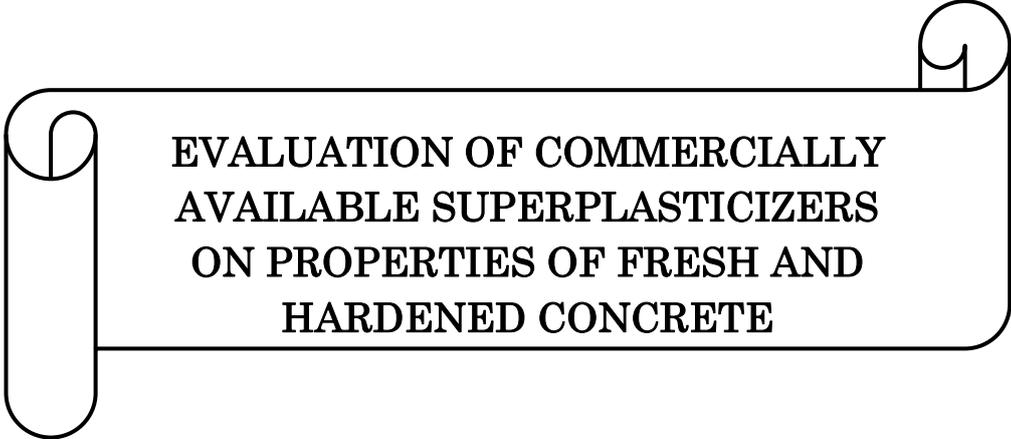


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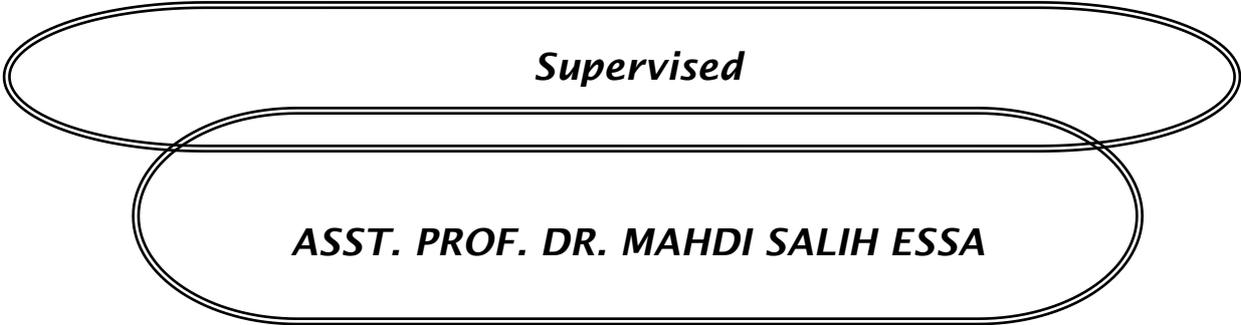


**EVALUATION OF COMMERCIALY
AVAILABLE SUPERPLASTICIZERS
ON PROPERTIES OF FRESH AND
HARDENED CONCRETE**

A Thesis

*Submitted To the College of Engineering of
The University of Babylon in Partial
Fulfillment of the Requirements For The
Degree of Master of Science in Civil
Engineering*

By



Supervised

ASST. PROF. DR. MAHDI SALIH ESSA

جمهورية العراق

وزارة التعليم العالي والبحث

العلمي
Jamad Al-Akhir ١٤٢٧

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تقييم الملدنات المتفوقة التجارية المتيسرة
على خواص الخرسانة الطرية والمتصلبة

رسالة

مقدمة إلى كلية الهندسة في جامعة
بابل كجزء من متطلبات نيل درجة
الماجستير في علوم الهندسة المدنية

