UNIVERSITY OF NAIROBI

USE OF PLASTICIZERS AND SUPER PLASTICIZERS TO INCREASE THE WORKABILITY OF CONCRETE

BY

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ABSTRACT

This paper is an experimental study that seeks to explore the properties of super plasticizers and plasticizer and how their effects change the workability of concrete and also the strength.

A stiff concrete mix with a low water/ cement ratio was compared with a similar mix with a low water/cement ratio but had a super plasticizer and a plasticizer added to see how effective these plasticizers. The plasticizers used were Pozzolith standard and Rheobuild 2000M.

Various tests were carried out and include the slump test, compaction factor test to test the workability of the concrete, compressive strength test and Tensile strength test to see how the plasticizers affected the strength of the concrete mix. The compaction factor and slump test were done on the fresh concrete mix while the Compressive strength and tensile test were done after 7 days and 28 days.

The results show that there was an increase in the workability of the concrete when plasticizers and super plasticizers were added to the mix. Also the 7 day strength and the 28day strength also increased in the concrete mix.

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My sincere appreciation goes to my supervisor Dr. John Mwero for his guidance throughout this project, to all the staff members who assisted me in the lab when carrying out the experiments, to my classmates who also assisted me and provided needed support allowing me to accomplish this research work.

I also want to appreciate my family members, specifically my parents who provided financial support enabling this project to get to its completion.

DEDICATION

I would like to dedicate this work to my family who have stood by me throughout my studies, who continued to believe in me even when things seemed impossible to achieve, to my close friends and last but not least to God almighty for his guidance.

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CHAPTER 1

1.0 Introduction

1.1 Background

When it comes to the designing of safe structures from concrete, the specific strength of the concrete and the durability of the concrete have to be known before the structure is erected so as to ensure that it will withstand all the stresses exerted on it safely and deliver the intended design purpose. It is therefore very essential to do a study on the various components that contribute to the concrete mix and evaluate the different ways that can be used to increase its strength.

As the need to build larger structures increases, so does the need to create a material that can be strong and durable enough to withstand the forces exerted by these large structures. Concrete is one of the most fundamental building materials used in the construction industry and therefore several tests are carried out to try and ensure that the concrete is able to be used to create structures that are safe. A fundamental discovery that was made from the various tests from combining the four essential components of concrete in different proportions to increase the strength of the concrete showed that an increase in the strength of the concrete made the mix less fluid meaning the concrete would not flow as easily when it was being poured. This was a problem of workability of the concrete.

There was therefore need to increase the workability of the concrete without compromising on the strength of the concrete mix and the durability. Workability of concrete is the ability of freshly mixed concrete to fill the voids in a form work without having any effect on the quality of the concrete. This ensures that the concrete is durable and strength of the structure is ensured.

When the workability of concrete is tampered with, it may have an effect on the strength and durability of the structure once the concrete mix has dried. The concrete mix may not fill all the voids in the structure leading to honey combs being left in the structure for example, that may expand and contract with changes in temperature causing the concrete to form small cracks. Poor workability of concrete may also compromise the finished appearance of the structure. It also has an effect on the cost of labour of the structure.

Concrete that is of low workability will require more compaction in order to ensure that it fills all the voids in the form or mould. This means that more energy will be used to ensure that the concrete is properly compacted.

There are several ways that have been discovered over the years to increase the workability of the concrete. One of the methods is by increasing the amount of water in the concrete. However an increase in the amount of water led to the reduction of the strength of the concrete. Excess water may also lead to segregation and bleeding. Segregation is the phenomena where aggregates and cement separate in the concrete mix and therefore cannot bind sufficiently in the curing process to provide the strength required for the concrete structure. Bleeding is the excess surface water formed in a concrete mix.

It was later discovered that the workability of concrete could be increased by adding other substances to the pre-existing mix to ensure that the concrete mix had better workability and still ensured that the strength and the durability of the structure was intact. In ancient times, Romans used milk, blood and animal fat to increase the workability of concrete.

Modern methods of increasing the workability of concrete is by using plasticizers in the concrete such as plasticizers to increase the workability and not reduce the quality of the concrete. Plasticizers are chemicals that are manufactured and then added to the concrete mix.

1.2 Study Justification

With the increase in the demand for larger structures that can withstand heavier loads, the strength of the concrete has to increase in order to meet the demands. An increase in the strength of the concrete will affect the workability of the concrete and therefore methods of increasing its workability without reducing the strength and quality have to be explored in order to meet the demand. This report will focus specifically on plasticizers and super plasticizers that are available in the construction industry in Kenya.

1.3 Problem Statement

Plasticizers have been around for a while and have been used for quite some time in the Kenyan construction industry. There is therefore need to understand how exactly these plasticizers work, their chemical composition and find out about the manufacture of the product and how it can be used to make construction more economical in the near future. A need to understand the different types of plasticizers that are used and their availability in the Kenyan market.

1.4 Research Objectives

1.4.1 General objective

To determine the use of plasticizers in concrete in order to increase the workability of a concrete mix.

1.4.2 Specific Objectives

- To find out about the effect of chemical plasticizers in a concrete mix
- To determine by how much the plasticizers affect the workability of a concrete mix.
- To determine how the plasticizers affect the strength of concrete mix

1.5 Limitation of study

The study will be limited to the testing of the available plasticizers and super plasticizers that are in the Kenyan market due to the cost and time that may take in importing a variety of plasticizers.

Chapter 2

2.1 Literature Review

2.1.1. Introduction

Concrete with high workability are also referred to as high slump concrete mixtures and are suitable for many concrete applications such as where the reinforcement of concrete are closely packed together, and also where there are thin sections of concrete required. Concrete with high slump achieve this level of workability by use of plasticizers specifically 'super plasticizers' and 'plasticizers'.

Plasticizers and super plasticizers reduce the amount of water content needed in a concrete mix and are therefore referred to as water reducing agents and achieve a certain amount of slump with less water. A low water to cement ratio means the concrete has a higher strength. These admixture are available in liquid or powder form and vary in chemical composition and are used in different proportions depending on the job at hand.

2.2 Concrete Composition

Before we explore the use of plasticizers and super plasticizers, it is essential that we understand the fundamental composition of a concrete mix.

Concrete is a composite material made from a combination of cement which acts as the binder of the material, course aggregate, fine aggregate which fills in the gaps in the mix of the course aggregate and water. Depending of the strength of concrete that is required, these materials can be varied in different quantities and proportions to obtain a concrete mix with the required strength and durability for a particular task. However changing the design of the concrete mix will have changes in the strength of the concrete mix.

2.2.1 Cement

Cement is a binder material meaning it is capable of holding other materials together. In the construction industry there are two general types of cement

- Hydraulic cement
- Non-hydraulic cement

Hydraulic cements harden and bind material by the chemical reaction between the anhydrous cement and water to form a hard material. This type of concrete can therefore harden underwater. Portland cement is an example of hydrated cement and is widely used in the construction industry

Non-hydraulic cements do not react with water to form a hard material and therefore cannot harden underwater. Slaked lime is an example or non-hydrated cement as it requires carbon dioxide to chemically react and form a hard binder material.

Portland cement is one of the most commonly used cement in the construction industry. It is made by heating limestone with small quantities of other materials such as clays in a kiln. This process is referred to as calcination. In the process, a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide or quicklime which is then blended with the other materials in the mix. The substance formed is called clinker and is ground down to powder and a small amount of gypsum is added to the mix to form Portland cement.

2.2.2 Aggregates.

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. In a concrete mix, fine and coarse aggregates in concrete generally occupy about 65%-75% of the concrete volume and about 70%-85% by mass of the mix and strongly influence the properties of the fresh mix and the overall properties of the hardened concrete. Naturally occurring concrete aggregates are a mixture of rocks and minerals however Recycled concrete, or crushed waste concrete, is a feasible source of aggregates and an economic reality, especially where good aggregates are scarce. Aggregates must conform to certain standards for optimum engineering use: they must be clean, hard, strong, durable particles free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste. Aggregate particles that are friable or capable of being split are undesirable. Aggregates containing any appreciable amounts of shale or other shaly rocks, soft and porous materials should be avoided.

Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio. Generally, flat and elongated particles are avoided or are limited to about 15 percent by weight of the total aggregate. Unit-weight measures the volume that graded aggregate and the voids between them will occupy in concrete.

The void content between particles affects the amount of cement paste required for the mix. Angular aggregates increase the void content. Larger sizes of well-graded aggregate and improved grading decrease the void content. Absorption and surface moisture of aggregate are measured when selecting aggregate because the internal structure of aggregate is made up of solid material and voids that may or may not contain water. The amount of water in the concrete mixture must be adjusted to include the moisture conditions of the aggregate.

2.2.2.1. Fine aggregates

Fine aggregates are aggregates whose size is less than 4.75mm and contain no more than 5% of coarser material. They may be classified as:

- Natural sand
- Crushed stone sand
- Crushed gravel sand

The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles. Thus, it reduces the porosity of the final mass and considerably increases its strength. Usually, natural river sand is used as a fine aggregate. However, at places, where natural sand is not available economically, finely crushed stone may be used as a fine aggregate.

2.2.2.2 Coarse aggregates.

Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from Primary, Secondary or Recycled sources. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

2.3 Concrete Mix Design

Concrete mix design is the process of selecting suitable ingredients of concrete and estimating their proportions with the objective of producing workable, strong and durable concrete at reasonable cost.

