A
Major Project
on

ROLE OF WATER AND FACTORS AFFECTING IT IN CONCRETE

Submitted in Partial fulfillment of the requirement

for the award of the degree of

MASTER OF ENGINEERING

(Structural Engineering)

Submitted by

SANJAY KUMAR

(University Roll No. 10312)

Under the Guidance of

Dr. AWADHESH KUMAR

Assistant professor

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING,

DELHI COLLEGE OF ENGINEERING,

BAWANA ROAD, DELHI -110042.

UNIVERSITY OF DELHI

July 2008

CERTIFICATE

This is to declare that the major project on "**Role of water and factors affecting it in concrete"** is a bonafide record of work done by me for partially fulfillment of requirement of degree of M.E. Civil Engineering (Structural Engineering) at Delhi College of Engineering

This project has been carried out under the supervision of Dr. Awadhesh Kumar, Assistant Professor, Delhi College of Engineering, Delhi.

I have not submitted the matter embodied in this report to any other University or Institution for the award of any Degree or Diploma.

Name - Sanjay Kumar
College Roll no - 12/STR/06
University Roll no - 10312

This is to certify that the above statement laid by the candidate is correct to the best of my knowledge.

Dr. Awadhesh Kumar
Assistant Professor
Dept. of Civil and
Environmental Engineering,
Delhi College of Engineering,
New Delhi - 110042

ACKNOWLEDGEMENT

It is a great pleasure to have the opportunity to extent my heartfelt gratitude to everybody who helped me throughout the course of this project.

It is distinct pleasure to express my deep sense of gratitude and indebtedness to my learned supervisor Dr. Awadhesh Kumar for his invaluable guidance, encouragement and patient reviews. His continuous inspiration has made me complete this major project. He kept on boosting me time and again for putting an extra ounce of effort to realize his work.

I would also like to take this opportunity to present my sincere regards to H.O.D. Dr. A. Trivedi for his support and encouragement.

I am thankful to our Librarian, Computer Center Head and other staff members for providing me unconditional and anytime access to the resources.

I am also thankful to my friends for their unconditional support and motivation during this work.

Sanjay Kumar
College Roll no 12/STR/06
University Roll no. 10312
M.E. (Structural Engineering)
Department of Civil and
Environmental Engineering,
Delhi College of Engineering,
Delhi-110042

List of Tables

List of Figures

CONTENTS

ABSTRACT

The water in a concrete mix possess same importance as the other ingredients in concrete. Perhaps it is most important factors because on the one side its presence is necessary to achieve the desirable properties of concrete, on the other side lack or excess of this, effect the desirable properties of concrete. In this project, it has been shown that how does the water affect the properties of fresh and hardened concrete and how can it be optimized to achieve desired properties. Superplasticizer and graded fine aggregate is used to optimize the water/cement ratio. These factors cause reduction in w/c ratio as well as help to achieve the high strength. Fine aggregate to coarse aggregate ratio is also fixed to improve the combined grading which helps to reduce the water content and to achieve the high strength concrete. The effect of shape and size of coarse aggregate has been also shown on the workability as well as on the compressive strength of concrete.

According to codal provision the maximum quantity of cement is restricted to 450kg/m^3. In most of the recent work done on concrete to achieve the high strength the quantity of cement in kg/m^3 exceed the maximum permissible limit specified by the IS: code 456-2000. Although maximum permissible limit of cement is specified in the code but it is also noticed that not too much work has been done by using this maximum limit of cement content. So in this project work a data is prepared for workability as well as strength by keeping the maximum quantity of cement constant and using the different types of fine aggregates in terms of their fineness.

It is also noticed that the mineral admixtures also called cement replacing material is generally partially replaced with cement which is a good aspect from economy point of view. Beside form this aspect this experimental work is also based on the fact that in a concrete mix, keeping the maximum quantity of cement constant, using the mineral admixtures as an additive and by making it workable for different degree of workability how much strength can be achieved.

CHAPTER 1

INTORDUCTION

1.1 Concrete as Construction Material

The concrete is a mixture of cement, fine aggregates, coarse aggregates water and admixtures if required which, when placed in the site and allowed to cure, becomes hard like a stone and give a significant strength. Due to the easily availability of constituent materials in bulk, it is the most common construction material now and in future. It has also been modified in different types of new forms like prestress concrete, fibre reinforced concrete, high strength concrete etc. The most important property which engineers like is that it can be readily moulded into desired structural items of various sizes and shapes at practically no considerable labour expenditure. It has a high compressive strength. It is free from corrosion in plain cement concrete form and also in R.C.C form if proper cover is provided. It hardens with age and the process of hardening continues for a long time after the concrete has attained sufficient strength. Due to this property it is superior among all the construction materials. It has binding property with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places to take up the tensile stresses. This is termed as Reinforced Cement Concrete. It forms a rigid surface which is capable of resisting abrasion and impact due to which it can also be used in road construction

From the above, it can be said that concrete is superior to remaining all the other materials of construction because it gives better strength, easily handled, better elastic material, environmental friendly, more economical and its ingredients are easily available and can be manufactured on large scale.

1.2 Classification of Concrete Mixes [As per IS Code: 456-2000]

Concrete mixes are classified in a number of ways. First one is the *prescriptive specifications* where the proportions of the ingredients and their characteristics such as

type of cement, maximum size of aggregate, grading of aggregate etc are specified. Second is the *performance oriented specification* can be used wherein the requirements of the desirable properties of concrete are specified such as strength, workability, durability.

Concrete can be classified either as ‘nominal mix’ concrete or ‘designed mix’ concrete as has been specified in IS:456-2000. The code has classified concrete into ‘controlled’ concrete and ‘ordinary’ concrete, depending upon the levels of control exercised in the works and the method of proportioning concrete mixes. When the mix proportions were fixed by designing, the concrete mixes with preliminary tests were called ‘controlled concrete’; and ‘ordinary concrete’ was one where ‘nominal’ concrete mixes were adopted. Mix proportioning is only one aspect of quality control of concrete and that quality control really encompasses many other aspects like choice of appropriate concrete materials after proper tests, proper workmanship in batching, mixing, transportation, placing, compaction and curing, coupled with necessary checks and tests for quality acceptance and quality control.

Concrete can be classified in many other ways like by its density such as light weight, normal weight and heavy weight concrete or by its workability such as flowing and pumpable concretes or by its durability in specific environments such as sulphate-resisting concrete, fire resistant concrete.

1.3 Grades of Concrete

Among the many properties of concrete, compressive strength of concrete is considered to be the most important property. Many other engineering properties of concrete appear to be generally related to its compressive strength. Concrete is, therefore, mostly graded according to its compressive strength. The various grades of concrete M10, M15, M20, M25, M30, M35, M40, M45, M50, M55, M60, M65, M70, M75 and M80 are given in IS: 456-2000. In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150mm size cube at 28 days, expressed in N/mm^2.

1.4 Concrete Making Materials:

The common ingredients of concrete are cement, fine aggregates, coarse aggregate and water. Sometimes a fourth ingredient known as 'admixtures' is used to obtain and improve certain specific properties of the concrete mix in fresh and hardened states. By doing the concrete ingredients proportioning or concrete mix designing we can achieve the desired properties in the fresh and hardened states, as per requirement of the site.

1.4.1 Cement:

Cement is the most important constituent of concrete because it acts as an excellent binding material in concrete mix as well as offers good resistance to the moisture and possesses good plasticity. A ordinary cement contains two basic ingredients called as argillaceous materials containing clay and calcareous materials containing calcium carbonate predominate. For general concrete constructions, IS:456-2000 permits the use of the following types of cement

(a) Ordinary Portland cement,

(b) Rapid hardening Portland cement,

(c) Portland slag cement,

(d) Portland pozzolana cement (fly ash based),

(e) Portland pozzolana cement (calcined clay based),

(f) Hydrophobic cement,

(g) Low heat Portland cement,

(h) Sulphate resisting Portland cement,

(i) High alumina cement.

1.4.2 Aggregate:

Aggregates are inert materials which when mixed with cement in the presence of water form concrete. They are used as filler in the concrete. Aggregates constitute the major portion to the total volume of concrete and hence they influence the strength of concrete to a great extent. Aggregate is derived from igneous, sedimentary and metamorphic rocks or is manufactured from clays, slags etc. The strength of concrete is directly related to properties of aggregate used in a concrete mix, so it should be hard, strong, dense, durable, and free from impurities. The presence of deleterious substances such as coal, lignite clay lump, and other materials prevent proper adhesion to the cement and thus affect the properties of concrete adversely.

Depending upon their size the aggregates are classified as:

(a) Fine Aggregate, and (b) Coarse Aggregate.

(a) Fine Aggregate:- The aggregates passing through I.S. sieve No 480 (4.75 mm. size) is termed as fine aggregate. The sum of percentage of all types of deleterious materials in fine aggregate should not exceed 5%. Natural sand or crushed stone dust is the fine aggregate mainly used in concrete mix. Sand obtained from sea, river, lake or pit, should be properly washed and tested to conform that total percentage of clay, silt, salts and other such organic matter does not exceed specified limit. Sea sand is not to be used in its natural state for R.C.C. work because due to the presence of salts, it tries to corrode the steel reinforcement. River sand is most suitable and economical fine aggregate but due to contaminate with mud, it should always wash before use. Pit sand is also suitable, but sometimes contains silt or other organic impurities. Hence before using it, all its impurities must be removed.

(b) Coarse Aggregates:- The aggregates retained on I.S. sieve No 480 (4.75 mm size) is termed as coarse aggregate. The size of the coarse aggregate used, depends upon the nature and type of work required. The maximum size may be 200mm for mass concrete, such as in dams etc. and 63 mm. for plain concrete work. For R.C.C. building construction aggregate having a maximum size of 20 mm are generally adopted The types of aggregate used in cement concrete work are briefly described below.

Crushed hard stone obtained from rocks and gravels obtained from pit or river are the common materials used as coarse aggregates for structural concrete. Coarse aggregates are usually obtained by crushing granite, gneiss, crystalline lime stone and good variety of sand stone etc. Broken bricks, the cheap aggregate can also be used as coarse aggregate only for plain concrete, but it provides low strength to the concrete so it should be used as per the situation. Clinker slag, coal ashes, coke breeze are also used as aggregates for light weight and insulating concrete where high strength is not desired. The sum of percentage of all type of deleterious substances in coarse aggregate should not exceed 5 %.

1.4.3 Water:

This is the least expensive but most important ingredient of concrete. The requirement of water is for proper hydration of cement, adequate workability in fresh concrete and for proper curing of hardened concrete. The water which is used for making concrete should be clean and free from harmful impurities such as oil, alkali, acid etc. In general, the water which is fit for drinking should be used for making concrete.

1.4.4 Admixtures:

Now in present day to obtain desired workability, increase and decrease of the initial and final setting time and high strength of the concrete with a low water/cement ratio a fourth ingredient called admixtures, in addition to cement, aggregates and water is added in the concrete mix. Admixtures are added to the concrete mix immediately during or after mixing, to modify one or more of the specific properties of concrete in the fresh or harden states.

Mainly the admixtures are classified into two categories

(a) Chemical Admixtures (b) Mineral Admixtures

The different types of chemical admixtures as per the IS: 9103-1979 are as follows:

(a) Accelerating admixtures,

(b) Retarding admixtures,

(c) Water-reducing admixtures,

(d) Air-entraining admixtures.

The different types of mineral admixtures as per the IS:456-2000 are as follows

(a) Pozzolanic admixtures: it is of the following types

(i) Fly ash,

(ii) Silica fume**,**

(iii) Rice husk ash,

(iv) Metakaolin

(b) Ground Granulated Blast Furnace Slag

Before using an admixture in concrete, its performance should be evaluated by comparing the properties of concrete with the admixture and concrete without any admixture.

CHAPTER 2

ROLE OF WATER AND EFFECT OF WATER CONTENT IN CONCRETE

2.1 Role of Water in Concrete:

Water is used in the concrete for two purposes:- water for mixing the dry concrete mix and water for curing the hardened concrete.

This is an important ingredient of concrete because without it, concrete cannot go into final shape which is necessary for any concrete structure. It is needed for hydration of cement and excess water added at the time of mixing works as lubricant between ingredients. The constituents bonded together give a stone like hard structure. It actively participates in the chemical reaction with cement which is necessary for setting and hardening of concrete. Since it helps to form the strength giving cement gel, the requirement of water in terms of quantity and quality is to be looked into very carefully. Normally properties of cement and aggregates are considered to a great extent before and at the time of concrete mix design but quality of water is often neglected. Since quality of water affects the strength, it is necessary for us to use good quality of water.

2.2 Qualities of Water

Generally it is considered if water is fit for drinking is fit for making concrete. This consideration is right to some extent. But waters containing sugar is suitable for drinking but cannot be used for mixing concrete. Water used for concrete mix should have pH value in the range of 6 to 8 and it should be free from organic matters. The best method to find out whether a particular source of water is suitable for concrete making or not, is to make cubes of concrete with this water and compare its 7 days and 28 days strength with cubes made with distilled water. If the compressive strength is not less than 90 per cent of the strength of concrete made with distilled water the source of water may be accepted. This method must be adopted in places where the available water is brackish in nature and of doubtful quality. Silts and suspended particles

interfere with setting, hardening and bond characteristics so they should be removed before using that water. Carbonates and bi-carbonates of sodium and potassium effect the setting time of cement. Higher concentrations of these salts are reduced the concrete strength so tests for setting time and 28 day strength should be carried out. Salts of Manganese, Tin, Zinc, Copper and Lead cause a large reduction in strength of concrete. Sodium iodate, sodium phosphate, and sodium borate reduce the initial strength of concrete to an extra-ordinarily high degree. Sodium sulphide is also a detrimental compound in water and even a small concentration (100ppm), water needs for testing. Algae in mixing water may cause a marked reduction in strength of concrete either by combining with cement to reduce the bond or by causing large amount of air entrainment in concrete. Permissible limits for solids and tolerable concentration of impurities in mixing water is given in SP: 23-1982

2.3 Use of Sea Water for Mixing Concrete

Salinity of sea water is about 3.5%. In that about 78% is in the form of sodium chloride and 15% is in the form of chloride and sulphate of magnesium. Sea water also contains small quantities of sodium and potassium salts. These can react with reactive aggregates if sea water is used for mixing the concrete. Therefore sea water should not be used even for plain cement concrete even if non-reactive aggregates are used. Although sea water slightly accelerates the early strength of concrete but it reduces the 28 days strength of concrete by about 10 to 15%. However; this loss of strength could be made up by redesigning the mix. It may also cause efflorescence and dampness in concrete. Sea water is also not to be use for plastering purpose.

