ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

The effects of mega flow SP1 superplasticizing admixture on the properties of concrete

BY

LETA HORA

ADVISOR: Dr. ESAYAS G/YOUHANNES

A Thesis Submitted to School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Construction Technology and Management)

August 2014

Addis Ababa

ACKNOWLEDGMENTS

This research has been a very helpful for me to grasp great knowledge, skill and experiences during the research work. So, I would like to express my gratitude to the almighty of God. In addition, I have four groups who provided endless support and assistance during the study.

First and foremost, I would like to express my heartfelt gratitude to Dr. Essays G/Yohannes for his never ending patience, tremendous advice, guidance, support, continuous discussion, suggestions and encouragement throughout the research period.

Secondly, my respectful thank you goes to Ato Demessew Melaku and Fikru Bedada, construction materials laboratory technical assistances in Civil and Environmental Engineering School. They have always given their heartfelt cooperation and assistance in this research. Besides that, I like to thank you highway staffs that have been provided me a help during materials testing.

Thirdly, my grateful thank goes to Mr. Wange Yang and Mr. Zeyede Tesfaye, general manager and human resource manager of CRBC Addis Engineering PLC which is found in Kality Wereda 27 for providing 10mm and 20mm size aggregate from their product.

Finally, I greatly appreciate all the help from my friends and family members who always been so supportive and motivating throughout the process.

ABSTRACT

Superplasticizing admixtures interact chemically with the ingredients of concrete and affect the concrete properties in the fresh and hardened state. Now a days, its possible to produce concrete having better quality with the addition of superplasticizing admixture in different ways by saving some amount of mixing water and cement for a given mix design.

The objective of this research was to study the effects of superplasticizing admixture on concrete properties, such as: workability, compressive strength, flexural strength and permeability. Therefore, in order to study those properties mega flow SP1 (chroride free, superplasticizing admixture based on selected sulphonated naphthalene polymers), type F complying with ASTM C494, BS EN 934-2 was used throughout the experiments. The experiments were performed on C-25 and C-60 concrete grades which have 0.58 and 0.33 water to cement ratio with a slump oabstractf 30-60mm and 10-30mm, respectively, at a dosage of 0%, 0.5%, 1% and 1.5% admixture. To facilitate the study, the experiments have been classified into four phases, such as: Phase I: to study the effects of superplasticizing admixture on workability, Phase II: to study the effects of way of superplasticizing admixture addition on concrete quality, Phase III: to study the effects of superplasticizing admixture on concrete quality by reducing amount of mixing water and Phase IV: to study the effects of superplasticizing admixture on concrete quality by reducing cement content.

Based on the work results 1.5% superplasticizing admixture have shown higher value of workability and 1% superplasticizing has been provided the optimum results on strength in phase I and IV. In case of phase II by using 1% superplasticizing admixture, addition of admixture at the end was shown better result on workability, but the strength was improved by adding admixture at the middle of mixing. However, in case of phase III 1.5% superplasticizing addition has shown higher result on compressive, flexural and premiblity.

Finally, the addition of superplasticizing admixture was shown improvement on workability, strength (compressive and flexural) and permeability from the reference concrete.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACI	American concrete institute
Al	Aluminum
ASTM	American society for testing material
BS	British standard
C_2AH_n	Aluminate phase
C_2S	Dicalcium Silicate
C_3A	Tricalcium Aluminate
C_3S	Tricalcium Silicate
C_4AF	Tetracalcium alumino ferrite
C_4AH_n	The hexagonal aluminate phase contain
C_6H_5	Phenyl ring
Ca	Calcium
CLS	Calcium lignosulphonate
Cm	Centimeter
ES	Ethiopian standard
Kg	kilogram
Kg/m^3	kilogram per cubic meter
kN	kilo Newton
Lit	Liter
Lit/kg	Liter per kilogram
M	Maximum Moment
m^3	Meter cubic
max	Maximum
Min	Minimum
MLS	Modified lignosulfonates
mm	Millimeter
MPa	Mega Pascal
MPa/s	Mega Pascal per second
SMF	Sulfonated melamine-formaldehyde condensate
SNF	Sulfonated naphthalene- formaldehyde condensate

Sp	Superplasticizer
SSD	Saturated surface dry
W/c	Water to cement ratio
%	Percentage
°C	Degree Celsius
µm	Micrometer

CHAPTER ONE

1. INTRODUCTION

1.1. GENERAL

The days when it was difficult to talk the benefit that admixtures provide have passed. It is now quite clear that admixtures can both solve technical problems and save substantial cost. However, they also have the potential to create technical problems if improperly selected or used.

According to Neil and Ravindra (1992), numerous benefits are available through the use of admixtures, such as: improved quality, acceleration or retardation of setting time, coloring, greater concrete strength, increased flow for the same water-to-cement ratio, enhanced frost and sulfate resistance, improved fire resistance, improved workability, cracking control and enhanced finishability. The specific effects of an admixture generally vary with the type of cement, mix proportion, ambient conditions (particularly temperature) and dosage [1].

It is important to realize both the complexity of the situation and the inaccuracies inherent in any attempt to compare the relative value of different admixtures. Different admixtures can have significantly different relative values when used with different cements or other different conditions. A difference in the time of addition (relative to that of the cement first coming into contact with the water) can substantially affect the performance of an admixture. Different results may be obtained from the same mix and admixtures when mixed in different way [2].

In the construction industry a lot of admixtures are used for different purposes to improve different properties of concrete. Generally, admixtures are classified in to two: mineral and chemical admixtures [2]. Water reducing admixture is one type of chemical admixture which provide a wide benefit for concrete in the fresh and hardened sates. Different water reducing admixtures can be available in the market; from those admixtures high range water reducing admixture also known as superplasticizer, type F is the main type of admixture which provide a lot of improvement for concrete properties. This admixture is produced in our country as mega flow SP1 and SP4, which has a capacity to improve the workability, strength and permeability of concrete. However, in our country researches and investigation are not yet done on admixtures.

Therefore, this research has investigated some benefits which are obtained by the use of superplasticizing admixture as a construction material. In order to show the effects of superplasticizing admixture on concrete properties, such as: workability, strength and permeability, laboratory experimentations were performed by adding dosages of 0%, 0.5%, 1% and 1.5% superplasticizing admixture in concrete mixes with four phases and results are conducted. Then, based on the experimental results conclusion are drawn and recommendations have been forwarded.

1.2. RATIONAL OF THE RESEARCH

The main focus of this research is to study the effects of superplasticizing admixture on concrete properties. Currently, in the developed countries the concrete technology has reached on the high level and remarkable successes have achieved by the development of admixtures for production of quality concrete. However, in our country the use of admixture is less recognized and the local construction parties that participate in the construction industry have little information and awareness about the uses and effects of admixtures on the production of quality concrete.

According to information obtained from different sources written by experienced professionals, the qualities of being constructed infrastructures are not as such strong and durable; crack and failure is frequent and the cost incur for construction is very high; this is due to less advancement of construction technology and materials usage. However, superplasticizing admixture can substantially reduce those problems, because they have a potential to reduce the water demand of a concrete mix without reducing workability, allowing to increase early and ultimate strengths without additional cement, reduce concrete permeability and thereby reduce aggressive penetration, like: chloride, carbonation, sulphate, etc and reduce crack and enhance durability.

Nowadays, a great problem for this world is global warming which is caused by depletion of natural resources and emission of gases during cement production. But, superplasticizing admixtures are sensitized or by-product which has ability to save cement consumption with some percentage, this helps to reduces environmental problems caused by too much cement production.

This research finally helps to create awareness and shows the benefits obtained by the use of superplasticizing admixtures.

1.3. OBJECTIVES OF THE RESEARCH

1.3.1. General objective

The general objective of this research is to study the effects of SP1 superplasticizing admixture on the properties of concrete in Ethiopia context.

1.3.2. Specific objective

The specific objectives of this research will explore the following points:

- Comparing the properties of concrete produced with and without using SP1 superplasticizing admixture.
- Examining the effects of different dosage of SP1 superplasticizing admixture on workability, strength and permeability of concrete.
- Investigating the effects of way of SP1 superplasticizing admixture addition on the properties of concrete.
- Studying the effects of SP1 superplasticizing admixture on concrete properties by reducing cement content.

1.4. METHODOLOGY OF THE RESEARCH

The study methodology will lead to accomplish the research objectives. The first activity in this research was review literatures related to the research from different sources like: text books, research papers, journals, magazine, internet, etc.

Then, laboratory experimentations have been carried out. So, in order to obtain the final results, first concrete making materials preparation and testing have been performed. Then, based on the test results concrete making materials proportioning have been executed and mix-design was prepared for C-25 and C-60 concrete grades. After that, concrete sample preparations at different dosages of superplasticizing admixture have been performed with four phases. Then, the prepared concrete samples have been tested for both in the fresh and hardened states. For the fresh state workability property of concrete has been checked and for hardened concrete compressive, flexural and permeability tests have been carried out. For compressive strength tests concrete samples have been checked at the age of 3, 7 and 28 days. For flexural strength concrete samples are tested at 7 and 28 days. In case of permeability concrete samples are tested at the age of 28day only.

The results obtained from experiment are discussed and presented in tables and figures. Finally, conclusions are drawn and recommendations have been forwarded

CHAPTER TWO

2. LITERATURE REVIEW

2.1 General

Concrete is the most widely used strongest construction material that forms the basis of our modern life. It is used in different structures, such as: dam, building, bridge, tunnels, highway etc. Starting from the past, concrete was produced by the combination of cementing materials, aggregate and water. However, when the concrete technology develops, additional materials known as admixture have produced. This additional material may be added to the basic mix to develop special properties of the concrete in fresh and hardened states [1] [2][3].

According to ACI 116R and ASTM C 125, admixtures are ingredients other than water, aggregates, hydraulic cement, and fibers that are added to the concrete batch immediately before or during mixing [3]. A proper use of admixtures offers certain beneficial effects to concrete, including: acceleration or retardation of setting time, enhanced strength development, improved workability, improve concrete durability and enhanced finishability. Basically, two categories of admixtures are available: mineral and chemical admixture. [4] [5]

Superplasticizing admixture is a type of high range water reducing chemical admixture, which have a capacity of reducing the mixing water up to 35%. This type of admixture will provide high quality improvement for concrete in both fresh and hardened states. Generally, superplasticizing admixtures improve workability, strength, and permeability of concrete [6].

Therefore, the main discussion of this chapter focus on reviewing admixtures, particularly on superplasticizing admixture used to produce quality concrete.

2.2. History of Admixtures

Historically, admixtures are almost as old as concrete itself. They have been recognized as important components of concrete used to improve its performance. The original use of admixtures in cementitious mixtures is not well documented. It would be a logical progression to use such materials, which imparted desired qualities to the surface, as integral parts of the mixture. It is known that the Romans used animal fat, milk, and blood to improve their concrete properties. Although these were added to improve workability, blood is a very effective air-entraining agent and might well have improved the durability of Roman concrete; eggs during the middle ages in Europe; polished glutinous rice paste, lacquer, tung oil, blackstrap molasses, and extracts from elm soaked in water and boiled bananas by the Chinese; and in Mesoamerica and Peru, cactus juice and latex from rubber plants [7]. The Mayans also used bark extracts and other substances as set retarders to keep stucco workable for a long period of time. In more recent times, calcium chloride was often used to accelerate hydration of cement. The systematic study of admixtures began with the introduction of air-entraining agents in the 1930s when people accidentally found that cement ground with beef tallow (grinding aid) had more resistance to freezing and thawing than a cement ground without it [7]. Nowadays, admixtures are important and necessary components for modern concrete technology. The concrete properties both in fresh and hardened states can be modified or improved by the addition of admixtures. Currently, admixtures are obtained as mineral and chemical admixtures which used to improve the short and long term properties of concrete [4].

2.3. Classification of Admixtures

Admixtures mainly grouped in to two, these are: mineral and chemical admixture [4]. Mineral admixtures are usually added to concrete in large amounts. Besides, cost reduction and enhancement of workability of fresh concrete, they can improve the resistance of concrete to thermal cracking, alkali-aggregate expansion, and sulfate attack. Due to numerous benefits associated with their use, they are also known as supplementary cementing materials. Mineral admixtures are mainly categorized in to four, these are: Fly ash, ground granulated blast furnace slag, silica fume and highly reactive metakaolin [4][8].

Chemical admixtures are additives designed to enhance the properties of concrete in the plastic and hardened states, increase efficiency of ingredients, and improve the economy of the concrete mixture. In certain instances, the desired objectives may be best achieved by changes to the mixture proportions in addition to using the proper admixture [4].

Chemical admixtures are not substitutes for suitable concrete mixture proportions and acceptable construction practices. However, chemical admixtures have variety function for concrete quality in the fresh and hardened state [4].

Chemical admixtures are used to modify the following properties of fresh concrete, like: increase workability without increasing water content, or decrease the water content without changing the workability, retard or accelerate the time of initial setting, reduce or prevent settlement, or create a slight expansion, modify bleeding characteristics, reduce segregation, improve pumpability, reduce the rate of slump loss and improve finishability [4][6][9].

Chemical admixtures also used to modify properties of hardened concrete, such as: reduce the rate of heat evolution during early cement hydration, accelerate the rate of strength development at early ages, increase strength (compressive, tensile, or flexural), increase resistance to freezing and thawing, decrease permeability, reduce expansion caused by alkali-aggregate reaction, increase bond to steel reinforcement and between existing and new concrete, improve impact resistance and abrasion resistance, inhibit corrosion of embedded metal, produce colored concrete or mortar and reduce drying shrinkage [4][6].

Generally, with respect to their characteristics chemical admixtures are classified into five groups; these are: air-entraining, accelerating, water-reducing and set-controlling, admixtures for flowing concrete, and miscellaneous [4][9]. Even though, different chemical admixtures are available the main focus of this thesis research is only about water reducing admixture, particularly superplasticizing admixture.

2. 4. Water-Reducing Admixtures

Water reducing admixtures can be defined as a water soluble organic compound that reduces the water requirement of concrete for a given consistency. It improves the properties of fresh and hardened concrete. The water reduction generally varies between 5 and 15%. Higher water reductions of the order of 25-35% are possible with superplasticizers [10].

The main compounds used in the manufacture of water reducers can be divided into four groups, these are: Lignosulfonates, Hydroxycarboxylic Acids, Carbohydrates and Other Organic Compound [6]. ASTM C 494 currently recognizes five categories of water- reducing admixtures. This classification scheme is based on the amount of water reduction achieved with a standard concrete mixture under laboratory test conditions, these classifications are [4] [5]:

- *Type A (Water-reducing admixtures):-* this admixture can have little effect on setting, and it reduce water content at least by 5%.
- *Type D (Water-reducing and retarding admixtures):-* retardation may be desired for higher temperature concreting conditions. Whenever the natural tendency of water-reducing admixtures to retard hydration is not adequate for the desired application, additional retarders are added. It helps to reduce water content (minimum 5%) and retard setting.
- *Type E (Water-reducing and accelerating admixtures):-* Many water reducing admixtures retard set times and are sometimes used with an accelerator for compensation. It helps to reduce water content (minimum 5%) and accelerate setting.
- *Type F (Water-reducing, high-range admixtures):-* it can be used to impart properties induced by regular water reducers, only much more efficiently. They can greatly reduce water demand and cement contents and make low water-cement ratio, high-strength concrete with normal or enhanced workability. A water reduction of 12% to 35% can be obtained through the use of this admixture.
- *Type G (Water-reducing, high-range, and retarding admixtures):-* As for water-reducing admixtures, high range water reducers tend to retard concrete setting times, but this effect may be compensated by the addition of accelerating admixtures or the further addition of retarding admixtures. It helps to reduce water content (minimum 12%) and retard setting. When a retarder is combined with a superplasticizer, the resulting admixture is classified by ASTM C 494 as Type G.

Generally, water reducing admixture can be used in different ways at different dosages to obtain the maximum benefit. For this reason, the following points deal about the additional procedure, dosage, hydration reactions and water reduction mechanism of water reducing admixture.

2.4.1. Addition Procedure of Water Reducing Admixture

Water reducers should be incorporated into the concrete mix in such a way that the most rapid and uniform dispersion of the admixture throughout the fresh mix is obtained. This can be achieved by discharging the admixture into the gauging water which subsequently is added to cement and aggregates, previously dry mixed. However, such a procedure generally does not give the best performance in terms of water reduction or increase in workability [6].

Maximum benefit is derived by adding the admixture just at the end of the mixing time of aggregates, cement and total gauging water. However, this procedure presents some practical difficulties in obtaining prefixed constant workability of the mix and the uniform dispersion of the admixture, particularly when large and frequent concrete mix batches have to be prepared [6].

A reasonable compromise between good technical performance and practical use of water reducer can be obtained by the following procedure. After an initial mixing period of 15 to 30 seconds of aggregates, cement and a portion (approximately 50%) of the mixing water, the admixture dissolved in a part (approximately 25%) of the gauging water is introduced into the mix, and finally the remainder of the gauging water is added until the required workability is obtained. The addition procedure will affect compressive strength of concrete. For this reason, attention should be given the addition procedure of admixtures [6].

2.4.2. Dosage of Water Reducing Admixture

It is reported that, in the production of high-strength concrete above 41 MPa, it is beneficial to increase the dosage of the admixture. This usually provided extra water reduction and typically a delay in setting time and slow early-strength gain. Concrete with slow-early strength gain generally exhibits higher later strengths. Generally, more than two additions are less effective and concrete may lose its workability faster than with a single dose. Redosing may result in lower air content, on the order of one to two percentage points for each redose. When redosages are used, the concrete might have a greater potential for bleeding, segregation, and possible retardation of setting time [4].

2.4.3. Hydration Reaction of Water Reducing Admixture

Using calcium lignosulphonate as the normal water reducer, the hydration products of cement at different intervals of time, range from 4hr to 28days. Micro-structural studies by scanning electron microscopy showed that the presence of the admixture does not change the morphology of cement hydration products [10].

Water reducing admixtures have been shown to have little, if any, effect on the total heat normally librated in the hydration of cement. The early heat development will depend on whether the admixture contains a retarding or an accelerating component. Ca Cl_2 accelerates the hydration of C_3S and also the reaction between C_3A and gypsum. Water reducer based on lignosulphate retard the hydration of C_3A and C_3S. A liner relationship is found between the heat development and the non-evaporable water content in cements hydrated for periods up to 90 days. This suggests that the same types of hydration products are formed at all stages of hydration. Recent studies by Ramachandran have indicated that even sugar free lignosulphonates act as retarders of the hydration of cement and cement minerals. They also decrease the water requirements by about 8% [10].

2.4.4. Water Reduction Mechanism

A large amount of experimental data has been collected on explaining the phenomenon underlying the plasticizing action of water reducers. The water reducing action seems to be adsorption and dispersion occurring in the cement-water system [10].

Attempts have been made to study the adsorption of water reducing admixtures on Portland cement and individual cement minerals such as C_2S, C_3S, C_3A and C_4AF. In most studies the amount of admixtures absorbed by the cement minerals was determined by exposure to an aqueous solution. By this method, hydration of the adsorbent could not be avoided and continuously conclusions drawn from such experiments are questionable. Hence, Ramachandran studied the action of calcium lignosulphonate (CLS) on the hydration products such as calcium hydroxide, haydrated C_3S, the hexagonal aluminate phase contain C_4AH_n and C_2AH_n and the cubic aluminate phase, C_3AH_6. Adsorption-desorption isotherms on these compounds were carried out in the aqueous and a non-aqueous medium. In a non-aqueous medium it was found that the phases C_3A, C_3S and C_3AH_6 adsorbed particularly no calcium lignosulphonate whereas the hexagonal aluminate phases adsorbed about 2% and the hydrated C_3S, about 7%.

In the C_3A-CLS-H_2O system it is not possible to determine the adsorption isotherms, as at very low concentrations of CLS both C_3A and the hexagonal phases are present. At higher concentrations, CLS forms a complex with C_3A and H_2O and is absorbed on the C_3A surface. At still higher concentrations, a gel containing excess Ca^{2+} and Al^{3+} is also precipitated. It is possible to determine an adsorption-desorption isotherm in the system, hexagonal aluminate hyderate-CLS-H_2O, provided the concentration of CLS is kept above a particular level.

2.5. Superplasticizer Admixture

Superplasticizers also known as high range water-reducer belong to classes of Type F and G water reducers chemically different from the normal water reducers and capable of reducing water contents by about 35%. They are used to produce normal workability at a lower w/c ratio. They may be used to produce a highly flowable concrete [6][5].

The original superplasticizers were melamine formaldehyde and sulphonated naphthalene. These are highly effective water reducers with a short period of effectiveness and apparently no permanent effects (no retardation or air-entrainment) [9].

There are three possible ways in which superplasticizer admixtures may be used in concrete: [6, 9].

1. *To produce concrete with very low water-to-cement ratio:* - To achieve high strength concrete, water content of the mixture is reduced while maintaining the same cement content. The reduced workability is compensated for by incorporating superplasticizers. By this method, water reductions of up to 35% can be achieved.

2. *To produce concrete with reduced cement content:* - Superplasticizers can be used to produce concretes with reduced cement contents while the water-to-cement ratio is maintained constant. The decrease in workability of concrete is compensated by incorporating superplasticizers.