The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

In mix design, use is normally made of previous experience and of several design tables, charts and curves. Final specifications are arrived at after testing trial mixes.

The old fashioned idea in concrete design is that concrete consists of cement, coarse aggregate, fine aggregate and water, thus the problem of mix design has been seen as how to select suitable aggregates, and determine their optimum relative proportions and the cement requirement to produce a given strength at a given slump. Early investigators tended to be concerned with how to define ideal concrete. These past specifications for concrete prescribed the proportions of cement, and fine aggregates. Certain traditional mixes were thus produced but, because of variability of the mix ingredients, concretes having fixed cement-aggregate proportions and a given workability vary widely in strength. For this reason, minimum compressive strength was later added but this is restrictive where good quality materials are available or poor quality materials are the only ones available. In summary, specifying at the same time strength as well as mix ingredients and their proportions, and also the aggregate shape and grading, leaves no room for economies in the mix selection, and makes progress in the production of economic and satisfactory mixes in the basis of the knowledge of the properties of concrete impossible.

Current consideration in designing for concrete mixes should be:

1. What aggregates are economically available,

2. What properties should the concrete have and

3. What is the most economical way of providing these required properties?

Modern tendency is for specifications to be less restrictive by providing just limiting values, but sometimes traditional mix proportions are stated for the benefit of the contractor who does not wish to use a high degree of quality control.

2.4 Requirements of concrete mix design

The requirements which form the basis of selection and proportioning of mix ingredients are:

a) The minimum compressive strength required from structural consideration

b) The adequate workability necessary for full compaction with the compacting equipment available.

c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions

d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

2.5 Workability

Concrete workability is the ability of a fresh concrete mix to fill all the voids in a form properly without changing the quality and durability of the concrete. Workability of concrete can be measured in the lab using the concrete slump test. A slump test is carried out using an Abram cone. The cone is placed on a non-absorptive surface with the large end facing down. A sample from a freshly mixed concrete is poured in 3 layers in the cone. Each layer is compacted with 15 blows from a rod that is allowed to fall by gravity in order to achieve compaction. After the 3 layers have been made, the cone is carefully lifted off. Some of the concrete will slump by a certain amount due to gravity. The amount of the concrete that has slumped is then measured.

Plasticizers are chemical additives that are used to improve the workability of concrete. These chemicals increase the fluidity of the concrete without adding water to the mixture. The amount of water content in a concrete mixture is inversely proportional to the strength of the concrete. There are plasticizer and super plasticizers that available in the construction industry depending on the type of job at hand.

A concrete mix that contains Super plasticizer or water reducing admixtures requires less water to obtain a required slump. The concrete treated with this admixture will have a lower water to cement ratio which is a property of high strength concrete. This would indicate that a higher strength concrete could be obtained without an increase in the amount of cement to the mix.

2.6 Concrete Plasticizers

Plasticizers are essentially high-range water reducers. These plasticizers are added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction while still remaining essentially free of excess bleeding or segregation.

There are of two types

- Plasticizers
- Super-plasticizers

Discussed below in detail are two examples of these plasticizers. A concrete plasticizer, POZZOLITH STANDARD and a super plasticizer, RHEOBUILD 2000M.

2.6.1 Pozzolith Standard

Pozzolith standard is the plasticizer chosen to test in the lab to represent the plasticizers readily available in the Kenyan Market. Pozzolith standard is a powerful plasticizer which deflocculates and disperses the cement particles within a concrete mix. It is brown in colour and it is used to improve the workability without the addition of extra water or to allow the reductions in the free water content of the concrete mix. Pozzolith standard conforms to British standards (BS 5075 part 1)

This plasticizer can be used with all types of Portland cement including sulphate resisting. Pozzolith standard should not be premixed with other admixtures and if other admixtures are to be used they must be dispensed separately.

Pozzolith standard should be added to the concrete mix during the mixing cycle at the same time as the water and the aggregates. It should never be added when the cement is dry.

Primary uses include:

- To increase concrete workability
- To increase the compressive strength if concrete
- To effect concrete economies
- For hot weather concreting
- To reduce the water content in a concrete mix

The following are the typical application of the plasticizer

- In pre-stressed concrete
- In areas of congested reinforcement where the high workability of the concrete is of benefit
- In pre-cast concrete manufacture
- In concrete brick and block manufacture
- Wherever reduced water content will beneficial to reduce permeability

The advantages of using this plasticiser include:

- Significant improvement in the workability and is therefore east to pour the concrete
- It improves the cohesive properties of the concrete mix helping to reduce the segregation and bleeding
- Allows water reduction by about 10% to be maintained while still maintaining workability therefore increasing the strength, durability and impermeability of the concrete mix
- It is particularly useful in hot climatic conditions when used to increase workability

Dosage

Field trails should be conducted to determine the optimum addition rates. A dosage in the range of 280ml to 560ml per 100kg cement in recommended as a starting point. For hot weather concreting where Pozzolith standard is to be used to extend the workability, a dosage of 400ml to800ml per 100kg cement is recommended.

Effects of overdosing of pozzolith will result in the following:

- Retardation of initial test
- Increase in air entrainment
- Increase in workability

Provided the concrete mix is properly used there will be no adverse effects in the strength of the concrete and will generally be higher than for normal concrete.

Storage

Pozzolith standard is stored away from direct sunlight and is protected from extreme temperatures. Failure to comply in the deteriorating of the project or the packaging.

2.6.2 Rheobuild 2000M Super plasticizer

Rheobuild 2000m is a readily available super plasticizer available in the Kenyan market. It is a chloride free admixture based on melamine formaldehyde formulated for the production of rheoplastic concrete. This admixture is available in liquid and powder for which must be dissolved in water prior to use. The form of plasticizer chosen for this project is the liquid form plasticizer which is clear to turbid in colour.

Concrete that has been treated with rheoplastic exhibits fluid tendencies but cohesive properties with a slump value of at least 200mm. when a concrete mix is treated with this super-plasticizer, it becomes virtually self-compacting but at the same time, free from segregation.

Rheobuild 2000m dramatically increases the workability of concrete by its powerful deflocculating and dispersing effect. It also acts catalytically to increase the rate of hardening of the cement particles thereby leading to higher early strength. These combined effects can be utilised to obtain a significant reduction in free water content or to produce a self-compacting, high workability flowing concrete which has increased early strengths.

Rheobuild can be used with all types of Portland cement including the sulphate resisting. This admixture however should not be premixed with other admixtures. If other admixtures are to be used in a concrete mix containing rheobuild then they must be dispensed separately.

The primary uses of rheobuild 2000m are as follows

- For the production of rheoplastic concrete
- To produce high early strength concrete
- Precast concrete production
- Concrete with white cement

The typical applications for this admixture is for the production of flowing, self-compacting concrete with high early strengths. Where reduced striking times would be of benefit such as precast and steam cured concrete. For the production of high early and high long term strength concrete.

Benefits

- Translucent colour enables use with white cement concrete.
- Produces highly impermeable, dense concrete with enhanced durability.
- Enables high strength and high workability concrete to be produced with normal cement contents.
- Enables precast units to be demoulded in 12 to 16 hours.
- Can be used to produce self-compacting flowing concrete which requires little or no vibration.

Method of use

Rheobuild 2000m should be added to the concrete mix during the mixing cycle at the same time as the water or aggregates. It should never be added to the dry cement. There is no need for extension time for the mixing process.

Alternatively when using this admixture to produce rheoplastic concrete on site using ready mix trucks, it can be added to the concrete via the feeder hopper at the rear of the truck a few minutes before placing. Ensure at least 3minutes mixing before use at a minimum drum revolution of 10rpm to produce a fully homogenous mix.

When using rheobuild 2000m to produce rheoplastic concrete it is essential for concrete mixes be designed to accommodate an increase in workability. A convection pumped concrete design with a further addition of 2-3% fine sand will normally accommodate this. For water reduced or high early strength concrete, adjustment must be made to account for volume changes.

Dosage

Field trials should be conducted to determine the optimum addition of rates of rheobuild 2000m. The following figures are recommended as a starting point

% water reduction	Dosage (mm) per 100kg cement
10-15	1500
15-20	2000
20-25	3000

Effects of over dosage

The effects of over dosage will result in

- Slight retardation of initial set
- Increase in workability
- Providing the concrete is properly cured, the ultimate strength of the concrete will not be adversely affected and will be generally higher than for normal concrete.

Storage

The admixture should be stored undercover and out of direct sunlight and be protected from extreme temperatures. Failure to do so more lead to premature deterioration of the product.

2.7 Problems Associated with High slump Concrete

2.7.1 Segragation

Segregation is defined as the separation of the constituent materials in a concrete mix. A good concrete mix is one where the ingredients that make the concrete mix are properly distributed to make a homogenous mixture. In the case of concrete, it is the differences in the size of particles and in the specific gravity of the mix constituents that are the primary causes of segregation, but its extent can be controlled by the choice of suitable grading and care handling.

Segregation can be of three types

- **Coarse aggregate** separating out or settling down from the rest of the matrix.
- **Water** separating out from the rest of the material being a material of lowest specific gravity.
- **Paste** separating away from coarse aggregate.