Corrosion of reinforcement is occurred due to permeability of concrete and insufficient cover provided to reinforcement. However, since these factors cannot be adequately taken care of always at the site of work so sea water should be avoided for making reinforced concrete. For economical or other reasons, if it is compulsory for making reinforced concrete then concrete must be made dense, by reducing the water/cement ratio and proper compaction and provide a minimum cover of 75mm. Sea water must be avoided in prestressed concrete work since it cause loss of stress due to corrosion of small diameter wires which result in reduction in cross-section of wires. IS 456-2000 prohibits the use of sea water for mixing and curing of reinforced concrete and pretressed concrete work. Sea water and water containing impurities is objectionable for curing those concrete where appearance and look is important because it cause staining on the surface of concrete. The most common cause of staining is usually high concentration of iron or organic matter in the water.

2.4 Water Requirement for Mixing the Concrete

When water reacts with cement, the hydration of cement is started and forms a product called calcium-silicate-hydrate which imparts the strength to concrete and calcium hydroxide is also liberated during this reaction. The reaction of compounds of cement and their products may be represented as:

$$\mathbf{2(3CaO.SiO_2) + 6H_2O = 3CaO.\ 2SiO_2.\ 3H_2O + 3Ca(OH)_2}$$

$$\mathbf{2(2CaO.SiO_2) + 4H_2O = 3CaO.\ 2SiO_2.\ 3H_2O + Ca(OH)_2}$$

It has been estimated that C_3S requires 24% and C_2S requires 21% water by weight of cement. On average approximately 23% of water by weight of cement is required for chemical reaction with ordinary cement. This 23% of water chemically combines with cement and is known as bound water. A certain quantity of water is consumed by gel-pores and is known as gel-water. It has been further estimated that water about 15% by weight of cement is required to fill up the gel-pores. So it implies that a total of 38% of water by weight of cement is required for the complete chemical reactions and to occupy the space within gel-pores and enough for full hydration of cement paste also no extra water available for the formation of undesirable capillary cavities. Therefore greater the water above the minimum (38%) required is used, the more will be the undesirable capillary cavities. With lower water/cement ratio the cement particles are closely packed to each other which reduce the air voids and undesirable capillary

cavities. With the progress of hydration of cement, the volume of gel also increases which fill up the space earlier occupied by water upto a limited water/cement ratio. It implies that a limited amount of water is required for complete hydration of cement and filling of gel pores. If the w/c ratio is further increased from the specified limit than increase in volume of the hydrated product is insufficient to fill up the voids created by water and concrete becomes porous.

2.5 Water Requirement for Curing of Concrete

Curing is a procedure to keep the concrete moist and warm enough by applying different techniques so that the hydration of cement can continue until the desired properties are developed to a sufficient degree to meet the requirement of service. To achieve a high strength and high performance concrete proper curing of concrete is necessary. If proper curing is neglected in the early period of hydration, the over all performance of concrete is reduced.

In hot and dry climatic region, concrete surface dries out quickly which make up poorly hydrated cement with inferior gel structure which does not give the desirable bond and strength characteristics. Road or floor pavement is also subjected to a large magnitude of plastic shrinkage stresses. The dried concrete naturally being weak, cannot withstand these stresses with the result that innumerable cracks develop at the surface. It also causes reduction in wearing and abrasion resistance which result in creation of mud in the rainy season and dust in summer. Due to quick surface drying of concrete results in the movement of moisture from the inner portion to the surface. This steep moisture gradient cause high internal stresses which are also responsible for internal micro cracks in the semi-plastic concrete.

There are different methods of curing of concrete in which water plays an important role. These methods are discussed below in detail.

2.5.1 Water Curing

This is the best method of curing among the others as it fulfills all the purposes of curing like promotion of hydration, elimination of shrinkage and absorption of the heat of hydration It is necessary that a certain extent of water curing is done before the concrete is covered with membranes in case of membrane curing. Water curing can be done in the following ways

(a) Immersion (b) Ponding

(c) Spraying or fogging (d) Wet covering

Immersion is a method in which precast concrete items are immersed in water tanks for certain duration. Ponding is a method in which Pavement slabs, roof slab etc. are covered under water by making small ponds. Spraying is generally adopted in vertical surfaces on which immersion or ponding is not possible such as vertical retaining wall or plastered surfaces or concrete columns etc. are cured by spraying water. Wet coverings is a method in which wet gunny bags, hessian cloth, jute matting, straw etc are wrapped to vertical surface for keeping the concrete wet. For horizontal surfaces saw dust, earth or sand is used as wet covering to keep the concrete in wet condition for a longer time.

2.5.2 Steam Curing at Ordinary Pressure

This method of curing can be adopted mainly for prefabricated concrete elements as application of steam curing to in situ construction is a difficult task. However, at some places it has been tried for in situ construction by forming a steam jacket with the help of tarpaulin or thick polyethylene sheets. But it is not much effective in in-situ construction. Steam curing at ordinary pressure is applied in chamber. The door is closed and steam is applied either continuously or intermittently. The benefit of steam curing is that concrete products attain the 28 days strength of normal concrete in about 3 days. The only one unfavourable effect of steam curing is that concrete subjected to higher temperature at the early period of hydration is found to lose some of the strength gained at a later age because concrete subjected to higher temperature in the

early period of hydration will yield poor quality gels and concrete which is subjected to rather low temperature will yield the best quality gel, and hence good concrete

2.5.3 Steam Curing at High Pressure

The high pressure steam curing is carried out in a closed chamber. The superheated steam at high pressure and high temperature is applied on the concrete. This process is also called "Autoclaving". This method is generally adopted for the lightweight concrete products. Concrete products attain the 28 days strength of normal concrete in about 1or less than 1 day and strength developed does not show retrogression. High pressure steam cured concrete exhibits higher resistance to sulphate attack, freezing and thawing action and chemical action. It also shows less efflorescence. High pressure steam cured concrete exhibits lower drying shrinkage, and moisture movement. In high pressure steam curing, concrete is subjected to a maximum temperature of about 175°C which corresponds to a steam pressure of about 8.5 kg/cm^2. High pressure steam curing exhibits higher strength and durability particularly in the case of cement containing a proportionately higher amount of C_3S. High pressure steam cured concrete is brittle and whitish in colour. Overall, high pressure steam curing produces good quality dense and durable concrete

2.6 Effect of Water Content on Strength of Concrete

The requirement of water in concrete is for chemical action of cement which causes setting and hardening of concrete and to lubricate the aggregates so that cement can move through voids of aggregates. The ratio of the amount of water to the amount of cement by weight is termed as the water/cement ratio and the strength and quality of concrete primarily depend upon this ratio. The minimum quantity of water is necessary to achieve desired degree of workability and excess water occupies space in concrete and on evaporation, the voids are left in concrete if proper compaction is not done. Thus the excess water affects strength of concrete or we can say that strength of concrete inversely proportional to the water/cement ratio. If too much water is added to concrete, the excess water along with cement comes to the surface by capillary action and this cement water mixture forms a scum or thin layer of chalky material known as laitance. This laitance prevents bond formation between the successive layers of concrete and forms a plane of weakness. Excess water may also leak through the joints of the formwork and make the concrete honeycombed. As a rule, the smaller the percentage of water, the stronger is the concrete subject to the condition that the required workability be achieved. The water-cement ratio for concrete structures which are exposed to weather should be carefully decided.

2.8 Effect of Water Content on Workability of Concrete

Workability of concrete is defined as the ease with which concrete can be mixed, handled, transported and compacted at the site with out any difficulty. Water content in a given volume of concrete produces significant influences on the workability. Addition of more water per cubic meter of concrete increases the fluidity of concrete, which is one of the important factors affecting workability. When the concrete mix is dried in a short duration due to the high temperature, addition of extra water is the last option to make the concrete workable. Although we can use some admixtures to maintain the same workability. But this is the easiest way to make the concrete workable. Addition of more water and further addition of some quantity of cement to keep the water/cement ratio constant, so that the strength remains the same.

2.9 Effect of Water Content on Durability of Concrete

To increase the durability of concrete reduction in the water/cement ratio is the main requirement so that we can produce dense and impermeable concrete. The reason of reducing the water/cement ratio is that higher water/cement ratio increases the permeability of concrete and higher permeability increases the risk of effect of chemicals on concrete because chemicals after dissolving into water penetrates into concrete and then deterioration of concrete take place. Using the low water/cement ratio, permeability could be decreased because the capillaries are so fine that water cannot flow any more through them and we get almost an impervious concrete. Sometimes it is impossible to reduce the water/cement ratio beyond certain limit so we have to use the superplasitercizers which help to reduce the water/cement ratio but there is not enough water available to fully hydrate all the cement particles. The water available can only hydrate the surface of cement particles and there exist plenty of unhydrated particles which can play an important role as they constitute strength in reverse. If for any reasons, concrete is cracked, the unhydrated cement particles begin hydrating as soon as water or moisture starts penetrating through cracks. Low water/cement ratio concrete with adequate cover also protects steel reinforcement against corrosion which is also an important aspect for durability.

CHAPTER 3
REVIEW OF LITERATURE

3.1 General

The general philosophy of different concrete mix proportioning methods is available in literature[1-7].

These are the steps to be followed in a mix design: (1) Select the w/c ratio for the required strength from chart or tables, (2) Arrive at the water content based on the required workability and the aggregates characteristics, (3) If superplasticizer (SP) is used reduce the water content by 10% - 30%, (4) Obtain cement content based on water content and w/c ratio, (5) Arrive at the coarse aggregate content based on either fineness modulus of sand or aggregate grading, (6) The optimum supplementary cementitious material content is assumed and the water /binder ratio is modified to obtain the required strength and finally (7) proportions are adjusted for the unit volume to obtain the fine aggregate content.

However, the water content depends on the desired workability of fresh concrete and type, shape and grading of aggregates. With the use of SP, it is possible to reduce the water content and yet produce same workability without affecting the strength of concrete if w/c ratio is kept constant. But the effectiveness of the SP depends on the dosage used, ambient temperature, types of cement, fineness and other characteristic of the binder. When the water content decreases in a concrete mix of a given w/c ratio, the amount of cement correspondingly decreases, but at the same time the amount of superplasticizer needed to achieve the desired workability is increased. Thus the saving in the cost of cement can compensate for the extra cost of superplasticizer. Hence it is necessary to obtain required water content after establishing a relationship between water content and cost of superplasticizer plus cement for a given set of ingredients and for the same workability.

Sood and others[1] shown the effect of different types of superplasticizers based on their chemical composition like sulphonated naphthalene formaldehyde, sulphonated melamine formaldehyde and carboxyl-acryl-ester on the workability as well as strength of concrete. They shown the effect of these superplasticizers on slump of concrete with time elapsed and development of compressive strength of concrete with these different types of superplasticizers.

Gutmann[2] showed the effect of Air entraining agents (AEA) on properties of concrete. The object of this test program was to provide an improved air-entrained Portland cement concrete and to increase compressive strengths over known air-entraining agents.

When pozzolanic material is used, its effect on the strength of concrete varies significantly depending on the properties of pozzolanic material and with the characteristics of concrete mix. Narayanan and others[3] used the fly ash and GGBS to partially replace cement with different w/c ratio and appropriate doses of SP. They found that the early age strength of cement replaced mixes show lower value for the same water/binder ratio because of slower pozzolanic reaction and concluded that same early strength can be achieved by increasing the binder content keeping the effective water/binder ratio and the water content constant.

D.L. Venkatesh Babu and S.C.Natesan[4] replaced Ordinary Portland Cement (OPC) and Pozzolanic Portland Cement (PPC) by silica fumes with 2.5%, 5%, 7.5%, 10%, 12.5% and 15% keeping the water/binder ratio as well as doses of SP constant. .He found that the optimum percentage of CSF is 7.5 and 5 percent for OPC and PPC concretes respectively.

Basu and others[5] instead of partially replacing cement with the high reactive metakaolin (HRM), used the HRM in addition with cement at 7.5%, 10%, 15% by weight of cement at different water/binder ratio. They achieved compressive strength upto 82.75Mpa having quite low permeability and high slump.

Gordian and Prakash Rao[6] shown the effect of stone crusher dust as fine aggregate on the fresh concrete as well as hardened concrete. They found that stone crusher dust as fine aggregate has in general no detrimental effect on the strength and performance of concrete when designed correctly

Malhotra and Carette[7] also had shown the effect of limestone dust as partially replacing to sand on the properties of fresh as well as hardended concrete. Thirteen concrete were made with w/c ratio ranging form 0.4 to 0.7 with the replacement of upto 20 percent. They concluded that use of limestone dust does impart more cohesiveness to fresh concrete and gives it a fatty appearance and concrete incorporating more than 10 percent lime stone dust, regardless of the w/c ratio, shows considerable loss in entrained-air content and slump.

