The Islamic University Gaza
Higher Education Deanship
Faculty of Engineering
Civil Engineering Department
Design and Rehabilitation of Structures Program

الجامعة الإسلامية بغزة
عمادة الدراسات العليا
كلية الهندسة
قسم الهندسة المدنية
برنامج تصميم وتأهيل المنشآت

A study of Fresh and Hardened Normal Concrete Properties by using Proposed Admixture as Superplasticizer

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A Research Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering – Design and Rehabilitation of Structures.

January - 2015

إقــرار

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A study of Fresh and Hardened Normal Concrete Properties by using Proposed Admixture as Superplasticizer

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التاريخ:23/2/2015

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الجامعة الإسلامية – غزة
The Islamic University - Gaza

مكتب نائب الرئيس للبحث العلمي والدراسات العليا   هاتف داخلي 1150

الرقم: س غ/35/ .... Ref

التاريخ: 2015/01/31 .... Date

نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ **طراد رمضان حميد النجيلي** لنيل درجة الماجستير في **لية *الهندسة*** قسم **الهندسة المدنية– تصميم وتأهيل المنشآت** وموضوعها:

دراسة خواص الخرسانة العادية الطازجة والصلبة باستخدام إضافات جديدة مقترحة

A study of fresh and hardened normal concrete properties by using proposed admixture as superplasticizer

وبعد المناقشة العلنية التي تمت اليوم السبت 11 ربيع الآخر 1436هـ، الموافق 2015/01/31م الساعة الواحدة ظهراً بمبنى القدس، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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د. ساري وليد أبو شرار	مناقشاً خارجياً	....

وبعد المداولة أوصت اللجنة بمنح الباحث درجة الماجستير في **كلية *الهندسة*/** قسم **الهندسة المدنية- تصميم وتأهيل المنشآت**.

واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق ،،،

مساعد نائب الرئيس للبحث العلمي وللدراسات العليا

أ.د. فؤاد علي العاجز

ABSTRACT

Ready-mixed concrete is a concrete which is manufactured in a mixing plant and delivered to construction site in unhardened and plastic stage. Because of technical and economic reasons, many chemical admixtures are used in ready-mixed concrete production. As a result of extra mixing and delayed placing of ready-mixed concrete (especially in hot weather conditions), there can be many problems about concrete, such as segregation and slump loss problems. The addition of water without proper adjustment in mixture proportions, adversely affects compressive strength.

The main aim of this research is to study the effect of proposed superplasticizer on the fresh and hardened properties of concrete in order to produce concrete with adequate workability. These admixtures are not very common in the industry of concrete production, note that the applied admixtures in this research were lignosulphonates (commercially used superplasticizer) (LS), styrene acrylic (SA), Praepagen HY (PHY) and acrylic polymer (AP).

The mechanical properties of fresh and hardened concrete first obtained for plain concrete (without admixtures) to serve as control mix. Then, four admixture contents were added to the concrete, 0.25%, 0.5% and 0.75% by cement weight. The slump tests, compressive strength tests and flexure strength tests were conducted for all specimens with and without admixtures.

As a result of this study, it has been observed that using LS, SA, PHY and AP admixtures at theirs best ratios in the concrete mixes would improve the slump loss problem by retarding the slump loss effect of mixing at all stages. Also, these admixtures improved the slump value from 70mm to 160, 235, 230 and 220 mm respectively. The use of Styrene Acrylic and Acrylic Polymer in concrete mixes enhanced the compressive strength as compared by the mix with commercially used superplasticizer (lignosulphonates). However, Praepagen HY admixture showed an adverse effect on the compressive strength compared with lignosulphonates.

الملخص

الخرسانة الجاهزة هي الخرسانة التي يتم تصنيعها في مصانع الباطون وتوصيلها إلى مواقع الانشاء في مرحلة غير متصلبة ، ولأسباب فنية واقتصادية تستخدم العديد من الإضافات الكيميائية في إنتاج الخرسانة الجاهزة. ونتيجة لزيادة الخلط وتأخر وصول الخرسانة الجاهزة (خصوصاً في ظروف الطقس الحار) إلى موقع العمل يمكن أن يحدث هناك العديد من المشاكل حول الخرسانة مثل انفصال مكونات الخرسانة و فقدان التشغيلية . كما أن إضافة المزيد من الماء دون التعديلات المناسبة في نسب الخلطة يؤثر سلباً على قوة الضغط.

الهدف الرئيسي من هذا البحث دراسة تأثير العديد من الإضافات على الخواص الميكانيكية للخرسانة بهدف إنتاج خرسانة ذات تشغيلية جيدة علماً بأن الإضافات المستخدمة في هذا البحث غير شائعة في مجال إنتاج الخرسانة.

المواد المستخدمة في هذا البحث كإضافات هي المضاف التجاري (لقنوسالفونات) والستايرين أكريلك والبراباجين و الأكريلك بوليمر.

تم دراسة الخواص الميكانيكية للخرسانة الطازجة والمتصلبة للخرسانة العادية دون مواد إضافية (عينة قياسية)، وتم أيضاً دراسة تلك الخواص مع إضافة أربعة مواد مختلفة وبشكل منفرد بثلاث نسب مختلفة 0.25% , 0.5% و0.75% نسبة إلى وزن الأسمنت، وقد تم إجراء اختبار الهطول واختبار تحمل الخرسانة للإجهاد الرأسي واختبار عزم الانحناء لجميع العينات سواء كانت تحتوي على مواد إضافية أو لا تحتوي عليها.

لقد أوضحت نتائج هذه الدراسة أن استخدام الملدن التجاري المستخدم محليا والستايرين أكريلك والبراباجين والأكريلك بوليمر بالنسب المطلوبة يعمل على تحسين التشغيلية بشكل كبير جدا وكذلك تعمل على حل مشكلة فقدان الهطول حيث تعمل على تأخير فقدان الهطول في جميع المراحل ، وقد قامت هذه المواد بتحسين قيمة الهطول من 70 مم الى 160،225،230 و 220 مم بالترتيب.

كما أوضحت النتائج أن استخدام الستايرين أكريلك والأكريلك بوليمر في الخلطات الخرسانية يعمل على تحسين قوة الخرسانة مقارنة مع الملدن التجاري المستخدم محليا (اللقنوسلفونات) ، بينما المادة الإضافية البراباجين تؤثر بشكل سلبي على قوة الخرسانة مقارنة مع المضاف التجاري المستخدم محليا (اللقنوسلفونات).

DEDICATIONS

I would like to dedicate this work to my family specially my mother whose loved and raised me and to my brothers and sisters, for their sacrifice and endless support and to whom I belong.

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to my supervisors ***Dr. Mohammed Arafa and Dr.Mamoun Alqedra*** from the Department of Civil Engineering at The Islamic University of Gaza, for their help, guidance and assistance in all stages of this research. The constant encouragement, support and inspiration they offered were fundamental to the completion of this research.

Special thanks go to the material and soil lab of the Islamic University of Gaza, for their logistic facilitations and their continuous support.

Special thanks for ***Dr. Mohammed Alaskalany and Eng Bassam Dabbour*** to their helps guidance and assistance through all stages of this research. The constant encouragement, support and inspiration they offered were fundamental to the completion of this research.

Finally, I would like to thank everyone who gave advice or assistance that contributed to complete this research.

Abbreviations

IUG	Islamic University of Gaza.
ACI	American Concrete Institute
ASTM	American Society for Testing and Material
PC	plain Concrete
W/C	Water Cement Ratio
S P	Superplasticizer.
L S	Lignosulphonate.
S A	Styrene acrylic emulsion polymer
PHY	PRAEPAGEN HY (alkyl dimethyl hydroxy ethyl ammonium chloride)
AP	pure acrylic polymer , (butyl acrylate)

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CHAPTER 1
INTRODUCTION

Chapter (1)-Introduction

1.1 Introduction

In modern days, the need of optimum and rapid construction has given rise to the use of chemical admixtures. Among these admixtures, particularly, superplasticizer has a great market nowadays as workability is one of the major issues of a freshly prepared concrete, which can be enhanced by superplasticizer (Shah et. al, 2014).

The presence of superplasticizers in a concrete mixture is quite advantageous, in that they assist in the effective dispersion of cement particles and hence improving the workability of concrete. Superplasticizers can be used in concrete mixtures for three different purposes or a combination of these (Collepardi et. al, 1999):

- To increase workability at a given mix composition, in order to enhance placing characteristics of concrete;
- To reduce the mixing water, at given cement content and workability, in order to reduce water cement ratio (w/c) and therefor to increase strength and improve workability;
- To reduce both water and cement, at given workability and strength, in order to save cement and reduce creep, shrinkage, and thermal strains caused by heat of cement hydration.

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 (Tamrakar and Mishra, 2013).

1.2 Problem Statement

Concrete is manufactured in a mixing plant to be delivered to construction sites in unhardened state. As a result of extra mixing and delayed placing of unhardened concrete, there can be many problems about concrete like segregation and slump loss. Addition of water on fresh concrete without proper adjustment in mixture proportions causes many problems which will adversely affect compressive strength, segregation, honeycombing, bleeding, and shrinkage of concrete.

This research study the effects of lignosulphonates (Commercially available superplasticizer admixture) and several uncommonly used admixtures styrene acrylic, Praepagen HY and acrylic polymer on properties of fresh and hardened concrete.

1.3 Research Aim and Objectives

The aim of this work is to study the effect of several uncommonly used admixtures on the mechanical properties of fresh and hardened concrete.

The objectives of this research are:

i. Using Styrene Acrylic, Acrylic Polymer and Praepagen HY as proposed new admixtures (superplasticizers).

ii. Investigation the effect of each admixture on the mechanical properties of fresh and hardened concrete.

iii. Identify the optimum admixture proportions (dosages) for each type.

iv. Produce the characteristic slump loss curve for each admixture type.

1.4 Methodology

The following methodology is followed:

1- Conduct literature review about the effect of superplasticizers on properties of fresh and hardened concrete.

2- Selection of the materials that will be used in the testing program.

3- Carrying out a test program and identifying the effect of each admixture on properties of fresh and hardened concrete.

4- Analysis of the results of the testing program and producing slump loss curve for each admixture dosage.

5- Making recommendations and conclusions.

1.5 Thesis structure

The research consists of five chapters, references and appendices arranged as shown below with brief description.

- **Chapter 1 (Introduction)**

  This chapter talks about general background about superplasticizers, problem statement, objective of research and the methodology adopted.

- **Chapter 2 (Literature review)**

  General review of previous research related to using the superplasticizer in concrete and its effects on mechanical properties of fresh and hardened concrete are included.

- **Chapter 3 (Constituent Material and Experimental Program)**

  This chapter discusses types of laboratory tests, standards, adopted procedures, materials properties and curing condition.

- **Chapter 4 (Results and discussion)**

  Test results, analysis of these results and discussion are included.

- **Chapter 5 (Conclusion and recommendations)**

  General conclusions and recommendations from this research work are stated.

CHAPTER 2
LITERATURE REVIEW

Chapter (2) - Literature Review

2.1 Introduction

This chapter reviews available previous studies which deal with superplasticizer admixture in concrete. The effects of these admixtures on the mechanical properties of fresh and hardened concrete are also reviewed.

2.2 Definition of admixture

Admixtures are chemicals, added to concrete, mortar or grout at the time of mixing, to modify the properties, either in the wet state immediately after mixing or after the mix have hardened. They can be a single chemical or a blend of several chemicals and may be supplied as powders but most are aqueous solutions because in this form they are easier to dispense accurately into, and then disperse through the concrete (Newman and Choo, 2003).

The major reasons for using admixtures are (Kosmatka et. al, 2003):

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.

2.2.1 Mechanism of admixtures

Admixtures work by one or more of the following actions (Newman and Choo, 2003):

1. Chemical interaction with the cement hydration process, typically causing an acceleration or retardation of the rate of reaction of one or more of the cement phases.
2. Adsorption onto cement surfaces, typically causing better particle dispersion (plasticizing or superplasticizing action).
3. Affecting the surface tension of the water, typically resulting in increased air entrainment.

4. Affecting the rheology of the water, usually resulting in an increased plastic viscosity or mix cohesion.
5. Introducing special chemicals into the body of the hardened concrete that can affect specific properties such as corrosion susceptibility of embedded steel or water repellence.

2.2.2 Types of admixtures

Admixtures being considered for use in concrete should meet applicable specifications as presented in appendix IV. Trial mixtures should be made with the admixture and the job materials at temperatures and humidity anticipated on the job. In this way the compatibility of the admixture with other admixtures and job materials, as well as the effects of the admixture on the properties of the fresh and hardened concrete, can be observed.

The amount of admixture recommended by the manufacturer or the optimum amount determined by laboratory tests should be used. The following paragraphs present the most commonly admixtures in concrete industry.

2.2.2.1 Air-Entraining Admixtures

Air-entraining admixtures are used to purposely introduce and stabilize microscopic air bubbles in concrete. Air-entrainment will dramatically improve the durability of concrete exposed to cycles of freezing and thawing. Furthermore, the workability of fresh concrete is improved significantly, and segregation and bleeding are reduced or eliminated.

Air-entrained concrete contains minute air bubbles that are distributed uniformly throughout the cement paste. Entrained air can be produced in concrete by use of an air entraining cement, by introduction of an air entraining admixture, or by a combination of both methods 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 (whiting and Nagi, 1998).

The primary ingredients used in air entraining admixtures are listed in appendix IV.

2.2.2.2 Water-Reducing Admixtures

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. The rate of slump loss, however, is not reduced and in most cases is increased. Rapid slump loss results in reduced workability and less time to place concrete. 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. Despite reduction in water content, water-reducing admixtures may cause increases in drying shrinkage.

Usually the effect of the water reducer on drying shrinkage is small compared to other more significant factors that cause shrinkage cracks in concrete. Using a water reducer to reduce the cement and water content of a concrete mixture, while maintaining a constant water-cement ratio, can result in equal or reduced compressive strength, and can increase slump loss by a factor of two or more (Whiting and Dziedzic, 1992).

The classifications and components of water reducers are listed in appendix IV.

2.2.2.3 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. Some can also entrain air and be used in low slump concretes (Nmai et. al, 1998).

2.2.2.4 High-Range Water Reducing Admixtures

High-range water reducers, ASTM C 494 (AASHTO M 194) 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 (10,000 psi), (2) increased early strength gain, (3) reduced chloride-ion penetration, and (4) other beneficial properties associated with low water-cement ratio concrete.

High-range water reducers are generally more effective than regular water-reducing admixtures in producing workable concrete. A significant reduction of bleeding can result with large reductions of water content; this can result in finishing difficulties on flat surfaces when rapid drying conditions are present. Some of these admixtures can cause significant slump loss. Significant retardation is also possible, but can aggravate plastic shrinkage cracking without proper protection and curing.

Concretes with high-range water reducers can have larger entrained air voids and higher void-spacing factors than normal air-entrained concrete. This would generally indicate a reduced resistance to freezing and thawing; however, laboratory tests have shown that concretes with a moderate slump using high-range water reducers have good freeze-thaw durability, even with slightly higher void-spacing factors. This may be the result of lower water cement ratios often associated with these concretes. When the same chemicals used for high-range water reducers are used to make flowing concrete, they are often called plasticizers or superplasticizers (Kosmatka et. al, 2003).

2.2.2.5 Plasticizer for flowing concrete

Plasticizers, often called superplasticizers, are essentially high-range water reducers meeting ASTM C 1017; these admixtures are added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction while still remaining essentially free of excessive bleeding or segregation.

