Sudan University of Science and Technology

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The Effect of High Performance Super Plasticizer Admixture on the Strength of Concrete

تأثير الملدنات عالية الأداء علي مقاومة الخرسانة

A Thesis Submitted in Partial Fulfillment for the Degree of Master of Science in Construction Engineering at Sudan University of Science and Technology

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الآية

قال الله تعالى

﴿قَالَ يَا قَوْمِ أَرَأَيْتُمْ إِنْ كُنْتُ عَلَىٰ بَيِّنَةٍ مِنْ رَبِّي وَرَزَقَنِي مِنْهُ رِزْقًا حَسَنًا ۚ وَمَا أُرِيدُ أَنْ أُخَالِفَكُمْ إِلَىٰ مَا أَنْهَاكُمْ عَنْهُ ۚ إِنْ أُرِيدُ إِلَّا الْإِصْلَاحَ مَا اسْتَطَعْتُ ۚ وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ ۚ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ﴾

سورة هود – الآية 88

Dedication

This thesis is dedicated to:

The sake of Allah, my creator and my master

My great teacher and messenger, Mohammed (May Allah bless and grant him) who taught us the purpose of life

To my mother, my father and my brother for their support and guidance

My homeland Sudan the warmest womb

My friends who encourage and support me

All the people in my life who touch my heart, i dedicate this research

Acknowledgement

In the name of Allah, the most merciful, the most compassionate all praise be to Allah, the lord of the worlds; and prayers and peace be upon Mohamed his servant and messenger

First and foremost, i must acknowledge my limitless thanks to Allah, the ever-magnificent; the ever-thankful, for his help and bless. i am totally sure that this work would have never become truth, without his guidance.

I owe a deep debt of gratitude to our university for giving us an opportunity to complete this work

I am grateful to some people, who worked hard with me from the beginning till the completion of the present research particularly my supervisor prof. dr. **Salih Elhadi Moh-Ahmed**, who has been always generous during all phases of the research

Finally, I also would like to express my wholehearted thanks to my family for their generous support they provided me throughout my entire life and particularly through the process of pursuing the master degree. Because of their unconditional love and prayers, i have the chance to complete this thesis

Abstract

This Research outlines an experimental study that measures the effects of high performance superplasticizer admixture on the compressive strength of concrete and the workability of the fresh concrete.

The study has focused on two mixes with compressive strength of 30 and 35 MPa at different ages. These mixes used Slag Cement as binder, maximum aggregate size of 16 and 32 mm and PCA® (I) as high performance superplasticizer.

To investigate the effects of high performance superplasticizer admixture on concrete compressive strength, one control mix was prepared without addition of any admixture was used as a comparison and then seven mixes were prepared using superplasticizer admixture. The experimental works were carried out at the Dam Complex of Upper Atbara Project laboratory.

The compressive strength tests were carried out on 150*150*150 mm concrete cubes at the ages of 7, 21 and 28 days. The test results were statistically analyzed to investigate the effect of addition of high performance superplasticizer admixture on the concrete compressive strength.

The analysis have shown that the compressive Strength of concrete has increased by 52% when 1% dosage of superplasticizer admixture was used for the design compressive strength of 35 MPa, while for design compressive strength mixes of 30 MPa, it was found that the increase percent ranges from 38% to 90.33% for the same dosage of superplasticizer admixture.

The results also have demonstrated the excellent relationship (R^2=1) between the workability of concrete mix (measured using the flow test) and the superplasticizer content (in Kg/m3).

المستخلص

هذا البحث يلخص دراسة تجريبية لقياس تأثير الملدنات عالية الأداء علي مقاومة الخرسانة وقابلية التشغيل.

ركزت الدراسة على خلطتين مقاومة الضغط لهما 30 و 35 ميقا باسكال في مختلف أعمار الخرسانة . و يتم في هذه الخلطات استخدام أسمنت الخبث المعدني كمادة اسمنتية ، و استخدام ركام المقاس الأقصي له 16 و 32 ملم ، و كملدنات عالية الأداء PCA® (I).

وللتحقق من تأثير اضافة الملدنات عالية الأداء علي مقاومة الخرسانة ، تم تحضير خليطه واحده بدون إضافة أي مضاف لغرض المقارنة ، ثم تم تحضير سبعة خلطات اخري باستخدام الملدنات عالية الأداء. تم تنفيذ الأعمال التجريبية في معمل مجمع سدي اعالي عطبرة وستيت.

وتم أجراء اختبارات مقاومة الضغط على مكعبات الخرسانة 150 * 150 * 150 ملم في اعمار 7 و 21 و 28 يوم. ثم تم تحليل نتائج الاختبارات إحصائيا للتحقيق من تأثير إضافة الملدنات عالية الأداء علي مقاومة الضغط للخرسانة.

وأظهر تحليل النتائج أن مقاومة الضغط للخرسانة قد زادت عن المقاومة التصميمية بنسبة 52٪ عندما تم اضافة جرعة مقدارها 1٪ من الملدنات عالية الأداء بالنسبة للمقاومة التصميمية 35 ميقا باسكال ، و بمقدار يتراوح بين 38٪ إلى 90.33٪ بالنسبة للمقاومة التصميمية 30 ميقا باسكال.

وأظهرت النتائج أيضا علاقة جيدة ($R^2 = 1$) بين قابلية التشغيل للخرسانة (مقاسة باستخدام اختبار التدفق) و اضافة الملدنات عالية الأداء (بالكيلوجرام /م3).

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List of Abbreviations

DCUAP	The Dam Complex of Upper Atbara Project
DIU	Dams implementation unit
PCA® (I)	a polycarboxylate polymer-based composite admixture
SMF	Sulphonated Melamine Formaldehyde Condensates
SNF	Sulphonated Naphthalene Formaldehyde Condensates
SP	Superplasticizers admixture
GGBFS	Ground Granulated Blast Furnace Slag (cement)
ASTM	American Society for Testing and Materials
ACI	American Concrete Institute
BS	British Standards
EN	This British Standard is the official English language version

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

In the world, about 90-95 percent of the construction materials market for both structural and non-structural applications is made of concrete compared with other materials used for similar functions. Concrete, generally, is a product made from cement, water and aggregates and an additional material known as admixture, is sometimes added to modify certain properties of concrete.

Today superplasticizers are used in all important projects across the world in high raise buildings, prestressed concrete, slender components with congested and densely packed reinforcement, beams. And slabs pre-cast elements and long slender columns.

Cement is the chemically active constituent but its reactivity is only brought into effect upon mixing with water. The aggregate plays no important roles in chemical reaction but its usefulness arises because it is an economical filler material or hard composite material with good resistance to volume changes which take place within the concrete after mixing, besides improving durability of concrete. In hardened state, concrete is a rock like material with a high compressive strength. In its plastic state, concrete may be moulded into any form of shapes, it may be used to advantages architecturally or solely for decorative purposes. Concrete has low tensile strength, and hence, this is the reason why it is used with steel bar to resist any tensile forces in the reinforced concrete. However, concrete is usually used in building for foundations, columns, beams and slabs, in shell structures, bridges, sewerage treatment plants, roads, cooling towers, railway sleepers and so on.

The ready mixed concrete producers are using a superplasticizier admixture like PCA (I) which is readily available from various manufacturers. Superplasticiser is used to increase the workability without changing the water/ cement ratio. Or, it can be used to increase the ultimate strength of concrete by reducing water content while maintaining adequate workability. Superplasticizer is a type of water reducers; however, the difference between superplasticizer and water reducer is that superplasticizer will significantly reduce the water required for concrete mixing .

Effects of superplasticizer are obvious, i.e. to produce concrete with a very high workability or concrete with a very high strength.

It has long been a concrete technologist's dream to discover method of making concrete at the lowest possible water/cement ratio while maintaining a high workability. To a considerable extent this dream has been fulfilled with the advent of superplasticizers. Have indeed added a new dimension to the application of admixtures with regards to production of high strength.

In this study explain how to increase the compressive strength of concrete by using superplasticizers admixture. And increased the workability by addition of superplasticizer admixture.

The data was taken from The Dam Complex of Upper Atbara Project (DCUAP) results.

1.2 Problem Statement

The problem of this research is how to produce concrete using Superplasticizer admixture. This problem is how Superplasticizer admixture Effect on:

- The strength development of concrete.
- The workability of concrete.

1.3 Research objectives

The purpose of this research how the compressive strength and workability of concrete increases with the use of superplasticizers admixture.

This Research outlines an experimental study that measures the effects of superplasticizer admixture on the compressive strength of concrete and the workability of the fresh concrete. Besides determining the optimum dosage for Superplasticizers admixture of concrete mix.

1.4 Research Question and Hypotheses

- How to increase the compressive strength of concrete by using superplasticizers admixture?
- Are the values of compressive strength by using different dosage of superplasticizer is higher than the concrete without adding Superplasticizers admixture?

- Is the workability of concrete can be increased by addition of superplasticizer?

1.5 Research mythology

To investigate the effect of superplasticizers admixture of the concrete compressive strength with used compressive strength tests of [150*150*150 mm] cubes at the ages of 7, 21 and 28 days.

To investigate the effect of Superplasticizer on workability of concrete slump and flow tests were checked.

To collect data trial mixes were prepared by varying the dosage of Superplasticizer admixture. In order to investigate characteristics of fresh state of mix proportion with varying dosages of Superplasticizer.

After that Analysis this results by the computer program like Microsoft excel.

1.6 The expected results

The increase of compressive strength of the concrete with used superplasticizers admixture. And the workability of concrete can be increased by addition of superplasticizer.

1.7 Thesis Structure

This thesis has been structured as follow:

Chapter one is taking about the Research importance, the aim of this research, Research question and hypotheses, Statements of the problem and the expected results. The content of chapter (2). Taking about Concrete, Admixtures and superplasticizers admixture. The content of chapter (3). Introduction, Materials Used and Properties and experimental program. The content of chapter (4). Introductions, Compressive Strength results, the slump and flow test results and the results and discussion. The content of chapter (5). In the end of the study, Conclusions and recommendations.

CHAPTER TWO
LITERATURE REVIEW

2.1 Concrete

2.1.1 Introduction

Concrete is a composite material composed of coarse aggregate bonded together with fluid cement that hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements, such as cimentfondu. However, asphalt concrete, which is frequently used for road surfaces, is also a type of concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer. When aggregate is mixed together with dry Portland cement and water, the mixture forms a fluid mass that is easily molded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix that binds the materials together into a durable stone-like material that has many uses. Often, additives (such as pozzolans or superplasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete. Famous concrete structures include the Hoover Dam, the Panama Canal, and the Roman Pantheon. The earliest large-scale users of concrete technology were the ancient Romans, and concrete was widely used in the Roman Empire. The Colosseum in Rome was built largely of concrete, and the concrete dome of the Pantheon is the world's largest unreinforced concrete dome. Today, large concrete structures (for example, dams and multi-storey car parks) are usually made with reinforced concrete. After the Roman Empire collapsed, use of concrete became rare until the technology was redeveloped in the mid-18th century. Today, concrete is the most widely used man-made material (measured by tonnage). The word concrete comes from the Latin word "concretus" (meaning compact or condensed), the perfect passive participle of "concrescere", from "con-" (together) and "crescere" (to grow). InMiddle Ages after the Roman Empire, the use of burned lime and pozzolana was greatly reduced until the technique was all but forgotten between 500 and the 14th century. From the 14th century to the mid-18th century, the use of cement gradually returned. The Canal du Midi was built using concrete in 1670[1] .

2.2 Composition of concrete

Many types of concrete are available, distinguished by the proportions of the main ingredients below. In this way or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application. Strength, density, as well chemical and thermal resistance are variables. Aggregate consists of large chunks of material in a concrete mix, generally a coarse gravel or crushed rocks such as limestone, or granite, along with finer materials such as sand. Cement, most commonly Portland cement, is associated with the general term "concrete." A range of materials can be used as the cement in concrete. One of the most familiar of these alternative cements is asphalt concrete. Other cementitious materials such as fly ash and slag cement, are sometimes added as mineral admixtures (see below) - either pre-blended with the cement or directly as a concrete component - and become a part of the binder for the aggregate. To produce concrete from most cements (excluding asphalt), water is mixed with the dry powder and aggregate, which produces a semi-liquid that workers can shape, typically by pouring it into a form. The concrete solidifies and hardens through a chemical process called hydration. The water reacts with the cement, which bonds the other components together, creating a robust stone-like material. Chemical admixtures are added to achieve varied properties. These ingredients may accelerate or slow down the rate at which the concrete hardens, and impart many other useful properties including increased tensile strength, entrainment of air, and/or water resistance. Reinforcement is often included in concrete. Concrete can be formulated with high compressive strength, but always has lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension, often steel. Mineral admixtures are becoming more popular in recent decades. The use of recycled materials as concrete ingredients has been gaining popularity because of increasingly stringent environmental legislation, and the discovery that such materials often have complementary and valuable properties. The most conspicuous of these are fly ash, a by-product of coal-fired power plants, ground granulated blast furnace slag, a byproduct of steelmaking, and silica fume, a byproduct of industrial electric arc furnaces. The use of these materials in concrete reduces the amount of

[1] https://en.wikipedia.org/wiki/Concrete

resources required, as the mineral admixtures act as a partial cement replacement. This displaces some cement production, an energetically expensive and environmentally problematic process, while reducing the amount of industrial waste that must be disposed of. Mineral admixtures can be pre-blended with the cement during its production for sale and use as blended cement, or mixed directly with other components when the concrete is produced. The mix design depends on the type of structure being built, how the concrete is mixed and delivered, and how it is placed to form the structure.

2.2.1 Cement

A few tons of bagged cement. This amount represents about two minutes of output from a 10,000 ton per day cement kiln. Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and many plasters. English masonry worker Joseph Aspdin patented Portland cement in 1824. It was named because of the similarity of its color to Portland limestone, quarried from the English Isle of Portland and used extensively in London architecture. It consists of a mixture of calcium silicates (alite, belite), aluminates and ferrites - compounds which combine calcium, silicon, aluminum and iron in forms which will react with water. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay and/or shale (a source of silicon, aluminum and iron) and grinding this product (called clinker) with a source of sulfate (most commonly gypsum). In modern cement kilns many advanced features are used to lower the fuel consumption per ton of clinker produced. Cement kilns are extremely large, complex, and inherently dusty industrial installations, and have emissions which must be controlled. Of the various ingredients used to produce a given quantity of concrete, the cement is the most energetically expensive. Even complex and efficient kilns require 3.3 to 3.6 gigajoules of energy to produce a ton of clinker and then grind it into cement. Many kilns can be fueled with difficult-to-dispose-of wastes; the most common being used tires. The extremely high temperatures and long periods of time at those temperatures allow cement kilns to efficiently and completely burn even difficult-to-use fuels.

2.2.2 Water

Combining water with a cementations material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. A lower water-to-cement ratio yields a stronger, more durable concrete, whereas more water gives a freer-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete to form a solid mass.

2.2.3 Aggregates

Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are used mainly for this purpose. Recycled aggregates (from construction, demolition, and excavation waste) are increasingly used as partial replacements for natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted. The size distribution of the aggregate determines how much binder is required. Aggregate with a very even size distribution has the biggest gaps whereas adding aggregate with smaller particles tends to fill these gaps. The binder must fill the gaps between the aggregate as well as pasting the surfaces of the aggregate together, and is typically the most expensive component. Thus variation in sizes of the aggregate reduces the cost of concrete. The aggregate is nearly always stronger than the binder, so its use does not negatively affect the strength of the concrete. Redistribution of aggregates after compaction often creates inhomogeneity due to the influence of vibration. This can lead to strength gradients. Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative "exposed aggregate" finish, popular among landscape designers. In addition to being decorative, exposed aggregate may add robustness to a concrete[2].

Figure 2-1: Crushed stone aggregate

[2] https://en.wikipedia.org/wiki/Concrete

2.2.4 Reinforcement

Constructing a rebar cage. This cage will be permanently embedded in poured concrete to create a reinforced concrete structure. Concrete is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. Reinforced concrete adds either steel reinforcing bars, steel fibers, glass fibers, or plastic fibers to carry tensile loads.

2.2.5 Admixtures

A material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to impart/ improve desirable properties of concrete or to minimize/ modify undesirable properties of concrete. The properties commonly modified are the heat of hydration, acceleration or retardation of setting time, workability, water reduction, dispersion and air-entrainment, impermeability and durability factors.

Concrete should be workable, finishable, strong, durable, watertight, and wear resistant. These qualities can often be obtained easily and economically by the selection of suitable materials rather than by resorting to admixtures. It should be borne in mind that no admixture of any type or amount can be considered a substitute for good concreting practice.

The major reasons for using admixtures are:

1. To reduce the cost of concrete construction
2. To achieve certain properties in concrete more effectively than by other means
3. To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions
4. To overcome certain emergencies during concreting operations

2.3 Types of Admixtures

2.3.1 Chemical admixtures

A. Water-reducing admixture / Plasticizers

These admixtures are used for following purposes:

1. To achieve higher strength by decreasing the water cement ratio keeping the workability at the same level.

2. To decrease the cement content so as to reduce the heat of hydration in mass concrete/ reduce cost, keeping the strength at same level.
3. To increase the workability so as to ease placing in inaccessible locations.

Plasticizers are commonly manufactured from pop lignosulfonates, a by-product from the paper industry. Super plasticizers have generally been manufactured from sulfonated naphthalene condensate or sulfonated melamine formaldehyde, although newer products based on polycarboxylic ethers are now available. Traditional lignosulfonate-based plasticizers, naphthalene and melamine sulfonate-based super plasticizers disperse the flocculated cement particles through a mechanism of electrostatic repulsion. In normal plasticizers, the active substances are adsorbed on to the cement particles, giving them a negative charge, which leads to repulsion between particles. Lignin, naphthalene and melaminesulfonate superplasticizers are organic polymers. The long molecules wrap themselves around the cement particles, giving them a highly negative charge so that they repel each other.

Polycarboxylateether superplasticizer (PCE) or just polycarboxylate (PC), work differently from sulfonate-based superplasticizers, giving cement dispersion by steric stabilisation, instead of electrostatic repulsion. This form of dispersion is more powerful in its effect and gives improved workability retention to the cementitious mix.

Dispersion: Surface active agents alter the physical-chemical forces at the interface. They are adsorbed on the cement particles, giving them a negative charge which leads to creation of particle to particle repulsive forces. The repulsive force which overcomes the attractive force is called as Zeta Potential. The overall result is that the cement particles are deflocculated and dispersed. This releases the water trapped inside the flock which is now available to fluidify the mix.

Lubrication: These agents lubricate the mix reducing the inter-particle friction thus increasing the workability. Retardation: A thin layer is formed over the cement particles protecting them from hydration and increasing the setting time. Most normal plasticizers are also retarders to some degree[3].

[3] ASTM C 494, “Standard Specification for Chemical Admixtures for Concrete

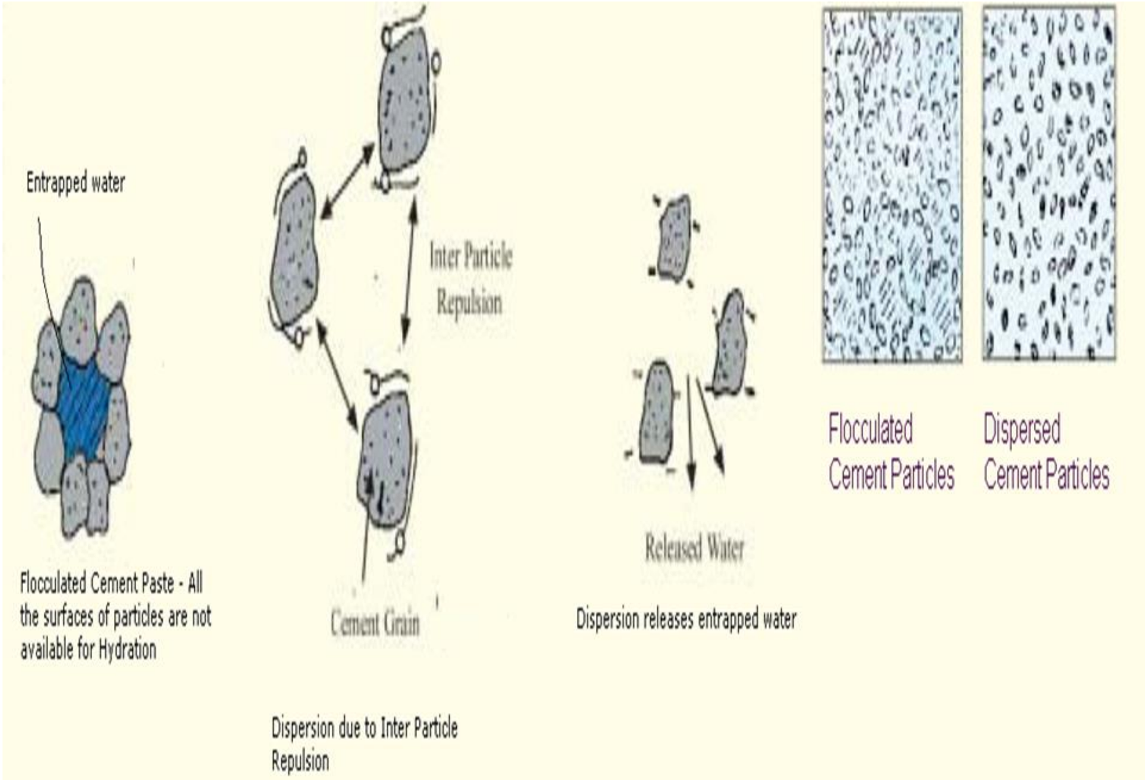

Figure 2-2 Explain Actions of Plasticizers

B. Super Plasticizers:

These are more recent and more effective type of water reducing admixtures also known as high range water reducer. These were developed during 1960s. Superplasticizers allow upto 30% reduction in water content, allowing w/c ratios as low as 0.25. The main benefits of super plasticizers can be summarized as follows:

- Increased fluidity:
- Flowing, Self-leveling, Self-compacting concrete
- Penetration and compaction around dense reinforcement
- Reduced W/C ratio, resulting in :

1. Very high early strength,
2. Very high later age strengths (>100 MPa.)
3. Reduced shrinkage, especially if combined with reduced cement content.
4. Improved durability by removing water to reduce permeability and diffusion.