The effects of above factors on water content are discussed in subsequent paragraph.

3.2 Effect of Chemical Admixtures

3.2.1 Effect of Water Reducing Admixtures:

The main use of water reducing admixtures is for two purposes. First one is to reduce the water content in a given mix for the same workability and second is to increase the workability for the same water content in a given mix

These are classified into two categories

(a) Plasticizers

(b) Superplasticizers

Plasticizers are the chemical admixtures which are used to reduce the water content in concrete. Plasticizers are used in the amount of 0.1% to 0.4% by weight of cement[9]. At these doses, the reduction in water content is approximately 5% to 15% to achieve the same workability as without plasticizer. Reduction in water/cement ratio obviously increases the strength of concrete which is the main purpose of concrete mix designing.

Superpasticizers are more powerful as dispersing agent and they are high range water reducers. Uses of superplasicizers permit the reduction of water upto 30% to achieve the same workability as without superplasicizer[9]. The reduction in water is approximately twice as compared to plasticizer.

Cement has a tendency to flocculate in wet concrete. This flocculation entraps certain amount of water used in the mix and thereby all the water is not freely available to fluidify the mix. When plasticizers are added they get adsorbed on the surface of cement particles. The adsorption of charged polymer on the cement particles creates repulsive forces between cement particles, which overcome the attractive forces resulted as deflocculating of cement particles. When cement particles are deflocculated, the water trapped inside the flocs gets released and becomes available to fluidify the mix.

Generally slump increases with increase in dosage. But there is no appreciable increase in slump beyond certain limit of dosage. Appropriate dose of SP can be decided from the results of compatibility test to be done with the help of Marsh Cone apparatus. As a matter of fact the overdosage may retard the setting of cement. A typical curve, showing the slump and % of superplasicizers by weight of cement is shown below in figure 3.1. Since plasticizers and superplasticizers improve the workability and provide reduction in w/c ratio, thereby increase the strength of concrete. It contributes to the over allimprovement in the properties of hardened concrete. Plasticizers or superplasticizers do not participate in any chemical reactions with cement or blending material used in concrete. Their actions are only physical in fluidizing the mix, made even with low water content. The relationship between the dosage of a superplasticizers and water reduction is shown below in fig 3.2. The one most important aspect of using the water reducing admixtures is that it should not be added into whole water required for mixing the concrete. First put half to two third water to wet the concrete mix. Than add the superplasticizer into remaining water and put into the wet concrete mix. This is because superplasticizer is more effective in wet mix as compared to dry mix.

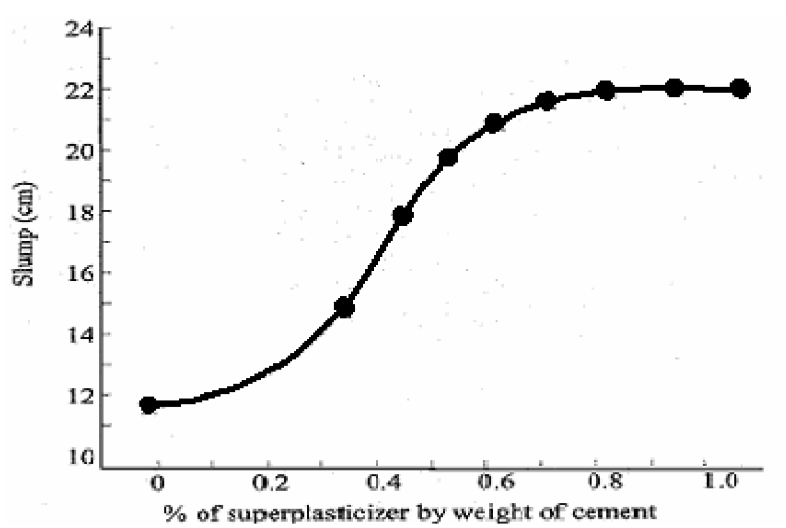


Fig: 3.1 Effect of superplasticizers (alklaryl sulphonateformaldehyde condensates) on the workability of Concrete[9]. cement content 300kg/m^3, w/c ratio = 0.6

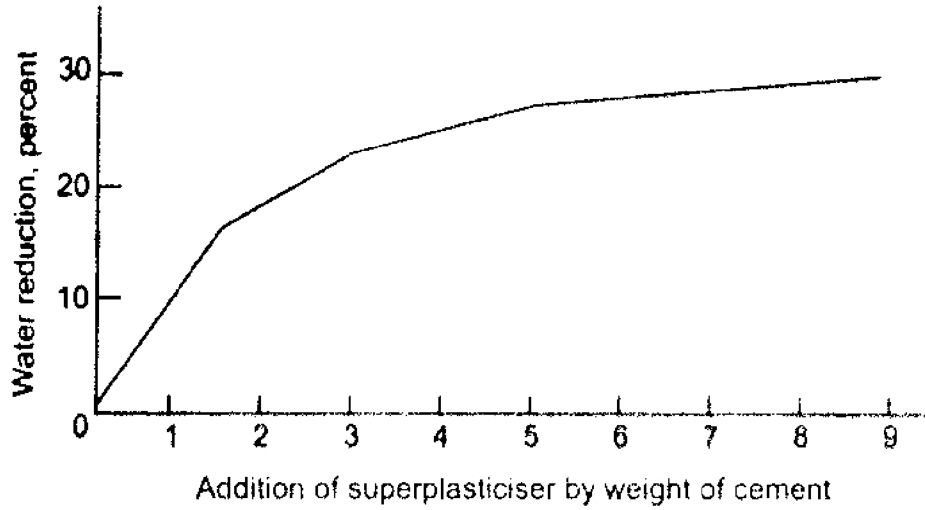


Fig 3.2 Water reduction with dose of a typical superplasticizer[1]

3.2.2 Effect of Retarding Admixtures or Retarders

Retarding admixtures slow down the chemical process of hydration of cement so that concrete remains plastic and workable for a longer time as compared to concrete without the retarder. Retarders are used in hot climatic regions where setting of fresh concrete occurs rapidly due to the evaporation of water and rapid hydration of cement.

By using the retarders setting time is increased which result as no further addition of water in concrete to increase workability. No addition of water result in no loss of strength. Sometimes concrete may have to be placed in difficult conditions and delay may occur in transporting and placing. It is also used in ready mixed concrete in which setting of concrete is required to retarded because concrete is manufactured in central batching plant and transported over a long distance to the job sites which may take considerable time.

Retarders delay setting of cement either by forming a thin coating on the cement particles and thus slowing down their dissolution and reaction with water or by increasing the intra-molecular distance of reacting silicates and aluminates from water molecules by forming transient compounds in the system. With the formation of silicates and aluminate hydrates, the influence of retarders diminishes and hydration process becomes normal.

3.2.3 Effect of Accelerating Admixtures or Accelerators

This type of admixture does not cause any reduction in the quantity of mixing water or increase in the workability. But by using the accelerating admixtures, concrete achieves its early strength rapidly due to which, required period of curing and quantity of water for curing is reduced. Early strength and early setting is very useful in underwater concreting and water front structures in the tidal zone. This type of concrete is also very useful in cold weather region.

3.2.4 Effect of Air-entraining Admixture

Air-entrainment admixture is that type of admixture in which air is allowed to mix in concrete by air entraining agent so that aggregate particles are spaced and they can move away from one another with comparative ease during mixing and placing which provide adequate workability with low water/cement ratio. Air entrained concrete having low slump is considerably more plastic and workable than non-air-entrained concrete having high slump. The minute spherical air bubbles act like fine aggregates and enable the reduction of sand. The reduction of fine aggregate further enables the reduction of water requirement without impairing the workability and slump. Due to incorporation of the system of air bubbles, segregation, bleeding and consequent formation of laitance are reduced to great a extent. This is because the bubbles decreases the effective area through which the differential movement of water may occur, buoy up the aggregates and cement hence reduce the rate at which sedimentation occurs in the freshly placed concrete and increase the mutual adhesion between cement and aggregate. Also the surface area of voids in the plastic concrete is sufficiently large to retard the rate at which water separates from the paste by drainage. These admixtures are useful in freezing and thawing situations.

3.3 Effect of Mineral Admixtures

3.3.1 Effect of Fly Ash

The fly ash or pulverized fuel ash is the residue from the combustion of pulverized coal collected by the mechanical dust collectors or electrostatic precipitators or cyclone precipitators. Due to hydration of cement calcium hydroxide is generated. Fly ash reacts this calcium hydroxide in presence of water at ambient temperature and gives additional strength. So a good quality of fly ash as a partial replacement with cement results in reduction of water content for desired slump or we can achieve higher slump for the same water content. Bleeding and drying shrinkage is also reduced due to the reduction in water content. Fly ash is not too much reactive in nature and due to the partial replacement with cement, the quantity of cement is reduced which result in

less heat of hydration. Although there is reduction in the water content by using the fly ash in concrete for the same workability and strength but it requires longer period of curing due to pore refinement which result as increase in the requirement of curing for longer period.

3.3.2 Effect of Silica Fumes

Silica fume also called micro silica, is a light to dark grey cementitious material composed of at least 85% ultra fine, amorphous non-crystalline spherical silicon dioxide particles[8]. It is a by product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. The particles are extremely fine, approximately one fiftieth the size of an average cement particles with minimum specific surface area of 15000 m^2/kg[8]. Due to the introduction of large surface area in the concrete mix by its addition, amount of water content increases in proportion to the amount of silica fumes partially replaced with cement. This increase in amount can be avoided by adjusting the aggregate grading and using
superplasticizers. The addition of silica-fumes leads to lower slump but make more cohesive mix. The silica-fumes make the fresh concrete sticky in nature and hard to handle. It also contributes in large reduction of bleeding. Concrete with silica-fumes could be handled and transported without segregation.

3.3.3 Effect of Ground Granulated Blast Furnace Slag (GGBFS)

It is a waste industrial by-product obtained during the production of iron. Partial replacement of cement with GGBFS reduces the water content necessary to obtain the same slump as without GGBFS. This reduction of water content is due to the increase in slag content and also fineness of slag. This is because of the surface configuration and particle shape of slag being different than cement particle. Water used for mixing is not immediately lost as the surface hydration of slag is slightly slower than that of cement.

3.4 Effect of Aggregates

3.4.1 Effect of Size of Aggregate

Size of aggregate is an important characteristic of an aggregate. As far as possible the maximum size of aggregate should be used as per the type and condition of work. Using the largest possible maximum size will result in reduction in cement requirement which further result in reduction in water requirement. Generally the maximum size of aggregate should be as large as possible within the limits specified, but in any case not greater than one-fourth of the minimum thickness of the member. From various other practical considerations, for reinforced concrete work, aggregates having a maximum size of 20mm are generally considered satisfactory. For high strength concrete where low water/cement ratio is required, maximum size of aggregate in the range of 10 to 12mm size should be used.

3.4.2 Effect of Shape of Aggregate

Shape of aggregate is also an important characteristic as it significantly influences the workability of fresh concrete and the bonding between the aggregates and cement. Flaky aggregate is generally not used as it makes very poor concrete. Angular aggregate with rough texture requires more water for a given workability as compared to rounded aggregates. The shape of the aggregates significantly effect in case of high strength concrete where very low water/cement ratio is required to be used to achieve a high strength. In such cases cubical shaped aggregates are required for better workability. Sometimes, crushed aggregates are further processed to convert them to well graded cubical aggregates.

3.4.3 Effect of Grading of Aggregates

Workability of concrete is directly related to water content and one of the most important factors for producing workable concrete is good gradation of aggregates.

Good grading indicates that a sample of aggregates contains all standard fractions of aggregate in required proportion so that the sample contains minimum air voids. To achieve this, the fine aggregates as well as the coarse aggregates should be graded suitably so that the smaller particles can occupy the voids between the larger particles and hence voids is reduced considerably. The reduction in voids results in corresponding reduction in the quantity of mortar required to fill the voids in the coarse aggregates and hence there is reduction in the quantity of cement required to make the concrete. A 'well graded aggregate' contains minimum air voids which result in the reduction of cement paste to fill up the air voids in the aggregates. Less quantity of cement indicate less quantity of water required for mixing which results in economy, higher strength, lower-shrinkage and greater durability.

The quantity of water required to produce a given workability depends to a large extent on the surface area of the aggregate. The surface area per unit weight of the material is termed as specific surface. It is an indirect measure of the aggregate grading. As the size of the aggregate reduces, specific surface increases because fine aggregates contribute more to the surface area as compare to coarse aggregates. Greater surface area requires more water for lubricating the concrete mix to provide the required workability. It implies that grading of fine aggregate create much greater effect on workability of concrete than does the grading of coarse aggregate. Usually very coarse sand or very fine sand is unsatisfactory for concrete making. The coarse sand results in harshness bleeding and segregation and the fine sand requires a comparatively greater amount of water to produce the necessary fluidity.

3.4.4 Effect of Presence of Deleterious Materials in Aggregates

The presence of such materials in aggregate is required more water for mixing of concrete because water is absorbed by these materials. They increase the specific surface of aggregate due to which more amount of water is required to wet the entire particle so that desired workability can be achieved.

