is not present in OPC.

9.2 Suggestions for future work:

Strength gaining of PPC can be studied for longer duration of time.

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