Following are a few of the applications where flowing concrete is used: (1) thin-section placements, (2) areas of closely spaced and congested reinforcing steel, (3) termite pipe (underwater) placements, (4) pumped concrete to reduce pump pressure, thereby increasing lift and distance capacity, (5) areas where conventional consolidation methods are impractical or cannot be used, and (6) for reducing handling costs.

The addition of a plasticizer to a 75-mm (3-in.) slump concrete can easily produce a concrete with a 230-mm (9-in.) slump. Flowing concrete is defined by ASTM C 1017 as a concrete having a slump greater than 190 mm (71⁄2 in.), yet maintaining cohesive properties. ASTM C 1017 has provisions for two types of admixtures: Type 1- plasticizing, and Type 2- plasticizing and retarding. Plasticizers are generally more effective than regular or mid-range water-reducing admixtures in producing flowing concrete.

The effect of certain plasticizers in increasing workability or making flowing concrete is short-lived, 30 to 60 minutes; this period is followed by a rapid loss in workability or slump loss. High temperatures can also aggravate slump loss. Due to their propensity for slump loss, these admixtures are sometimes added to the concrete mixer at the jobsite. They are available in liquid and powder form.

Extended-slump-life plasticizers added at the batch plant help reduce slump loss problems. Setting time may be accelerated or retarded based on the admixture’s chemistry, dosage rate, and interaction with other admixtures and cementing materials in the concrete mixture.

High-slump, low-water-content, plasticized concrete has less drying shrinkage than a high-slump, high water content conventional concrete; however this concrete has similar or higher drying shrinkage than conventional low- slump, low-water-content concrete (Whiting and Dziedzic, 1992).

The effectiveness of the plasticizer is increased with an increasing amount of cement and fines in the concrete. It is also affected by the initial slump of the concrete. Plasticized flowing concrete can have larger entrained air voids and greater void spacing factors than conventional concrete. Air loss can also be significant. Some research has indicated poor frost and deicer scaling resistance for some flowing concretes when expose to a continuously moist environment without the benefit of a drying period

(Whiting and Dziedzic, 1992). However, field performance of flowing concretes with low water to Portland cement ratios has been good in most frost environments. Appendix IV lists the primary components and specifications for plasticizing (superplasticizer) admixtures.

2.2.2.6 Retarding Admixtures

Retarding admixtures are used to delay the rate of setting of concrete. High temperatures of fresh concrete (30°C [86°F]) are often the cause of an increased rate of hardening that makes placing and finishing difficult. One of the most practical methods of counteracting this effect is to reduce the temperature of the concrete by cooling the mixing water and/or the aggregates. Retarders do not decrease the initial temperature of concrete. The bleeding rate and bleeding capacity of concrete is increased with retarders.

Retarding admixtures are useful in extending the setting time of concrete, but they are often also used in attempts to decrease slump loss and extend workability, especially prior to placement at elevated temperatures (Kosmatka et. al, 2003).

Retarders are sometimes 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; or (3) delay the set for special finishing techniques, such as an exposed aggregate surface.

The amount of water reduction for an ASTM C 494 (AASHTO M 194) Type B retarding admixture is normally less than that obtained with a Type A water reducer. Type D admixtures are designated to provide both water reduction and retardation. In general, some reduction in strength at early ages (one to three days) accompanies the use of retarders. The effects of these materials on the other properties of concrete, such as shrinkage, may not be predictable. Therefore, acceptance tests of retarders should be made with actual job materials under anticipated job conditions. The classifications and components of retarders are listed in appendix IV.

2.3 Definition of superplasticizer

Superplasticizers are an essential component in modern concretes, providing workability enhancement at low water to cement ratios, and resulting in the production of durable and sustainable concrete.

2.3.1 Mechanism of superplasticizer

To visualize how superplasticizers work it is important to understand what happens when cement and water are combined.

Cement particles are fine grains with irregular shapes. Positive and negative charged sites are placed within their crystal lattice. When mixed with water the cement particles flocculate due to the electrostatic attraction between the positive and negative charge sites (Figure 2.2). Within the flocculated cement and water mixture are voids that trap part of the mixing water.

When an anionic superplasticizer is added the negative segments of the polymer adsorb to the surface of the cement particles and increase the negative charge of each particle. This causes the particles to repel each other which breaks up the flocculation and releases the trapped water (Figure 2.3).

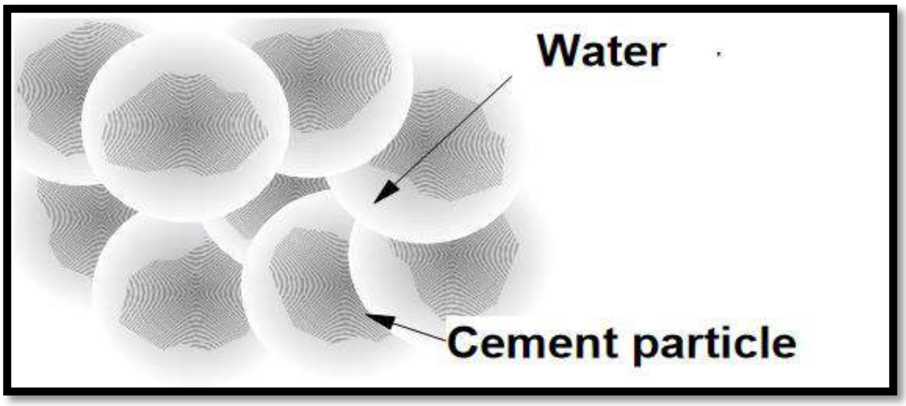

Figure 2.1 Schematic visualization of the flocculated cement particles with water trapped in the voids (BASF, 2008).

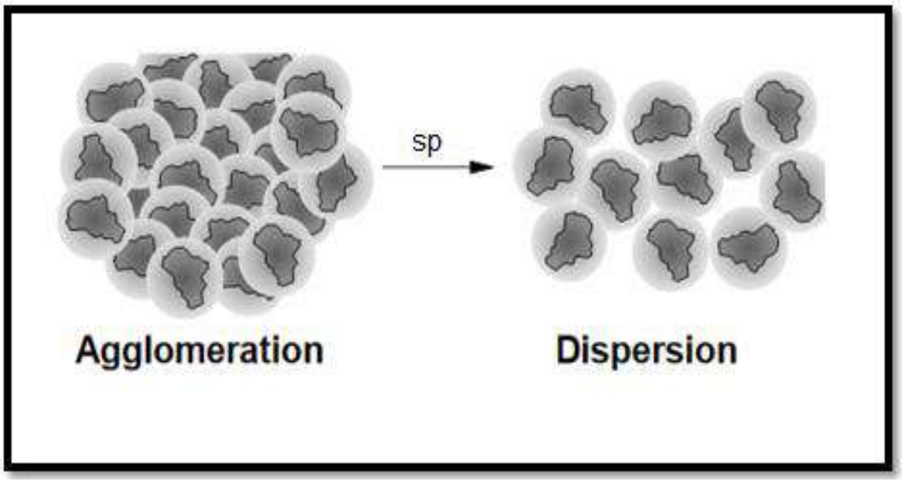

Figure 2.2 Schematic visualization of the flocculated and dispersed states (BASF, 2008).

The dispersion of the cement and release of the trapped water results in a reduction of the plastic viscosity of the concrete, grout or mortar. Workability is enhanced and the water/cement ratio can be reduced.

The molecular structure of the superplasticizer is of central importance in the mode of action and performance. The charge density of the polymer must be tuned to the cement to enable it to dock on the positive charge sites of the cement particles, cause the dispersion and keep the cement from returning to a flocculated state long enough to provide sufficient slump/flow life. Enhanced tuning of the polymer to the cement increases the dispersing efficiency of the superplasticizer and improves the rheology of the concrete, grout or mortar **(BASF, 2008).**

2.3.2 Advantages of superplasticizer

The advantages derived by the use of superplasticizers can be summarized in three ways (Stefan, 2010):

- by adding a water-reducing admixture and consequentially reducing the water amount, a concrete having the same workability as the control concrete can be obtained, while the compressive strengths will exceed those of the control mix at all ages
- If the admixture is added directly to a concrete as part of the gauging water with no other changes to the mix proportions, a concrete with similar strength development characteristics is obtained, while having a greater workability than the control concrete

- A concrete with similar workability and strength development characteristics can be obtained at lower cement contents than a control concrete, without affecting the durability or engineering properties of the concrete.

2.3.4 Application of superplasticizer

The main characteristics of superplasticizing admixtures are their capability to reduce the water content of a mix design. An enhanced durability is one of the consequences of the water reduction, induced by a low concrete permeability. Superplasticizers respond mainly to the current trend to use flowable concrete types. Therefore superplasticized concrete is suitable to be placed in congested reinforcement and in hard accessible areas. Concrete with a fluid consistency can be used to cast any type of structural element. Superplasticizers have also been used for tunnel linings and spray applications.

One of the industries where superplasticizers are indispensable is the wet heavy precast industries, where initial compressive strengths of 40 MPa are needed after 12-18 hrs. Self-Compacting Concrete and high strength concrete (> 100MPa) are impossible to produce without the latest superplasticizing admixtures (Stefan, 2010).

2.3.5 History of superplasticizers

The history of superplasticizers considered to be initiated in Japan and Germany 1960s. Kenichi Hattori introduced the first superplasticizer in 1964 which was constituted of beta-naphthalene sulphonated.

The second superplasticizer, Melment was contained of sulphonated melamine formaldehyde condensate and introduced in Germany in the same year. After a decade, the use of superplasticizers was reached to the American continent in 1970.

Tattersall and Bloomer (1979) defined the pros and cons of various tests used to determine concrete strength and workability. He pointed out the major drawbacks in these tests. He also determined that how much slump increases with the percentile increase in superplasticizer keeping water-cement ratio constant and its effect on the strength of concrete.

Guennewig (1988) opened the doors of a new research and proved successfully that these materials can be used cost effectively for construction applications such as hot-weather concreting, crane, wall placements, bucked placements, slabs on grade, and pumped concrete.

Hanna et. al, (1989) developed a special apparatus, Rheo pump, in order to study the interaction between either a given superplasticizer with different Portland cements or the interaction of different superplasticizers on a given Portland cement.

Masahiro et. al, (2007) discussed the effect of superplasticizer on the balance between flow ability and viscosity of mortar in self-compacting concrete.

Flatt and F.Y (2001) produced three different categories to check the chemical effects that can perturb the performance of superplasticizer. They found that at equal dosage of all the three categories, larger cement quantity covered relatively small surface area. Hence, produced poor workability until superplasticizer was added.

Ravina and Mor (1968) studied the sulphonated melamine formaldehyde condensate effect on concrete. They studied the influence of variation in dosage quantity and number of superplasticizer addition. They also emphasized on settlement duration of superplasticizer. They recommended high dosages after an experiment in which lower dosage did not produce any significant effect. They also recommended late mixing and double dosage of superplasticizer.

Hsu et. al, (1999) Also studied the effects of different time interval of naphthalene-based superplasticizer addition. They concluded that increase in addition time, gradually decreased the saturation of SNF and caused gradual decline in workability of concrete. Khatib and Mangat (1999) concluded that the superplasticizers reduce the percentage of openings. These chemicals increase the efficiency of the openings, keeping the size of hole remain same.

In recent researches about the superplasticizers, Ramachandran (1995) presented a book about the properties and applications of superplasticizers in concrete, mainly focusing on the advantages of superplasticizers. He put forwarded a theory that these chemicals substantially scatter the particles of cement. In his support, he referred to an inspection of cement particles which revealed that after the mixing of water and cement, massive clusters are formed. Superplasticizers break these clusters into tiny particles.

Yamada and Hanehara (2001) discussed the errors in analytic methods used for the investigation of interaction mechanism between cement and superplasticizer and provided some chemical equations to overcome the errors appear during applying superplasticizer to cement.

Colak (2005) investigated the effect of latex concentration on the workability and strength characteristics of Portland cement pastes with and without superplasticizer and produced some analytical methods as a result.

The influence of polycondensate and polycarboxylate superplasticizers on the adhesion strength between aged and fresh concrete was investigated by Reese et. al, (2013). They measured the imbibition of pore solution released from fresh concrete into aged concrete bars and SEM imaging of minerals formed in the cement transition zone. Polycarboxylate superplasticizer exhibited better performance (shah et. al, 2014).

2.4 Previous studies of using superplasticizers in concrete

Several investigations have been conducted to study the effect of use SP on concrete to enhancing the mechanical properties of fresh and hardened concrete, the studies below explain that.

Alsadey (2012) presented the effect of superplasticizer (SP) on properties of fresh and hardened concrete has studied; the properties of concrete inspected are compressive strength and slump test, hence, an experimental investigation conducted to determine the optimum dosage for the admixture and to study the effect of over dosage of the mentioned admixture, together with one control mixed. The difference between concrete mixes comes from dosages of admixture, which used at amounts 600, 800, 1000, and 1200 ml/100 kg of cement were prepared. However, compressive strength is improved by dosage 1.0 % of SP after 28 days curing is 55 N/ mm^2 , which is higher than that of control concrete, the optimum amount of admixture must be 1 %. Over dosage of SP found to deteriorate the properties of concrete with indication of lower compressive strength. The workability of concrete can be increased by addition of superplasticizer and the slump loss can be reduced by using the chemical admixtures.

Tamrakar and Mishra (2013) studied the effects of three superplasticizers (Rheobuild 1125, Glenium 140, Pozzolith 225) on fresh and hardened concrete. The experiment program included test on workability, slump loss and compressive strength. In this experimental works we are comparing the properties of superplasticizer based concrete with that of without superplasticizer added concrete. From the results of the study the workability of concrete can be increased by addition of superplasticizer. However, very high dosages of SP tend to impair the cohesiveness of concrete. Slump loss can be reduced by using the chemical admixtures. However, effectiveness is higher for superplasticizer concrete. Superplasticizer permitted a significant water reduction while maintain the same workability.

Khatib and Mangat (1999) studied the influence of one type of SP (Sikament® R2002) on porosity and pore size distribution under deferent curing regimes. Most concrete produced today contains admixtures. Superplasticizers (SP) are used for the purpose of improving workability and reducing the water to cement ratio; therefore producing more durable concrete. SP cause better dispersion even at high water to cement ratio. Although SP improves the dispersion of particles, it is not quite clear how the addition of SP affect the porosity and pore size distribution of cement paste.

Hameed (2012) discussed the results of an experimental investigation into the properties of self-compacting concrete (SCC) mixes having varying dosage of high-performance superplasticizer (Glenium 51) (0.5%-3.0%) L per 100 kg of cement material. The properties investigated are workability on the fresh state of concrete by using one mix with five superplasticizer dosage (0.5%,1.0%,1.5%,2.5% and 3.0%) is used. The workability was assessed using three tests according to the specification of self-compacted concrete (slump flow, L- box differential height and V-funnel tests. The three dosage (1.0%, 1.5% and 2.5%) comply with requirement for production of SCC while 0.5% and 3.0% don't comply with specification requirement .Dosage of superplasticizer need to produce self-compacted concrete range between (1.0%-2.5%) L/100 kg of cement according to the condition and material used in this paper.

Dubey and kumar (2012) Investigated experimental study of six trial mixes were prepared by varying the dosage of SP from 2% to 12% of cementious material with an increment of 2% for each test series (Polycarboxylate ether based superplasticizer complying with ASTM C 494 type F, with density 1.08 kg/l and pH 4.8 was used in the present investigation as SP). In order to investigate self-compacting characteristics in fresh state of mix proportion with varying dosages of SP slump flow test (slump flow diameter and T50cm time), and L-Box test (blocking ratio) were performed.

