A Major Project Report on

"Fluidity and Workability Study of Cement (OPC) and Super-plasticizer"

Submitted towards partial fulfillment of the requirement

for the award of degree of

MASTER OF ENGINEERING

IN

CIVIL ENGINEERING

(With specialization in Structures)

Submitted by

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CERTIFICATE

This is to certify that Major Project Report entitled **"Fluidity And Workability Study of Cement (OPC) and Super-plasticizer"** is an authentic record of my own work carried out in partial fulfillment of the requirements for the award of degree of Master of Engineering (Structural Engineering), Department of Civil Engineering, Delhi College of Engineering, Delhi under the guidance of **Er. Amit Kumar Shrivastava**, Assistant Professor .

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It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

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Abstract

Concrete incorporates a mixture of chemical and mineral admixtures in present scenario. Chemical admixtures are materials available in the form of powders or fluids that are added to concrete to give certain characteristics not obtainable with ordinary concrete mixes. An admixture's performance is dependent on its type and dosage, composition, specific surface area of the cement, type and proportions of the aggregate, sequence of addition of water and admixture, compatibility of admixtures, water/cement ratio, and temperature and conditions of curing. Requirement of right workability is the essence of good concrete and concrete in different situations require different degree of workability. High range water reducers referred as super plasticizers help in obtaining higher workability without use of excess water. It is very difficult to ensure that a super-plasticizer that produces all the desired effects with cement of one type and brand would do the same with cement of other type and brand. Incompatibility may exist due to different types of cement or due to different brands of cement. Users, who are unaware of compatibility issues, often suffer when the supply of cement and/or super-plasticizer is changed. In the Present work we find the optimum doses of super-plasticizers for different brands of cement (OPC 43 grade) available in the market at different water cement ratio using Marsh Cone to adjudge best combination of cement and super-plasticizer and found that different Super-plasticizers give different optimum dose with different brand of ordinary Portland cement. Also, slump retention characteristics of concrete is of great importance as workability is lost with the passage of time and the efforts are made to retain the slump with time so that concrete remains workable for long time. Slump retention depends on both, type of cement and type of super-plasticizer. So the current work is carried out to ascertain the water reduction by different combination of cement and super-plasticizer at which slump loss is minimal.

Chapter 1

INTRODUCTION

Apart from the chemical admixtures, a number of different types and brands of cement are available in the market today. With the increasing number of types and brands of cement, as well as variants of the water-reducing chemicals, there are issues that arise related to the compatibility between these two ingredients of concrete.

1.1 Cement

With the advent of technology and need for the development of infrastructure construction industry focus on the requirement of a reliable construction material that lead to the evolution of cement which is initially used for making mortar but later its use is extended to concrete. A cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The raw materials required for manufacture of Portland cement are calcareous materials such as limestone or chalk and argillaceous materials such as shale or clay. The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity and composition and burning them in kiln at very high temperature at which raw materials fuses to form complex compounds such as dicalcium silicate, tricalcium silicate, tricalcium aluminate and tetracalcium aluminoferrite called as Bogue's compounds. Anhydrous cement does not bind fine and coarse aggregate and acquire adhesive property only when mixed with water. The chemical reaction that takes place between cement and water referred as hydration of cement on account of which certain products are formed which have cementing or adhesive value, the most important of which is the reaction of C3S and C2S with water.

1.1.1 Types of Cement

To cater the need of the construction industry for specific purposes, continuous effort are made to produce different kinds of cement suitable for different situations by changing oxide composition and fineness of grinding.

Different types of cement available are-

(i) Ordinary Portland cement- OPC is most important type of cement and available in three grades namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988. High grade cements offer many advantages for making stronger concrete, one of the most important benefits is the faster rate of development of strength

(ii) Rapid hardening Cement- As the name indicates Rapid hardening cement develops strength rapidly, the rapid rate of development of strength attributed to higher fineness of grinding and higher C3S and lower C2S content and find its application mainly in cold weather concreting or where speedy construction is required.

(iii) Sulphate resisting cement- Ordinary Portland cement is susceptible to the attack of sulphates. To reduce the sulphate attack the use of cement with low C3A content is found to be effective.

(iv) Quick Setting Cement- As the name indicates this cement sets very early which is brought by reducing the gypsum content at the time of clinker grinding and used mostly in under water construction.

(v) Low Heat Cement- Since the process of hydration of cement is Exothermic action which produces large quantity of heat , low heat evolution is achieved by reducing the contents of C3S and C3A generally required in mass concreting operations.

(vi) Portland Pozzolana Cement – Portland pozzolana cement is manufactured by intergrinding of OPC clinker with 10 to 25 % of pozzolanic material which is essentially a silicious or aluminous material possessing no cementitious propertiesand produces less heat of hydration and offers greater resistance to attack of aggressive waters than OPC.

Besides from above mentioned cements many other different types of cement are available in the market.

1.2 Super-plasticizer

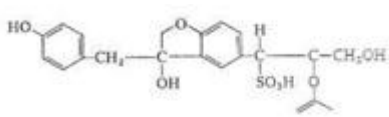
Today concrete is being used for wide varieties of purposes in different conditions. In these conditions ordinary concrete may fail to exhibit required quality performance or durability. So admixture is used to modify the properties of ordinary concrete so as to make it more suitable for any situation. A water reducing chemical, as the name implies, is used to reduce the water content of a concrete mixture while maintaining a constant workability. The resultant effect of the reduced water content is the increased strength and durability of concrete and super-plasticizers (high range water reducers) constitute this class. The addition of the super-plasticizers makes the concrete flow better. Another use of water reducers is to lower the amount of cement since water is proportionately reduced without affecting both strength and workability. This makes the concrete cheaper and environmentally friendly, as less cement is consumed

1.2.1 Types of super-plasticizers

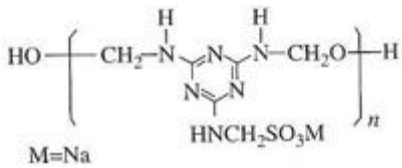
The high range water reducers known as super-plasticizers can cause a reduction of 15 – 40%. Water reducing chemicals are generally supplied as liquid formulations, with the active solids content in the range of 30 – 40%. High range water reducers are capable of being used at higher dosages of 0.7 – 1% (or more) liquid by weight of cement. Reducing the water content in a concrete mixture should be done in such a way so that complete cement hydration process may take place and sufficient workability of concrete is maintained for placement and consolidation during construction. The w/c ratio needed forcement to complete its hydration process ranges from 0.22 to 0.25. The existence of additional water in the mixture is needed for ease of concrete placing and finishing (workability of concrete). All the super-plasticizers are water soluble polymers and as for other polymers, the behavior of super-plasticizers is also a function of the structure and the degree of polymerization. Lignosulphonates are generally regarded as '1st generation' super-plasticizers while the sulphonated formaldehyde condensates are called '2nd generation super-plasticizers and the polycarboxylates and polyacrylates are termed as 3rd generation super-plasticizers. Currently, the most widely used super-plasticizers are the sulphonated formaldehyde condensates. However, the beneficial effects of polycarboxylates are ensuring a gradual shift towards these chemicals. Used at high dosages, lignosulphonates are capable of producing high range water reduction. Sulphonated salts of melamine formaldehyde condensates are good to achieve a high initial slump. However, due to their poor slump retention characteristics, they are unsuitable for long haul applications. Sulphonated salts of naphthalene formaldehyde condensates possess all the necessary characteristics to make them suitable for hot weather concreting. Mainly, these possess good slump retention characteristics, enabling their use in ready mixed concrete where long hauls are common. Slump retention characteristics are also improved by blending SNF with lignosulphonates.. Polycarboxylates and acrylic copolymers are the most effective of all the chemicals. These can cause a reduction in water content of as much as 40%. Thus, they are highly preferred to make high and ultra high strength concrete, where the w/c may be as low as 0.20. Generally, these chemicals exhibit excellent slump retention characteristics and do not cause any delay in the gain of strength of the concrete. Limited experience with these chemicals indicates that they work well at low water cement ratios, and exhibit fewer compatibility problems compared to SNF.

1.2.2 Structure of Superplasticizing Chemicals

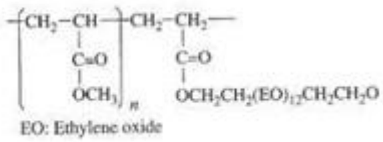
Lignosulphonates



Sulphonated melamine formaldehyde (SMF)



Polycarboxylic ether (PCE)



Sulphonated Naphthalene Formaldehyde (SNF)

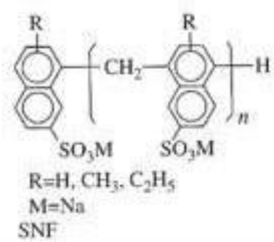


Fig 1 Super-plasticizing chemicals (Rixom and Maivaganam, 2003)

1.3 Objective of work-

Today different admixtures and different types and brands of cement are available in the market. Segregation of the mix can occur when larger dosages of the admixture are used. Fresh concrete mixtures typically experience continuous stiffening and slump loss with time. At moderate temperatures, this stiffening and associated slump loss do not create real difficulties and concrete remains workable long enough for its handling and placement. However, hot weather environments cause serious problems in the placement of fresh concrete due to the acceleration of cement hydration and faster water evaporation Thus, significant slump loss is usually experienced under high temperature. It is very difficult to ensure that a super-plasticizer that produces all the desired effects with cement of one type and brand would do the same with cement of other type and brand. So the current work deals with the:

(i) Effect of super plasticizers on the plastic properties of green concrete especially workability
(ii) Compatibility of different Super-plasticizers with different types of cement (OPC) at different water cement ratio
(iii) Water Reduction by particular super-plasticizer and slump retention at different time intervals