3. *To produce flowing concrete:* - Superplasticizers have been used to produce self-compacting, self-leveling flowing concretes. In this application, no attempt is made to reduce either the water-to-cement ratio or the cement content. Instead, the aim is to

increase the slump up to 75-200 mm without causing any segregation so that the concrete can be placed in heavily steel-reinforced sections.

2.5.1. Classification of Superplasticizers

Superplasticizers are either synthesized or obtained as industrial by-products. Another way of production of superplasticizer is to use naturally occurring plant materials, like: cashew nuts shell. For example, cashew nut shell liquid is fractionated, sulfonated and condensed with formaldehyde in the presence of additives to produce a superplasticizer. Superplasticizers admixtures are broadly classified into four groups: sulfonated melamine-formaldehyde condensate (SMF); sulfonated naphthalene- formaldehyde condensate (SNF); Polyether-polycarboxylates and modified lignosulfonates (MLS) [6].

- **Sulfonated melamine-formaldehyde condensate (SMF):-** The sulfonated melamine formaldehyde is obtained from melamine which is first converted to trimethyl melamine and then treated with formaldehyde. It is then reacted with sodium bisulfite and polymerized.
- **Sulfonated naphthalene-formaldehyde condensate (SNF):-** The sulfonated naphthalene formaldehyde is obtained by sulfonation of naphthalene with sulfuric acid or SO_3 and then reacted with formaldehyde. The acid is then treated with sodium hydroxide.
- **Polyether-polycarboxylates**:- is prepared by oxidizing copolymers of furan and maleic anhydride, and other polyether polycarboxylate compositions prepared by oxidizing novel, intermediate polymers of furan, maleic anhydride, and at least one copolymerizable comonomer, selected from the group consisting of furan, alkenyl alkyl ethers, alkyl acrylates, alkenyl carboxyalkyl ethers, vinyl esters of carboxylic acids, unsaturated carboxylic acids, unsaturated dicarboxylic acids and their anhydrides and esters, and olefins.

- **Modified lignosulfonates (MLS)**:-are water soluble anionic polyelectrolyte polymers; they are by product of wood pulp using sulfite pulping

2.5.2. Effect of Superplasticizers Admixture on Concrete

The effect of Superplasticizing admixture on concrete depends on type, dosage, and time of addition, w/c ratio, nature and amount of cement, aggregate, temperature. Generally, Superplasticizing admixture will have some effect on fresh and hardened concrete [6].

2.5.2.1. Effect of Superplasticizers on Fresh Concrete

Superplasticizing admixtures have different effects on the fresh concrete and the effects can observe on the following parameters, such as: water reduction, workability, slump loss, bleeding and segregation, air content and finishing [4, 6].

Water Reduction: - High range water reducing admixture should reduce the water requirement at least 12%. High range water reducing admixture can be used to significantly increase slump without increasing water content and may be used to achieve a combination of these two objectives; a slump increase with a reduction in water content [4]. The amount of water reduction achievable with a particular superplasticizer depends on the dosage and the initial slump. Investigation shows that water reduction capabilities of ammonium salt of SNF at w/c ratio of 0.25 was better than sodium-based SMF, and a mixture of lignosulfonate and alkyl aryl sulfonate [6].

Workability: - Workability of concrete is improved when superplasticizer admixtures are incorporated in the mixture at given water content. The ability of superplasticizers to increase the slump of concrete depends on the type, dosage, and time of addition of the superplasticizer, w/c ratio, nature and amount of cement, aggregate, temperature, etc. The time when the superplasticizer is added to concrete affects the slump values. By adding the superplasticizer with the mixing water, the slump value is increased considerably. Even higher slump values are possible by the addition of admixture a few minutes after the concrete is mixed with water. In the temperature range of 5-30°C, there is no radical difference in the slump values attained by the addition of a superplasticizer. Results show that sulfonated naphthalene- formaldehyde condensate (SNF) outperforms sulfonated melamine-formaldehyde condensate (SMF) by increasing the slump at a given dosage [6].

Rate of slump loss: - The rate of slump loss may be decreased by adding water-reducing, especially in concrete made with high range water reducing admixture. Because of the slump loss, high range water reducing admixture may be added at the job site. Working time can be extended with the careful use of Type D water-reducing and retarding admixture or with the use of Type G retarding high range water reducing admixture [4]. At 0.6% SMF, SNF, or modified lignosulfonate, the rate of loss may be the highest with SMF. The reaction of the aluminate phase will have an important effect on the workability of concrete. It has been shown that the addition of superplasticizer enhances the reaction between the aluminate phase and gypsum. Concrete containing superplasticizer can maintain about 30-60 minutes higher than normal workability [6].

Bleeding and Segregation: - In a water-reduced superplasticized concrete, no undue segregation or bleeding occurs. Generally, the bleeding decreases because of the decreased w/c ratio. When repeated dosages of superplasticizers are used to control the loss of slump, bleeding and segregation may occur if the repeated dosing exceeds two or three times [6].

Air Content: - Some commercial water reducers at normal dosages cause entrainment of 2 or 3 percent of air. Even higher values, up to 7 to 8 percent entrained air, can be entrapped using admixtures at higher dosage rates than those recommended by manufacturers, particularly at lower temperatures. Superplasticizers based on SNF and lignosulfonates entrain some air in concrete. Incorporation of SNF admixture sometimes leads to the phenomenon called bubbling concrete

Finishing: - Some water-reducing admixtures improve the concrete's finishing characteristic compared to concrete without admixture. This is also beneficial where deficient aggregate properties or gradation result in finishing difficulties.

2.5.2.2. Effect of Superplasticizers on Hardened Concrete

The addition of superplasticizer admixture in the concrete mix can affect hardened concrete properties such as strength, permeability, shrinkage, and creep.

Strength: - The reduction in water caused by water reducing agents results a net increase in strength at 28 days. When high range water reducing admixtures are used by decrease the w/cm the 28-day compressive strength can increase by 20% or more. This seems to be related to the greater degree of hydration at later ages caused by these admixtures, and hence leads to a higher strength even at the same water-cement. At very early ages, such as 1 day, compressive strength of concretes containing water reducing agents, such as lignosulfonate, gluconic acid and sucrose, is lower than that of the reference mix at the same water-cement ratio, because of the retarding effect of admixtures on the early hydration of cement. However, at 3 and 7 days the strength increase is generally greater than at 1 day and 28 days [6].

Increase in flexural strength of about 10% for concrete at 7 days to 1 year have been reported for lignosulfonate or hydroxycarboxylic acid admixtures at a given slump and cement content. For a given flexural strength, a reduction in cement content of about 15% is possible in admixture treated concrete with respect to the plain mix [6]. The increase in mechanical properties i.e., compressive and flexural strength and modulus of elasticity is generally achieved with reductions in water-to-cement ratio [4, 6, 10].

Permeability:- concrete produced by superplasticzer admixture can be placed easily; therefore, the resultant concrete, if properly cured, can have extremely low permeability and good resistance to the penetration of aggressive solutions. Resistance to chloride penetration is similar to, or slightly better than, that of conventional concrete with the same w/cm. When the admixture is used to reduce the w/cm, the resistance of the concrete to chloride penetration is even greater [6, 10].

Shrinkage and Creep: - The shrinkage of superplasticized concrete is comparable to, or is less than, that of the reference concrete. The general consensus appears to be that concretes made with superplasticizers have approximately the same creep as the reference concrete [6].

2.6. Health and Safety Effect of superplasticizing Admixtures

The major admixture companies all supply safety data sheets for their products and these should be carefully checked and any advice on handling passed to those working with the products. Superplasticizing admixtures are water based and non-hazardous, but at worst they are irritants. Small groups of admixtures have a high PH and are therefore harmful or corrosive; this particularly applies to some air-entrainers, water proofers and shotcrete accelerators. A very small number; mainly from the accelerators and corrosion inhibitors, may be toxic if ingested [12].

Some organic admixtures have a high oxygen demand under biological break down that, during disposal or in the event of a major spillage, may cause problems for fish in rivers and in processing of effluent in water-treatment plants. Any such problem should be notified to the appropriate authorities immediately it occurs [12].

As reviewed from the above discussions, supeplasticizing admixtures have variety effects on the properties of fresh and hardened concrete. According to different scholars, the effects are mainly depending on the dosage of admixture, way of addition, type and amount of each ingredient. For this reason, the next chapters have made study on the effects of mega flow SP1 superplasticizing admixtures on the concrete properties in Ethiopia context for different way of usages.

CHAPTER THREE

3. MATERIAL PREPARATION, MIX DESIGN AND CONCRETE PRODUCTION

3.1. Introduction

Concrete is a building material composed of cement, sand as fine aggregate, crushed rock as coarse aggregate, water and admixture. It's obvious that, concrete can be produced by anybody through mixing of concrete ingredients, but the important point bear in mind is producing acceptable concrete quality with a reasonable economy. To produce acceptable quality, it's important to make physical characteristic tests on materials used for the investigation before any concrete experiments are carryout. So, this chapter elaborates concrete making materials used for the research and their physical test results conducted from the experiment, mix design and proportion, and concrete production process.

3.2. Material preparation

The physical characteristics of concrete making materials (Cement, fine aggregate, Coarse aggregate, Water and Admixture) used for the research were examined and appropriate mix design was made.

3.2.1. Cement Used For the Experiment

Ordinary Portland cement (OPC) produced as per CEM-I-42.5 grade contains 95% clinker and 5% gypsum produced by Derba MIDROC Cement PLC was used throughout the experiment. The reason to select only one cement type is due to financial and time limitation to perform experiments. According to the tests result, the normal consistency of this hydraulic cement was of 27%. This test is used to determine the amount of water required to prepare a standard cement paste. The initial and final setting time was 2:13 hr and 3:00 hr respectively.

3.2.2. Aggregate Used For the Experiment

Aggregates are materials basically used as filler with binding material in the production of concrete. Aggregates form the body of the concrete, reduce the shrinkage and affect economy. Therefore, it is significantly important to obtain right type and quality of aggregates on site. They should be clean, hard, strong, durable and graded in size to achieve utmost economy from the paste. Therefore, to judge the quality of the aggregate physical characteristics tests have to be conducted. So, in this research the following physical testes are performed on the properties of fine and coarse aggregate.

3.2.2.1. Properties of Fine Aggregate

Normal river sand commonly known as Lafesa sand, which is extracted from Lafesa area which is found in Oromia region about 150km from Addis Ababa, was used to prepare the concrete samples. Since, the aggregate is extracted from the river side; it’s full of dust film on their surface. For this reason, the fine aggregates were washed thoroughly and dried to saturated surface dry (SSD) state before any test was carried out. In addition to this, all fine aggregate which retain on 9.5mm sieve size were no longer relevant, and all the passing fine aggregate were used for experimentation. Then, the following tests were conducted for fine aggregates.

- **Sieve Analysis**

According to ES C.D3.201, the gradation result of the original sample sand is out of range on 300µm and 150µm sieve size. So, it is blended with finer sand to make within the range. The grading requirements for fine aggregates according to ES C.D3.201 and, the particle size distribution of original and blended aggregate used for the experiment is shown in Table 3.1 and Figure 3.1 below. Therefore, based on BS specification as shown in Table 3.2 below, the grading of the blended aggregate has failed under zone one.

Table 3.1: The particle size distribution for fine aggregates

Sieve size	Cumulative passing ES C.D3.201 (%)	Cumulative passing (original sand) (%)	Cumulative passing (blended sand) (%)
9.5mm	100	100	100
4.75mm	95-100	97.8	97.8
2.36mm	80-100	88.4	88.4
1.18mm	50-85	66.8	66.8
600µm	25-60	28.6	29.8
300µm	10-30	3.8	10.0
150µm	2-10	0.4	2.0

Fineness Modules $= \frac{\sum \text{cumulative coarser (\%)}}{100} = \frac{305.2}{100} = 3.05$, this can be interpreted that the third sieve, i.e. 600µm is the average size. However, depending upon their size, sand can be classified as coarse sand when a fineness modulus is between 2.90 to 3.20; medium sand with a fineness modulus of 2.60 to 2.90 and; fine sand with a fineness Modulus of 2.20 to 2.60. So, the sample was classified as coarse sand.

Table 3.2: BS and ASTM grading requirements of fine aggregate [13].

Sieve size	Percentage by weight passing sieves				
	BS882:1973				ASTM standards (C33-78)
BS	Grading Zone 1	Grading Zone2	Grading Zone3	Grading Zone 4	
9.5mm	100	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100	95-100
2.36mm	60-95	75-100	85-100	95-100	80-100
1.18mm	30-70	55-90	75-100	90-100	50-85
600µm	15-34	35-59	60-79	80-100	25-60
300µm	5-20	8-30	12-40	15-50	10-30
150µm	0-10	0-10	0-10	0-15	2-10

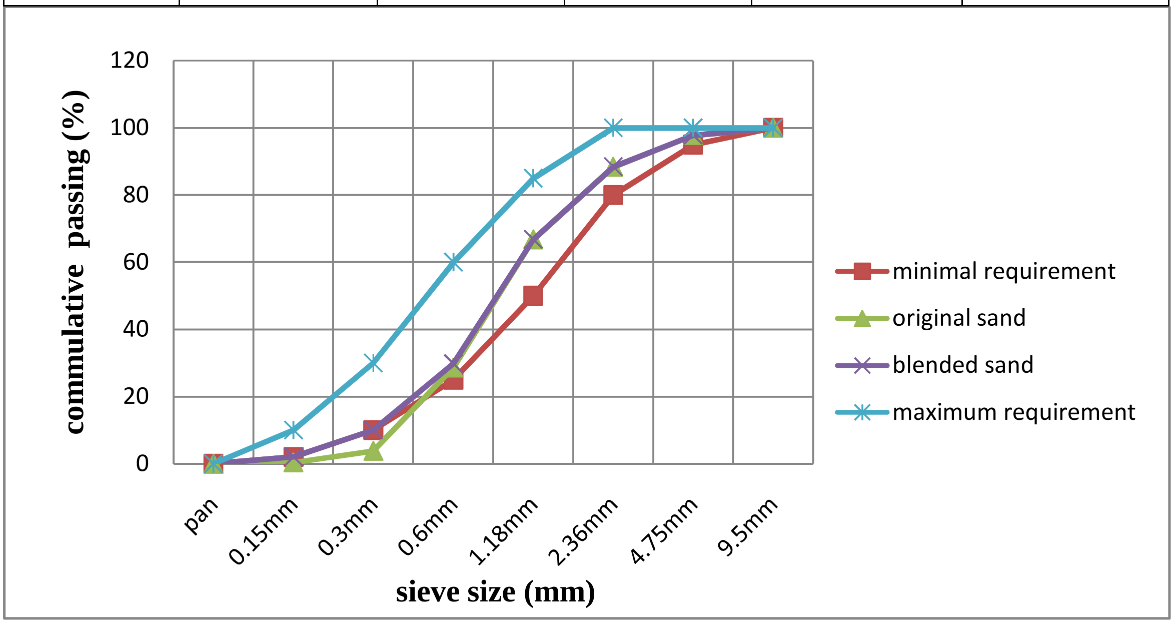


Figure 3.1: Fine aggregate gradation chart

- **Silt Content**

According to the Ethiopian Standard it is recommended to wash the sand or reject if the silt content exceeds a value of 6% [11]. From the test result obtained, the silt content of the sand used for this experiment before washing was 8.35%, which is above the maximum requirement of Ethiopian standard. For this reason, it was washed thoroughly and the result becomes 2.85%.

- **Unit weight of Aggregates**

The unit weight is simply measured by filling a container of known volume and weighing it. Then, dividing the aggregate weight by the volume of the container provides the unit weight of the aggregate. The compacted and loose unit weight of this sample fine aggregate was 1504 kg/m^3 and 1410 kg/m^3.

- **Specific Gravity and Absorption Capacity of fine Aggregates**

Since aggregates generally contain pores, both permeable and impermeable, the meaning of the term specific gravity has to be carefully defined, and there are indeed different types of specific gravity, like: apparent specific gravity and bulk specific gravity. Bulk specific gravity refers to total volume of the solid including pores of the aggregate, and Apparent specific gravity refers to the volume of the solid is consider to include the impermeable pores but not the capillary ones. The bulk specific gravity, bulk specific gravity (saturated- surface dry) and apparent specific gravity results obtained from the experiment are 2.41, 2.47 and 2.56 respectively. And, the absorption capacity was 2.46%.

- **Moisture Content of Aggregates**

The moisture content of fine aggregate was determined by Oven dry 500gm of fine aggregate (sand) for about 24hrs with a temperature of 105 °C to 110 °C and cool for an hour. Then, dividing the weight difference by oven dry weight and multiplying by hundred provide the moisture content. Therefore, the moisture content of the sample fine aggregate was 2.04%.

Table 3.3: Summarized test results for fine aggregate (sand)

No	Physical test for fine aggregate		Results
1	Silt content	before washing	7.14%
		after washing	2.9%
2	Fineness modulus		3.05
3	Unit weight	Compacted unit weight	1501 kg/m^3
		Loose unit weight	1410 kg/m^3
4	Specific gravity	Bulk specific gravity	2.41
		Bulk specific gravity(SSD)	2.47
		Apparent specific gravity	2.56
5	Absorption capacity		2.46%
6	Moisture content		2.04%

3.2.2.2. Properties of coarse aggregate

The coarse aggregate used for this research was basaltic crushed rock from china crusher which is located around Kality sub-city, locally known as “Berta sefer”. The aggregate coming from the crusher site was washed thoroughly and dried in air inside the laboratory room. The size of coarse aggregate used for experimental investigation was a mixture of 20mm and 10mm diameter aggregate sizes and it was sieved and stored in different grades for blending. In this study a maximum size of 19 mm diameter aggregate was used in all the concrete mix design. The physical properties of coarse aggregate test results are shown in the Table 3.4 and 3.5 below. The value of coarse aggregate grading is shown as a Figure in Figure 3.2 below.

Table 3.4: Sieve analysis for coarse aggregate

Sieve size (mm)	Cumulative passing ES C.D3.201 (%)	Cumulative passing (Original coarse agg.) (%)	Cumulative passing (Blended coarse agg.) (%)
19 mm	95-100	97.3	97.3
12 mm	-	37.8	66.3
9.5 mm	25-55	8.7	34
4.75 mm	0-10	0.27	0.27

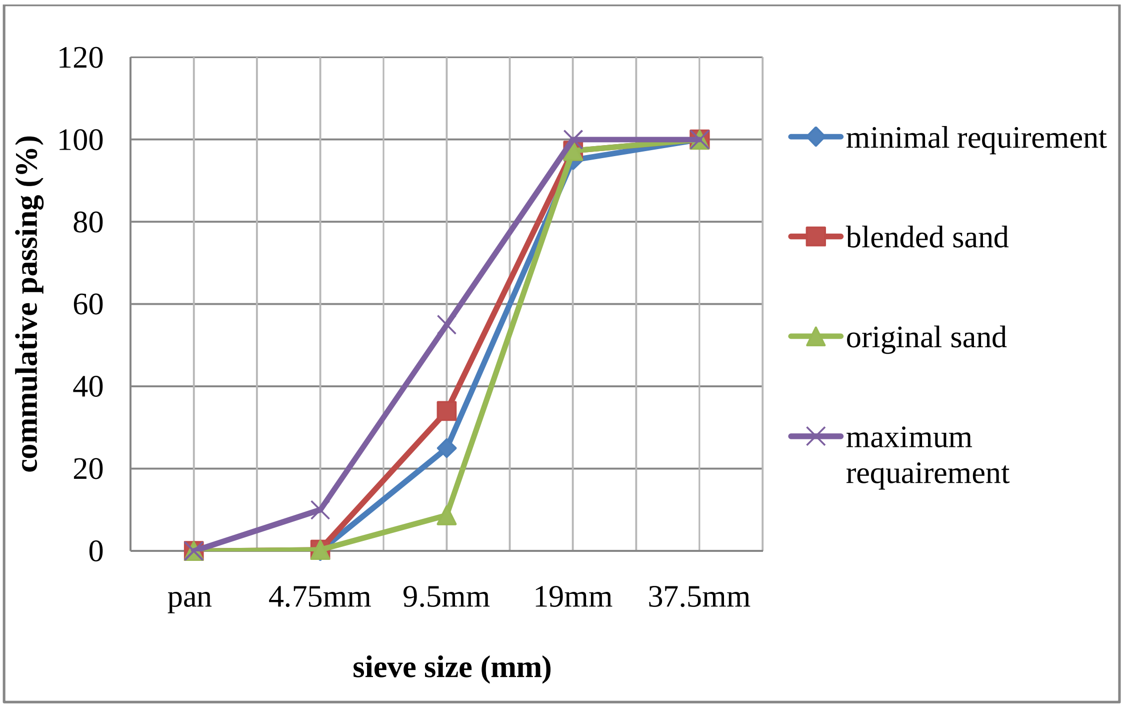


Figure 3.2: Coarse aggregate gradation chart

Table 3.5: Summarized test results for coarse aggregate

No	Physical test for coarse aggregate		Results
1	Unit weight	Compacted unit weight	1435.4 kg/m^3
		Loose unit weight	1382.1kg/m^3
2	Specific gravity	Bulk specific gravity	2.47
		Bulk specific gravity(SSD)	2.53
		Apparent specific gravity	2.61
3	Absorption capacity		2.1 %
4	Moisture content		2.4%
5	Aggregate Impact Value		12.9 %
6	Aggregate Crushed Value		17.9 %

3.2.3. Water Used For the Experiment

Mixing water used in this research was drinkable water supplied by Addis Ababa Water and Sewerage Authority found in the laboratory area.