3.4.5 Effect of Absorption and Moisture Content of Aggregate

Porosity and absorption are natural characteristics of the aggregates. Porosity and absorption of aggregate affect the water requirement which further affects the strength and workability of concrete. The porosity of aggregate also affects the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids. The water absorption of aggregate is determined by measuring the increase in weight of an oven dry sample when immersed in water for 24 hours. The ratio of the increase in weight to the weight of the dry sample expressed in percentage is known as absorption of aggregate. In proportioning of the materials for concrete, the aggregates should be saturated and surface dry condition to determine the relative weight of the aggregates. But in practice,

aggregates in such ideal condition are rarely found. Aggregates are either dry or absorptive to various degrees or they have surface moisture. The aggregates exposed to rain or washed before use attains surface moisture or the aggregates exposed to the sun for a long time are dried and absorptive. Fine aggregates obtained from river bed usually contain surface moisture. Dry aggregates are absorbing water from the mixing water and thereby affect the workability. If the aggregates contain surface moisture they contribute extra water to the mix and there by increase the available. Both these conditions are harmful for the concrete mix. So corrective measure should be adopted for proper concrete mix design. The absorption capacity of the coarse aggregate is about 0.5% to 1% by weight of aggregate. The natural fine aggregates often-contain free moisture from 1 to 10% or more In weigh batching, determination of free moisture content of the aggregate is necessary and then correction to water/cement ratio is applied. Although it is not necessary when volume batching is adopted but consequent bulking of sand and correction of volume of sand must be applied.

3.5 Effect of Temperature

Temperatures of any region directly affect the workability, rate of gain of strength and curing of concrete. In hot climate the requirement of water is increased for curing and for a given workability due to the evaporation of water from concrete mix results in rapid hydration of cement in the concrete. In cold climate the water added into concrete mix may get freeze and effect the workability

3.6 I.S. Codes recommendation:

- Minimum cement content including pozzolanic materials is 300 kg/m^3 and max cement content excluding pozzolanic materials is 450 kg/m^3
- IS: 9103-1999 recommends maximum dosage of superplasticizer as 2% by weight of cementatious material
- IS: 456-2000 also fixed different range of workability for different types of construction works which is reproduced below in tabular form

Table 3.1 Degree of workability and range of workability for different construction work

Placing Conditions	Degree of Workability	Slump (mm)
Blinding concrete; Shallow sections; Pavements using pavers	Very low	*
Mass concrete; lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns;	Medium	50-100
Slipform work; Pumped concrete	Medium	75-100
Trench fill;	High	100-150
In-situ piling Tremie concrete	Very high	**

* In the 'very low' category of workability where strict control is necessary, for example pavement quality concrete, measurement of workability by determination of compaction factor will be more appropriate than slump and a value of compaction factor of 0.75 to 0.8 is suggested

** In the 'very high' category of workability, measurement of workability by determination of flow will be appropriate

CHAPTER 4
EXPERMINTAL PROGRAM

4.1 General

We give more weightage to compressive strength than workability. While instead of simply asking workability we should ask at sometime after addition of water. This time will depend on how much time is required in mixing, transporting and spreading concrete at site upto start of compaction. Also workability should be decided on site condition and staff available at site otherwise site staff will add water to increase workability whenever it gets opportunity which will result in loss of strength. Since this thesis topic is related to role of water so it has been tried to show that how the quantity of water affect the concrete mix. The term water/cement ratio plays an important role in the concrete mix. As explained in the literature that decrease in w/c ratio cause increase in the compressive strength of concrete. But makes unworkable concrete and generally to achieve the strength of concrete we ignore the workability of concrete. Technically,a concrete which gives desired strength in the given range of workability is considered the best one. I.S. Code also fixed some range of workability for different types of works.

4.2 Objective of Project Work

The objective of the project is to study the affects of variation in fine aggregate, coarse aggregate and cement grade with in the specified codal provisions. To study the above effects it has been tried to produce those concrete mixes which are workable as well as possess desirable strength with different cement contents and varying fineness modulus of fine aggregates. The effect of shape and size of coarse aggregates on the strength of concrete has also been considered.

During the study normal strength concretes of ‘low’ degree of workability (slump ranging between 25-75 mm) and high strength concretes of ‘very low’ degree of workability with a compaction factor ranging between 0.75-0.80 were prepared

4.3 Experimental Work

The project work has been completed in the following sequences:

In the beginning various tests were carried out to know the basic properties of all the ingredients of concrete to ascertain their suitability for use in normal and high strength concretes

After that some trial mixes were prepared and tested to see that how much strength can be achieved by the given set of cement, fine aggregate and coarse aggregate. In this study, much attention was not paid to the workability of concrete.

In the next stage, Concretes with minimum cement content using different aggregates of workability in terms of slump ranging from 50±25mm were studied. Not only plain concretes, but fly ash concretes also with 20 % replacement of cement by fly ash for minimum cement content and 50±25mm slump have been studied.

After that concrete mixes, taking maximum cement content 450 kg/m^3 as per codal provision in the same range of workability (i.e. 50±25mm) with different aggregate have been studied. Another set of concrete have also studied using the fly ash in addition to maximum cement content.

In the final stage high strength concrete with 53 grade cement has been prepared using used with maximum cement quantity (i.e. 450 kg/m^3) and superplasticizer. The latter has been used to reduce the water content. Fly ash is also used as an addition with maximum cement to achieve further high strength.

All concrete mixes were prepared by hand mixing. Only cubes of 150mm size were prepared. A vibrating table was used to compact the concrete mix. Warm water curing method was adopted for trial mixes while normal water curing method was adopted for real mixes for the curing purpose and superplasticizer was added into wet mix.

4.4 Methods of Concrete Mix Design used in the Project

Two types of method of concrete mix design are used to design the concrete mix.

(1) Department of Environment method (D.O.E. method)

(2) American Concrete Institute method (A.C.I. method)

4.4.1 Department of Environment Method (D.O.E. method)

The method uses the relationship between water-cement ratio and compressive strength of concrete depending on type of cement and the type of aggregate used. The water contents required to give various levels of workability, namely, very low, low, medium and high (expressed in terms of slump or compacting factor) are determined from Table for crushed aggregates. The method gives mix proportions in terms of quantities of materials per unit weight of concrete. The method is suitable for the design of normal concrete mixes having 28 day cube compressive strength as high as 75 Mpa for non-air-entrained concrete. The method can also be used for concrete containing fly ash. In present study, this method was used only for some mixes

4.4.2 American Concrete Institute Method (A.C.I. method)

The ACI method is based on the fact that for a given maximum size of well-shaped aggregate, the water-content (kg/m^3) determines the workability of mix, i.e. it is largely independent of mix proportions. The method further assumes that the optimum ratio of the bulk volume of coarse aggregate to the total volume of concrete depends only on the maximum size of aggregate and on the grading of fine aggregate. The water-cement ratio is determined as in other methods to satisfy both strength and durability requirements. The air content in concrete is taken into account for calculating the volume of fine aggregate.

A computer program based on these two methods has been used for concrete mix designing in the project work.

4.5 Materials used in the project work and their properties

4.5.1 Cement:

Two types of cement are used

(1) 43 grade Ordinary Portland cement (Binani) conforming to IS Code : 8112

The specific gravity of this cement is as 3.13. The consistency of this cement is 31% and initial setting time is 3 hours 45 minute

(2) 53 grade Ordinary Portland cement (Ultra tech) conforming to IS Code : 12269

The specific gravity of this cement is 3.15.The consistency of this cement is 33% and initial setting time is 1 hour 20 minute.

4.5.2 Water:

Potable tap water available in the laboratory is used for mixing as well as curing of concrete.

4.5.3 Fine Aggregates:

Following types of Fine Aggregates are used and all of them are type of badarpur sand.

(1) Fine aggregate having fineness modulus 2.92 and named as FA1

(2) Fine aggregate having fineness modulus 2.1 and named as FA2

(3) Fine aggregate having fineness modulus 3.19 and named as FA3

(4) Fine aggregate having fineness modulus 3.21 and named as FAT1

(5) Fine aggregate having fineness modulus 3.38 and named as FAT2

The last two are the tailored aggregates which are prepared by mixing the selected proportion from material retained on 4.75 mm to 150μ sieve. The properties of each type of fine aggregate are given below