1.4 Mechanism of action of water reducers

Water-reducing chemicals belong to a group of chemicals known as ‘dispersants’. The action of the dispersant is to prevent the flocculation of fine particles of cement. These dispersants are basically surface-active chemicals consisting of long-chain of organic molecules, having a polar hydrophilic group (water-attracting) such as $-COO^-$, $-SO_3^-$, $-NH_4^+$) attached to a non-polar hydrophobic organic chain (water-repelling) with some polar groups (-OH). The polar groups in the chain get adsorbed on the surface of the cement grains, and the hydrophobic end with the polar hydrophilic groups at the tip project outwards from the cement grain. The hydrophilic tip is able to reduce the surface tension of water, and the adsorbed polymer keeps the cement particles apart by electrostatic repulsion. The adsorption of the admixture leads to a decrease of the zeta potential, and eventually causes like charges on the cement particles. With the progress of hydration, the electrostatic charge diminishes and flocculation of the hydrating product occurs. Lignosulphonates (normal, and sugar-refined), SMF, and SNF based super-plasticizers work on the mechanism of lowering zeta potential that leads to electrostatic repulsion. On the other hand, polymers with backbone and graft chains, such as PCEs, acrylic esters, and cross-linked acrylic polymers, cause dispersion of cement grains by steric hindrance. This phenomenon relates to the separation of the admixture molecules from each other due to the bulky side chains. Steric hindrance is a more effective mechanism than electrostatic repulsion. The side chains, primarily of polyethylene oxide extending on the surface of cement particles, migrate in water and the cement particles are dispersed by the steric hindrance of the side chains.

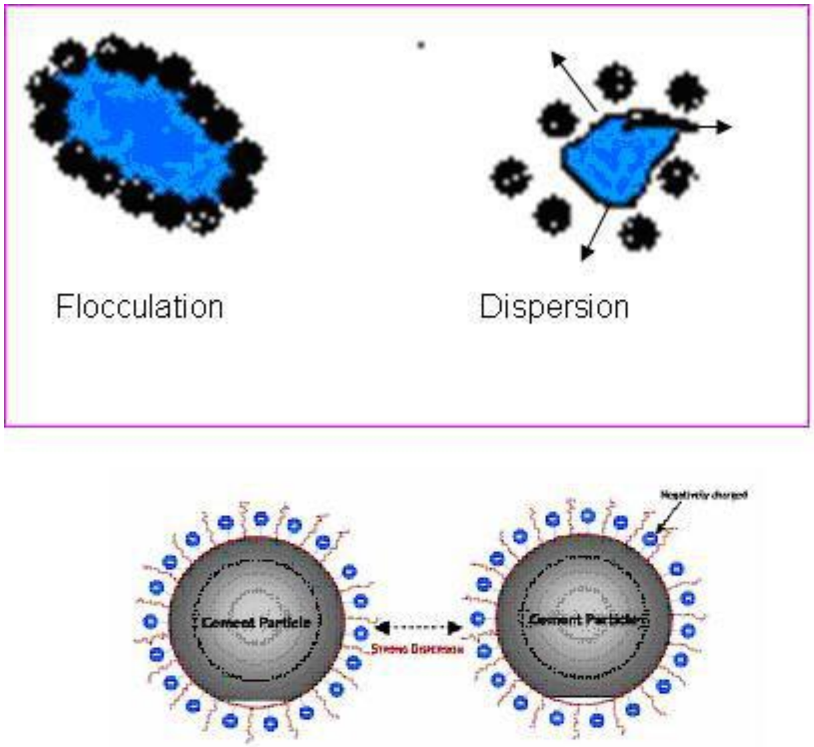


Fig. 2 Mechanism of Electrostatic repulsion and steric hindrance (Nakajima and Yamada (2004) and Sugiyama et al. (2003))

Electrostatic repulsion depends on the composition of the solution phase and the adsorb amount of the SP (greater the adsorption, better the repulsion) Nakajima and Yamada, (2004). On the other hand, steric repulsion depends on the length of main chain, length and number of side chains Sugiyama et al., (2003).

1.5 Factors affecting compatibility

Interaction problems are caused by the effect of the admixtures on the hydration reaction of cement and due to adsorption of the admixture to the cement particles. These are different from problems in fresh concrete that are caused due to poor material selection.

However, compatibility problems arise even when the material selection and design is supposedly proper. Compatibility between cements and super-plasticizers is affected by a combination of reasons, including cement composition, admixture type and dosage, concrete mixture proportions etc Cement is composed of four major compounds, namely, C_3S (tricalcium silicate), C_2S (dicalcium silicate), C_3A (tricalcium aluminate), and C_4AF (tetracalcium aluminoferrite). In addition, a number of minor oxides, such as alkali oxides (K_2O and Na_2O), MgO, and SO_3 – which is contributed by gypsum, which is added in the final stages of cement manufacture as a set regulator. Because of the final grinding operation, the particles of cement are charged the surface charge being measured as the Zeta potential. While C_3S and C_2S possess a negative zeta potential, C_3A and C_4AF particles are positively charged.

1.6 Problems due to incompatibility

The term incompatibility refers to the adverse effect on performance when a specific combination of cement and super-plasticizer is used. Common problems include flash setting, delayed setting, rapid slump loss, improper strength gain, low workability, low strength gain etc. These issues in turn affect the hardened properties of concrete, primarily strength and durability. It is very difficult to ensure that a super-plasticizer that produces all the desired effects with cement of one type and brand would do the same with cement of other type and brand. Incompatibility may exist due to different types of cement or due to different brands of cement available in market of same type. Users, who are unaware of compatibility issues, often suffer when the supply of cement and/or super-plasticizer is changed midway through a project. Problems arising out of compatibility issues are often mistaken for problems with concrete mix design because of the lack of knowledge. Incompatibility could also arise as a result of the use of additional mineral additives, or while using multiple chemicals. This further complicates the physico-chemical behavior of the cement-based system since the mineral admixtures play an important role in the evolution of the hydration reactions and the availability of free water during the early ages of concrete. For a more comprehensive approach, a through understanding of the causes and remedies of incompatibility is necessary

1.7 Workability

Workability is defined as the ease with which concrete can be mixed, transported, placed, compacted and finished without segregation and bleeding. To enable the concrete to be fully compacted with given efforts certain quantity of water is required to lubricate the concrete required for handling concrete without segregation, placing without loss of homogeneity, compacting with the amount of efforts forth coming and finish it easily. The quality of concrete satisfying the above requirement is termed as workable concrete.

1.7.1 Factors affecting workability-

(i) Water content- Water content in given volume of concrete have significant influence on the workability. Higher the water content per cubic meter of concrete higher will be the fluidity which is one of the important factor affecting workability. Though the practice of addition of water for increasing the workability may prove detrimental to concrete as it affects the strength of concrete so addition of excess water should be accompanied by addition of cement so that water cement ratio remains constant and strength remains same.

(ii) Mix Proportions- Aggregate/cement ratio is an important factor influencing workability. The higher the ratio leaner is the concrete. Lean concrete has less quantity of paste available for lubrication per unit surface area of concrete while rich concrete with low aggregate/cement ratio has more paste available to make the mix cohesive and hence give better workability.

(iii) Size of aggregate- The bigger the size of aggregate less is the surface area and

hence less amount of water is required for wetting the surface area and less paste is required for lubrication and hence lead to higher workability but within certain limits.

(iv) Shape of aggregate- Angular, elongated or flaky aggregate makes the concrete very harsh when compared to rounded aggregate or cubical shaped aggregate.

Better workability in case of rounded aggregate is attributed to the fact that for given volume they have less surface area and less voids than angular or flaky aggregate.

(v) Surface texture- Surface texture influence the workability again due to the fact that total surface area of rough textured aggregate is more than surface area of smooth rounded aggregate of same volume.

(vi) Grading of aggregates- This is one of the most important factor which will have maximum influence on workability. A well graded aggregate has least amount of voids in given volume and thus excess paste is available to give better lubricating effect.

(vii) Use of admixtures- Use of plasticizers and super-plasticizers greatly improve the workability many folds. Use of air entraining agent reduces the internal friction between the particles. The air bubbles act as a sort of ball bearing between the particles and give easy mobility to the particles thus giving better workability.

1.7.2 Measurement of workability

Numerous attempts have been made to quantitatively measure the workability which is an important and vital property of concrete but none of the methods are satisfactory for precisely measuring the workability though some of the tests measure the parameter very close to workability and provide useful information. Following tests employed to measure workability are-

(i) Slump test

(ii) Compacting factor test

(iii) Flow test

(iv) Kelly Ball test

(v) Vee Bee Consistometer test

Of all these, most commonly used method of measuring consistency of concrete is slump test. It is used conveniently as a control test and gives an indication of uniformity of concrete from batch to batch though this test is not suitable for very wet or very dry concrete. The apparatus for conducting the slump test essentially consist of a metallic mould in the form of frustum of the cone having bottom diameter as 20 cm, top diameter as 10 cm and height as 30 cm. For measuring the slump the mould is placed on a smooth, horizontal, rigid and non absorbent surface and the mould is then filled in four layers each layer being tamped 25 times by tamping rod taking care to distribute strokes evenly over the cross section. After the top layer has been rodded the concrete is struck off level with trowel and tamping rod. The mould is then raised carefully in vertical direction which allows the concrete to subside. This subsidence of concrete is referred as slump of concrete. The pattern of slump indicates the characteristic of concrete in addition to slump value. If concrete slumps evenly it is called true slump and if one half of concrete slides down is called shear slump that indicates concrete is non cohesive and show characteristic of segregation. Slump test has more practical utility than other tests for workability.