من قبل

نعم عبد الزهرة شعلان الماضي

إشراف

أ. د. مهدي صالح عيسى

حزيران ٢٠٠٦م

جمادي الآخر ١٤٢٧هـ

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ

وَمَا كُنَّا مِنْ حَيْثُ
أَمْرِهِمْ أَبْوَاهُمْ مَا كَانَ يَنْبَغِي
عَنْهُمْ مِنَ اللَّهِ مِنْ شَيْءٍ إِلَّا
حَاجَةً فِي نَفْسٍ يَحْقِرُهَا
قَسَاتُهَا، وَأَنَّهُ لَدُوٌّ حَلِيمٌ
عَلِمَانَهُ وَلَكِنْ أَكْثَرُ النَّاسِ لَا
يَعْلَمُونَ

في السنوات الأخير **الخلاصة** نية الحصول على مستوى عالي من قابلية التشغيل للخرسانة الطرية والسيطرة على مساحل فقدان الهطول بدون زيادة في المحتوى المائي للخرسانة وبالتالي الوصول إلى إنتاج خرسانة بمواصفات مناسبة من حيث (قوة التحمل، المتانة، مقاومة التغييرات الحجمية، التعرض للظروف القاسية).

هذه الدراسة أجريت لاختبار الفائدة من استخدام الملدنات المتفوقة كمضافات بنسب مختلفة إلى الخلطة الخرسانية لتحسين قابلية التشغيل لها والسيطرة على مشاكل فقدان الهطول وكذلك لتقييم تأثيرها على خواص الخرسانة علمائياً حرفاً وأضاً لي قيس

استخدمت في هذا البحث ثلاثة أنواع من الملدنات المتفوقة (SMF, SNF, MLS) لاختبارات الخرسانة الطرية (الهطول الأولي، فقدان الهطول، إعادة تطبيع الخرسانة) و لاختبارات الخرسانة المتصلبة (قوة التحمل، الكثافة). **المعروف وزرع فيما ح الحرف والكلمة** **والحقيقة**

لحوصات الخرسانة الطرية يمكن ملاحظة زيادة في الهطول الأولي مع مختلف أنواع الملدنات المتفوقة المستخدمة وللنسب (٥.٥ الكروم) % من وزن الأسمت المستخدم، فمع Sulfonated melamine formaldehyde condensates الزيادة بالنسبة المئوية للهطول كانت (١٧-٢١) %، ولنفس النسب من Sulfonated Naphthaline Formaldehyde condensates كانت تشبه الزيادة في الهطول الأولي (٢٥-٢٨) %، ومع (Melfy Lignosulfonates) كانت الجهد يتكون البنية خير في

تُظهر النتائج بأن النسبة المثلى لكل أنواع الملدنات المتفوقة التي تُستعمل للوصول إلى فقدان الهطول المناسب هي (٣، ٢.٥، ٢) % من وزن الإسمت، وكانت النسبة المئوية للتقليل في فقدان الهطول خلال الـ (٥-٥) دقيقة من الخلطة (SNF) (٣-٣) %، (٣.٣-٠) % على التوالي ولفتره من (٤٠-٦٠) دقيقة مع (SMF, SNF, MLS) كانت (١) % (١) % (١) % على التوالي. النسبة المئوية للملدن التفوق المستعمل والتي تسبب تدهور أو تشوه في الخلطات الخرسانية الطرية كانت (٣.٥، ٣.٧٥، و٤) % من وزن الأسمت ويزداد هذا التأثير بزيادة نسبة الماء/الأسمت. **إلى أمي الغالية**

أظهرت النتائج أن الجرعات المثلى هي (١) % (١) % (١) % لإعادة تطبيع الخرسانة الملدنة للحصول على قابلية تشغيل بشكل مناسب خلال (٩٠-١٢٠) دقيقة من زمن الخلط كانت (٠.٢٧، ٠.٢٩، ٠.٣٢) %، (٠.٢٨، ٠.٣، ٠.٣٥) %، (٠.٢٥، ٠.٢٥، ٠.٣) % من وزن الإسمت مع نسبة ماء/أسمت (٠.٤، ٠.٤٥، ٠.٥) على التوالي. وعند استعمال الماء لإعادة تطبيع الخرسانة الملدنة فإن النسبة المئوية المثلى للملدن المستعمل هي (٢.٧) % لـ (SMF)، و (٢.٧٥) % لـ (SNF)، و

(٢.٥) % لـ (MLS) لإعطاء زيادة في النسبة المئوية للهطول (قابلية التشغيل) هي (٤٨.٦ , ٥٣ , ٥٣) % على التوالي ولنفس نسبة الماء/الأسمنت خلال الـ ٧٥ دقيقة من زمن الخلط.