The commonly used Super Plasticizers are as follows:

1. Sulphonated Melamine Formaldehyde Condensates (SMF): Give 16–25%+ water reduction with little or no retardation, which makes them very effective at low temperatures or where early strength is most critical. However, at higher temperatures, they lose workability relatively quickly. SMF generally give a good finish and are colorless, giving no staining in white concrete. They are therefore often used where appearance is important.
2. Sulphonated Naphthalene Formaldehyde Condensates (SNF): Typically give 16–25%+ water reduction. They tend to increase the entrapment of larger, unstable air bubbles. This can improve cohesion but may lead to more surface defects. Retardation is more than that with SMF but still does not normally exceed 90 minutes. SNF is very cost-effective.
3. Polycarboxylate Ether Superplasticizers (PCE): Typically give 20–35%+ water reduction. They are relatively expensive per liter but are very powerful so a lower dose (or more dilute solution) is normally used.

Commercially available water-reducing admixtures categorized by basic or primary ingredients, are as follows:

1. Lignosulfonic acids and their salts.
2. Hydroxylated polymers
3. Hydroxylated carboxylic acids and their salts.
4. Sulfonated melamine or naphthalene formaldehyde condensates
5. Polyether-polycarboxylates.

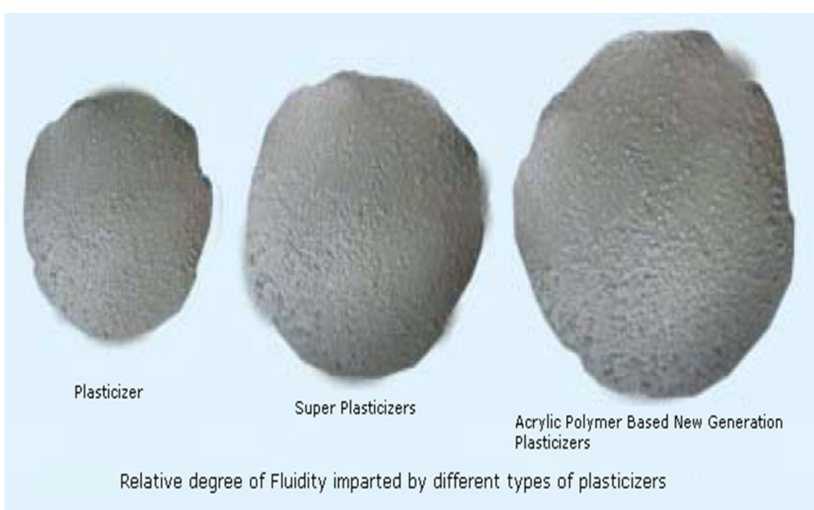

Figure 2-3 Explain relative degree of fluidity imparted by different types of plasticizer

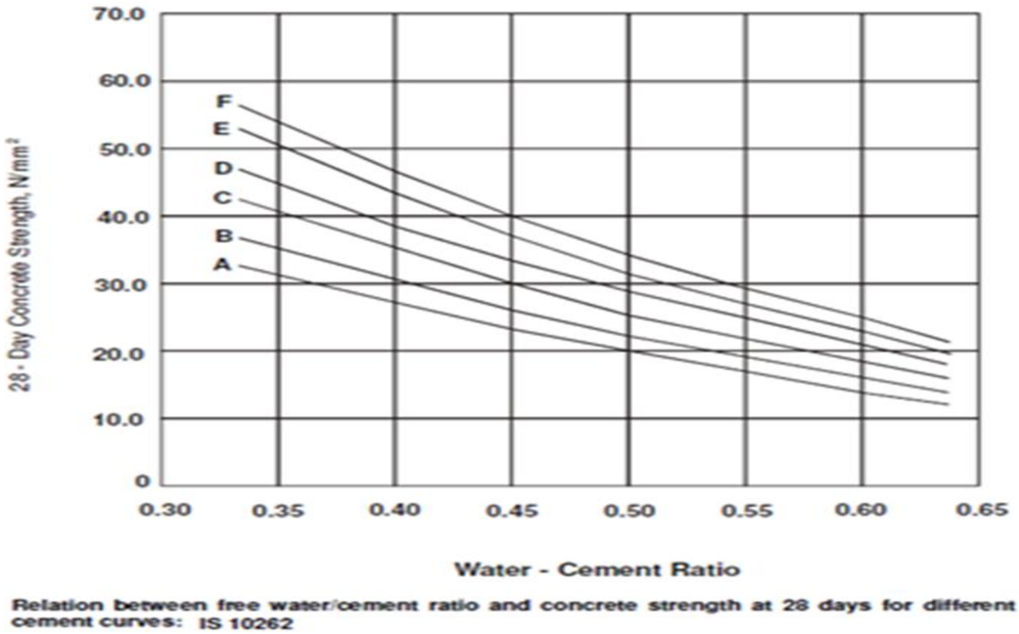

Figure 2-4 Explain relation between water and cement ratio

ASTM Classification of Water-Reducing Admixtures[4]

- ❖ Water-reducing admixtures are used to reduce the quantity of mixing water required to produce concrete of a certain slump, reduce water-cement ratio, reduce cement content, or increase slump. Typical water reducers reduce the water content by approximately 5% to 10%. Adding a water-reducing admixture to concrete without reducing the water content can produce a mixture with a higher slump.

An increase in strength is generally obtained with water-reducing admixtures as the water-cement ratio is reduced.

For concretes of equal cement content, air content, and slump, the 28-day strength of a water-reduced concrete containing a water reducer can be 10% to 25% greater than concrete without the admixture. Water-reducing admixtures may cause small increases in drying shrinkage. Using a water reducer, while maintaining a constant water-cement ratio, can result in equal or reduced compressive strength.

ASTM C 494, "Standard Specification for Chemical Admixtures for Concrete," classifies admixtures into seven types as follows:

[4] (American Society for Testing and Materials)

1. Type A Water-reducing admixtures;
2. Type B Retarding admixtures;
3. Type C Accelerating admixtures;
4. Type D Water-reducing and retarding admixture;
5. Type E Water-reducing and accelerating admixtures;
6. Type F Water-reducing, high-range, admixtures; and
7. Type G Water-reducing, high-range, and retarding admixtures.

Each of the seven types of admixtures covered by ASTM C 494 is designed to function in a specific manner. Type A water reducers can have little effect on setting, while Type D admixtures provide water reduction with retardation, and Type E admixtures provide water reduction with accelerated setting. Type D water-reducing admixtures usually retard the setting time of concrete by one to three hours. Some water-reducing admixtures may also entrain some air in concrete. Lignin-based admixtures can increase air contents by 1 to 2 percentage points. Concretes with water reducers generally have good air retention.

- ❖ MID-RANGE WATER REDUCING ADMIXTURES

Mid-range water reducers were first introduced in 1984. These admixtures provide significant water reduction (between 6 and 12%) for concretes with slumps of 125 to 200 mm (5 to 8 in.) without the retardation associated with high dosages of conventional (normal) water reducers. Normal water reducers are intended for concretes with slumps of 100 to 125 mm (4 to 5 in.). Mid-range water reducers can be used to reduce stickiness and improve finishability, pumpability, and placeability of concretes containing silica fume and other supplementary cementing materials.

- ❖ HIGH-RANGE WATER REDUCING ADMIXTURES (HRWR) or Superplasticizers

The mechanism of action of superplasticizers is more or less same as in case of ordinary plasticizer. Only thing is that the superplasticizers are more powerful as dispersing agents and are therefore called as high range water reducers.

High-range water reducers, ASTM C 494 Types F (water reducing) and G (water reducing and retarding), 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 30% can be obtained through the use of these admixtures. The reduced water content and water-cement ratio can produce concretes with

(1) Ultimate compressive strengths in excess of 70 MPa,

(2) Increased early strength gain,

(3) Reduced chloride-ion penetration, and

(4) Other beneficial properties associated with low water-cement ratio concrete.

POTENTIAL ADVANTAGES OF HRWR ADMIXTURES:

1. Significant water reduction;
2. Reduced cement contents;
3. Increased workability;
4. Reduced effort required for placement;
5. More effective use of cement;
6. More rapid rate of early strength development;
7. Increased long-term strength; and
8. Reduced permeability.

POTENTIAL DISADVANTAGES OF HRWR ADMIXTURES:

1. Additional admixture cost;
2. Slump loss greater than conventional concrete;
3. Modification of air-entraining admixture dosage;
4. Less responsive with some cement;
5. Mild discoloration of light-colored concrete; and
6. Air-void and color blemishes on exposed and formed finishes.

C. Accelerators

An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set in concrete, or increases the rate of hardening or strength development.

Accelerating admixtures can be divided into groups based on their performance and application:

1. Set Accelerating Admixtures: Reduce the time for the mix to change from the plastic to the hardened state. Set accelerators have relatively limited use, mainly to produce an early set.
2. Hardening Accelerators: Hardening Accelerators increase the 24 hours strength by at least 120% and 48 hours strength by at least 130%. Hardening accelerators find use where early stripping of

shuttering or very early access to pavements is required. They are often used in combination with a high range water reducer, especially in cold conditions.

D. Set Retarders

The function of retarder is to delay setting or extend the setting time of cement paste in concrete. These are helpful for concrete that has to be transported a long distance, and helpful in placing the concrete at high temperatures.

When water is first added to cement there is a rapid initial hydration reaction, after which there is little formation of further hydrates for typically 2–3 hours. The exact time depends mainly on the cement type and the temperature. This is called the dormant period when the concrete is plastic and can be placed. At the end of the dormant period, the hydration rate increases and a lot of calcium silicate hydrate and calcium hydroxide is formed relatively quickly. This corresponds to the setting time of the concrete.

Retarding admixtures delay the end of the dormant period and the start of setting and hardening. This is useful when used along with the plasticizers to give workability retention. Used on their own, retarders allow later vibration of the concrete to prevent the formation of cold joints between layers of concrete placed with a significant delay between them.

Retarders are used to:

1. Offset the accelerating effect of hot weather on the setting of concrete.
2. Delay the initial set of concrete or grout when difficult or unusual conditions of placement occur, such as placing concrete in large piers and foundations, cementing oil wells, or pumping grout or concrete over considerable distances
3. Delay the set for special finishing techniques.

E. Air Entraining Admixtures

An addition for hydraulic cement or an admixture for concrete or mortar which causes air, usually in small quantity, to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase its workability and frost resistance.

An air-entraining cement is a portland cement with an air-entraining addition interground with the clinker during manufacture. An air-entraining admixture, on the other hand, is added directly to the concrete materials either before or during mixing.

Air-entraining admixtures are surfactants that change the surface tension of the water. Traditionally, they were based on fatty acid salts or vinsol resin but these have largely been replaced by synthetic surfactants or blends of surfactants to give improved stability and void characteristics to the entrained air.

Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. These include:

1. Resistance to freeze–thaw action in the hardened concrete.
2. Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.
3. Compaction of low workability mixes including semi-dry concrete.
4. Stability of extruded concrete.
5. Cohesion and handling properties in bedding mortars.

F. Damp Proofing & Water Proofing Admixtures

In practice one of the most important requirements of concrete is that it must be impervious to water under two conditions, firstly, when subjected to pressure of water on one side(water proof), secondly, to the absorption of surface water by capillary action (damp proof). Concrete, carefully designed, efficiently executed with sound materials will be impermeable to water. However, since the usual design, placing, curing and in general the various operations involved at the site of work leave much to be desired, it is accepted that a use of admixtures may prove to be of some advantage in reducing the permeability.

It is to be noted that the use of admixture should not be treated as a substitute for bad materials, bad design or workmanship. In no case can an admixture be expected to compensate for cracks or large voids in concrete causing permeability.

Waterproofing admixtures may be obtained in powder, paste or liquid form and may consist of pore filling or water repellent materials. The chief materials in the pore filling class are silicate of soda, aluminum and zinc sulphates and aluminum and calcium chloride. These are chemically active pore fillers. In addition they also accelerate the setting time of concrete and thus render the concrete more impervious at early age.

The chemically inactive pore filling materials are chalk, fullers earth and talc. These are used in a very finely ground form. Their chief action is to improve the workability and to facilitate the reduction of water for given workability and to make dense concrete which is basically impervious.

2.3.2 Mineral Admixtures

Types of Mineral Admixtures

i. Cementations

These have cementing properties themselves. For example:

Ground granulated blast furnace slag (GGBFS)

A. Ground Granulated Blast Furnace Slag (GGBFS)

The impurities in the molten iron ore come to its surface. These impurities are removed. This removed material is called slag. It consists mainly of the silicates and alumino-silicates of calcium, which are formed in the blast furnace in molten form (a by-product of iron and steel making). The blast furnace slag is rapidly cooled (quenched) by immersion in water. It is a granular product, highly cementitious in nature when ground to cement fineness, hydrates like Portland cement. Blast furnace slag is blended with Portland cement clinker to form Portland Blast Furnace Slag Cement.

GGBFS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBFS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its contribution to concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

Concrete made with GGBFS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBFS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rise, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

- Benefits:
  1. Durability
  2. GGBFS cement is routinely specified in concrete to provide protection against both sulphate attack and chloride attack
  3. GGBFS is also routinely used to limit the temperature rise in large concrete pours. The more gradual hydration of GGBFS cement generates both lower peak and less total overall heat than Portland cement.
  4. Appearance: In contrast to the stony grey appearance of concrete made with Portland cement, the near-white color of GGBFS cement permits architects to achieve a lighter colour for exposed fair-faced concrete finishes, at no extra cost.
  5. Higher Strength: Concrete containing GGBFS cement has a higher ultimate strength than concrete made with Portland cement. It has a higher proportion of the strength-enhancing Calcium Silicate Hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength. Concrete made with GGBFS continues to gain strength over time, and has been shown to double its 28 day strength over periods of 10 to 12 years.

ii. Pozzolanic

A pozzolan is a material which, when combined with calcium hydroxide (lime), exhibits cementations properties. Pozzolans are commonly used as an addition (the technical term is "cement extender") to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete and in some cases reduce the material cost of concrete. Examples are

A. Fly Ash

Fly ash is finely divided residue resulting from the combustion of ground or powdered coal. Fly ash is generally captured from the chimneys of coal-fired power plants; it has POZZOLANIC properties, and is sometimes blended with cement for this reason.

Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Toxic constituents include arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium.

- ❖ Classification of Fly Ash

Class F Fly Ash: The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 10% lime (CaO). The glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementations compounds.

Class C Fly Ash: Fly ash produced from the burning of younger lignite or subbituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes.

In addition to economic and ecological benefits, the use of fly ash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali-aggregate reaction, and enhances sulfate resistance. Even though the use of fly ash in concrete has increased in the last 20 years, less than 20% of the fly ash collected was used in the cement and concrete industries.

- ❖ Effect of Fly Ash on Fresh Concrete

Use of right quality fly ash, results in reduction of water demand for desired slump. With the reduction of unit water content, bleeding and drying shrinkage will also be reduced. Since fly ash is not highly reactive, the heat of hydration can be reduced through replacement of part of the cement with fly ash.

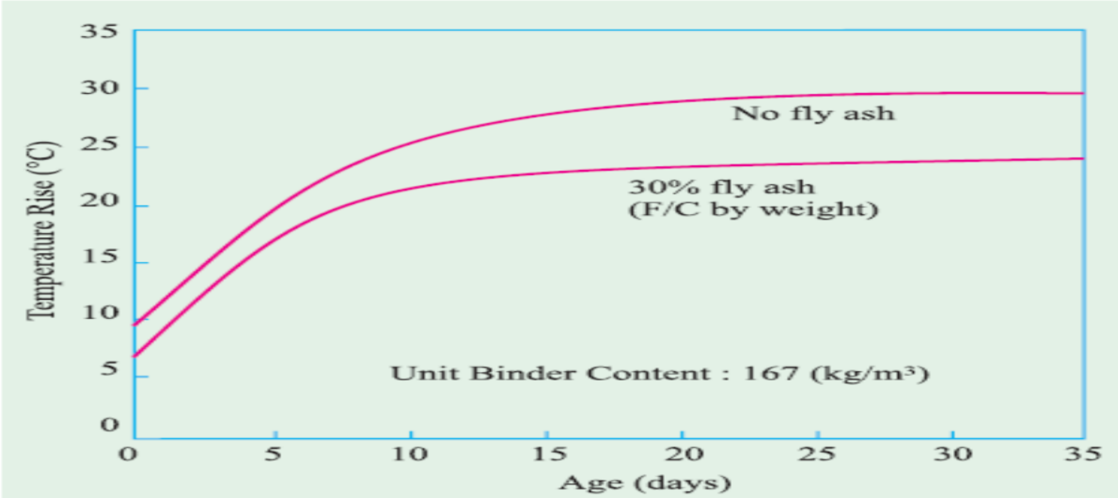

Figure 2-5 Effects of Fly Ash on Hardened Concrete

Fly ash, when used in concrete, contributes to the strength of concrete due to its pozzolanic reactivity. However, since the pozzolanic reaction proceeds slowly, the initial strength of fly ash concrete tends to be lower than that of concrete without fly ash. Due to continued pozzolanic reactivity concrete develops greater strength at later age, which may exceed that of the concrete without fly ash. The pozzolanic reaction also contributes to making the texture of concrete dense, resulting in decrease of water permeability and gas permeability. It should be noted that since pozzolanic reaction can only proceed in the presence of water, enough moisture should be available for long time. Therefore, fly ash concrete should be cured for longer period. In this sense, fly ash concrete used in under water structures such as dams will derive full benefits of attaining improved long term strength and water-tightness.

- ❖ Effect of Fly Ash on Durability of Concrete

Although fly ash is an industrial waste, its use in concrete significantly improve the long term strength and durability and reduce heat of hydration. In other words good fly ash is an indispensable mineral admixture for high performance concrete.

B. Silica Fume

This is a by-product of semiconductor industry. The terms condensed silica fume, microsilica, silica fume and volatilized silica are often used to describe the by-products extracted from the exhaust gases of silicon, ferrosilicon and other metal alloy furnaces. However, the terms microsilica and silica fume are used to describe those condensed silica fumes that are of high quality, for use in the cement and concrete industry.

Silica fume was first ‘obtained’ in Norway, in 1947, when environmental restraints made the filtering of the exhaust gases from the furnaces compulsory.

Silica Fume consists of very fine particles with a surface area ranging from 13,000 to 30,000 m^2/kg. The silica fume particles are approximately 100 times smaller than the average cement particles. Because of its extreme fineness and high silica content, Silica Fume is a highly effective pozzolanic material. Silica Fume is used in concrete to improve its properties. It has been found that Silica Fume improves compressive strength, bond strength, and abrasion resistance; reduces permeability of concrete to chloride ions; and therefore helps in protecting reinforcing steel from corrosion, especially in chloride-rich environments such as coastal regions.

C. Rice Husk Ash

This is a bio waste from the husk left after the grains of rice have been removed. It is used as a pozzolanic material in cement to increase durability and strength. The silica is absorbed by the rice plant from the ground. It gathers in the husk where it makes a structure and is filled with cellulose. When the cellulose is burned, only silica is left. The burnt rice husk is ground to a fine powder which is used as pozzolana.

D. Metakaolin

Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration.

Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete’s strength or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together. Less calcium hydroxide and more cementing compounds results in stronger concrete.

Metakaolin is very fine and highly reactive, gives fresh concrete a creamy, nonsticky texture that makes finishing easier. Efflorescence, which appears as a whitish haze on concrete, is caused when calcium hydroxide reacts with carbon dioxide in the atmosphere. Because metakaolin consumes calcium hydroxide, it reduces efflorescence.

Alkali-silica reaction is a reaction between calcium hydroxide (the alkali) and glass (the silica) which can cause decorative glass embedments in concrete to pop out. Because metakaolin consumes calcium hydroxide, it takes away the alkali and the reaction does not occur.

The high reactive metakaolin has the potential to compete with silica fume. High reactive metakaolin is being manufactured and marketed in India by trade name “Metacem”.

❖ Advantages of using Metakaolin

1. Boosts compressive strength
2. Produces Creamy Concrete. Makes finishing easier
3. Reduce efflorescence
4. Mitigate alkali-silica reaction
5. Maintains color, especially in white concrete
6. Improved durability – Due to better resistance to ASR, Sulphate& Chloride attack

❖ Disadvantages of using Metakaolin

1. Increased water demand (125%)
2. Increased heat of hydration

2.4 Superplasticizer

A superplasticizer is a material other than water, aggregates and cement used as an ingredient of concrete and added to the batch immediately before or dur-ing the mixing .plasticizers in concrete technology. A normal water reducer is capable of reducing water requirements by 10 to 15%. Higher water reductions, by incorporating larger amounts of these admixtures, result in undesirable effects on concrete like bleeding, segregation and hardening . So, a new class of water reducers, chemically different from the normal water reducer and capable of reducing water content by about 30% has been developed. The admixtures belonging to this class are known as super plasticizers. Superplasticisers are infact the extended version of plasticisers. At a given water /cement ratio and water content in the mix, the dispersing action of superplasticizer increases the workability of concrete, typically by raising the slump from 75mm to 200 mm, the mix remaining cohesive. The resulting concrete can be placed with little or no compaction and is not subject to excessive bleeding or segregation. Such concrete is termed as flowing concrete and is useful for placing in very heavily reinforced sections, in inaccessible areas, in floor or road slabs, and also where very rapid placing is desired. The principal mode of action of superplastcizers is their ability to disperse cement particles very efficiently. As they do not entrain air, they can be used at high dosage rates without affecting strength[5].

2.4.1 Chemical Composition:

There exist four main categories of superplasticizers based on their chemical composition:

1. Sulfonated melamine formaldehyde condensates
2. Sulfonated naphthalene formaldehyde condensates
3. Modified lignosulfonates
4. Others such as sulfonic acid esters and carbohydrate esters

2.4.2Advantages:

1. Cement content can be reduced to a greater extent keeping the same water/cement ratio. This will lead to economy.
2. Water-cement ratio can be reduced significantly keeping same cement content and workability. This will lead to increase in strength.
3. Higher workability at very low water cement ratio like casting concrete with heavy reinforcement..
4. Reduction in permeability
5. Where early strength development is required in prestressed concrete or casting of floor, where early access for finishing equipment is required.