A well-prepared concrete mix, taking into consideration various parameters such as grading, size, shape and surface texture of aggregate with optimum quantity of waters makes a cohesive mix. Such concrete will not exhibit any tendency for segregation. The cohesive and fatty characteristics of matrix do not allow the aggregate to fall apart, at the same time; the matrix itself is sufficiently contained by the aggregate. Similarly, water also does not find it easy to move out freely from the rest of the ingredients.

The following are conditions that will favour segregation in a concrete mix

- Insufficiently mixed concrete with excess water content
- When dropping of concrete from heights as in the case of placing concrete in column concreting
- a badly proportioned mix where there is not enough paste to bind and contain aggregates
- when concrete is discharged from a poorly designed mixer or where the blades in the mixer are worn out

- When concrete is conveyed over long distances on a conveyer belt, wheelbarrows or in a truck can lead to segregation of concrete because of the vibrations associated with the transport of material.

Vibration of a concrete mix is one of the main ways of achieving compaction of concrete. Vibration however should be used on concrete that is relatively dry. If the concrete mix is too wet, this may lead to the segregation of the concrete constituents if a vibrator is used. Vibration is carried out for an optimum amount of time to acquire desired results. if the vibration is carried out for too long it is likely to result in segregation because of settlement of the course aggregates.

Segregation is difficult to measure quantitatively, but is easily detected when concrete is handled on a site in an improper way. A good picture of cohesion of the mix is obtained by the flow test. As far as proneness to segregation on over vibration is concerned, a good test is to vibrate a concrete cube for about 10 min and then to strip it and observe the distribution of coarse aggregate: any segregation will be easily seen.

2.7.2 Bleeding

Bleeding is a form of segregation in which some of the water in the mix tends to rise to the surface of freshly placed concrete by capillary action. This is caused by the inability of the solid constituents of the mix to hold all of the mixing water when they settle downwards.

Bleeding can be expressed quantitatively as the total settlement per unit height of concrete.

As a result of bleeding the top of every lift may become too wet and if the water is trapped by superimposed concrete, porous, weak, and non-durable concrete will result. If the bleeding water is remixed during finishing of the top surface a weak wearing surface will be formed. This can be avoided by delaying the finishing operations until the bleeding water has evaporated, and also by the use of wood floats and avoidance of overworking the surface. On the other hand if evaporation of water from the surface of the concrete is faster than the bleeding rate plastic shrinkage cracking may result.

Bleeding need not necessarily be harmful. If it is undisturbed (and the water evaporates) the effective W/C ratio may be lowered with a resulting increase in strength. On the other hand, if the rising water carries with it a significant amount of the finer cement particles a layer of laitance will be formed. If this is at the top of a slab a porous surface will result, with a permanently dusty surface. At the top of a lift a plane of weakness would form and the bond with the next lift would be inadequate. For this reason, laitance should always be removed by brushing and washing.

Bleeding depends largely on the properties of cement; increased alkali content and fineness of cement decreases the tendency to bleed. Addition of pozzolanas and air entraining agent may also decrease bleeding.

2.8 Slump Test

A slump test is a method of determining the workability of a fresh concrete mix. it is a measure of the consistency of a fresh mix of concrete and it is very popular because of its simplicity as a way of determining whether the right amount of water has been added to the mix.

The steel slump cone is placed on a solid, impermeable, level base and filled with the fresh concrete in three equal layers. Each layer is rodded 25 times to ensure compaction. The third layer is finished off level with the top of the cone. The cone is carefully lifted up, leaving a heap of concrete that settles or ‘slumps’ slightly. The upturned slump cone is placed on the base to act as a reference, and the difference in level between its top and the top of the concrete is measured and recorded to the nearest 5 mm to give the slump of the concrete

When the cone is removed, the slump may take one of three forms.

1. In a **true slump** the concrete simply subsides, keeping more or less to shape.
2. In a **shear slump** the top portion of the concrete shears off and slips sideways.
3. In a **collapse slump** the concrete collapses completely.

Only a true slump is of any use in the test. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which the flow test is more appropriate.

2.9 Compaction Factor Test

Workability is the ease with which concrete can be handled, deposited or placed and spread into its final location and compacted. Compaction factor test is based on the principle that the workability of concrete is reflected or indicated by its compaction by standard amount of work done on it. By allowing it to fall under gravity through a standard height. In a standard cylinder, the ratio of density of fully compacted concrete is called compacted factor.

Compaction factor $= \frac{density\ of\ partially\ \ compacted\ concrete}{density\ of\ fully\ compacted\ concrete}$

The purpose of this test is to know the workability of a fresh concrete mix. it is used while designing of concrete mix during trial mixes.

The upper hopper is filled concrete, which is then successively dropped into the lower hopper and then into the cylindrical mould. The excess of concrete is struck off and the compaction factor is defined as the weight of the ratio of concrete in the cylinder to the same concrete fully compacted in the cylinder.

Figure 1. Compaction factor apparatus

$$\text{Compaction factor} = \frac{W1}{W2}$$

Where W1 = weight of partially compacted concrete

W2 = weight of fully compacted concrete

This method has its limitation.

- Not suitable for field application
- Mixes can stick to the sides of the hoppers
- Not consistent

The compressive test is the most widely used method of determining the compressive strength of specimens. Two types of specimens are used

1. Cubes
2. Cylinders

2.9 Compressive Test

For the experiment, cubes of 100mm by 100mm by 100m were chosen to carry out the test.

The cylinders chosen had a diameter of 150mm and a height of 300mm.

Cubes for the compression test are cast in steel moulds. Compaction was achieved using a vibrating apparatus. Compression test carried out were the 7 day test and the 28 day test.

On the day of testing the cubes were placed in a compression test machine at right angles to the position of cast. The load is applied at a general rate of stress. Under pure uniaxial loading stress the cracks developed are parallel to the direction of load application.

In addition to compressive stresses, lateral shear stresses are also effective in the concrete specimen. Effects of this shear decrease towards the centre of the cube so that sides of cubes have near vertical cracks at centre of cube.

It has been observed that the strength of the concrete specimen depends on the size and shape and proportion of sides of test specimen. The compressive strength is found to be higher for cube specimens of 150mm and below. For cube specimens of 100mm, a modification factor of 0.8 is applied to the results. Smaller specimens are found to have a higher strength because they can be easily compacted and there is a less likely hood of bleeding and therefore the mix would be more consistent and therefore stronger.

Figure 2. Compression testing machine.

Chapter 3

3.0 Methodology

The methodology used for the testing of the plasticizers is by carrying out laboratory experiments and testing the locally available plasticizers in different ratios and proportions in order to find out how they behave and what effect the have on the concrete mix.

The cement used in the experiment was Bamburi 32.5N Nguvu cement which is sourced locally from athi river, Fine aggregates used was river sand and the coarse aggregate used was 10mm aggregates sourced from Mlolongo.

3.1 Grading of materials

3.1.1 Fine aggregates

When determined in accordance with BS 812-103.1, using test sieves of the sizes given in Table 4 complying with BS 410, full tolerance, the grading of the sand should comply with the overall limits given in Table 4. Additionally, not more than one in ten consecutive samples shall have a grading outside the limits for any one of the grading C, M or F, given in Table 4 (CL 5.2.1).

3.1.2 Coarse aggregate

Coarse aggregate is defined as aggregate mainly retained on a 5.0 mm BS 410 test sieve and containing no more finer material than is permitted for the various sizes in this specification (CL 2.2).

Coarse aggregate may be described as gravel (uncrushed, crushed or partially crushed) as defined in 2.2.1, or as crushed rock as defined in CL2.2.2, or as blended coarse aggregate as defined in CL2.2.3.

When determined in accordance with BS 812-103.1 using test sieves of the sizes given in Table 3, complying with BS 410, full tolerance, the grading of the coarse aggregate should be within the appropriate limits given in Table 3.

3.2 Mixing parameters

The mixing parameters used for the preparation of concrete were done using absolute volumes of the constituents needed in the concrete mix which are in accordance with accepted standards and specifications.

3.3 Concrete mix design

Concrete mix design was carried out to determine the proportions of constituents of concrete that met the desired strength and other properties. This was done according to accepted standards and specifications.

Mix design enables in choosing of a mix that will be recommended in the casting of precast element for testing.

It entailed coming up with adequate water/ cement ratio that will give adequate compressive strength.

The procedure is as follows:

Selection of target water/cement ratio

The standard deviation to be adopted in determining the target strength should be that obtained from line A from the graph showing the relationship between standard deviation and characteristic strength.

The margin can then be derived from

$$M = k \times s$$

Where

M = the margin

k = a value appropriate to the percentage defectives permitted below the characteristic strength

s = the standard deviation

The target mean strength is determined through

$$fm = fc + M$$

Where

fm = the target mean strength

fc = the specified characteristic strength

M = the margin

Using this value, the water/cement ratio is obtained from the graph showing the relationship between compressive strength and free water/cement ratio.

Stage 2 consists simply of determining the free water content depending upon the type and maximum size of the aggregate to give a concrete of the specified slump.

Determination of cement content

The cement content is determined from:

$$\text{Cement content} = \frac{\text{free water content}}{\text{free water/cement ratio}}$$

The resulting value should be checked against any maximum or minimum value that may be specified. If the calculated cement content is below a specified minimum, this minimum value must be adopted and a modified free water/cement ratio calculated.