Fine aggregate having fineness modulus 2.92

Fine aggregate having fineness modulus 2.1

Fine aggregate having fineness modulus 3.19

4.5.3.1 Properties of Fine Aggregate (FA1)

Specific Gravity = 2.7

Moisture content = 0.2%

Water Absorption = 1.5%

Fineness Modulus = 2.92

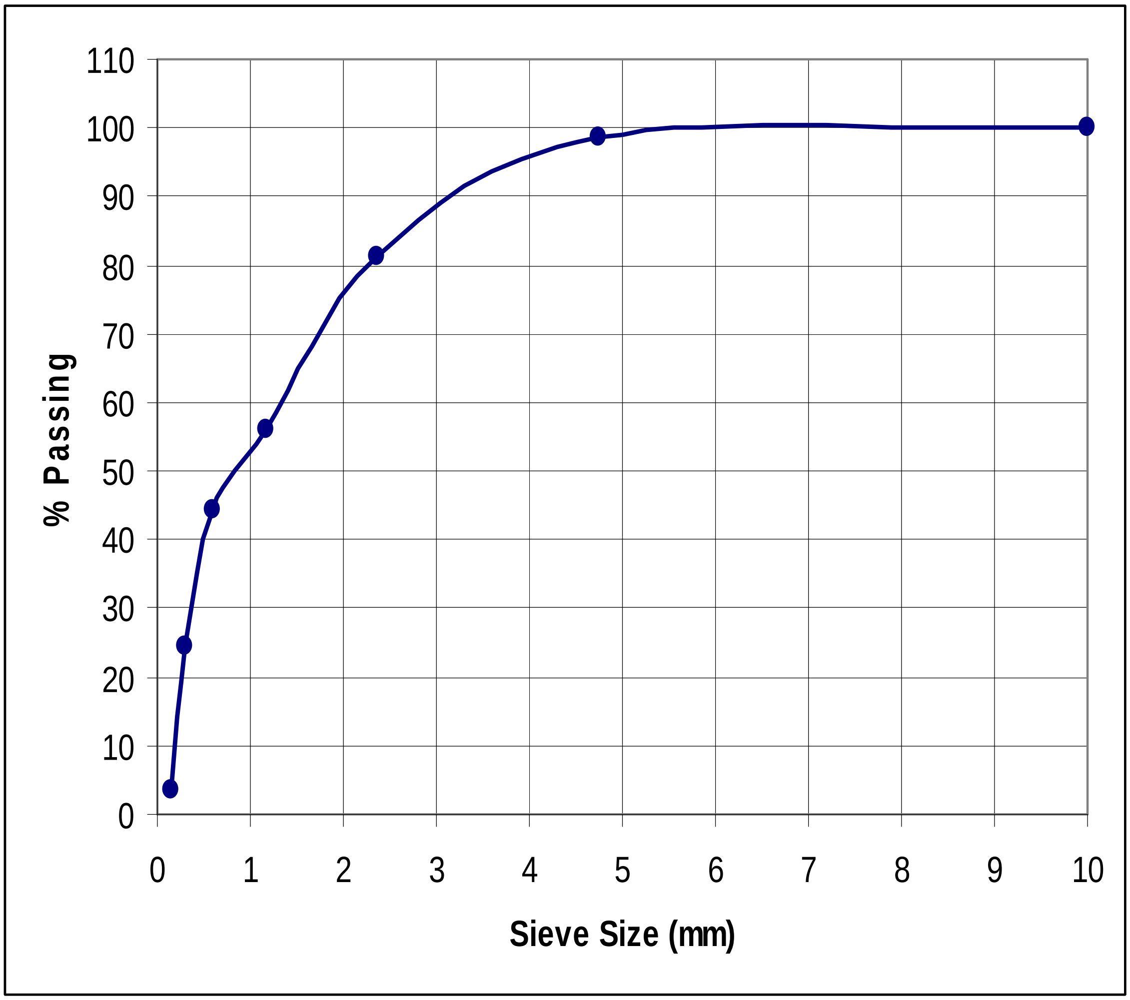


Fig 4.1 Particle Size Distribution Curve for FA1

4.5.3.2 Properties of Fine Aggregate (FA2)

Specific Gravity = 2.58

Moisture content = 0.2%

Water Absorption = 4.5%

Fineness Modulus = 2.1

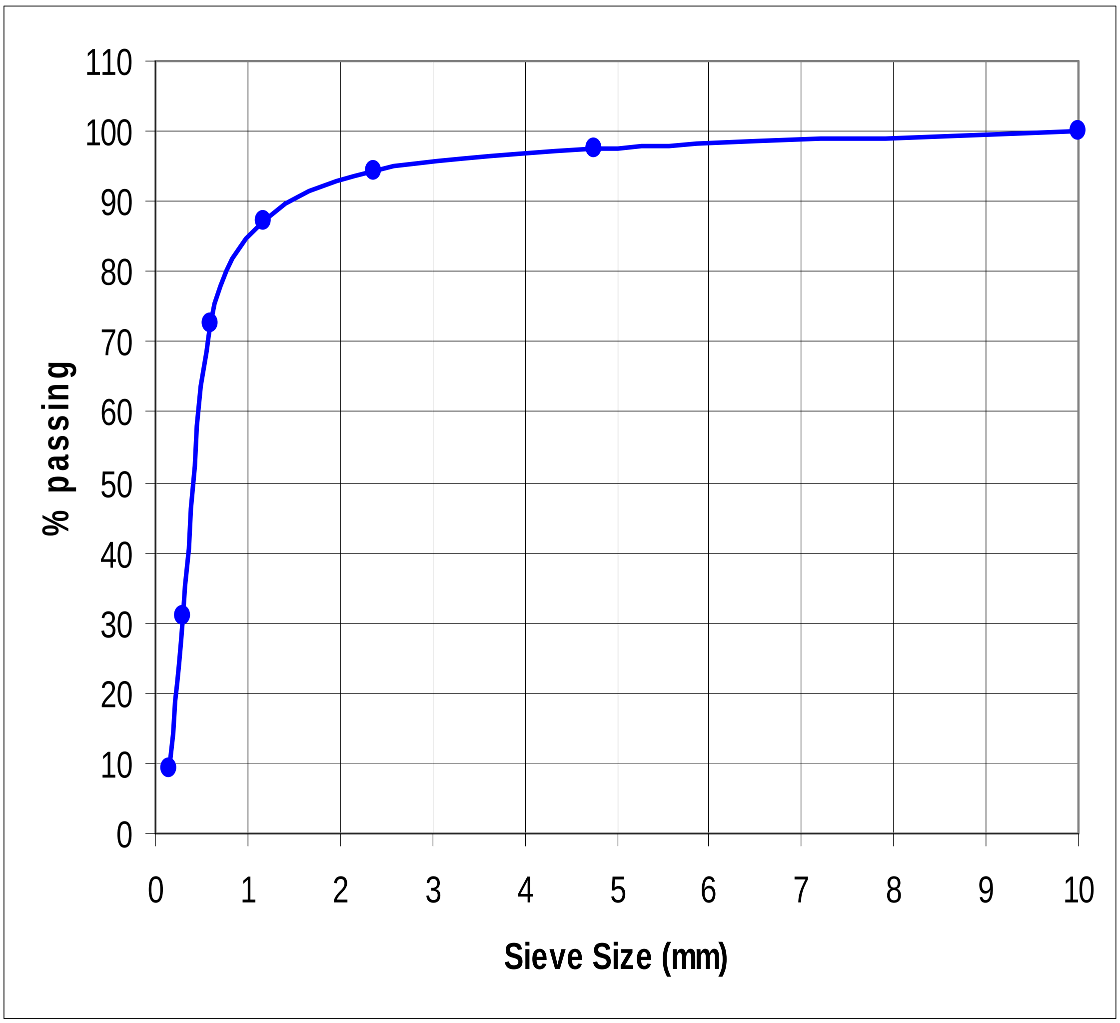


Fig 4.2 Particle Size Distribution Curve for FA2

4.5.3.3 Properties of Fine Aggregate (FA3)

Specific Gravity = 2.7

Moisture content = 0.2%

Water Absorption = 1.5%

Fineness Modulus = 3.19

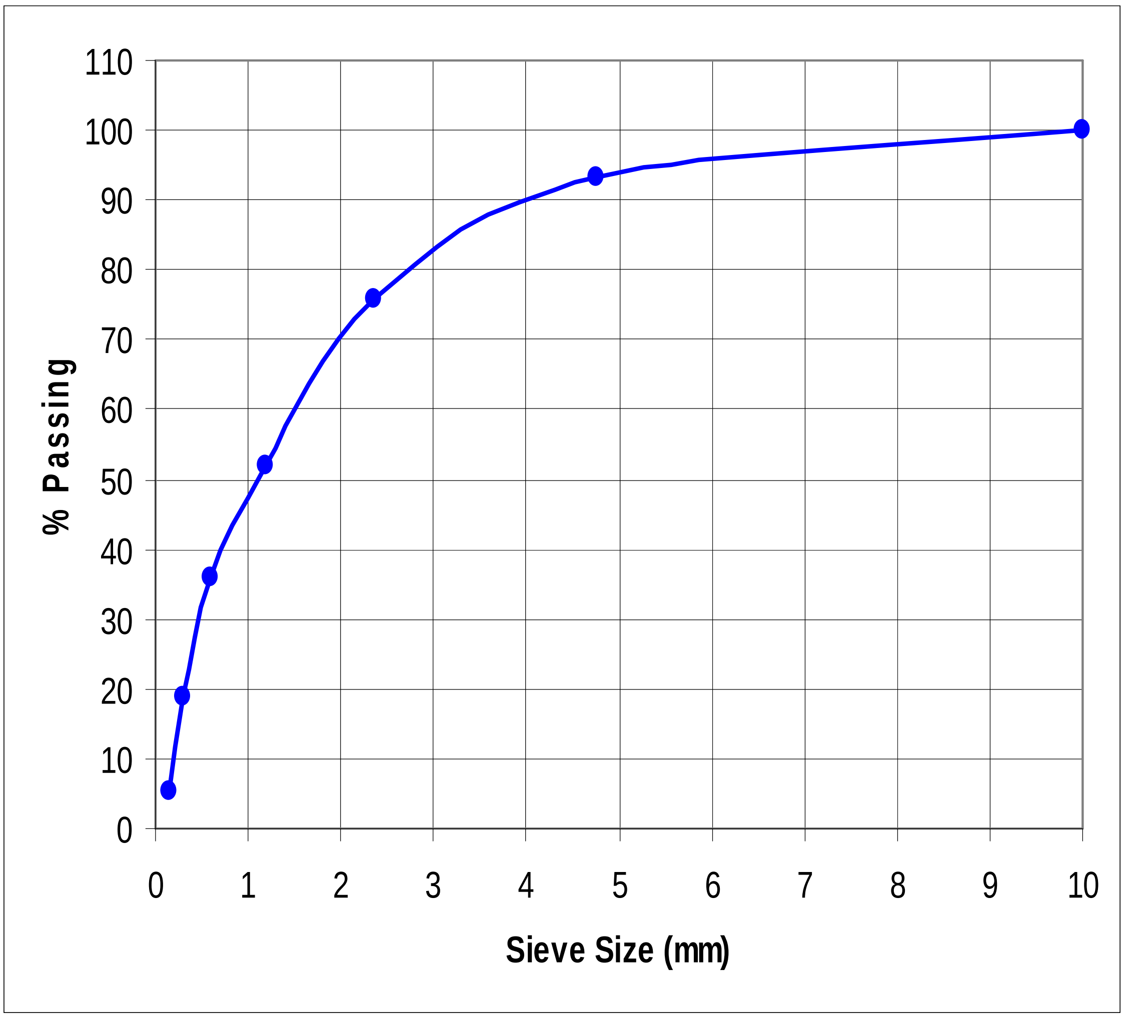


Fig 4.3 Particle Size Distribution Curve for FA3

4.5.3.4 Properties of Tailored Fine Aggregate (FAT1)

Specific Gravity = 2.65

Moisture content = 0.2%

Water Absorption = 1%

Fineness Modulus = 3.21

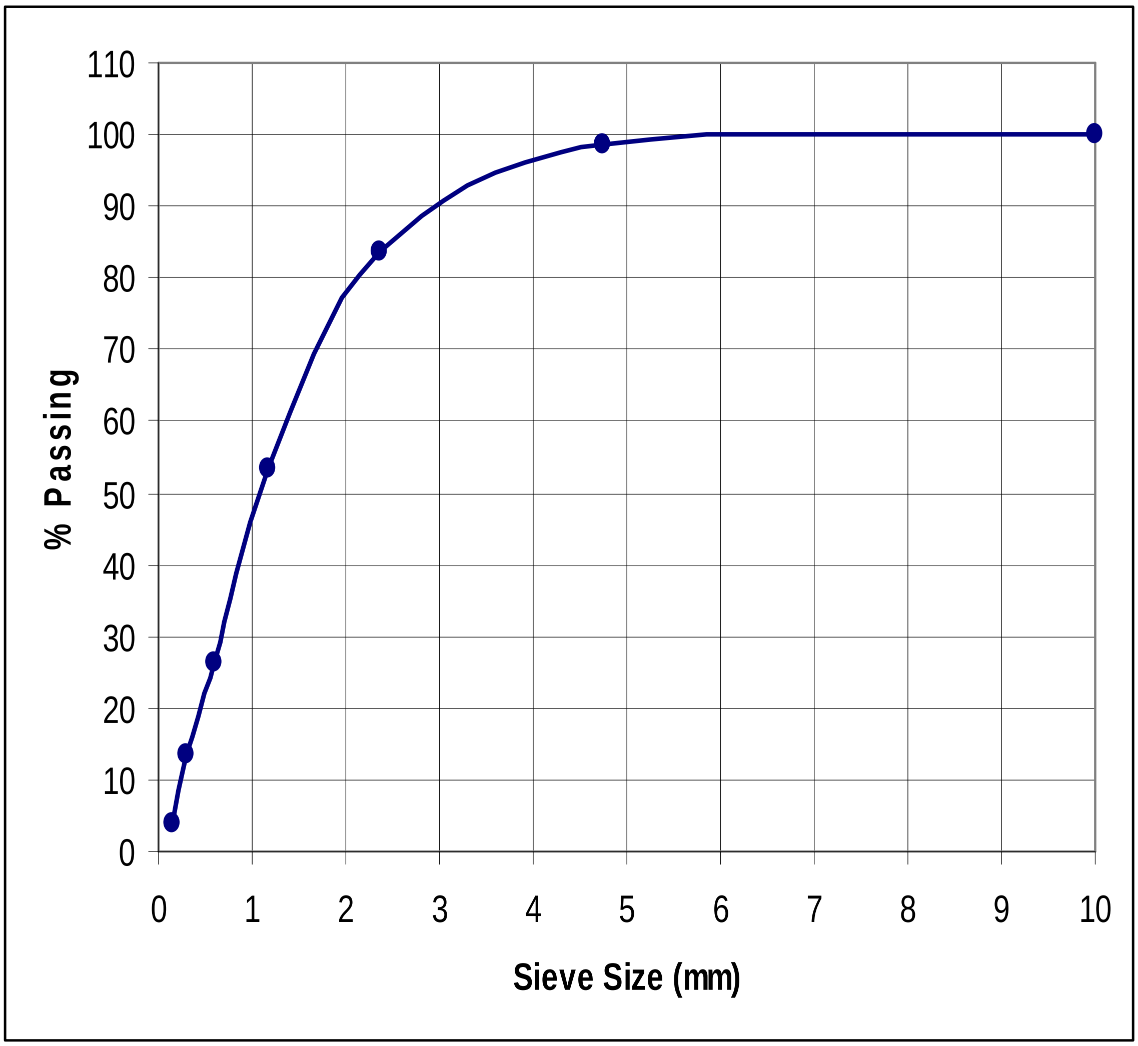


Fig 4.4 Particle Size Distribution Curve for FAT1

4.5.3.5 Properties of Tailored Fine Aggregate (FAT2)

Specific Gravity = 2.65

Moisture content = 0.2%

Water Absorption = 1%

Fineness Modulus = 3.38

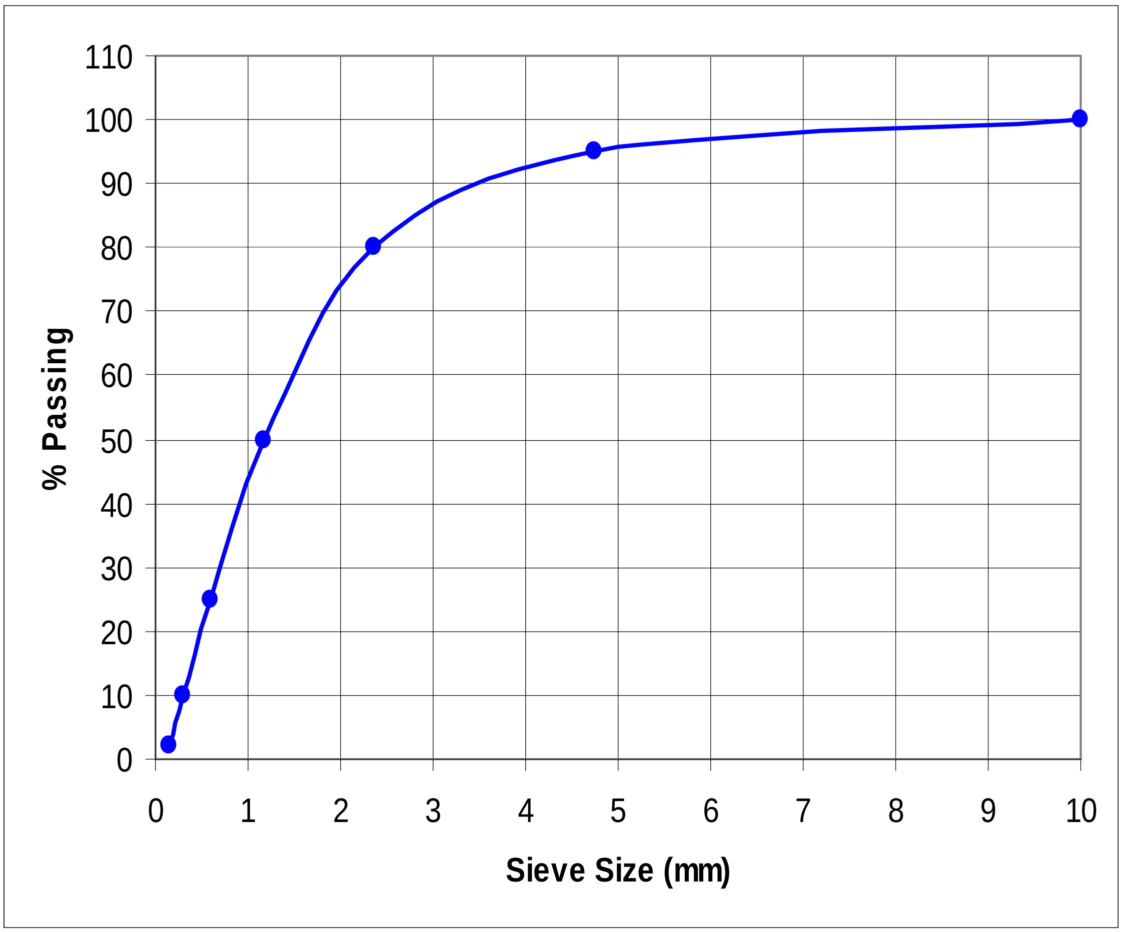


Fig 4.5 Particle Size Distribution Curve for FAT2

4.5.3.6 Comparison of Fine Aggregates

% passing for different particle sizes for comparison of all fine aggregates are given in table 4.1 and plotted in fig. 4.6