2.5 Previous research

2.5.1 Influence of Superplasticizer on Strength of Concrete

Dr. Salahaldein Alsadey [6]he say "This paper was conducted to study the effect of superplasticizer on properties of concrete with characteristic

[5] https://en.wikipedia.org/wiki/Superplasticizer.
[6] International Journal of Research in Engineering and Technology (IJRET) Vol. 1, No. 3, 2012.

strength of 30 N/mm2. The properties of concrete containing SP had been successfully studied. From the results of the study presented earlier, the following conclusions are offered:

1. The workability of concrete can be increased by addition of superplasticizer. However, very high dosages of SP tend to impair the cohesiveness of concrete.
2. Slump loss can be reduced by using the chemical admixtures. However, effectiveness is higher for superplasticizer concrete.
3. Compressive strength is improved by SP compared with control; On the other hand, even its ultimate strength is higher than the desired characteristic strength.

- Results and discussion

1. Effect Of Superplasticizer On Slump Test The results for slump loss of superplasticized concrete summarize in Table below

Table 2-1 showing slump loss for superplasticized concrete

Concrete mix	Sikament® R2002 ratio %	Slump (mm)
Control (M)	0.0	95
600 ml/100 kg of cement (M1)	0.6	120
800 ml/100 kg of cement (M2)	0.8	140
1000 ml/100 kg of cement (M3)	1.0	150
1200 ml/100 kg of cement (M4)	1.2	170

2. Effect Of Superplasticizer On Compressive Strength

Table 2-2 Showing Compressive Strength of Superplasticized Concrete

Concrete mix	Dimension in (mm) L x B x H	Sikament® R2002 ratio%	Compressive strength in N/mm2
M	150x150x150	0.0	44
M1	150x150x150	0.6	52
M2	150x150x150	0.8	54
M3	150x150x150	1.0	55
M4	150x150x150	1.2	43

2.5.2 Effect of Superplasticizer on Fresh and Hardened Properties of Concrete

Dr. Salahaldein AlsadeyIn[7], he says “recent years, significant attention has been given to use superplasticizer as a chemical admixture on concrete. However, the use of chemical admixtures in concrete is a common solution to achieve high performance concrete. The past researchers have been underscored the use of chemical admixtures imparts the desirable properties to concrete in both fresh and hardened state. This paper has been made an attempt to study the influence of superplasticizer dose of 0.6, 0.8, 1.2, 1.8 and 2.5 percentage on performance of concrete. The experimental tests for fresh and hardened properties of concrete for M35 grade are studied and the results are compared with normal concrete. The tests considered for study are, slump test and compressive strength test The results show that the increase of superplasticizer dose in concrete leads to gain of good ability in addition to slump. Moreover, there is also slightly increase in compressive strength than that of normal concrete.

1. Experimental Results and Discussion

Table 2-3 Compressive strength of various concrete mixes at 28 days

Concrete Mix	SP %	Compressive Strength N/mm^2
		28 Days
Mc 1	0.0	37.68
MS 2	0.6	37.17
MS 3	0.8	40.24
MS 4	1.2	36.75
MS 5	1.8	36.75
MS 6	2.5	36.17

[7] Faculty of Engineering, Civil Engineering Department, Azzaytuna University, Beni Walid City, Libya

2.5.3 Strength and Workability Characteristics of Concrete by Using Different Super Plasticizers

Dr. Venu Malagavelli[8], in the research above says “Based on the experiments conducted, the following conclusions are drawn.

1. Superplasticizers are to test in the laboratory before using in the mass concrete applications.
2. The workability and compressive strength of concrete increases with the use of super plasticizers
3. The average slump of measuring workability of concrete with SNP3 super plasticizer is near to the designed value of the concrete.
4. The average 56 days compressive strength of M30 concrete by using SNP3 admixture is increased by 11.69% compared to concrete without admixture.
5. The concrete with admixture SNP3 is consistent and uniform in giving the experimental results. Also it is evident from standard deviation which is of laboratory precision.
   - Results & Discussions

Slump tests are conducted using slump cone for all samples of concrete without and with super plasticizers (SNP 1 to 4) for water cement ratio 0.45.The maximum, minimum and average slumps (in mm) of 25 samples with or without super plasticizer are listed below.

Table 2-4 Showing slump test results

	Max. Slump	Min. Slump	Avg. Slump
No Admixture	86	40	61.42
SNP 1	102	48	66.12
SNP 2	98	52	68.81
SNP 3	112	90	95.10
SNP 4	101	58	72.11

[8] Department of Civil Engineering BITS, India, 2001.

Table 2-5 Showing Compressive strength of concrete at the age of 56 days

Compressive strength (N/mm2)	Without SP	SNP1	SNP 2	SNP 3	SNP 4
Maximum	33.88	41	41.48	36.81	39.22
Minimum	29.52	29.85	31.42	33.7	32.72
Average	31.78	37.03	36.31	35.5	35.95

2.5.4 Effect of High Range Water Reducers (HRWR) On The Properties And Strength Development Characteristics Of Fresh And Hardened Concrete

Dr.Allama Iqbal[9] , in the research above say " The increase in compressive strength, flexural strength and cylinder tensile strength is relatively greater in the case of Polycarboxylates group (SP-2).

1. Substantial reduction in water demand has been observed with use of SP.
2. With Polycarboxylates group (SP-2), more than 40% strength (14MPa) can be obtained after 3 days which makes it very suitable for Very Early Strength (VES) Concrete.
3. The 28 days compressive strength of SP added concrete with Polycarboxylates group (SP-2), gives High Strength Concrete (HSC) having 28 days compressive strength in excess of 75 MPa . Further research is required for cost optimization of the HRWR concrete.

- Results & Discussions

The Table below showing effect of superplasticizers on the workability and compressive strength.

[9] Open University-Islamabad Pakistan,2013.

Table 2-6 Effect of superplasticizers on the workability and compressive strength.

Concrete Mix	w/c ratio	SP Type	Slump (mm)	Compressive strength (MPa)		
				7 Days	14 Days	28 Days
A(1:1:2)	0.40	Nil	25	29.75	32.30	40.10
		SP-1	75	30.50	36.0	41.55
		SP-2	200	30.79	38.86	43.59
	0.35	Nil	15	25.17	36.21	41.50
		SP-1	50	28.38	37.55	43.60
		SP-2	175	29.30	37.60	45.17
	0.30	Nil	10	25.80	34.55	42.20
		SP-1	45	27.70	36.80	44.50
		SP-2	125	30.10	38.70	47.20
B(1:1.5:2.5)	0.40	Nil	35	20.30	28.30	35.90
		SP-1	95	20.90	30.40	37.30
		SP-2	150	21.70	36.70	39.55
	0.35	Nil	30	22.40	31.20	38.00
		SP-1	85	25.10	32.80	40.20
		SP-2	110	26.00	36.24	43.00
	0.30	Nil	05	22.50	32.00	35.50
		SP-1	50	24.50	33.90	37.0
		SP-2	80	24.90	34.90	43.60
C(1:1.5:3)	0.40	Nil	15	25.60	29.90	36.90
		SP-1	65	30.69	32.60	39.70
		SP-2	80	32.50	36.80	43.20
	0.35	Nil	50	21.40	23.25	36.25
		SP-1	95	23.80	31.85	38.65
		SP-2	250	25.20	32.00	41.00
	0.30	Nil	25	21.00	31.25	34.25
		SP-1	65	23.15	32.15	35.15
		SP-2	90	24.15	33.02	41.25

CHAPTER THREE
THE LABORATORY TESTS

3.1 Introduction

This study will focus on normal strength concrete with characteristic strength of (30 and 35) N/mm^2 28 days, which used Slag Cement 42.5N Cement as binder, (32 and 16) mm granite coarse aggregate ,sand and PCA (I) as high performance superplasticizers admixture.

One control mix will be prepared without the use of any admixture. To investigate the effects of superplasticizer, seven additional mixes was prepared using PCA (I) high performance superplasticizers admixture.

Slump and flow test used to assess the workability of the concrete mixes. Compressive strength used to determine on concrete cube at 28 days. All samples for hardened concrete test cured in water maintain at temperature of 27 + 2°C (BS 1881: Part 111: 1983). However, all specimens with the dimension of 150 mm x 150 mm x 150 mm. fabricated in the Engineering Laboratory of the Dam Complex of Upper Atbara Project (DCUAP)[10].

Compressive strength is improved by used PCA (I) superplasticizer compared with control; On the other hand, even its ultimate strength is higher than the desired characteristic strength.

This Research outlines an experimental study that measures the effects of superplasticizer admixture on proprieties of concrete .However; Superplasticizers are the most important admixtures enhancing concrete strength.

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[10] See Appendix (A)

Figure 3-1 General view of The Dam Complex of Upper Atbara Project Downstream

3.2 Materials Used and Properties

The materials used for this study are cement, fine and coarse aggregates. However, a chemical admixture (superplasticizer) is added in order to change the characteristics of concrete for certain applications. Since the materials are important in determining the quality of produced concrete, they should be properly selected and chosen before the beginning of the experiment.

3.2.1 Cement

Cement is a hydraulic binder, i.e. a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water.

Cement conforming to EN 197-1, termed CEM cement, shall, when appropriately batched and mixed with aggregate and water, be capable of producing concrete or mortar which retains its workability for a sufficient time and shall after defined periods attain specified strength levels and also possess long-term volume stability.

The cement used in this study is a product from Sharjah of UAE. This type Slag (CEM II) cement .It is available in 1320 kg /bag. The properties of this cement explained in Table (3-1) below

Table 3-1 Explain the cement properties

Sample No	cement Type	Density g/cm^3	Normal Consistency %	Setting Time (min)		Soundness mm	Fineness %	Compressive Strength (MPa)		
				Initial Setting Time	Final Setting Time			2days	7days	28days
1	Slag (CEM II) cement	2.93	32.9	180	246	0.25	0.8	13.1	30.6	53.7

3.2.2 Fine Aggregates:

The fine aggregates with well-graded, crushed sand and the source (jabel akait) mountain a confirming to ASTM Standard. And the envelope according to ASTM-33 passing through 4.75 mm sieve with a Fineness modulus of 2.85 and the other properties explained in Table (3-2)[11].

Table 3-2 Explain the Fine Aggregates properties

Sample No	Finest content %	Fineness modulus	Soundness %	specific Gravity	water Absorption %
1	1.32	2.85	15.5	2.611	3.20

3.3.3 Corse Aggregates (5-16) mm:

Whereas crushed stones having size (5-16) mm as coarse aggregates. The envelope according to (EN 12620:2000) is used. Crushed Aggregate and the source (jabel akait) mountain a confirming to EN Standard. And the properties of Corse Aggregates according to

(The European Standard EN 1097-6:2000 has the status of a British Standard) are explained in Table (3-3). On the other hand see Appendix (B).

[11] See Appendix (B).

Table 3-3 Explain the Corse Aggregates (5-16) mm properties

Sample No	particle density	Water Absorption (%)	Flakiness Index (%)	Los Angeles Abrasion (%)
1	2.62	3.14	9.2	21

3.4.4 Corse Aggregates (16-32) mm:

Whereas crushed stones having size (16-32) mm as coarse aggregates. the envelope according to (EN 12620:2000) are used . Crushed Aggregate and the source (jabel akait) mountain a confirming to EN Standard. The properties of Corse Aggregates according to (The European Standard EN 1097-6:2000 has the status of a British Standard) are explained in Table (3-4). On the other hand see Appendix (B).

Table 3-4 Corse Aggregates (16-32) mm properties

Sample No	particle density	Water Absorption (%)	Flakiness Index (%)
1	2.60	2.78	8.4

3.5.5 PCA (I) high performance superplasticizers admixture

A. DESCRIPTION

PCA (I) high performance superplasticizers admixture is a polycarboxylate polymer-based composite admixture. It is a liquid which has the performances of high range water reduction, excellent slump retention and strengthening. It is specially adapted to the production of high durability concrete, self-compacting concrete, high compressive strength concrete, and high workability concrete. PCA® (I) superplasticizer is formulated to comply with the following specification for concrete admixture: ASTM494, Type G; GB8076-1997. The relative densities of PCA®(I) whose solid content are 21.7% and 50% are approximately 1.06 and 1.17 respectively.

B. TECHNICAL PROPERTIES

1. **High range water reduction:**
   The water reduction rate can be up to 35% at high dosage rates.

2. High compressive strengths:
   It can improve the compressive strengths of concrete by 60-100% at the age of 3 days, 60-90% at the age of 28 days and 30-50% at the age of 90 days.
3. High slump-retention:
   Almost no slump loss of the concrete within 2 hours.
4. Excellent workability:
   No bleeding or segregation, no bleeding mark or obvious bubble defect on appearance.
5. Low alkali content: alkali content is less than 1.8%.
6. No chloride ions and non-corrosion to steel bar.
7. High durability:
   It effectively improves the frost resistance and carbonation resistance of the concrete. It can decreases drying shrinkage of the concrete by 20% or more compared to naphthalene-based admixture.
8. High compatibility:
   Compatible with a far greater range of cement types and mineral additives. It particularly fits for the preparation of high durability concrete and self-compacting concrete with fly ash and grinding slag.
9. High stability:
   No delamination and sedimentation during its shelf life and no crystallization in winter.

C. SCOPE OF APPLICATIONS:

PCA(I) is in particular suitable to the production of the concrete requiring excellent workability, strong slump-retention ability, high strength, good appearance and high durability.

D. DOSAGE:

The addition rate of PCA(I) normally is 0.6~1.2% by weight of cementitious materials, and can be increased to 1.3-1.8% for ultra-high strength and durability concrete.

E. **USAGE**:

Do not mix with naphthalene-based admixture. If other admixtures, such as retarded or corrosion-inhibiting admixture, are required simultaneously for some special projects, compatibility tests should be conducted beforehand.Curing. The concrete should be wet-cured and covered after final setting, and surface-cured in winter to prevent frost attack.

F. **PACKAGING**

PCA (I) is in the state of liquid and should be stored and transported in plastic barrel. The net weight is 55kg or 220 kg per barrel. The product has one year of shelf life when stored in the sealed barrel. Avoid frost in the shelf life.

G. **AFTER-SALE SERVICES**

To ensure desired concrete performances, we offer technical consultation service on mix proportion design and optimization experiment on mix proportion. Our technical personnel will provide on-site direction service free of charge.

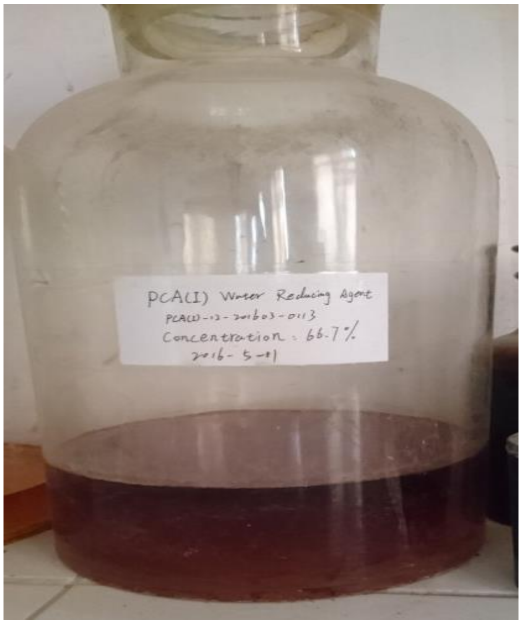


Figure 3-2 high performance superplasticizers admixture

3.3 Experimental programs:

This Research outlines an experimental study that measures the effects of superplasticizer admixture on proprieties of concrete. Besides determine the workability of the fresh concrete. I will do these steps to confirm the general requirements:

3.3.1 Step (1) Making Trial mixes:

Eight trial mixes were prepared by varying the dosage of Superplasticizer from 0% to 1% of cementious material. In order to investigate characteristics of fresh state of mix proportion with varying dosages of Superplasticizer .

The Superplasticizer dosage used in design mixes explained in Table (3-5) below.

Table 3-5 high performance superplasticizers admixture dosage used in design mixes

No.	Symbol	No. of Mix	(Super plasticizers) (kg/m3)	Super plastici zers %	Remark
1	M(0)	M (A)	Nil	0	The design strength (35 Mpa)
2	M(1)	M (B)	3.98	1	
3	M(2)	M (47)	4.22	1	The design strength (30 Mpa)
4	M(3)	M (spc-16)	3.17	0.80	
5	M(4)	M (spc 5-1)	3.68	1	
6	M(5)	M (spc-20)	3.44	1	
7	M(6)	M (SPC-23)	1.74	0.50	
8	M(7)	M (41)	3.85	1	

- M (A) and M (B) are trail mix were prepared in the laboratory. M (47), M (spc-16), M (spc 5-1), M (spc-20), M (SPC-23) and M (41) are trail mix were prepared in The Dam Complex of Upper Atbara Project (DCUAP).

3.3.2 Step (2) The design of concrete mix[12]

Required average strength will be 35 MPa with slump of 75 to 100 mm. The coarse aggregate has a nominal maximum size of 37.5 mm and

[12] (ACI 211.1-91), 2002, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete ,"

dry-rodded mass of 2600 kg/m3. Other properties of the ingredients in section 3.2. Design the mix in two cases.

- With add Superplasticizer Admixture
- Without add Superplasticizer Admixture

A. The mix design Without add Superplasticizer Admixture

i. Step 1 -- The slump is required to be 75 to100 mm.

ii. Step 2 -- The aggregate to be used has a nominal maximum size of 37.5 mm.

iii. Step 3 -- The concrete will be non-air entrained since the structure is not exposed to severe weathering. From Table (3-6) the estimated mixing water for a slump of 75 to 100 mm in non-air-entrained concrete made with 37.5 mm aggregate is found to be 181 kg/m3.

Table 3-6 Approximate mixing water

Slump, mm	Water, Kg/m³ of concrete for indicated nominal maximum sizes of aggregate							
	9.5*	12.5*	19*	25*	37.5*	50†*	75†‡	150†‡
Non-air-entrained concrete								
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	—
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-entrained concrete								
25 to 50	181	175	168	160	150	142	122	107
75 to 100	202	193	184	175	165	157	133	119
150 to 175	216	205	197	184	174	166	154	—
Recommended average§total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5**††	1.0**††
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5**††	3.0**††
Extreme exposure‡‡	7.5	7.0	6.0	6.0	5.5	5.0	4.5**††	4.0**††

iv. Step 4 -- The water-cement ratio for non-air- entrained concrete with a strength of 35 MPa is found from Table (3-6) to be 0.47.

Table 3-7 The water-cement ratio for non- entrained

Compressive strength at 28 days, MPa*	Water-cement ratio, by mass	
	Non-air-entrained concrete	Air-entrained concrete
40	0.42	—
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

v. Step 5 -- From the information developed in Steps 3 and 4, the required cement content is found to be $\frac{181}{0.47} = 398\ \frac{\text{kg}}{\text{m}^3}$.

Table 3-8 The quantity of coarse aggregate

Nominal maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate* per unit volume of concrete for different fineness moduli† of fine aggregate			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

vi. Step 6 -- The quantity of coarse aggregate is estimated from Table (3-4) For a fine aggregate having a fineness modulus of 2.8 and a 37.5 mm nominal maximum size of coarse aggregate, the table indicates that $0.71\ \text{m}^3$ of coarse aggregate, on a dry-rodded basis, may be used in each cubic meter of concrete. The required dry mass is, therefore, $0.71 \times 1600 = 1136$ kg.

vii. Step 7 With the quantities of water, cement and coarse aggregate established, the remaining material comprising the cubic meter of concrete must consist of fine aggregate and whatever air will be entrapped. The required fine aggregate may be determined on the basis of either mass or absolute volume as shown below:

Mass basis -- From Table (3-5), the mass of a cubic meter of non-air-entrained concrete made with aggregate having a nominal maximum size of 37.5 mm is estimated to be 2410 kg. (For a first trial batch, exact adjustments of this value for usual differences in slump, cement factor, and aggregate specific gravity are not critical.) Masses already known are:

- Water (net mixing)181kg, Cement 398kg , Coarse aggregate 1136kg , Total 1715kg

  - The mass of fine aggregate, therefore, is estimated to be $2410 - 1715 = 695$ kg

Absolute volume basis -- With the quantities of cement, water, and coarse aggregate established, and the approximate entrapped air content (as opposed to purposely entrained air) of 1 percent determined from Table (3-2), the sand content can be calculated as follows:

- Volume of water= 181/100= 0.181 m^3
- Solid volume of cement= 398/(3.15*1000)= 0.126 m^3
- Solid volume of coarse aggregate= 1136/(2.68*1000)= 0.424m^3
- Volume of entrapped air = 0.01*1.000=0.010m^3
- Total solid volume of ingredients except fine aggregate = 0.708m^3
- Solid volume of fine aggregate required $= 1.000 - 0.708 = 0.268$ m^3
- Required weight of dry fine aggregate$= 0.268$ x $2.7 * 1000 = 726$ kg

Batch masses per cubic meter of concrete calculated on the two bases are compared below:

Table 3-9 Mass basis of concrete

	Based on estimated concrete mass, kg	Based on absolute volume of ingredients, kg
Water (net mixing)	181	181
Cement	398	398
Coarse aggregate(dry)	1136	1136
Sand (dry)	695	726

viii. Step 8 -- Tests indicate total moisture of 2 percent in the coarse aggregate and 6 percent in the fine aggregate. If the trial batch proportions based on assumed concrete mass are used, the adjusted aggregate masses become

- $\text{Coarseaggregate(wet)} = 1136 * (1.02) = 1159$ kg
- $\text{Fineaggregates(wet)} = 695 * (1.06) = 737$kg

Absorbed water does not become part of the mixing water and must be excluded from the adjustment in added water. Thus, surface water contributed by the coarse aggregate amounts to 2 - 0.5 = 1.5 percent; by the fine aggregate 6 -0.7 = 5.3 percent. The estimated requirement for added water, therefore, becomes

- $181 - 1136(0.015) - 695(0.053) = 127$ kg

The estimated batch masses for a cubic meter of concrete are:

Table 3-10 The estimated batch masses for a cubic meter of concrete

Water (to be added)	127 kg
Cement	398 kg
Coarse aggregate (wet)	1159 kg
Fine aggregate (wet)	737kg
Total	2421 kg

ix. Step 9 -- For the laboratory trial batch, it is found convenient to scale the masses down to produce 0.01 m3 of concrete. the amount actually used in an effort to obtain the desired 75 to 100 mm slump is 1.27 kg. The batch as mixed, therefore, consists of

Table 3-11 The masses for a cubic meter of concrete

Water	1.27 kg
Cement	3.98 kg
Coarse aggregate (wet)	11.59 kg
Fine aggregate (wet)	7.37kg
Total	24.21 kg

B. the mix design With add Superplasticizer admixtures

i. dosage

- The addition rate of Superplasticizer normally is 0.6~1.2% by weight of cementation materials
- $\therefore$ Take 1%
- $\therefore \text{the wight of Superplasticizer} = 1\% * 3.98 = 0.0398 \text{ kg}$

The batch as mixed, therefore, consists of

Table 3-12 the masses for a cubic meter of concrete with Superplasticizer admixtures

Water	1.27 kg
Cement	3.98 kg
Coarse aggregate (wet)	11.59 kg
Fine aggregate (wet)	7.37kg
Superplasticizer admixtures	0.0398kg
Total	24.2498 kg

3.3.3 step (3) Six trial mixes were added by varying the dosage

The new and old mix are explained in Table (3-13)

3.3.4 Step (4) Casting and curing[13]:

Immediately after making specimens store them in a place free from vibration and in conditions which will prevent loss of moisture. If it is necessary to move the specimens to place of storage, move them in their moulds ensuring no loss of concrete.