Shah et. al, (2014) calculated the consequences on strength of concrete when water-cement ratio is constant and the increase in slump occurs with the increase in amount of superplasticizer by percentage. The rest of the investigation is carried out to study the effects of superplasticizer with different dosages under different curing regimes at an ambient field temperature ranges between 45°C-50°C. For this purpose, a concrete mix at 20MPa with all parameters constant was prepared by using an ASTM C494 type A, and F, anionic melamine polycondensate non-toxic superplasticizer with no chlorides. Different dosages of superplasticizers were used in different batches of all 95 specimens, and cured under different curing conditions and then tested for compressive and tensile strengths following ASTM standards. In all cases, the water curing up to 28 days testing showed maximum strength. The highest and lowest values of compressive strength were obtained with the addition of 0.5% and 1% superplasticizer respectively.

2.5 Cement hydration

Hydration of cement is the chemical reactions that occur when cement is mixed with water producing new materials causing hardening of concrete. These reactions liberate heat and require time to reach full hydration. The hydration characteristics of the cement compounds are summarized in Table (2.1).

Table 2.1 Characteristics of hydration of cement compound (Midness et. al, 2002).

Compounds	Reaction Rate	Amount of Heat Liberated	Contribution to Cement	
			Strength	Heat Liberation
C_3S	Moderate	Moderate	High	High
C_2S	Slow	Low	Low initially, high later	Low
$C_3A + CSH_2$	Fast	Very high	Low	Very high
$C_4AF + CSH_2$	Moderate	Moderate	Low	Moderate

Clearly, the calcium silicates (C_3S and C_2S) provide most of the strength developed by Portland cement. C_3S provides most of the early strength in the first three to four weeks and both C_3S and C_2S contribute equally to ultimate strength (Midness et. al, 2002).

2.5.1 Hydration Chemistry

An adequate understanding of the chemistry of hydration is necessary for a full appreciation of the properties of cements and concretes. Hydration of cement involves chemical and physical processes between water and cement that influence the characteristics of the hardened concrete. The reactions result in an increase in solid volume on the expense of water volume and the rate of reactions increased with increased temperature (Rikard, 2013).

It is assumed that the hydration of each compound occurs independently of the others that are present in Portland cement. This assumption is not completely true but it is a reasonable approximation to understanding how cement hydrates. The hydration of each compound is as follows:

1. **Calcium Silicates**

$$\mathbf{2C_3S + 6H \rightarrow C_3S_2H_8 + 3CH}$$

Tricalcium silicate + Water → C-S-H + Calcium hydroxide

$$\mathbf{2C_2S + 4H \rightarrow C_3S_2H_8 + CH}$$

Dicalcium silicate + Water → C-S-H + Calcium hydroxide

Both C_3S and C_2S react with water to produce an amorphous calcium silicate hydrate known as C-S-H gel and calcium hydroxide (CH). C-S-H is a poorly crystalline material comprising 50 to 60 % of the volume of the cement paste and thus dominates its behavior. C-S-H forms a coat around the cement grain of a spiny appearance (Figure (2.2)) which presents a physical barrier for the hydration of the inside part of the grain. (IRICEN, 2007).
Calcium hydroxide is a well crystalline material comprising 20 to 25 % of the cement paste volume. Calcium hydroxide grows within the capillary pore space (Figure (2.4)) and stops growing in a particular direction when it meets an obstacle (Rikard, 2013).

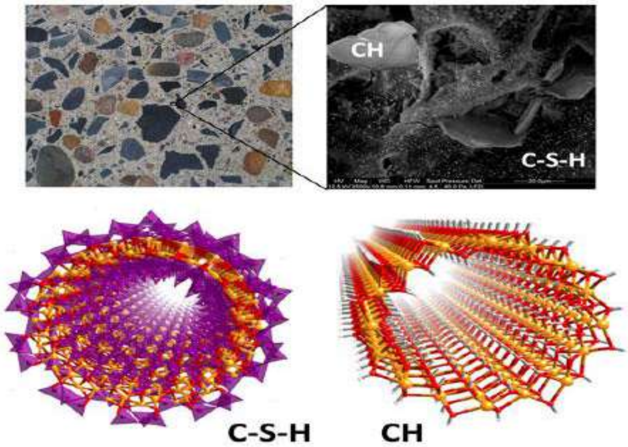

Figure 2.3 C-S-H and CH in hydrated cement paste (Rikard, 2013).

2. **Tricalcium Aluminates**

$$\mathbf{C_3A + 3C\underline{S}H_2 + 26H \rightarrow C_6A\underline{S}_3H_{32}}$$

Tricalcium aluminates + Gypsum + Water → Ettringate

Calcium sulfoaluminate hydrate is commonly called ettringate. Ettringate is a stable hydration product only while there is an ample supply of sulfate available. If the sulfate is all consumed before the C_3A has completely hydrated, then the developed ettringate reacts once again with C_3A and water producing another form of calcium sulfoaluminates hydrate called monosulfoaluminate containing less sulfate**:**

$C_6A\underline{S}_3H_{32}$ + $2C_3A$ + 4H → $3C_4A\underline{S}H_{12}$

Ettringate + Tricalcium aluminates + Water → Monosulfoaluminates

3. **Ferrite**

C_4AF + $3C\underline{S}H_2$ + 21H → $C_6(A,F)\underline{S}_3H_{32}$ + $(A,F)H_3$

Ferrite + Gypsum + Water → Ettringate + amorphous

Where the amorphous is hydrous oxides of iron or alumina.

As can be seen in above reaction, C_4AF forms similar products to C_3A. The calcium sulfoaluminates (ettringate) are a relatively minor constituent of cement paste making up only 10 to 15 % by solid volume. Ettringate is seen as long slender needles (Figure (2.5)) growing into the capillary pores between cement grains (Rikard, 2013).

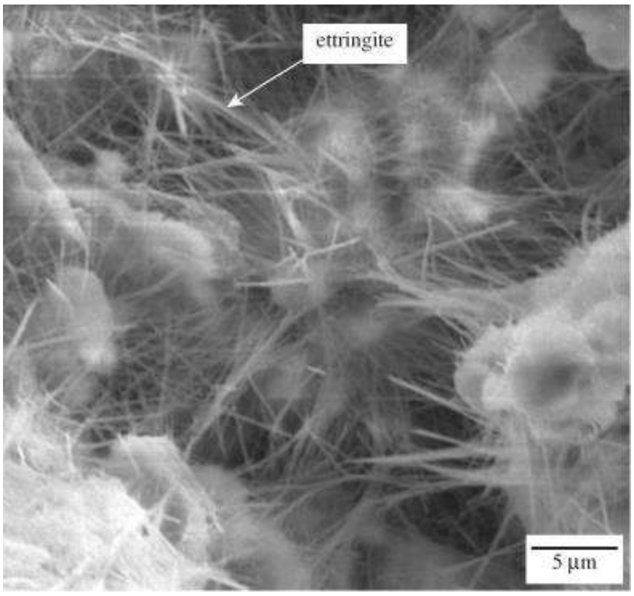

Figure 2.4 Formation of ettringate within hydrated cement paste (Gemelli et. al, 2004).

CHAPTER 3
EXPERIMENTAL PROGRAM AND CONSTITUENT MATERIALS

Chapter (3) - Experimental Program and Constituent Materials

3.1 Introduction

This chapter includes the experimental program and the constituent materials used to study fresh and hardened concrete properties by using proposed superplasticizers.

The properties of several constituent materials used in this work are also discussed such as moisture content, unit weight, specific gravity and the grain size distribution.

The laboratory investigation consisted of testing fresh and hardened concrete properties, the fresh concrete was tested using slump test to measure its workability. Also used these to compare slump result between plain concrete and concrete with adding several type and percent of admixture and measure the amount of workability. The testing on hardened concrete was made according to the ASTM and British Standard. These tests are compressive strength and flexural test of hardened concrete.

3.2 Experimental program

lignosulphonates (LS), styrene acrylic (SA), Praepagen HY (PHY) and acrylic polymer (AP) have been selected for this study, Also concrete composite material as cement, three types of aggregates which have different gradients with three sizes, clean sand and water were selected according to ASTM specification.

Physical tests were made for aggregate, sand and cement to ensure conformity to international standards (ASTM). The results of physical tests will be used in design of concrete job mix. The main test for aggregate and sand were specific gravity in three form, absorption and sieve analysis. All results were in the range according to the specifications. The tests for cement were such as fineness, normal consistency, initial and final set and compressive strength. All cement tests were according to ASTM specification.

After insuring that all materials used conform to standard specifications , it will be used to design the concrete job mix with compressive about 30 MPa and slump about 60-100 mm.

The testing program comprises studying the effect of each admixture at several contents for obtaining the mechanical properties of fresh and hardened concrete. Through the basic tests, the optimal contents of each material can be defined. These tests were as slump test for fresh concrete, and cubic compressive strength and flexural for hardened concrete.

The admixtures that used in mix were added to the water at three contents as 0.25%, 0.5% and 0.75% by cement weight. These contents were chosen to study the amount and rate of slump loss of fresh concrete by measuring the slump value at 0, 15, 30 ... 120 minute). The compressive strength for hardened concrete of all admixture contents was tested at 7, 14 and 28 days using 10*10*10 cm cubic sample. Figure 3.1 presents the details of the conducted experimental program.

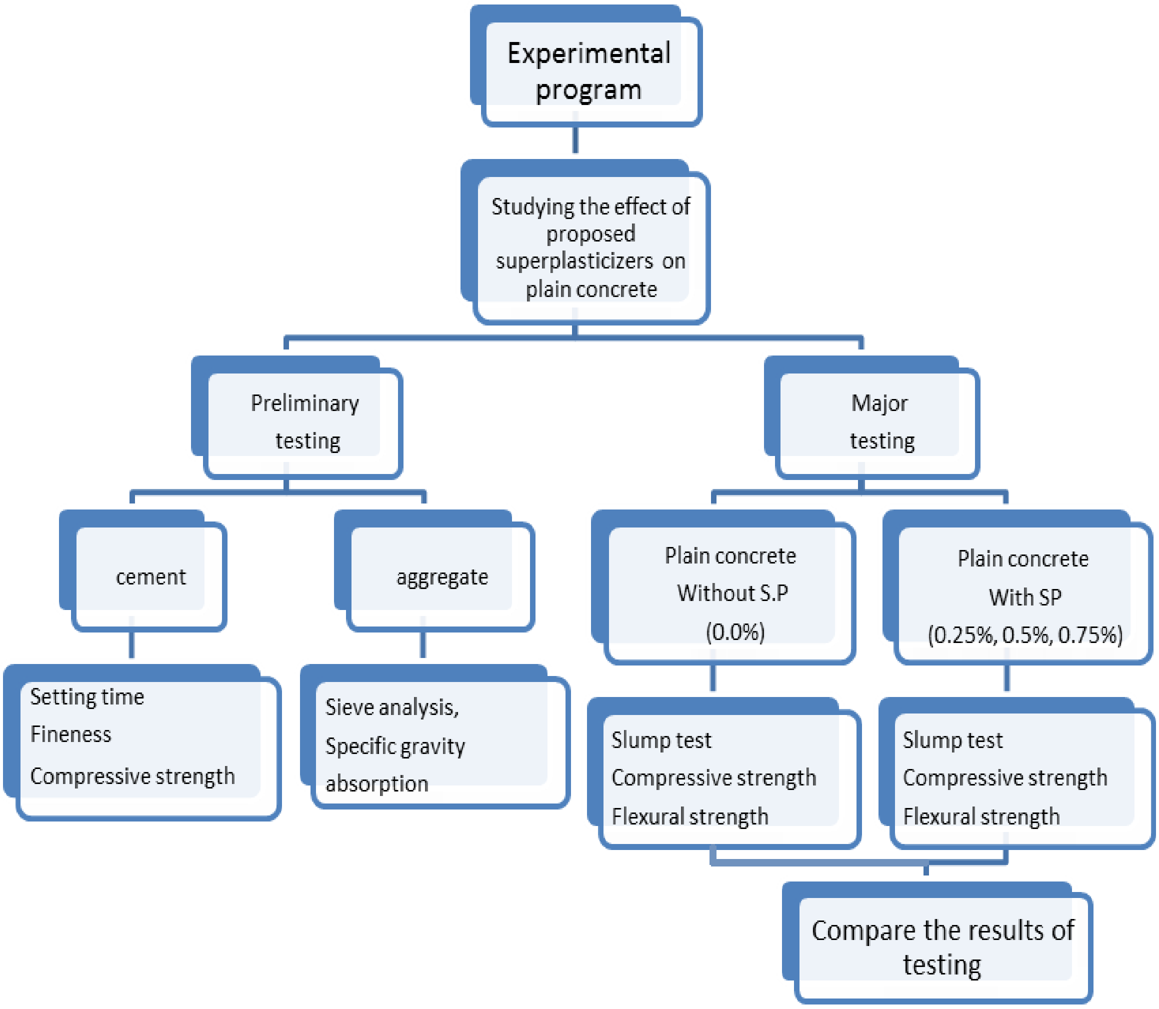

Figure 3.1 Experimental program chart

3.3 Preliminary investigation of concrete contituent

3.3.1 Cement

In this research, the Combined Portland cement type CEM II/B-V 42.5 N "Portland fly ash cement" was used. The cement tested according to ASTM C109, C187, C191 and C204 and the result are accepted according to the specification of ASTM C150. The results physical and a mechanical properties and the specification requirement according to ASTM C150 of the cement was mentioned in Table (3.5).

Table 3.1 Cement characteristic according to testing and (ASTM C150)

Type of test	Related ASTM specification	Characteristic	Result	Type II Cement ASTM C150
Setting time using Vicat test (minutes)	C191	Initial	105	>60
		final	315	<600
Mortar compressive strength (MPa)	C109	At age 3 days	13.5	Min 12
		At age 7 days	29.6	Min 17
		At age 28 days	47.3	No limit
Blain fineness (cm^2/g)	C204	-	3035	Min. 2800
Water demand (%)	C187	-	27.5	No limit

3.3.2 Aggregate

The physical property of fine and coarse aggregate are listed as below:

1. Sieve analysis

The sieve analysis of fine and coarse aggregate was made according to ASTM C136; the result was listed in the Table (3.6), and Figure (3.2).