Determination of total aggregate content

Stage 4 requires an estimate of the density of the fully compacted concrete which is obtained depending upon the free water content and the relative density of the combined aggregate in the saturated surface dry condition (SSD).

Total aggregate content = D – C - W

(Saturated and surface dry)

Where D = the wet density of concrete (kg/m3)

C = the cement content (kg/m3)

W = the free water content (kg/m3)

Selection of fine and coarse aggregate contents

Fine aggregate content = total aggregate content x proportion of fine Coarse aggregate = total aggregate content – fine aggregate content

Batching

Batching of the constituents of the concrete was done after the mix design of the concrete was completed and the plasticizers were added in varying proportions ranging from the recommended amount to amount both below the recommended dosage and above to determine how the concrete mix would behave before it hardened and after it has hardened.

The batching process was done so as to estimate the exact amount of concrete that would be required to carry out the compressive test on the cubes of concrete and to avoid wastage of material.

Mixing of the concrete

The concrete was mixed by hand using a flat pan where all the constituents of concrete were added. The dry contents were added 1st and thoroughly mixed then the water was added in slowly to ensure that there was an even distribution of the constituent materials throughout the mix. As the water was being added, the plasticizers were also added after being carefully measured to the concrete mix. The mixing was continuous to ensure the production of a homogenous mix.

Dosage of Plasticizer and super plasticizer to concrete mix

For the *Pozzolith Standard plasticizer*, it has a recommended dosage of 400ml to 800ml per 100kg of cement. Samples will have varied amounts of plasticizer between 400ml and 1600ml so as to see the effects of over dosage .The concrete mix will have a low water/cement ratio of 0.35, this will provide a very stiff mix so as to properly see the effects of plasticizers on a concrete mix and testing will conform to BS 5075 part 1. The slump test will also be carried out for all the samples to determine the amount of slump for each amount of treatment of the plasticizer

The plasticizer is used in concrete mixes to increase the workability of the concrete. The water/cement ratio used in the experiment was 0.35.

	Admixture Dosages (ml)		
Per 100kg Cement	400	800	1600
For 4.883 kg cement	19.5	39.1	78.13

For the Rheobuild 2000m super plasticizer, there is a recommended dosage of 1000- 3000cc per 100kg of cement for 10% reduction. Samples will be tested in increments between 1000cc and 3000cc to determine the optimal quantity of super plasticizer required. The concrete mix will have a low water/cement ratio of 0.35 this will conform to BS 5075. The slump test will be carried out for every dosage increment and the amount of slump measured in each case.

The specific design used in the experiment for the amount of plasticizer used in the mix is presented below. It represents the dosage in millilitres.

Design mix for super plasticizer Table 1.

	Admixture Dosages (ml)		
Per 100kg Cement	1000	2000	3000
For 4.883 kg cement	48.83	97.66	146.5

3.4 Slump Test Procedure.

1. A representative sample of the mix was taken from the fresh concrete
2. The inside of the cone was dampened and placed on a smooth, moist and non-absorbent level surface which was large enough to accommodate both the slumped concrete and the slump cone. The cone was secured firmly in place.
3. The cone was filled 1/3 full by volume and rodded 25 times with 5/8 inch diameter * 24 inch long hemispherical tip steel tamping rod. The rodding was distributed evenly over the entire cross section of the sample.
4. The cone was filled to 2/3 and procedure 3 was repeated with the rod penetrating into but not through the 1st layer. This procedure was repeated for the final layer in the cone.
5. The excess concrete was removed from the top of the cone using the tamping rod as a screed and overflow was cleaned from the base of the cone.
6. The cone was lifted vertically with slow even motion taking care not to jar the concrete or tilt the cone during the process. The withdrawn cone was then inverted and placed next to the slumped concrete.
7. A straight edge across the top of the slump was laid and the slump measured from the bottom of the straight edge to the top of the slumped concrete at a point over the original centre of the base.

3.5 Compaction factor test procedure

1. The sample of concrete was placed in the upper hopper up to the brim.
2. The trap-door was opened so that the concrete fell into the lower hopper.
3. The trap-door of the lower hopper was opened and the concrete was allowed to fall into the cylinder.
4. The excess concrete remaining above the top level of the cylinder was then cut off with the help of plane blades.
5. The concrete in the cylinder was weighed. This is known as weight of partially compacted concrete.
6. The cylinder was filled with a fresh sample of concrete and vibrated to obtain full compaction. The concrete in the cylinder was weighed again. This weight is known as the weight of fully compacted concrete.

Compacting factor = (Weight of partially compacted concrete)/(Weight of fully compacted concrete)

3.6 Compressive strength of concrete procedure

1. Specimens were removed from the water and when still in the wet condition were placed on the compression testing machine. Surface water and grit were wiped off the specimens and other projections
2. The specimens tested were cubes that were 100m by 100mm by 100mm
3. The bearing surface of the testing machine was wiped clean and any loose material was removed from the surface of the specimen.
4. The cubes were placed on the machine in such a manner that the load was applied to the opposite sides of the cubes as cast. The axis of the specimen was carefully aligned with the centre of thrust of the spherically seated plate.
5. As the spherically seated block was brought down to bear on the specimen, the moveable portion was rotated gently by hand so that uniform seating was obtained.
6. The load was applied without shock and it was increased continuously until the resistance of the specimen to the increasing load broke down and could take no greater applied load

7. The maximum load that caused failure in the specimen was then recorded and the appearance of the concrete and any unusual features were observed.

$$\sigma = \frac{F}{A}$$

Where: F= load applied A=area of application of load (mm2)

3.7 Tensile Test

The tensile strength of concrete is very important to concrete because concrete structures are very vulnerable to tensile cracking due to various effects and applied loading. The tensile strength of concrete is very low however compared to its compressive strength.

Due to difficulty in applying uniaxial tension to a concrete specimen, the tensile test is obtained by indirect methods. For the experiments carried out, the method used was the split cylinder test.

The split-cylinder test is a method of determining the tensile strength of concrete in an indirect way. A cylinder of 150mm by 300mm length was placed horizontally on a compression testing machine. The load was applied diametrically and uniformly along the length of the cylinder. To allow for uniform distribution of load and to avoid high compressive stress at the point of application, plywood strips were placed between the loading specimen and the compressive surface of the compression test machine. Concrete cylinders split in half along the vertical plane due to indirect tensile strength generated by poisons effect.

Due to the compressive loading, an element lying across the vertical diameter of the cylinder was subjected to compressive stress and horizontal stress. The loading conditions produce high compressive stress immediately beneath the loading points. It is estimated that the compressive stress acts to about a $1/6^{th}$ depth and the rest is subject to tensile stress due to Poisson's effect.

Assuming concrete specimen behaves as an elastic body, a uniform tensile force Ft acting along the vertical plane causes failure of the specimen which can be calculated as follows

$$Ft = \frac{2P}{\pi DL}$$

Where P = Compressive load at failure

L = length of cylinder

D = Diameter of cylinder

The above test result represent the Splitting Tensile Strength that varies between $1/8^{th}$ and a $1/12^{th}$ of the cube compressive strength results.

Chapter 4

4.0. RESULTS AND DISCUSSION

4.1 Slump test.

The slump test results were essential in determining the workability of the concrete design.

The design mix chosen was a very low slump concrete mix with a water/cement ratio of 0.35. The low water/cement ratio was chosen so as to clearly see the effects of the plasticizers and super plasticizes and how they affected the concrete workability.

4.1.1 RHEOBUILD 2000M SUPER PLASTICIZER

Table 1. Results of slump test for super plasticizer

Sample	Amount of admixture (ml)	Slump (mm)
A	0	5
B	49	50
C	98	129
D	147	170

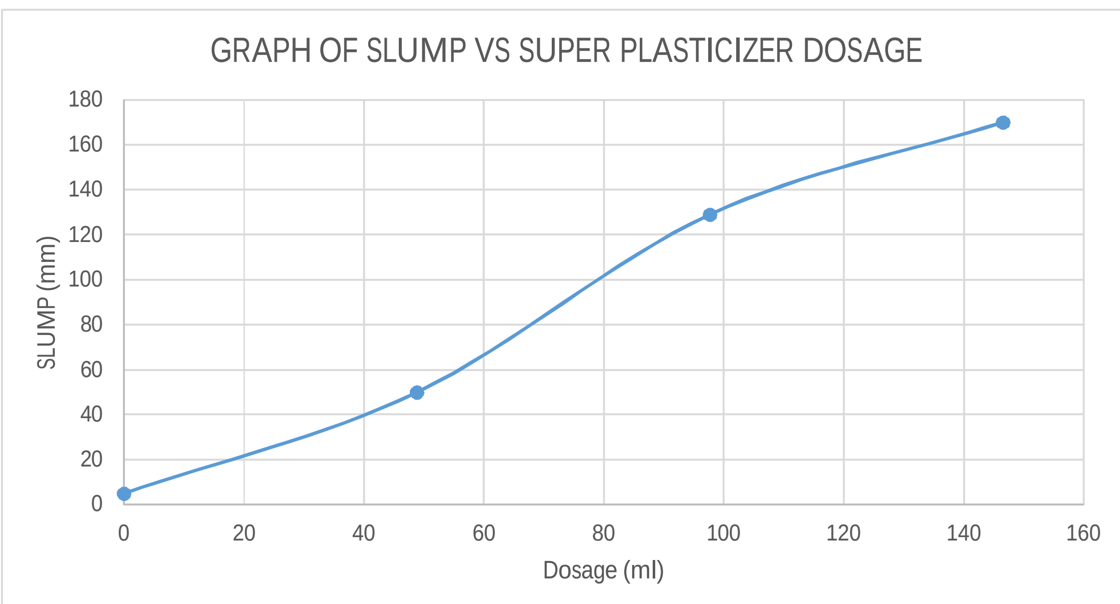

Figure 3. Graph of slump vs Super plasticizer

Figure 4. control mix with No super plasticizer added showing normal slump

Figure 5. Concrete mix with Super plasticizer added showing shear slump

From the above figure 4 and 5 it demonstrates the effects of plasticizers on the workability of the concrete. The images are for a slump test carried out.