3.2.4. Admixture Used For the Experiment

Different chemical admixtures are available in the local market which are import from abroad countries, like: India, USA etc, and there is also admixture produced in our country. For this research locally produced admixture was selected. The local producing factory produces two types of high range water reducing superplasticizers admixture such as: mega flow SP1 (chloride free, superplasticizing admixture based on selected sulphonated naphthalene polymers) and SP4 (chloride free, superplasticizing admixture based on modified Sulphonated naphthalene formaldehyde) around Holota area. The chemical admixture used in this study was mega flow SP1, a highly effective water reducing superplasticizer and an extremely powerful deflocculating agent on soluble salt of polymeric naphthalen sulphonate, type F complying with ASTEM C494, BS EN 934-2. The recommended dosage is 0.5-3% by weight of cementitious material. This admixture is effective on properties such as workability, strength, permeability etc. according to the manufacturer data this admixture has a shelf life of 12 months when stored under warehouse condition. The Table 3.6 below shows the typical properties of mega flow sp1, type F admixture at 25°C described by the supplier.

Table 3.6: Typical properties of type F admixture at 25°C

Properties	Test method	Value
Component	-	Single
Form	-	Liquid
Colour	-	Brown
Specific gravity	ASTM C494	1.20±0.02
Air entrainment	-	Up to 1%over control mix
Chloride content	BS EN 480-10	Nil to BS EN934-2
PH	ASTM C494	7-9

3.3. Concrete Mix Design and Materials Proportion

The DOE Method of concrete mix design was used to design C-25 and C-60 concrete grade. For C-25 and C-60 the target mean strength was 38N/mm^2 and 73N/mm^2, and the water to cement ratio was 0.58 and 0.33 respectively. In addition to this, the slump was 30 to 60mm and

10 to 30mm for C-25 and C-60 grade respectively. The quantity of concrete materials was calculated by using the physical properties of the materials and table 3.7and 3. 8 show the quantity of materials for one cubic meter for C-25 and C-60 concrete grade. The Standard cast iron moulds of size 15x15x15cm are used in the preparation of concrete cubes for compressive strength and permeability tests. Whereas, for flexural strength the standard cast iron moulds of size 50 x 10 x 10cm are used.

Table 3.7: Quantity of materials in kg for 1m^3 C-25 concrete grade production

For C-25 concrete grade ; W/C = 0.58				
Materials	Cement (kg)	Water(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	330	190	840	931

Table 3.8: Quantity of materials in kg for 1m^3 C-60 concrete grade production

For C-60 concrete grade ; W/C =0.33				
Materials	Cement (kg)	Water(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	515	170	610	1041

3.4 Concrete Production Process

The concrete moulds and mixer were cleaned from all dust and coated with releasing agent (oil) to smooth the surface and to prevent sticking of mixed concrete with the mold and mixer. The ingredients, such as; cement, fine aggregate (sand), coarse aggregate water and admixture were measured by weight balance. After that the weighted coarse aggregate was first added to the mixer and the cement was added after the coarse aggregate and then the fine aggregate is added next to cement and dry mixed for a minute. Then, water and admixture was added to the dry mixed concrete ingredients mixture and thoroughly mixed for two more minute. The mixed concrete was checked for workability by filling the standard slump cone with three layers by rodding each layer with 25 times. Then, after checked the slump the mixed concrete was placed in the mould and was well compacted in two layers with the help of a table vibrator for 45 and 30 seconds for double and single cast iron moulds respectively. The concrete moulds are kept for 24 hours and then the casted concrete cubes were removed from the mould and placed inside water for curing to take place until the testing age was reached.

CHAPTER FOUR

4. EXPERIMENTAL PROGRAMS AND DISCUSSIONS

According to the research objectives and methodology, effect of superplasticizing admixture on concrete properties, such as: workability, strength and permeability of concrete have been studied with four different phases at dosages of 0%, 0.5%, 1% and 1.5% of the cement amount. The laboratory experiments were performed in four different phases, these are:

- **Phase I:** The effect of superplasticizing admixture on workability at a constant W/C ratio.
- **Phase II:** The effect of way of superplasticizing admixture addition on concrete properties at a constant W/C ratio.
- **Phase III:** The effect of superplasticizing admixture on concrete properties by reducing amount of mixing water at a constant workability.
- **Phase IV:** The effect of superplasticizing admixture on concrete properties by reducing cement content at constant W/C ratio.

4.1. Phase I: The Effect of Superplasticizing Admixture on Workability at a constant W/C ratio

This phase was performed to study the effects of superplasticizing admixture on workability at a constant volume of liquid for convectional strength concrete (C-25) and high strength concrete (C-60) grade with different dosage of admixture. In this case superplasticizing admixture was used as a substitution of water. So, equivalent amount of water was reduced as the amount of superplasticizing admixture added to the concrete mix.

The effects of superplasticizing admixture on workability were assessed, and parallel to workability the rate of compressive strength development has been also investigated. For both investigation experiments are carried out for fresh and hardened concrete with and without the presence of superplasticizing admixture for C-25 and C-60 concrete grades. For fresh concrete property, slump tests were conducted to assess the workability of concrete and, for hardened concrete property compressive strength tests were performed with 15cm cubes at the ages of 3^{rd}, 7^{th} and 28^{th} days.

4.1.1. Workability and Compressive Strength Tests for C-25 Concrete Grade

For the C-25 concrete, workability and strength tests were conducted. The slump test results were conducted to investigate the impact of superplasticizing admixture dosage on workability. While, the strength development, and strength of concrete with dosage of superplasticizing admixture to determine the hardness of concrete.

The objective of workability test is to assess whether the concrete is effective enough for easy compaction and placing. Slump test is the simplest test for workability. On the other hand, the purpose of compressive strength tests is used to determine the rate of compressive strength development of hardened concrete; the cubes can be tested to failure in a compression testing machine in order to measure the strength development of the hardened concrete. Figure 4.1 and 4.2 below illustrates a typical concrete cube sample ready for testing and after testing.

Figure 4.1: sample ready for testing

Figure 4.2: concrete cube sample after testing

The compressive strength of concrete was determined by testing the cubes in a compression testing machine at a rate of 0.28MPa/s. For every cube the compressive strength is recorded in MPa and, then the mean values of three samples were taken as their compressive strength value for 3^{rd}, 7^{th} and 28^{th} days. Table 4.1 below shows slump and rate of compressive strength development test results for C-25 concrete grade with different dosage of superplasticizing admixture.

Table 4.1: Workability and compressive strength results at constant volume of liquid for C-25

Effect of superplasticizer on workability and compressive strength								
Admixture	W*/C ratio	Slump (mm)	3rd days		7th days		28th days	
			Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)
0%	0.58	33	338.97	15.06	483.13	21.47	733.4	32.60
0.5%	0.58	47	348.1	15.47	511.13	22.72	761.6	33.84
1%	0.58	54	360.6	16.03	537.7	23.88	800.8	35.59
1.5%	0.58	140	340.5	15.72	513.2	22.81	772.3	34.32

Note: W* indicates the amount of pure water plus superplasticizing added to the concrete

The values of slump and rate of compressive strength development test for C-25 with different dosages of superplasticizing admixture are shown as a graph in Figure 4.3 and Figure 4.4, respectively.

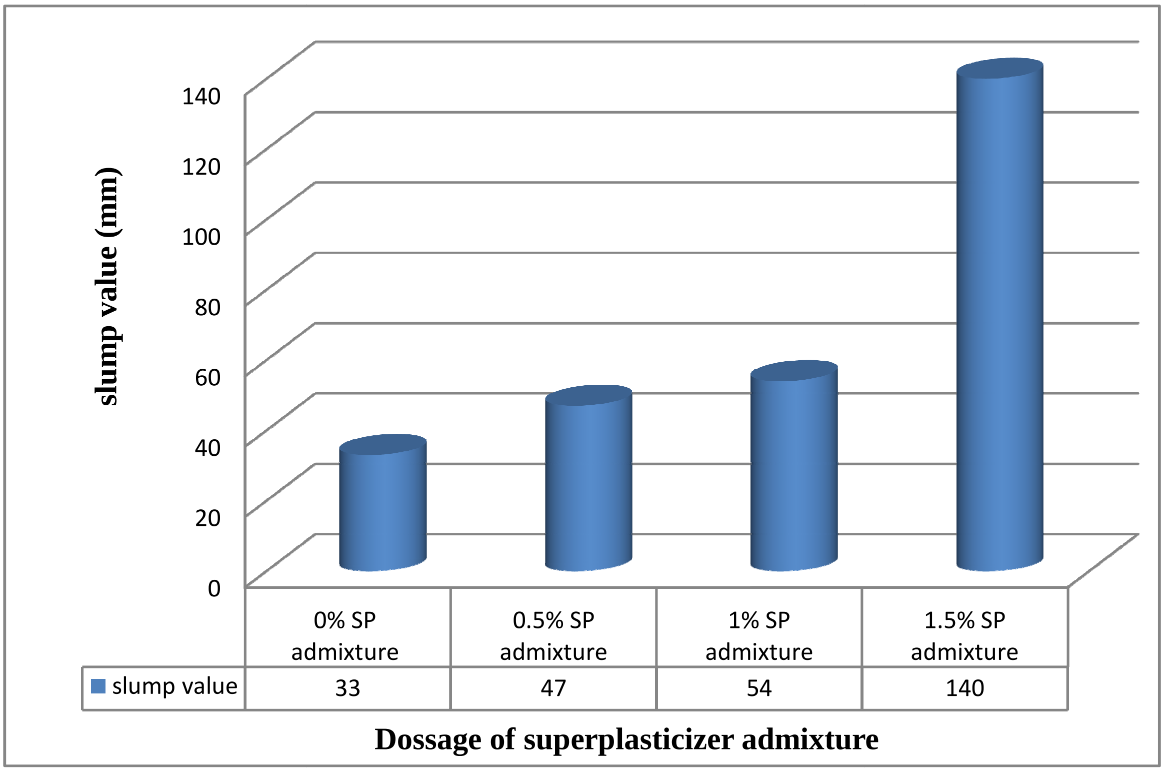


Figure 4.3: Effects of superplasticizing on workability at constant volume of liquid for C-25

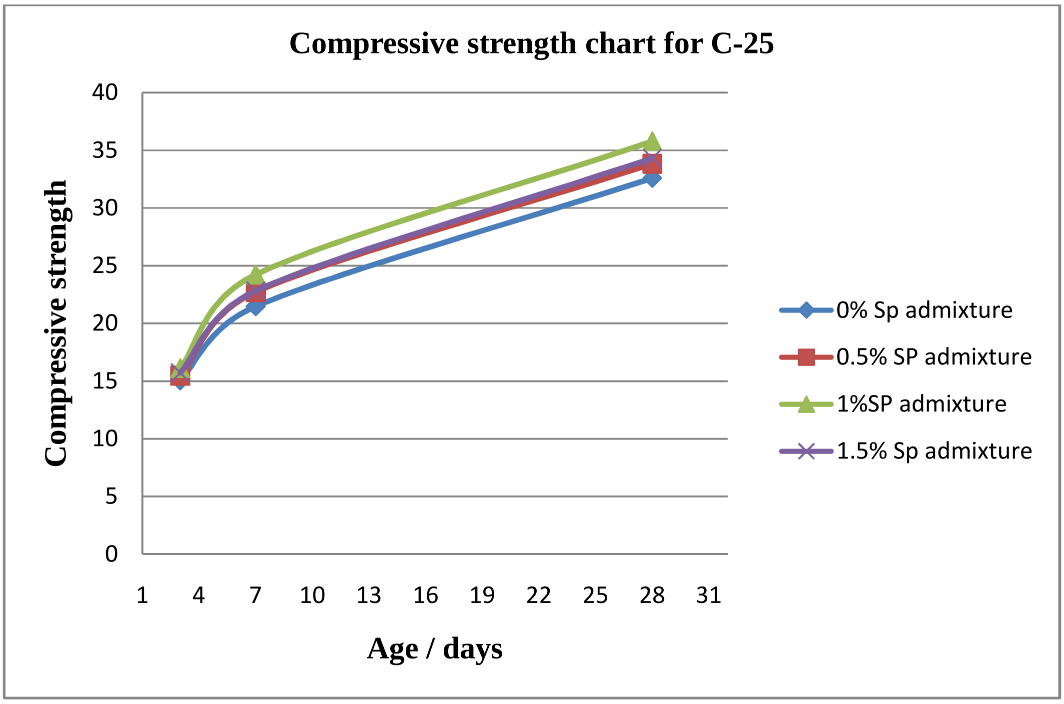


Figure 4.4: Effects of superplasticizing on compressive strength at constant volume of liquid

Based on the observed slump measurements, the concrete mix produced without superplasticizing admixture a slump 33mm was observed. Similarly, the observed slump for a dosage of 0.5% superplasticizing admixture added concrete was 47mm. The observed difference between the two slumps was 14mm. However, according to ASTM C143 standard the variability for a slump of 33mm is about 17mm. If the analysis is based on the recommendation of ASTM C143 standard, 0.5% dosage of superplasticizing admixture does not bring a significant workability improvement. However, given the fact the experiments are carried under controlled situations, the actual variability of slump is expected to be lower, thus though not significant the 0.5% superplasticizing admixture shows tendency of workability increment.

For a dosage of 1% superplasticizing admixture added concrete, the observed slump was measured 54mm. The observed difference between the two slumps, which is produced by without adding superplasticizing admixture and 1% superplasticizing admixture added concrete was 21mm. This shows addition of 1% superplasticizing admixture have brought improvement over the reference concrete and provided a higher result than ASTM C143 standard recommendation.

The highest increment of slump value was observed by addition of 1.5% superplasticizing admixture, which was measured 140mm. This shows the workability of 1.5% superplasticizing admixture added concrete was improved by 107mm from reference concrete and provided very high slump difference than ASTM C143 standard recommendation.

According to the test observation, the slump of 0%, 0.5%, and 1% superplasticizing admixture added concrete were within the range and produced true slump. But, the slump of 1.5% superplasticizing admixture added concrete was above the stated designed range and form shear slump. This shows that slump can increase by increasing the admixture dosages. So, 1.5% superplasticizing admixture will help to obtain workable concrete for a longer time, and this will reduce the quick slump loss during the transportation and placing of concrete on site. However, over dosage of admixtures leads to high slump, which will not give the desired slump as expect. Therefore, it will affect the strength of produced concrete. This does not mean too much slump will no longer relevant, it will be preferable to use in congested areas with steel reinforcement as a self compacted concrete, and this can reduce wastage of time and money incurred for compaction.

Parallel to workability, the mean rate of compressive strength development of concrete at the age of 3^{th}, 7^{th}, and 28^{th} with those percentages are also discussed as follows.

At the age of three day, the observed rate of compressive strength development of 0% superplasticizing admixture added concrete was 15.06MPa. Similarly, for 0.5% superplasticizing admixture added concrete the observed rate of compressive strength development was 15.47MPa. This indicates the rate of compressive strength development was increased by 0.41MPa or 2.7% from 0% superplasticizing admixture added concrete. For 1% superplasticizing admixture added concrete the observed rate of compressive strength development was 16.03MPa, which was increased by 0.97MPa or 6.04%, 0.56 MPa or 3.62% and 0.31 MPa or 1.97% from 0%, 0.5% and 1.5% superplasticizing admixture added concrete. For 1.5% superplasticizer admixture added concrete the observed rate of compressive strength development was 15.72Mpa. It was increased by 0.66Mpa or 4.4% and 0.25 MPa or 1.6% from 0% and 0.5%, but it was reduced by 0.31Mpa or 1.93% from 1% superplasticizing admixture added concrete.

At the age of seven day, the observed rates of compressive strength development of 0%, 0.5%, 1% and 1.5% of superplasticizing admixture added concrete were 21.47MPa, 22.72MPa, 23.88MPa and 22.81MPa respectively. This indicates the observed rate of compressive strength development of 0.5% was increased by 1.25MPa or 5.8% from 0% superplasticizing admixture added concrete. For 1% superplasticizing admixture added concrete the observed rate of compressive strength development was increased by 2.41MPa or11.23%, 1.16MPa or 5.1% and 1.07MPa or 4.69% from 0%, 0.5% and 1.5% superplasticizing admixture added concrete. However, 1.5% was increased by 1.34MPa or 6.2% and 0.09MPa or 0.4% from 0% and 0.5% and reduced by 1.07MPa or 4.48% from 1% superplasticizing admixture added concrete.

At the age of twenty eight day, the observed rates of compressive strength development of 0%, 0.5% 1% and 1.5% superplasticizing admixture added concrete were 32.6MPa, 33.84MPa, 35.59MPa and 34.32MPa respectively. This shows the rate of compressive strength development of 0.5% was increased by 1.24MPa or 3.8% from 0% superplasticizing admixture added concrete. 1% superplasticizing admixture added concrete was increased by 2.99MPa or 9.17%, 1.75MPa or 5.17% and 1.27MPa or 3.7% from 0%, 0.5% and 1.5% superplasticizing admixture added concrete. Whereas, 1.5% was increased by 1.72MPa or 5.3% and 0.48MPa or 1.4% from 0% and 0.5% superplasticizing admixture added concrete and reduced by 1.27MPa or 3.6% from 1% superplasticizing admixture added concrete.

According to ASTM C 192 standard, the 7-day compressive strength results of properly conducted tests on two trial batches made in the same laboratory should not differ by more than 574 psi (4MPa). If the analysis is based on the recommendation of ASTM C192 standard, all added dosage of superplasticizing admixture does not bring a significant change on strength. However, based on the test observed results, concrete casted with the addition of superplasticizing admixture has been shown a slight difference on the rate of compressive strength development at all ages than the reference concrete. This indicates, the rate of compressive strength development of concrete can be improved by the addition of superplasticizing admixture, but based on the observed result, addition of superplasticizing admixture not always increases the compressive strength of concrete, on the other hand, it can reduces the strength significantly and become worse when the dosage is beyond the optimum amount. For this reason, there is an optimum limit for the usage of admixture. According to the test observation the optimum dosage of superplasticizing admixtures which produce better strength is 1% superplasticizing admixture.

4.1.2. Workability and Compressive Strength Tests for C-60 Concrete Grade

Results for slump and rate of compressive strength development of concrete for C-60 at different dosage of superplasticizing admixture obtained from the experiment are shown in Table 4.2.

Table 4.2: Workability and compressive strength results at constant volume of liquid for C-60

Effect of super plasticizer on workability and compressive strength								
Admixture	W*/C ratio	Slump (mm)	3rd days		7th days		28th days	
			Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)
0%	0.33	14	822.6	36.56	1037.7	46.11	1378.0	61.23
0.5%	0.33	25	833.9	37.06	1057.6	47.00	1413.6	62.82
1%	0.33	32	875.6	38.90	1106.1	49.15	1461.9	64.97
1.5%	0.33	120	846.0	37.60	1064.4	47.30	1424.2	63.29

Note: W* indicates the amount of pure water plus superplasticizing added to the concrete

The values of slump and compressive strength test for C-60 at different dosages of superplasticizing admixture are shown as a graph in Figure 4.5 and figure 4.6 respectively.