اعتماداً على نتائج فحوصات مقاومة الانضغاط، فمن الممكن القول أن كل أنواع الملدنات المتفوقة تعمل كمقلات للماء الأمر الذي يعطي التأثير الواضح على تطور مقاومة الانضغاط للخرسانة لجميع الأعمار، النسبة المئوية للزيادة في مقاومة الانضغاط للخرسانة الملدنة مع نسبة ماء/أسمنت (٠.٤ , ٠.٤٥ , ٠.٥) على التوالي، لـ (SMF) هي (٤٦ , ٤٣.٥ , ٣٩.٥) %، ولـ (SNF) هي (٤٦ , ٢٦ , ٤١) %، ومع (MLS) هي (٩ , ١٦ , ٢٧) %.

تشير النتائج بأن مقاومة الانضغاط للخرسانة الملدنة بعد إعادة تطبيعها أقل من مقاومة الانضغاط للخرسانة الأصلية، فعند إعادة التطبيع باستخدام (SMF, SNF, MLS) على التوالي، تنخفض النسبة المئوية لمقاومة الانضغاط لعمر ٧ أيام إلى (١٨ , ٢٧.٥ , ٢٢.٥) %، ولعمر ٢٨ يوم هي (١٦ , ٢٧.٥ , ١٩) %، ولعمر ٩٠ يوم (٢٦ , ٣٢.٦ , ٣٣) % لنسب ماء/أسمنت (٠.٤ , ٠.٤٥ , ٠.٥) على التوالي.

أظهرت النتائج أن كثافة الخلطة الخرسانة الأصلية فـ (SMF, SNF, MLS) تعطي زيادة في الكثافة تصل نسبتها المئوية إلى (١ , ٢ , ٦) % لنسبة ماء/أسمنت (٠.٤ , ٠.٤٥ , ٠.٥) على التوالي.

CERTIFICATION

We certify that the thesis titled “Evaluation of Commercially available Superplasticizers on Properties of Fresh and Hardened Concrete”, was prepared by “Nagham Abd Al-Zahra Shalan Al-Madhi”,

under our supervision at Babylon University in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

Signature:

Name: Asst. Prof. Dr. Mahdi s. Essa

Date:

Signature:

Name: Asst. Prof. Dr. Maher B. Al-Samaani

Date:

CERTIFICATION

We certify that we have read this thesis, titled **“Evaluation of Commercially available Superplasticizers on Properties of Fresh and Hardened Concrete”**, and as examining committee examined the student **“Nagham Abd Al-Zahra Shalan Al-Madhi”**, in its contents and in what is connected with it, and that in our opinion it meets the standard of thesis for the Degree of Master of Science in Civil Engineering (Construction Materials).

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Nagham Abd Al-Zahra Shalan Al-Madhi

٢٠٠٦

ABSTRACT

In recent years, considerable search work has been conducted to investigate the possibility of producing high workability concrete and controlling the slump loss problems without an increase in the water content which lead to produce concrete with suitable properties such as (compressive strength, durability, sever exposure resistance, volume change).

This study was, thus, conducted to examine the feasibility of using superplasticizers as admixtures with different percent in concrete mix to improve workability and controlling the slump loss problems and evaluate their effect in concrete properties.

In this search three types of superplasticizers are used (SMF, SNF, MLS), test of fresh concrete (slump measurement) for (Initial slump, Slump loss, Re-tempering superplasticized concrete) and tests of hardened concrete (compressive strength, density) are used.