The above graph, figure 3, it shows there was an increase in the amount of slump as the dosage of admixture was increased. This is because of the effects of the plasticizer on the particles within the mix. Rheobuild 2000M has powerful deflocculating and dispersing effects. It therefore prevents the particles from binding together after being mixed. As the dosage is increased, there is an increase in the amount of particles within the mix that get into contact with the plasticizer and therefore there is an increase in the slump of the concrete mix.

The control mix from the experiment which did not have any admixture present slumped by only 5mm. This is because the concrete mix had a very low water/cement ratio that decreased the workability of the concrete.

4.1.2 Pozzolith Standard Plasticizer

The plasticizer add mixture used for this test was *POZZOLITH STANDARD* which is a powerful plasticizer.

Results of slump test.

Table 2. Slump Test results for plasticizer

Sample	Amount of plasticizer (ml)	Slump (mm)
H	0	0
E	20	19
F	39	35
G	78	60

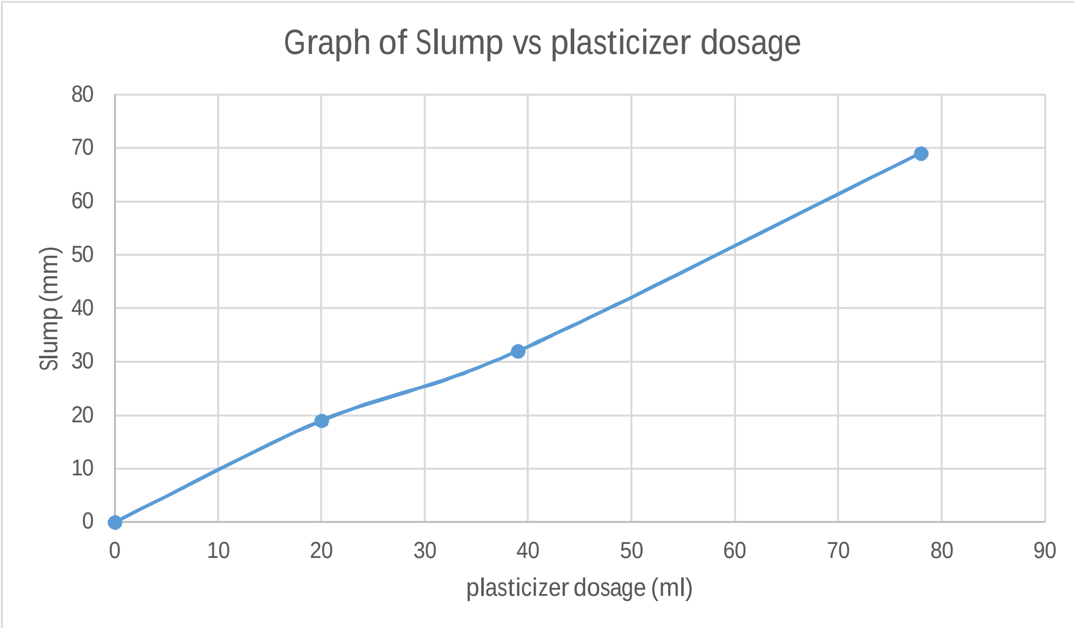

Figure 6. Graph of Slump vs Plasticizer dosage.

From figure 6 above it is observed can see that the use of the plasticizer had very little effect on the workability of the concrete mix.

The reason for the poor workability of the concrete mix is because the plasticizer was not strong enough to deflocculate and disperse the particles in the concrete mix even within the recommended dosage of the plasticizer. However as the amount was increased beyond the recommended dosage, there was a significant increase in the workability of the concrete. From the data collected we can adequately conclude that a further increase in the dosage will lead to increased workability but may have other effects on the concrete mix such as reduction in strength or may lead to segregation of the aggregates within the mix.

4.2 Result for Compaction factor

Compaction factor is an alternative way of determining the workability of a fresh concrete mix. The compaction factor was taken for all the samples containing different amounts of plasticizers and super plasticizer. The concrete mix had a water/cement ratio of 0.35

4.2.1 Super plasticizer Rheobuild 2000M

Table 3. Compaction factor results for super plasticizer

Sample	Dosage (ml)	Compaction factor
A	0 ml	0.69
B	48ml	0.84
C	98ml	0.91
D	147ml	0.95

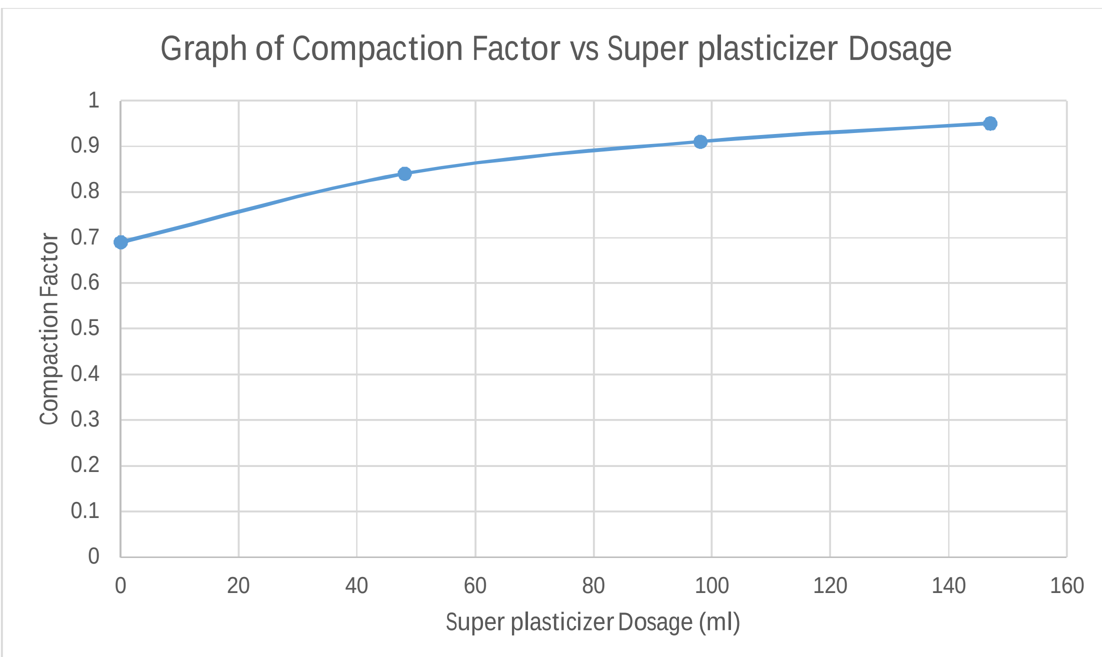

Figure 7. Graph of Compaction Factor Vs Super plasticizer Dosage

Compaction factors of below 0.7 are undesirable for concrete structures. Sample A had a very low compaction factor of 0.69 and is therefore unfavourable for construction. However during the test, some fresh concrete was observed to stick to the sides of the hoppers leading to the low compaction factor. As the dosage of super plasticizer was increased, the compaction factor increased. This was due to the strong deflocculating properties that the super plasticizer has leading to a more workable fresh concrete mix.