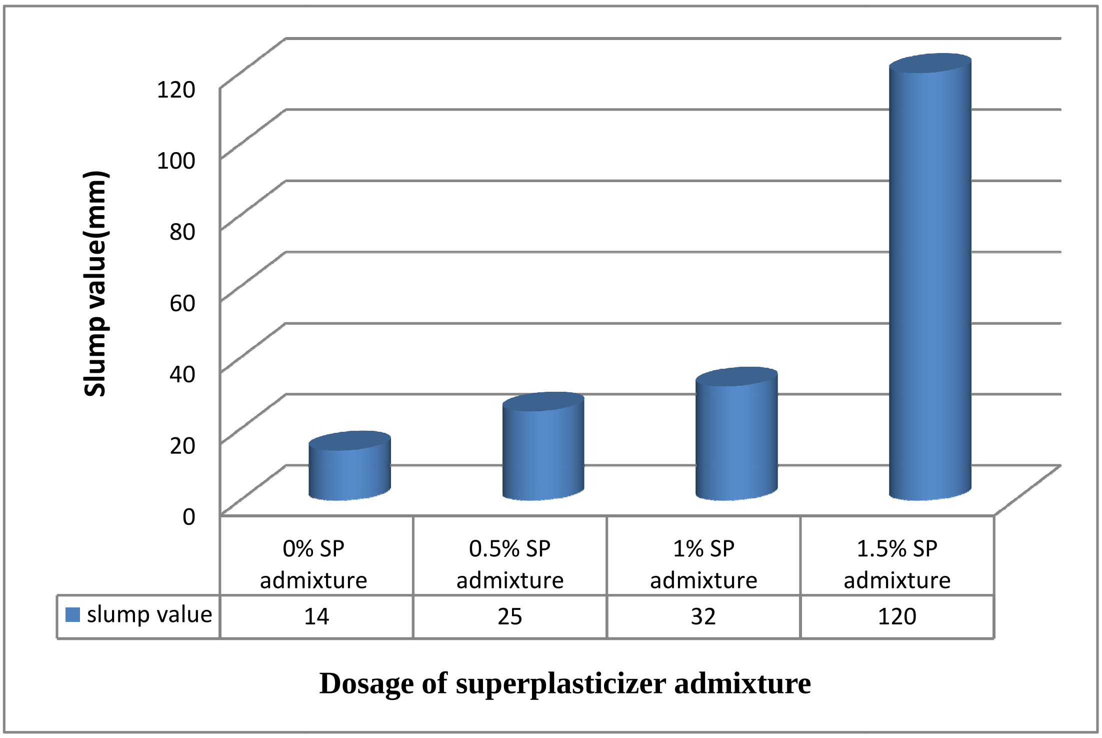


Figure 4.5: effect of supper plasticizer on workability at constant volume of liquid for C-60

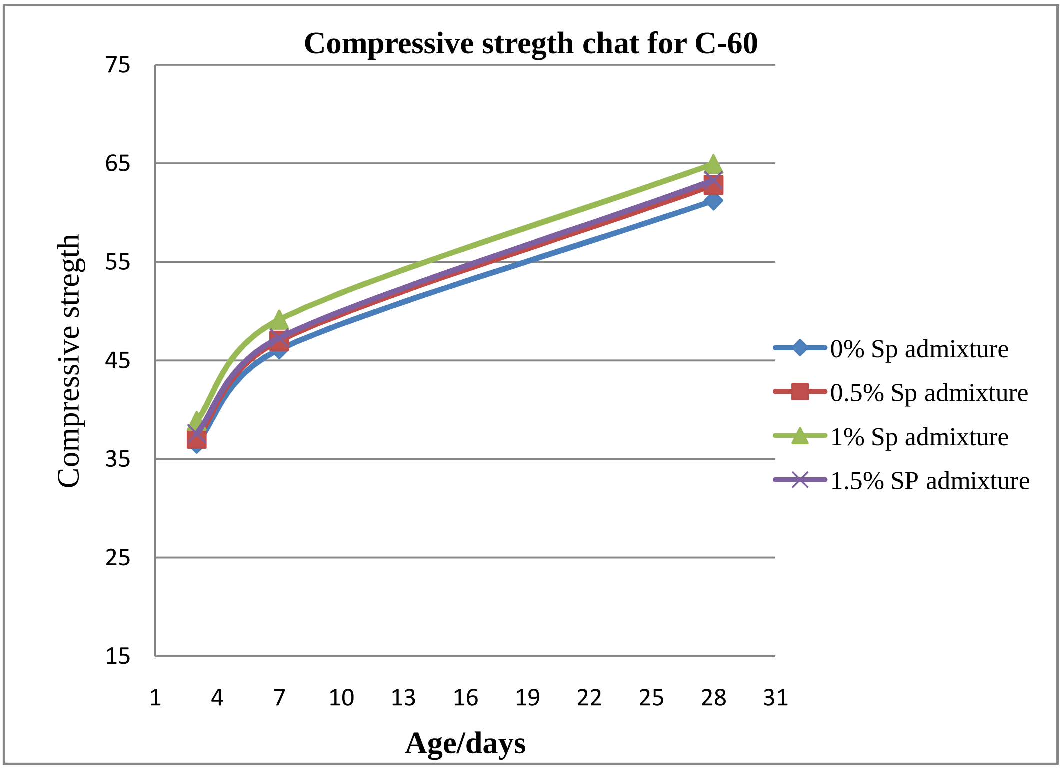


Figure 4.6: Effect of superplasticizing on compressive strength at constant volume of liquid

According to the observed test results, the slump of concrete produced without adding superplasticizing admixture was measured 14mm. similarly, for 0.5% of superplasticizing admixture added concrete, the slump was 25mm. The observed difference between the two slumps was 11mm. However, according to ASTM C143 standard the variability for a slump of 14mm is going to be about 14mm, which means zero slump value. If the analysis is based on the recommendation of ASTM C143 standard, 0.5% dosage of superplasticizing admixture does not bring a significant workability improvement. However, the experiments are carried under controlled situations; the actual variability of slump is expected to be lower. On the other hand, the observed slumps of 1% and 1.5% were 32mm and 120mm. This indicates, the observed slump of 1% and 1.5% superplasticizing admixture added concrete was shown differences by 18mm and 106mm from the reference concrete respectively. For this reason, the observed results of 1% and 1.5% superplasticizing admixture added concrete have satisfied the requirements on workability of ASTM C143 standard.

The effects of superplasticizing admixture on the rate of compressive strength development for C-60 concrete grade have also discussed as follows.

At the third day, the observed rate of compressive strength development of 0%, 0.5%, 1% and 1.5% of superplasticizing admixture added concrete were 36.56MPa, 37.06MPa, 38.90MPa and 37.60Mpa respectively. This indicates the observed rate of compressive strength development of 0.5% superplasticizing admixture added concrete was increased by 0.5MPa or 1.37% from the reference concrete. 1% was increased by 2.34MPa or 6.4%, 1.84MPa or 5% and 1.3 MPa or 3.5% from 0%, 0.5% and 1.5% superplasticizing admixture added concrete. However, 1.5% was increased by1.04MPa or 2.9% and 0.54MPa or 1.5% from 0% and 0.5%, but it was reduced by 1.3Mpa or 3.3% from 1% superplasticizing admixture added concrete.

At the seven days, the observed rate of compressive strength development of 0%, 0.5%, 1% and 1.5% of superplasticizing admixture added concrete was 46.11MPa, 47.00MPa, 49.15MPa and 47.30MPa respectively. This indicates the observed rate of compressive strength development of 0.5% superplasticizing admixture added concrete was increased by 0.89 MPa or 1.9% from 0% superplasticizing admixture added concrete and 1% was increased by 3.04MPa or 6.6 %, 2.15MPa or 4.6% and 1.85MPa or 3.9% from 0%, 0.5% and 1.5% superplasticizing admixture added concrete. However, 1.5% was increased by 1.19MPa or

2.6% and 0.3MPa or 0.6% from 0% and 0.5% and reduced by 1.85MPa or 3.8% from 1% superplasticizing admixture added concrete.

At the twenty eight days, the observed rate of compressive strength development of 0%, 0.5% 1% and 1.5% was 61.23MPa, 62.82MPa, 64.97MPa and 63.29MPa respectively. This shows the observed rate of compressive strength development of 0.5% superplasticizing admixture added concrete was increased by 1.59MPa or 2.6% from 0% superplasticizing admixture added concrete. 1% superplasticizing admixture added concrete was increased by 3.74MPa or 6.1%, 2.15MPa or 3.4% and 1.68MPa or2.7% from 0%, 0.5% and 1.5% superplasticizing admixture added concrete. Whereas, 1.5% superplasticizing admixture added concrete was increased by 2.06MPa or 3.4% and 0.47MPa or 0.8 % from 0% and 0.5% superplasticizing admixture added concrete and reduced by 1.68MPa or 2.6% from 1% superplasticizing admixture added concrete.

According to ASTM C 192 standard, the 7-day compressive strength results of properly conducted tests on two trial batches made in the same laboratory should not differ by more than 574 psi (4MPa). If the analysis is based on the recommendation of ASTM C192 standard, all added dosage of superplasticizing admixture does not bring a significant change on strength. However, based on the test observed results, concrete casted with the addition of superplasticizing admixture has been shown some difference on the rate of compressive strength development at all ages than the reference concrete. This indicates, the rate of compressive strength development of concrete can be improved by the addition of superplasticizing admixture. According to the test observation the optimum dosage of superplasticizing admixtures which produce better strength is 1% superplasticizing admixture.

4.2. Phase II: The Effect of Way of superplasticizing Admixture Addition on Concrete properties at a constant W/C ratio

In this phase 1% superplasticizing admixture was incorporated into the concrete mix in three different ways and different results on workability and rate of compressive strength development have been recorded. The first way of superplasticizing admixture addition was by discharging the full amount of admixture into the total gauging water. The second way of superplasticizing admixture addition was after an initial mixing of approximately 50% of the mixing water, the admixture was dissolved with approximately 25% of the gauging water (middle), and finally the remainder of the gauging water was added. The third way of superplasticizing admixture addition was at the end of mixing time. So, in order to study the effect of way of additional, workability and compressive strength tests were performed for C-25 concrete grade at the age of 3^{rd}, 7^{th} and 28^{th} days. In this case 1% superplasticizing admixture was added throughout the mixes. The results of the experiments on workability and rate of compressive strength development are recorded in the table 4.3. Figure 4.7 and 4.8 also show the graphs of slump and rate of compressive strength development of concrete respectively.

Table 4.3: The effect of way of superplasticizing admixture addition on workability and compressive strength for C-25

Effect of super plasticizer on workability and compressive strength								
Way of Admixture addition	W*/C ratio	Slump (mm)	3^{rd} days		7^{th} days		28^{th} days	
			Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)
1% with full gauging water	0.58	54	360.6	16.03	537.7	23.88	800.8	35.59
1% @ the middle of mixing (50% H_2O+25% H_20 with SP +25% H_20)	0.58	52	379.03	16.86	572.93	25.46	834.7	37.09
1%@ the end of mixing	0.58	56	355.7	15.81	522.8	23.23	785.3	34.90

Note: W* indicates the amount of pure water plus superplasticizer added to the concrete

The values of slump and compressive strength test results for the three ways of superplasticizing admixture additions are shown as a graph in Figure 4.7 and figure 4.8 respectively.

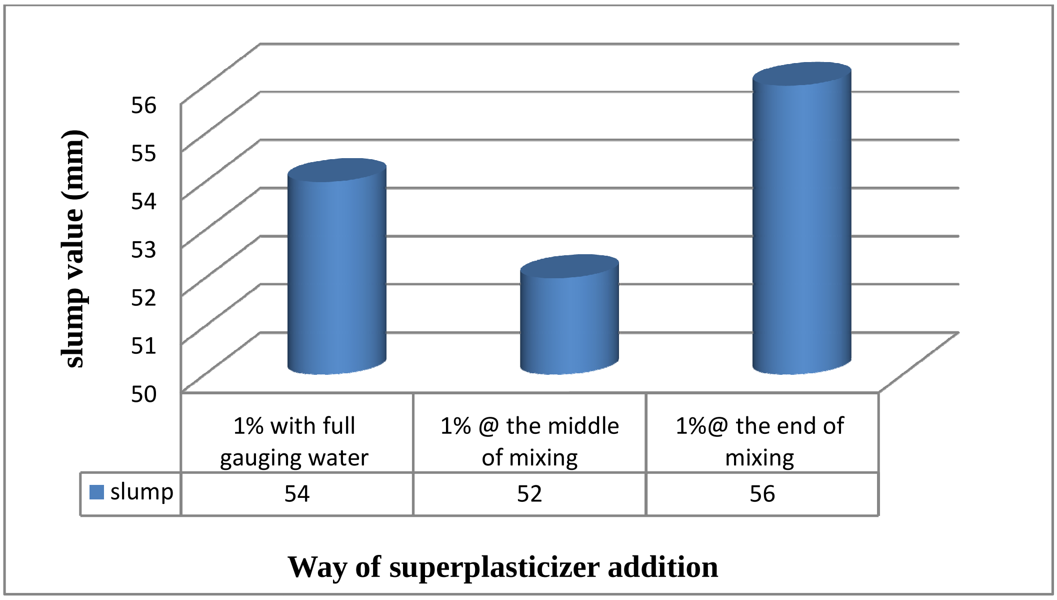


Figure 4.7: Effect of way of superplasticizing admixture addition on workability

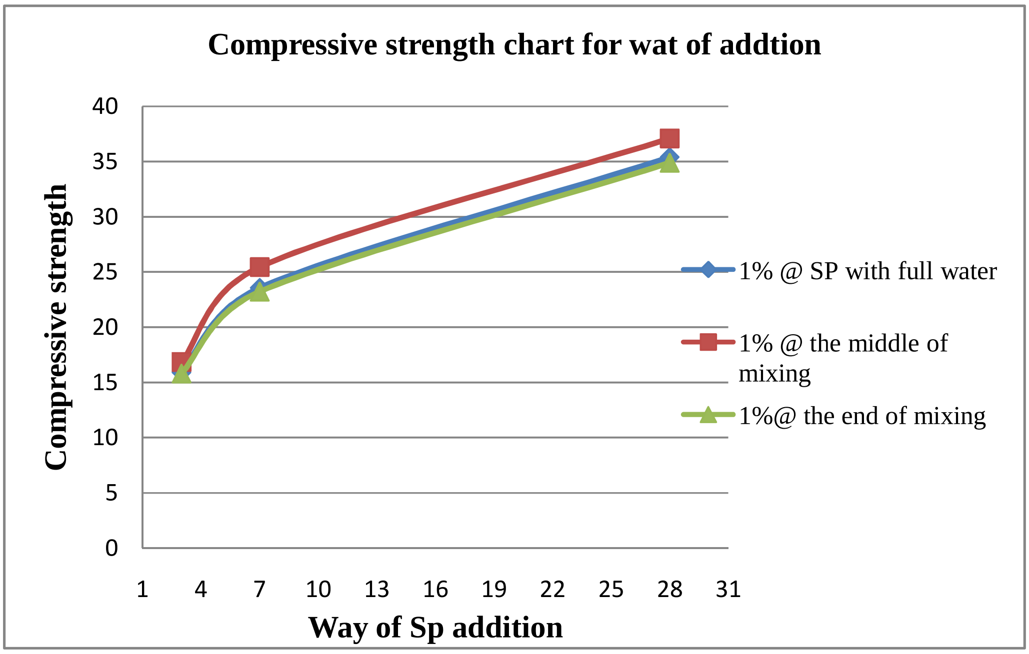


Figure 4.8: Effect of way of superplasticizing admixture addition on compressive strength

According to the observed test results conducted, the slump of concrete produced by discharging the full amount of superplasticizing admixture into the total gauging water was measured 54mm. The observed slump of concrete produced by discharging superplasticizing admixture with approximately 25% of the gauging water at the middle, after initial mixing of approximately 50% of mixing water was 52mm and the observed slump of concrete produced by adding superplasticizing admixture at the end of mixing time was 56mm.

The observed test results were shown; there is a slight increment on the workability and rate of compressive strength development of the concrete when the superplasticizing admixture is added in different ways.

According to the observed slump results, the workability of concrete produced by discharging the full amount of superplasticizing admixture into the total gauging water was increased by 2mm from superplasticizing admixture discharged with approximately 25% of the gauging water at the middle after initial mixing of approximately 50% of total gauging water, but it was reduced by 2mm from superplasticizing admixture at the end of mixing time. The observed slump of concrete produced by discharging superplasticizing admixture with approximately 25% of the gauging water at the middle after initial mixing of approximately 50% of water was reduced by 2mm and 4mm from superplasticizing admixture added into the total gauging water and at end of mixing time respectively. The observed slump of concrete produced by adding superplasticizing admixture at the end of mixing time was increased by 2mm and 4mm from superplasticizing admixture discharged into the total gauging water and discharged with approximately 25% of the gauging water at the middle after initial mixing of approximately 50% of water respectively.

The effects of the three ways superplasticizing admixture addition on compressive strength have been also discussed as follows. At the age of three day, the observed rate of compressive strength development of concrete produced by discharging the full amount of superplasticizing admixture into the total gauging water was 16.03MPa. The observed rate of compressive strength development of concrete produced by discharging superplasticizing admixture with approximately 25% of the gauging water at the middle after initial mixing of approximately 50% of total water was 16.86MPa, and the observed rate of compressive strength development of concrete produced by adding superplasticizing admixture at the end of mixing time was15.81MPa. This shows that, the observed rate of compressive strength development of concrete produced by discharging superplasticizing admixture with the full mixing water was reduced by 0.83MPa or 4.9% form superplasticizing admixture added at the middle of mixing time, but, it is slightly increased by 0.22MPa or 1.4% from superplasticizing admixture added at the end of mixing time. The observed rate of compressive strength development of concrete produced by discharging superplasticizing admixture at the middle of mixing was increased by 0.83MPa or 5.2% and 1.05MPa or 6.6% from superplasticizing admixture added with the full mixing water and at the end of mixing time respectively. The observed rate of compressive strength development of concrete produced by discharging superplasticizing admixture at the end of mixing time was reduced by 0.22MPa or 1.4% and 1.05 MPa or 6.2% from superplasticizing admixture added with the full mixing water and at the middle of mixing respectively.

At the age of seven day, the observed rates of compressive strength development of concrete produced by discharging superplasticizing admixture with the full mixing water, at the middle of mixing and at the end of mixing were 23.88MPa, 25.46MPa and 23.23MPa respectively. This indicates the observed rate of compressive strength development of concrete produced by discharging superplasticizing admixture with the full mixing water was reduced by 1.58MPa or 6.2 % from superplasticizing admixture added at the middle of mixing and slightly increased by 0.65MPa or 2.8% form superplasticizing admixture added at the end of mixing. The observed rate of compressive strength development of concrete produced by discharging superplasticizing admixture at the middle of mixing was increased by1.58MPa or 6.6% and 2.23MPa or 9.6% from superplasticizing admixture added with the full mixing water and at the end of mixing time respectively. The rate of compressive strength development of concrete produced by discharging superplasticizing admixture at the end of mixing time was reduced by 0.65MPa or 2.7% and 2.23MPa or 8.8% from superplasticizing admixture added with the full mixing water and at the middle of mixing respectively.

At the age of twenty eight day, the observed rates of compressive strength development of concrete produced by discharging the superplasticizing admixture with the full mixing water, at the middle of mixing and at the end of mixing were 35.59MPa, 37.09MPa and 34.90MPa respectively. This indicates the observed rate of compressive strength development of concrete produced by discharging superplasticizing admixture with the full mixing water was reduced by 1.5MPa or 4.0 % from superplasticizing admixture added at the middle of mixing and increased by 0.68MPa or 1.98 % form superplasticizing admixture added at the end of mixing. The rate of compressive strength development of concrete produced by discharging superplasticizing admixture at the middle of mixing was increased by1.5MPa or 4.2% and 2.19MPa or 6.3%

from superplasticizing admixture added with the full mixing water and at the end of mixing time respectively. The rate of compressive strength development of concrete produced by discharging superplasticizing admixture at the end of mixing time was reduced by 0.69MPa or 1.94% and 2.19MPa or 5.6 % from superplasticizing admixture added with the full mixing water and at the middle of mixing respectively.

According to different scholars, the ability of superplasticizing admixture to improve the slump and compressive strength of concrete depends on the time of addition. But, in this research the way of superplasticizing admixture addition have provided a slight difference on workability and rate of compressive strength development. According to ASTM C143 and ASTM C129, the way of superplasticizing admixture addition dose not also provide a significant effect on workability and the rate of compressive strength development of concrete.

4.3. Phase III: The effect of superplasticizing admixture on concrete properties by reducing amount of mixing water at a constant workability

This phase studied the effect of superplasticizing admixture on concrete properties by reducing amount of mixing water at a constant workability. In this case the water content was gradually increased until to achieve constant slump like that of the reference concrete by keeping all other ingredients similar to the mix design. The dosages of superplasticizing admixture was added with 25% mixing water after the addition of 50% of water and then to kept the workability constant, the reminder water was added by the method of successive trials through checking the workability of concrete.

As per the specific objective of phase III, the effect of superplasticizing admixture on compressive strength, flexural strength and permeability by reduction of mixing water at constant workability were assessed by the addition 0%, 0.5%, 1% and 1.5% superplasticizing admixture. In order to check the effect, experiments were performed on C-25 concrete grade with 15cm cubes. For the rate compressive strength development, concrete cubes were tested at the age of 3rd, 7th and 28th days, and for flexure strength at the age of 7th and 28th days were tested. However, for permeability test results only at the age of 28th day were conducted.

4.3.1. Experimental results and discussion on compressive strength of concrete

The proportion of materials used for producing a m^3 concrete and results of rate of compressive strength development of concrete with different dosages of superplasticizing at a constant workability by reduction of mixing water for 3rd, 7th and 28th days are shown below in Table 4.4 and table 4.5 respectively.

Table 4.4: Quantity of materials in kg for 1m^3 C-25 concrete grade production by reduction of mixing water for compressive strength

For C-25 concrete grade nil SP					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	330	190	-	840	931
For C-25 concrete grade with 0.5% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	334	178.76	1.67	850.17	942.3
For C-25 concrete grade with 1% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	334.78	175.44	3.35	852.16	944.48
For C-25 concrete grade with 1.5% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	336.96	168.63	5.05	857.72	950.64

Table 4.5: The effect of superplasticizing admixture on compressive strength by reducing amount of mixing water

Mean value of compressive strength test									
Admixture	W/C ratio	Water reduction (%)	Slump (mm)	3rd days		7th days		28th days	
				Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)
0%	0.58	0%	33	338.97	15.06	483.13	21.47	733.4	32.6
0.5%	0.54	5.92%	32	453.6	20.00	653.0	29.02	855.2	37.71
1%	0.52	7.66%	32	473.7	21.05	689.6	30.70	902.3	40.10
1.5%	0.50	11.25%	33	513.8	22.83	712.4	31.66	931.4	41.39

The values of rate of compressive strength development test for C-25 with different dosages of superplasticizing admixture by reducing amount of mixing water are shown as a graph in Figure 4.9 below.