For the fresh concrete investigations it can be seen an increase in the initial slump with different percentage and types of superplasticizers, for (1, 2, 2.5, 3, 3.5)% Sulfonated melamine formaldehyde condensates by the weight of cement respectively the percentage increase was (17-21)%, and with the same percentage of Sulfonated naphthalene formaldehyde condensates by the weight of cement (20-28)%, with Modify Lignosulfonates, (30-233)%, with w/c ratio (0.4-0.6).

The results show that the optimum percent for all types of superplasticizers that used to reach from suitable slump loss are (2, 2.5, 3)% by weight of cement, the percentage reduction in slump loss for (0-40) minutes after mixing with SMF, SNF (4-6)%, (0-3.3)%, respectively and for interval (40-60) minutes with SMF, SNF, MLS (0-2)%, (0-3.6)%, (0.0-4, 4)% respectively. Superplasticizers percents which are used cause deformations in the fresh concrete properties and hardened concrete are (3.0, 3.70, and 4) % by the weight of cements and become higher with high w/c ratios.

Results indicate that the optimum dosages of (SMF, SNF, MLS) superplasticizers for Re-tempering superplasticized concrete mix to give suitable workability through (90-120) minutes after mixing were (0.27, 0.29, 0.32)%, (0.28, 0.3, 0.30)%, (0.20, 0.20, 0.3)% by the weight of cement for (0.5, 0.45, 0.4) w/c ratio respectively. When using water for Re-tempering superplasticized concrete mix the optimum percents are (2.7)% SMF, (2.70)%

SNF, (2.0)% MLS gives percentage increases in slump (48.6, 53, 53)% respectively with the same w/c ratio through 90 minutes after mixing.

Depending on the results of compressive strength investigations, it can be said that, all types of superplasticizers work as water reducer, which gives clear effect on compressive strength for all ages of concrete, the percentage increases in compressive strength for mixes with 0.4, 0.45, 0.5 w/c ratio, SMF (46, 43.5, 39.5)%, and, SNF (46, 46, 41)%, MLS (9, 16, 27)%.

Results show, that the compressive strength for Re-tempering superplasticized concrete mixes less than compressive strength of original superplasticized concrete mixes, when used Re-dosing by (SMF, SNF, MLS) respectively, the percentage reduction in compressive strength for 7 days age is (18, 27.5, 22.5)%, for 28 days age (16, 27.5, 19)%, and for 90 days age (26, 32.6, 33)% with (0.4, 0.45, 0.5) w/c ratio.

The results indicate that the density of normally superplasticized concrete mix increase for (MLS, SNF, SMF) respectively the percentage of this increase is (1, 2, 6)% for (0.4, 0.45, 0.5) w/c ratio compare with original concrete mix.

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Chapter one

Introduction

۱. ۱. *General:*

Concrete is one of the important materials for construction and its use increases with the gradual improvement in concrete technology and concrete practice over the years, it is used in heavy construction as well as the other civil engineering projects. “Ready mix” method is used in manufacture and delivery of concrete, in this method the concrete is continuously mixed for different period. The economical and technological considerations dictate minimization of the hauling and mixing time ^[۱].

The major factor that makes high workability and high strength concrete be widely and much sufficiently used in modern construction industry uses a variety of chemical admixtures to concrete, to reach desirable quality ^[۲].

The most usable additives are the high range water reducing agents (superplasticizers), rendering the concrete highly plastic at reduced water content, saving cement, production time and expenses. ASTM C ۴۹۴-۱۹۸۹ was

modified to include high-range water-reducing admixtures in the edition published in July 1981 [3]. The use of superplasticizers (high range water reducer) has become a quite common practice. These classes of water reducers were originally developed in Japan and Germany in the early 1960s; they were introduced in the United States in the mid-1970s. Since they were first introduced in Japan about 30 years ago they have been used to produce several million cubic meters of concrete; in the construction of the olympic stadium in montreal alone, 6000 pre-cast concrete unites were produced utilizing superplasticizers [4].

Superplasticizer (high range water reducer) is a chemical admixture that reduces the quantity of mixing water required to produce concrete of a given consistency by 12% or greater.