Table 4.1 Sieve test results of different fine aggregates

Sieve Size	**% age passing**				
	FA1	**FA2**	**FA3**	**FAT1**	**FAT2**
4.75mm	98.5	97.5	93.4	98.5	95
2.36mm	81.1	94.4	75.9	83.5	80
1.18mm	56.2	87.1	51.9	53.5	50
600µ	44.3	72.6	35.9	26.5	25
300µ	24.5	30.8	18.7	13.5	10
150µ	3.5	9.3	5.2	4	2
Fineness Modulus	**2.92**	**2.1**	**3.19**	**3.21**	**3.38**

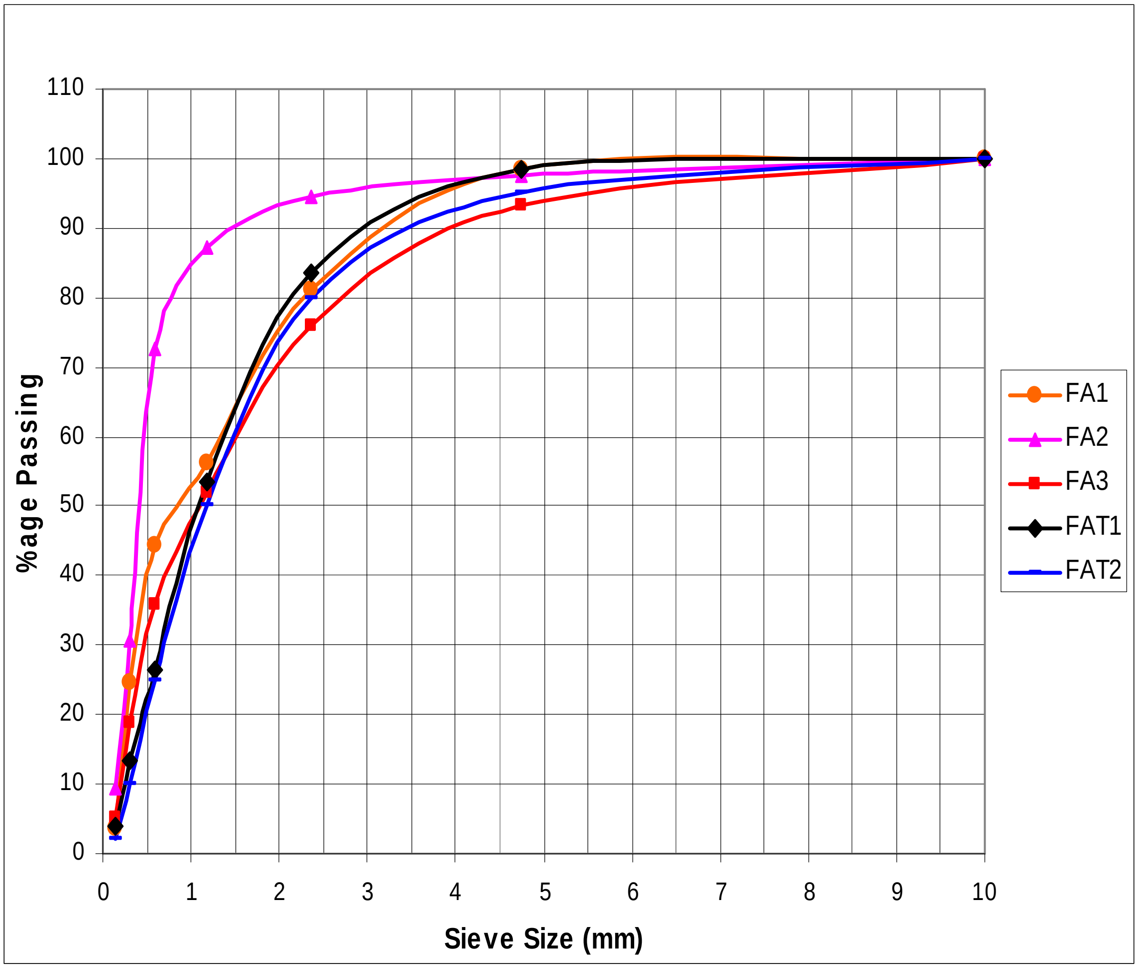


Fig 4.6 Comparison of All Fine Aggregates

4.5.4 **Coarse Aggregates** :

Following types of Coarse Aggregates are used and all are of angular shape.

(1) Coarse Aggregates having maximum size 20mm and fineness modulus 7 named as CA1

(2) Coarse Aggregates having maximum size 20mm and fineness modulus 7 named as CA2

(3) Coarse Aggregates having maximum size 12.5mm and fineness modulus 5.95 named as CA3

(4) Coarse Aggregate having maximum size 20mm and fineness modulus 6.9 named as CAT1

(5) Coarse Aggregate having maximum size 20mm and fineness modulus 6.8 named as CAT2

(6) Coarse Aggregate having maximum size 20mm and fineness modulus 6.7 named as CAT3

(7) Coarse Aggregate having maximum size 12.5mm and fineness modulus 6.6 named as CAT4

The difference in first two types of Aggregates is in terms of flakiness index. First one having more flaky particles as compared to the second one. The last four are the tailored aggregates which are prepared by mixing the selected proportion from material retained on 20 mm to 4.75 mm sieve. The particle size distribution and other properties of these coarse aggregates are given in next section.

4.5.4.1 Properties of Coarse Aggregate (CA1)

Specific Gravity = 2.67

Moisture content = 0.2%

Water Absorption = 0.5%

Fineness Modulus = 7.00

Flakiness Index = 29.33%

Elongation Index = 25.7%

Table 4.2 Particle Size Distribution of CA1

Sieve Size	% Passing
40.0mm	100
20.0mm	90.17
10.0mm	3.50
4.75mm	1.60
2.36mm	1.60
1.18mm	1.60
600µ	1.40
300µ	0.40
150µ	0.33

4.5.4.2 Properties of Coarse Aggregate (CA2)

Specific Gravity = 2.67

Moisture content = 0.2%

Water Absorption = 0.5%

Fineness Modulus = 7.00

Flakiness Index = 16.33%

Elongation Index = 28.2%

Table 4.3 Particle Size Distribution of CA2

Sieve Size	% Passing
40.0mm	100
20.0mm	91.87
10.0mm	3.53
4.75mm	0.53
2.36mm	0.53
1.18mm	0.33
600µ	0.23
300µ	0.17
150µ	0.07

4.5.4.3 Properties of Coarse Aggregate (CA3)

Specific Gravity = 2.69

Moisture content = 0.2%

Water Absorption = 0.5%

Fineness Modulus = 5.95

Table 4.4 Particle Size Distribution of CA3

Sieve Size	% Passing
20.0mm	100
12.5mm	95.83
10.0mm	73.1
4.75mm	34.43
2.36mm	1.17
1.18mm	0.23
600μ	0.17
300μ	0.12
150μ	0.05

4.5.4.4 Properties of Coarse Aggregate (CAT1)

Specific Gravity = 2.67

Moisture content = 0.2%

Water Absorption = 0.5%

Fineness Modulus = 6.9

Flakiness Index = 21.15%

Elongation Index = 24.75%

.

Table 4.5 Particle Size Distribution of CAT1

Sieve Size	% Passing
40.0mm	100
20.0mm	90
10.0mm	20
4.75mm	0

4.5.4.5 Properties of Coarse Aggregate (CAT2)

Specific Gravity = 2.67

Moisture content = 0.2%

Water Absorption = 0.5%

Fineness Modulus = 6.8

Flakiness Index = 20.4%

Elongation Index = 26.3%

Table 4.6 Particle Size Distribution of CAT2

Sieve Size	% Passing
20.0mm	100
10.0mm	20
4.75mm	0

4.5.4.6 Properties of Coarse Aggregate (CAT3)

Specific Gravity = 2.67

Moisture content = 0.2%

Water Absorption = 0.5%

Fineness Modulus = 6.7

Flakiness Index = 20.65%

Elongation Index = 25.95%

Table 4.7 Particle Size Distribution of CAT3

Sieve Size	% Passing
20.0mm	100
10.0mm	30
4.75mm	0

4.5.4.7 Properties of Coarse Aggregate (CAT4)

Specific Gravity = 2.68

Moisture content = 0.2%

Water Absorption = 0.5%

Fineness Modulus = 6.6

Flakiness Index = 29.7%

Elongation Index = 25.2%

Table 4.8 Particle Size Distribution of CAT4

Sieve Size	% Passing
12.5mm	100
10.0mm	40
4.75mm	0

4.5.5 Fly Ash:

Fly ash named as (FS) collected form forth chamber (second last chamber) of Indraprastha thermal power station, New Delhi is used in the project work. The specific gravity of fly ash is 2.14 and particle size distribution is shown below:

Table 4.9 Sieve Test Results of Fly Ash

Sieve Size	150µ	90µ	75µ	63µ	45µ
% Passing	97.75	95.5	91.75	84.25	42.25

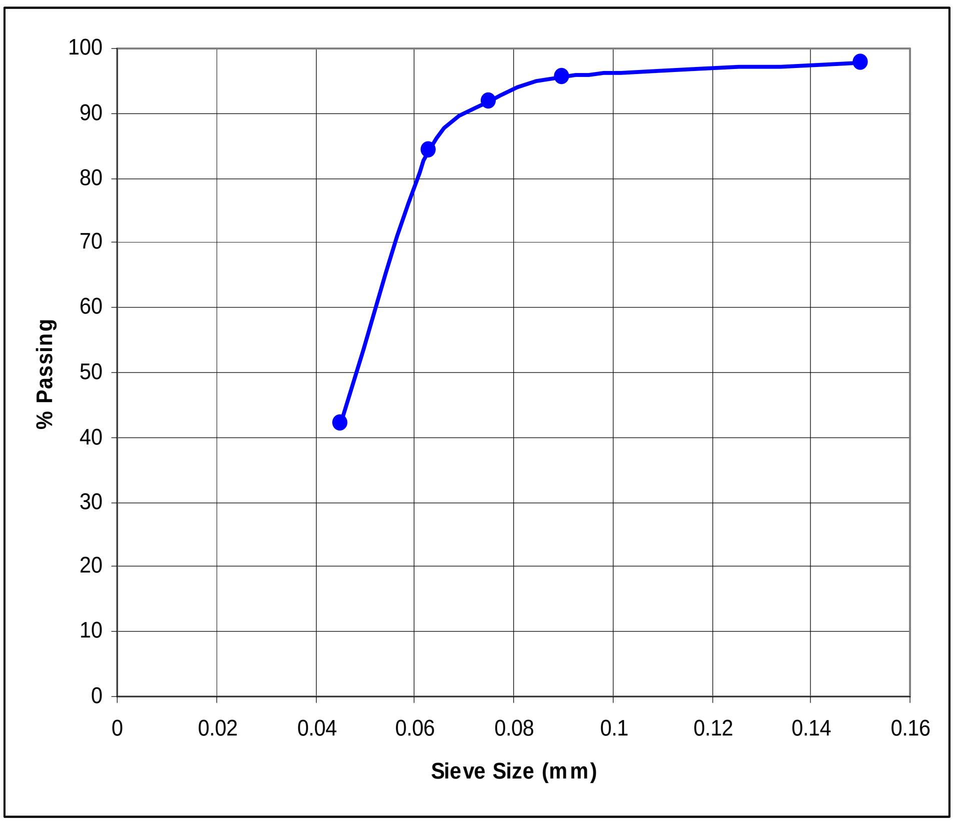


Fig 4.7 Particle Size Distribution Curve of Fly Ash

4.5.6 **Superplasticizer** :

Two types of Superplasticizers brought from Asian Laboratory, new okhla industrial estate, New Delhi are used in the project work.

4.5.6.1 CEMWET SP-3000(SR)

It is used to achieve high strength concrete and required workability by keeping the low water/cement ratio. The product is sulphonated polymer made by modifying Naphthalene Formaldehyde Condensate which allows mixing water to be reduced considerably maintaining slump of concrete for longer period of time as compared to normal naphthalene and melamine Polymer condensates. It is compatible with all types of cements such as OPC, PPC, slag cement and high alumina cement. It is suitable for ready mixed concrete and pre-cast concrete mixes. Therefore it is used for ordinary concrete mix in this project.

The compatibility of this superplasticizer is tested with 53 grade Ordinary Portland cement at w/c ratio 0.38 by marsh cone apparatus and a graph is plotted and it can be concluded that an optimum dose of 2% of this superplasticizer is consider satisfactory.