Whichever method of moist air storage is used, maintain the temperature of the specimens at 20 + 5 C if the specimens are to be tested at an age of 7 days or more, or at 20 + 2 C if the specimens are to be tested at an earlier age.
Demould specimens to be tested at 24 h just before testing. Demould specimens to be tested at greater ages within the period 16 h to 28 h after the addition of water to the other constituents in the mix unless the concrete has not achieved sufficient strength to enable specimens to be demoulded during this period. In such cases, delay demoulding for a further 24 h. During this further period, continue the cured age of the specimens in the moist air conditions.
Mark each specimen clearly and indelibly with an Identification number or code. Unless required for test at 24 h, either submerge the specimens immediately in the curing tank or immediately prepare them for transporting another location. Keep all specimens which are ‘immediately transferred to the curing tank submerged and remove them just before testing unless it is necessary to Transport them to another location for testing. immediately after removal from the moulds or from the curing tank, pack specimens to be transported in such as to prevent any significant change in moisture content.
After filling, seal each box or enclose it in polythene. Alternatively, the specimens may be packed in damp sand or in wet sacks and enclosed in a polyethylene bag. Store the transported specimens in the curing tank for not less than 24 h before the time of testing[14].

[13] British Standard Institution, BS 1881 : Part 3 (1970) British Standard Methods of Making and Curing Test Specimens”.
[14] See Appendix (C)

Table 3-13 The mix design properties

Mix Design Symbol	Mix Design NO	(Super Plasticizers) (kg/m^3)	Cement (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)	RETARDER	Flow(Slump) Test (cm)	W/C Ratio	Remark
M (0)	M (A)	Nil	398	695	1136	181	Nil	SLUMP 15	0.454	- Max aggregate size (37.5 mm) - The design strength 35 Mpa
M(1)	M (B)	3.98	398	695	1136	181	Nil	SLUMP 15	0.454	
M(2)	M (47)	4.22	422	765	973	190	1.27	FLOW 60	0.45	- Max aggregate size (16 mm) - The design strength 30 Mpa
M(3)	M (spc-16)	3.17	396	727	1091	186	0.79	FLOW 48	0.467	
M(4)	M (spc 5-1)	3.68	368	736	1061	173	0.74	FLOW 49	0.47	
M(5)	M (spc-20)	3.44	344	749	1122	165	0.69	FLOW 48	0.479	- Max aggregate size (32 mm) - The design strength 30 Mpa
M(6)	M (SPC-23)	1.74	348	718	1124	160	0.348	FLOW 50	0.459	
M(7)	M (41)	3.85	385	760	1050	185	0.96	FLOW 54	0.48	

3.3.5 Step (5) Testing:

A. Testing fresh concrete

Slump and flow test used to assess the workability of the concrete mixes.

i. Slump-test

Dampen the mould and base plate and place the mould on the horizontal base plate/surface. During filling of the mould hold it firmly against the base plate/surface by clamping in place, or by standing on the two foot pieces.

Fill the mould in three layers, each approximately one-third of the height of the mould when compacted. Compact each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross-section of each layer. For the bottom layer this will necessitate inclining the rod slightly and positioning approximately half the strokes spirally toward the centre. Compact the first layer throughout its depth, taking care not striking the base. Compact the second layer and the top layer each throughout its depth, so that the strokes just penetrate into the immediately underlying layer. In filling and compacting the top layer, heap the concrete above the mould before tamping is started. If the tamping operation of the top layer results in subsidence of the concrete below the top edge of the mould, add more concrete to keep an excess above the top of the mould at all times. After the top layer has been compacted, strike off the surface of the concrete by means of a sawing and rolling motion of the compacting rod. Remove spilled concrete from the base plate/surface. Remove the mould from the concrete by raising it carefully in a vertical direction. Perform the operation of raising the mould in 2 s to 5 s, by a steady upward lift, with no lateral or torsional motion being imparted to the concrete. Carry out the entire operation from the start of the filling to the removal of the mould without interruption and complete it within 150 s. Immediately after removal of the mould, measure and record the slump h by determining the difference between the height of the mould and that of the highest point of the slumped test specimen[15] .

[15] British Standard Institution, BS 1881: Part 102 (1983). “Methods for Determination of Slump”.

ii. Flow table test

First find a suitable location for a flow table. It must be placed on a firm, flat and level surface. It may be necessary to prepare an area for the table. Empty the sampling buckets onto the mixing tray. Scrape each bucket clean. Thoroughly remix the sample as described for the slump test . Ensure the mould and table is clean and damp. Place the mould on the center of the table and stand on the foot-pieces. Fill the mould in two layers, tamping each layer ten times with the tamping bar. If necessary add more concrete to fill the top layer. Use the tamping bar to strike the top layer level with the top of the mould . Carefully clean off spillage from around the mould and table top. Wait 30 seconds from striking off. Carefully lift the mould straight up and clear to a count of between 3 and 6 seconds. Stabilise the flow table by standing on the toe board at the front of the table. Slowly lift the table top by the handle until it reaches the upper. Allow the table to fall freely. Repeat this cycle to give a total of 15 drops . Each cycle should take about 4 seconds. Measure the largest dimension of concrete spread in two directions, parallel to the table edges. Record the flow value as d1 + d2 divided by 2 . Report any segregation which may have occurred around the sample edge . Complete the sampling and testing certificates[16].

B. Testing hardened concrete

i. Compressive strength of test specimens[17]

after making specimens (see 3.3.4 step (4) Casting and curing) Wipe all testing machine bearing surfaces clean and remove any loose grit or other extraneous material from the surfaces of the specimen that will be in contact with the platens. Do not use packing, other than auxiliary platens or spacing blocks (see EN 12390-4) between the specimen and the platens of the testing machine. Wipe the excess moisture from the surface of the specimen before placing in the testing machine. Position the cube specimens so that the load is applied perpendicularly to the direction of casting. Centre the specimen with respect to the lower platen to an accuracy of 1 % of the designated size of cubic, or designated diameter of cylindrical specimens. If auxiliary platens are used, align them with the top and bottom face of the specimen. With two-column testing machines, cubic specimens should be placed with

[16] See Appendix (C)

[17] British Standard BS EN (12390-3:2009). “Testing hardened concrete - Part 3: Compressive strength of test specimens”.

the trowelled surface facing a column. Select a constant rate of loading within the range 0,6 ± 0,2 MPa/s ($N/mm^2 \cdot s$). After the application of the initial load, which does not exceed approximately 30% of the failure load, apply the load to the specimen without shock and increase continuously at the selected constant rate ± 10 %, until no greater load can be sustained. When using manually controlled testing machines, correct any tendency for the selected rate of loading to decrease, as specimen failure is approached by appropriate adjustment of the controls. Record the maximum Compressive strength in MPa .

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Introduction

In this is chapter the tests results were present, cube compressive strength tests, (slump and flow) tests, different relationship between compressive strength, (slump and flow) and superplasticizer dosage are presented and discussed.

4.2 Compressive Strength results

Standard cast iron moulds of size $(150x150x150\,)mm$ are used in the preparation of cubes. The area of this cubes $= 22500\,mm^2$ and the Volume of cube $= 3375000\,mm^3$. The Compressive strength of test specimens according to (EN 12390-3:2009). The moulds have been cleaned to remove dust particles and applied with mineral oil on all sides before the concrete is poured into the mould. In all cases at (7 ,21, 28) days, the water curing up to testing is showing maximum strength. Eight trial mixes were prepared by varying the dosage of Superplasticizer from 0% to 1% of cementious material. As showing in table (3-4).The test result of concrete mix are used in this study is shown below

4.2.1 Compressive Strength result of concrete mix M (0)

Table 4-1 The Compressive Strength result of concrete mix M (0)

NO	Age (days)	Weight of cube (kg)	Density (kg/m³)	*Load breaking KN*	*Compressive Strength* (N/mm^2)	*Average Compressive strength(N/mm²)*
1	7	8.085	2395	700	31	29
2		7.850	2325	620	27.5	
3		7.840	2322	635	28	
4	21	8.655	2567	780	34.7	31.8
5		8.155	2416	690	30.7	
6		7.925	2348	672	29.87	
7	28	8.00	2370	910	40	40
8		8.215	2434	915	40.6	
9		8.52	2524	890	39.5	

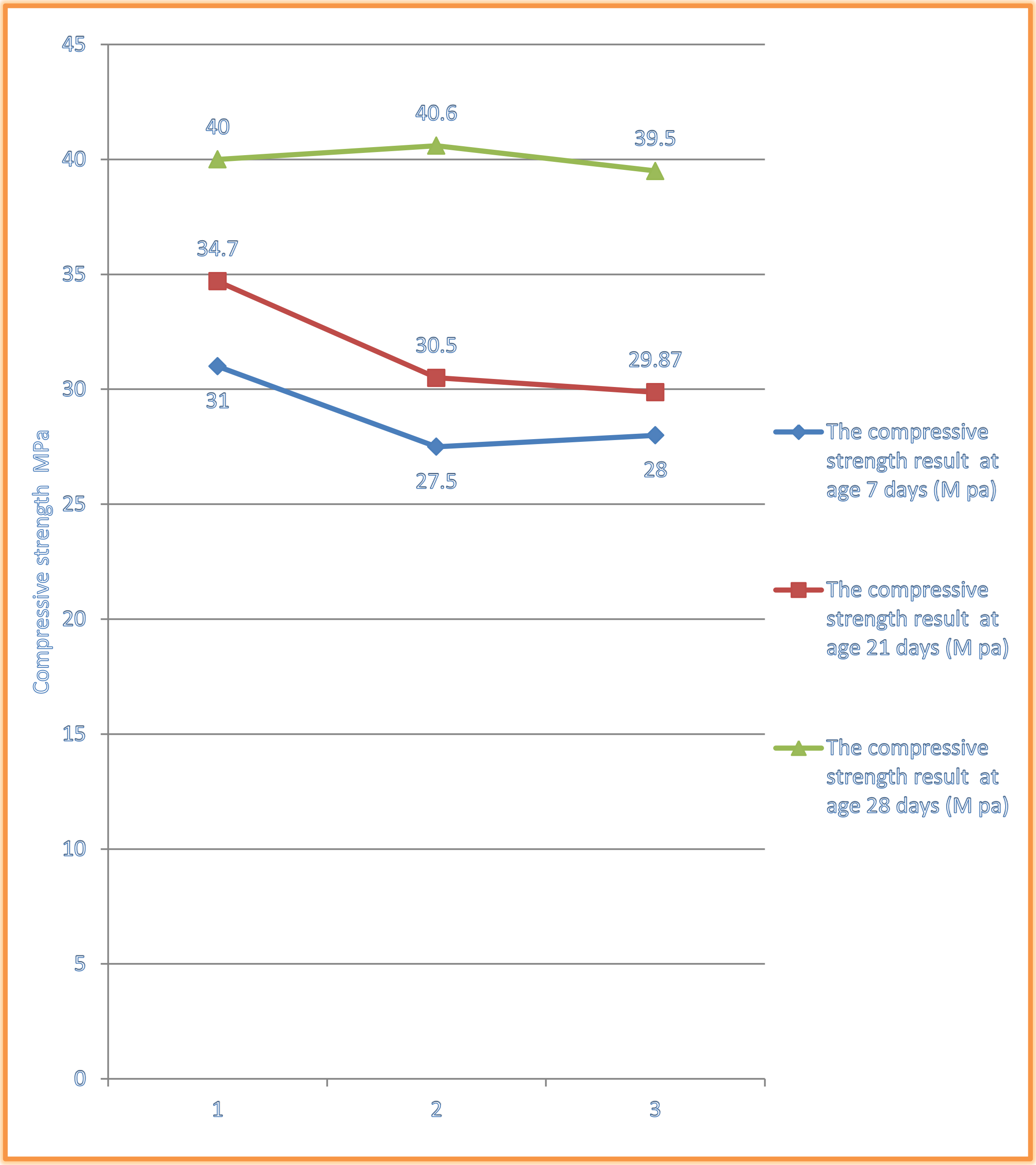


Figure 4-1 The Compressive Strength result of concrete mix M (0)

4.2.2 Compressive Strength result of concrete mix M (1)

Table 4 - 2 The Compressive Strength result of concrete mix M (1)

NO	Age (days)	Weight of cube (kg)	Density (kg/m³)	*Load breaking KN*	*Compressive Strength(N/mm^2)*	*Average Compressive strength(N/mm²)*
1	7	7.955	2395	810	36	40.6
2		7.850	2325	920	40	
3		7.840	2322	1055	46	
4	21	8.050	2385	1050	46.67	47.3
5		8.390	2485	1100	48.89	
6		8.645	2561	1045	46.44	
7	28	8.040	2382	1175	52.2	53.2
8		7.975	2462	1220	54.2	
9		8.385	2476	1200	53.3	

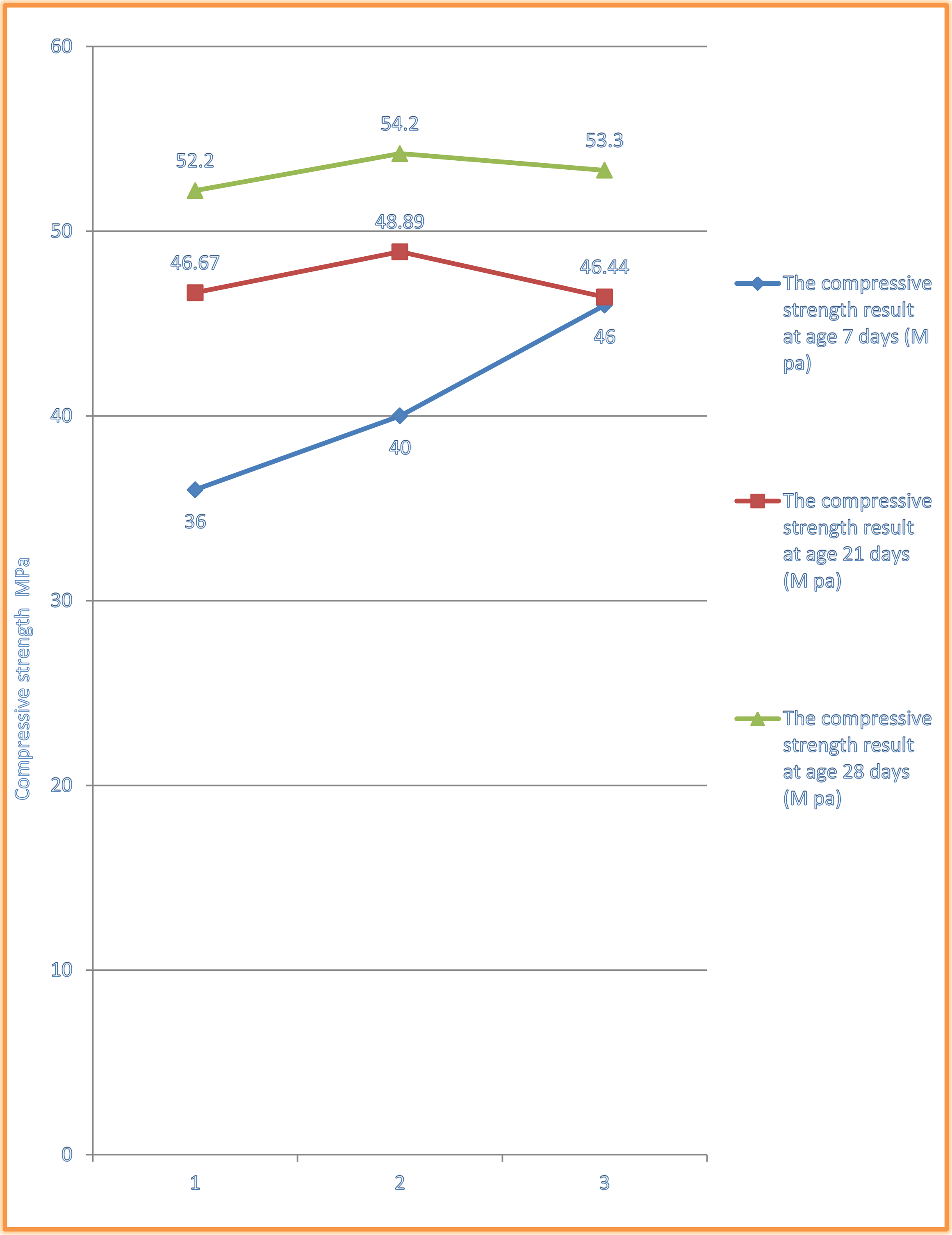


Figure 4-2 The Compressive Strength result of concrete mix M (1)

4.2.3 Compressive Strength result of concrete mix M (2)

Table 4 -3 The Compressive Strength result of concrete mix M(2)

NO	Age (days)	Weight of cube (kg)	Density (kg/m³)	*Load breaking KN*	*Compressive Strength* (N/mm^2)	*Average Compressive strength(N/mm²)*
1	7	7.700	2281	792.9	35.2	34.3
2		7.800	2311	858.8	38.5	
3		7.850	2326	665.6	29.6	
4	28	7.600	2252	1202	53.4	53.4
5		7.550	2237	1181	52.5	
6		7.600	2252	1224	54.4	

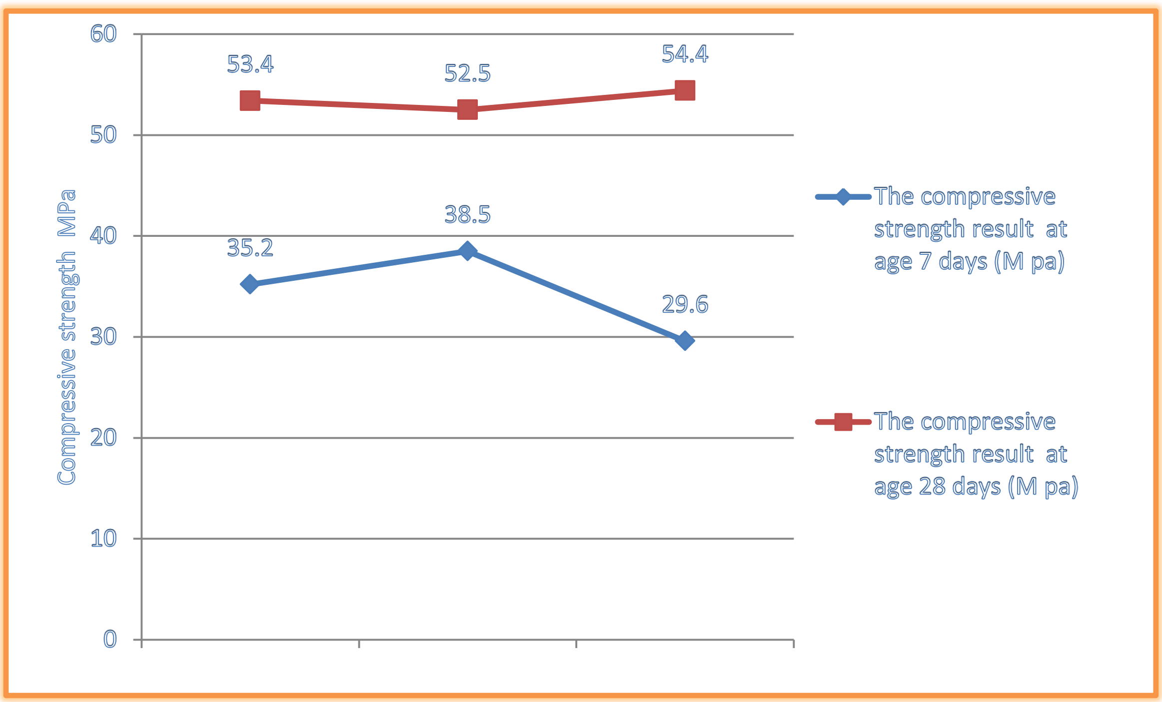


Figure 4-3 The Compressive Strength result of concrete mix M (2)

4.2.4 Compressive Strength result of concrete mix M (3)

Table 4 - 4 The Compressive Strength result of concrete mix M (3)

NO	Age (days)	Weight of cube (kg)	Density (kg/m^3)	*Load breaking KN*	*Compressive Strength* (N/mm^2)	*Average Compressive strength* (N/mm^2)
1	7	7.785	2307	507.4	22.55	23.5
2		7.795	2310	530.0	23.56	
3		7.785	2307	545.8	24.26	
4	28	7.785	2307	1257	55.8	55.2
5		*7.730*	2290	1203	53.4	
6		7.730	2290	1265	56.4	