1.7.2.1 Limitation of slump test- The slump test is suitable for slumps of medium to high workability. The test fails to determine the difference in workability in stiff mixes which have zero slump, or for wet mixes that give a collapse slump. It is limited to concrete formed of aggregates of less than 38 mm.

Fig 3 Slump test apparatus

Chapter 2

Literature Review

Cement–admixture compatibility problems are becoming more frequent, especially in the field of super-plasticizers. It is well known that the variety of cements and the variability of different chemical compounds concerning super-plasticizers make “incompatibility” situations in the chemical complexity of cementitious systems. Super-plasticizer efficiency depends on properties of both the cement and the admixture. Literature reveals that cement–super-plasticizer compatibility is affected by the following parameters related to the cement like chemical and phase composition of especially C_3A content, alkali content, amount and type of calcium sulphate, cement fineness and free lime content. Taking into account the properties of a super-plasticizer, the factors that are of great importance are chemical nature and average molecular weight, super-plasticizer degree of sulphonation, admixture dosage and addition method. The super-plasticizers performance was evaluated experimentally by observing changes of selected cement paste properties in the specified region of interest. During the experiments, water-to-cement ratio (w/c), amount of super-plasticizer (SP), and amount of tricalcium aluminate (C_3A) were controlled. C_3A content was taken into consideration as the most relevant parameter among cement phase components. Chemical admixtures affect the properties of concrete in diverse ways and more than one effect can occur at a time e.g., chemical interference with hydration reactions or physical interaction with the hydration products. These effects result in the alteration of the rate of hydration or in the composition and morphology of the hydrated products. As more chemicals are added to the mix, compatibility with the cement and other admixtures becomes the central parameter governing the selection. The different mineral phases of cement react with water at different rates. Calcium aluminate phases react faster than silicates. Gypsum plays a crucial role in cement hydration, particularly setting and the influence of chemical admixtures on any process where it is involved may be significant.

2.1 Loss of Workability in High-Performance Concrete

Cement super-plasticizer incompatibility problems are magnified in high performance concrete because of the much-reduced water/cement ratios and higher super-plasticizer doses. Cement-super-plasticizer compatibility is critical in making HPC such that some cement are rejected not because of the difficulty in achieving the required strength but rather because of the very rapid slump loss. Segregation of the mix can occur when larger dosages of the super-plasticizer are added to offset the lack of initial fluidizing of the concrete or to reinstate workability. The saturation point for the admixture varies for different cement types and mix showing signs of segregation can be recovered by adding extra quantities of cement to the mix that consume the excess of super-plasticizer. Super-plasticizers used in concrete technology make it possible to obtain very low water-to-cement (w/c) ratios while maintaining the required concrete workability. Although admixtures have been widely recognized, their application in concrete technology is still subject to imprecision and uncertainty due to insufficient reliable qualitative and quantitative data concerning their influence on concrete workability. Tattersall (1973) demonstrated the limitations and deficiencies of Vee bee tests, slump tests, and cone flow tests in fully defining and quantifying workability yet those tests are still used extensively because of their simplicity and portability. The potential for greater precision and control over concrete workability by use of super-plasticizers thus restricted especially with regard to high strength concrete and high performance concrete, which are practically unworkable without super-plasticizers. An objective estimation of the influence of super-plasticizers (i.e., their type, dosage volume, and dosage time) on fresh concrete mix workability can be provided only if the changes in the rheological parameters of fresh concrete are identified

2.2 Influence of Super-plasticizer Type and Dosage

High w/c ratios result in a reduction in the performance of the super-plasticizers According to the results of the experimental measurements, for $w/c > 0.5$ the changes in the rheological properties of the concrete are minimal, and there is increasing likelihood of mix segregation. This phenomenon results because with an increasing w/c ratio the proportion of total water to the adsorbed capillary and floc water increases. Therefore the water released by the super-plasticizer constitutes a decreasing proportion of the total water in the mix. As would be expected when the w/c ratio increases a smaller super-plasticizer dosage is required to obtain the same mix workability, and when w/c decreases the dosage must accordingly be larger. Thus, summing up, it is evident that both the super-plasticizer type and the dosage volume are important modifiers of the rheological properties of concrete mixes but over a limited range of w/c ratios. The introduction of super-plasticizers into concrete mixes improves their workability by lowering the shear and flow resistance. However, this effect gradually disappears with the passage of time. The range of the changes depends on w/c ratio, super-plasticizer type, and dosage. The lower the w/c ratio, the more effective is the super-plasticizer in increasing the mix workability when applied at constant dosage. The range of possible workability improvements increases along with decreasing w/c ratio yet conversely this requires bigger dosages of super-plasticizer. The optimal dosage depends on the mix composition, and it can be determined by experimental methods only. At high w/c ratios (e.g., w/c = 0.5), the super-plasticizer becomes ineffective and segregation of the mix may occur. Among the super-plasticizers tested at low w/c ratios, for a given dosage NF super-plasticizers are more effective in increasing workability than are MF super-plasticizers. The reactivity of cement constituents, such as C_3A, C_4AF, and SO_3, is the main factor in concrete slump loss and is believed to be more rapid at high temperatures, Hewlett (1998). This constitutes a real challenge in hot-weather concreting because concrete does not remain workable for the period of time required for its transporting, placement, compaction, and finishing. Measurements of fluidity were conducted using a mini slump test at 10, 30, 60, 90, and 120 min. It was observed that the addition of the super-plasticizer improved the initial slump and that the slump loss was strongly dependent on the admixture adsorption which in turn was related to the NS dosage and mixing time. The use of super-plasticizers in concrete having a low water cement ratio highlights the problem of more or less rapid slump loss in the case of some combinations of cement and super-plasticizers while in other cases a high slump can be maintained during the first 60 to 90 minutes following contact between the cement and water without any sign of segregation and bleeding. In the first case, the cement and the super-plasticizer are said to be non-compatible, and in the second case, they are said to be compatible. Compatibility problems are now well documented in the case of polynaphthalene sulphonate-based super-plasticizers (PNS) which are presently the most used super-plasticizers in the concrete industry. But in the literature, some cases of incompatibility involving normal water reducers based on lignosulphonates have been reported .When studying the rheological behavior of super-plasticized grouts with PNS using a Marsh cone, it has been found that there exists a critical dosage beyond which any additional increase of PNS does not generate an increase in fluidity of the cement paste and the initial slump of concrete. This point had been called the saturation point and the PNS dosage at this point is called the saturation dosage **.**When studying the evolution of flow time through a Marsh cone as a function of super-plasticizer dosage, some cements do not present any difference between their flow time at 5 minutes and at 60 minutes after contact between the cement and water, while for some other cements the flow time increases very much even when a higher dosage of PNS is used Increase of slump is different according to its type and dosage.

2.3 Super-plasticizers (High Range Water reducer)

The main disadvantage of super-plasticizer usage is loss of workability as a result of rapid slump loss and incompatibility of cement and super-plasticizers. Super-plasticizers are soluble macromolecules which are hundreds of times larger than water molecule, Gani(1997). Mechanism of the super-plasticizers is known as adsorption by C_3A, whichbreaks the agglomeration by repulsion of same charges and releases entrapped water. The use of super-plasticizers (high range water reducer) has become a quite common practice. Most of the commercial formulations belong to one of four families:

(i) Sulphonated melamine-formaldehyde condensates (SMF)
(ii) Sulphonated naphthalene-formaldehyde condensates (SNF)
(iii) Modified lignosulphonates (MLS)
(iv) Polycarboxylate derivatives

The sulphonic acid groups are responsible for neutralizing the surface charges on the cement particles and causing dispersion, thus releasing the water tied up in the cement particle agglomerations and thereafter reducing the viscosity of the paste and concrete, Mindess and Young (1981).

2.4 Effect of Super-plasticizers on Concrete Properties.

The main purpose of using super-plasticizers is to produce flowing concrete with very high slump in the range of 7-9 inches (175-225 mm) to be used in heavily reinforced structures and in placements where adequate consolidation by vibration cannot be readily achieved. The ability of super-plasticizers to increase the slump of concrete depends on factors such as the type, dosage , and time of addition of super-plasticizer, w/c ratio and the nature or amount of cement. It has been found that for most types of cement, super-plasticizer improves the workability of concrete. The capability of super-plasticizers to reduce water requirements 12-25% without affecting the workability leads to production of high-strength concrete and lower permeability A study conducted by Siebel (1987) indicated that high workability concrete containing super-plasticizer can be made with a high freeze-thaw resistance, but air content must be increased relative to concrete without super-plasticizer. This study also showed that the type of super-plasticizer has nearly no influence on the air-void system. One problem associated with using a high range water reducer in concrete is slump loss. In a study of the behavior of fresh concrete containing conventional water reducers and high range water reducer, Whiting and Dziedzic (1989) found that slump loss with time is very rapid in spite of the fact that second-generation high range water reducer are claimed not to suffer as much from the slump loss phenomenon as the first-generation conventional water reducers. Incompatibility of cement and super-plasticizers can be a result of cement reactivity or poor performance of super-plasticizers. Cross testing can be performed to evaluate the problem by applying other admixtures and other cement.