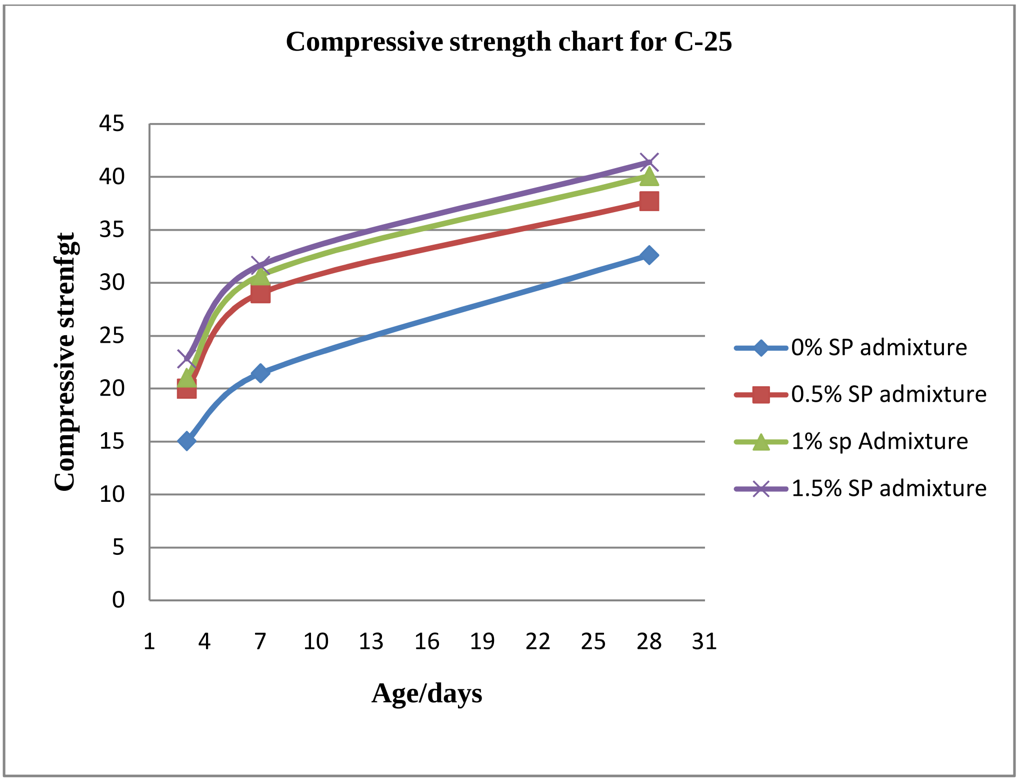


Figure 4.9: Effect of superplasticizing admixture on compressive strength by reducing amount of mixing water

In this test, it's possible to save 5.92%, 7.66% and 11.25% mixing water by addition of 0.5%, 1% and 1.5% superplasticizing admixture, then the rate of compressive strength development at the age of 3^{rd}, 7^{th} and 28 days were as follows. But, according to ASTM C494 standard the minimum amount of water reduction for high range water-reducing admixture at a given consistency is 12 % or greater. So, based on the observed test results, for the considered percentages it is not possible to say this admixture is superplasticizing admixture.

At first third day the rate of compressive strength development of 0% superplasticizing admixture added concrete was 15.06MPa. Whereas, for 0.5% superplasticizing admixture added concrete the rate of compressive strength development was 4.94MPa. This indicates the rate of compressive strength development of 0.5% superplasticizing admixture added concrete was improved by 4.94MPa or 32.8% from 0% superplasticizing admixture added concrete. For 1% superplasticizing admixture added concrete the rate of compressive strength development was 21.05MPa, which was improved by 5.99MPa or 39.77%, 1.05 MPa or 5.3% , but it was reduced by 1.78Mpa or 7.8% from 1.5% superplasticizing admixture added concrete. For 1.5% superplasticizing admixture added concrete the rate of compressive strength development was 22.83MPa, it was improved by 7.77MPa or 51.6 %, 2.83MPa or 14.2% and 1.78MPa or 8.5% from 0%, 0.5% and 1% superplasticizing admixture added concrete.

At the age of seven days, the rate of compressive strength development of 0%, 0.5%, 1% and 1.5% of superplasticizing admixture added concrete was 21.47MPa, 29.02MPa, 30.70MPa and 31.66MPa respectively. This indicates the rate of compressive strength development of 0.5% superplasticizing admixture added concrete was improved by 7.55MPa or 35.2% from 0%. For 1% superplasticizing admixture added concrete, the rate of compressive strength development was improved by 9.23MPa or 42.99%, 1.68 MPa or 5.8%, but it was reduced by 0.96Mpa or 3.0% from 1.5% superplasticizing admixture added concrete. For 1.5% superplasticizing admixture added concrete the rate of compressive strength development was improved by 10.19Mpa or 47.5 %, 2.64MPa or 9.1% and 0.96MPa or 3.1% from 0%, 0.5% and 1% superplasticizing admixture added concrete.

At the age of twenty eight day, the rate of compressive strength development of 0%, 0.5%, 1% and 1.5% of superplasticizing admixture added concrete was 32.6MPa, 37.71MPa, 40.10MPa and 41.39MPa respectively. This indicates the rate of compressive strength development of

0.5% superplasticizing admixture added concrete was improved by 5.1MPa or 15.6% from 0%. For 1% superplasticizing admixture added concrete the rate of compressive strength development was improved by 7.5MPa or 23%, 2.39 MPa or 6.3% from 0% and 0.5%, but it reduced by 1.29Mpa or 3.1% from 1.5% superplasticizing admixture added concrete. For 1.5% superplasticizing admixture added concrete the rate of compressive strength development was improved by 8.79Mpa or 26.96%, 3.68MPa or 9.8% and 1.29MPa or 3.2% from 0%, 0.5% and 1% superplasticizing admixture added concrete.

According to V.S Ramachandran (1995), concretes of equal cement content and slump, the 28-day strength of a water-reduced concrete containing a water reducer can be 20% greater than the reference. Based on experiment results, concrete produced by 1% and 1.5% superplasticizing added concrete can achieve more than 20%, whereas, 0.5% superplasticizing added concrete was slightly below the predicted percentage. This shows better increase in ultimate strength has been achieved with addition of superplasticizing admixture by reduction of mixing water at a constant workability than concrete produced without superplasticizing admixture. In addition, the result had shown that 1% and 1.5% superplasticizing added concrete provided higher result than the target mean strength of concrete. In addition, in this test all 0.5%, 1% and 1.5% superplasticizing added concrete have satisfied the ASTM C129 standard recommendation. Finally, this indicates, the reduction of water and addition of superplasticizing admixture has a great impact on improvement of concrete strength

4.3.2. Experimental Results and Discussion on Flexural Strength of Concrete

The flexural strength test is used to determine the tensile strength of the concrete. When point load is applied at the center of the sample concrete, the member is subjected to bending moment.

In this test, the concrete sample to be tested was supported at 4cm towards its both ends and loaded at the interior (center) location by a gradually failure load as illustrated in the figure 4.10 below. The failure load at which the concrete cracks was then recorded in kN as follows and by using formula, calculations were carried out to determine the flexural strength in MPa.

Figure 4.10: Center point loading flexural strength test

Then, the flexural strength for center point loading has been calculated by using the following general formula.

Flexural strength $= \frac{3FL}{2bd^2}$ ………………………………………….......... [12]

where:

F = the total load

L = the distance between the lower supporting rollers

b = breadth of the beam

d = depth of the beam

This test was performed for seven and twenty eight days for 0 %, 0.5%, 1% and 1.5% superplasticizing admixture added concrete. Table 4.6 show the quantity of materials used to produce a m^3 concrete by reducing mixing water. The results obtained from the experiment and through calculation are recorded in table 4.7 below.

Table 4.6: Quantity of materials in kg for 1m^3 C-25 concrete grade production by reduction of mixing water for flexural strength

For C-25 concrete grade nil SP					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	330	190	-	840	931
For C-25 concrete grade with 0.5% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	333.1	180.96	1.67	847.9	939.74
For C-25 concrete grade with 1% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	334.66	175.7	3.348	851.9	944.17
For C-25 concrete grade with 1.5% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	336.11	170.74	5.04	855.56	848.2

Table 4.7: Mean flexural strength test results by water reduction

Mean flexural strength[MPa]							
Admixture	W/C ratio	Water reduction (%)	Slump (mm)	7th days		28th days	
				Failure Load (kN)	flexural strength (MPa)	Failure Load (kN)	flexural strength (MPa)
0%	0.58	0%	32	4.2	2.65	6.8	4.29
0.5%	0.54	4.76%	33	4.6	2.9	7.3	4.6
1%	0.52	7.53%	32	6.05	3.8	8.4	5.3
1.5%	0.50	10.14%	34	6.55	4.13	8.65	5.45

The values of flexural strength test for C-25 with different dosage of superplasticizing admixture by reducing amount of mixing water at a constant workability are shown as a graph in figure 4.11.

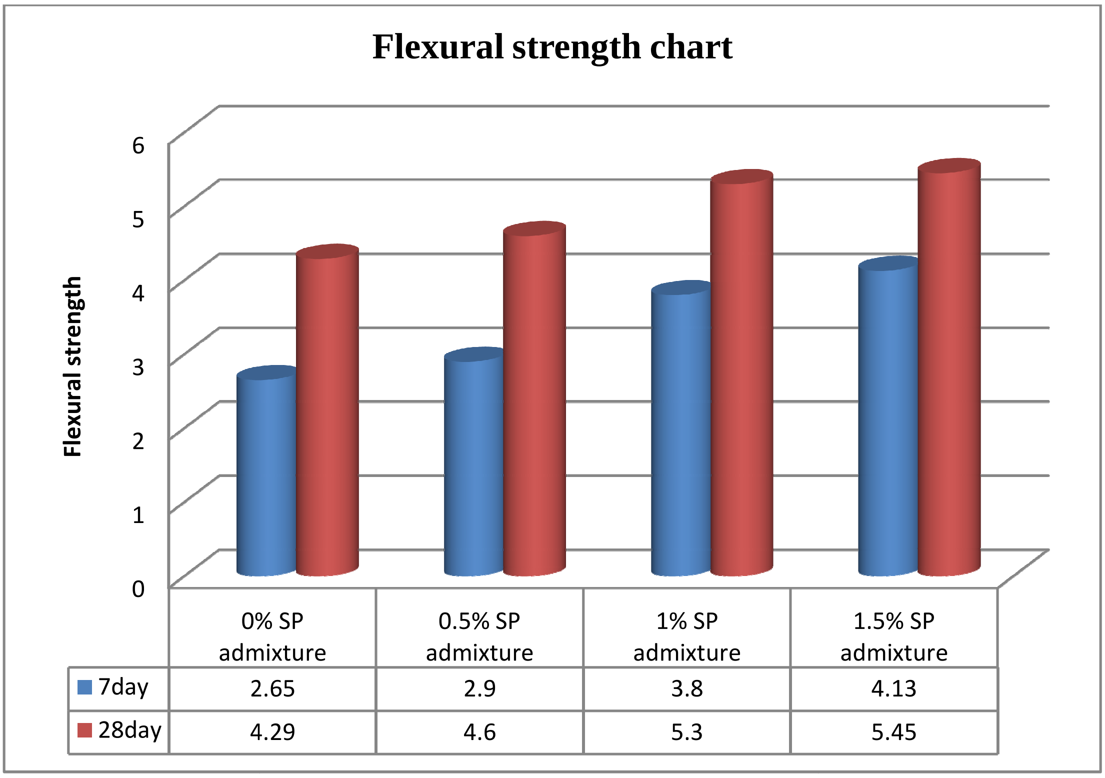


Figure 4.11: Effect of superplasticizing admixture on flexural strength at a constant workability

In this test, it's also possible to save 4.76%, 7.53% and 10.14% mixing water by addition of 0.5%, 1% and 1.5% superplasticizing admixture from the normal concrete, and then the strength development at the age of 7^{th} and 28^{th} days are discussed as follows.

At the age of seven days, the rate of flexural strength development of 0%, 0.5%, 1% and 1.5% of superplasticizing admixture added concrete was 2.65MPa, 2.9MPa, 3.8MPa and 4.13MPa respectively. This indicates the rate of flexural strength development of 0.5% superplasticizing admixture added concrete was improved by 0.251MPa or 9.4% from 0%. For 1% superplasticizing admixture added concrete the rate of flexural strength development was improved by 1.15MPa or 43.4% and 0.9 MPa or 31% from 0% and 0.5%, but it was reduced by 0.33Mpa or 7.99% from 1.5% superplasticizing admixture added concrete. For 1.5% superplasticizing admixture added concrete the rate of flexural strength development was improved by 1.48Mpa or 55.84 %, 1.23MPa or 42.4% and 0.33MPa or 8.7% from 0%, 0.5% and 1% superplasticizing admixture added concrete.

At the twenty eight days, the rate of flexural strength development of 0%, 0.5%, 1% and 1.5% of superplasticizing admixture added concrete was 4.29MPa, 4.6MPa, 5.3MPa and 5.45MPa respectively. This indicates the rate of flexural strength development of 0.5% superplasticizing admixture added concrete was improved by 0.31MPa or 7.2% from 0%. For 1% superplasticizing admixture added concrete the rate of flexural strength development was improved by 1.01MPa or 23.5% and 0.7 MPa or 15.2% from 0% and 0.5%, but it was reduced by 0.15Mpa or 2.8% from 1.5% superplasticizing admixture added concrete. For 1.5% superplasticizing admixture added concrete the rate of flexural strength development was improved by 1.16Mpa or 27 %, 0.83MPa or 18% and 0.15MPa or 2.8% from 0%, 0.5% and 1% superplasticizing admixture added concrete.

According to the reference discussed in the literature part, the flexural strength of superplasticizing admixture added concrete can improve about 10% from the reference concrete. This research have been also shown that the flexural strength of 0.5%,1% and 1.5% superplasticizing added concrete at the 28day have been shown 7.2%,23% and 27% from the reference concrete. Therefore, based on the test results, the flexural strength has been well improved when the dosage of admixture increase by reducing the amount of mixing water.

4.3.3. Experimental Results and Discussion on Permeability Test of Concrete

In this research non-steady state water permeability test was selected to study the effect of 0%, 0.5%, 1% and 1.5% superplasticizing admixture on concrete permeability by reducing 0%, 5.65% , 8.82% and 11.77% mixing water respectively. The test was conducted on 15cm concrete cubes which have been cured for 28th days and surface dried on air. Before directly started the laboratory test, the top surface of the cubes was cleaned and smoothen the surface of concrete. Then, the cleaned and smoothen concrete was placed on the permeability testing device and the bolts were tightened at the top of concrete sample to prevent any leakage of water when pressure is applied. Figure 4.12 below showed the typical concrete samples ready for permeability test.

Figure 4.12: Typical concrete samples ready for permeability test.

After adjusting the samples, water was filled into the reservoir of the test cells and the air compressor machine was on and then pressure of the water was applied to the specimens for a successive three days to 3 bar (0.3 MPa) for the first 24 hours, 5 bar (0.5MPa) for the next 24 hours and 7 bar (0.7 MPa) for the last 24 hours.

At the end of the last 24 hours, all the valves supplying water and compressed air to the samples were closed and the cubes were removed from the permeability testing device and split at the center. After splitting the samples, the portion of the sample into which water get penetrated looks darker than the rest, then immediately after splitting, the darker zone was marked and measurements were taken at 10mm intervals to determine the average depth of penetration with more accurate way. Figure 4.13 and 4.14 shows a typical concrete cube splited by a compressive machine and water penetrated sample after splitting. Table 4.8 shows the minimum, mean and maximum non-steady flow depth penetrations obtained from 0%, 0.5%, 1% and 1.5% superplasticizing admixture added concrete samples at the age of 28th day.

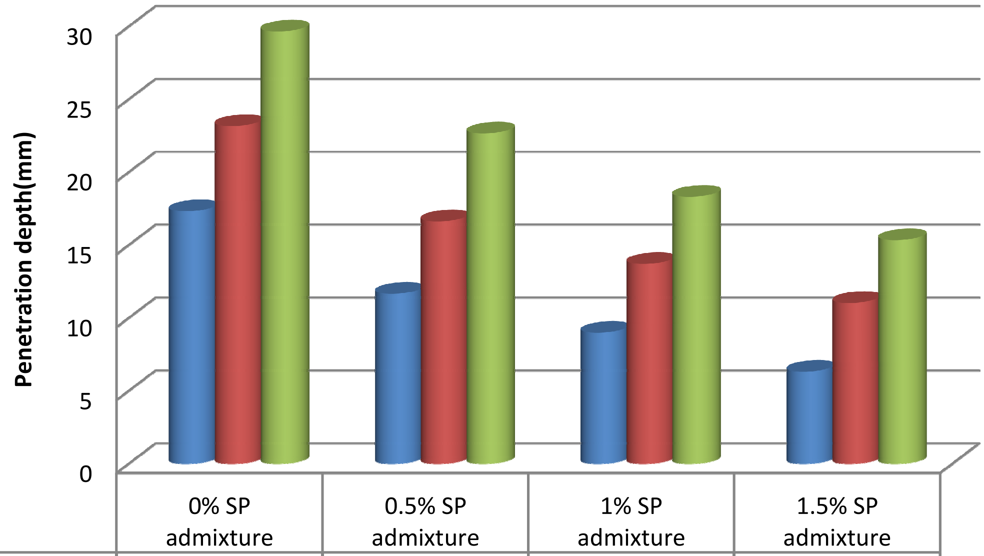
Figure 4.13: Sample after splitting

Figure 4.14: Water penetrated sample

Table 4.8: water penetration depth test results

Admixture percentage	Penetration depth(mm)		
	Minimum	Mean	maximum
0% SP admixture	17.33	23.18	29.67
0.5% SP admixture	11.67	16.64	22.67
1.0% SP admixture	9.00	13.72	18.33
1.5% SP admixture	6.33	11.05	15.35

The values of depth penetration test for C-25 with different dosage of superplasticizing admixture by reducing amount of mixing water at a constant workability has shown as a graph in Figure 4.15 below.



	0% SP admixture	0.5% SP admixture	1% SP admixture	1.5% SP admixture
minimum	17.33	11.67	9	6.33
mean	23.18	16.64	13.72	11.05
maximum	29.67	22.67	18.33	15.35

Figure 4.15: water penetration test graph

According to the laboratory results, the effect of superplasticizing admixture on water penetration through concrete with dosages of 0.5%, 1% and 1.5% by reduction of mixing water have been shown improvement over reference concrete. The minimum water penetration depths were 17.33mm, 11.67mm, 9.00mm and 6.33mm respectively. This indicates the penetration of water through concrete which is produced without superplasticizing admixture was increased by 5.66mm or 32.7%, 8.3mm or 48% and 11mm or 63.5% from 0.5%, 1% and 1.5% superplasticizing admixture added concrete. The penetration of water through 0.5% superplasticizing admixture added concrete was increased by 2.67mm or 22.9% and 5.34mm or 45.8% from 1% and 1.5% superplasticizing admixture added concrete. 1% superplasticizing admixture added concrete was increased by 2.67mm or 22.9% from 1.5% superplasticizing admixture added concrete

The mean water penetration depths were 23.18mm, 16.64mm, 13.72mm and 11.05mm. This indicates the penetration of water through concrete which is produced without superplasticizing admixture was increased by 6.54mm or 28.2%, 9.46mm or 40.8% and 12.13mm or 52.3% from

0.5%, 1% and 1.5% superplasticizing admixture added concrete. The penetration of water through 0.5% superplasticizing admixture added concrete was increased by 2.92mm or 17.5% and 5.59mm or 33.6% from 1% and 1.5% superplasticizing admixture added concrete. 1% superplasticizing admixture added concrete was increased by 2.67mm or 19.5% from 1.5% superplasticizing admixture added concrete

The maximum water penetration depths were 29.67mm, 22.67mm, 18.33mm and 15.35mm. This indicates the penetration depth of water through concrete which is produced without adding superplasticizing admixture was increased by 7mm or 23.6%, 11.34mm or 38.2% and 14.32mm or 48.3% from 0.5%, 1% and 1.5% superplasticizing admixture added concrete. The penetration of water through 0.5% superplasticizing admixture added concrete was increased by 4.34mm or 19.1% and 7.32mm or 32.3% from 1% and 1.5% superplasticizing admixture added concrete. 1% superplasticizing admixture added concrete was increased by 2.98mm or 16.3% from 1.5% superplasticizing admixture added concrete.

The depth of penetration of water through concrete less than 50mm classifies the concrete as impermeable; and depth less than 30mm, as impermeable under aggressive conditions[13]. Therefore, based on the experiment results all the concrete produced samples are impermeable under aggressive conditions.

4.4. Phase IV: The Effect of superplasticizing Admixture on Concrete Properties by Reducing Cement Content at constant W/C ratio

To check the effect of superplasticizing admixture on concrete properties by reducing cement content, laboratory tests were performed on concrete compressive strength at the age of 3th, 7th and 28th days. In this test both cement and water content were reduced based on the percentage of admixture added with respect to the weight of total cement content, but the water to cement ratio was kept constant for all mixes. Table 4.9 shown the quantity of materials used to produce a m^3 concrete at a constant water to cement ratio. The compressive strength results observed from the experiments are shown in the table 4.10 below.