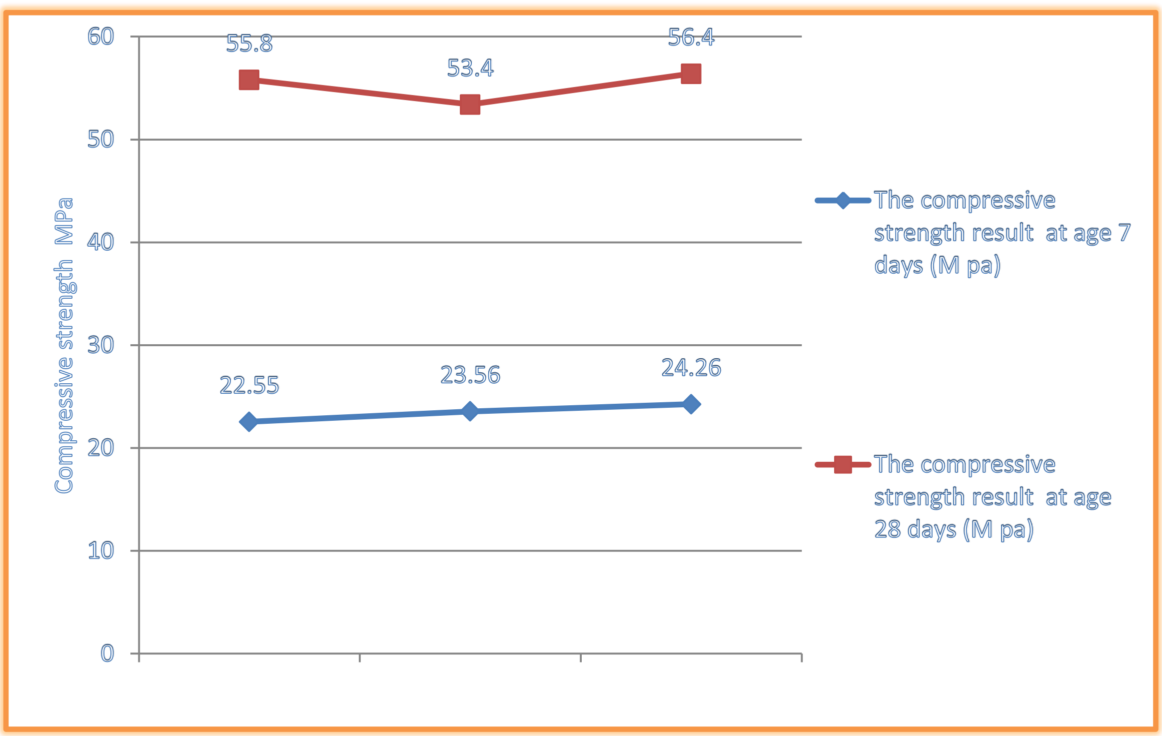


Figure 4-4 The Compressive Strength result of concrete mix M (3)

4.2.5 Compressive Strength result of concrete mix M (4)

Table 4 -5 The Compressive Strength result of concrete mix M (4)

NO	Age (days)	Weight of cube (kg)	Density (kg/m³)	*Load breaking KN*	*Compressive Strength* (N/mm^2)	*Average Compressive strength(N/mm²)*
1	7	8.060	2388	753.7	33.6	33.2
2		8.070	2391	743.7	33.1	
3		8.070	2391	738.2	32.9	
4	28	8.130	2409	1338.0	59.5	57.1
5		*8.110*	2403	1317.0	58.5	
6		8.030	2379	1197.0	53.2	

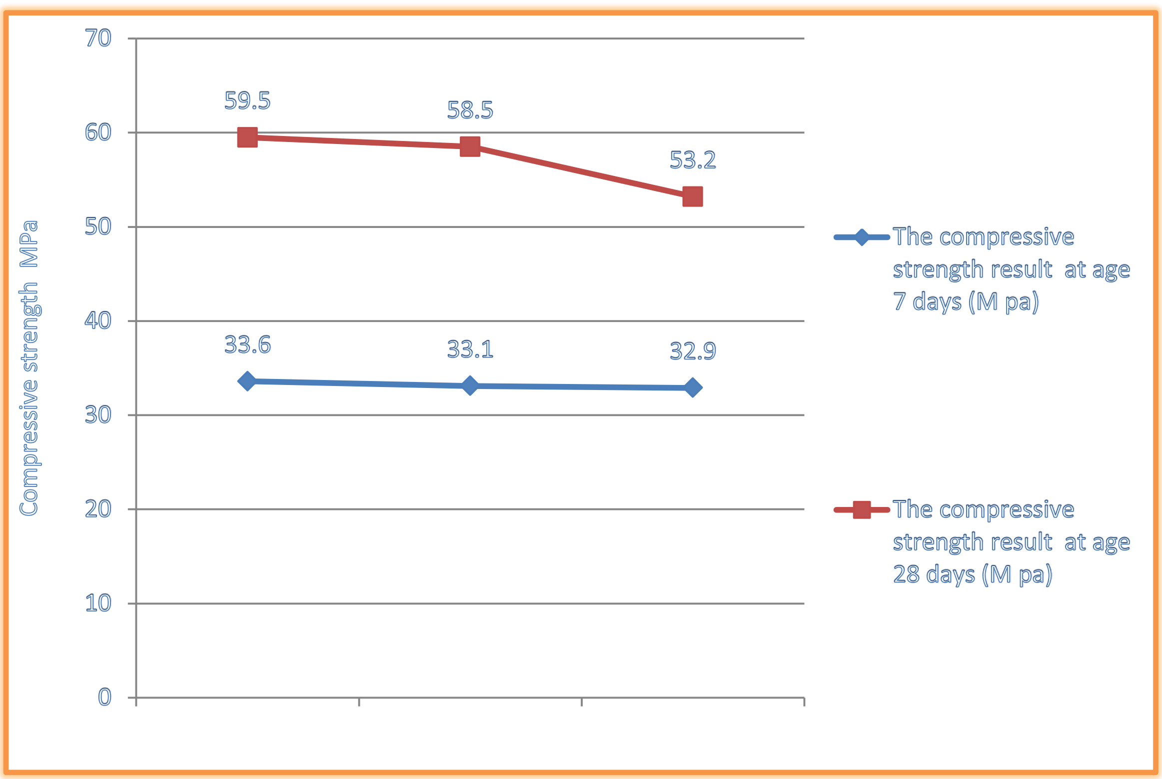


Figure 4-5 The Compressive Strength result of concrete mix M (4)

4.2.6 Compressive Strength result of concrete mix M (5)

Table 4 - 6 The Compressive Strength result of concrete mix M (5)

NO	Age (days)	Weight of cube (kg)	Density (kg/m³)	*Load breaking KN*	*Compressive Strength* (N/mm^2)	*Average Compressive strength(N/mm²)*
1	7	8.110	2403	592.2	26.3	26.3
2		8.000	2370	571.6	25.4	
3		8.040	2382	609.6	27.1	
4	28	8.150	2415	1236.0	54.9	55.0
5		*8.100*	2400	1262.0	56.1	
6		8.160	2418	1218.0	54.1	

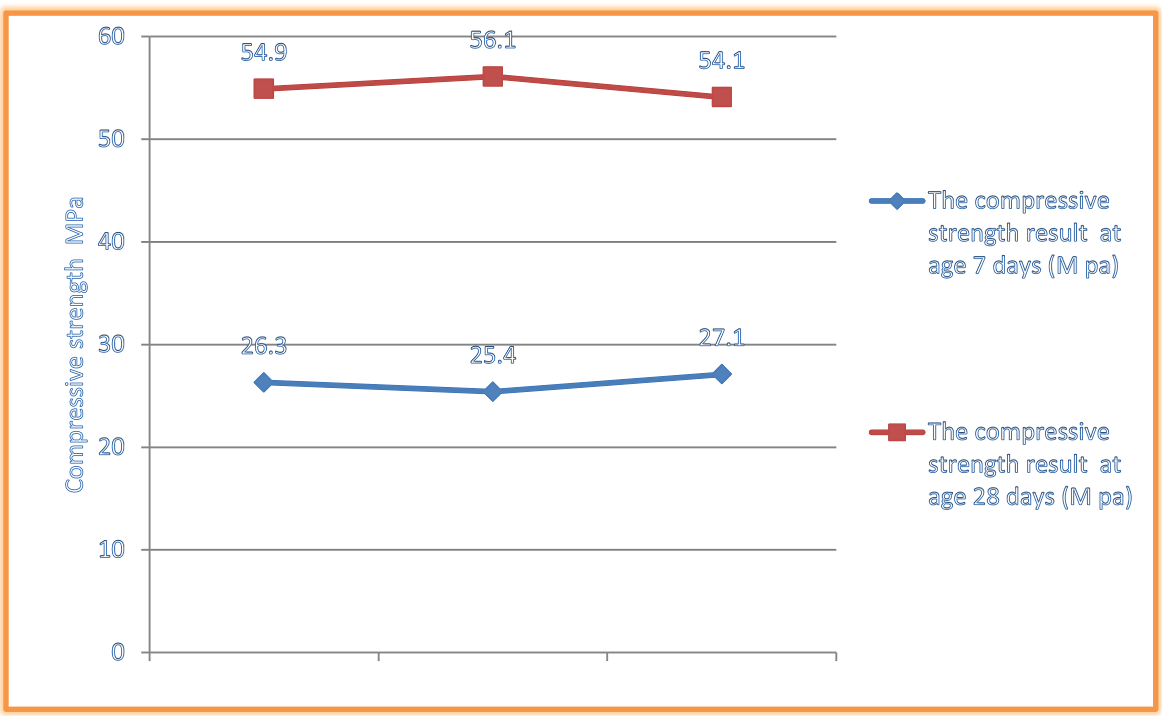


Figure 4-6 The Compressive Strength result of concrete mix M (5)

4.2.7 Compressive Strength result of concrete mix M (6)

Table 4 - 4-7 The Compressive Strength result of concrete mix M (6)

NO	Age (days)	Weight of cube (kg)	Density (kg/m³)	*Load breaking KN*	*Compressive Strength* (N/mm^2)	*Average Compressive strength(N/mm²)*
1	7	8.100	2400	721.7	32.07	31.5
2		8.125	2407	711.7	31.63	
3		8.130	2409	692.5	30.78	
4	28	8.170	2421	1085.8	48.26	50.6
5		*8.160*	2418	1175.6	52.25	
6		8.155	2416	1155.7	51.36	

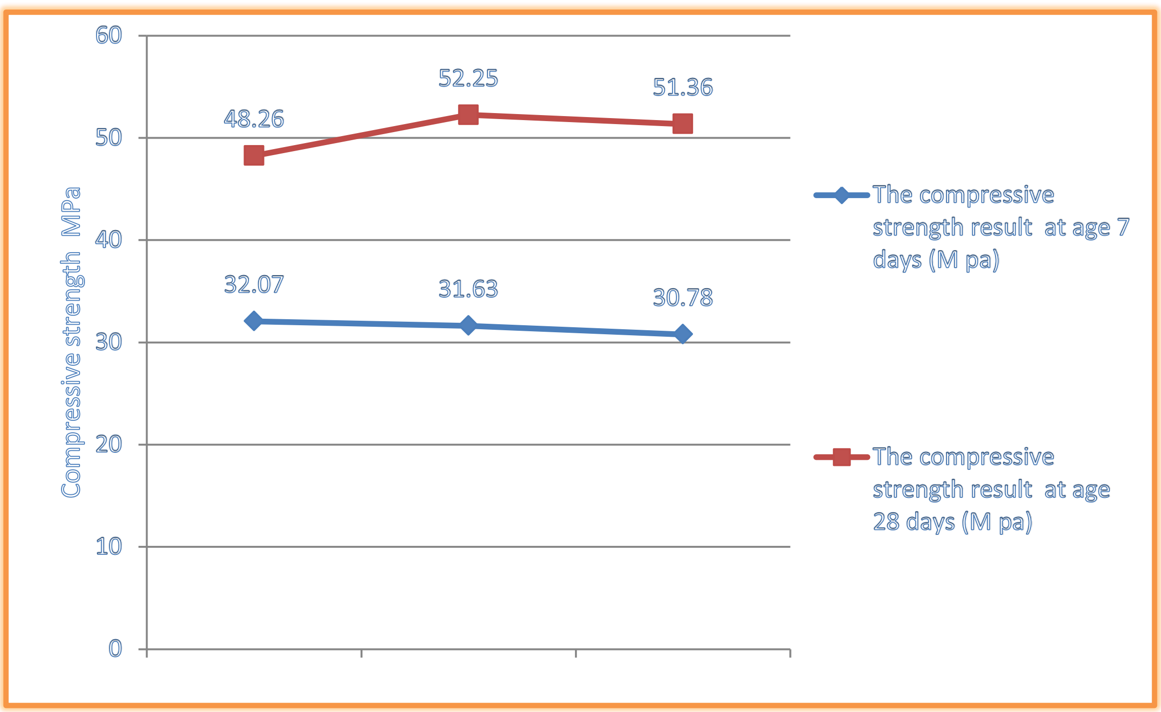


Figure 4-7 The Compressive Strength result of concrete mix M (6)

4.2.8Compressive Strength result of concrete mix M(7)

Table 4 - 8 The Compressive Strength result of concrete mix M (7)

NO	Age (days)	Weight of cube (kg)	Density (kg/m³)	*Load breaking KN*	*Compressive Strength* (N/mm^2)	*Average Compressive strength(N/mm²)*
1	7	7.850	2326	567.4	25.2	24.2
2		7.800	2311	483.2	21.5	
3		7.900	2341	584.4	26.0	
4	28	7.900	2341	972.7	43.2	41.4
5		*7.850*	2326	850.4	37.8	
6		7.900	2341	968.7	43.1	

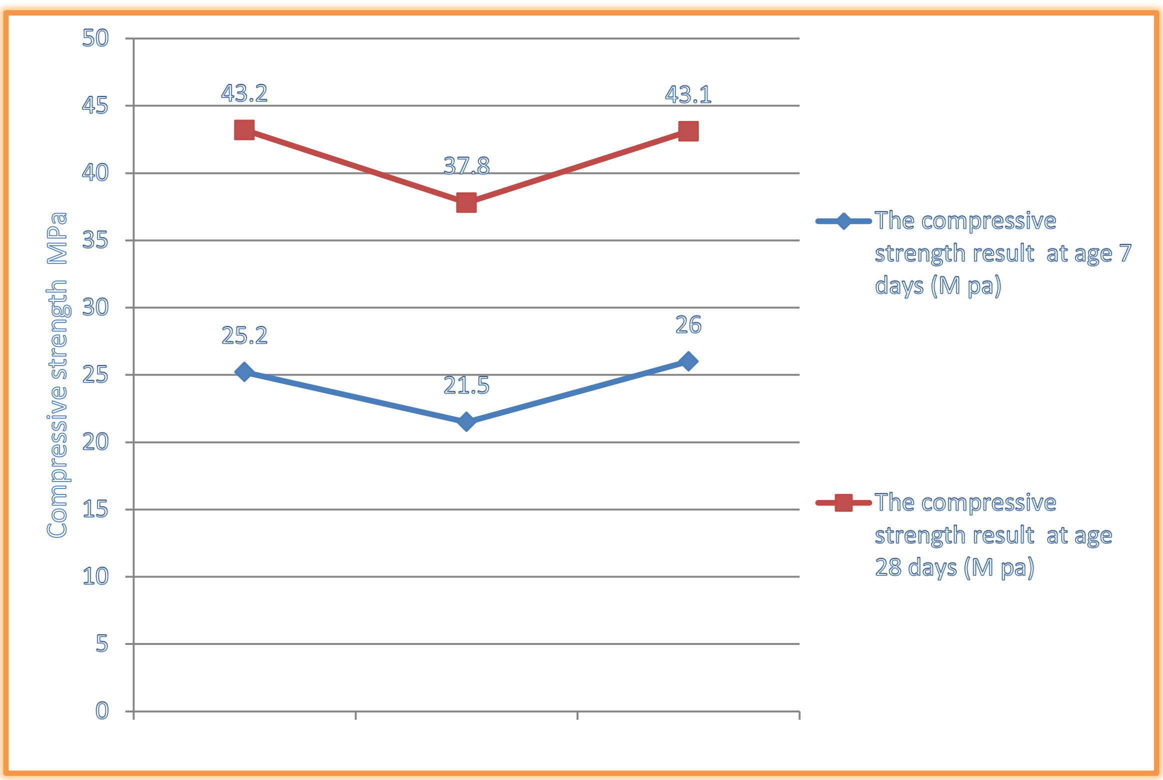


Figure 4-8 The Compressive Strength result of concrete mix M (7)

4.2.9 Average Compressive Strength result of 7 days sample

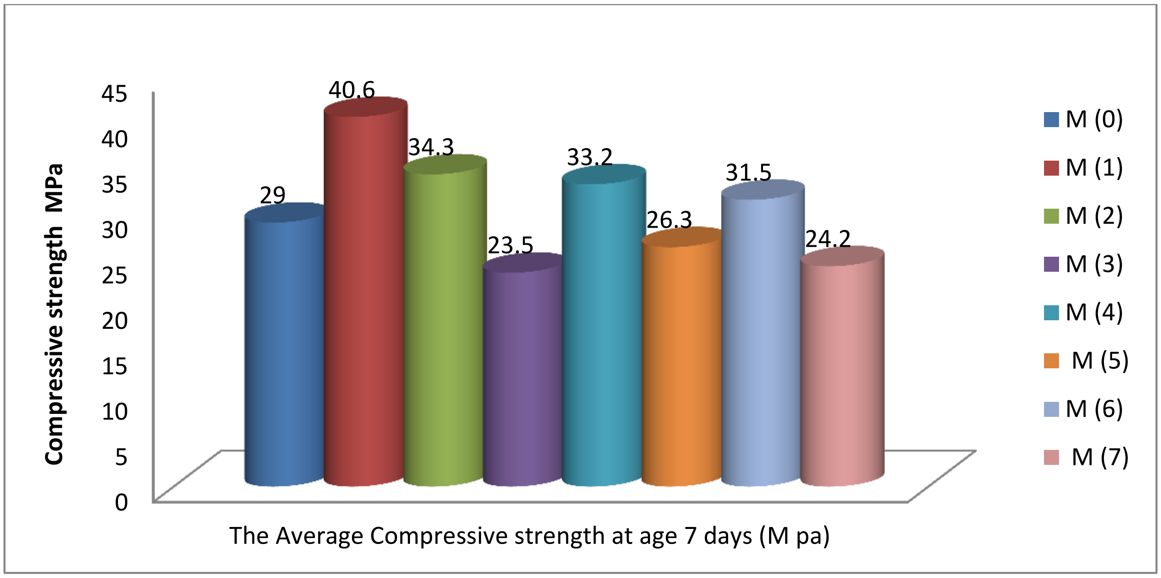


Figure 4-9 The Average Compressive Strength result of 7 days sample

4.2.10 Average Compressive Strength result of 28 days sample[18]

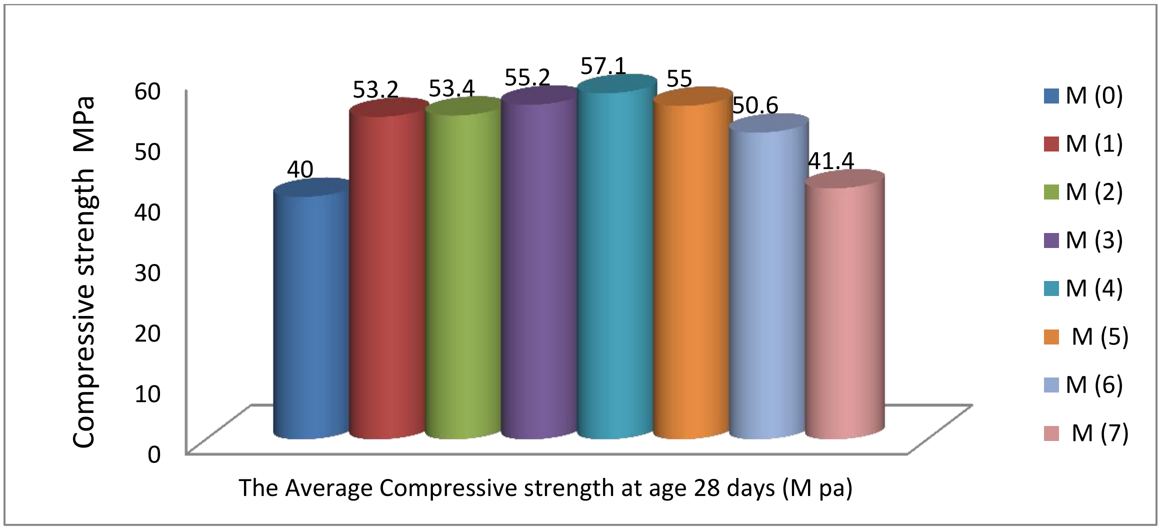


Figure 4-10 The Average Compressive Strength result of 28 days sample

[18] See Appendix (D)

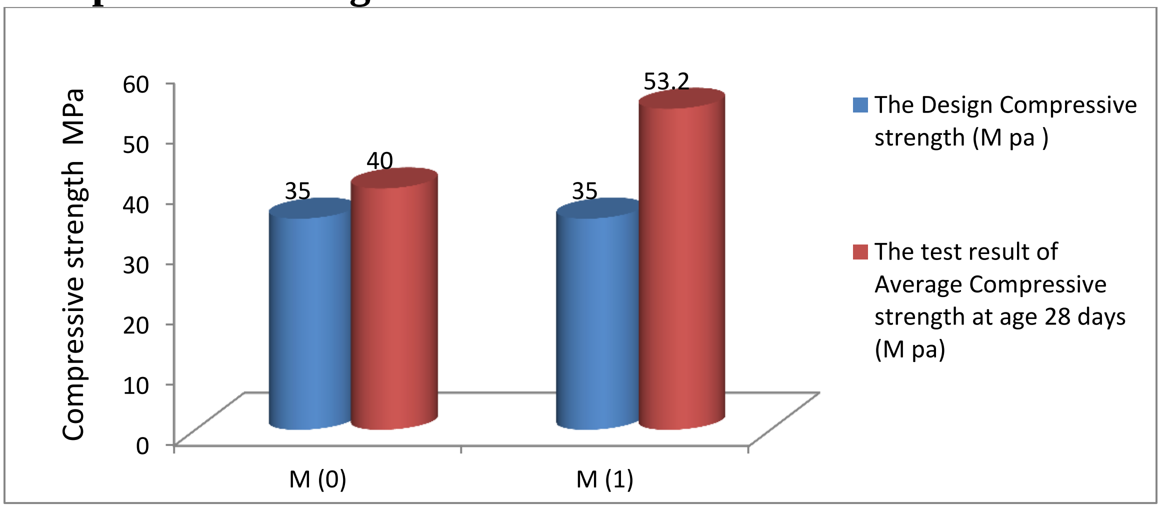
4.3 The Slump and flow test results

Table 4-9 the slump and flow test results

No	Mix No	Flow and Slump test (cm)	REMARK
1	M(0)	15	Slump Test
2	M(1)	15	
3	M(2)	60	Flow Test
4	M(3)	48	
5	M(4)	49	
6	M(5)	48	
7	M(6)	50	
8	M(7)	54	

4.4 The results and discussion

4.4.1 The Compressive Strength at 28 days vs. design Compressive Strength



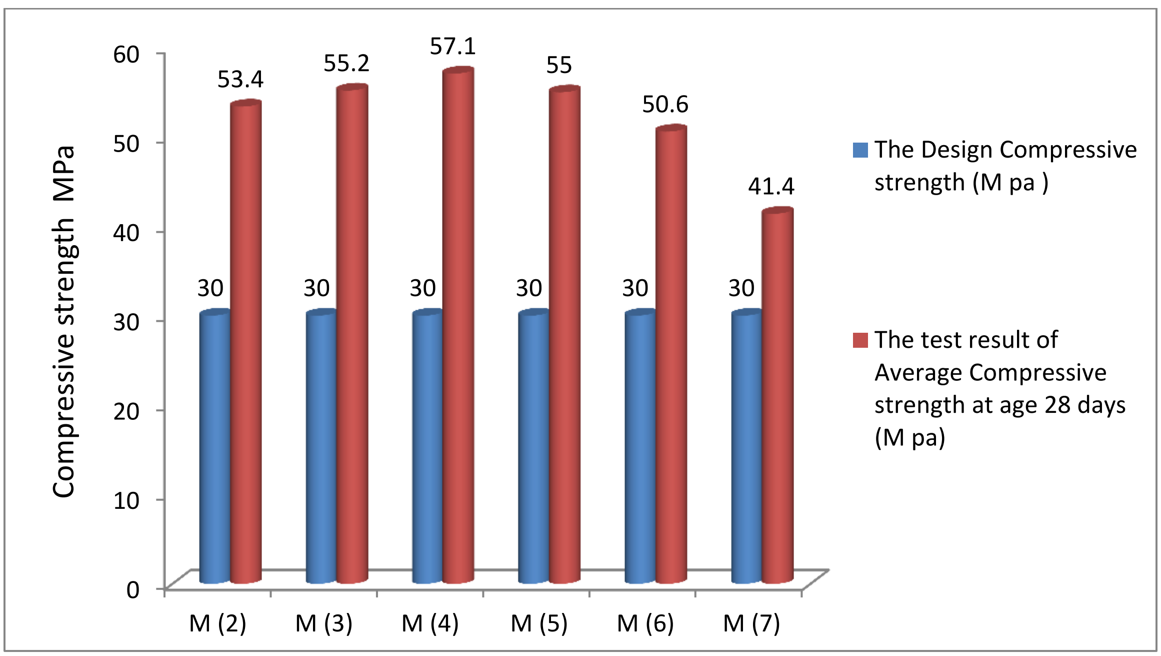


Figure 4-11 The Compressive Strength at 28 days vs. design Compressive Strength

- Discussion: From the Figures above we can observe that, we have 8 trials mix design. The minimum compressive strength for 28 days is 40 (MPa), the maximum once up to 57.1 (MPa), these mean we are achieve the desired aim to used Superplasticizer Admixture.