Chapter 3

Marsh cone apparatus

The Marsh Cone is 6 inch in diameter at the top and 12 inch long, and tapers to join a tube 2 inch long and 3/16 inch inside diameter. The capacity of the funnel is 1500 cc. Time in seconds required to flow out 1000 cc of slurry from cone is taken as marsh cone time in seconds. It is experienced that marsh cone with aperture of 5 mm is not useful for finding marsh cone time of thick slurry so other attachments with bigger aperture may be used. In our experimental program we take cone of 6 inch in diameter at top and 12 inch long with an orifice of 10mm diameter at the bottom . Time in seconds required to flow out 1000 cc of slurry from cone is taken as marsh cone time in seconds. Dosage needed for a concrete mixture is unique and determined by the Marsh Cone Test. Apart from marsh cone mini slump test and flow table test may be used to ascertain the compatibility but marsh cone test is used since it gives better results. The marsh cone test also shows optimum dose of super-plasticizers to cement. In mash cone test , marsh cone time in seconds is plotted on ordinate and doses of super-plasticizers on absicca at a particular water cement ratio and a graph is plotted between two. The dose of super-plasticizers corresponding to marsh cone time in seconds is the saturation point which gives optimum dose of super-plasticizers for that particular cement at given water cement ratio.

3.1 Fabrication of Marsh Cone

For making the marsh cone to be used in our experiment we take a MS Sheet of 26 gauge from the market. On that sheet first of all we mark a line of length equal to 471mm equal to the circumference of 15 cm diameter circle at top and mark a line of length equal to 31.4 mm equal to circumference of an orifice of 10 mm diameter at the bottom both separated by distance of 30 cm to get the desired height of cone. Then we cut the extra sheet and the sheet is moulded in the form of cone joined by gas welding.

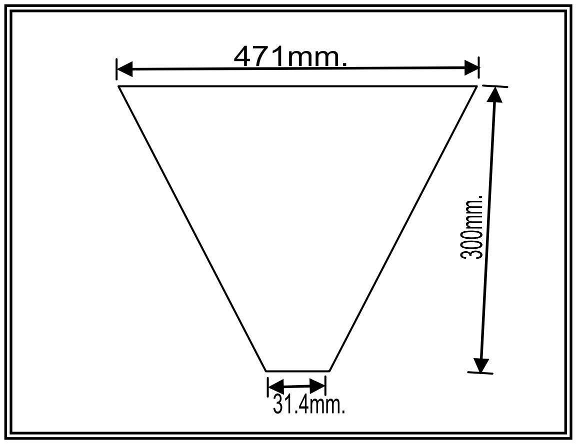


Fig.4 Cut out from MS sheet

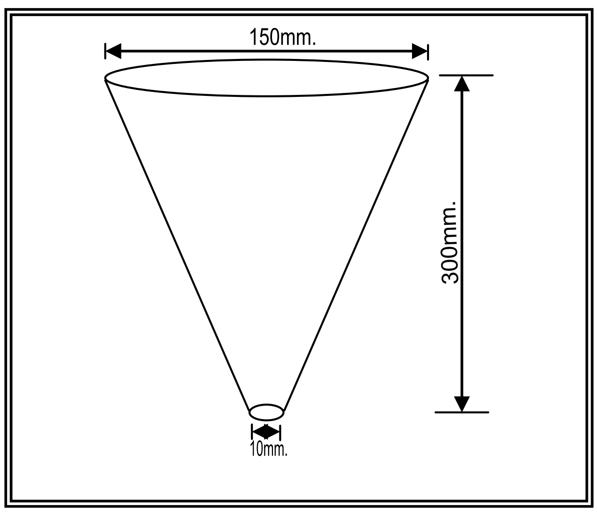


Fig 5 Fabricated marsh cone

Chapter 4

Experimental program

In our experimental program to find the compatibility between different super-plasticizer and cement(OPC), we take two different brands of cement and different types of super-plasticizer. At different water cement ratio we find the optimum dose for a particular super-plasticizer for particular selected brand of cement.

(i) We take 2 kg of Cement and thus corresponding quantity of water i.e 800 ml for w/c ratio of 0.4, 900 ml for w/c ratio of 0.45 and different doses of super-plasticizers (% by weight of cement).

(ii) After measuring all the ingredients cement paste is prepared and pass it through 1.18 mm sieve to avoid lump formation.

(iii) The 1 litre prepared cement paste is put into Marsh Cone after 5 minutes and the time of flowing out is noted down in seconds called marsh cone time.

(iv) Now same cement paste is again put in marsh cone at intervals of 60 minutes, 120 minutes subjecting to continuous agitation at equal intervals of time and same amount of agitation.

(v) Now Graph is plotted between marsh cone time in seconds on abscissa and dosage of super-plasticizer(% by wt. of cement) on ordinate. The dose corresponding to minimum marsh cone time called as saturation point is taken as optimum dose of super-plasticizer for that particular brand of cement at selected water cement ratio . The same procedure is repeated for other brand of cement at different water cement ratio.

(vi) After finding the optimum dose for a particular super-plasticizer we go for mix design of M30 grade concrete and prepare trial mixes assuming different % of water reduction of a particular super-plasticizer and using slump test apparatus we find the slump value at different time intervals such as after the preparation of mix, after 1 hr and 2 hr. to know the slump retention by a particular super-plasticizer.

(vii) Trial mixes is prepared for different super-plasticizer and same procedure is repeated.

4.1 Apparatus used

(i) Marsh Cone
(ii) Graduated Jug
(iii) Porcelain Tray
(iv) Graduated Tube
(v) Weighing Balance
(vi) 1.18 mm Sieve
(vii) Slump test apparatus

Fig 6 Apparatus used

4.2 Material used

(i) OPC based cement

C1 (43 grade)

C2 (43 grade)

(ii) Super-plasticizer of different types:-

P1- Polycarboxylate based super-plasticizer(Type I)

P2- Polycarboxylate based super-plasticizer(Type II)

P3- Polycarboxylate based super-plasticizer(Type III)

N1- Naphthalene based super-plasticizer(Type I)

N2- Naphthalene based super-plasticizer(Type II)

Chapter 5

Results and discussions

The data obtained from Marsh Cone test is plotted on graph between Marsh Cone time in seconds at different intervals of time from cement paste preparation and dosage of super-plasticizer by weight of cement at different w/c ratio for different brand of cement. The results are as follows:

5.1 Results- The dosage of super-plasticizer (% by wt. of cement) and Marsh cone time in seconds observed after 5 min, 60 min and 120 min. of cement slurry preparation is tabulated below and the optimum dose of particular super-plasticizer with different brands of cement is worked out. Further the optimum dose obtained by different combination of cement and super-plasticizer is used to find water reduction by particular super-plasticizer and the corresponding slump values at different time intervals.

Fig 7 Cement paste flowing from Marsh cone

Table 1 Dosage of superplasticizer and Marsh cone time for C1-P1 at w/c ratio of 0.40

Dosage of Super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min	Marsh cone time in sec. After 60. min	Marsh cone time in sec. After 120 min.
0.3	31.34	54.57	Not flow able
0.5	17.84	24.05	25.48
0.7	16.4	22.19	23.29
0.9	15.81	17.40	17.75
1.1	15.23	16.28	16.75

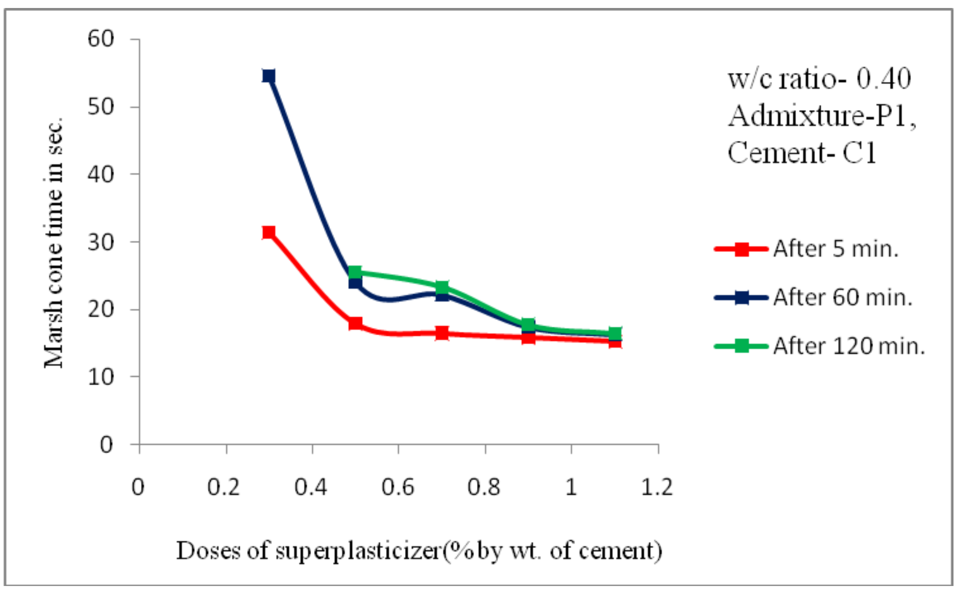


Fig.8 Dosage of superplasticizer and Marsh cone time for C1-P1 at w/c ratio of 0.40.