Table 3.2 Sieve analysis results for fine and coarse aggregate

		Sample Name			
Sieve #	**Sieve Size**	**Type I (FOOLIIA)**	**Type II (ADDASIA)**	**Type III (SOMSOIA)**	**Type IV (Sand)**
1.5"	**37.5**	100.00			
1"	**25**	98.56			
3/4"	**19**	59.80	100.00		
1/2"	**12.5**	1.78	55.44	100.00	
3/8"	**9.5**	0.00	8.95	95.20	
#4	**4.75**	0.00	0.00	23.32	
#8	**2.36**	0.00	0.00	0.20	100.00
#16	**1.19**				94.45
#30	0.6				76.77
#100	**0.18**				1.05
#200	**0.075**				0.00

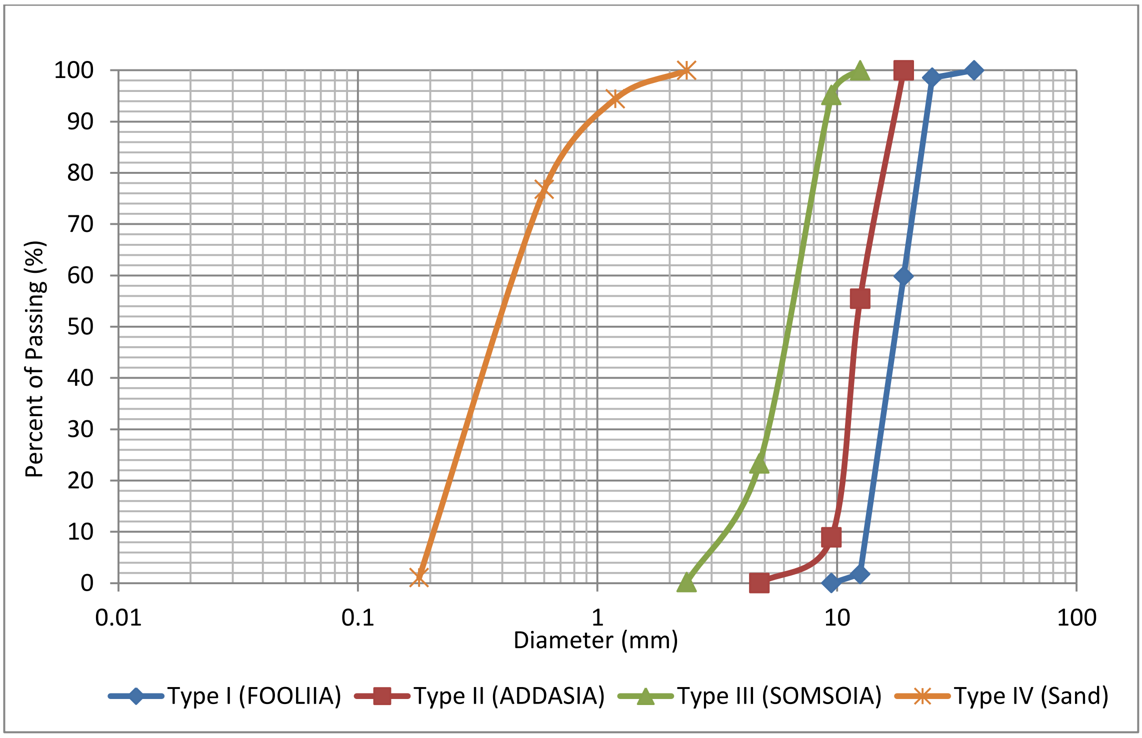

Figure 3.2 Aggregate graduation of fine and coarse aggregate

2. Absorption and Specific Gravity

The Absorption and specific gravity of fine and coarse aggregate was made according to ASTM C 128 & ASTM C 127 and the results are presented in Table (3.7).

Table 3.3 Absorption and specific gravity of fine and coarse aggregate

Sample Name	Absorption After 24 hour	Specification	Apparent specific gravity	Bulk specific gravity	Bulk specific gravity in SSD
Type I	1.25%	Max. 2%	2.654	2.549	2.588
Type II	1.23%	Max. 2%	2.667	2.541	2.592
Type III	1.14%	Max. 2%	2.538	2.505	2.590
Type IV (Sand)	0.57%	Max. 2%	2.664	2.577	2.638

3.3.3 Water

Drinkable tap water was used for all mixing and curing of concrete.

3.4 Physical and chemical properties of proposed superplasticizer

3.4.1 Lignosulphonate (LS)

The single largest use for lignosulphonates is as plasticizers in making concrete, where they allow concrete to be made with less water (giving stronger concrete) while maintaining the ability of the concrete to flow. Lignosulphonates are also used during the production of cement, where they act as grinding aids in the cement mill and as a raw mix slurry deflocculates (that reduces the viscosity of the slurry).The lignosulphonate admixture is used as commercially superplasticizer in Gaza. The main manufacture physical and chemical properties were listed in Table (3.1) according to Alibaba Company.

Table 3.4 the main manufacture Physical and chemical properties

Index items	Standard value
Appearance	Yellow Brown Liquid
PH Value	7--9
Solids Content (%)	45%min
Total Sugar	3% max
content of cl- (%)	5% max
Ash content (%)	20%max
Water-Insoluble	5% max
Reducing Sugar	1% max

3.4.2 Styrene acrylic polymer (SA)

Styrene Acrylic emulsions polymer use in flexible coatings, maintenance coating for metal and asphalt roofing surfaces suitable for moderate climates. SA has good adhesion to various substrates, including galvanized metal and concrete and good water resistance properties. Because of the properties of this material (Organic, emulsion, latex and synthetic polymers) and refer to appendix IV, we choose it in this research.

The main manufacture physical and chemical properties were listed in Table (3.2) according to Rohm and Haas Company.

Table 3.5 The main manufacture Physical and chemical properties

Item	Characteristic
Appearance	Milky, white liquid
% Solids, by weight	55 ± 1.0
pH (as packed)	7-8
Specific Gravity (g/cc)	1.03
Density (lbs/gal), wet	8.61
Density (lbs/gal), dry	8.84
Storage Stability	Unchanged at 10 days; 60°C
Viscosity, cps	100-300
Storage Precautions	Protect from freezing

3.4.3 Praepagen HY (PHY)

The Chemical characterization of Praepagen HY is an aqueous solution of an alkyl dimethyl hydroxy ethyl ammonium chloride. Praepagen HY is used as raw material for detergents. Because of the properties of this material (foaming agent, cationic and synthetic detergents) and refer to appendix IV, we choose it in this research. The main manufacture physical and chemical properties were listed in Table (3.3) according to clariant Company.

Table 3.6 the main manufacture Physical and chemical properties

Item	Characteristic
Form	Liquid
Colour	slightly yellow
Odour	slight, original odour
Pour point	0 °C , Method : DIN/ISO 3016
Flash point	> 100 °C, Method : DIN/ISO 2592 (open cup)
Vapour pressure	approx. 23 hPa (20 °C), Corresp. to vapour pressure of water
Density	0,963 g/cm3 (40 °C) Method : DIN EN ISO 12185 0,984 g/cm3 (20 °C)
Solubility in water	soluble, clear
pH value	5,5 - 8,5 (20 °C, 10 g/l)
Viscosity (dynamic)	approx. 100 mPa.s (20 °C)

Dissolved Organic carbon (DOC)	252 mg/g Method : DIN 38409 T. 3
Chemical oxygen demand (COD)	767 mg/g Method : DIN 38409-H41

3.4.4 Acrylic polymer (AP)

Acrylic polymer is a small particle size and excellent response to rheology modifiers. It is resulting in coatings with excellent long-term durability. AP is noted for its excellent adhesion on wide variety of surfaces such as wood, smooth concrete surfaces, old chalky painted surfaces, etc. It also has excellent abrasion resistance, alkali resistance and UV resistance. Because of the properties of this material (Organic, acrylic polymer, latex, polycarboxylate and synthetic polymers) and refer to appendix IV, we choose it in this research. The main manufacture physical property was listed in Table (3.4) according to Dow Chemical Company.

Table 3.7 The main manufacture Physical and chemical properties

Property	Typical Values
Appearance	Milky white emulsion
Solids, by weight, %	50.0
Density (g/ml), wet	1.06
pH	9.5
Minimum Film Formation Temperature (± 2ºC)	16
Viscosity (Brookfield LV #2, 60 rpm), cps	< 300
Stabilization	Anionic
Storage precautions	Protect from freezing

3.5 Mix proportioning

By finishing of all tests for concrete constituent and ensure that all material as water, aggregate , sand and cement are according to ASTM specification, the concrete job mix with a target strength of 30 MPa at 28 day is designed. The job mix will be designed according to Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91).The design criteria which used in the current study are as:

1. **Compressive strength:** The most strength of plain concrete for general use was 30 MPa for 10*10*10 cm cubes, so the mix will be design for that strength.
2. **Slump:** The most slump of plain concrete for general use is between 25 to 100 mm and the mix was designed for slump around 60 to 90 mm.
3. **Nominal maximum aggregate size:** The nominal maximum aggregate size in the job mix was 25 mm.
4. **The final average weight for job mix:** The final average weight for the job mix was listed in Table (3.8).

Table 3. 8 The final average weight for the job mix

Material	**Weight (kg)**	**Volume (m3)**
Entrapped air	0	0.015
Water	177	0.165
Cement	300	0. 095
Coarse aggregate	1220	0.471
Fine aggregate	670	0.254
Total	**2367**	**1.000**

5. **The aggregate graduation:** Final material weight of concrete job mix and final graduation of aggregate as mentioned in the Table (3.9) and figure (3.3).

Table 3.9 Concrete aggregate graduations

Material	aggregate						
	Type 1 1”	Type 2 ¾”	Type 3 ½”	Sand #8	Cement	Water	Total kg
	407	425	388	670	300	177	2367

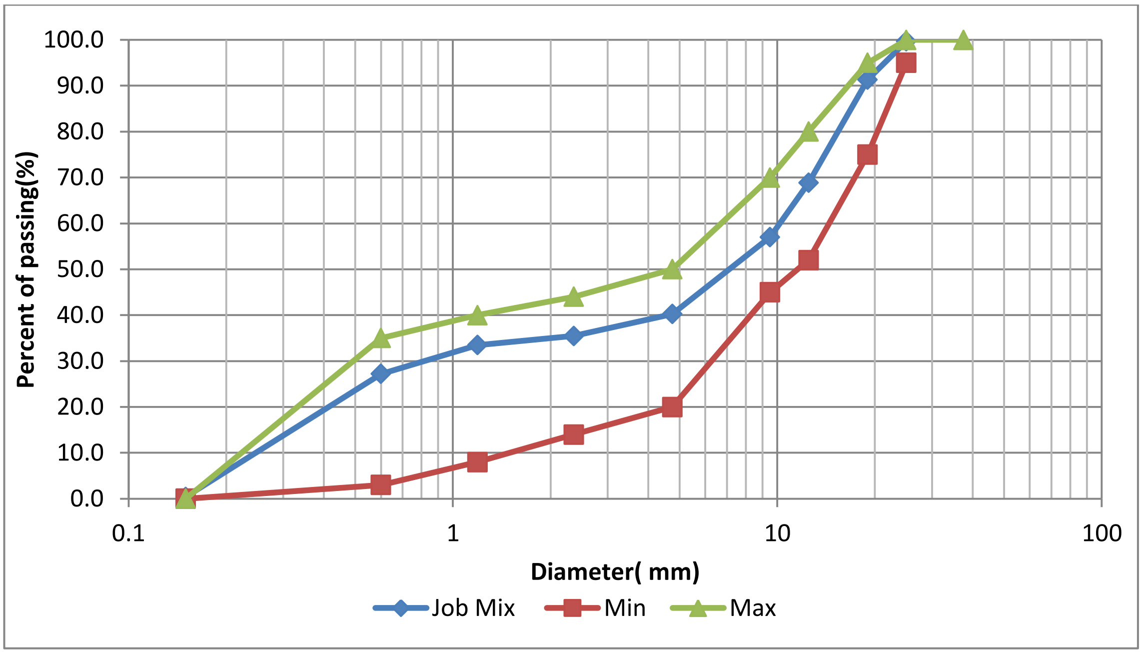

Figure 3.3 Concrete Job Mix Graduation and Specifications

6. **The above job mix was tested in the lab and the following remarks were observed**

- The slump was found 70 mm without any segregation.
- The average compressive strength was 21.90 MPa at 7 days age for cubic sample.
- The average compressive strength was 30.60 MPa at 28 days age for cubic sample.

3.6 Preparation of specimens

3.6.1 Mixing procedure

The preparation of the concrete specimens was made in the Soil and Material Lab at IUG .The concrete is mixed according to the Standard Method of Making and Curing Test Specimens in the Laboratory ASTM C192. Firstly, the coarse aggregate is added with some of the mixing water then starting rotation of the mixer. After that, fine aggregate, cement and remain mixing water are added. The SP material is added to water (mixing water). Note that the open end or top of the mixer will be covered to prevent evaporation during the rest period. A power-driven tilting revolving drum mixer is used in the mixing process (Figure 3.4).

Figure 3.4 the drum mixer

3.6.2 Curing of hardened concrete

After 24 hour, the hardened concrete removed from the molds with very carefully to prevent any defect in the samples. After that the samples placed in curing water tank at temperature 21-25°C until the period of testing.

3.7 Testing of specimens

The main aim of this research is to study the effect of proposed superplasticizers on the mechanical properties of fresh and hardened concrete using component as limestone aggregate, sand, cement and superplasticizer. The following tests were applied to obtain the effects of proposed superplasticizers on the mechanical properties of fresh and hardened concrete.

3.7.1 Fresh concrete tests

After completing the mixing of fresh concrete there are many test can be done to measure the workability of concrete, in this research will depend on slump test to measure the workability.

- **Slump Test according to ASTM C143**

The test was made to measure the workability of fresh test according to the standard Test Method for Slump of Portland Cement Concrete ASTM C 143, the scope of this test is determination of the slump of hydraulic-cement concrete.

3.7.2 Hardened concrete tests

After completing the curing process for hardened concrete as mention previously, there are many tests should be made to study the mechanical property of hardened concrete as compressive strength and modulus of rupture. These tests must be made according to ASTM specification as mention below.

1. Compressive strength According to ASTM C39 and BS 1881, Part 127

The main Objective of compressive strength test of hardened concrete is knowing the ability of cubic or cylinder samples of hardened concrete to withstand the vertical stress at several ages at 7,14 and 28 days. This test can made by continuous loading with rate 0.15 to 0.35 MPa/s on a concrete sample until the sample collapse, and by knowing the dimensions of the mold and maximum crushing load can calculate the maximum stress whish the sample can carry, the calculation equation as below:

For cubic sample according to BS 1881 PART 127

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

Where: σ is normal stress in N/mm^2 or MPa, P is normal crushing force in N and A is area in mm^2.

The compressive strength machine in soil and material laboratory at the IUG was used for determining the maximum compressive loads carried by concrete specimen cubes, as shown in Figure (3.5).

Figure 3.5 Compressive strength test at the lab

2. Flexure strength for beam Test according to ASTM C293

This test method covers the determination of the flexural strength of concrete by the use of a Simple Beam with center-Point Loading. Total number of 42 prisms was manufactured. The load will be applied in specimen continuously and without shock until rupture occurs. The specimens are prisms 100 x 100 x 500 mm.

The modulus of rupture can be calculated as follows:

$$R = \frac{3Fl}{2bd^2}$$

Where:

- *F* is the load (force) at the fracture point.
- *L* is the length of the support span (mm).
- *b* is width (mm).
- *d* is thickness (mm).

The flexural strength machine in soil and material laboratory at the IUG was used for determining the maximum flexural load carried by concrete specimen is shown in Figure (3.6).

Figure 3.6 flexure tests at the lab

CHAPTER 4
Test Results and Discussion

Chapter (4) - Test Results and Discussion

4.1 Introduction

Series of tests were carried out on the concrete specimens to develop, study and evaluate the mechanical properties of fresh and hardened concrete under lignosulphonates (commercially admixture) (LS), styrene acrylic (SA), Praepagen HY (PHY) and acrylic polymer (AP) admixtures. This chapter discusses the results obtained using slump test, compressive strength and flexure strength tests. For each admixture three ratios were added to the normal job mix to obtain the optimum ratios.

4.2 Plain Concrete (without admixture)

A plain concrete was prepared to serve as a control mix (control No.1). The control No.1 does not have any admixture to compare it with commercial admixture (LS).

4.2.1 Slump test results

Figure (4.1) represents the relation between slump loss and time for plain concrete without any admixture. Figure (4.1) shows that the slump value decreases from 70mm at 0min to 0 mm at 120 min, and the slump value decreases to 6 mm at 90 min. It means that the concrete became very stiff without any workability after 90 min.