4.4.2 The relationship between the design Compressive Strength and The Compressive Strength increase %

Table 4-10 The design Compressive Strength and The Compressive Strength increase %

No	Mix No	The Compressive Strength increase %	Remark
1	M(0)	14.28	The design strength (35 Mpa)
2	M(1)	52	
3	M(2)	78	The design strength (30 Mpa)
4	M(3)	74	
5	M(4)	90.33	
6	M(5)	83.33	
7	M(6)	68.66	
8	M(7)	38	

- Discussion : From the Table above the Average Compressive Strength increase % is 52 % for The design strength (35 Mpa) .

4.4.3 The relationship between the Superplasticizers (kg/m^3) and the Compressive Strength at 28 days (Mpa)

Table 4-11 The Superplasticizers (kg/m3) and the Compressive Strength at 28 days (Mpa)

No	Mix No	The Superplasticizers (kg/m^3)	The Compressive Strength at 28 days (Mpa)	Remark
1	M(0)	0	40	The design strength (35 Mpa)
2	M(1)	3.98	53.2	
3	M(2)	4.22	53.4	The design strength (30 Mpa)
4	M(3)	3.17	55.2	
5	M(4)	3.68	57.1	
6	M(5)	3.44	55	
7	M(6)	1.74	50.6	
8	M(7)	3.85	41.4	

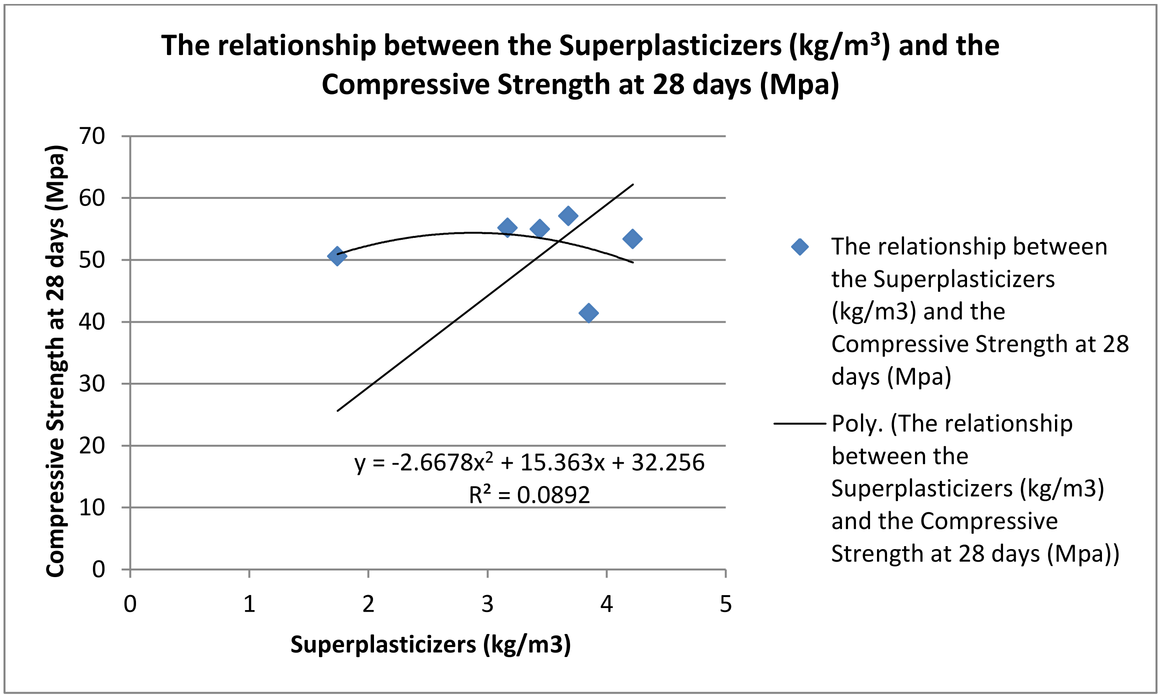


Figure 4-12 The relationship between Superplasticizers (kg/m^3) and the Compressive Strength at 28 days (Mpa) for The design strength (30 Mpa)

- Discussion: From the Table and Figure above the values of compressive strength for the different dosage of superplasticizer are high.

4.4.4 The relationship between the Superplasticizers dosage (%) and Compressive Strength at 28 days (Mpa)

Table 4-12 The Superplasticizers dosage (%) and Compressive Strength at 28 days (Mpa)

No	Mix No	The Superplasticizers dosage (%)	The Compressive Strength at 28 days (Mpa)	Remark
1	M(0)	0	40	The design strength (35 Mpa)
2	M(1)	1	53.2	
3	M(2)	1	53.4	The design strength (30 Mpa)
4	M(3)	0.8	55.2	
5	M(4)	1	57.1	
6	M(5)	1	55	
7	M(6)	0.5	50.6	
8	M(7)	1	41.4	

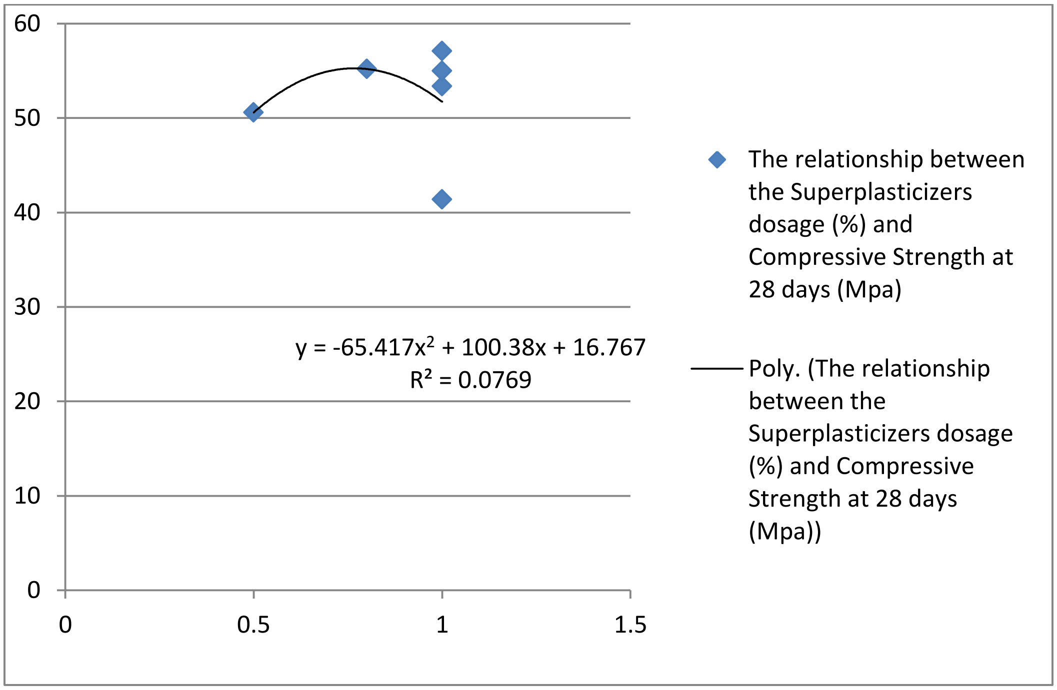


Figure 4-13 the relationship between the Superplasticizers dosage (%) and Compressive Strength at 28 days (Mpa) for the design strength (30 Mpa)

- Discussion: From the Table and Figure above the optimum dosage for Superplasticizers admixture is (1%).

4.4.5 The Relationship between the Superplasticizers (kg/m^3) and the flow

Table 4-13 the relationship between the Superplasticizers (kg/m3) and the flow

No	Mix No	The Superplasticizers (kg/m^3)	Flow test (cm)	REMARK
1	M(2)	4.22	60	The Max aggregate size (16 mm)
2	M(3)	3.17	48	
3	M(4)	3.68	49	

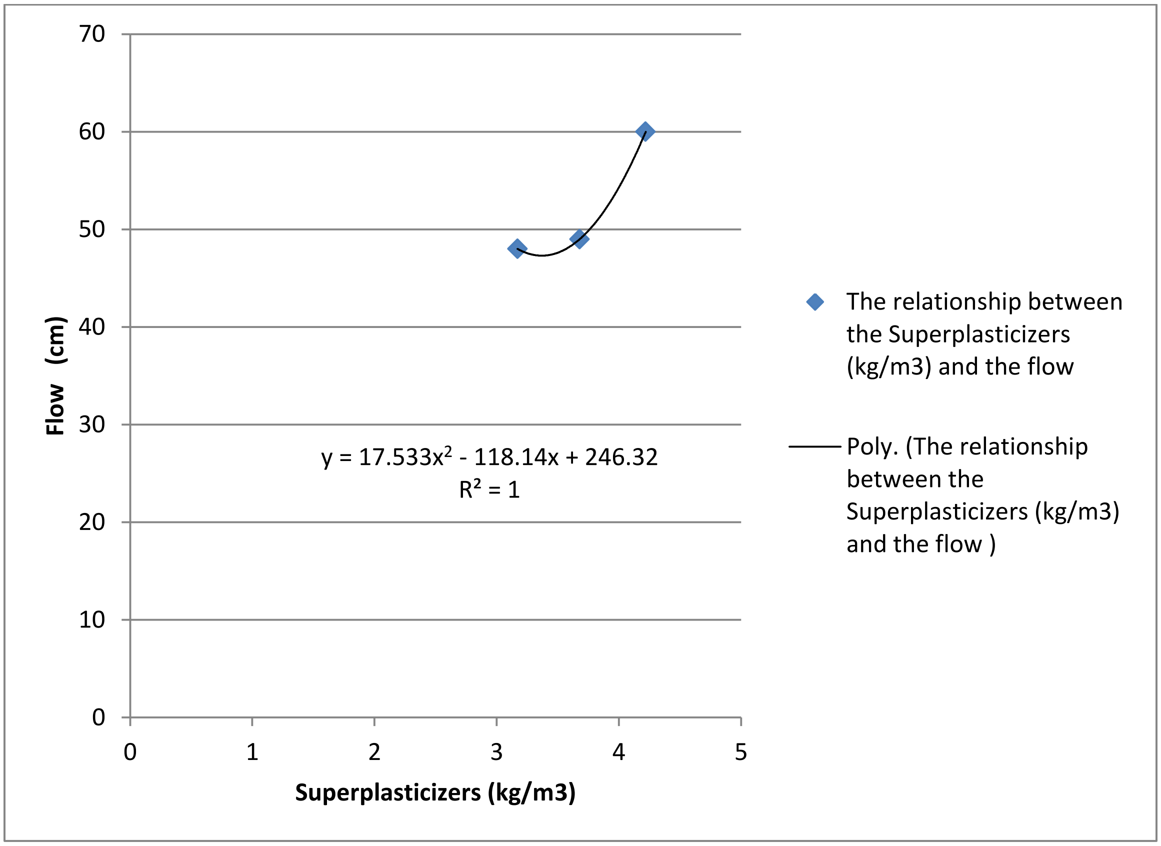


Figure 4-14 The relationship between the Superplasticizers (kg/m3) and the flow

- Discussion: From the Table and Figure above the workability of concrete mix increase by adding of superplasticizer admixture.

4.4.6The relationship between the Superplasticizers (%) and the flow

Table 4-14 The Superplasticizers (%) and the flow

No	Mix No	The Superplasticizers (%)	Flow test (cm)	REMARK
1	M(2)	1	60	The Max aggregate size (16 mm)
2	M(3)	0.80	48	
3	M(4)	1	49	

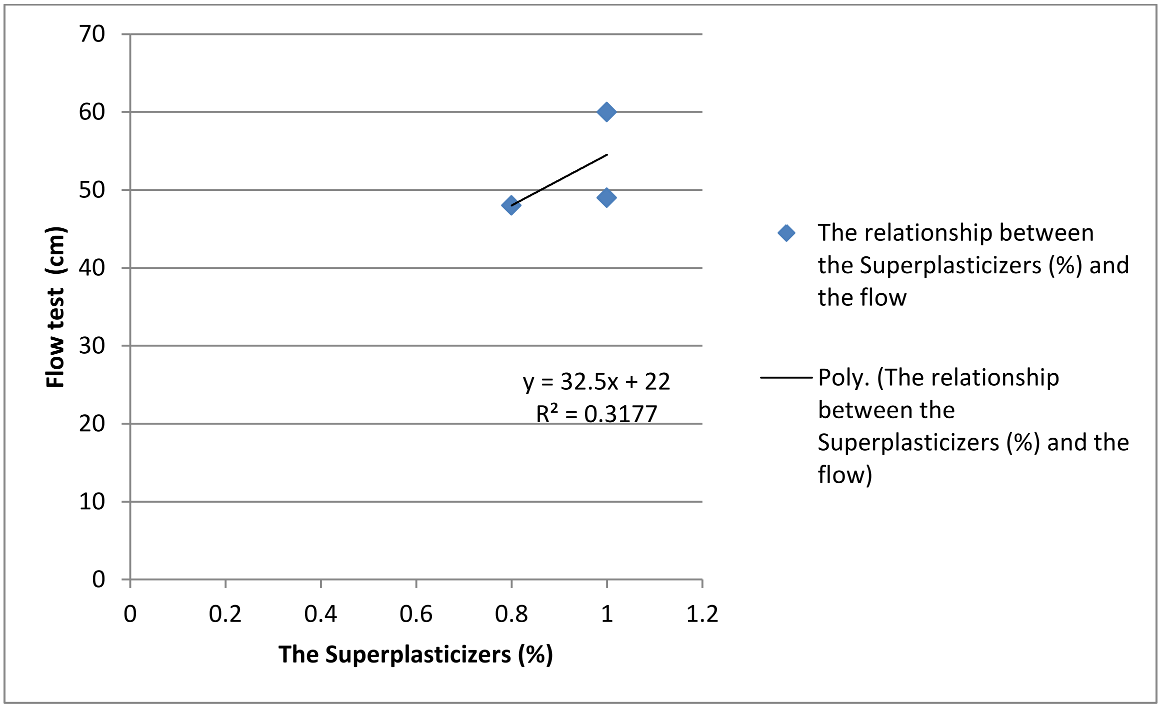


Figure 4-15 the relationship between the Superplasticizers (%) and the flow

- Discussion: From the Table and Figure above the workability of concrete can be increased by addition of superplasticizer admixture.

4.4.7 The relationship between the mixes M (0) and M (1).

You now the mix M (0) and mix M (1) have same quantity But in mix M (0) haven't add Superplasticizers admixture.

- See Table (3-12) and Table (3-4)

Table 4-15 the relationship between the Superplasticizers of mix (M (0), M (1)) and Compressive Strength at 28 days (Mpa)

No	Mix No	The Superplasticizers (kg/m^3)	The Superplasticizers dosage (%)	The Compressive Strength at 28 days (Mpa)	The increase of Compressive Strength %
1	M(0)	0	0	40	33 %
2	M(1)	3.98	1	53.2	

- Discussion: From Table above the increase of Compressive Strength of concrete is (33 %) mix if used Superplasticizers admixture.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Properties of concrete containing high performance superplasticizer had been successfully studied. From the results of the study presented earlier, the following conclusions are offered:-

1. Compressive strength is improved by high performance superplasticizer admixture. On the other hand, its ultimate strength is higher than the design Compressive strength.
2. The highest compressive strength was obtained in concrete mix M (4) when 1% superplasticizer has been added and cured in water for 28 days.
3. The lowest compressive strength was obtained in concrete mix M (0) when 0% superplasticizer has been added and cured in water for 28 days.
4. The analysis have shown that the compressive Strength of concrete has increased by 52% when 1% dosage of superplasticizer admixture was used for the design compressive strength of 35 MPa, while for design compressive strength mixes of 30 MPa, it was found that the increase percent ranges from 38% to 90.33% for the same dosage of superplasticizer admixture.The values of compressive strength for the different dosage of superplasticizer are higher than the concrete without adding Superplasticizers admixture.
5. The workability of concrete can be increased by addition of superplasticizer.
6. The optimum dosage for high performance superplasticizer admixture is (1%).

5.2 Recommendations

The following are few recommendations that can be done to further enhance the usefulness of the experiment:

1. Determination of accurate optimum dosage. Since there are only 3 dosages of admixture used, accurate optimum dosage of high performance superplasticizer is difficult to estimate. For this reason, more concrete mixes that contain different dosages of high performance superplasticizer should be prepared in order to obtain the precise optimum dosage of admixture through the best fit line drawn on the graph.
2. Inclusion of various types of superplasticizer. Since different kinds of superplasticizer will react differently when contacts with cement even though they are categorized in the same type, therefore, study should be done to determine which admixture perform better under certain exposure condition.
3. The values of compressive strength for the different dosage of superplasticizer are higher than the concrete without adding Superplasticizers admixture so use it of different concrete mix.