4.2.2 Plasticizer Pozzolith Standard

Table 4. Compaction factor results for plasticizer

Sample	Amount of plasticizer (ml)	Compaction factor
H	0	0.67
E	20	0.72
F	39	0.77
G	78	0.81

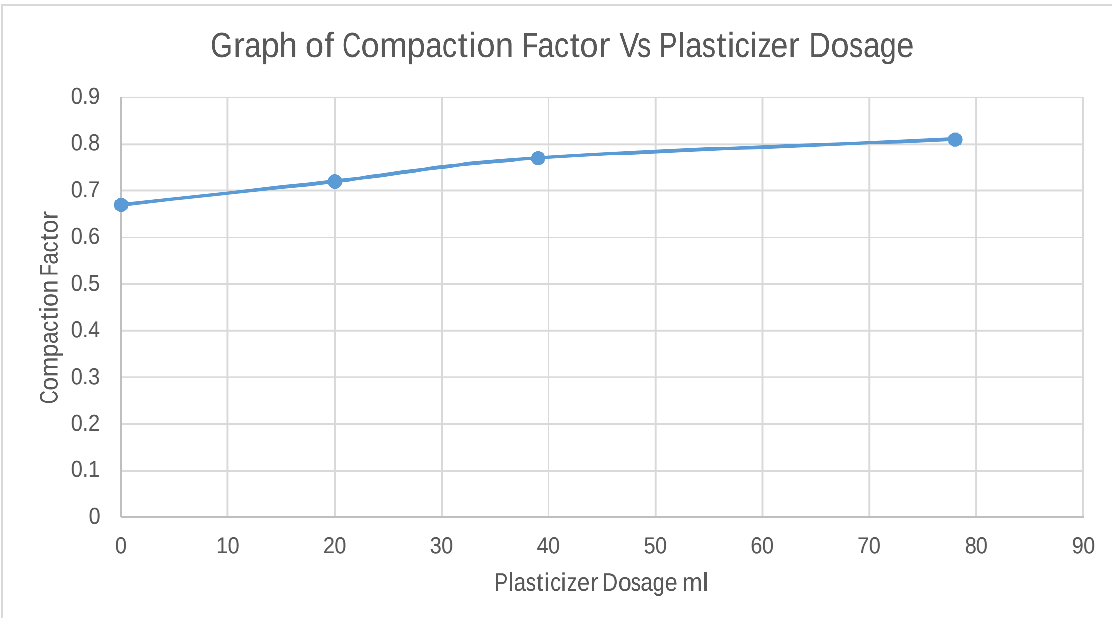

Figure 8. Graph of Compaction Factor vs Plasticizer Dosage.

The compaction factor for the samples containing the plasticizer pozzolith standard, had a very slight but steady increase compared to the samples containing the super plasticizer. This is due to the deflocculation strength of the super plasticizer which is more than that of the plasticizer. The sample containing 0 ml of plasticizer had a very low compaction factor of 0.67 which is renders the mix unsuitable.

4.3 COMPRESSIVE TEST.

The compressive strength test is essential in determining whether the use of plasticizers had any effect on the strength of concrete. The cubes used were 100mm by 100mm by 100mm.

4.3.1 Rheobuild 2000M Super Plasticizer

7 day Compressive Test

The results for the 7 day compressive test

Table 5. compressive results for 7 day for super plasticizer

Sample	Admixture added (ml)	Strength N/mm^2
A1	0	11 N/mm^2
B1	49	46 N/mm^2
C1	98	41 N/mm^2
D1	147	36 N/mm^2

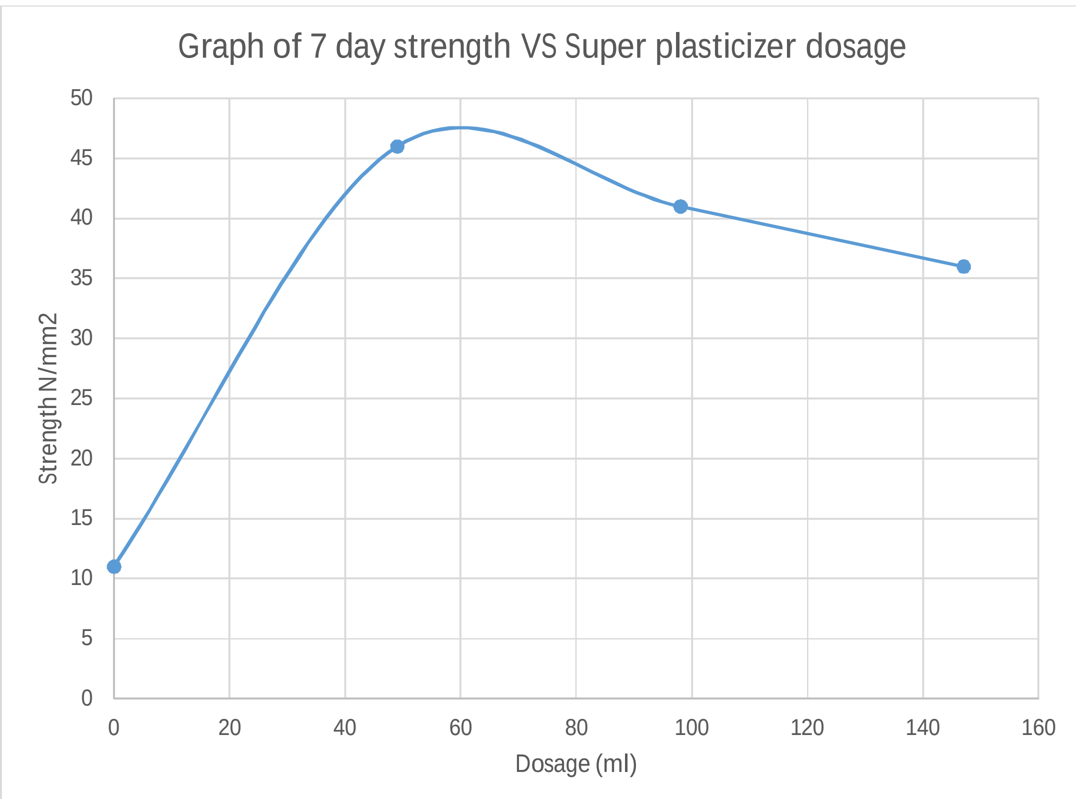

Figure 8. Graph of 7 day strength vs Super plasticizer dosage

28 day compressive test

For ever sample, there were 3 cubes cast. The average values of strength of each of the samples was then calculated and tabulated below.

Table 6. Compressive test result for 28 days for super plasticizer

Sample	Dosage (ml)	Strength average (N/mm^2)
A	0	28
B	49	48
C	98	63
D	147	37

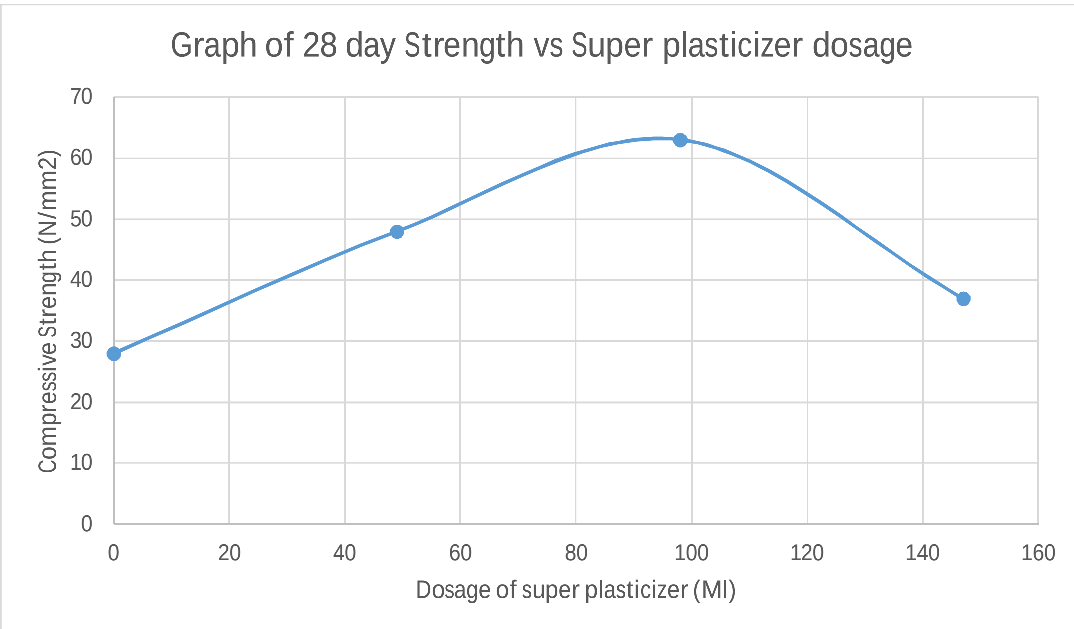

Figure 9. Graph of 28 day strength vs Super plasticizer Dosage

7 day test

From the above results and graph, we can clearly see that the use of the admixture had an increase in the 7 day strength of the hardened concrete.

The control of the experiment had a very low strength of 11 N/mm^2. The cube before testing was observed to have honey combs within the structure. This gaps within the structure led to the weakness of the concrete because the concrete had not properly settled in the mould.

The cause of the concrete not settling is because of its very stiff water/cement ratio of 0.35 which limited the workability of the concrete

Samples containing the super plasticizer had an increase in the 7 day strength test. As the amount of admixture was increased, the strength seemed to also decrease marginally. As compared to the control, the samples containing the super plasticizer had a much greater strength. The recommended dosage gave the highest strength for the concrete mix of for the 7 day test.

28 day test

The graph of the 28 day strength of the concrete cubes was similar to that of the 7 day test in terms of shape of the graph.

The control containing no super plasticizer had a lower strength compared to the samples of concrete that contained the super plasticizer. As the amount of super plasticizer was increased, there was an increase in the strength of the concrete until it reached a point where there was a slight decrease in the strength of the concrete.

For both the results for the 7 day test and the 28 day compressive tests, the observed decrease in concrete strength beyond the recommended dosage of 98ml was due to an increase in the amount of liquid in the concrete design. The increase of dosage of super plasticizer caused an increase in the water cement ratio of the samples. As the water cement ratio of a sample is increased, the strength of the concrete decreases.