Certainly the plasticized concrete production have created a continuous need for more information concerning recommended for the production of plasticized concrete, as well as concerning various admixtures that may be used to improve the efficiency [5].

Research and practice has shown that superplasticizers can successfully be used to achieve the intended properties of the fresh concrete and to improve the performance of the hardened concrete especially in hot weather. The “impact” of superplasticizers took its maximum extent in pre-cast industry (central concrete mixers, precast concrete elements factories,..ect..) [6].

1. 2. Advantages of using superplasticizers:

In general, plasticized concrete has been advantageously used for manufacturing of concrete in hot weather, long transport time, and mass constructions, to avoid structural joints in large casting, in wide-spreading steel in structural members and where architectural consideration requires more difficult sections.

Several different advantages are reported such as Cement content reduction, heat treatment reduction or elimination, reduction in the depreciation costs of the moulds, reduction in breakage and wastage, improvement in the appearance of the formed surface of concrete, vibration energy reduction, reduction in the noise pollution, and increase of labour productivity ^[M].

With the production and use of plasticized concrete the following advantages can be summarized from the previous literature:

١. To increase workability without changing the mix composition in order enhances placing characteristics of concrete and reducing cost of placing ^[^].
٢. To reduce the mixing water and the water – cement ratio (w/c) in order to increase strength and improve durability at a given workability ^[^].
٣. To reduce both water and cement at a given workability in order to save cement and reduce creep, shrinkage and thermal strains caused by heat of cement hydration ^[^].
٤. Improve cohesion, minimizing segregation and improving surface finish ^[^].

- . The use of superplasticizers in concrete designed to provide long-term sulfate resistance [9].
- ٦. Superplasticizers are used to produce flowing concrete and to produce very high strength concrete given respectively in ASTM C 1017 – 92 and ASTM C 494 – 92.
- ٧. Superplasticizers are used to produce flowing concrete and are useful for placing in very heavily reinforced sections, in inaccessible area [11].

١. ٢. *Objective of the study:*

The need for concrete mix with a suitable workability in work site and in factories of construction industry with suitable compressive strength, an attempt is made to study the effect of some types of superplasticizers on properties and behavior of fresh and hardened concrete

This thesis specifically consists of the following objectives:

- ١. Estimating the required mix proportions to produce suitable compressive strength concrete with a required workability.
- ٢. Investigating the effect of adding different dosages of superplasticizers on the concrete mixes.
- ٣. Studying and investigating different properties of plasticized concrete as initial slump, slump-loss, and compressive strength.

- ε. Estimating the possible cement content and w/c ratio reduction.
- ο. The main variables used in this study are the w/c ratio, type and dosage of superplasticizer.

1. ε. *Layout of thesis:*

The thesis consists of five chapters. Chapter one includes the general introduction, and the advantages of superplasticizers uses in concrete. Chapter two includes the previous literature that is related to the production of (plasticized concrete). Furthermore, information about superplasticizers use are discussed in the same chapter. The experimental work, materials and testing procedure are pointed out in chapter three. In chapter four, the analysis and discussion of experimental work are presented. Chapter five contains the conclusions and recommendations for further work. Below Fig (1-1) presents the flow chart of the study.

Chapter two

Literature Review

2. 1. *Introduction*

It is well known that a reduction in the w/c ratio improves all properties of concrete and in particular increases its strength. Unfortunately, the w/c ratio cannot be reduced below a certain value since the workability of concrete becomes so low that for a given method of compaction, the concrete cannot be completely compacted.

If one excludes some particular and sophisticated methods of compaction, the stiffest concrete that can be satisfactorily placed is the “no

slump” concrete, that is concrete with a slump less than (20) mm. However, a no slump concrete is very difficult to place especially if it is to be placed in highly reinforced, precast element. If vibration of fresh concrete is not fully and carefully performed macroscopic voids and in some cases honeycombing can result in the concrete elements. This causes differences between the strength of the actual well-compacted concrete specimens and the strength of the actual concrete placed in the element, the difference being higher for stiffer concrete. It shall be assumed that when this difference is low the concrete is “reliable”.