Discussion- C1-P1 combination at w/c ratio of 0.40 gives optimum dose of 0.9% by wt. of cement

Table 2 Dosage of superplasticizer and Marsh cone time for C1-P1 at w/c of 0.45

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min.
0.3	17.6	20.61	24.37
0.5	15.24	16.12	17.55
0.7	14.07	14.73	14.83
0.9	13.88	14.5	14.67

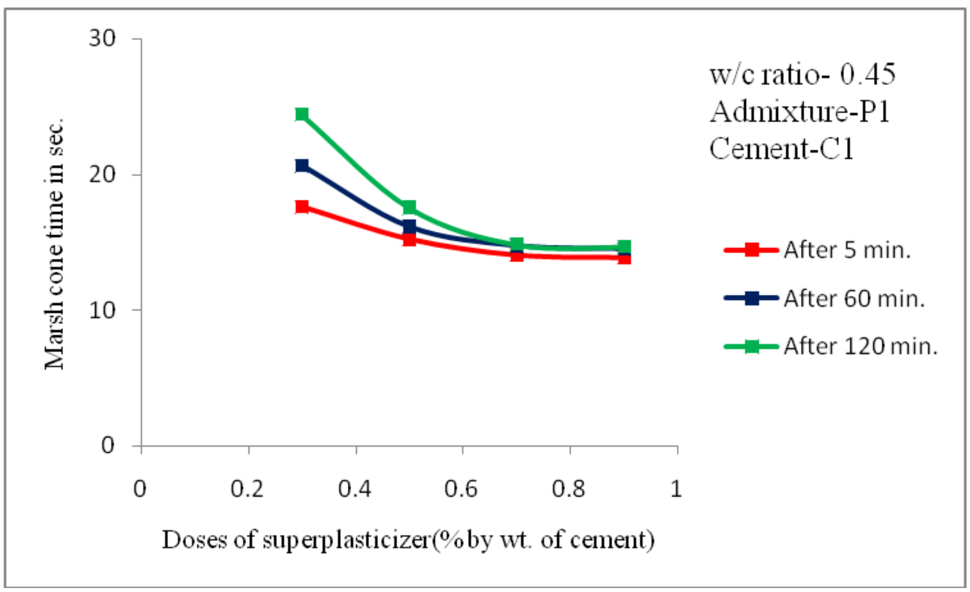


Fig.9 Dosage of superplasticizer and Marsh cone time for C1-P1 at w/c ratio of 0.45

Discussion- C1-P1 combination at w/c ratio of 0.45 gives optimum dose of 0.7% by wt. of cement

Table 3 Dosage of superplasticizer and Marsh cone time for C1-N1 at w/c of 0.40

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min.
0.3	39.57	51.48	Not flow able
0.5	18.74	21.75	23.75
0.7	15.8	17.43	18.72
0.9	14.34	15.07	15.55
1.1	14.28	14.94	15.54

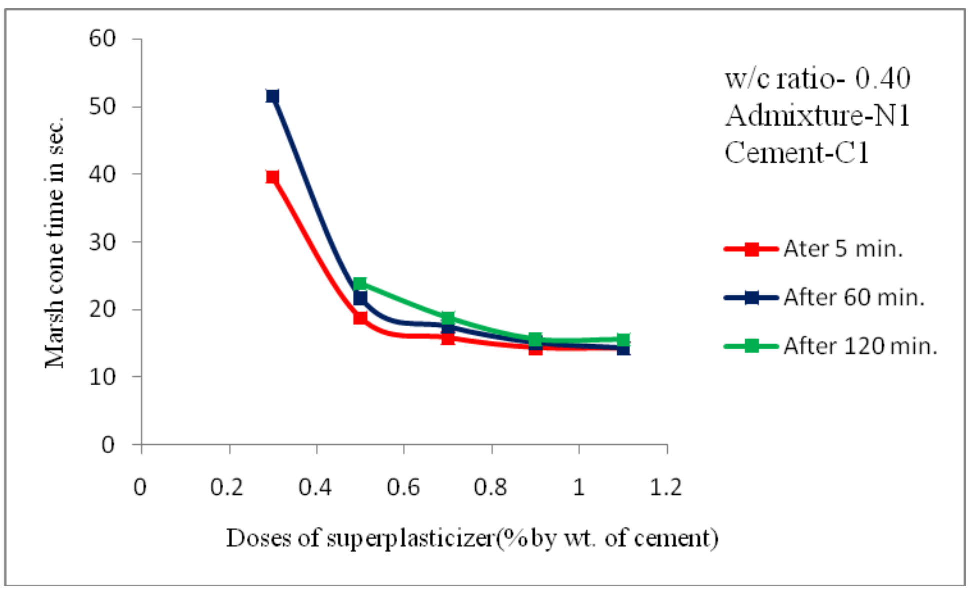


Fig.10 Dosage of superplasticizer and Marsh cone time for C1-N1 at w/c ratio of 0.40

Discussion- C1-N1 combination at w/c ratio of 0.40 gives optimum dose of 0.9% by wt. of cement

Table 4 Dosage of superplasticizer and Marsh cone time for C1-N1 at w/c of 0.45

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min.
0.3	16.66	17.59	18.06
0.5	15.25	16.61	17.35
0.7	14.42	15.17	15.34
0.8	14.39	14.59	14.63
0.9	14.36	14.41	14.32

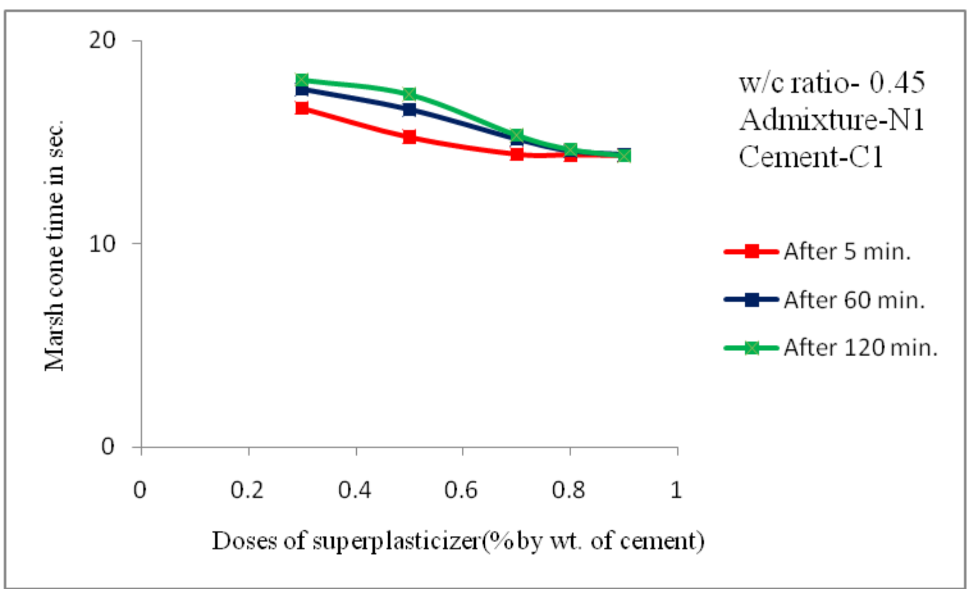


Fig.11 Dosage of superplasticizer and Marsh cone time for C1-N1 at w/c of 0.45

Discussion- C1-N1 combination at w/c ratio of 0.45 gives optimum dose of 0.8% by wt. of cement

Table 5 Dosage of superplasticizer and Marsh cone time for C2-N1 at w/c of 0.40

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min.
0.5	25.1	32.35	78.34
0.7	21.14	22.91	23.84
0.9	19.04	19.24	19.72
1.1	18.86	19.09	19.17
1.3	17.93	18.34	18.36
1.5	17.74	18.26	18.31

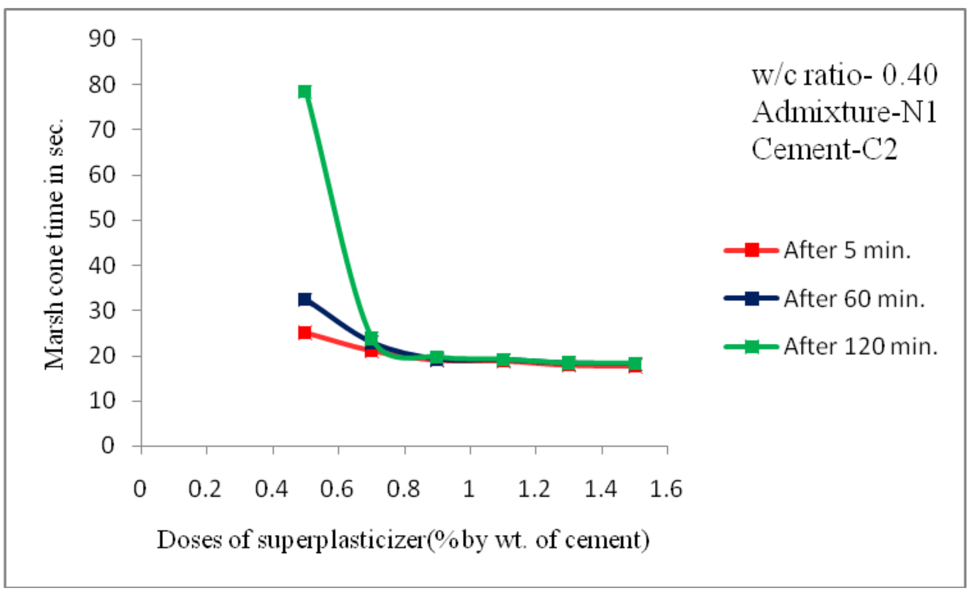


Fig.12 Dosage of superplasticizer and Marsh cone time for C2-N1 at w/c of 0.40

Discussion- C2-N1 combination at w/c ratio of 0.40 gives optimum dose of 1.3% by wt. of cement

Table 6 Dosage of superplasticizer and Marsh cone time for C2-N1 at w/c of 0.45

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.3	23.31	24.77	61.58
0.5	17.69	18.75	18.89
0.7	17.22	18.71	18.77
0.9	17.09	17.81	18.22
1.1	16.8	16.95	17.36
1.3	16.49	16.89	17.28