4.3.2 Plasticizer (Pozzolith Standard)

Results for 7 day test

Table 7. Compressive test results for 7 day for plasticizer

Sample	Admixture dosage (ml)	Strength (N/mm^2)
H1	0	13 N/mm^2
E1	20	22 N/mm^2
F1	39	20 N/mm^2
G1	78	11 N/mm^2

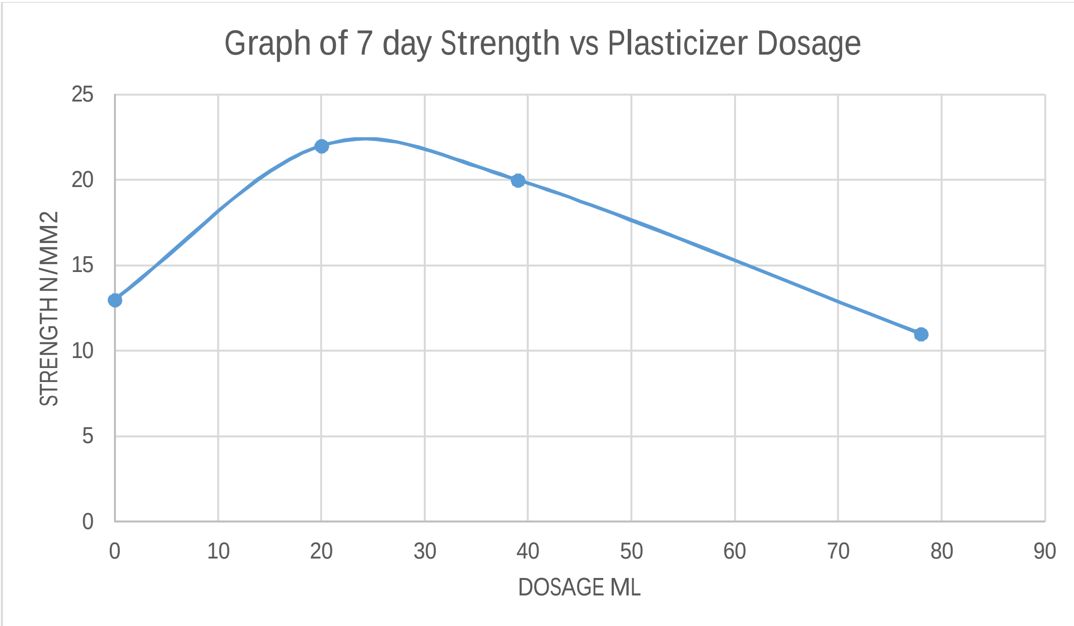

Figure 10. Graph of 7 day strength vs Plasticizer Dosage.

Results for 28 day compressive test

For ever sample, there were 3 cubes cast. The average values of strength of each of the samples was then calculated and tabulated below.

Table 8. Compressive test results for 28 day for plasticizer

Sample	Dosage (ml)	Strength average (N/mm^2)
H	0	15 N/mm^2
E	20	41 N/mm^2
F	39	43 N/mm^2
G	78	20 N/mm^2

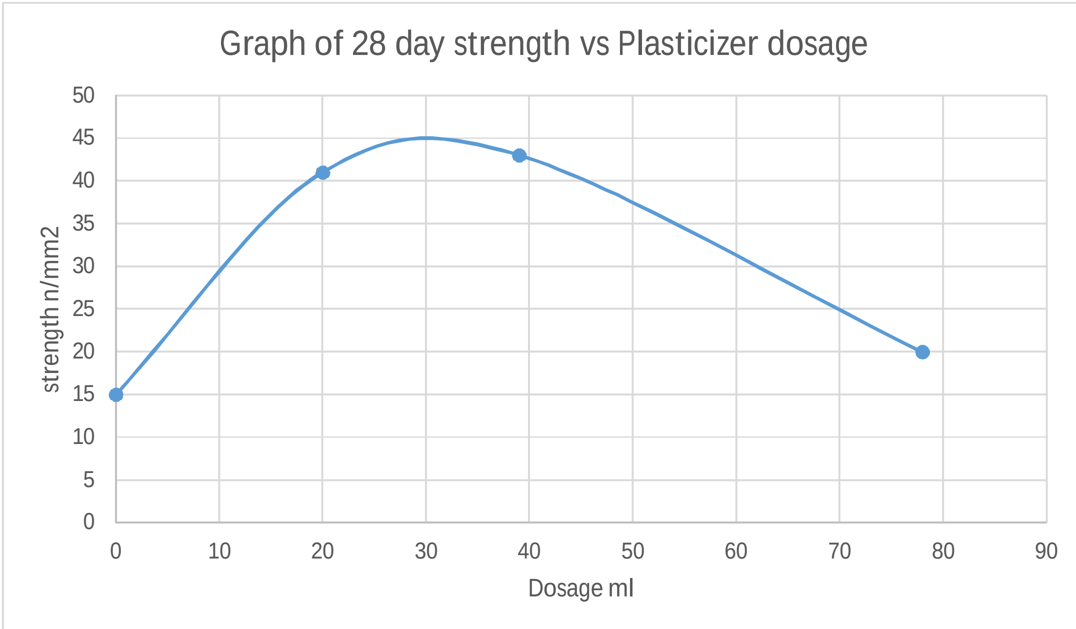

Figure 11. Graph of 28 day strength vs Plasticizer Dosage

7day test

The samples containing the plasticizer had a higher compressive strength compared to the control H1 of the experiment which contained no plasticizer. This is because the plasticizer allowed the concrete to cure faster because of its chemical composition. The cube or the control also had large number of honeycombs within its structure showing that the concrete had not settled well into the mould. This was caused by the low water/cement ratio of 0.35. This made it hard for the concrete mix to fully settle and fill all the gaps within the mould.

The sample G1 had a very low strength of 11 N/mm^2 compared to the other samples containing the plasticizer. It was also observed that the cube appeared not to have properly set compared to the other cube samples. This was caused by the use of the plasticizer in the mix which had an effect on the rate of curing when added in excess of the recommended amount. It also had an increase in the workability of the concrete and the sample had self-setting properties.

28 day test

There was an increase in the strength of the concrete after 28 days. For the control sample, before crushing was done, the cube was observed to have several honey combs within its structure. This was due to the low water cement ratio that reduced the workability of the concrete and led to the reduction of overall strength of the concrete.

For the samples containing the plasticizer, there was an increase in the strength of the concrete as the dosage was increased. However for the sample containing 78ml, there was a decrease in the 28day strength of the concrete compared to the sample containing 39 ml of the plasticizer. The strength of the concrete containing 39ml was 43 N/mm^2 while the concrete mix containing 78ml plasticizer was 20 N/mm^2 .The difference in strength is due to the increase of the amount of liquid to the concrete mix. Addition of the plasticizer increased the amount of water cement ratio therefore reducing the strength of the concrete. This factor should be considered when making a mix design so as to ensure the required strength is achieved and the plasticizer does not decrease the strength of the concrete.

For both the 7 day and 28 day test it can be seen that the optimal recommended dosage of 39ml gave the highest compressive strength.

4.4 Comparison of Strength between plasticizers and super plasticizers for 7 day and 28 day compressive strength

Table 9. Comparison between Plasticizer and super plasticizer strength

	7 day Strength		**28 day Strength**	
Dosage per mix	Plasticizers	Super plasticizers	Plasticizers	Super plasticizers
Below recommended	22 N/mm^2	46 N/mm^2	41 N/mm^2	48 N/mm^2
Recommended dosage	20 N/mm^2	41 N/mm^2	43 N/mm^2	63 N/mm^2
Above recommended dosage	11 N/mm^2	36 N/mm^2	20 N/mm^2	37 N/mm^2

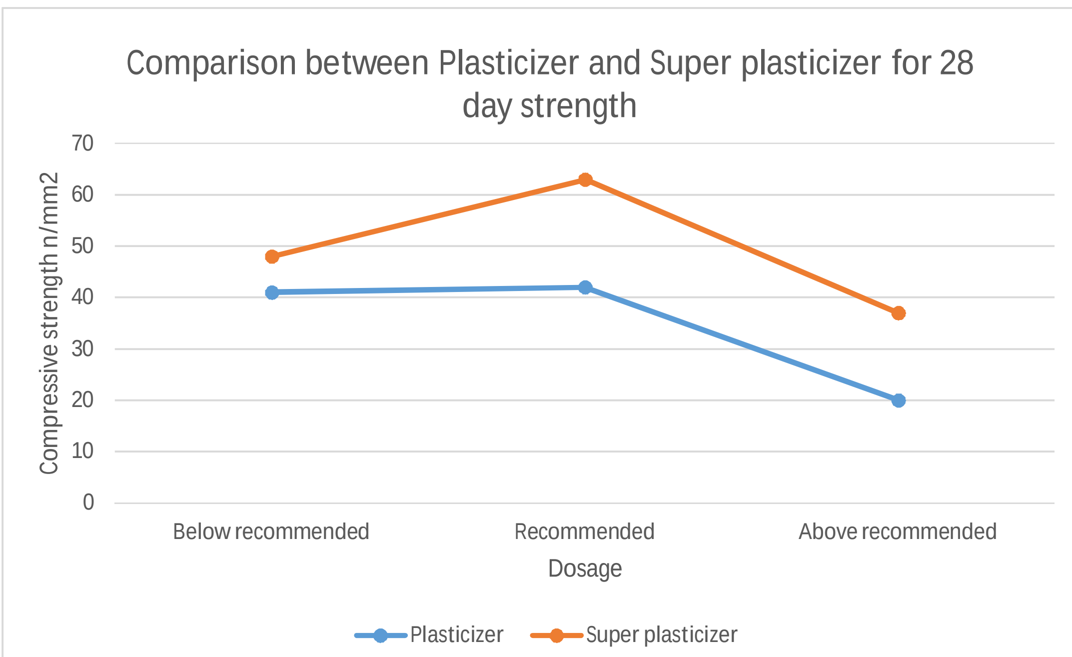

Figure 12. Comparison between plasticizer and super plasticizer for 28 day strength

Both samples had the same water cement ratio of 0.35.