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APPENDICES

Appendix A- the Dam Complex of Upper Atbara Project (DCUAP) picture

A-1 General view of Upstream

A-2 General view of Downstream

A-3 General View of Traffic Bridge

A-4General View of Power House

A-5 General View of Operation Building

A-6 General View Power House and Power intake

A-7 the Metal Structure

A-9 The Road of Dam Crest

Appendix B - Materials Used and Properties

1.Density-By using Le CF(Kerosene Liquid)

Weight of Cement (g)	Initial Liquid Surface (ml)	Final Liquid Surface (ml)	SG	Average SG
60.00	0.8	21.3	2.93	2.93
60.00	0.8	21.2	2.94	

2.Normal Consistency—By Using Vicat Needle

Weight of Cement (g)	Start of Mixing Time (h:min)	Mixing Water (g)	Normal Consistency (%)
500.0	11:00	164.7	32.9

3.Setting time –By Using Vicat Needle

Initial Time (h:min)	Initial Setting Time (min)	Final Time (h:min)	Final Setting Time (min)
11:00	180	15:16	246

4.Soundness—By Using Le CM

Space between finger before see the A (mm)	Space between finger after seethe C (mm)	Expansion C-A (mm)	Average C-A (mm)
9.0	9.5	0.5	0.25
7.0	7.0	0.0	

5. Fineness—By Using 0.08mm Sieve

Weight of Cement (g)	Retain 0.08mm (g)	Retain 0.08mm Percent (%)	Average (%)
10.00	0.09	0.9	0.8
10.00	0.07	0.7	

6.Loss on Ignition—By Using Electric Furnace

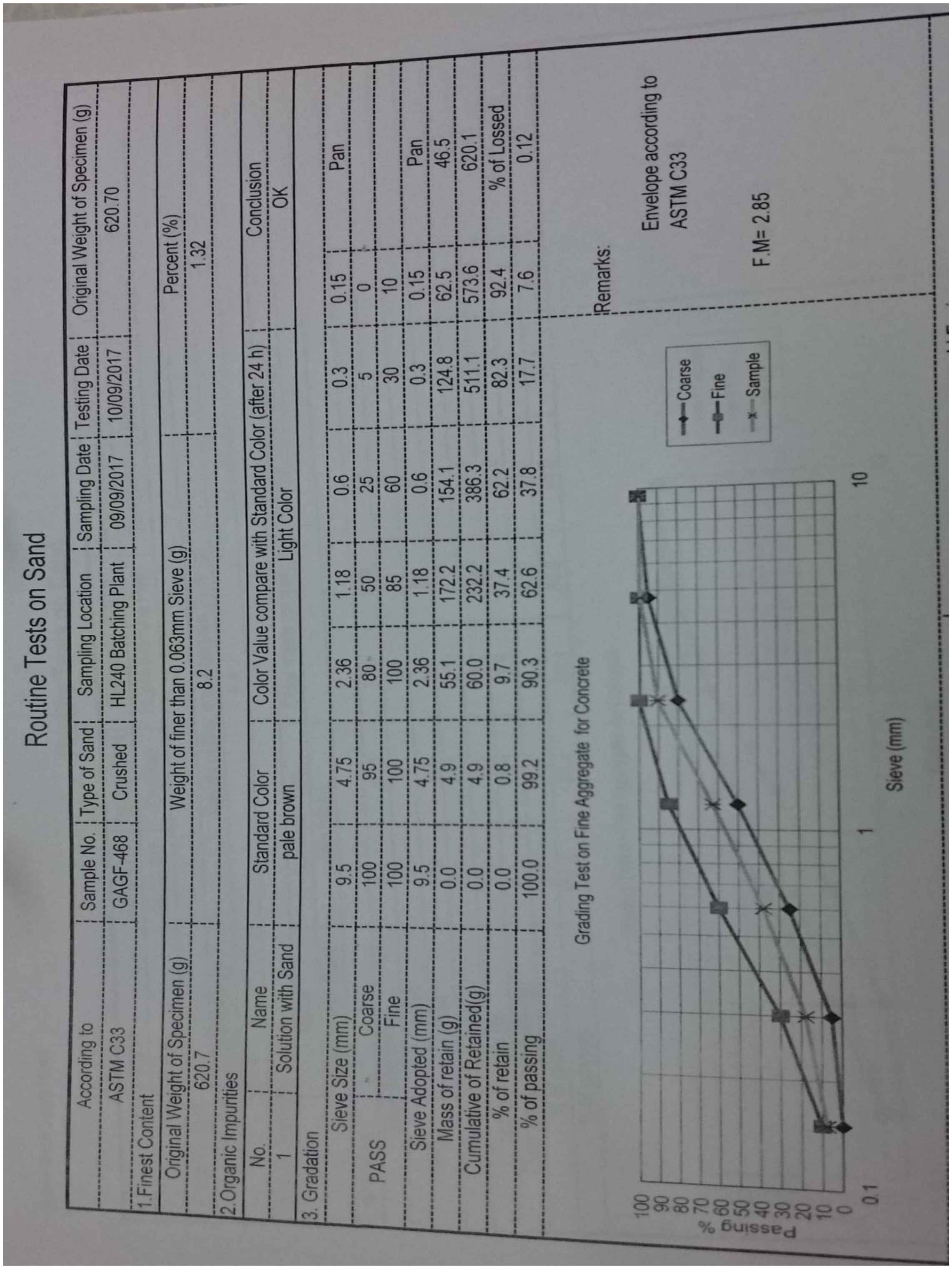
Weight of Cement (g)	Weight of Crucible + Cement (g)	Weight of Crucible+Cement after Heating (g)	Weight of Lossing Cement after Heating (g)	Loss on Ignition (%)	Average (%)
-	-	-	-	-	-

7. Compressive & Flexural Strength (40×40×160)—By Using Compressive & Flexural Machine

C (g)	450	S (g)	1350			W (ml)	225	
Date of Test	Flexural Strength (MPa)		1		2		3	Average
			3.5		3.5		3.5	3.5
2 Days	Compressive Test	Ultimate Load (KN)	22.77	20.85	21.93	19.02	20.99	20.23	21.0
21/02/2017		Strength (MPa)	14.23	13.03	13.71	11.89	13.12	12.64	13.1
Date of Test	Flexural Strength (MPa)		1		2		3	Average
			5.9		5.6		5.9	5.8
7 Days	Compressive Test	Ultimate Load (KN)	48.07	46.83	48.46	50.39	50.00	50.00	49.0
26/02/2017		Strength (MPa)	30.04	29.27	30.29	31.49	31.25	31.25	30.6
Date of Test	Flexural Strength (MPa)		1		2		3	Average
			8.2		7.5		8.4	8.0
28 Days	Compressive Test	Ultimate Load (KN)	84.66	81.68	90.31	86.82	84.57	87.55	85.9
19/03/2017		Strength (MPa)	52.91	51.05	56.44	54.26	52.86	54.72	53.7

Remarks:

B-1Test report of cement



Routine Tests on Sand

According to	Sample No.	Type of Sand	Sampling Location	Sampling Date	Testing Date	Original Weight of Specimen (g)
ASTM C33	GAGF-468	Crushed	HL240 Batching Plant	09/09/2017	10/09/2017	620.70

1.Finest Content

Original Weight of Specimen (g)	Weight of finer than 0.063mm Sieve (g)	Percent (%)
620.7	8.2	1.32

2.Organic Impurities

No.	Name	Standard Color	Color Value compare with Standard Color (after 24 h)	Conclusion
1	Solution with Sand	pale brown	Light Color	OK

3. Gradation

Sieve Size (mm)		9.5	4.75	2.36	1.18	0.6	0.3	0.15	Pan
PASS	Coarse	100	95	80	50	25	5	0	
	Fine	100	100	100	85	60	30	10	
Sieve Adopted (mm)		9.5	4.75	2.36	1.18	0.6	0.3	0.15	Pan
Mass of retain (g)		0.0	4.9	55.1	172.2	154.1	124.8	62.5	46.5
Cumulative of Retained(g)		0.0	4.9	60.0	232.2	386.3	511.1	573.6	620.1
% of retain		0.0	0.8	9.7	37.4	62.2	82.3	92.4	% of Lossed
% of passing		100.0	99.2	90.3	62.6	37.8	17.7	7.6	0.12

Remarks:

Envelope according to ASTM C33

F.M= 2.85

B-2 Routing test of sand

Test Report of Sand

Sample No.	GAGF-468	Sampling Date	09/09/2017	Testing Date	10/09/2017
Sample Source	Jebel Aklait	Sampling Place	HL240 Batching Plant	Type	0-5mm

1. Soundness of Aggregates (Cycle.No.:5)

Sieve Size (mm)	Retain Mass (g)	Retain Mass after Cycle (g)	Mass of loss (g)	Loss Percent %	Grading of Sample%	Total %
2.36~4.75	100.0	85.1	14.9	14.90	11.78	15.5
1.18~2.36	100.0	87.7	12.3	12.30	33.17	
0.6~1.18	100.0	82.9	17.1	17.10	30.89	
0.3~0.6	100.0	81.8	18.2	18.20	24.16	

2. Organic Impurities

No.	Name	Standard Color	Color Value compare with Standard Color (after 24 h)	Conclusion
1	Solution with Sand	pale brown	/	/

3. Specific Gravity

Mass of Sample (g)	Weight of Flask & Water (g)	Weight of Sample, Flask & Water (g)	S.G (kg/m³)	
/	/	/	/	/
/	/	/	/	

4. Water Absorption

Mass saturated-surface-dry (SSD) (g)	Mass (Oven Dry) (g)	Absorption %	Average
/	/	/	/
/	/	/	

5. Chloride content

Mass of Sample (g)	Percentage of NaCl	Chloride content (%)
/	/	/

B-3Test report of sand – soundness test

Test Report of Sand

Sample No.	GAGF-468	Sampling Date	09/09/2017	Testing Date	10/09/2017
Sample Source	Jebel Aklait	Sampling Place	C1-B	Type	0-5mm

1. Soundness of Aggregates (Cycle.No.:5)

Sieve Size (mm)	Retain Mass (g)	Retain Mass after Cycle (g)	Mass of loss (g)	Loss Percent %	Grading of Sample%	Total %
2.36~4.75	100.0					
1.18~2.36	100.0					
0.6~1.18	100.0					
0.3~0.6	100.0					

2. Organic Impurities

No.	Name	Standard Color	Color Value compare with Standard Color (after 24 h)	Conclusion
1	Solution with Sand	pale brown	/	/

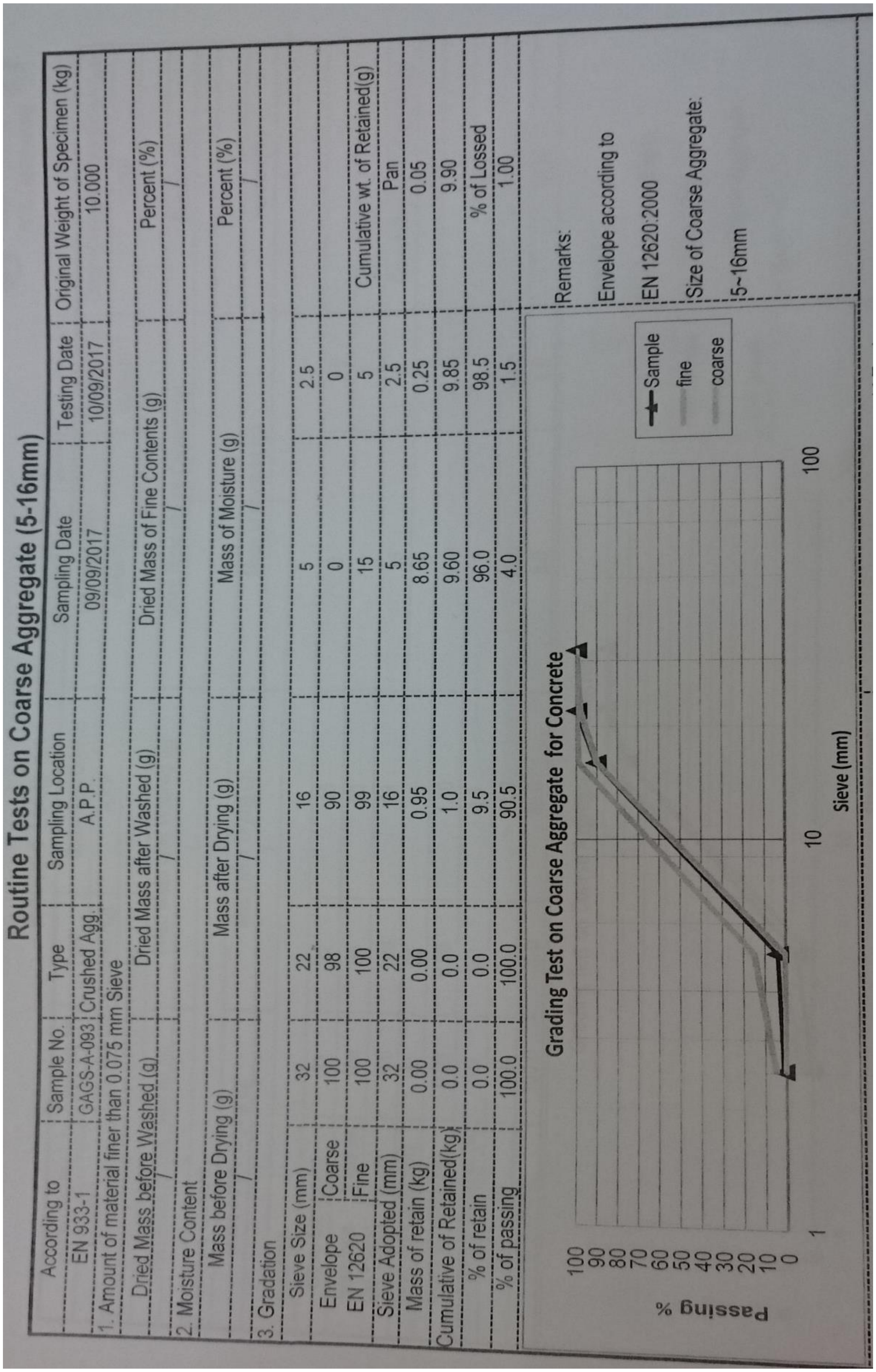
3. Specific Gravity

Mass of Sample (g)	Weight of Flask & Water (g)	Weight of Sample, Flask & Water (g)	S.G	
600.0	1346.2	1716.4	2.611	2.611
/	/	/	/	

4. Water Absorption

Mass saturated-surface-dry (SSD) (g)	Mass (Oven Dry) (g)	Absorption %	Average
500.0	484.5	3.20	3.20
/	/	/	

B-4 Test report of sand – (specific Gravity and water Absorption) test



Routine Tests on Coarse Aggregate (5-16mm)

According to	Sample No.	Type	Sampling Location	Sampling Date	Testing Date	Original Weight of Specimen (kg)
EN 933-1	GAGS-A-093	Crushed Agg.	A.P.P.	09/09/2017	10/09/2017	10.000

1. Amount of material finer than 0.075 mm Sieve

Dried Mass before Washed (g)	Dried Mass after Washed (g)	Dried Mass of Fine Contents (g)	Percent (%)
/	/	/	/

2. Moisture Content

Mass before Drying (g)	Mass after Drying (g)	Mass of Moisture (g)	Percent (%)
/	/	/	/

3. Gradation

Sieve Size (mm)		32	22	16	5	2.5	Cumulative wt. of Retained(g)
Envelope EN 12620	Coarse	100	98	90	5	0	
	Fine	100	100	99	15	5	
Sieve Adopted (mm)		32	22	16	5	2.5	Pan
Mass of retain (kg)		0.00	0.00	0.95	8.65	0.25	0.05
Cumulative of Retained(kg)		0.0	0.0	1.0	9.60	9.85	9.90
% of retain		0.0	0.0	9.5	96.0	98.5	% of Lossed
% of passing		100.0	100.0	90.5	4.0	1.5	1.00

Remarks:
Envelope according to
EN 12620:2000
Size of Coarse Aggregate:
5~16mm

B-5 Routing test of Corse Aggregates (5-16) mm

Gadaref Water Supply Project

Particle Density and Water Absorption

According to: EN 1097-6

Source from: HL240 Batching Plant

Sampling Date: 2017/9/9

Sample No.: GAGS-A-093

Particel Size: 5~16 mm

Testing Date: 2017/9/10

Determination of Particle Density			
Test Items	No.1	No.2	Average Value
The apprent mass in water of basket containing the sample of saturated aggregate, M_2 g	1969	/	1969
The apprent mass in water of empty basket, M_3, g	0	/	0
The mass of saturated and surface dried aggregate in the air, M_1, g	3188	/	3188
The mass of oven-dried test portion, M_4, g	3091	/	3091
Apprent particle density, ρ_a g/cm^3	2.75	/	2.75
Particle density on an oven-dried basis, ρ_{rd} g/cm^3	2.54	/	2.54
Particle density on an saturated and surface-dried basis, ρ_{ssd} g/cm^3	2.62	/	2.62
Determnation of Water Aborsption			
The water absorption after immersion 24hours, WA_{24}, %	3.14	/	3.14

Remarks:

Apprent particle density, ρ_a $$\rho a = \rho w \frac{M4}{M4-(M2-M3)}$$

Particle density on an oven-dried basis, ρ_{rd} $$\rho rd = \rho w \frac{M4}{M1-(M2-M3)}$$

Particle density on an saturated and surface-dried basis, ρ_{ssd} $$\rho ssd = \rho w \frac{M1}{M1-(M2-M3)}$$

The water absorption after immersion 24hours, W_{A24} $$WA24 = \frac{100\times(M1-M4)}{M4}$$

The calculation can be cheched using the following equation $$\rho ssd = \rho rd + \rho w(1-\rho rd/\rho a)$$

ρ_w(20.0℃)= 0.998203 g/cm3

$$\rho_{ssd}=\rho_{rd}+\rho_w(1-\rho_{rd}/\rho_a)$$

B-6 Test report of Corse Aggregates (5-16) mm – (particle density and water Absorption) test

Flakiness Index of Coarse Aggregate

Sample No.	GAGS-A-093	Sampling Date	09/09/2017	Testing Date	10/09/2017
Sample Source	Jebel Alkait	Sampling Place	A.P.P.	Sample Type	Crushed Agg. (5~16mm)

Test portion mass M_0 (g)	Mass retained on 16mm sieve(g)	Mass passing 5 mm sieve(g)	Sum of discarded masses(g)
10000	950	300	1250

Sieving on test sieves		Sieving on bar sieves		
Particle size fraction d_i/D_i (mm)	Mass of particle size fraction d_i/D_i (g)	Nominal width of slot in bar sieve (mm)	Mass passing bar sieve (m_i)	$FI_i = (m_i/R_i) \times 100$
63/80		40		
50/63		31.5		
40/50		25		
31.5/40		20		
25/31.5		16		
20/25		12.5		
16/20		10		
12.5/16	1900	8	200	10.5
10/12.5	2650	6.3	250	9.4
8/10	2100	5	150	7.1
6.3/8	1350	4	150	11.1
5/6.3	650	3.15	50	7.7
4/5		2.5		
$M_1=\Sigma R_i=$	8650.0	$M_2=\Sigma m_i=$	800.0	9.2

$FI=(M_2/M_1)\times 100=9.2$

$100\times\{M_0-[\Sigma R_i+\Sigma(\text{discarded masses})]\}/M_0=\underline{1.0}<1\%$

Remarks:

B-7 Test report of Corse Aggregates (5-16) mm – (Flakiness Index) test

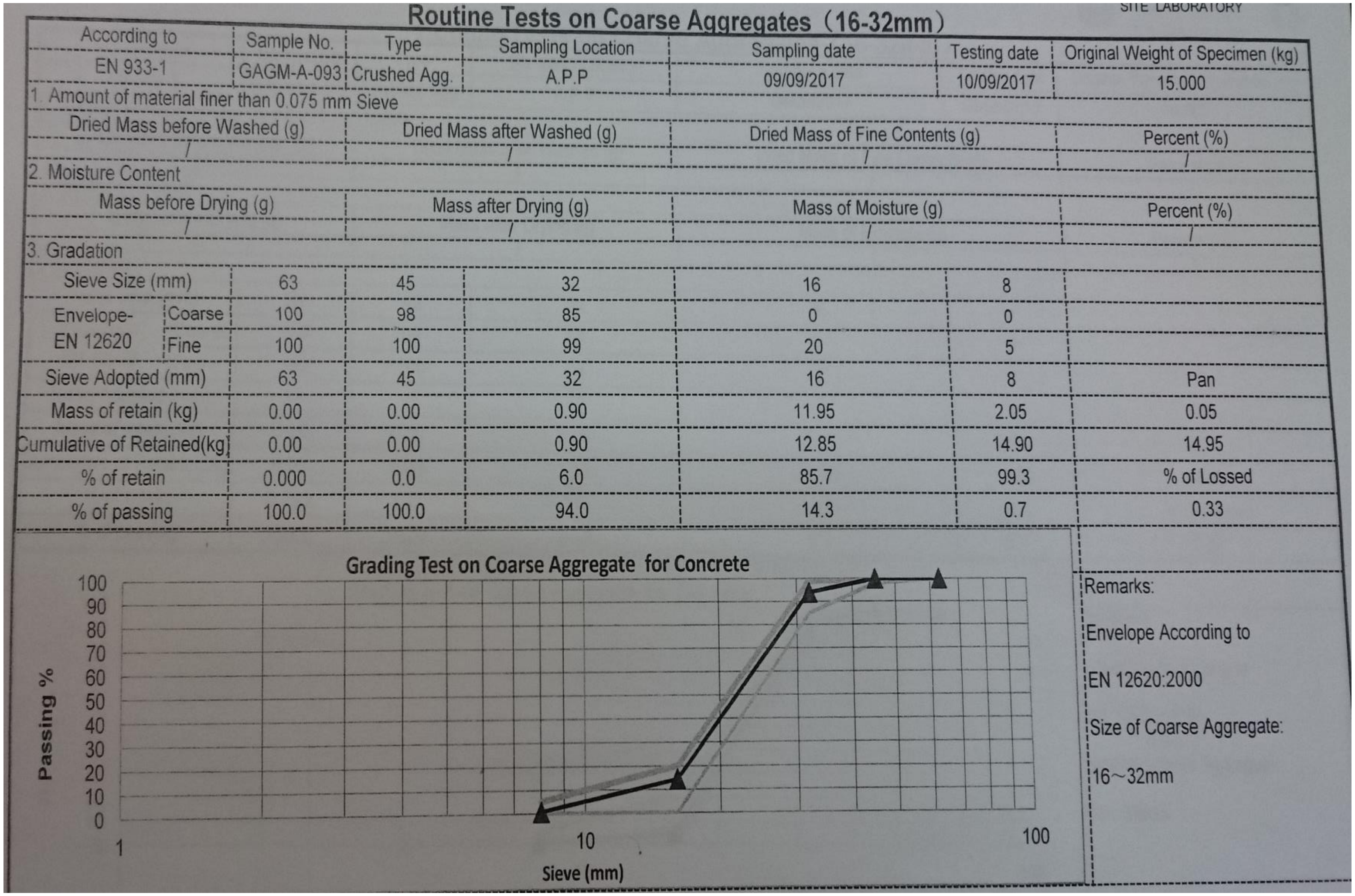
LAA Test on Coarse Aggregate

Sample No.	GAGS-A-093	Sampling Date	09/09/2017	Testing Date	10/09/2017
Sample Source	Jebel Aklait	Sampling Place	A.P.P.	Sample Type	Crushed Rock
1. Abrasion Test -By Using 1.7mm Sieve					
Size (mm)	Number of balls	Mass of charge (g)	Mass of Sample (g)	Mass of after 500r (g)	LAA Value (%)
10~14	12	5000	5000	3950	21.0

Remarks:

1. Coarse aggregate size: 5～16mm

B-8 Test report of Corse Aggregates (5-16) mm – (Los Angeles Abrasion) test



SITE LABORATORY

Routine Tests on Coarse Aggregates（16-32mm）

According to	Sample No.	Type	Sampling Location	Sampling date	Testing date	Original Weight of Specimen (kg)
EN 933-1	GAGM-A-093	Crushed Agg.	A.P.P	09/09/2017	10/09/2017	15.000

1. Amount of material finer than 0.075 mm Sieve

Dried Mass before Washed (g)	Dried Mass after Washed (g)	Dried Mass of Fine Contents (g)	Percent (%)
/	/	/	/

2. Moisture Content

Mass before Drying (g)	Mass after Drying (g)	Mass of Moisture (g)	Percent (%)
/	/	/	/

3. Gradation

Sieve Size (mm)		63	45	32	16	8	
Envelope- EN 12620	Coarse	100	98	85	0	0	
	Fine	100	100	99	20	5	
Sieve Adopted (mm)		63	45	32	16	8	Pan
Mass of retain (kg)		0.00	0.00	0.90	11.95	2.05	0.05
Cumulative of Retained(kg)		0.00	0.00	0.90	12.85	14.90	14.95
% of retain		0.000	0.0	6.0	85.7	99.3	% of Lossed
% of passing		100.0	100.0	94.0	14.3	0.7	0.33