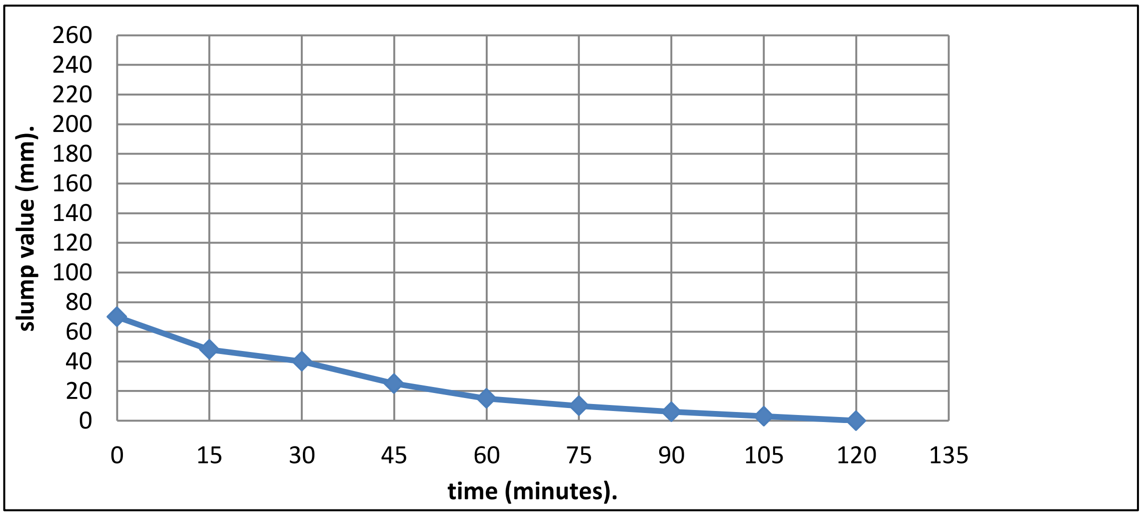

Figure 4.1 Relation between time and slump value of plain concrete

4.2.2 Compressive strength test results

The compressive strength of plain concrete mixes without any admixture (control mixes) is shown in Figure (4.2). This figure shows that the 7, 14 and 28 day's compressive strength of plain concrete are 219, 274 and 306, as designed. The compressive strength at 7 day is about 70% of the 28 days compressive strength, and the compressive strength at 14 day is about 90% of the 28 days compressive strength.

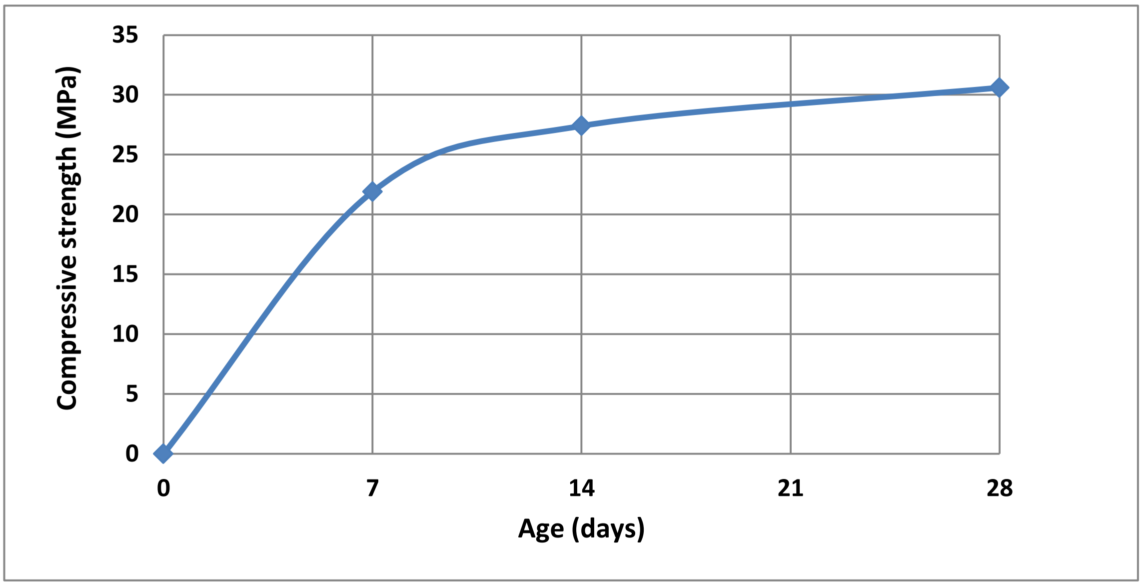

Figure 4.2 Compressive strength of plain concrete without admixtures

4.3 Concrete with lignosulphonates "LS"

This mix is prepared by adding lignosulphonate (commercially available admixture) to serve as a control mix (control No.2) to compare it with SA, PHY and AP admixtures. The effects of this admixture in the mechanical properties of fresh and hardened concrete explained are presented as follow:

4.3.1 Slump test results

The slump values at 0, 15, 30 ... and 120 minutes were measured for concrete mixes with different ratios of lignosulphonate, the used lignosulphonate contents are 0.25%, 0.5%, 0.75% and 1% by cement weight. The relation between slump loss and time for each contents of lignosulphonate admixture compared with plain concrete is shown in Figure 4.3.

The figure shows that at zero minute the slump values were increased from 70 to 100, 105,160 and 170 mm at 0.0%, 0.25%, 0.5%, 0.75% and 1% by cement weight of lignosulphonate respectively. Also, the slump values were increased from 6 to 20, 23, 40 and 50 mm at 0.0%, 0.25%, 0.5%, 0.75% and 1% by cement weight of lignosulphonate at 90 minute respectively. The increasing of workability was essentially due to the air entraining in the concrete mix.

The slump decreased with a rate of 0.88 mm /minute at 0.25% and 0.5% content of LS, while the slump at 0.75% and 1% content was decreased with a rate of 1.33 mm /minute of LS. The optimum content of LS is 0.75% by cement weight because adding additional dosage above this ratio does not show significant improvement to concrete slump.

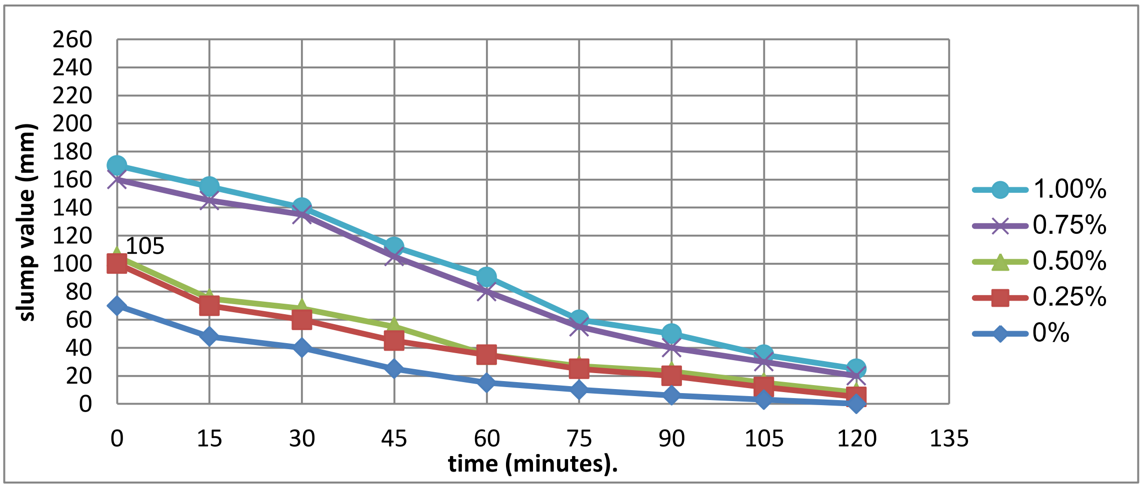

Figure 4.3 Relations between the time and slump value of concrete with LS admixture

4.3.2 Compressive strength tests

The 7 days, 14 days and 28 days compressive strength of concrete mixes having 0.25%, 0.5%, and 0.75% by cement weight of lignosulphonate admixture are shown in Figure (4.4).

The Figure reveals that the compressive strength decreased by increasing the dosages of lignosulphonate admixture, where the 7days compressive strength decreased linearly from 21.1 MPa at 0.25% of LS to 18.6 MPa at 0.75 of LS with 5.9% for each 0.25 content. The 14 days compressive strength decreased linearly from 25.7 MPa at 0.25% of LS to 23.2 MPa at 0.75 of LS with 4.8% for each 0.25 content. The 28 days compressive strength decreased linearly from 28.7 MPa at 0.25% of LS to 25.5 MPa at 0.75% of LS with 5.5% for each 0.25 content.

At all dosages of lignosulphonate we observed that the 7 days compressive strength is about 70% of 28 days compressive and the 14 days compressive strength is about 90% of 28 days compressive strength.

The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete. The air entraining increases as the content of lignosulphonate increases.

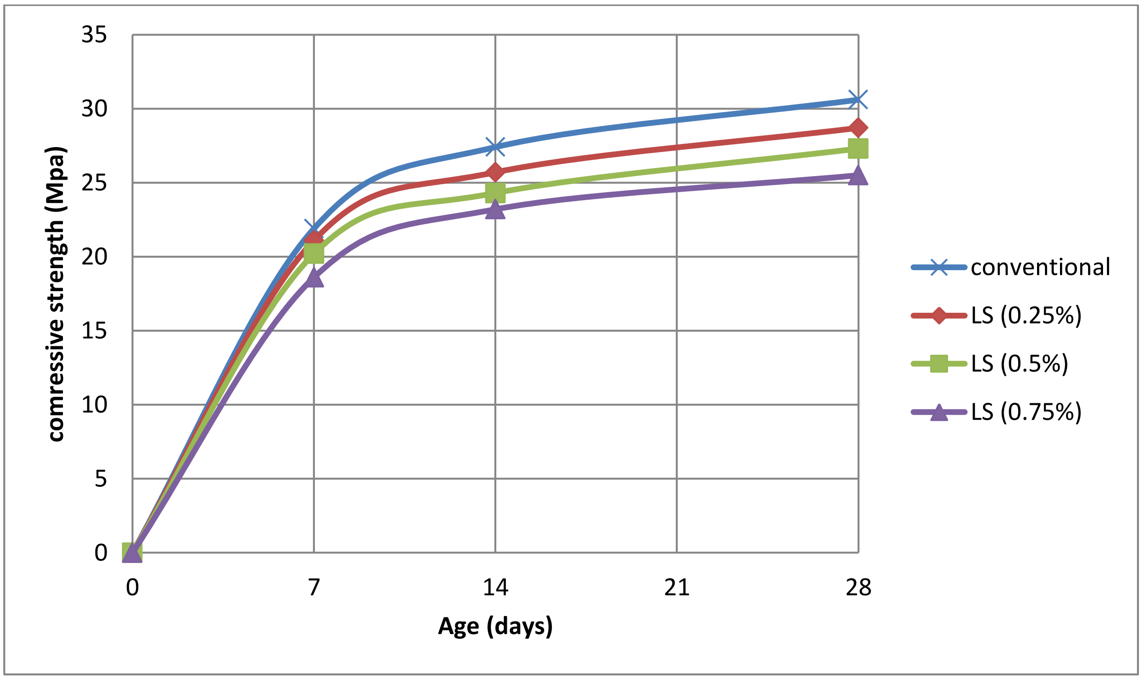

Figure 4.4 Relations between the ratio of LS and 7 days, 14 days and 28 days compressive strength

4.4 Concrete with Styrene Acrylic "SA"

This mix is prepared by adding styrene acrylic "SA" admixture. The effects of this admixture on the mechanical properties of fresh and hardened concrete are shown below.

4.4.1 Slump test results

Several contents of SA were used to study the amount and rate of slump loss of fresh concrete by measure the slump values at 0, 15, 30 to 120 minutes for each ratio. The slump values of mixes having 0.0%, 0.25%, 0.5% and 0.75% by cement weight of SA admixtures are shown in Figure (4.5).

The Figure represents the relation between slump loss and time for each SA admixture contents. From the figure it is clear that the slump values at first specimens (0 minute) was 70, 160, 215and 235 mm at 0, 0.25, 0.5 and 0.75% by cement weight of SA respectively, and the slump value was 6, 52, 75 and 110 mm at 0, 0.25, 0.5 and 0.75% by cement weight of SA at 90 minute. The increasing of workability was essentially due to the air entraining in the concrete mix.

At 0.25% content of SA admixture, there was a slump reduction rate of 1.1 mm/min, while the slump reduction rate was 1.4mm/min at 0.5% content of SA. However at 0.75% content, the slump reduction rate was 1.13mm/min at first 75 min, and 2mm/min at the last 45 min. The optimum content of SA is 0. 5% by cement weight because adding additional dosage above this ratio does not show significant improvement to concrete slump.

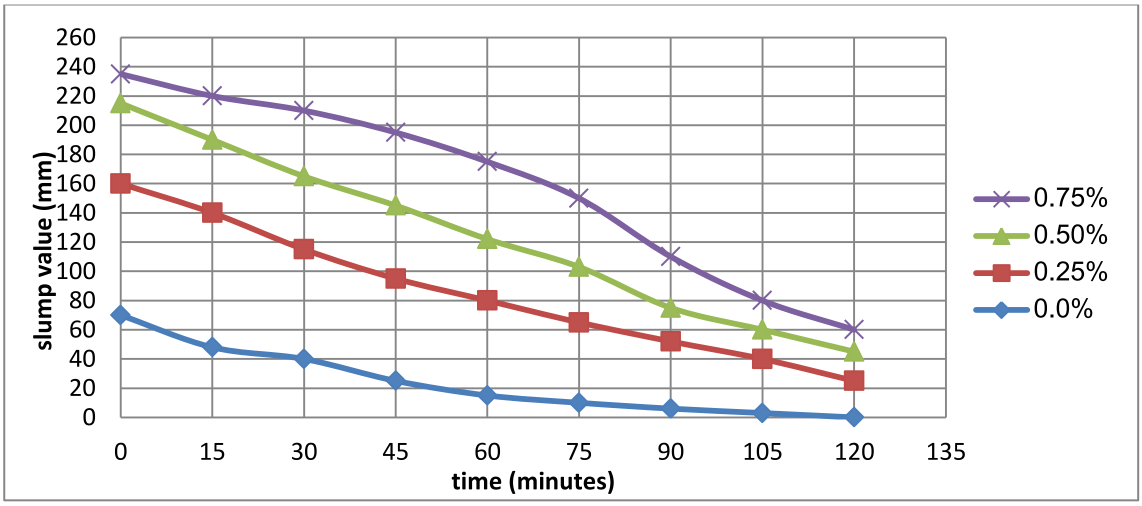

Figure 4.5 Relations between the ratio of SA and slump values

4.4.2 Compressive strength test results

The 7 days, 14 days and 28 days compressive strength of concrete mixes having 0.25%, 0.5%, and 0.75% of SA admixture by cement weight are shown in Figure (4.6).

Figure (4.6) shows that there was a very slight decrease in compressive strength as increasing the ratios of SA admixture, where the 7 days compressive strength decreased from 22.3 MPa to 20.5 MPa at 0.25%to 0.75% respectively with percent 4.0% for each 0.25 ratio, the 14 days compressive strength decreased from 26.8 MPa at 0.25% of SA to 25.2 MPa at 0.75% of SA with percent 2.98 %, and the 28 days compressive strength decreased from 29.8 MPa at 0.25% of SA to 28.4 MPa at 0.75% of SA with percent 2.3 %.

It is clear that the 7 days compressive strength is about 75% of 28 days compressive and the 14 days compressive strength is about 90% of 28 days compressive strength. The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete. The air entraining increased as increased the content of styrene acrylic.