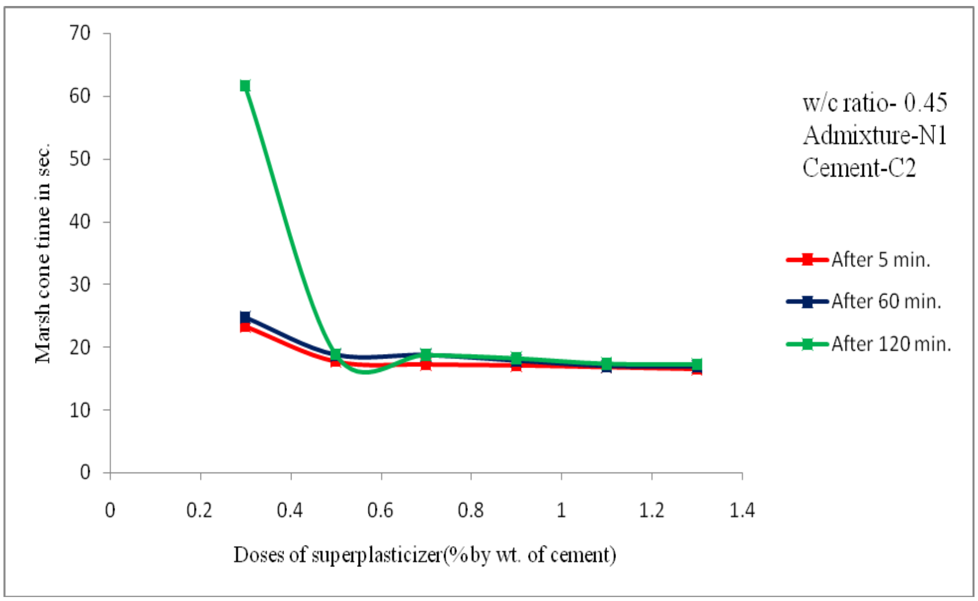


Fig.13 Dosage of superplasticizer and Marsh cone time for C2-N1 at w/c of 0.45

Dicussion- C2-N1 combination at w/c ratio of 0.45 gives optimum dose of 1.1% by wt. of cement

Table 7 Dosage of superplasticizer and Marsh cone time for C2-N2 at w/c of 0.40

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.5	31.68	47.59	Not flow able
0.7	30.16	31.68	36.5
0.9	19.84	20.1	21.04
1.1	18.09	19.17	19.27
1.3	17.9	18.29	18.41

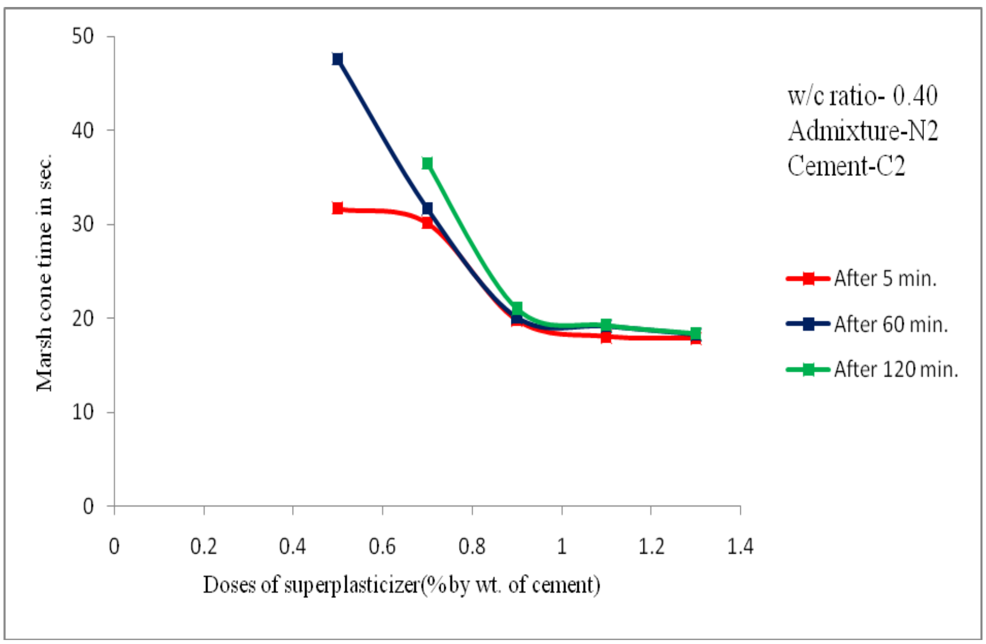


Fig.14 Dosage of superplasticizer and Marsh cone time for C2-N2 at w/c of 0.40

Dicussion- C2-N2 combination at w/c ratio of 0.40 gives optimum dose of 1.1% by wt. of cement

Table 8 Dosage of superplasticizer and Marsh cone time for C2-N2 at w/c of 0.45

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.3	35.37	62.84	Not flow able
0.5	16.3	17.94	18.75
0.7	15.73	16.26	16.41
0.9	15.22	15.34	15.45
1	15.07	15.3	15.39

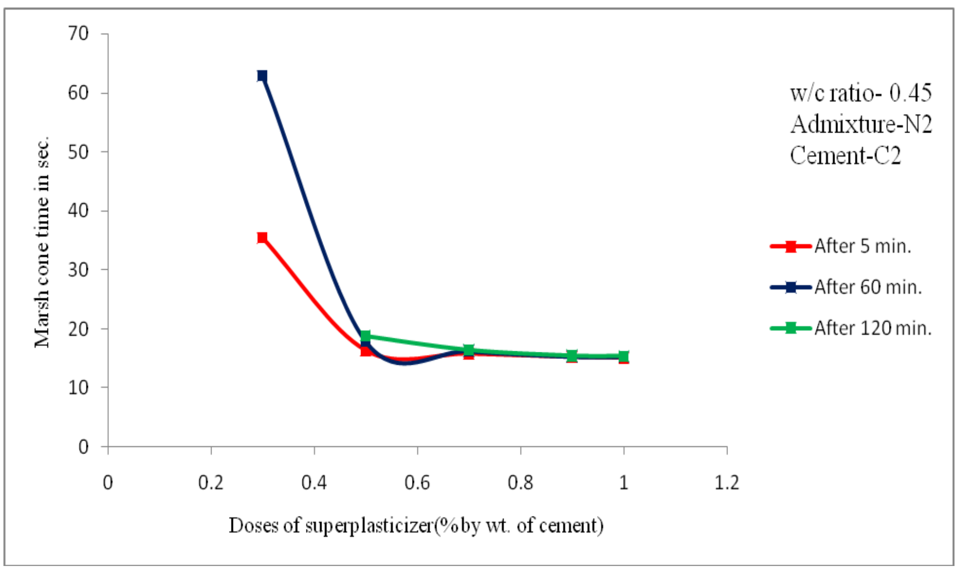


Fig.15 Dosage of superplasticizer and Marsh cone time for C2-N2 at w/c of 0.45

Dicussion- C2-N2 combination at w/c ratio of 0.45 gives optimum dose of 0.9% by wt. of cement

Table 9 Dosage of superplasticizer and Marsh cone time for C1-N2 at w/c of 0.40

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.5	34.98	32.91	Not flow able
0.7	20.61	21.72	21.93
0.9	19.22	19.73	19.79
1.1	18.5	18.83	19.03
1.3	16.64	16.81	17.09
1.5	16.47	16.72	16.87

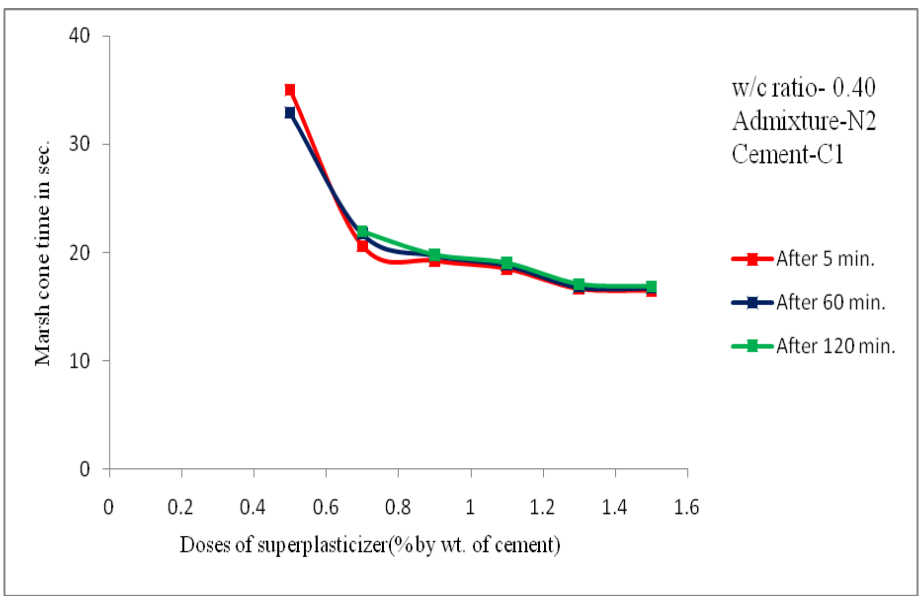


Fig.16 Dosage of superplasticizer and Marsh cone time for C1-N2 at w/c of 0.40

Dicussion- C1-N2 combination at w/c ratio of 0.40 gives optimum dose of 1.3% by wt. of cement

Table 10 Dosage of superplasticizer and Marsh cone time for C1-N2 at w/c of 0.45

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min.	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.2	19.63	22.09	26.17
0.4	17.22	18.62	18.78
0.6	15.12	15.24	15.54
0.8	15.06	15.58	15.61
1	14.99	15.22	15.27