Table 4.9: Quantity of materials in kg for 1m^3 C-25 concrete grade production at constant water to cement ratio by saving cement

For C-25 concrete grade nil SP					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	330	190	-	840	931
For C-25 concrete grade by 0.5% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	325.6	188.7	1.653	841.56	932.73
For C-25 concrete grade by 1% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	323	187.28	3.31	842.6	933.88
For C-25 concrete grade by 1.5% SP admixture					
Materials	Cement (kg)	Water(lt)	Admixture(lt)	fine aggregate (kg)	Coarse aggregate(kg)
Quantities per m^3	320.38	185.85	4.97	843.63	935.01

Table 4.10: Effect of superplasticizing admixture on compressive strength by cement reduction

mean value of compressive strength test for cement saving									
Admixture	W/C ratio	Cement reduction (%)	Slump (mm)	3rd days		7th days		28th days	
				Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)	Failure Load (kN)	Comp. strength (MPa)
0%	0.58	0%	33	338.97	15.06	483.13	21.47	733.4	32.6
0.5%	0.58	1.33%	51	340.7	15.14	487.07	21.64	739.97	32.88
1%	0.58	2.12%	59	349.2	15.52	514.87	22.88	766.97	34.08
1.5%	0.58	2.92%	145	343.3	15.25	494.4	21.97	784.47	33.26

The values of compressive strength test for C-25 with different dosage of superplasticizing admixture by reducing amount of cement content at a constant water to cement ratio has shown as a graph in Figure 4.16.

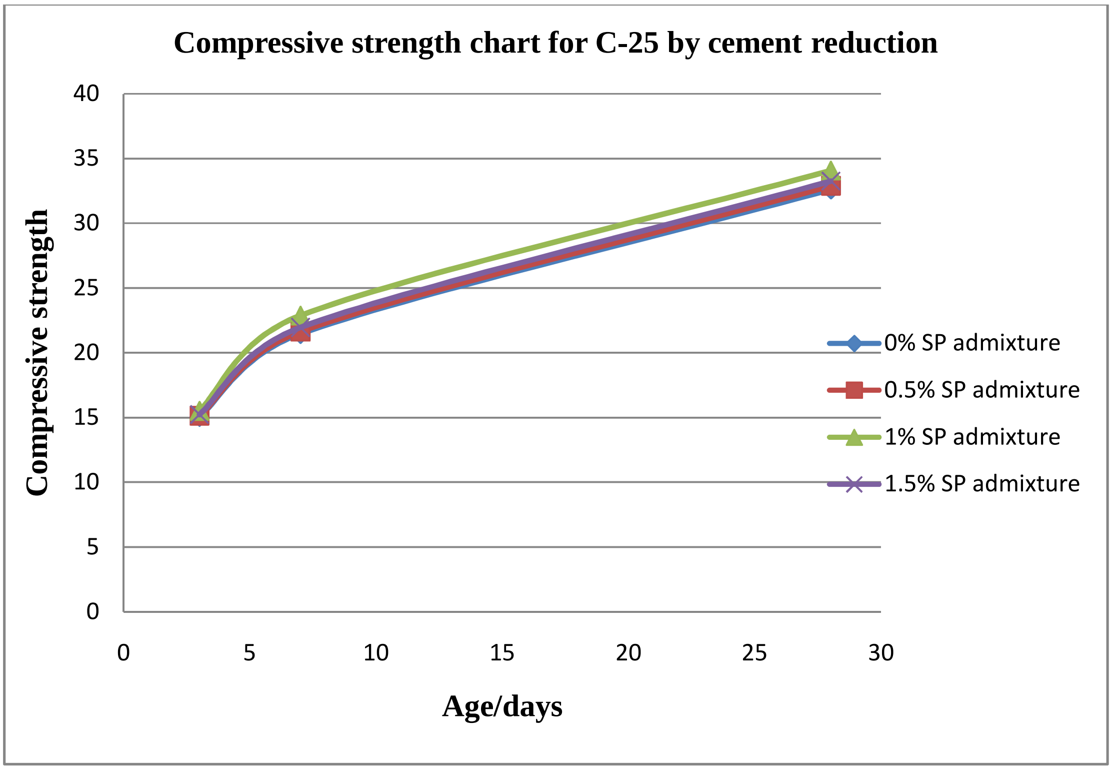


Figure 4.16: Effect of superplasticizing admixture on compressive strength by cement reducing

It clear that better strength can be obtained by addition of more cement and reduction of mixing water, i.e lower water to cement ratio. It's obvious that reduction of cement amount can reduce the concrete strength, but in same extent the addition of admixture can improve the strength of concrete. The results obtained from the experiment by reduction of cement content and addition of superplasticizing admixture was discussed as follows.

During the third day, the compressive strength of concrete without superplasticizing admixture was 15.06Mpa. For 0.5%, 1% and 1.5% of superplasticizing admixture added concrete were 15.14MPa, 15.52MPa, 15.25MPa. This shows the compressive strength of 0.5% superplasticizing added concrete was slightly higher than the reference concrete by 0.08MPa or 0.5%, however its reduced by 0.38MPa or 2.5% and 0.11MPa or 0.72% from 1% and 1.5% superplasticizing admixture added concrete. The compressive strength of 1% superplasticizing added concrete was improved by 0.46MPa or 3.1%, 0.38MPa or 2.5% and 0.27MPa or 1.8% from the reference concrete, 0.5% and 1.5% added concrete. For 1.5% superplasticizing added concrete, the compressive strength was improved by 0.19MPa or 1.3%, 0.11MPa or 0.73% from the reference concrete and 0.5% superplasticizing admixture added concrete, but it was reduced by 0.27MPa or 1.7% from 1% superplasticizing admixture added concrete.

At the seventh day, the compressive strength of concrete without superplasticizing admixture was 21.47Mpa. For 0.5%, 1% and 1.5% of superplasticizing admixture added concrete were 21.64MPa, 22.88MPa, 21.97MPa. This shows the compressive strength of 0.5% superplasticizing added concrete was higher than reference concrete by 0.17MPa or 0.8%, but it was reduced by1.24MPa or 5.4% and 0.33MPa or 1.5% from 1% and 1.5% superplasticizing admixture added concrete. The compressive strength of 1% superplasticizing added concrete was improved by 1.41MPa or 6.6%, 1.24MPa or 5.7% and 0.91MPa or 4.1% from reference concrete, 0.5% and 1.5% added concrete. For 1.5% superplasticizing added concrete, the compressive strength was improved by 0.5MPa or 2.3%, 0.33MPa or 1.5% from the reference concrete and 0.5% superplasticizing added concrete, but it was reduced by 0.91MPa or 4% from 1% superplasticizing added concrete.

At the twenty eighth day, the compressive strength of concrete without superplasticizing admixture was 32.6Mpa. For 0.5%, 1% and 1.5% of superplasticizing admixture added concrete were 32.88MPa, 34.08MPa, 33.26MPa. This shows the compressive strength of 0.5%

superplasticizing added concrete is higher than reference concrete by 0.28MPa or 0.9%, however it was reduced by1.2MPa or 3.5% and 0.38MPa or 1.1% from 1% and 1.5% superplasticizing admixture added concrete. The compressive strength of 1% superplasticizing added concrete was improved by 1.48MPa or 4.5%, 1.2MPa or 3.7% and 0.82MPa or 2.5% from reference concrete, 0.5% and 1.5% added concrete. For 1.5% superplasticizing added concrete, the compressive strength was improved by 0.66MPa or 2%, 0.38MPa or 1.16% from the reference concrete and 0.5% superplasticizing added concrete, however it was reduced by 0.82MPa or 2.4% from 1% superplasticizing added concrete.

Therefore, optimum dosage of superplasticizing is found based on the highest ultimate strength that they provide at age 28 days. i.e, 1% superplasticizing added concrete was provided the highest optimum compressive strength. Dosage with lower or higher than this optimum value will reduce the strength. Since, the compressive strength of concrete is improved by the addition of superplasticizing admixture by the reduction of cement; it's possible to conclude that a better improvement can also be obtained on flexural strength and permeability. In this case it is possible to save at least 1.33%, 2.12%, 2.9% of cement by the addition of type F, superplasticizing admixture. For this reason, it possible to call that type F superplasticizing admixture is a cement replacement material. On the other hand, a better cement saving can also obtained by reduction of mixing water at a constant workability as the reference concrete through trials, because phase III has been shown great result on strength and permeability than the reference concrete. This great result difference shows to save too much cement till the strength become equivalent to the reference concrete.

CHAPTER FIVE

5. ENVIRONMENTAL AND QUALITATIVE ECONOMIC ANALYSIS

5.1. Introduction

Currently, the construction industry is developing dramatically from time to time and the technology on materials usage has also reached on a high level. One of the modern construction materials comes in every engineers mind is concrete, which is mainly produced from cement, aggregate and water. Cement is obtained by extraction of natural resources (rock) as raw materials and processing in factory. But, the production of cement has some adverse impacts on environmental and economical points of view. However, nowadays additional materials known as admixtures have developed as a concrete making material to improve concrete properties by reducing cement content. This can minimize environmental and economical problems caused by production of huge amount cement. Superplasticizing admixture is one of additional materials which is obtained as a by-product of paper factories or synthesized materials from plants that can be easily renewable recourses. Here, I wonder to show the effects of superplasticizing admixture on environmental and economical points of view. So, based on the results of phase III (at a constant workability) and IV (at a constant water to cement ratio), to obtain equivalent strength as the reference concrete, the following environmental and economic comparative analysis are made between cement and superplasticizing admixture.

5.2. Environmental Impacts

Cement production is one of the most energy intensive industrial manufacturing processes which cause severe environmental impacts at all stages of the process. These include: change of landscape, depletion of natural resources due to quarrying and production process. According to researchers, the mass of raw materials needed to manufacture Portland cement is assumed to be 1.6 times as much as the mass of finished Portland cement [14]. Therefore, this can cause environmental problems like global warming due to depletion of natural resources, dust and noise, gas emissions, such as carbon dioxide emission from clinker production, which is nearly estimated that the production of one ton of Portland cement is associated to release in the environment of an equivalent amount of CO_2 by the operation of kiln systems, clinker coolers, mills, electrical energy consumption, fuel, usually coal and petroleum [14, 15]

However, superplasticizing admixture can be obtained as a by-product in paper factories or synthesized from plants, which is easily renewable resource. So, reusing those by-products as a construction material can save the environment from pollution. Since, addition of superplasticizing admixture with some percentage can save cement with some percentages, this helps to save natural resource depletion and damage of landscapes to extract too much raw materials for cement production, this can reduces the effect of global warming caused by huge amount of CO_2 emission. In addition, using superplasticizing admixture obtained as a by-product from factories can avoid discharge of chemicals to rivers, which causes pollution of rivers water. Table 5.1 shows the amount cement saved with different dosages of superplasticizing admixture at constant workability and water to cement ratio for C-25 concrete grade based on result obtained from this research on phase III and IV and CO_2 emission for one cubic meter concrete production.

Table 5.1 Amount of cement saving and carbon dioxide emission relation

Admixture	W*/C	Water reduction (%)	SP added (kg/m^3)	Water used (kg/m^3)	SP added +water used (kg/m^3)	Cement used (kg/m^3)	Cement Saved (kg/m^3)	raw materials saved (kg/m^3)	Reduction in CO_2 emission (kg/m^3)
0%	0.58	0	0	190	190	330	-		-
0.5%	0.58	5.23	1.68	180.07	181.75	313.28	16.72	26.75	16.72
1%	0.58	6.88	3.38	176.93	180.31	310.87	19.13	30.61	19.13
1.5%	0.58	10.18	5.11	170.65	175.76	303.03	26.97	43.15	26.97

The amount of cement saved per cubic meter by using 0.5%, 1% and 1.5% superplasticizing admixture is 16.72kg or 5.07%, 19.13kg or 5.8% and 26.97kg or 8.17% from the reference concrete. The amount of CO_2 emissions can reduce by 16.72kg, 19.13kg and 26.97kg from the reference concrete, respectively. In addition, it is possible to reduce the depletion of natural resources with 26.75kg, 30.61kg and 43.15kg per cubic meter respectively.

However, the European Federation of Concrete Admixtures Associations collected manufacturing data for the synthesis and blending of superplasticizing in 2000-2001 based on the figures from eight of Europe's largest admixture producers. The Eco-profile for a kg sulfonated naphthalene formaldehyde superplasticizers, CO_2 emission per kg is 0.69 [16]. Table 5.2 shows the amount of cement saved and carbon dioxide emission by using synthesized superplasticizing admixture.

Table 5.2: The amount of cement saved and carbon dioxide emission by using synthesized superplasticizing admixture.

Admixture	W*/C	Water reduction (%)	SP added (kg/m^3)	CO2 emission (kg/m^3) From SP	Water used (kg/m^3)	SP added +water used (kg/m^3)	Cement used (kg/m^3)	CO2 emission (kg/m^3) From cement	CO2 emission (kg/m^3) From SP + cement	Reduction in CO_2 emission (kg/m^3)
0%	0.58	0	0	-	190	190	330	330	330	-
0.5%	0.58	5.23	1.68	1.16	180.07	181.75	313.28	313.28	314.44	15.56
1%	0.58	6.88	3.38	2.33	176.93	180.31	310.87	310.87	313.2	16.8
1.5%	0.58	10.18	5.11	3.53	170.65	175.76	303.03	303.03	306.56	23.44

In this case the CO_2 emitted from the production of sulfonated naphthalene formaldehyde for the use of 0.5%, 1%and 1.5% superplasticizing admixture per cement amount for a cubic meter concrete is 1.16kg/m^3, 2.33kg/m^{3}and 3.53kg/m^3 respectively. Therefore, the total CO_2 emission by the use of 0.5%, 1% and 1.5% synthesized sulfonated naphthalene formaldehyde superplasticizing admixture with the given cement content can be 314.44kg/m^3, 313.2kg/m^{3}and 306.56kg/m^3. So, in this case it is possible to reduce the CO_2 emission by 15.56kg or 4.72%, 16.8kg or 5.09% and 23.44kg or 7.1% from the reference concrete, respectively.

5.3. Qualitative Economic Analysis

The economical impact of superplasticizing admixture has not been deeply investigated and it was difficult to get the exact figure about its production cost of superplasticizing admixture due to lack of recorded information and data. But, it's possible to make an economic comparative analysis based on the cement saved and superplasticizing admixture used for the experiments.

This comparative analysis is carried out based on the market price during 2013, when those materials: cement, SP1 superplasticizing admixture, fine aggregate, coarse aggregate and water are purchased for the research. The market prices were 282birr per quintal, 45birr per liter, 312.5 birr per cubic meter, 350 birr per cubic meter and 21 birr per cubic meter respectively.

According to the result which is shown in table 5.1 above, it is possible to save 16.72kg/m^3, 19.13kg/m^3 and 26.97kg/m^3 cement by the addition of 0.5%, 1% and 1.5% superplasticizing admixture at a constant workability and W/C ratio for the same strength. Table 5.3 shows the cost comparisons between cement saved and superplastering admixtures used for 1m^3 concrete.

Table 5.3: Cost comparisons between cement saved and superplasticizing admixtures used

Admixture	Amount of cement (kg/m^3) and Cost	water (lt/m^3) and Cost	Cement saved (kg/m^{3}and Cost)	Amount of admixture (kg/m^3 and Cost)	Sand used (kg/m^3 and Cost)	Gravel used (kg/m^3 and Cost)	Total Cost incurred by per 1m^3 concrete
0%	330 *(930.6ETB)*	190 *(3.99* ETB*)*	-	-	840 *(174.88 ETB)*	931 *(227.07ETB)*	1336.54 ETB
0.5%	313.28 *(883.45ETB)*	180.07 *(3.78*ETB*)*	16.72 *(47.2*ETB*)*	1.68 *(75.6*ETB*)*	856.4 *(178.3ETB)*	949.2 *(231.5ETB)*	1372.63 ETB
1%	310.87 *(876.65ETB)*	176.93 (3.72 ETB)	19.13 *(53.95*ETB*)*	3.38 *(152.1*ETB*)*	859.38 *(178.92ETB)*	952.48 *(232.31ETB)*	1443.7 ETB
1.5%	303.03 (854.55*ETB)*	170.65 *(3.58* ETB)	26.97 *(76.1*ETB)	5.11 *(229.95* ETB)	867.98 *(180.71 ETB)*	962.0 *(234.63 ETB*)	1503.42 ETB

Based on the market price of cement and SP1 superplasticizing admixture, the cost incur by the use of 0.5%, 1% and 1.5% superplasticizing admixture for a m^3 concrete is about 36.1ETB, 107.16ETB and 166.88ETB more expensive than the reference concrete. This value is mainly depending on the market price of cement and superplasticizing admixture during purchasing the materials. When the price of cement is increased, it can be beneficial to use superplasticing admixture, but it will incur high cost, when the cost of cement is minimum.

CHAPTER SIX

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the conducted laboratory results by using Derba cement PLC and SP1 superplasticizing admixture, conclusions and recommendations are forwarded on the effect of superplasticizing admixture on the properties of concrete

6.1. CONCLUSIONS

This research was investigated the effect of superplasticizing admixture on concrete properties, such as: workability, strength (compressive and flexural) and permeability. The results obtained from the study are summarized as follows:

1. According to the observed test results, the addition of 0.5%, 1% and 1.5% superplasticizing admixture in the concrete mix by reduction of equivalent amount of water as the amount of superplasticizing admixture added have shown some differences on workability. But, based on the requirement of ASTM C143 standard the addition of 0.5% superplasticizing admixture in the concrete mix does not provide a significant improvement on workability. However, 1% and1.5% superplasticizing admixture added to concrete mix can provide a significant change on workability.
2. Based on the observed test results, the addition of superplasticizing admixture in the concrete mix by reduction of equivalent amount of water as the amount of superplasticizing admixture added have shown a slight variation on compressive strength than the reference concrete. However, according to ASTM C129 all dosages did not show a significant change on compressive strength.
3. Though, way of dosing superplasticizing admixtures is reported to have effect on the workability of concrete mix, in this research no significant difference was observed for the considered cases.
4. From my investigation, it’s possible to reduce 5.92%, 7.66% and 11.25% of the mixing water from a m^3 concrete by the addition of 0.5%, 1% and 1.5% of the superplasticizing admixture, respectively, at a constant workability. However, according to ASTM C494

standard the minimum amount of water reduction for high range water-reducing (superplasticizing) admixture at a given consistency is 12 % or greater. So, based on the observed test results, for the considered percentages it is not possible to say this admixture is superplasticizing admixture.

5. The addition of the superplasticizing `admixture at concrete workability has improved compressive strength, flexural strength and the resistance against water penetration. Increment up to 26.96%, 27.3% and 52.3% were observed for compressive strength, flexural strength and the resistance against water penetration, respectively at a dosage of 1.5% superplasticizing admixture.
6. Based on the experimental results, it's possible to save 16.72kg/m^3, 19.13kg/$m^3$and 26.97kg/$m^3$of cement by the addition of 0.5%, 1% and 1.5% superplasticizing admixture at the same workability, water to cement ratio and strength, respectively. On the contrary, the amount of extra cost incur for the considered cases are 36.1 ETB, 107.16 ETB and 166.88 ETB respectively than the reference concrete. However, this cost is depending on the market price of cement and superplasticizing admixture.
7. By using the considered dosages of superplasticizing admixture, it's also possible to minimize depletion of natural resource by 26.75kg/m^3, 30.61kg/m^3 and 43.15kg/m^3, and it possible to save at least CO_2 emission by 15.56 kg/m^3, 16.8kg/$m^3$and 23.44kg/m^3.

6.2. RECOMMENDATIONS

Based on the research study, the following recommendations have forwarded.

1. This research studied only on 0%, 0.5%, 1% and 1.5% superplasticizing admixture. So, further studies are required in different dosages of admixture on different properties of concrete to obtain the maximum benefit.
2. Before using superplasticizing admixtures, the effect of way of superplasticizing admixture addition should be investigate on workability, strength, resistance to water penetration and other properties.
3. In our country investigations are not yet done on admixtures, therefore, to obtain the best benefit from admixtures, further researches should have to be done on effects of different types of admixture on different cement.
4. Superplasticizing admixtures can be obtained as synthesized form plants or by-product from paper and coal industry. So, it better to make further study by establishing research teams on the by-product potential of different paper factories found in our country, which used as a source for superplasticizing admixture. And, it important to harvest trees used as a sources for superplasticizing production and setup factories used to produce admixtures.

REFERENCES

[1] Irving Kett, Engineered Concrete Mix Design and Test Methods; Second Edition.

[2] Kumar M. P. and Paulo M. J. M., Concrete Microstructure, Properties, and Materials, Third Edition, University Of California at Berkeley, Department Of Civil And Environmental Engineering, United States of America, 2006

[3] Duggal S. K., Building Materials, Third Revised Edition, Motilal Nehru Institute of Technology, New Delhi, 2003.

[4] ACI. Manual of concrete practice, 2009

[5] Steven Kosmatka H., Beatrix Kerkhoff, and William Panarese C., Design and Control of Concrete Mixtures, USA, 2003.