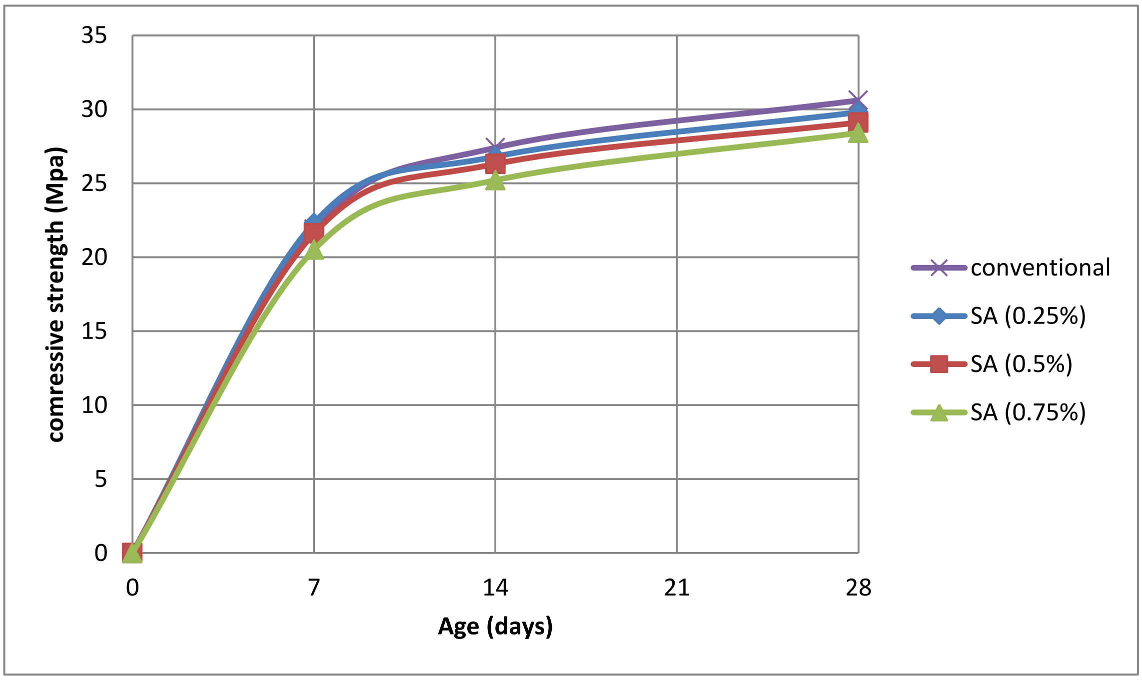

Figure 4.6 Relations between the ratios of SA admixture and 7 days, 14 days and 28 days compressive strength

4.5 Concrete with Praepagen HY "PHY" admixture

This mix is prepared by adding Praepagen HY "PHY" admixture. The effect of this admixture in the mechanical properties of fresh and hardened concrete explained as below.

4.5.1 Slump test results

The slump values at 0, 15, 30 to 120 minutes were measured for concrete mixes with several contents of PHY; The slump values of mixes having 0.25%, 0.5% and 0.75% by cement weight. The relations between slump loss and time for each percentage ratios of HY admixture is shown in figure 4.7.

From figure (4.7) it is clear that the slump results were 70, 200, 220and 230 mm at 0.0%, 0.25%, 0.5% and 0.75% by cement weight of PHY at first specimen (0 minute) respectively, The slump results increased by 6, 57, 125 and 147 mm at 0, 0.25, 0.5 and 0.75% by cement weight of PHY at 90 minute respectively. The increasing of workability was essentially due to the air entraining in the concrete mix.

The slump of the 0.25% PHY content showed a reduction by 1.4 mm/min, while at 0.5% and 0.75% content the slump results showed a reduction by 0.5mm/min at first 60 min, and 2.2mm/min at the last 60 min. The optimum content of PHY is 0. 5% by cement weight because adding additional dosage above this ratio does not show significant improvement to concrete slump.

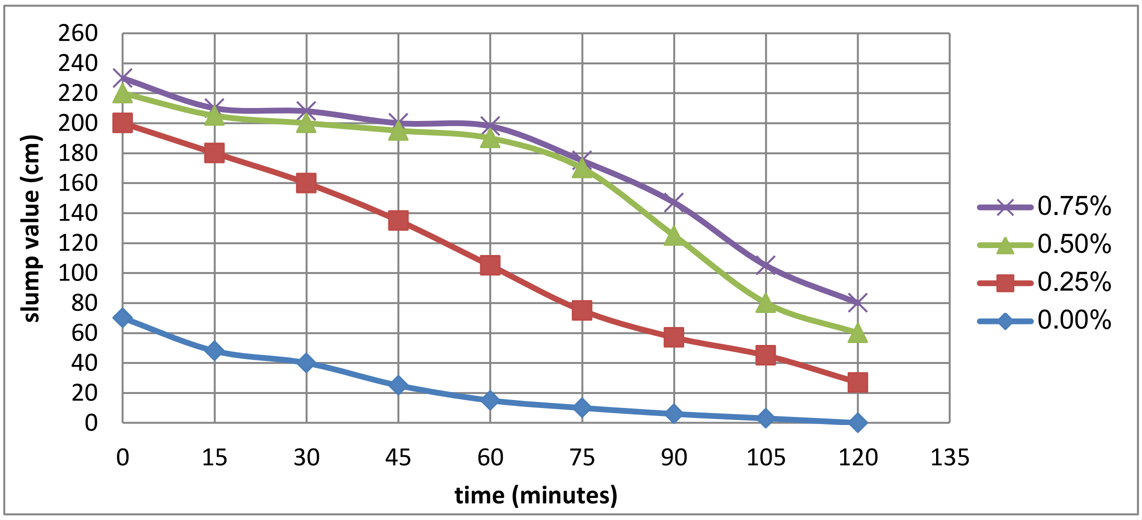

Figure 4.7 Relations between the Ratios of "PHY" admixture and slump values

4.5.2 Compressive strength test results

The 7 days, 14 days and 28 days compressive strength of concrete mixes having 0.25%, 0.5%, and 0.75% of PHY admixture by cement weight are shown in Figure (4.8). It is clear that the 7 days compressive strength is about 75% of 28 days compressive and the 14 days compressive strength is about 90% of 28 days compressive strength for all contents.

Figure (4.8) shows that the compressive strength was decreasing by increasing the dosages of PHY admixture, the 7days compressive strength decreased linearly from 18.3 MPa at 0.25% of PHY to 14.9 MPa at 0.75 of PHY, i.e. 9.2% reduction for each 0.25 content. The 14 days compressive strength decreased linearly from 23.2 MPa at 0.25% of PHY to 18.5 MPa at 0.75 of PHY, i.e. 10.1% reduction for each 0.25 content. The 28 days compressive strength decreased linearly from 25.3 MPa at 0.25% of PHY to 20.9 MPa at 0.75% of PHY, i.e. 8.7% reduction for each 0.25 content.

The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete. The air entraining increased as increased the content of Praepagen HY.

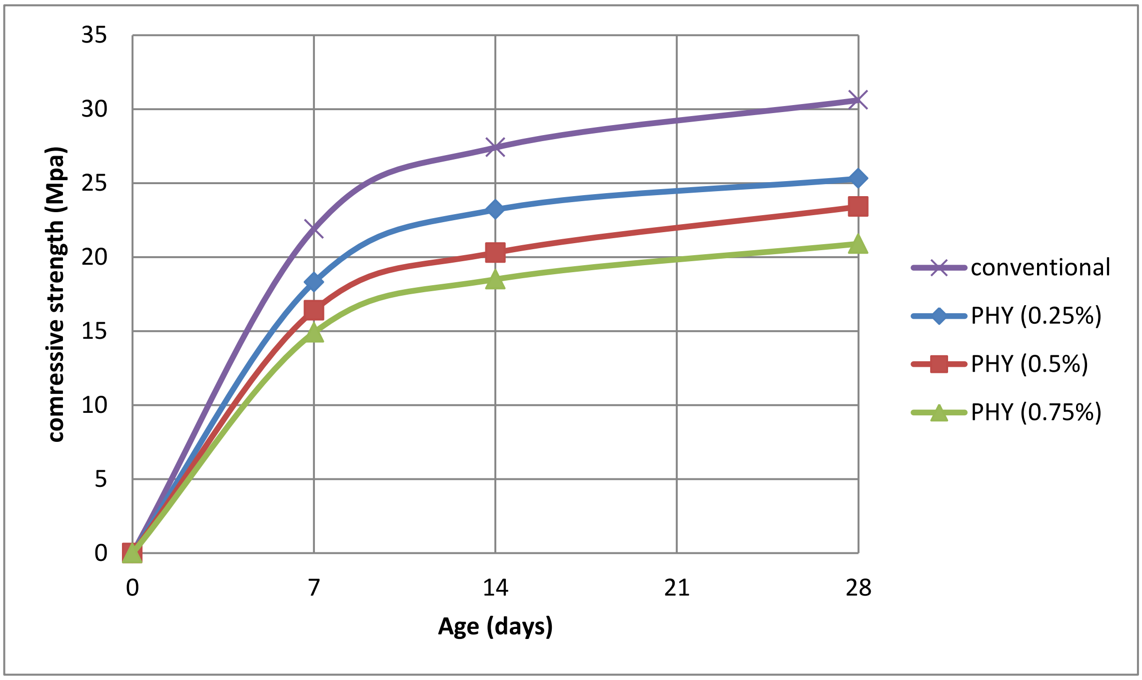

Figure 4.8 Relations between the ratios of "PHY" admixture and 7 days, 14 days and 28 days compressive strength

4.6 Concrete with acrylic polymer “AP”

This mix is prepared by adding “AP” admixture. The effect of this admixture in the mechanical properties of fresh and hardened concrete explained as below.

4.6.1 Slump test results

The slump value at 0, 15, 30 ... and 120 minute were measured for concrete mixes with several contents of AP, the used AP contents are 0.25%, 0.5% and 0.75% by cement weight. Figure (4.9) represents the relation between slump loss and time for each contents of AP admixture.
From figure (4.9) it is clear that the slump value was 70, 190, 220 and 225 mm at 0.0%, 0.25%, 0.5% and 0.75% by cement content of AP at first specimen (0 minute), and the slump value was 6, 80, 140 and 175 mm at 0, 0.25, 0.5 and 0.75% by cement content of "AP" at 90 minute. The increasing of workability was essentially due to the air entraining in the concrete mix.

At 0.25% content of AP admixture, there was a slump reduction rate of 0.52 mm/min at first 105 min, while the slump reduction rate was 2mm/min at the last 15 min. At 0.5% content of AP, the slump reduction rate decreased by 0.8mm/min at first 75 min, while the slump reduction rate decreased with 1.7mm/min at the last 45 min. However, at 0.75% ratio the slump reduction rate was 0.55mm/min at first 45 min while, the slump reduction rate decreased with 1.7mm/min at the last 75 min. The optimum content of AP is 0. 5% by cement weight because adding additional dosage above this ratio does not show significant improvement to concrete slump.

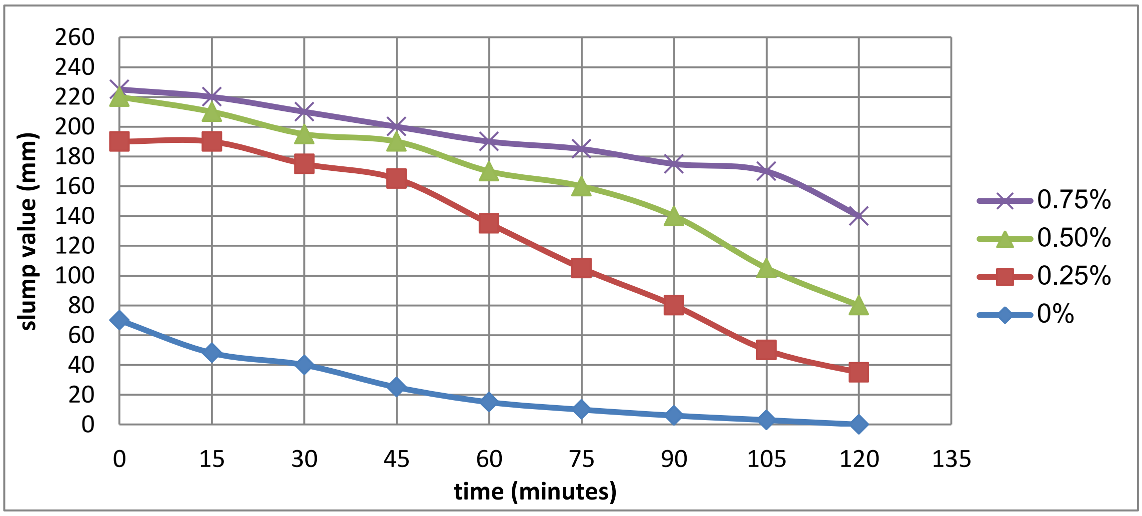

Figure 4.9 Relations between the ratios of AP admixture and slump values

4.6.2 Compressive strength test results

The 7 days, 14 days and 28 days compressive strength of concrete mixes having 0.25%, 0.5%, and 0.75% of AP admixture by cement weight are shown in Figure (4.10).

Figure (4.10) shows that the 7 days compressive strength is about 75% of 28 days compressive and the 14 days compressive strength is about 90% of 28 days compressive strength.

Figure (4.10) reveals that there was a very slight decrease in compressive strength as the AP admixture increases. The 7 days compressive strength decreased from 21.4 MPa at 0.25% of AP to 19.6 MPa at 0.75% of AP, i.e. 4.2% reduction for each 0.25 ratio. The 14 days compressive strength decreased from 26 MPa at 0.25% of AP to 24.1 MPa at 0.75% of AP with a percent 3.6 % reduction. The 28 days compressive strength decreased from 28.9 MPa at 0.25% of AP to 27 MPa at 0.75% of AP with a percent of 3.2 % reduction. The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete. The air entraining increased as increased the content of AP.

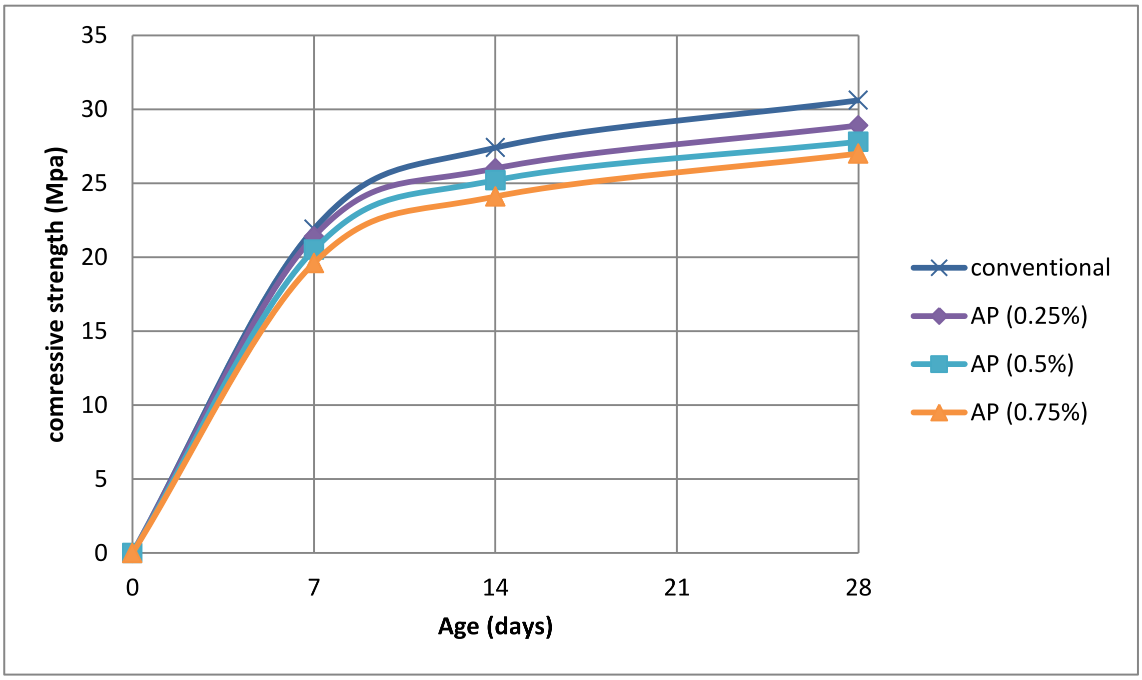

Figure 4.10 Relation between the ratios of AP admixture and 7 days, 14 days and 28 days compressive strength

4.7 Comparison between the performances of the four admixtures

4.7.1 Slump test results

- **At 0.25% contents of admixtures**

The slump values of concrete mix having 0.25% of several admixtures by cement weight are shown in Figure (4.11).