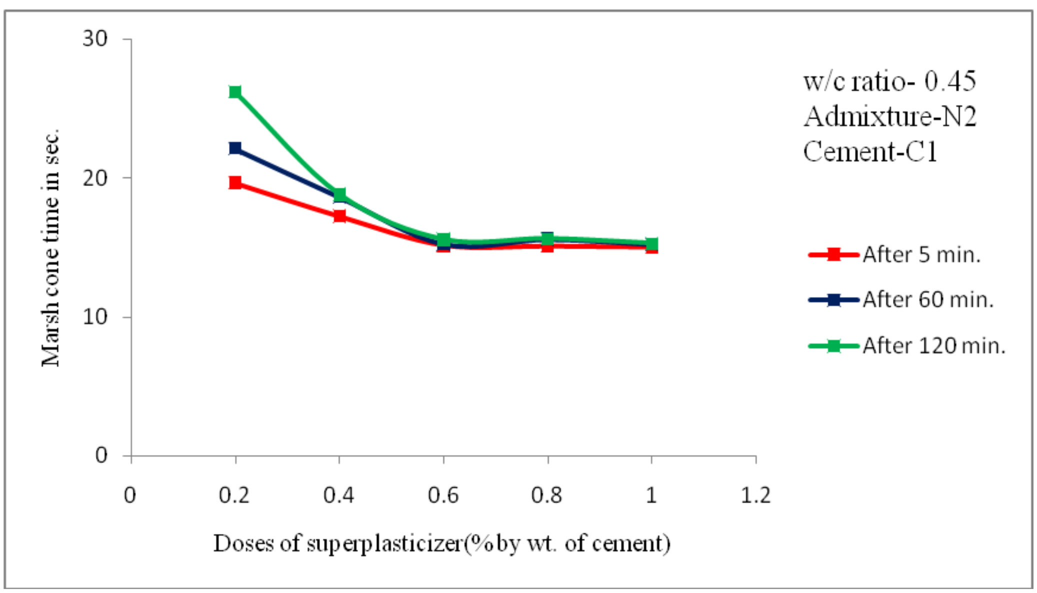


Fig.17 Dosage of superplasticizer and Marsh cone time for C1-N2 at w/c of 0.45

Dicussion- C1-N2 combination at w/c ratio of 0.45 gives optimum dose of 0.8 % by wt. of cement

Table 11 Dosage of superplasticizer and Marsh cone time for C2-P2 at w/c of 0.40

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.4	27.07	28.22	45.42
0.6	22.62	26.72	34.93
0.7	22.13	23.92	29.07
0.9	19.33	20.51	27.29
1.1	19.03	20.43	27.08
1.3	18.74	20.34	26.48
1.5	18.56	19.88	26.43

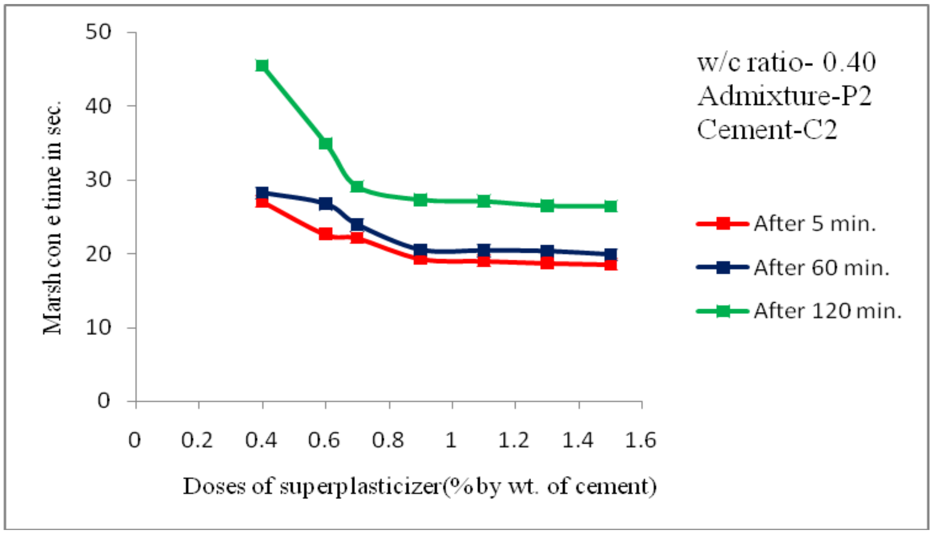


Fig 18 Dosage of superplasticizer and Marsh cone time for C2-P2 at w/c of 0.40

Dicussion- C2-P2 combination at w/c ratio of 0.40 gives optimum dose of 1.3 % by wt. of cement

Table 12 Dosage of superplasticizer and Marsh cone time for C2-P3 at w/c of 0.40

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.5	27.96	28.45	31.56
0.7	25.17	25.25	27.19
0.9	24.57	24.80	26.87
1.1	17.63	20.27	21.93
1.3	16.29	20.25	21.59
1.4	16.15	17.96	18.19
1.5	16.11	17.8	18.07

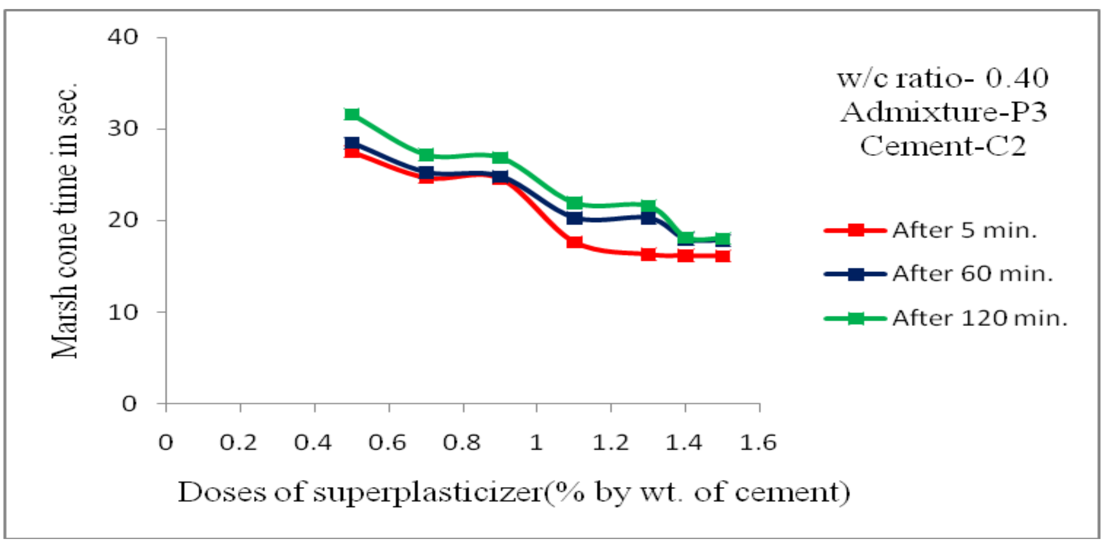


Fig.19 Dosage of superplasticizer and Marsh cone time for C2-P3 at w/c of 0.40

Dicussion- C2-P3 combination at w/c ratio of 0.40 gives optimum dose of 1.4 % by wt. of cement

Table 13 Dosage of superplasticizer and Marsh cone time for C2-P3 at w/c of 0.45

Dosage of super-plasticizer(% by wt. of cement)	Marsh cone time in sec. After 5 min	Marsh cone time in sec. After 60 min	Marsh cone time in sec. After 120 min
0.3	20.27	21.02	23.19
0.5	16.94	18.77	20.59
0.7	16.3	18.03	19.64
0.9	14.78	17.16	17.87
1	14.19	15.81	15.95
1.1	14.16	15.59	15.73

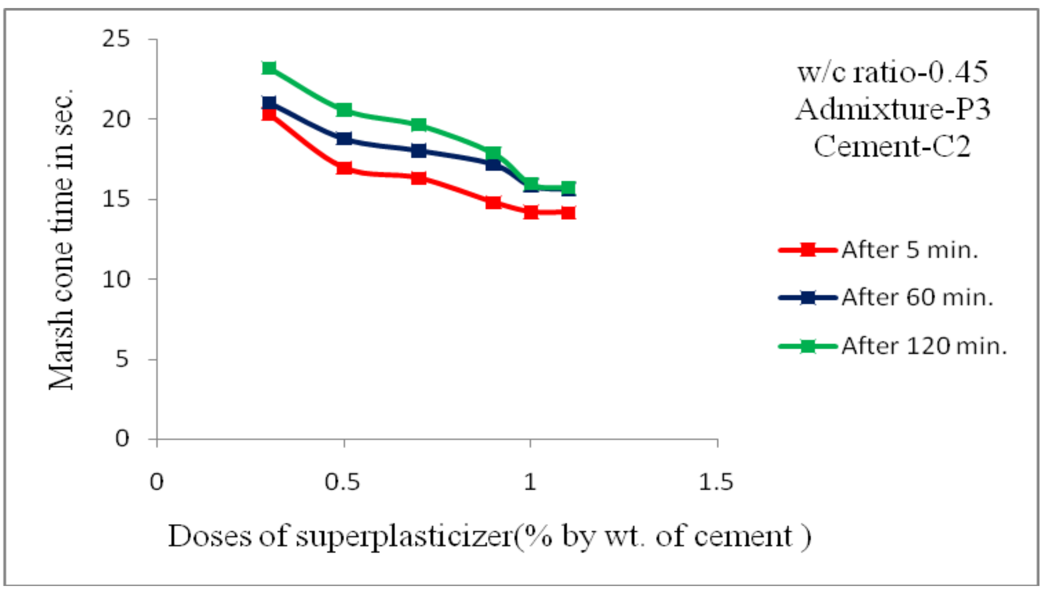


Fig.20 Dosage of superplasticizer and Marsh cone time for C2-P3 at w/c of 0.45

Dicussion- C2-P3 combination at w/c ratio of 0.45 gives optimum dose of 1% by wt. of cement

5.2 Mix design – The objective of proportionating concrete mixes is to arrive at the most economical and practical combination of different ingredients to produce concrete that will satisfy the performance requirements under specified conditions of use. The most important part of concrete proportionating is the preparation of trial mixes and adjustments to such trials to strike a balance between workability and strength satisfying durability requirements.