[6] Ramachandran V. S., Concrete Admixtures Handbook: Properties, Science, and Technology, Second Edition, Institute for Research in Construction, National Research Council Canada, Ottawa, Ontario, Canada, 1995

[7] http://ict.concrete.org.uk/downloads/yearbooks/ict_2004.pdf

[8] Edward G.N, Concrete Construction Engineering Handbook, Second Edition, the State University of New Jersey New Brunswick, New Jersey, 2008.

[9] Ken W.D, concrete mix design, quality control and specification, second edition, E & FN Spon , London, 1999.

[10] Esayas G/Y., chemical admixture, handout for civil engineering students, Addis Ababa University, Institutes of Technology, 2006.

[11] Abebe Dinku, Addis Ababa University Institute of Technology, Construction Materials Laboratory Manual, Faculty of Technology, Department of Civil Engineering, Construction Technology and Management, June 2000.

[12] John Newman, Advanced Concrete Technology: Constituent Materials, Department of Civil Engineering, Imperial College, London, 2003.

[13] Neville A.M., Properties of Concrete, Third Edition, Long Man Scientific & Technical Series, Singapore, 1994

[14] Biruk Hailu, Bagasse ash as a cement replacing material, Addis Ababa University, Department of Civil Engineering, School Of Graduate Studies, December 2011.

[15] Monique Pagé and Nelu Spiratos, the Role of Superplasticizers in the Development of Environmentally-Friendly Concrete, Canada, April 19-20, 2000,

http://ecosmartconcrete.com/docs/trpage99.pdf

[16] EFCA (European Federation of Concrete Admixture Associations) Environmental Declaration Superplasticizing Admixtures, June 2002. http://www.admixtures.org.uk/downloads/xIS%20Environmental%20Declaration%20Superplasticizer.PDF

APPENDIX 1

MATERIALS TEST RESULTS

1.1. Properties of cement

1.1.1. Normal consistency of cement

Wt of cement (gm)	500	500	500	500	500	500	500	500
% of water	26	27	28	29	30	31	32	33
Wt of water (gm)	130	135	140	145	150	155	160	165
Penetration depth(mm)	5	11	21	-	-	-	-	-

1.1.2. Initial and final setting time

Time (min)	8:10	8:40	8:50	9:00	9:10	9:20	9:30	9:40	9:50	10:00	10:10	10:20	10:30	10:40	10:50	11:00	11:10
Penetration(mm)	-	40	40	39	40	39	38	35	36	34	34	28	15	13	10	5	0

1.2. Properties of Fine Aggregate

1.2.1. Silt content

Silt content Before washing			
Sample	Amount of Silt deposit	Amount of clear sand	Silt content
Sample 1	22ml	280ml	7.9
Sample 2	25ml	285ml	8.8
		mean	8.35
Silt content after washing			
Sample	Amount of Silt deposit	Amount of clear sand	Silt content
Sample 2	5ml	150ml	3.3
Sample 3	7ml	290ml	2.4
		mean	2.85%

1.2.2. Sieve analysis

1.2.2.1. Sieve analysis for original sand

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
9.5 mm	585	585	0	0	0	100
4.75 mm	429	440	11	2.2	2.2	97.8
2.36 mm	383	430	47	9.4	11.6	88.4
1.18 mm	354	462	108	21.6	33.2	66.8
600 µm	326	517	191	38.2	71.4	28.6
300 µm	304	428	124	24.8	96.2	3.8
150 µm	460	477	17	3.4	99.6	0.4
Pan	255	257	2	0.4	100	0

1.2.2.2. Sieve analysis for blended aggregate

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
9.5 mm	585	585	0	0	0	100
4.75 mm	429	440	11	2.2	2.2	97.8
2.36 mm	383	430	47	9.4	11.6	88.4
1.18 mm	354	462	108	21.6	33.2	66.8
600 µm	326	511	185	37	70.2	29.8
300 µm	304	403	99	19.8	90	10.0
150 µm	460	500	40	8	98	2.0
Pan	255	265	10	2	100	0

1.2.2. Unit weight

1.2.2.1. Compacted Unit weight

Compacted Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m^3)	Compacted unit eight (kg/m^3)
Sample 1	4.835	26.315	0.28	0.255	21.48	0.0142925	1503
Sample 2	4.835	26.345	0.28	0.255	21.51	0.0142925	1505
						mean	1504

1.2.2.2. Loose unit weight

Loose Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate(kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m^3)	Loose unit weight (kg/m^3)
Sample 1	4.835	24.940	0.28	0.255	20.105	0.0142925	1406.7
Sample 2	4.835	25.048	0.28	0.255	20.213	0.0142925	1414.2
						mean	1410

1.2.3. Specific gravity

Weight of pycnometer = 291g

Weight of sand = 500 g

Va = Volume of water added to pycnometer = $797cm^3$

V = Volume of pycnometer = $1000cm^3$

A = weight of oven-dry sample in air, [g] = 488g

Formula

$$C = 0.9976Va + 500 + W$$

Where:

C = weight of pycnometer filled with sample plus, water, [g]

Va = volume of water added to pycnometer, [cm^3]

W = weight of the pycnometer, [g]

C = 0.9976Va + 500 + W

C = 0.9976*797 + 500 + 291

C = 1586.09

$$B=0.9976V + W$$

Where:

B = weight of flask filled with water, [g]

V = volume of flask, [cm^3]

W = weight of flask empty, [g]

$$B=0.9976V + W$$

B = 0.9976 *1000 + 291

B = 1288.6

Bulk specific gravity

$$\text{Bulk sp gr} = \frac{A}{B+500-C}$$

$$\text{Bulk sp gr} = \frac{488}{1288.6+500-1586.09}$$

$$\text{Bulk sp gr} = \frac{488}{202.51} = 2.41$$

Bulk specific gravity (saturated- surface dry)

Bulk sp. gr. (saturated- surface dry) = $\frac{500}{B+500-C}$

Bulk sp. gr. (saturated- surface dry) = $\frac{500}{1288.6+500-1586.09}$

Bulk sp. gr. (saturated- surface dry) = $\frac{500}{202.51} = 2.47$

Apparent specific gravity

Apparent sp. gr. = $\frac{A}{B+A-C}$

Apparent sp. gr. = $\frac{488}{1288.6+488-1586.09} =$

Apparent sp. gr. = $\frac{488}{190.51} = 2.56$

Absorption capacity

Absorption capacity (%) = $\frac{500-A}{A} * 100 = \frac{12}{488} * 100 = 2.46$

1.2.4. Moisture content

A = weight of original sample = 500gm

B= weight of oven dry sample = 490gm

W= moisture content (%)

W = $\frac{A-B}{B} * 100$

W = $\frac{500-490}{490} * 100 = 2.04\%$

1.3. Properties Coarse aggregate

1.3.1. Sieve analysis

1.3.1.1. Sieve analysis for original coarse aggregate

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
19 mm	1395	1540	145	2.70	2.70	97.3
12 mm	1160	4370	3210	59.50	62.2	37.8
9.5 mm	1165	2735	1570	29.10	91.3	8.7
4.75 mm	1175	1630	455	8.43	99.73	0.27
Pan	1060	1075	15	0.27	100	0

1.3.1.2. Sieve analysis for blended coarse aggregate

Sieve size(mm)	Wt. of sieve (gm)	Wt. of sieve and aggregate (gm)	Wt. retained (gm)	Percentage retained (%)	Cumulative coarser (%)	Cumulative passing (%)
19 mm	1395	1540	145	2.70	2.70	97.3
12 mm	1160	2832	1672	31.0	33.7	66.3
9.5 mm	1165	2908	1743	32.30	66	34
4.75 mm	1175	2994	1820	33.73	99.73	0.27
Pan	1060	1075	15	0.27	100	0

1.3.2. Unit weight

1.3.2.1. Compacted Unit weight

Compacted Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m^3)	Compacted unit eight (kg/m^3)
Sample 1	4.835	25.250	0.28	0.255	20.415	0.0142925	1428.4
Sample 2	4.835	25.450	0.28	0.255	20.615	0.0142925	1442.4
						mean	1435.4

1.3.2.2. Loose unit weight

Losse Unit weight							
Sample	Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m^3)	Loose unit weight (kg/m^3)
Sample 1	4.835	24.940	0.28	0.255	20.105	0.0142925	1406.7
Sample 1	4.835	24.2	0.28	0.255	19.4	0.0142925	1357.4
						mean	1382.1

1.3.3. Specific gravity

- Weight of oven dry sample in air (mass A) = 4886g
- Weight of saturated surface dry sample in air (mass B) = 4989g
- Weight of saturated sample in water (mass C) = 3014 g

Bulk specific gravity

$$\text{Bulk sp. gr.} = \frac{A}{B-C}$$

$$\text{Bulk sp. gr.} = \frac{4886}{4989-3014} = \frac{4886}{1975} = 2.47$$

Bulk specific gravity (saturated surface dry basis)

Bulk sp. gr. (saturated surface dry basis) = $\frac{B}{B-C}$

Bulk sp. gr. (saturated surface dry basis) = $\frac{4989}{4989-3014} = \frac{4989}{1975} = 2.53$

Apparent specific gravity

Apparent sp gr = $\frac{A}{A-C}$

Apparent sp gr = $\frac{4886}{4886-3014} = \frac{4886}{1872} = 2.61$

Absorption capacity:

Absorption capacity (%) = $\frac{B-A}{A} * 100$

Absorption capacity (%) = $\frac{4989-4886}{4886} * 100$

Absorption capacity (%) = $\frac{108}{4886} * 100$ = 2.1 %

1.3.4. Moisture content

A = weight of original sample = 2000gm

B= weight of oven dry sample = 1953gm

W= moisture content (%)

W = $\frac{A-B}{B} * 100$

W = $\frac{2000-1953}{1953} * 100 = 2.4\%$

1.3.5. Determination of Aggregate Impact Value

A= the mass of surface dry sample aggregate = 324.6 gm

B= the mass of the fraction passing on 2.36mm sieve = 41.8 gm

C = the mass of the fraction retained on 2.36mm sieve = 282.74 gm

Total fraction of passing and retained = 41.8gm + 282.74gm = 324.54gm

The total aggregate loss = 324.6gm - 324.54gm = 0.06gm

Percentage fines= $\frac{B}{A}$*100

Percentage fines= $\frac{41.8}{324.6}$*100 = 12.9 %

1.3.6. Determination of Aggregate Crushed Value

A = the mass of surface dry sample =2542gm

B= the mass of the fraction passing the 2.36mm BS test sieve = 455gm

Percentage fines= $\frac{B}{A} = \frac{455gm}{2542gm} * 100$ = 17.9 %

APPENDIX 2: EXPERIMENTAL RESULTS

2.1 2.1. Phase I: The effect of superplasticizer admixture on workability

Zero % super plasticizer on workability and compressive strength for C25

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
1	3	15	15	15	0.58	33	8605	3375	339.1	15.07	0.280	2.550
2		15	15	15			8740	3375	334.6	14.87	0.280	2.590
3		15	15	15			8015	3375	343.2	15.25	0.280	2.375
						mean	**8453**	**3375**	**338.97**	**15.06**	**0.280**	2.505
1	7	15	15	15	0.58	33	8008	3375	494.6	21.98	0.280	2.373
2		15	15	15			8660	3375	496.4	22.06	0.280	2.566
3		15	15	15			8036	3375	458.4	20.37	0.280	2.381
						mean	**8235**	**3375**	**483.13**	**21.47**	**0.280**	2.440
1	28	15	15	15	0.58	33	8055	3375	738.6	32.83	0.280	2.387
2		15	15	15			8053	3375	760.1	33.78	0.280	2.386
3		15	15	15			8579	3375	701.6	31.18	0.280	2.542
						mean	**8229**	**3375**	**733.4**	**32.60**	**0.280**	2.438

0.5 % super plasticizer on workability and compressive strength for C25

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
1	3	15	15	15	0.58	47	8050	3375	345.4	15.35	0.280	2.385
2		15	15	15			8065	3375	351.6	15.63	0.280	2.390
3		15	15	15			8615	3375	347.2	15.43	0.280	2.553
						mean	**8243**	**3375**	**348.1**	**15.47**	**.280**	2.442
1	7	15	15	15	0.58	47	7961	3375	495.7	22.03	0.280	2.359
2		15	15	15			8029	3375	510.0	22.67	0.280	2.379
3		15	15	15			8129	3375	527.7	23.45	0.280	2.409
						mean	**8040**	**3375**	**511.13**	**22.72**	**0.280**	2.382
1	28	15	15	15	0.58	47	8045	3375	762.4	33.88	0.280	2.384
2		15	15	15			8093	3375	765.6	34.02	0.280	2.398
3		15	15	15			8108	3375	756.8	33.63	0.280	2.402
						mean	**8082**	**3375**	**761.6**	**33.84**	**0.280**	**2.395**

1 % super plasticizer on workability and compressive strength for C25												
No	Test age [days]	Dimensions (cm)			w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H								
1	3	15	15	15	0.58	54	8348	3375	361.2	16.05	0.280	2.47
2		15	15	15			8059	3375	363.7	16.16	0.280	2.39
3		15	15	15			7994	3375	357	15.87	0.280	2.37
	mean						**8134**	**3375**	**360.6**	**16.03**	0.280	**2.41**
1	7	15	15	15	0.58	54	8093	3375	544.1	24.18	0.280	2.40
2		15	15	15			8162	3375	545.1	24.22	0.280	2.42
3		15	15	15			8317	3375	523.9	23.25	0.280	2.46
	mean						**8191**	**3375**	**537.7**	**23.88**	0.280	**2.43**
1	28	15	15	15	0.58	54	8120	3375	804.6	35.76	0.280	2.41
2		15	15	15			8574	3375	791.2	35.17	0.280	2.54
3		15	15	15			8235	3375	806.6	35.85	0.280	2.44
	mean						**8309**	**3375**	**800.8**	**35.59**	0.280	**2.46**

1.5 % superplasticizer on workability and compressive strength for C25												
No	Test age [days]	Dimensions (cm)			w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H								
1	3	15	15	15	0.58	140	8000	3375	318.8	15.95	0.280	2.370
2		15	15	15			8023	3375	342.3	15.21	0.280	2.377
3		15	15	15			8065	3375	360.3	16.01	0.280	2.390
	mean						**8029**	**3375**	**340.5**	**15.72**	**0.280**	2.379
1	7	15	15	15	0.58	140	8062	3375	515.5	22.91	0.280	2.389
2		15	15	15			8048	3375	496.2	22.05	0.280	2.385
3		15	15	15			8061	3375	527.9	23.46	0.280	2.388
	mean						**8057**	**3375**	**513.2**	**22.81**	**0.280**	2.387
1	28	15	15	15	0.58	140	8012	3375	790.1	35.11	0.280	2.374
2		15	15	15			8040	3375	774.3	34.41	0.280	2.382
3		15	15	15			8059	3375	752.5	33.44	0.280	2.388
	mean						**8037**	**3375**	**772.3**	**34.32**	**0.280**	2.381

2.1.2. Experimental results for workability and compressive strength for C-60

zero % super plasticizer on workability and compressive strength

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
1	3	15	15	15	0.33	14	8191	3375	811.7	36.07	0.280	2.427
2		15	15	15			8208	3375	822.9	36.57	0.280	2.432
3		15	15	15			8839	3375	833.3	37.03	0.280	2.619
						mean	**8413**	**3375**	**822.6**	**36.56**	**0.280**	**2.493**
1	7	15	15	15	0.33	14	8202	3375	1052.9	46.79	0.280	2.430
2		15	15	15			8903	3375	1024.1	45.51	0.280	2.638
3		15	15	15			8828	3375	1036.0	46.04	0.280	2.616
						mean	**8644**	**3375**	**1037.7**	**46.11**	**0.280**	**2.561**
1	28	15	15	15	0.33	14	8210	3375	1364.6	60.64	0.280	2.433
2		15	15	15			8249	3375	1371.6	60.95	0.280	2.444
3		15	15	15			8383	3375	1397.7	62.11	0.280	2.484
						mean	**8280**	**3375**	**1378.0**	**61.23**	**0.280**	**2.453**

0.5 % super plasticizer on workability and compressive strength

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
1	3	15	15	15	0.33	25	8314	3375	830.1	36.89	0.280	2.463
2		15	15	15			8994	3375	838.0	37.24	0.280	2.665
3		15	15	15			8447	3375	833.5	37.04	0.280	2.502
						mean	**8585**	**3375**	**833.9**	**37.06**	**0.280**	**2.544**
1	7	15	15	15	0.33	25	8203	3375	1055.2	46.89	0.280	2.431
2		15	15	15			8249	3375	1062.1	47.20	0.280	2.444
3		15	15	15			8462	3375	1055.4	46.90	0.280	2.507
						mean	**8305**	**3375**	**1057.6**	**47.00**	**0.280**	**2.461**
1	28	15	15	15	0.33	25	7973	3375	1414.1	62.84	0.280	2.362
2		15	15	15			8145	3375	1419.5	63.08	0.280	2.413
3		15	15	15			8252	3375	1407.3	62.54	0.280	2.445
						mean	**8123**	**3375**	**1413.6**	**62.82**	**0.280**	**2.407**

1 % super plasticizer on workability and compressive strength												
No	Test age [days]	Dimensions (cm)			w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H								
1	3	15	15	15	0.33	32	8288	3375	869.7	38.65	0.280	2.456
2		15	15	15			8291	3375	867.9	38.57	0.280	2.457
3		15	15	15			8315	3375	889.3	39.52	0.280	2.464
	mean						**8298**	**3375**	**875.6**	**38.9**	**0.280**	**2.459**
1	7	15	15	15	0.33	32	8322	3375	1110.5	49.35	0.280	2.466
2		15	15	15			8078	3375	1110.3	49.34	0.280	2.394
3		15	15	15			8172	3375	1097.5	48.77	0.280	2.421
	mean						**8191**	**3375**	**1106.1**	**49.15**	**0.280**	**2.427**
1	28	15	15	15	0.33	32	8380	3375	1457.3	64.76	0.280	2.483
2		15	15	15			8264	3375	1456.6	64.73	0.280	2.449
3		15	15	15			8253	3375	1471.9	65.41	0.280	2.445
	mean						**8299**	**3375**	**1461.9**	**64.97**	**0.280**	**2.458**

1.5 % super plasticizer on workability and compressive strength												
No	Test age [days]	Dimensions (cm)			w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H								
1	3	15	15	15	0.33	120	8724	3375	841.8	37.41	0.280	2.585
2		15	15	15			8318	3375	855.6	38.02	0.280	2.465
3		15	15	15			8109	3375	840.7	37.36	0.280	2.403
	Mean						**8384**	**3375**	**846.0**	**37.60**	**0.280**	**2.484**
1	7	15	15	15	0.33	120	8240	3375	1054.7	46.87	0.280	2.442
2		15	15	15			8226	3375	1072.0	47.64	0.280	2.437
3		15	15	15			8273	3375	1066.4	47.39	0.280	2.451
	Mean						**8246**	**3375**	**1064.4**	**47.30**	**0.280**	**2.443**
1	28	15	15	15	0.33	120	8206	3375	1419.0	63.06	0.280	2.431
2		15	15	15			8274	3375	1437.0	63.86	0.280	2.452
3		15	15	15			8406	3375	1416.6	62.95	0.280	2.491
	Mean						**8295**	**3375**	**1424.2**	**63.29**	**0.280**	**2.458**

2.2. Phase II: The effect of way of superplasticizing admixture addition on concrete properties

1 % super plasticizer on workability and compressive strength for C25

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
1	3	15	15	15	0.58	54	8348	3375	361.2	16.05	0.280	2.47
2		15	15	15			8059	3375	363.7	16.16	0.280	2.39
3		15	15	15			7994	3375	357	15.87	0.280	2.37
	mean						**8134**	**3375**	**360.6**	**16.03**	0.280	**2.41**
1	7	15	15	15	0.58	54	8093	3375	544.1	24.18	0.280	2.40
2		15	15	15			8162	3375	545.1	24.22	0.280	2.42
3		15	15	15			8317	3375	523.9	23.25	0.280	2.46
	mean						**8191**	**3375**	**537.7**	**23.88**	0.280	**2.43**
1	28	15	15	15	0.58	54	8120	3375	804.6	35.76	0.280	2.41
2		15	15	15			8574	3375	791.2	35.17	0.280	2.54
3		15	15	15			8235	3375	806.6	35.85	0.280	2.44
	mean						**8309**	**3375**	**800.8**	**35.59**	0.280	**2.46**

Discharging the admixture at the middle with 25% of gauging water after adding 50% mixing water

No	Test age [days]	Dimensions (cm) L	W	H	w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
1	3	15	15	15	0.58	52	8052	3375	383.2	17.07	0.280	2.386
2		15	15	15			8008	3375	379.0	16.84	0.280	2.373
3		15	15	15			8120	3375	374.9	16.66	0.280	2.406
	mean						**8060**	**3375**	**379.03**	**16.86**	**0.280**	**2.388**
1	7	15	15	15	0.58	52	8200	3375	566.0	25.15	0.280	2.430
2		15	15	15			8083	3375	566.4	25.17	0.280	2.395
3		15	15	15			8034	3375	586.4	26.06	0.280	2.380
	mean						**8106**	**3375**	**572.93**	**25.46**	**0.280**	**2.402**
1	28	15	15	15	0.58	52	8183	3375	825.4	36.68	0.280	2.425
2		15	15	15			8108	3375	844.1	37.51	0.280	2.402
3		15	15	15			8087	3375	834.6	37.09	0.280	2.396
	mean						**8126**	**3375**	**834.7**	**37.09**	**0.280**	**2.408**