The Figure reveals that all admixture were enhanced the slump, and the slump were improved by using SA, PHY and AP admixtures compared to LS (commercially admixture), AP admixture give the higher slump values over the other admixtures, the slump values of 0.25 % of LS, SA, PHY and AP admixtures are 100, 160, 190 and 200 mm at 0 minute respectively, while the slump values are 20, 52, 57 and 80 mm at 90 minutes respectively.

AP and PHY admixtures increased the slump by 200% compared to LS admixture, while AP admixture increased the slump by 160% compared to LS admixture. The LS admixture losses its workability at 120 minute, however the mixes with SA, PHY and AP admixtures can be acceptable.

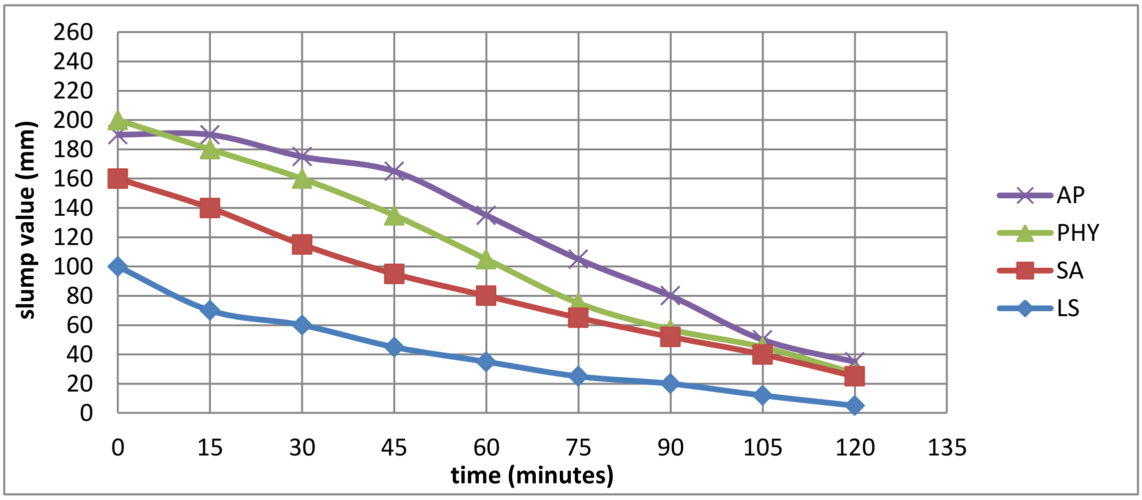

Figure 4.11 Relation between several admixtures with 0.25% ratio and slump values

- **At 0. 5% contents of admixtures**

The slump values of concrete mix having 0.5% of several admixtures by cement weight are shown in Figure (4.12).

Figure (4.12) shows that all admixture were enhanced the slump, and the slump were improved by using SA, PHY and AP admixtures compared to LS (commercially admixture), AP and PHY admixtures give the higher slump values over the other admixtures, the slump values at 0.5% content of LS, SA, PHY and AP admixtures are 105, 215, 220 and 220 mm at 0 minute, and 2.3, 6, 12.5 and 13 mm at 90 minute respectively. The slump loss of AP and PHY are significantly reduction at first 75 minute after that it was decreasing linearly, and the slump loss of SA and LS was decreasing linearly.

The slump results showed that the slump improved by using suggested admixtures (SA, PHY and AP admixtures) compared to LS (commercially admixture).

AP, SA and PHY admixtures increased the slump by 210% compared to LS admixture. The LS admixture losses its workability at 120 minute, however the workability of concrete mixes with SA, PHY and AP admixtures is very good and acceptable.

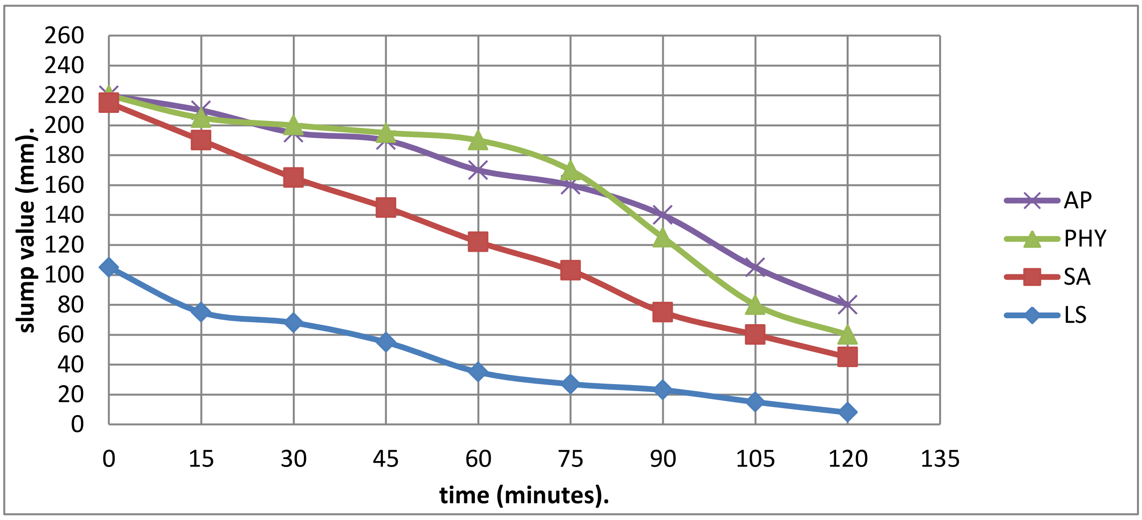

Figure 4.12 Relation between several admixtures with 0.5% ratio and slump values

- **At 0.75% contents of admixtures**

The slump values of concrete mix having 0.75% of several admixtures by cement content are shown in Figure (4.13).

From figure (4.13) it is clear that all admixture were enhanced the slump, the new admixture (SA, PHY and AP) were enhanced the slump compared with commercially superplasticizer (LS).The slump values at 0.5% content of LS, SA, PHY and AP admixtures are 160, 235, 230 and 225 mm at 0 minute, and 40, 110, 147 and 175 mm at 90 minute respectively.

The slump loss of SA, AP and PHY are minimized or eliminated especially at first 90 minute but the slump loss LS was decreasing linearly. AP, SA and PHY admixtures increased the slump by 150% compared to LS admixture. The LS admixture losses its workability at 120 minute, however the workability of concrete mixes with SA, PHY and AP admixtures is very good and acceptable.

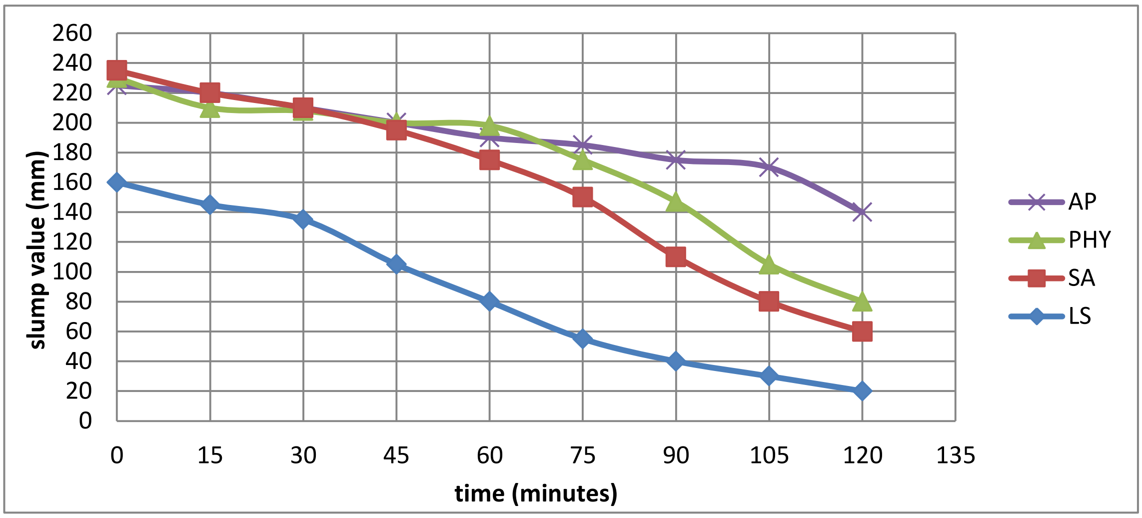

Figure 4.13 Relation between several admixtures with 0.75% ratio and slump values

4.7.2 Compressive strength test results

The 7 days, 14days and 28 days compressive strength of concrete for proposed admixtures (SA, PHY and AP admixtures) contents and commercially admixture (LS) is presented in Figures (4.14), (4:15) and (4:16). For all used admixture the increasing dosage of admixture decreased the compressive strength as shown in the figures.

❖ **7 days Compressive strength**

From Figure (4.14) it is clear that SA and AP admixtures were improved the compressive strength compared with LS (commercially admixture), where SA improved compressive strength more than LS admixture by 5%, 7% and 10% at 0.25%, 0.5% and 0.75% contents respectively. AP improved compressive strength more than LS admixture by 1.4%, 1.5% and 5.4% at 0.25%, 0.5% and 0.75% contents respectively. However the PHY admixture affected adversely for compressive strength compared with LS. The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete. The air entraining increased as increased the content of admixtures.

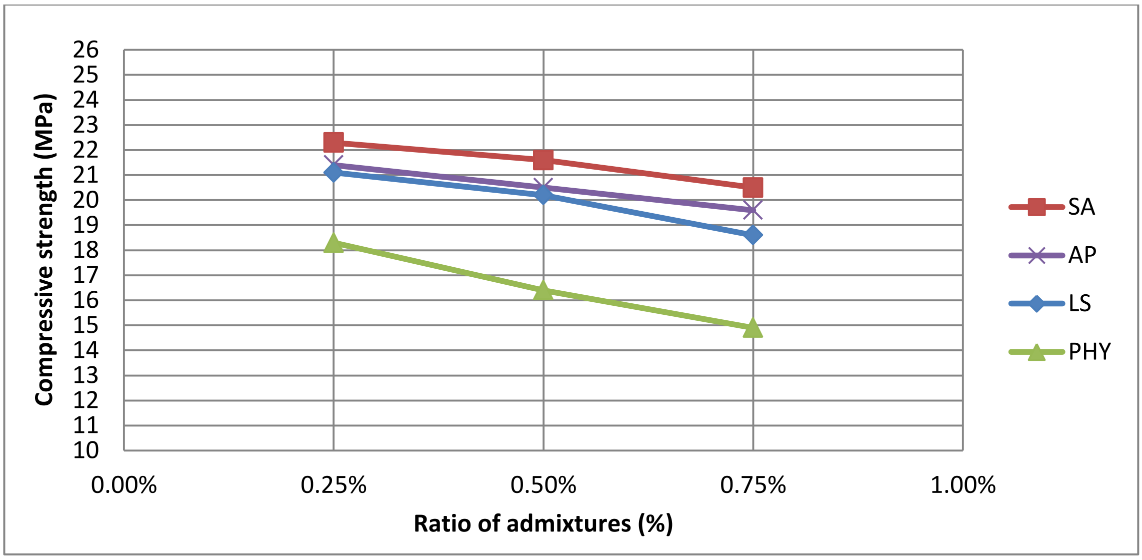

Figure 4.14 Comparison between 7 days age compressive strength for several admixtures contents

❖ 14 days Compressive strength

Figure (4.15) shows that SA and AP admixtures were improved the compressive strength compared with LS admixture, where SA improved compressive strength more than LS admixture by 4.2%, 8.2% and 8.6% at 0.25%, 0.5% and 0.75% contents respectively. AP improved compressive strength more than LS admixture by 1.16%, 3.7% and 3.4% at 0.25%, 0.5% and 0.75% contents respectively. However the PHY admixture affected adversely for compressive strength compared with LS. The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete.

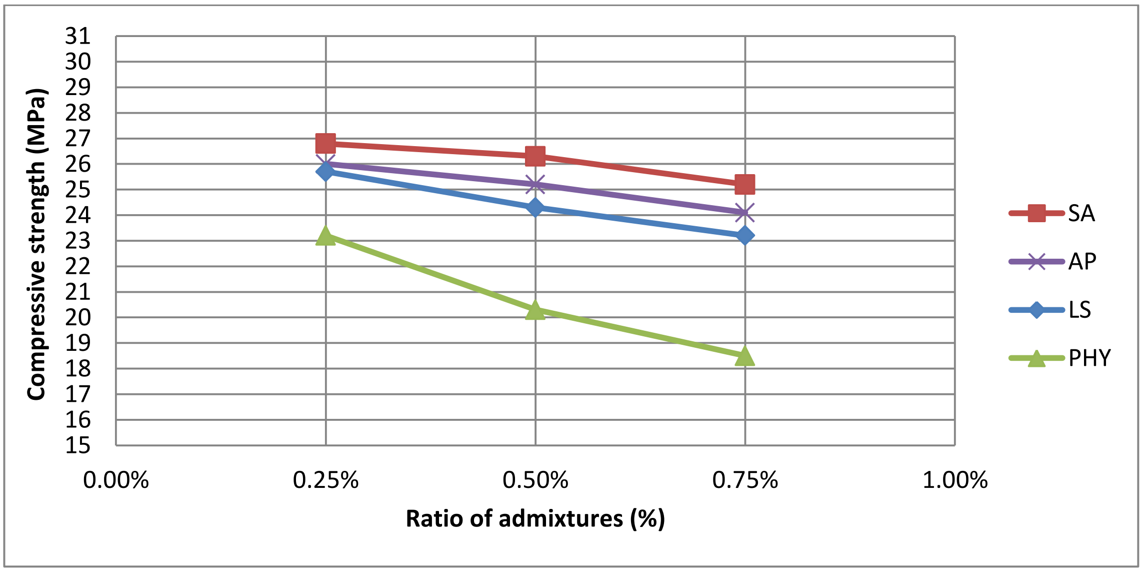

Figure 4.15 Comparison between 14 days age compressive strength for several admixtures contents

❖ **28 days Compressive strength**

Figure (4.16) shows that SA and AP admixtures were improved the compressive strength compared with LS admixture, where SA improved compressive strength more than LS admixture by 3.9%, 6.7% and 11.3% at 0.25%, 0.5% and 0.75% contents respectively. AP improved compressive strength more than LS admixture by 0.7%, 1.8% and 5.8% at 0.25%, 0.5% and 0.75% contents respectively. However the PHY admixture affected adversely for compressive strength compared with LS. The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete.