It can be clearly seen that the concrete samples that contained the super plasticizer had a much higher compressive 7 day strength than the samples that contained the plasticizer. This is because the super plasticizer and plasticizers have a different chemical composition. The super plasticizer and plasticizer both catalytically increase the rate of hardening of the concrete but the super plasticizer has a stronger catalytic effect therefore has a higher compressive strength on the 7 day test.

For the 28 day results it can be seen that there was a difference in the strength of the concrete mixes. Those containing super plasticizer had a higher strength than those containing the plasticizer. This was due to the stronger deflocculating effect of the super plasticizer which caused the concrete to be more compact when being poured and therefore produced a higher compressive strength when tested.

4.5 Tensile Strength Results

This test is of considerable importance in resisting cracking due to changes in moisture content or temperature.

Results for 28 day test

Super plasticizer

Table 10. Table showing results for tensile strength of super plasticizer

Sample	Dosage (ml)	Tensile strength
A	0	2.6
B	49	4.0
C	98	5.7
D	147	3.6

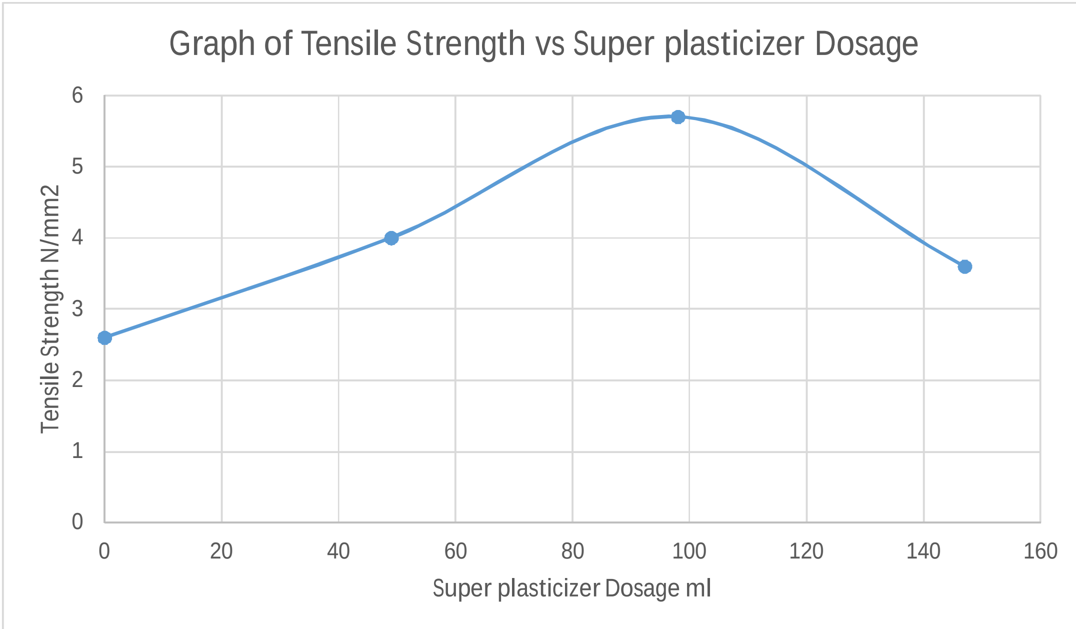

Figure 13. Graph of Tensile strength Vs Super plasticizer Dosage

From the above graph, it can be clearly seen that as the amount of super plasticizer was increased, the tensile strength of the concrete also increased. It can also be seen that after a certain amount of super plasticizer was added, the strength of the concrete reduced. This is due to the addition of the water/cement ratio caused by an increase in the super plasticizer. The use of super plasticizer increased the overall strength of the concrete mix because of its binding properties as it hardened. The sample containing 0 ml of plasticizer was observed to contain several honey combs leading to its very weak strength even though it had a low water cement ratio of 0.35. This low strength can be attributed to the poor workability of the stiff concrete mix which was very difficult to set to the final position in the mould without causing segregation of the components of the concrete mix therefore leading to honey combs in its structure.

Plasticizer

Table 11. Table showing results for Tensile Test for Plasticizer

Sample	Dosage	Tensile strength
H	0	1.5
E	20	3.9
F	39	4.1
G	78	1.8

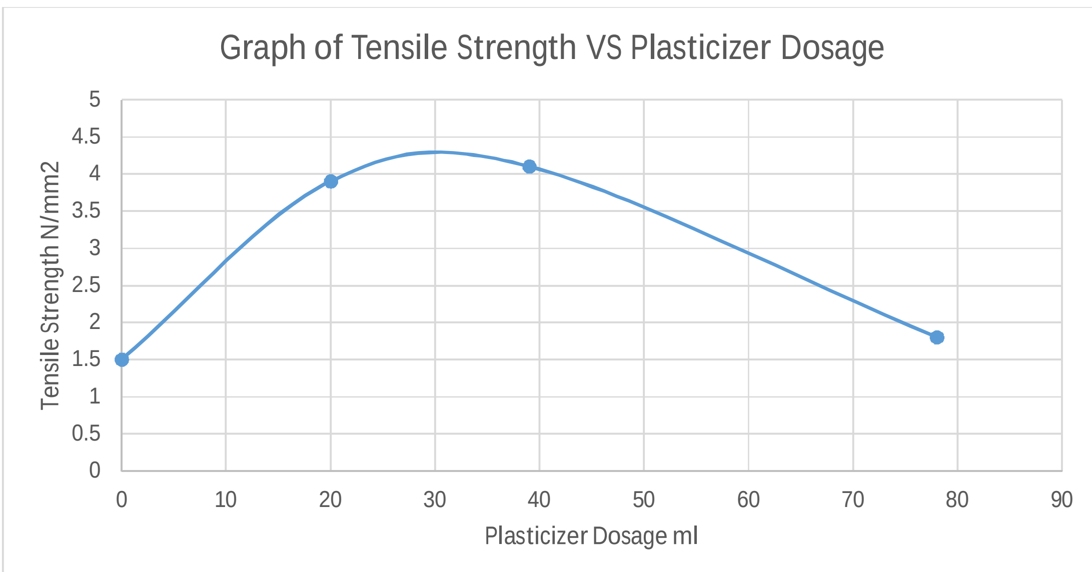

Figure 14. Graph of Tensile Strength vs Plasticizer Dosage

As the plasticizer was added to the mix, there was an increase in the strength of the tensile strength of the concrete. For the sample containing 78ml plasticizer which is excess of the recommended dosage, there was a noticeable sharp decrease in the tensile strength of the concrete. The decrease in strength was due to an increase in the fluid by the plasticizer to the concrete mix which increased the water/cement ratio leading to a decrease in the overall strength.

It can also be noted that for the concrete samples containing super plasticizer, Rheobuild 2000M had a higher overall strength for both tensile strength and compressive strength than the samples containing plasticizer Pozzolith Standard. Both mixes had a low water cement ratio of 0.35. The super plasticizer had a stronger deflocculation ability than the plasticizer therefore allowing the concrete mix to set better in the moulds by increasing its workability and reducing the formation of honey combs in the structure which reduce the overall strength of concrete.

It can also be noted that some of the sources of errors in the experiment were due to the uneven moulds used in the testing of the concrete. The shape of a structure influences the distribution of forces in the structure when a load is applied and therefore has a direct connection to the strength results.

Chapter 5.

5.0 Conclusion and Recommendations

5.1 Conclusion

The objective of the experiment carried out were achieved and below are the conclusions from the experiment.

- The use of plasticizers and super plasticizers increased the workability of the concrete mix. The super plasticizers had a more significant effect on the workability than the plasticizers.
- Plasticizers and super plasticizers improved the compaction of the concrete. The samples with the super plasticizer had self-compacting properties.
- The use of plasticizers and super plasticizers increased the overall strength of the concrete mix.
- The use of plasticizers and super plasticizers also increased the tensile strength of the concrete
- Sources of errors in the experiment were minimal and some of them were unevenly shaped moulds which had an effect on the compression strength of the concrete.

5.2 Recommendations

- Plasticizers and super plasticizers should be 1st tested before large scale use to determine their optimum dosage to a concrete mix so as to ensure the desired properties are achieved
- Super plasticizers are more expensive than plasticizers therefore plasticizers should be considered first if they can achieve the required properties of concrete. This will be more cost effective to a project.
- If self-compacting concrete is required for a project then super plasticizers should be used because of their strong deflocculating abilities compared to plasticizers.
- For projects that require quick setting concrete then super plasticizers can be used as was shown from their 7 day strength results.

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