Table 14 Sieve Analysis data for fine aggregate

Weight of sample -1000gm

Sieve size	Weight retained (in gm)	Cumulative weight retained (in gm)	% cumulative weight retained	% cumulative weight passed
10 mm	0	0	0	100
4.75mm	48.5	48.5	4.85	95.15
2.36mm	107.2	155.7	15.57	84.43
1.18mm	150.2	305.9	30.59	69.41
600 micron	198.7	504.6	50.46	49.54
300 micron	260.8	765.4	76.54	23.46
150 micron	182.2	947.6	94.76	5.24
Less than 150 micron	52.4	1000	100	0

Sand conforms to zone II as per table 4 of IS 383:1970

5.2.1 Mix Design for M-30 grade concrete

Target mean strength = $f_{ck} + 1.65s$

= 30 + 1.65*5

= 38.25 N/mm^2

Maximum water cement ratio for durability requirement as per IS 456:2000 = 0.45(for severe exposure condition)

Corresponding to 28 day compressive strength of concrete, free water cement ratio is approximately 0.40

Assuming w/c ratio = 0.43<0.45 thus ok

Now as per table 2 of IS 10262:2009 maximum water content for 20 mm aggregate nominal size = 186 litres (for slump range of 25 to 50 mm)

Estimated water content for 100 mm slump requirement = 186 + (6*186/100)

= 197 litres

Now for trial mix let us assume Polycarboxylate base super-plasticizer(Type III) make water reduction of 20% with C1 at optimum dose of 0.8 % so

Water content = 197*0.8 = 158 litres/m^3

Cement content = 158/0.43 = 367 kg/m^3 > 320 kg/m^3 hence ok

Now from table 3 of IS 10262:2009 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate zone II for water cement ratio of 0.50 = 0.62

Corrected volume of coarse aggregate for water cement ratio of 0.43 = 0.635

Volume of fine aggregate = 1- 0.635 = 0.365

Volume of concrete = 1 m^3

Volume of cement = 367/ (3.15*1000) = 0.116 m^3

Volume of water = 158/1000 = 0.158 m^3

Volume of chemical admixture = 2.93/ (1.09* 1000) = 0.0027m^3

Volume of all in aggregate = 1-(0.116 + 0.158 + .0027) = 0.723m^3

Mass of coarse aggregate = 0.723*0.635*2.58*1000 = 1185 kg/m^3

Mass of fine aggregate = 0.723*0.365*2.49*1000 = 657 kg/m^3

The calculation of other trial mixes with different super-plasticizer and cement are shown in the table below:

Table 15- Trial mix calculations for C1-P3

Maximum water content	Estimated water content	Water content after reduction	Cement content	Volume of coarse aggregate	Volume of fine aggregate	Volume of concrete	Volume of cement
186	197	158	367	0.635	0.365	1	0.116
186	197	167	389	0.635	0.365	1	0.123
186	197	154	357	0.635	0.365	1	0.113
186	197	148	344	0.635	0.365	1	0.109
186	197	162	376	0.635	0.365	1	0.119

Volume of water	Volume of chemical admixture	Volume of all in aggregate	Mass of coarse aggregate	Mass of fine aggregate	Water reduction in %	Type of super-plasticizer	Type of cement
0.158	0.0027	0.723	1185	657	20	P3	C1
0.168	0.0028	0.706	1157	642	15	P3	C1
0.154	0.0026	0.730	1196	664	22	P3	C1
0.148	0.0025	0.741	1213	673	25	P3	C1
0.162	0.0027	0.716	1174	651	18	P3	C1

Table 16- Trial mix calculations for C1-N1 and C2-N1

Maximum water content	Estimated water content	Water content after reduction	Cement content	Volume of coarse aggregate	Volume of fine aggregate	Volume of concrete	Volume of cement
186	197	158	367	0.635	0.365	1	0.116
186	197	177	412	0.635	0.365	1	0.131
186	197	167	389	0.635	0.365	1	0.124
186	197	173	403	0.635	0.365	1	0.128
186	197	177	412	0.635	0.365	1	0.131
186	197	167	389	0.635	0.365	1	0.124
186	197	173	403	0.635	0.365	1	0.128

Volume of water	Volume of chemical admixture	Volume of all in aggregate	Mass of coarse aggregate	Mass of fine aggregate	Water reduction in %	Type of super-plasticizer	Type of cement
0.158	0.0028	0.723	1185	657	20	N1	C1
0.177	0.0031	0.689	1128	626	10	N1	C1
0.167	0.0030	0.706	1157	642	15	N1	C1
0.173	0.0031	0.696	1140	632	12	N1	C1
0.177	0.0042	0.688	1127	625	10	N1	C2
0.167	0.0040	0.705	1155	641	15	N1	C2
0.173	0.0041	0.695	1138	631	12	N1	C2

Table 17 Trial mix calculations for C2-P3

Maximum water content	Estimated water content	Water content after reduction	Cement content	Volume of coarse aggregate	Volume of fine aggregate	Volume of concrete	Volume of cement
186	197	158	367	0.635	0.365	1	0.116
186	197	164	380	0.635	0.365	1	0.121
186	197	148	344	0.635	0.365	1	0.109
186	197	154	357	0.635	0.365	1	0.113

Volume of water	Volume of chemical admixture	Volume of all in aggregate	Mass of coarse aggregate	Mass of fine aggregate	Water reduction in %	Type of super-plasticizer	Type of cement
0.158	0.0040	0.722	1183	656	20	P3	C2
0.164	0.0042	0.712	1166	647	17	P3	C2
0.148	0.0038	0.739	1211	672	25	P3	C2
0.154	0.0039	0.729	1194	663	22	P3	C2

5.3 Slump retention for trial mixes

Table 18 Slump retention for Trial mix C1-P3 at water reduction as 20%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	150
After 1 hr.	110

Table 19 Slump retention for Trial mix C1-P3 at water reduction as 25%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	140
After 1 hr.	120

Table 20 Slump retention for Trial mix C1-P3 at water reduction as 15%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	Collapse
After 1 hr.	150

Table 21 Slump retention for Trial mix C1-P3 at water reduction as 22%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	140
After 1 hr.	130

Table 22 Slump retention for Trial mix C2-P3 at water reduction as 25%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	140
After 1 hr.	130
After 2 hr.	100

Table 23 Slump retention for Trial mix C2-P3 at water reduction as 20%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	150
After 1 hr.	140
After 2 hr.	120

Table 24 Slump retention for Trial mix C2-P3 at water reduction as 17%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	160
After 1 hr.	130
After 2 hr.	110

Table 25 Slump retention for Trial mix C2-N1 at water reduction as 15%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	Zero Slump
After 1 hr.	Zero Slump
After 2 hr.	Zero Slump

Table 26 Slump retention for Trial mix C2-N1 at water reduction as 12%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	140
After 1 hr.	Zero Slump
After 2 hr.	Zero Slump

Table 27 Slump retention for Trial mix C2-N1 at water reduction as 10%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	150
After 1 hr.	140
After 2 hr.	Zero Slump

Table 28 Slump retention for Trial mix C1-N1 at water reduction as 15%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	140
After 1 hr.	Zero slump
After 2 hr.	Zero slump

Table 29 Slump retention for Trial mix C1-N1 at water reduction as 12%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	Collapse
After 1 hr.	160
After 2 hr.	140

Table 30 Slump retention for Trial mix C1-N1 at water reduction as 10%

Time at which Slump is measured	Slump value (in mm)
Just after preparation of mix	Collapse
After 1 hr.	170
After 2 hr.	130

Fig. 21 Filling of mould and tamping of subsequent layers

Fig. 22 Profile of obtained slump showing Collapse, Zero slump and Shear slump

Chapter-6

Conclusions

From the above results of slump retention characteristic of concrete we draw the following inference

(i) Polycarboxylate base super-plasticizer (Type III) with C1 (43 grade) causes water reduction of 22% as the slump value has very small difference or we can say that at 22% of water reduction slump is retained.

(ii) Polycarboxylate base super-plasticizer (Type III) with C2(43 grade) causes water reduction of 20% as the slump value has very small difference or we can say that at 20% of water reduction slump is retained.

(iii) Naphthalene base super-plasticizer (Type I) with C2 (43 grade) causes water reduction of 10% as the slump value has very small difference or we can say that at 10% of water reduction slump is retained.

(iv) Naphthalene base super-plasticizer (Type I) with C1 (43 grade) causes water reduction of 12% as the slump value has very small difference or we can say that at 12% of water reduction slump is retained.

(v) The water reduction by the polycarboxylate base super-plasticizer give more water reduction in comparison to Naphthalene base super-plasticizer.

6.1 Future Scope of work – The above study is useful in adjudging the best combination of cement and super-plasticizer, water reduction by a super-plasticizer with different brands of cement and slump retention at different time intervals. Today concrete has bypassed the stage of mere four component system and can be the combination of far more number of ingredients such as fly ash, ground granulated blast furnace slag, silica fume, rice husk ash, metakaoline and super-plasticizer. In the present study we find the water reduction by chemical admixture such as super-plasticizer with different combination of cement. Therefore the study can be extended to the use of mineral admixtures like fly ash, silica fume, rice husk ash, metakaoline etc. and the corresponding results may be obtained since use of mineral admixtures is common practice now a days as they may be used as part replacement of cement provided uniform blending with the cement is ensured and also reduces the water demand.

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