Remarks:

Envelope According to

EN 12620:2000

Size of Coarse Aggregate:

16~32mm

B-9 Routing test of Corse Aggregates (16-32) mm

Particle Density and Water Absorption

According to:	EN 1097-6	Sample No.:	GAGM-A-093
Source from:	HL240 Batching Plant	Particel Size:	16~32 mm
Sampling Date:	2017/9/9	Testing Date:	2017/9/10

Determination of Particle Density

Test Items	No.1	No.2	Average Value
The apprent mass in water of basket containing the sample of saturated aggregate, M_2 g	2617	/	2617
The apprent mass in water of empty basket, M_3 g	0	/	0
The mass of saturated and surface dried aggregate in the air, M_1, g	4252	/	4252
The mass of oven-dried test portion, M_4 g	4137	/	4137
Apprent particle density, ρ_a g/cm^3	2.72	/	2.72
Particle density on an oven-dried basis, ρ_{rd} g/cm^3	2.53	/	2.53
Particle density on an saturated and surface-dried basis, ρ_{ssd} g/cm^3	2.60	/	2.60
Determnation of Water Aborsption			
The water absorption after immersion 24hours, WA_{24}, %	2.78	/	2.78

Remarks:

Apprent particle density, ρ_a $$\rho a = \rho w \frac{M4}{M4-(M2-M3)}$$

Particle density on an oven-dried basis, ρ_{rd} $$\rho rd = \rho w \frac{M4}{M1-(M2-M3)}$$

Particle density on an saturated and surface-dried basis, ρ_{ssd} $$\rho ssd = \rho w \frac{M1}{M1-(M2-M3)}$$

The water absorption after immersion 24hours, W_{A24} $$WA24 = \frac{100 \times (M1-M4)}{M4}$$

The calculation can be cheched using the following equation $$\rho ssd = \rho rd + \rho w(1 - \rho rd/\rho a)$$

ρ_w(20.0)= 0.998203 g/cm3

$$\rho_{ssd}=\rho_{rd}+\rho_w(1-\rho_{rd}/\rho_a)$$

B-10 Test report of Corse Aggregates (16-32) mm– (particle density and water Absorption) test

Flakiness Index of Coarse Aggregate

Sample No.	GAGM-A-093	Sampling Date	09/09/2017	Testing Date	10/09/2017
Sample Source	Jebel Alkait	Sampling Place	A.P.P	Sample Type	Crushed Agg. (16~32mm)

Test portion mass M_0 (g)	Mass retained on 32mm sieve(g)	Mass passing 16 mm sieve(g)	Sum of discarded masses(g)
15000	900	2100	3000

Sieving on test sieves		Sieving on bar sieves		
Particle size fraction d_i/D_i (mm)	Mass of particle size fraction d_i/D_i (g)	Nominal width of slot in bar sieve (mm)	Mass passing bar sieve (m_i)	$FI_i=(m_i/R_i)\times 100$
63/80		40		
50/63		31.5		
40/50		25		
31.5/40		20		
25/31.5	3450	16	350	10.1
20/25	4700	12.5	400	8.5
16/20	3800	10	250	6.6
12.5/16		8		
10/12.5		6.3		
8/10		5		
6.3/8		4		
5/6.3		3.15		
4/5		2.5		
$M_1=\sum R_i=$	11950.0	$M_2=\sum m_i=$	1000.0	8.4

$FI=(M_2/M_1)\times 100=8.4$

$100\times\{M_0-[\sum R_i+\sum(\text{discarded masses})]\}/M_0=$ 0.3 < 1%

Remarks:

B-11Test report of Corse Aggregates (16-32) mm – (Flakiness Index) test

Appendix C- Experimental Program

C-1 Balances and cubes are used

The concrete mix M (0) without add Superplasticizer admixture

C-2 The concrete mix M (1) with add Superplasticizer admixture

The white of cubes and curing path

C-3 The crushed machine

C-4 The flow test

Appendix D - Compressive Strength results

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-47	C25/30	GWSP	48~65	HL 240	8	60	GWSP-CMD-155/156

Cement	Manufacturer	Shar jah
	Type	Slag
	Strength Class	42.5N
Fly Ash	Manufaturer	-
	Grade	-
	Dosage (%)	-
Silica Fume	Manufaturer	-
	Type	-
	Dosage (%)	-
Super Plasticizer	Manufacturer	Jiang Su New Bote
	Type	PCA-1
	Dosage (%)	1.0
Fine Aggregate	Type	Crushed 0-5mm
	Absorption (%)	3.0
	Free Water Content (%)	6.3
Coarse Aggregate	Type	Crushed Max. 16mm
	Absorption (%)	3.2
	Free Water Content (%)	0
Placing Location		Elevated Water Tank Office Building-2(Groud Bwam1&2&3) Elevated Water Tank Septic Tank-2 EL 668.97~669.27 668.00~669.00

Water (kg/m^3)	Sand Content (%)	W/C (ACI 211)	W/(C+F) (EN206)	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(l) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%) 5-12.5	5-16	16-32	32-63	Coarse Aggregate (kg/m^3) 5-12.5	5-16	16-32	32-63	Unit Weight (kg/m3)
190	44	0.45	0.45	422	-	4.220	765	-	100	-	-	-	973	-	-	2350

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-CMD-146	21/05/2017	28/05/2017	7	792.9	1.000	792.9	7.700	2281	2306	150×150×150	35.2	34.3
C-CMD-146	21/05/2017	28/05/2017	7	858.8	1.000	858.8	7.800	2311		150×150×150	38.2	
C-CMD-146	21/05/2017	28/05/2017	7	665.6	1.000	665.6	7.850	2326		150×150×150	29.6	

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC 47	C25/30	GWSP	48~65	HL 240	8	60	GWSP-CMD-155/156

Cement	Manufacturer	Shar jah
	Type	Slag
	Strength Class	42.5N
Fly Ash	Manufaturer	-
	Grade	-
	Dosage (%)	-
Silica Fume	Manufaturer	-
	Type	-
	Dosage (%)	-
Super Plasticizer	Manufacturer	Jiang Su New Bote
	Type	PCA-1
	Dosage (%)	1.0
Fine Aggregate	Type	Crushed 0-5mm
	Absorption (%)	3.0
	Free Water Content (%)	6.3
Coarse Aggregate	Type	Crushed Max. 16mm
	Absorption (%)	3.2
	Free Water Content (%)	0
Placing Location		Elevated Water Tank Office Building-2(Groud Bwam1&2&3) Elevated Water Tank Septic Tank-2 EL 668.97~669.27 668.00~669.00

Water (kg/m^3)	Sand Content (%)	W/C (ACI 211)	W/(C+F) (EN206)	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(l) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%) 5-12.5	5-16	16-32	32-63	Coarse Aggregate (kg/m^3) 5-12.5	5-16	16-32	32-63	Unit Weight (kg/m3)
190	44	0.45	0.45	422	-	4.220	765	-	100	-	-	-	973	-	-	2350

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-CMD-146	21/05/2017	18/06/2017	28	1202.0	1.000	1202.0	7.600	2252	2247	150×150×150	53.4	53.4
C-CMD-146	21/05/2017	18/06/2017	28	1181.0	1.000	1181.0	7.550	2237		150×150×150	52.5	
C-CMD-146	21/05/2017	18/06/2017	28	1224.0	1.000	1224.0	7.600	2252		150×150×150	54.4	

Remarks: Concrete Quantity 9.5 m^3

D-1 Compressive Strength results of concrete mix M (2) or M (47)

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-16	C25/30	Rumela Spillway	45~52	HL 240	6	48	PC-A-373

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	Zou Xian	Silica Fume	Manufaturer	-	Placing Location
	Type	OPC		Grade	I		Type	-	Rumela Spillway SP2 II-3 EL:488.25~491.25
	Strength Class	42.5N		Dosage (%)	25.0		Dosage (%)	-	
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 32mm	
	Type	PCA-1		Absorption (%)	-		Absorption (%)	-	
	Dosage (%)	0.8		Free Water Content (%)	11.0		Free Water Content (%)	-	

Water (kg/m^3)	Sand Content (%)	W/C	W/(C+F)	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(I) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%)				Coarse Aggregate(kg/m^3)				Unit Weight (kg/m3)
		ACI 211	EN206					5-12.5	5-16	16-32	32-63	5-12.5	5-16	16-32	32-63	
186	40	0.47	0.47	396	-	3.170	727	-	100	0	-	-	1091	-	-	2400

Specimen No.	Making Date 17:45	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Compressive Strength (MPa) Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-SW-A-817-4	10/01/2013	17/01/2013	7	508.4	0.998	507.4	7.785	2307	2308	150×150×150	22.55	23.5
C-SW-A-817-4	10/01/2013	17/01/2013	7	531.1	0.998	530.0	7.795	2310		150×150×150	23.56	
C-SW-A-817-4	10/01/2013	17/01/2013	7	546.9	0.998	545.8	7.785	2307		150×150×150	24.26	

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-16	C25/30	Rumela Spillway	45~52	HL 240	6	47	PC-A-373

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	Zou Xian	Silica Fume	Manufaturer	-	Placing Location
	Type	OPC		Grade	I		Type	-	Rumela Spillway SP2 II-3 EL:488.25~491.25
	Strength Class	42.5N		Dosage (%)	25.0		Dosage (%)	-	
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 32mm	
	Type	PCA-1		Absorption (%)	-		Absorption (%)	-	
	Dosage (%)	0.8		Free Water Content (%)	11.0		Free Water Content (%)	-	

Water (kg/m^3)	Sand Content (%)	W/C	W/(C+F)	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(I) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%)				Coarse Aggregate(kg/m^3)				Unit Weight (kg/m3)
		ACI 211	EN206					5-12.5	5-16	16-32	32-63	5-12.5	5-16	16-32	32-63	
186	40	0.47	0.47	396	-	3.170	727	-	100	0	-	-	1091	-	-	2400

Specimen No.	Making Date 19:44	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Compressive Strength (MPa) Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-SW-A-817-4	10/01/2013	07/02/2013	28	1260.0	0.998	1257	7.786	2307	2296	150×150×150	55.8	55.2
C-SW-A-817-4	10/01/2013	07/02/2013	28	1205.0	0.998	1203	7.730	2290		150×150×150	53.4	
C-SW-A-817-4	10/01/2013	07/02/2013	28	1268.0	0.998	1265	7.730	2290		150×150×150	56.4	

D-2 Compressive Strength results of concrete mix M (3) or M (SPC-16)

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-5-1	C25/30	Power Intake	45~52	HL 240	6	49	PC-A-1979

Material	Property	Value	Material	Property	Value	Material	Property	Value	Placing Location
Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	-	PBC e-1 & d-5 EL:502.55~503.66
	Type	Slag		Grade	-		Type	-	
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-	
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 16mm	
	Type	PCA-1		Absorption (%)	3.0		Absorption (%)	3.2	
	Dosage (%)	1.0		Free Water Content (%)	5.2		Free Water Content (%)	0	

Water (kg/m^3)	Sand Content (%)	W/C ACI 211	W/(C+F) EN206	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(l) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%) 5-12.5	5-16	16-32	32-63	Coarse Aggregate(kg/m^3) 5-12.5	5-16	16-32	32-63	Unit Weight (kg/m3)
173	41	0.47	0.47	368	-	3.680	736	-	100	-	-	-	1061	-	-	2338

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-PI-489	13/04/2016	20/04/2016	7	755.2	0.998	753.7	8.060	2388	2390	150×150×150	33.6	33.2
C-PI-489	13/04/2016	20/04/2016	7	745.2	0.998	743.7	8.070	2391		150×150×150	33.1	
C-PI-489	13/04/2016	20/04/2016	7	739.7	0.998	738.2	8.070	2391		150×150×150	32.9	

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-5-1	C25/30	Power Intake	45~52	HL 240	6	49	PC-A-1979

Material	Property	Value	Material	Property	Value	Material	Property	Value	Placing Location
Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	-	PBC e-1 & d-5 EL:502.55~503.66
	Type	Slag		Grade	-		Type	-	
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-	
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 16mm	
	Type	PCA-1		Absorption (%)	3.0		Absorption (%)	3.2	
	Dosage (%)	1.0		Free Water Content (%)	5.2		Free Water Content (%)	0	

Water (kg/m^3)	Sand Content (%)	W/C ACI 211	W/(C+F) EN206	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(l) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%) 5-12.5	5-16	16-32	32-63	Coarse Aggregate(kg/m^3) 5-12.5	5-16	16-32	32-63	Unit Weight (kg/m3)
173	41	0.47	0.47	368	-	3.680	736	-	100	-	-	-	1061	-	-	2338

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-PI-489	13/04/2016	11/05/2016	28	1338.0	1.000	1338.0	8.130	2409	2397	150×150×150	59.5	57.1
C-PI-489	13/04/2016	11/05/2016	28	1317.0	1.000	1317.0	8.110	2403		150×150×150	58.5	
C-PI-489	13/04/2016	11/05/2016	28	1197.0	1.000	1197.0	8.030	2379		150×150×150	53.2	

D-3 Compressive Strength results of concrete mix M (4) or M (SPC 5-1)

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-20	C25/30	Rumela Spillway	45~52	HL 240	6	48	PC-A-1838,1839

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	-	Placing Location
	Type	Slag		Grade	-		Type	-	Spillway WALL 274# 276# EL:523.75~525.65
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-	
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 32mm	
	Type	PCA-1		Absorption (%)	3.0		Absorption (%)	3.2	
	Dosage (%)	1.0		Free Water Content (%)	5.2		Free Water Content (%)	0	

Water (kg/m^3)	Sand Content (%)	W/C	W/(C+F)	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(I) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%)				Coarse Aggregate(kg/m^3)				Unit Weight (kg/m3)
		ACI 211	EN206					5-12.5	5-16	16-32	32-63	5-12.5	5-16	16-32	32-63	
165	40	0.48	0.48	344	-	3.440	749	-	50	50	-	-	561	561	-	2380

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Compressive Strength (MPa): Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-SW-1583	07/01/2016	14/01/2016	7	592.2	1.000	592.2	8.110	2403	2385	150×150×150	26.3	26.3
C-SW-1583	07/01/2016	14/01/2016	7	571.6	1.000	571.6	8.000	2370		150×150×150	25.4	
C-SW-1583	07/01/2016	14/01/2016	7	609.6	1.000	609.6	8.040	2382		150×150×150	27.1	

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-20	C25/30	Rumela Spillway	45~52	HL 240	6	48	PC-A-1838,1839

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	-	Placing Location
	Type	Slag		Grade	-		Type	-	Spillway WALL 274# 276# EL:523.75~525.65
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-	
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 32mm	
	Type	PCA-1		Absorption (%)	3.0		Absorption (%)	3.2	
	Dosage (%)	1.0		Free Water Content (%)	5.2		Free Water Content (%)	0	

Water (kg/m^3)	Sand Content (%)	W/C	W/(C+F)	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(I) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%)				Coarse Aggregate(kg/m^3)				Unit Weight (kg/m3)
		ACI 211	EN206					5-12.5	5-16	16-32	32-63	5-12.5	5-16	16-32	32-63	
165	40	0.48	0.48	344	-	3.440	749	-	50	50	-	-	561	561	-	2380

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Correction Factor	Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Compressive Strength (MPa): Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-SW-1583	07/01/2016	04/02/2016	28	1236.0	1.000	1236.0	8.150	2415	2411	150×150×150	54.9	55.0
C-SW-1583	07/01/2016	04/02/2016	28	1262.0	1.000	1262.0	8.100	2400		150×150×150	56.1	
C-SW-1583	07/01/2016	04/02/2016	28	1218.0	1.000	1218.0	8.160	2418		150×150×150	54.1	

D-4 Compressive Strength results of concrete mix M (5) or M (SPC -20)

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-23	C25/30	Rumela Spillway	42~53	HL 240	6	50	PC-A-549

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	-	Placing Location
	Type	Slag		Grade	-		Type	-	Rumela Spillway SB1 III-10 EL:486.5~489.5
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-	
Super Plasticizer	Manufacturer	Conmix	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 32mm	
	Type	Mege Flow 2000		Absorption (%)	-		Absorption (%)	-	
	Dosage (%)	0.5		Free Water Content (%)	10.0		Free Water Content (%)	-	

Water (kg/m^3)	Sand Content (%)	W/C	W/(C+F)	Cement (kg/m^3)	Fly Ash (kg/m^3)	MF2000 (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%)				Coarse Aggregate(kg/m^3)				Unit Weight (kg/m3)
		ACI 211	EN206					5-12.5	5-16	16-32	32-63	5-12.5	5-16	16-32	32-63	
160	39	0.46	0.46	348	-	1.740	718	-	50	50	-	-	562	562	-	2350

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN)			Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Compressive Strength (MPa)		
				Ultimate	Correction Factor	Calibration				Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-SW-A-980	19/04/2013	26/04/2013	7	723.1	0.998	721.7	8.100	2400	2405	150×150×150	32.07	31.5
C-SW-A-980	19/04/2013	26/04/2013	7	713.1	0.998	711.7	8.125	2407		150×150×150	31.63	
C-SW-A-980	19/04/2013	26/04/2013	7	693.9	0.998	692.5	8.130	2409		150×150×150	30.78	

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-23	C25/30	Rumela Spillway	42~53	HL 240	6	49	PC-A-549

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	-	Placing Location
	Type	Slag		Grade	-		Type	-	Rumela Spillway SB1 III-10 EL:486.5~489.5
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-	
Super Plasticizer	Manufacturer	Conmix	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 32mm	
	Type	Mege Flow 2000		Absorption (%)	-		Absorption (%)	-	
	Dosage (%)	0.5		Free Water Content (%)	10.0		Free Water Content (%)	-	

Water (kg/m^3)	Sand Content (%)	W/C	W/(C+F)	Cement (kg/m^3)	Fly Ash (kg/m^3)	MF2000 (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%)				Coarse Aggregate(kg/m^3)				Unit Weight (kg/m3)
		ACI 211	EN206					5-12.5	5-16	16-32	32-63	5-12.5	5-16	16-32	32-63	
160	39	0.46	0.46	348	-	1.740	718	-	50	50	-	-	562	562	-	2350

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN)			Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Compressive Strength (MPa)		
				Ultimate	Correction Factor	Calibration				Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-SW-A-980	19/04/2013	17/05/2013	28	1088.0	0.998	1085.8	8.170	2421	2418	150×150×150	48.26	50.6
C-SW-A-980	19/04/2013	17/05/2013	28	1178.0	0.998	1175.6	8.160	2418		150×150×150	52.25	
C-SW-A-980	19/04/2013	17/05/2013	28	1158.0	0.998	1155.7	8.155	2416		150×150×150	51.36	

D-5 Compressive Strength results of concrete mix M (6) or M (SPC -23)

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-41	C25/30	GWSP	48~65	HL 240	8	50	GWSP-CMD-39

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	-
	Type	Slag		Grade	-		Type	-
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 16mm
	Type	PCA-1		Absorption (%)	3.0		Absorption (%)	3.2
	Dosage (%)	1.0		Free Water Content (%)	4.5		Free Water Content (%)	0

Placing Location
Elevated Water Tank Clean-water Tank(1/2)-1.2 (Blinding Concrete) EL:666.25~667.55

Water (kg/m^3)	Sand Content (%)	W/C ACI 211	W/(C+F) EN206	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(l) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%) 5-12.5	5-16	16-32	32-63	Coarse Aggregate(kg/m^3) 5-12.5	5-16	16-32	32-63	Unit Weight (kg/m3)
185	42	0.48	0.48	385	-	3.850	760	-	50	50	-	-	630	420	-	2380

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Load (KN) Correction Factor	Load (KN) Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-CMD-40-1	07/10/2016	14/10/2016	7	567.4	1.000	567.4	7.850	2326	2326	150×150×150	25.2	24.2
C-CMD-40-1	07/10/2016	14/10/2016	7	483.2	1.000	483.2	7.800	2311		150×150×150	21.5	
C-CMD-40-1	07/10/2016	14/10/2016	7	584.4	1.000	584.4	7.900	2341		150×150×150	26.0	

Concrete Compressive Strength Test

Mix Design No.	Specification Class	Project Identification	Required Flow (cm)	Batching Plant No.	Quantity with This Truck (m^3)	Test Flow (cm)	Mix Sheet No.
SPC-41	C25/30	GWSP	48~65	HL 240	8	54	GWSP-CMD-39

Cement	Manufacturer	Shar jah	Fly Ash	Manufaturer	-	Silica Fume	Manufaturer	
	Type	Slag		Grade	-		Type	-
	Strength Class	42.5N		Dosage (%)	-		Dosage (%)	-
Super Plasticizer	Manufacturer	Jiang Su New Bote	Fine Aggregate	Type	Crushed 0-5mm	Coarse Aggregate	Type	Crushed Max. 16mm
	Type	PCA-1		Absorption (%)	3.0		Absorption (%)	3.2
	Dosage (%)	1.0		Free Water Content (%)	4.5		Free Water Content (%)	0

Placing Location
Elevated Water Tank Clean-water Tank(1/2)-1.2 (Blinding Concrete) EL:666.25~667.55

Water (kg/m^3)	Sand Content (%)	W/C ACI 211	W/(C+F) EN206	Cement (kg/m^3)	Fly Ash (kg/m^3)	PCA(l) (kg/m^3)	Crushed Sand (kg/m^3)	Coarse Aggregate ratio (%) 5-12.5	5-16	16-32	32-63	Coarse Aggregate(kg/m^3) 5-12.5	5-16	16-32	32-63	Unit Weight (kg/m3)
185	42	0.48	0.48	385	-	3.850	760	-	50	50	-	-	630	420	-	2380

Specimen No.	Making Date	Testing Date	Age (days)	Load (KN) Ultimate	Load (KN) Correction Factor	Load (KN) Calibration	Specimen Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)	Dimensions of Cube Specimens (mm)	Strength of Each Specimen (MPa)	Average Strength (MPa)
C-CMD-40-1	07/10/2016	04/11/2016	28	972.7	1.000	972.7	7.900	2341	2336	150×150×150	43.2	41.4
C-CMD-40-1	07/10/2016	04/11/2016	28	850.4	1.000	850.4	7.850	2326		150×150×150	37.8	
C-CMD-40-1	07/10/2016	04/11/2016	28	968.7	1.000	968.7	7.900	2341		150×150×150	43.1	

D-6 Compressive Strength results of concrete mix M (7) or M (SPC -41)