Discharging superplasticizing Admixture addition at the end of mixing time												
No	Test age [days]	Dimensions (cm)			w/c ratio	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H								
1	3	15	15	15	0.58	56	8188	3375	356.2	15.83	0.280	2.426
2		15	15	15			8684	3375	352.9	15.68	0.280	2.573
3		15	15	15			8029	3375	358.0	15.91	0.280	2.379
						mean	**8300**	**3375**	**355.7**	**15.81**	**0.280**	**2.459**
1	7	15	15	15	0.58	56	7992	3375	517.8	23.01	0.280	2.368
2		15	15	15			8055	3375	544.6	24.20	0.280	2.387
3		15	15	15			8065	3375	506.1	22.49	0.280	2.390
						mean	**8037**	**3375**	**522.8**	**23.23**	**0.280**	**2.381**
1	28	15	15	15	0.58	56	7850	3375	785.4	34.90	0.280	2.326
2		15	15	15			8077	3375	788.3	35.03	0.280	2.393
3		15	15	15			8073	3375	782.2	34.76	0.280	2.392
						mean	**8000**	**3375**	**785.3**	**34.90**	**0.280**	**2.370**

2.3. Phase III: The effect of Superplasticizer admixture on concrete properties by reducing mixing water

Effect of zero % super plasticizer admixture on compressive strength													
No	Test age [days]	Dimensions (cm)			w/c ratio	Water reduction (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.58	0%	33	8605	3375	339.1	15.07	0.280	2.550
2		15	15	15				8740	3375	334.6	14.87	0.280	2.590
3		15	15	15				8015	3375	343.2	15.25	0.280	2.375
							mean	**8453**	**3375**	**338.97**	**15.06**	**0.280**	**2.505**
1	7	15	15	15	0.58	0%	33	8008	3375	494.6	21.98	0.280	2.373
2		15	15	15				8660	3375	496.4	22.06	0.280	2.566
3		15	15	15				8036	3375	458.4	20.37	0.280	2.381
							mean	**8235**	**3375**	**483.13**	**21.47**	**0.280**	**2.440**
1	28	15	15	15	0.58	0%	33	8055	3375	738.6	32.83	0.280	2.387
2		15	15	15				8053	3375	760.1	33.78	0.280	2.387
3		15	15	15				8579	3375	701.6	31.18	0.280	2.542
							mean	**8229**	**3375**	**733.4**	**32.6**	**0.280**	**2.438**

Effect of 0.5 % super plasticizer admixture on compressive strength													
No	Test age [days]	Dimensions (cm)			w/c ratio	Water reduction (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.54	5.92	32	7846	3375	449.7	19.99	0.280	2.325
2		15	15	15				8061	3375	462.3	20.05	0.280	2.388
3		15	15	15				8249	3375	448.9	19.95	0.280	2.444
							mean	**8052**	**3375**	**453.6**	**20.00**	**0.280**	**2.386**
1	7	15	15	15	0.54	5.92	32	8039	3375	649.0	28.84	0.280	2.382
2		15	15	15				8002	3375	640.2	28.45	0.280	2.371
3		15	15	15				8047	3375	669.7	29.76	0.280	2.384
							mean	**8029**	**3375**	**653.0**	**29.02**	**0.280**	**2.379**
1	28	15	15	15	0.54	5.92	32	8631	3375	837.6	37.23	0.280	2.557
2		15	15	15				8112	3375	893.7	38.83	0.280	2.404
3		15	15	15				8354	3375	834.4	37.08	0.280	2.475
							mean	**8366**	**3375**	**855.2**	**37.71**	**0.280**	**2.479**

Effect of 1 % super plasticizer admixture on compressive strength													
No	Test age [days]	Dimensions (cm)			w/c ratio	Water reduction (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.52	7.66	32	8033	3375	473.4	21.04	0.280	2.381
2		15	15	15				8663	3375	490.9	21.82	0.280	2.567
3		15	15	15				8017	3375	456.8	20.30	0.280	2.375
							mean	**8238**	**3375**	**473.7**	**21.05**	**0.280**	**2.441**
1	7	15	15	15	0.52	7.66	32	8690	3375	679.6	30.35	0.280	2.575
2		15	15	15				8716	3375	690.6	30.69	0.280	2.583
3		15	15	15				7970	3375	698.7	31.05	0.280	2.362
							mean	**8459**	**3375**	**689.6**	**30.70**	**0.280**	**2.506**
1	28	15	15	15	0.52	7.66	32	8072	3375	903.5	40.16	0.280	2.392
2		15	15	15				7979	3375	898.1	39.91	0.280	2.364
3		15	15	15				7988	3375	905.4	40.24	0.280	2.367
							mean	**8.013**	**3375**	**902.3**	**40.10**	**0.280**	**2.374**

Effect of 1.5 % super plasticizer admixture on compressive strength													
No	Test age [days]	Dimensions (cm)			w/c ratio	Water reduction (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.50	11.25	33	8.067	3375	503.8	22.39	0.280	2.390
2		15	15	15				8.105	3375	523.6	23.27	0.280	2.402
3		15	15	15				8.065	3375	513.9	22.84	0.280	2.390
							mean	**8079**	**3375**	**513.8**	**22.83**	**0.280**	**2.394**
1	7	15	15	15	0.50	11.25	33	8.018	3375	707.7	31.45	0.280	2.376
2		15	15	15				8.083	3375	723.9	32.17	0.280	2.395
3		15	15	15				7.995	3375	705.5	31.35	0.280	2.369
							mean	**8023**	**3375**	**712.4**	**31.66**	**0.280**	**2.377**
1	28	15	15	15	0.50	11.25	33	8.046	3375	923.1	41.03	0.280	2.384
2		15	15	15				8.076	3375	961.8	42.74	0.280	2.393
3		15	15	15				8.045	3375	909.3	40.41	0.280	2.384
							mean	**8056**	**3375**	**931.4**	**41.39**	**0.280**	**2.387**

Effect of zero % super plasticizer admixture on flexural strength of concrete									
No	Test age [days]	Dimensions [cm]			Wt (gm)	W/C ratio	Water reduction (%)	slump	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12261	0.58	0%	32	4.1	2.58
2		50	50	50	12086				4.3	2.71
								mean	**4.2**	**2.65**
1	28	50	50	50	12516	0.58	0%	32	6.9	4.35
2		50	50	50	12306				6.7	4.22
								mean	**6.8**	**4.29**

Effect of 0.5 % super plasticizer admixture on flexural strength of concrete										
No	Test age [days]	Dimensions [cm]			Wt (gm)	W/C ratio	Water reduction (%)	Slump (mm)	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12080	0.54	5.65	33	4.5	2.84
2		50	50	50	12140				4.7	2.96
								mean	**4.6**	**2.9**
1	28	50	50	50	12566	0.54	5.65	33	7.4	4.66
2		50	50	50	12436				7.2	4.54
								mean	**7.3**	**4.6**

Effect of 1 % super plasticizer admixture on flexural strength of concrete										
No	Test age [days]	Dimensions [cm]			Wt (gm)	W/C ratio	Water reduction (%)	slump (mm)	F [kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12741	0.52	8.82	32	6.2	3.91
2		50	50	50	12923				5.9	3.72
								mean	**6.05**	**3.8**
1	28	50	50	50	12515	0.52	8.82	32	8.5	5.36
2		50	50	50	12173				8.3	5.23
								mean	**8.4**	**5.3**

Effect of 1.5 % super plasticizer admixture on flexural strength of concrete										
No	Test age [days]	Dimensions [cm]			Wt (gm)	W/C ratio	Water reduction (%)	slump	F[kN]	σ[MPa]
		L	B	D						
1	7	50	50	50	12409	0.50	11.77	34	6.7	4.22
2		50	50	50	12723				6.4	4.03
								mean	**6.55**	**4.13**
1	28	50	50	50	12360	0.50	11.77	34	8.6	5.42
2		50	50	50	12823				8.7	5.48
								mean	**8.65**	**5.45**

Laboratory test result for permeability test

Penetration depths(mm)	Admixture percentages			
	0%	0.5%	1%	1.5%
D1	17.67	11.67	9.33	7.33
D2	18.33	13.33	11	9.67
D3	20.67	16.33	12.33	10.33
D4	22.33	15.67	13.83	11.67
D5	23.33	17.17	14.5	13.83
D6	25.17	19.33	16.67	14.67
D7	27.67	18.67	17.17	15.35
D8	27.33	22.67	18.33	13.33
D9	29.67	21.33	16.33	12.67
D10	26.33	19.67	15.17	11.33
D11	24.67	17.33	15.5	12.33
D12	25.17	15.67	14.67	10.17
D13	22.67	13.17	12.33	9.5
D14	19.33	15.33	9.67	7.17
D15	17.33	12.33	9	6.33
Minimum	**17.33**	**11.67**	**9.00**	**6.33**
Mean	**23.18**	**16.64**	**13.72**	**11.05**
maximum	**29.67**	**22.67**	**18.33**	**15.35**

2.4. Phase IV: The effect of superplasticizer admixture on concrete properties by reducing cement content

Effect of Zero % superplasticizer on workability and compressive strength													
No	Test age [days]	Dimensions (cm)			w/c ratio	Cement saving (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.58	0%	33	8605	3375	339.1	15.07	0.280	2.550
2		15	15	15				8740	3375	334.6	14.87	0.280	2.590
3		15	15	15				8015	3375	343.2	15.25	0.280	2.375
							mean	**8453**	**3375**	**338.97**	**15.06**	**0.280**	2.505
1	7	15	15	15	0.58	0%	33	8008	3375	494.6	21.98	0.280	2.373
2		15	15	15				8660	3375	496.4	22.06	0.280	2.566
3		15	15	15				8036	3375	458.4	20.37	0.280	2.381
							mean	**8235**	**3375**	**483.13**	**21.47**	**0.280**	2.440
1	28	15	15	15	0.58	0%	33	8055	3375	738.6	32.83	0.280	2.387
2		15	15	15				8053	3375	760.1	33.78	0.280	2.386
3		15	15	15				8579	3375	701.6	31.18	0.280	2.542
							mean	**8229**	**3375**	**733.4**	**32.60**	**0.280**	2.438

Effect of 0.5 % superplasticizer admixture on compressive strength

No	Test age [days]	Dimensions (cm)			w/c ratio	Cement saving (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.58	1.33%	51	8.243	3375	344.3	15.30	0.280	2.442
2		15	15	15				8.643	3375	340.9	15.15	0.280	2.561
3		15	15	15				8.121	3375	336.6	14.96	0.280	2.406
							mean	**8.336**	**3375**	**340.7**	**15.14**	**0.280**	**2.470**
1	7	15	15	15	0.58	1.33%	51	8.084	3375	496.7	22.07	0.280	2.395
2		15	15	15				8.192	3375	494.4	21.97	0.280	2.427
3		15	15	15				8.160	3375	470.1	20.89	0.280	0.242
							mean	**8.145**	**3375**	**487.07**	**21.64**	**0.280**	**2.413**
1	28	15	15	15	0.58	1.33%	51	8.116	3375	715.6	31.80	0.280	2.405
2		15	15	15				8.050	3375	756.1	33.60	0.280	2.385
3		15	15	15				8.167	3375	748.2	33.25	0.280	2.420
							mean	**8.111**	**3375**	**739.97**	**32.88**	**0.280**	**2.403**

Effect of 1 % super plasticizer admixture on compressive strength

No	Test age [days]	Dimensions (cm)			w/c ratio	Cement saving (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.58	2.12%	59	8.173	3375	347.2	15.43	0.280	2.422
2		15	15	15				8.898	3375	353.8	15.72	0.280	2.636
3		15	15	15				8.133	3375	346.6	15.40	0.280	2.410
							mean	**8.401**	**3375**	**349.2**	**15.52**	**0.280**	**2.489**
1	7	15	15	15	0.58	2.12%	59	8.805	3375	505.2	22.45	0.280	2.609
2		15	15	15				8.074	3375	518.2	23.03	0.280	2.392
3		15	15	15				8.099	3375	521.2	23.16	0.280	2.400
							mean	**8.326**	**3375**	**514.87**	**22.88**	**0.280**	**2.467**
1	28	15	15	15	0.58	2.12%	59	8.078	3375	775.0	34.44	0.280	2.394
2		15	15	15				8.168	3375	766.2	34.05	0.280	2.420
3		15	15	15				8.128	3375	759.7	33.76	0.280	2.408
							mean	**8.125**	**3375**	**766.97**	**34.08**	**0.280**	**2.408**

Effect of 1.5 % super plasticizer admixture on compressive strength														
No	Test age [days]	Dimensions (cm)			w/c ratio	Cement saving (%)	Slump (mm)	Weight (gm)	Volume (cm^3)	Failure load (kN)	Comp. Strength (MPa)	Rate of loading (MPa/s)	Unit weight (gm/cm^3)
		L	W	H									
1	3	15	15	15	0.58	2.92%	145	8.049	3375	345.4	15.35	0.280	2.385
2		15	15	15				8.102	3375	341.4	15.17	0.280	2.401
3		15	15	15				8.139	3375	343.0	15.24	0.280	2.412
							mean	**8.097**	**3375**	**343.3**	**15.25**	**0.280**	**2.399**
1	7	15	15	15	0.58	2.92%	145	8.265	3375	494.6	21.98	0.280	2.449
2		15	15	15				8.494	3375	499.8	22.21	0.280	2.517
3		15	15	15				8.197	3375	488.8	21.72	0.280	2.429
							mean	**8.319**	**3375**	**494.4**	**21.97**	**0.280**	**2.465**
1	28	15	15	15	0.58	2.92%	145	8.100	3375	737.9	32.79	0.280	2.400
2		15	15	15				8.013	3375	756.3	33.61	0.280	2.374
3		15	15	15				8.210	3375	751.2	33.38	0.280	0.243
							mean	**8.108**	**3375**	**748.47**	**33.26**	**0.280**	**2.40**

APPENDIX 3

SAMPLE PHOTO GALLERY TAKEN DURING THE RESEARCH

Photo: Cement sample

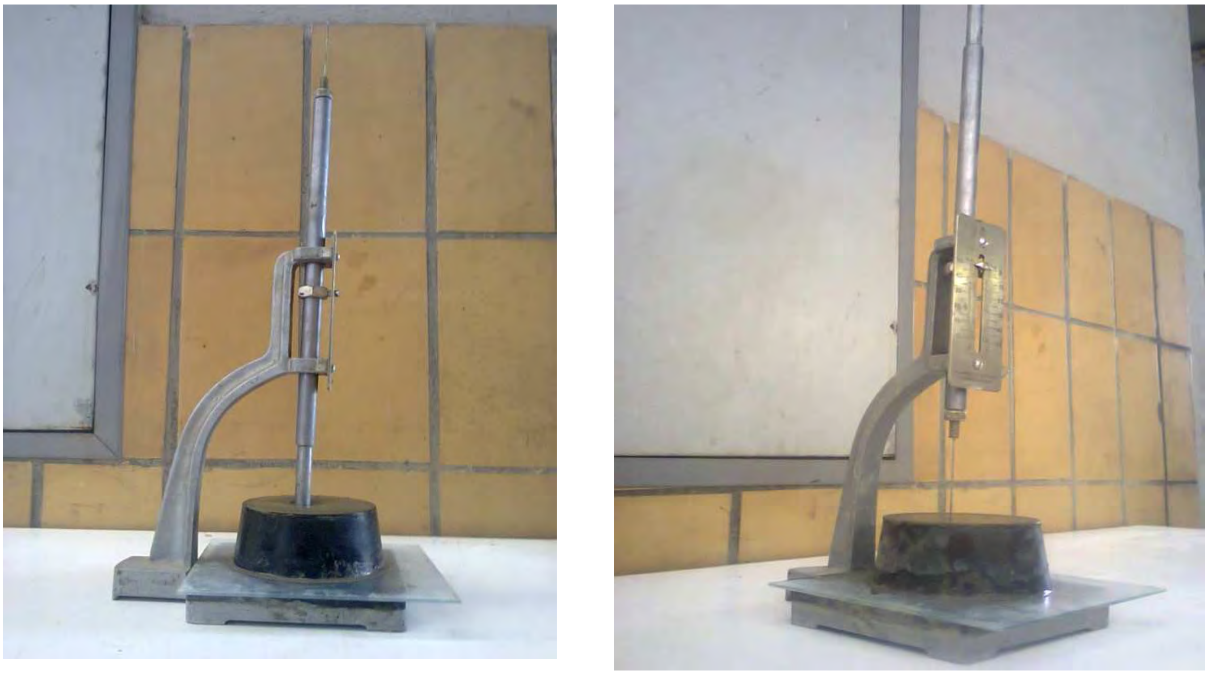


Photo: Initial and final setting time tests for cement

Photo: Riffle Box for quartering fine aggregates and sieves Shaker with series of sieves

Photo: Graded fine aggregate sample

photo: Specific gravity test for fine aggregate

Photo: Unit weight tests

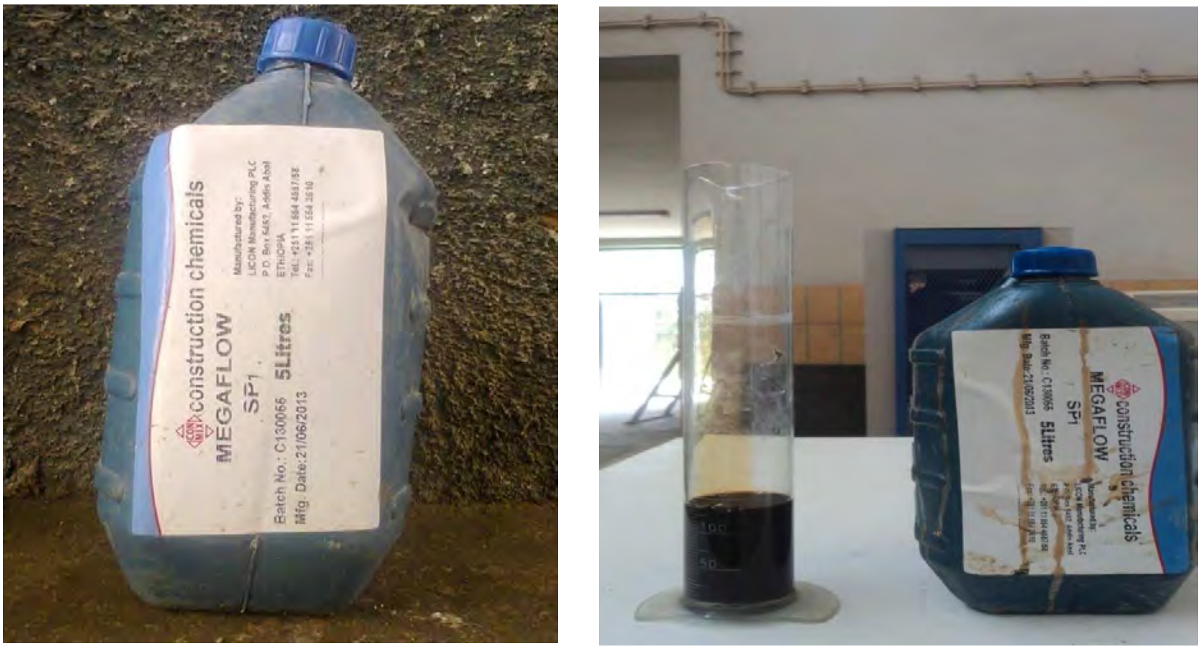


Photo: Mega flow SP1 sample

Photo: Coarse aggregate washing

photo: Air drying coarse aggregate sample

Photo: Sample quartering for coarse aggregate

photo: Coarse aggregate crushing value test

Photo: Mould tightening and loosening tools

Photo: Mechanical concrete mixer

Photo: Casted concrete sample

Photo: Concrete ready for compressive strength test

Photo: Concrete cube sample after testing

Photo: Flexural test concrete sample

Photo: Sample ready for flexural strength test

Photo: Sample after flexural strength test

Photo: Sample ready for permeability tests

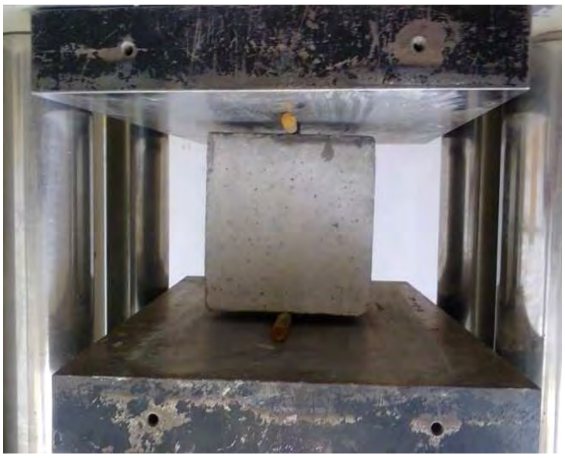


Photo: Sample ready for splitting test

Photo: Concrete sample after splitting

Photo: Water penetrated sample