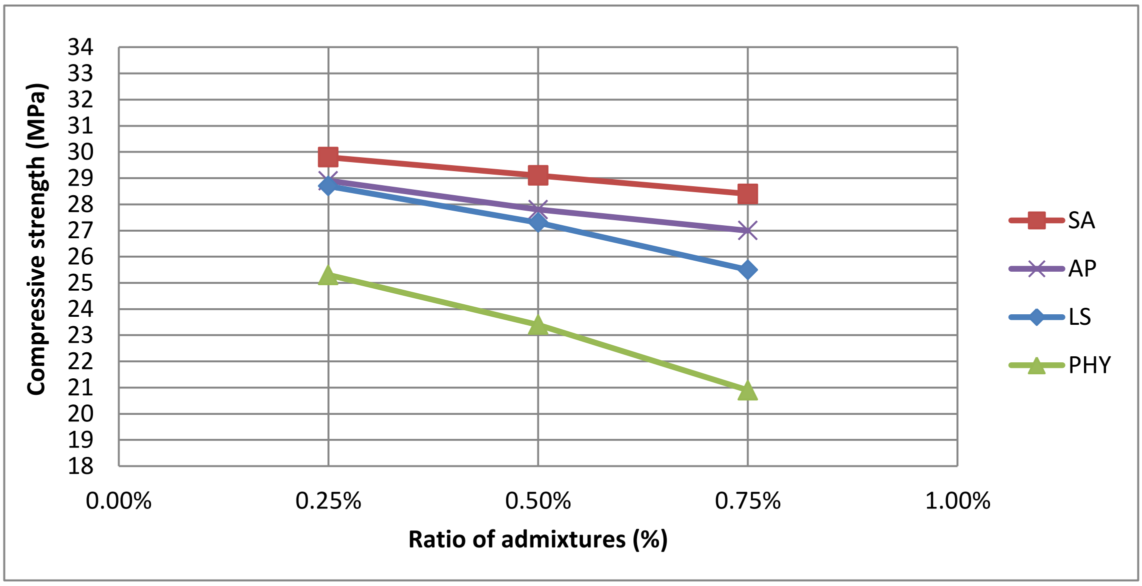

Figure 4.16 Comparison between 28 days age compressive strength for several admixtures contents

4.8 Effect of admixtures on Flexural strength.

The 28 days flexural strength for each admixtures contents and the control mix which applied in this study is presented in Figure (4.17). The flexural strength of plain concrete without any admixture is measured to be 4.73 MPa.

LS improved flexural strength of concrete from 4.73 to 5.06 with increasing percent 6.9% at 0.25% ratio by cement weight. But it was affected adversely at 0.5 and 0.75% ratios where the flexural strength decreased from 4.73 to 4.71 and 4.52 MPa respectively.

AP improved flexural strength of concrete compared with LS admixture with increasing percent of 7.6%, 9.1% and 6.2% at ratios 0.25%, 0.5% and 0.75 % by cement weight respectively.

SA improved flexural strength of concrete compared with LS admixture with increasing percent of 6.7% and 3.5% at ratios 0.5% and 0.75 % by cement weight respectively, however at 0.25 ratios the flexural strength decreasing with 2.4%.

PHY affected adversely on flexural strength of concrete compared with LS admixture with decreasing percent 6%, 7% and 10.24% at ratios 0.25%, 0.5% and 0.75 % by cement weight respectively.

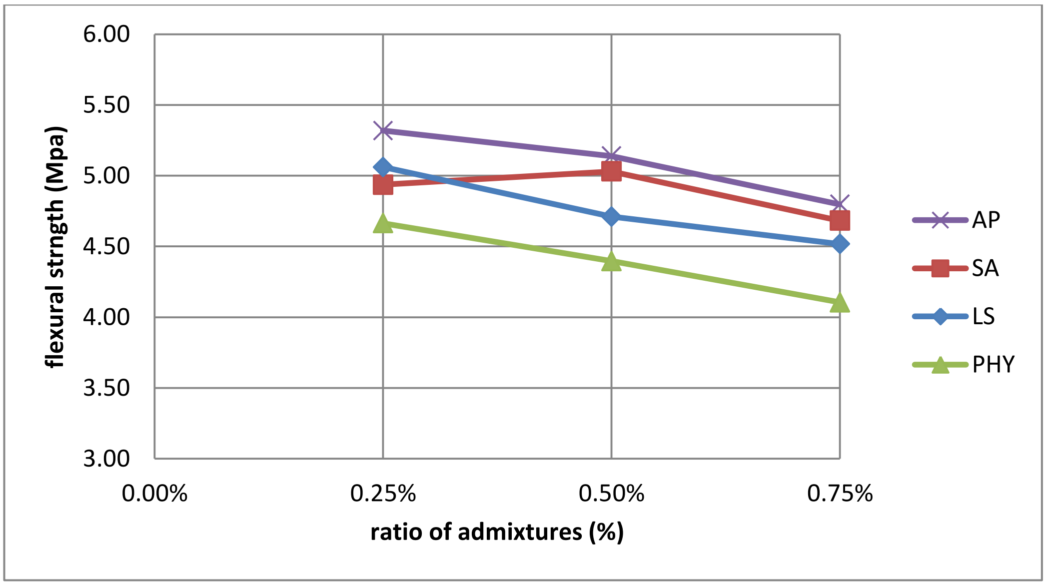

Figure 4.17 Relation between admixtures with several ratios and flexural strength

CHAPTER 5
Conclusion & Recommendations

Chapter (5) - Conclusion & Recommendations

5.1 Introduction

This research investigates the effect of LS, SA, PHY and AP admixtures on the mechanical properties of fresh and hardened concrete. This investigation made by adding three contents for each admixture to plain concrete. The mechanical properties of fresh concrete made by conducting slump test for every mix at 0, 15, 30 to 120 minutes.

5.2 Conclusion

The results of this research showed that applied admixtures styrene acrylic (SA), Praepagen HY (PHY) and acrylic polymer (AP) can enhance the workability of concrete, and reduced slump loss problem, and new admixtures SA and AP can improve the compressive strength compared with LS (locally commercial admixture). The following concluding remarks were obtained from the obtained experimental observation:

1. Proposed admixture enhanced the workability of concrete.
2. All admixtures enhanced the slump, where the slump improved by using SA, PHY and AP admixtures compared with LS (commercially admixture).
3. Admixtures show enormous increase in slump without any significant segregation.
4. Compressive strength improved by SA and AP admixtures compared with LS (commercially admixture); while the PHY admixture affected adversely compared with LS.
5. The slump values of plain concrete were 70 mm and 6 mm with true shape at zero and 90 minute respectively, the compressive strength of plain concrete was 21.9 MPa at 7 days age, 27.4 MPa at 14 days age and 30.6 MPa at 28 days age.

6. The flexural strength of plain concrete was 4.73 MPa and the fracture was normal in the middle span.

7. The loss of strength was essentially due to the air entraining in the concrete mix, these air voids weaken the strength of concrete. The air entraining increased as increased the content of admixtures.

8. The optimum content of LS is 0.75% by cement weight; the using of higher dosage than 0.75% does not show any significant improvement to concrete slump. At 0.75% content of LS admixture the slump value of concrete was enhanced to reach 160 mm. However the compressive strength at this content was 25.5 MPa and the flexural strength was 4.52MPa; also the fracture was normal in the middle span.

9. The optimum content of SA is 0. 5% by cement weight; the using of higher dosage than 0.5% does not show any significant improvement to concrete slump. At 0.5% content of SA admixture the slump value of concrete was enhanced to reach 215 mm with increasing of 105% compared with LS admixture. However the compressive strength at this ratio is 29.1 MPa. The flexural strength was 5.03 MPa; also the fracture was normal in the middle span.

10. The optimum content of PHY is 0.5% by cement weight; the using of higher dosage than 0.5% does not show any significant improvement to concrete slump. At 0.5% content of PHY admixture the slump value of concrete was enhanced to reach 220 mm with increasing of 110% compared with LS admixture. However the compressive strength at this ratio is 23.4 MPa and the flexural strength was 4.40MPa; also the fracture was normal in the middle span.

11. The optimum content of AP is 0.5% by cement weight; the using of higher dosage than 0.5% does not show any significant improvement to concrete slump. At 0.5% content of AP admixture the slump value of concrete was enhanced to reach 220 mm with increasing of 110 % compared with LS admixture. However the compressive strength at this ratio 27.8 MPa. The flexural strength was 5.14MPa also the fracture was normal in the middle span.

5.3 Recommendation for further studies

The following recommendations are purposed for further research:

1. Study the effect of these admixtures (LS, SA, PHY and AP) on the mechanical properties of concrete at different w/c ratios.
2. Study the effect of these admixtures on the long term compressive strength.
3. Study the effect of these admixtures on the mechanical properties of concrete for different cement types.
4. Study the performance of normal concrete and concrete with these admixtures under freezing and thawing condition.
5. Study the effect of adding these admixtures on the porosity and permeability of concrete.
6. Investigate the durability of concrete with these admixtures with time.
7. Study the effect of these admixtures on concrete with recycle aggregates.
8. Study the effect of these admixtures on concrete under changeable temperature degrees.

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APPENDICES

APPENDICES

i. **Results of slump tests**

1. **For adding LS admixture**

TIME	0%	0.25%	0.50%	0.75%
0	70	100	105	160
15	48	70	75	145
30	40	60	68	135
45	25	45	55	105
60	15	35	35	80
75	10	25	27	55
90	6	20	23	40
105	3	12	15	30
120	0	5	8	20

2. **For adding SA admixture**

TIME	0%	0.25%	0.50%	0.75%
0	70	160	215	235
15	48	140	190	220
30	40	115	165	210
45	25	95	145	195
60	15	80	122	175
75	10	65	103	150
90	6	52	75	110
105	3	40	60	80
120	0	25	45	60

3. **For adding HY admixture**

TIME	0%	0.25%	0.50%	0.75%
0	70	200	220	230
15	48	180	205	210
30	40	160	200	208
45	25	135	195	200
60	15	105	190	198
75	10	75	170	175
90	6	57	125	147
105	3	45	80	105
120	0	27	60	80

4. **For adding AP admixture**

TIME	0%	0.25%	0.50%	0.75%
0	70	190	220	225
15	48	190	210	220
30	40	175	195	210
45	25	165	190	200
60	15	135	170	190
75	10	105	160	185
90	6	80	140	175
105	3	50	105	170
120	0	35	80	140

ii. **Results of compressive strength tests:**

1. **For 7 days compressive strength**

Type	0.00%	0.25%	0.50%	0.75%
LS	21.9	21.1	20.2	18.6
SA	21.9	22.3	21.6	20.5
HY	21.9	18.3	16.4	14.9
AP	21.9	21.4	20.5	19.6

2. **For 14 days compressive strength**

Type	0.00%	0.25%	0.50%	0.75%
LS	27.4	25.7	24.3	23.2
SA	27.4	26.8	26.3	25.2
HY	27.4	23.2	20.3	18.5
AP	27.4	26	25.2	24.1

3. **For 28 days compressive strength**

Type	0.00%	0.25%	0.50%	0.75%
LS	30.6	28.7	27.3	25.5
SA	30.6	29.8	29.1	28.4
HY	30.6	25.3	23.4	20.9
AP	30.6	28.9	27.8	27

iii. Results of flexural strength tests

- **For 28 days flexural strength**

Type	0.00%	0.25%	0.50%	0.75%
LS	4.73	5.06	4.71	4.52
SA	4.73	4.94	5.03	4.68
HY	4.73	4.66	4.40	4.10
AP	4.73	5.32	5.14	4.80

iv. Concrete Admixtures by Classification

Type of admixture	Desired effect	Material
Accelerators (ASTM C 494 and_AASHTO M 194, Type C)	Accelerate setting and early-strength development	Calcium chloride (ASTM D 98 and AASHTO M 144), Triethanolamine, sodium thiocyanate, calcium formate, calcium nitrite, calcium nitrate
Air-entraining admixtures (ASTM C 260 and_AASHTO M 154)	Improve durability in freeze-thaw, deicer, sulfate, and alkali-reactive environments Improve workability	Salts of wood resins (Vinsol resin), some synthetic detergents, salts of sulphonated lignin, salts of petroleum_acids, salts of proteinaceous material, fatty and resinous_acids and their salts, alkyl benzene sulphonated, salts of sulphonated hydrocarbons
Alkali-aggregate reactivity inhibitors	Reduce alkali-aggregate reactivity expansion	Barium salts, lithium nitrate, lithium carbonate, lithium hydroxide.
Antiwashout admixtures	Cohesive concrete for underwater placements	Cellulose, acrylic polymer
Bonding admixtures	Increase bond strength	Polyvinyl chloride, polyvinyl acetate, acrylics, butadiene-styrene copolymers.
Coloring admixtures (ASTM C 979)	Colored concrete	Modified carbon black, iron oxide, phthalocyanine, umber, chromium oxide, titanium oxide, cobalt blue
Corrosion inhibitors	Reduce steel corrosion activity in a chloride-laden environment	Calcium nitrite, sodium nitrite, sodium benzoate, certain phosphates or fluosilicates, fluoaluminates, ester amines
Dampproofing admixtures	Retard moisture penetration into dry concrete	Soaps of calcium or ammonium stearate or oleate Butyl stearate, Petroleum products.
Foaming agents	Produce lightweight, foamed concrete with low density	Cationic and anionic surfactants, Hydrolized protein.
Fungicides, germicides, and insecticides.	Inhibit or control bacterial and fungal growth	Polyhalogenated phenols Dieldrin emulsions Copper compounds
Gas formers	Cause expansion before setting	Aluminum powder
Grouting admixtures	Adjust grout properties for specific applications	See Air-entraining admixtures, Accelerators, Retarders, and Water reducers

Hydration control admixtures	Suspend and reactivate cement hydration with stabilizer and activator	Carboxylic acids Phosphorus-containing organic acid salts
Permeability reducers	Decrease permeability	Latex Calcium stearate
Pumping aids	Improve pumpability	Organic and synthetic polymers. Organic flocculants Organic emulsions of paraffin, coal tar, asphalt, acrylics Bentonite and pyrogenic silica's. Hydrated lime (ASTM C 141)
Retarders (ASTM C 494 and AASHTO M 194, Type B)	Retard setting time	Lignin Borax Sugars Tartaric acid and salts
Shrinkage reducers	Reduce drying shrinkage	Polyoxyalkylene alkyl ether Propylene glycol
Superplasticizers* (ASTM C 1017, Type 1)	Increase flowability of concrete Reduce water-cement ratio	Sulphonated melamine formaldehyde condensates. Sulphonated naphthalene formaldehyde condensates Lignosulphonates Polycarboxylate
Superplasticizer* and retarder (ASTM C 1017, Type 2)	Increase flowability with retarded set. Reduce water–cement ratio.	See superplasticizers and also water reducers
Water reducer (ASTM C 494 and AASHTO M 194, Type A)	Reduce water content at least 5%	Lignosulphonates Hydroxylated carboxylic acids Carbohydrates (Also tend to retard set so accelerator is often added)
Water reducer and accelerator (ASTM C 494 and AASHTO M 194, Type E).	Reduce water content (minimum 5%) and accelerate set	See water reducer, Type A (accelerator is added).
Water reducer and retarder (ASTM C 494 and AASHTO M 194, Type D)	Reduce water content (minimum 5%) and retard set	See water reducer, Type A (retarder is added)
Water reducer—high range (ASTM C 494 and AASHTO M 194, Type F)	Reduce water content (minimum 12%)	See superplasticizers
Water reducer—high range—and retarder (ASTM C 494 and AASHTO M 194, Type G)	Reduce water content (minimum 12%) and retard set.	See superplasticizers and also water reducers
Water reducer—mid range	Reduce water content (between 6 and 12%) without retarding	Lignosulphonates. Polycarboxylate.

* Superplasticizers are also referred to as high-range water reducers or plasticizers. These admixtures often meet both ASTM C 494 (AASHTO M 194) and ASTM C 1017 specifications (Kosmatka et. al, 2003).