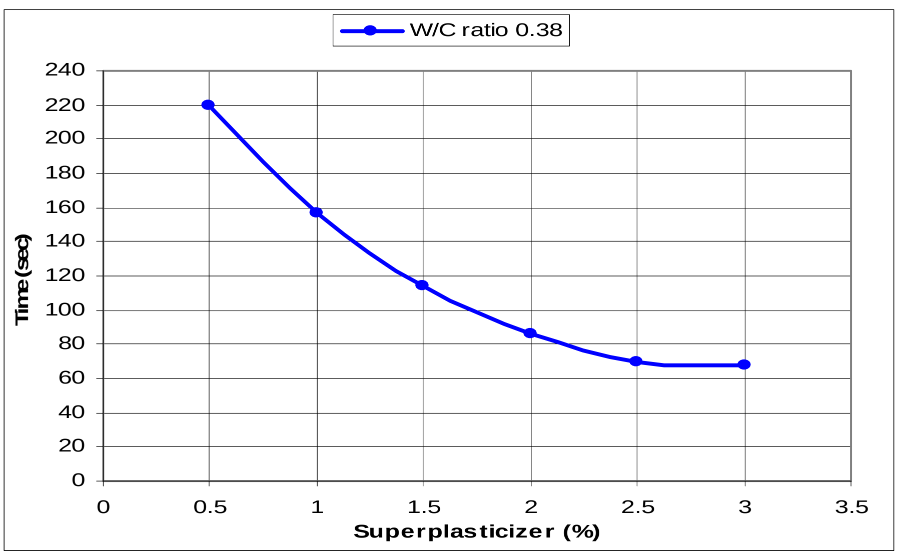


Fig. 4.8 Compatibility test results of CEMWET SP-3000(SR) with 53 grade OPC

4.5.6.2 CEMWET SP-3000 (PCE):

It is a new generation Superplasticizer having high molecular weight. The product is poly-carbo-ether based product, which allows mixing water to be reduced considerably maintaining slump of concrete for long period of time as compare to normal naphthalene and melamine polymer condensates. It is also compatible with all types of cements such as OPC, PPC, high alumina cement and slag cement. It is more effective in high volume fly ash concrete. Therefore it is used for fly ash concrete in my project work.

The compatibility of this type of superplasticizer is also tested with 53 grade Ordinary Portland Cement with w/c ratio 0.38 and plotted and it can be concluded that an optimum dose of 1.5% by weight of cement is considered satisfactory.

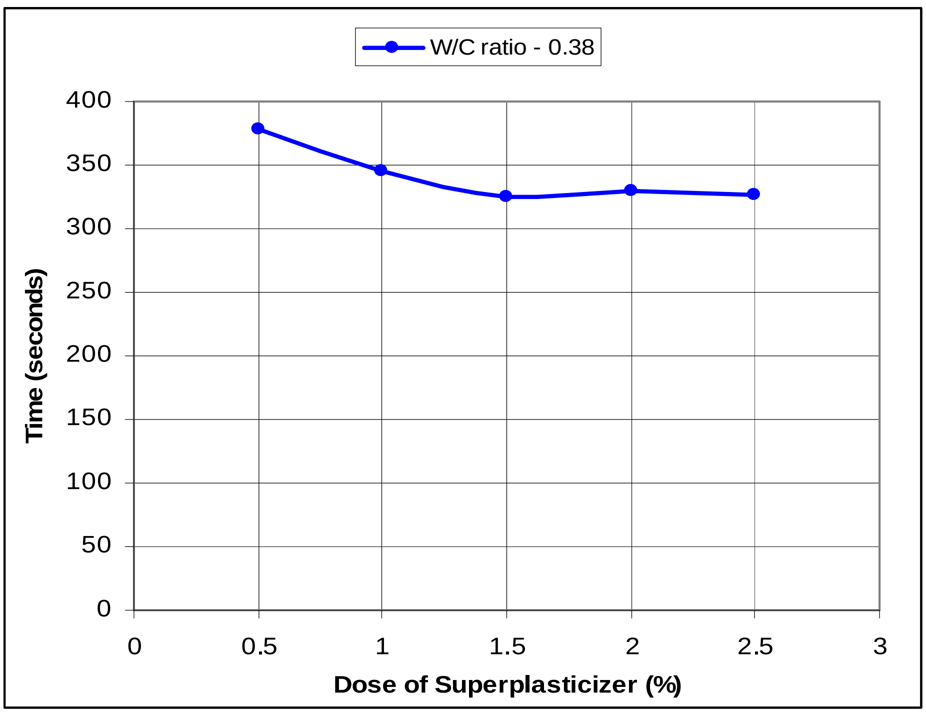


Fig. 4.9 Compatibility test results of CEMWET SP-3000(PCE) with 53 grade OPC.

4.6 Trial Mix

Initially some trial mixes have been prepared and tested. The strength of these mixes were obtained by warm water curing method. The details of these mixes are given in table 4.10

Table 4.10 Trial Mixes to Achieve Strength by Warm Water Curing Method

Mix No.	Mix Proportion	Cement (kg/m^3)	W/C ratio	SP (%)	Slump (mm)	Comp factor	28 days predicted strength (Mpa)	Materials used
1	1:1.24:3.01	405	0.43	-	0	0.62	37.13	Cement - 43 grade (O.P.C.) Fine Aggregate - FA1 Coarse Aggregate - CA1
2	1:1.24:3.01	405	0.48	-	-	0.72	32.41	Cement - 43 grade (O.P.C.) Fine Aggregate - FA1 Coarse Aggregate - CA1
3	1:1.01:3.03	420	0.32	2	11	0.64	-*	Cement - 43 grade (O.P.C.) Fine Aggregate - FA1 Coarse Aggregate - CA1(66.66%) Coarse Aggregate - CA3 (33.33%)
4	1:1.01:3.03	420	0.38	1	7	0.68	42.07	Cement - 43 grade (O.P.C.) Fine Aggregate - FA1 Coarse Aggregate - CA1(66.66%) Coarse Aggregate - CA3 (33.33%)
5	1:1.203:2.67	450	0.346	1.2	0	0.64	47	Cement - 43 grade (O.P.C.) Fine Aggregate - FAT1 Coarse Aggregate - CAT3
6	1:1.139:2.76	450	0.323	1.5	-	0.62	72	Cement - 53 grade (O.P.C.) Fine Aggregate - FAT1 Coarse Aggregate - CAT3
7	1:1.148:2.78	450	0.29	2	-	0.58	65.1**	Cement - 53 grade (O.P.C.) Fine Aggregate - FAT1 Coarse Aggregate - CAT3

* A different superplasticizer is used in this mix and due to the overdosage of this, concrete did not set so strength cannot be determined

** Due to very low w/c ratio, it was very difficult to compact the concrete so there is a reduction in strength as compared to mix 6

4.7 Real Mix

Series A

Five different type of mixes have been studied in view of minimum grade of concrete M20 and minimum cement content is 300 kg/m^3. These mixes were design in such a way that they have a low slump value. These mixes are mentioned under series A in the table 4.12

Series B

In this group of mixes natural fine aggregates of lowest and highest fineness modulus alongwith tailored fine aggregate were studied for practical slump value, M20 grade concrete and minimum cement content of 300 kg/m^3.

Series C

In this group, mixes of series B have been studied for the same parameters with 20% cement replacement with fly ash.

Series D

Maximum cement content (i.e. 450 kg/m^3) and a practical slump value was the criteria with different aggregates in studying the compressive strength.

Series E

In this group, all mixes of series D have been studied with 20 % more cementitious content in the form of fly ash.

Series F

In this group of mixes 53 grade of cement with a 20mm maximum size of aggregate have been studied with or with out fly ash to achieve high compressive strength.

Series G

In this group of mixes 53 grade of cement with a 12.5mm maximum size of aggregate have been studied with or with out fly ash to achieve more high compressive strength

Table 4.11 Details of Materials used in Different Mixes

Mix Series	Mix No.	Cement	Fine Aggregate	Coarse Aggregate	Fly Ash	Super-plasticizer
Series A	1A	43 Grade	FA1	CA1	-	-
	2A	43 Grade	FA1	CA2	-	-
	3A	43 Grade	FA2	CA1	-	-
	4A	43 Grade	FA2	CA2	-	-
	5A	43 Grade	FAT2	CAT1	-	-
Series B	1B	43 Grade	FA2	CA1	-	-
	2B	43 Grade	FA3	CA1	-	-
	3B	43 Grade	FAT2	CAT1	-	-
Series C	1C	43 Grade	FA2	CA1	FS	-
	2C	43 Grade	FA3	CA1	FS	-
	3C	43 Grade	FAT2	CAT1	FS	-
Series D	1D	43 Grade	FA2	CA1	-	-
	2D	43 Grade	FA3	CA1	-	-
	3D	43 Grade	FAT2	CAT1	-	-
Series E	1E	43 Grade	FA2	CA1	FS	-
	2E	43 Grade	FA3	CA1	FS	-
	3E	43 Grade	FAT2	CAT1	FS	-
Series F	1F	53 Grade	FAT1	CAT3	-	SP3000(SR)
	2F	53 Grade	FAT1	CAT3	FS	SP3000(PCE)
	3F	53 Grade	FAT1	CAT3	FS	SP3000(PCE)
Series G	1G	53 Grade	FAT1	CAT4	-	SP3000(SR)
	2G	53 Grade	FAT1	CAT4	FS	SP3000(PCE)
	3G	53 Grade	FAT1	CAT4	FS	SP3000(PCE)

Table 4.12 Quantities of materials used in different mixes.

Mix Series	Mix No.	Cement (kg/m^3)	Total Water (kg/m^3)	Hydration, Lubrication water	w/(c,c$_m$) ratio	Fine Agg. (kg/m^3)	Coarse Agg. (kg/m^3)	Fly Ash (%)	SP (%)
Series A	1A	372.7	205	85.72, 119.28	0.55	819.94	995.11	-	-
	2A	372.7	205	85.72, 119.28	0.55	819.94	995.11	-	-
	3A	372.7	205	85.72, 119.28	0.55	611.228	1170.28	-	-
	4A	372.7	205	85.72, 119.28	0.55	611.228	1170.28	-	-
	5A	336.5	176.5	77.40, 99.1	0.52	540.07	1296.29	-	-
Series B	1B	408.3	272.3	93.91, 178.39	0.6	563.45	1033	-	-
	2B	405	255.2	93.15, 162.05	0.6	732.64	900.32	-	-
	3B	411.7	255.3	94.69, 160.61	0.6	552.9	1049.83	-	-
Series C	1C	344	281.9	79.12, 202.78	0.6	485.04	1035.44	20	-
	2C	361.3	281.3	83.10, 198.20	0.6	588.92	899.64	20	-
	3C	358.7	276.4	82.50, 193.90	0.6	436.9	1048.84	20	-
Series D	1D	450	271.7	103.5, 168.2	0.55	525.15	1034.55	-	-
	2D	450	253.8	103.5, 150.3	0.55	637.65	960.75	-	-
	3D	450	253.1	103.5, 149.6	0.55	463.05	1111.95	-	-
Series E	1E	450	291.1	103.5, 187.6	0.49	328.5	1035	20	-
	2E	450	277.5	103.5, 174	0.49	472.5	900	20	-
	3E	450	284.8	103.5, 181.3	0.48	405	972	20	-
Series F	1F	450	177.75	103.5, 74.25	0.38	508.52	1220.47	0	1.5
	2F	450	202.5	103.5, 99	0.395	481.5	1152	20	1.5
	3F	450	218.8	103.5, 115.3	0.33	454.5	1084.5	30	1.5
Series G	1G	450	182.75	103.5, 79.25	0.41	507.06	1216.9	0	1.5
	2G	450	208.13	103.5, 104.63	0.36	468	1129.5	20	1.5
	3G	450	225.22	103.5, 121.72	0.34	441	1062	30	1.5

CHAPTER 5

RESULT AND DISCUSSION

5.1 The results of mixes of different series are produced in table 5.1

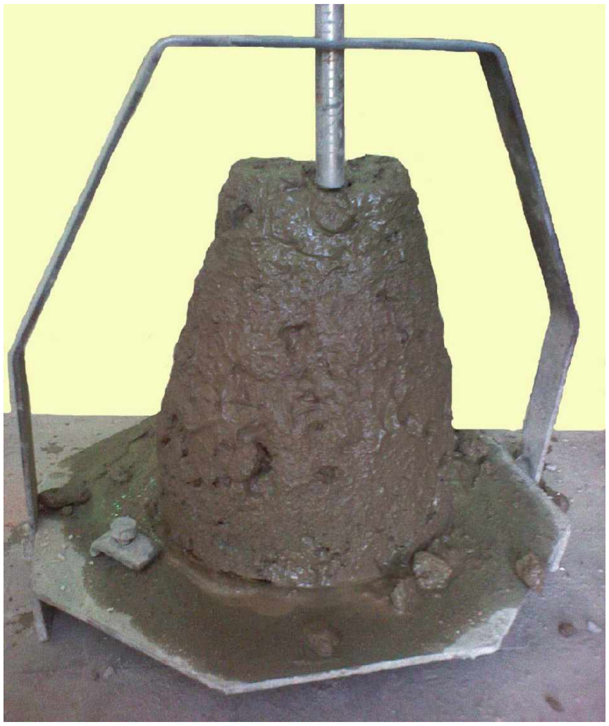
Table 5.1 Results of different mixes

Mix Series	**Mix No.**	**Slump (mm)**	**Compaction factor**	**28 days strength (Mpa)**	**56 days strength (Mpa)**
Series A	1A	8	-	27.17	-
	2A	9	-	28.78	-
	3A	8	-	22.09	-
	4A	9	-	24.99	-
	5A	10	-	30.66	-
Series B	1B	44	-	24.78	27.26*
	2B	48	-	25.58	28.14*
	3B	58	-	28.56	31.42*
Series C	1C	58	-	23.83	28.77
	2C	55	-	24.56	30.95
	3C	46	-	25.36	31.83
Series D	1D	32	-	28.48	31.33*
	2D	58	-	29.36	32.30*
	3D	42	-	31.97	35.17*
Series E	1E	37	-	29.8	36.04
	2E	38	-	31.83	37.28
	3E	44	-	33.72	39.02

Series F	1F	-	0.8	55.08	60.59*
	2F	-	0.79	59.15	62.13
	3F	-	0.78	60.17	63.66
Series G	1G	-	0.8	60.31	66.34*
	2G	-	0.78	62.06	65.62
	3G	-	0.77	63.37	67.36

* Representing 90 days strength and it is estimated from the provision given in IS: 456-1978 which enumerate that in plain concrete, there is 10% increase in strength form 28 days to 90 days.

The discussion on the results obtained above has been done on the next section.



Slump of Mix 2B

Slump of Mix 2D

5.2 Discussion on Results

The discussion on the results shown in table 5.1 are given below

(1) In series A, comparing mix 1A to 2A, although the mix proportion is same in mix 1A and 2A and also same fine aggregate has been used in both the mix but strength increased in mix 2A this is because coarse aggregate CA2 used in mix 2A have less flakiness index as compared to coarse aggregate CA1 used in mix 1A which implies that CA1 have more flaky particle as compare to CA2. And the same reason is applicable for comparing mix 3A to 4A. Hence it can be said that increase in flakiness Index reduces the compressive strength of concrete.

(2) Again in series A, comparing mix 1A to 3A, although the same coarse aggregate has been used in both the mixes, but the strength decreased in mix 3A this is because fine aggregate used in mix 3A is finer than fine aggregate used in mix 1A. And same concept is applicable for comparison of mix 2A to 4A. Hence it can be said that fine aggregate having low fineness modulus gives low strength.

(3) Again in series A, because of using the tailored fine and coarse aggregate in mix 5A, water content slightly reduced for marginal increase in workability and better strength has been achieved in mix 5A in comparison of remaining mixes of series A. Hence it can be said that a graded aggregate consumes less water for the same workability and gives better strength.

(4) Comparing the mixes of series B to the corresponding mixes of series A, to achieve more slump there is an increase in lubricating water requirement in mixes of series B which may cause decrease in strength due to increase in w/c ratio. And to maintain the desirable strength, cement content has been increased in mixes of series B in comparison of cement content used in mixes of series A. Since increase in cement content requires more water for hydration which cause an overall increment in the total quantity of water in mixes of series B.

(5) In Series B, comparing mix 1B to 2B. Both the mixes have same coarse aggregate but fine aggregate in mix 2B is of high fineness modulus which again cause increase in strength in mix 2B.

(6) Comparing mixes of series B to the corresponding mixes of series C, although the water/binder ratio is same, the 28 days strength is less in mixes of series C because cement is partially replace to fly ash in mixes of series C and due to the slow pozzolanic reaction between fly ash and calcium hydroxide, the strength of fly ash concrete at 28 days is marginally less than the plain concrete. As per IS: 456-1978 a provision in regard to increase in strength at periods later than 28 days exist and the same has been adopted to estimate the 90 days strength of mixes of series B. The 90 days compressive strength of mixes of series B (plain mixes) is still less than the 56 days corresponding strength of mixes of series C (fly ash mixes) which is again due to the continuous pozzolanic reaction after 28 days.

(7) In series D, all the mixes were workable, comparing mix 1D and 2D to 3D although water/cement ratio as well as cement content is also constant but strength increased in mix 3D. This is because first, there is a graded aggregate having good fineness modulus and second, fixed the ratio of fine to coarse aggregate in proportion 1:2.4 has been also fixed which cause an improved combined grading of total aggregate. The comparison of these three mixes combined grading is shown in fig. 5.1.

(8) Comparing mixes of series D to corresponding mixes of series B, although both the series has been design to achieve a slump in the range of 50±25mm and quantity of total water content is almost same. But quantity of lubricating water decreased in mixes of series D. This is because there is an increase in cement content in mixes of series D, which requires more water for hydration form the total water available.

(9) Comparing mixes of series D to the corresponding mixes of series E, the 28 days strength has been increased in mixes of series E, because, instead of using the fly

ash as partially replacement material, it is added in addition with maximum cement content (450 kg/m^3) which contribute additional strength in concrete. And the same effect can also be seen in mixes of series F and series G in which fly ash is used as an additional cementitious material with maximum cement content. The strength has been increased continuously by using the fly ash as addition form 0 to 30%.

(10) Comparing mix 1F to 1G, although same cement content, fine aggregate has been used in both the mixes and w/c ratio is slightly more than in mix 1G, but there is more gain of strength in mix 1G. This is because of using the 12.5mm down coarse aggregate which possess more surface area for binding with cement.

(11) In trial mix no.6, Strength achieved upto 72Mpa at w/c ratio 0.32 with 1.5% superplasticizer but got an unworkable concrete. Further redesigning the above mix as mix 1F by increasing the water and keeping the maximum cement content and dosage of superplasticizer constant to achieve a value of compaction factor in the range of 0.75-0.8 for the workability, the strength reduced upto 55 Mpa at w/c ratio 0.38. Since this superplasticizer is compatible upto 2% so further reduction in w/c ratio can be done by using this dose to achieve same workability and more strength.

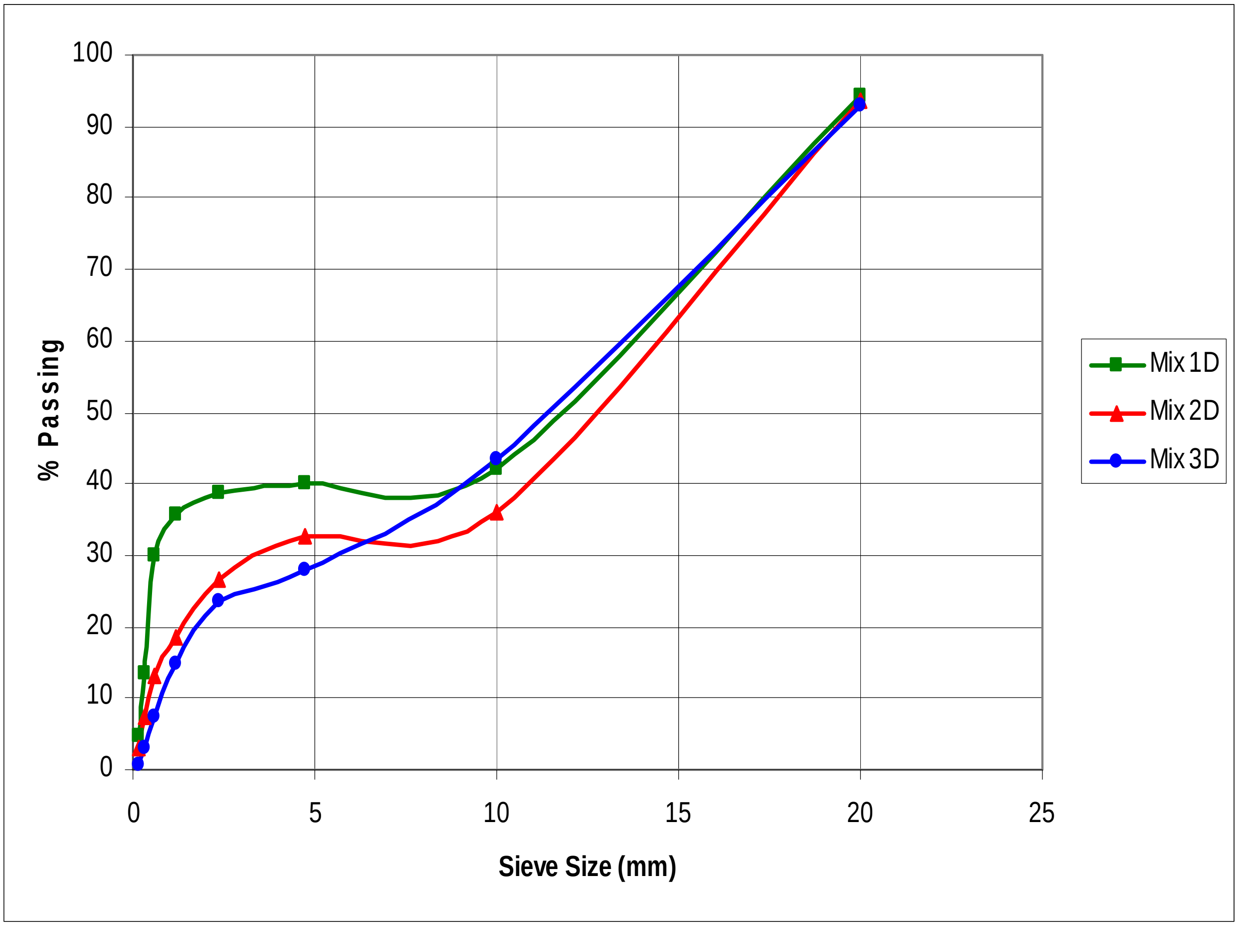


Fig 5.1 Combined grading of aggregate for mixes of series D

CHAPTER 6

CONCLUSION AND FURTHER SCOPE OF WORK

6.1 Conclusion

Following conclusion have been made from the discussion done on the results obtained of different mixes

(1) From the comparison of mix 1A to 2A, it can be concluded that presence of flaky particle in coarse aggregate cause reduction in compressive strength of concrete.

(2) From the comparison of mix 1A to 3A, it can be concluded that fine aggregate having low fineness modulus gives low strength.

(3) From the comparison of mix 5A to remaining mixes of series A, it can be concluded that a graded tailored aggregate consumes less water and gives better strength in comparison of natural aggregate.

(4) Form the comparison of series B to series A, it can be concluded that to achieve the more workable mix if there is an increase in water demand then it is necessary to increase the cement content to maintain the desirable strength.

(5) Form the comparison of series C to series B, it can be concluded that using the fly ash as partially replacement material to cement, the 28 days strength obtained becomes less than plain concrete but 56 days strength is become more than plain concrete.

(6) From the comparison of mix 3D to 1D and 2D, it can be concluded that the combined grading also plays an important role to achieve more workability as well as compressive strength of concrete.

(7) Form the comparison of series E to series D, it can be concluded that using the fly ash as additional cementitious material with maximum cement content, the 28 days strength is increased in comparison of plain concrete. To achieve more high strength it is necessary to keep the low water/cement ratio. But using the fly ash as addition with maximum cement content may cause increase in water demand if fine aggregate is used in its natural state. Therefore to minimize this effect, tailored aggregates has been used and it can be seen in mixes of series F and series G that using the incremental addition of fly ash, the strength is increasing progressively.

(8) In the mixes of series A, B, C, D, E, the workability has been achieved only by using the water. Hence it can be concluded that same workability and more strength can be achieved in the same mixes by reducing the water content and using the superplasticizer. Since the superplasticizer (SP 3000-SR) is compatible upto 2% by weight of cement and the maximum dosage (1.5%) has been used in the mixes of series F and series G. Therefore it can be again concluded that further water reduction can be done in these mixes using this dosage to achieve almost same workability and more strength.

(9) From the comparison of mix 1F to 1G, it can be concluded that 12.5mm down coarse aggregate gives more strength in comparison of 20mm down coarse aggregate

(10) Maximum strength achieved upto 60Mpa without any mineral admixture with angular-flaky type of coarse aggregate by maintaining both the provision like max cement 450kg/m^3 and workable mix. Further increase in strength can achieved by using cubical shaped coarse aggregate

6.2 Further Scope of Work

(1) Since All these work is done by using angular-flaky type of coarse aggregate which is not so good for workability as well as strength point of view This work further be extended by using cubical shaped coarse aggregate to achieve more strength.

(2) As only fly ash is used as mineral admixture in this project so further work can be done by using other mineral admixture like rice husk ash, metakaolin etc.

(3) As only badarpur sand is used as fine aggregate so further work can be done by using stone dust or any other fine material

References

(1) Tike G.K., Satander Kumar and Sood V.K., Use of chemical admixtures for pavement quality concrete, The Indian Concrete Journal, September 2004, pp 46-50

(2) Gutmann Paul F., Bubble Characteristics as They Pertain to Compressive Strength and Freeze-Thaw Durability, ACI Materials Journal, September-October 1988, pp 361-366

(3) Bharatkumar B.H., Narayanan R., Raghuprasad B.K., Ramachandramurthy D.S., Mix proportioning of high performance concrete, Cement and Concrete Composites 23(2001), pp 71-80

(4) Venkatesh Babu D.L. and Natesan S.C., Some investigations on silica fume concrete, The Indian Concrete Journal, September 2004, pp 57-60

(5) Mavinkurve Shreeti S., Basu Prabir C. and Kulkarni Vijay R., High performance concrete using high reactivity metakaolin, The Indian Concrete Journal, May 2003, pp 1077-1085

(6) Parakash Rao D.S. and Giridhar Kumar V., Investigations on concrete with stone crusher dust as fine aggregate, The Indian Concrete Journal, July 2004, pp 45-50

(7) Malhotra V.M. and Carette G.G., Performance of Concrete Incorporating Limestone Dust as Partial Replacement for Sand, American Concrete Institute (ACI) Journal, May-June 1985, pp 363-371

(8) Gambhir M.L., Concrete technology, Third edition, Tata Mcgraw-Hill Publishing Company, 2007

(9) Shetty M.S., Concrete technology, fifth edition, S. Chand Publishing Company, 2002

(10) Neville A.M., Properties of concrete, forth edition, Pitman publishing company, 1996

(11) IS: 456-2000 (forth revision), Code of practice for plain and reinforced concrete.

(12) IS: 8112-1989 (first revision), Specification for 43 grade ordinary Portland cement.

(13) IS: 12269-1987, Specification for 53 grade ordinary Portland cement.

(14) IS: 9013-1978, Method of making, curing and determining compressive strength of accelerated cured concrete test specimens.

(15) IS: 9103-1979, Specification for admixtures for concrete.

(16) IS: 383-1970 (second revision) Specification for coarse and fine aggregates from natural sources for concrete.

(17) SP: 23-1982, Handbook on concrete mixes, Bureau of Indian Standards, New Delhi, 1982