Reliability depends on [1]:

- a. Efficiency, care and degree of compaction.
- b. Density of reinforcement and geometry of elements.
- c. Workability of fresh concrete.

The literature review describes the previous investigations that are related to the production of concrete with superplasticizers. This chapter consists of two parts. The first part deals with the nature of materials used the second part reviews literature related to mix proportions, the dosages of superplasticizers and discusses the investigations achieved for the fresh and hardened concrete with the effect of high temperature climate.

2.1.1. *Nature of materials:*

Originally the concrete was made by using a mixture of only three materials; cement, aggregate, and water. With time and for many reasons other materials had interred the mixture such as superplasticizers [1]. In contrast to the common admixtures, these materials can alter the fundamental nature of the cement past and the relations between its different property [1].

2. 1. 1. 1. **Cement:** ordinary Portland cement (ASTM Type I) is the commonest cement type that is used to produce superplasticized concrete.

2. 1. 1. 2. **Fine aggregate:** natural sand with rounded particle shape, smooth texture, and high fineness modulus (2.0-3) require less mixing water in concrete and give the best workability and compressive strength results [12].

2. 1. 1. 3. **Coarse aggregate:** The maximum size of the aggregate should be kept to a minimum at (12.5 or 9.5) mm [13]. The better results with that aggregate are attributed to the reduced average bond stress due to the increased surface area of the individual aggregate and the less severe concentration of stresses around the particles, which are caused by the differences between the elastic modulus of paste and the aggregate [14]. It could be stated that, the influence of aggregate characteristics on concrete strength increases because the matrix strength is close to the rock strength [15].

2. 1. 2. **Superplasticizers**

Superplasticizers are one of the chemical admixtures. Chemical admixtures are materials that differ from materials that are added at the manufacturing process of cement [16]. The materials that added to the cement during the manufacturing process such as grinding aids or behavior modifiers are called (additive). Usually admixtures are classified according to their major purpose of use. They are used to modify the properties of concrete or mortar and make them more suitable for the work by hands, economy or such other purposes as saving energy [17]. Specific influences of an admixture depend on many factors such as; the admixture type, admixture amount and

chemical composition of the admixture, the cement type, the chemical composition of cement, gypsum content in cement, period of mixing [17].

Superplasticizers do not alter fundamentally the structure of hydrated cement past, the main effect being a better distribution of cement particles and, consequently, they're better hydrated. This would explain why, in some cases the use of superplasticizers was found to increase the strength of concrete at a constant w/c ratio [18].

Kishitani et al., [19] used Polycarboxylate and lignosulfonates superplasticizers for producing flowing concrete. Their study included the effect of superplasticizer on both of the hardened and fresh concrete properties and a comparison with reference concrete. They stated that when a superplasticizers dosage less than 3.0% was used, the air content did not change, and they showed that there was no difference between compressive and tensile strengths for high flowing and ordinary concrete. But the modulus of elasticity for high flowing concrete is a little higher than that of ordinary concrete. In other hands Yap and Dhir., [20] pointed out that air content would be reduced by adding the superplasticizer, and they obtained a similar conclusion about compressive strength that Kishitani obtained.

Brettmann et al., [21] stated that bond resistance between high flowing concrete with reinforcing steel is less than its counterpart obtained in ordinary concrete. While Collepardi and Corradi [22] showed that bonds resistance between concrete and reinforcing steel increases when a superplasticizer is used.

2. 1. 2. 2. Composition:

Superplasticizers are admixtures which are water reducing but significantly and distinctly more so than the water reducing admixtures.

Superplasticizers are also usually highly distinctive in their nature, and they make possible the production of concrete, which in its fresh or hardened state, is substantially different from concrete made using water reducing admixtures [1]. Superplasticizer as “water reducing high range admixtures” but this name seems to be too long and too complex, therefore, the term superplasticizer will be used [2].

Superplasticizers are linear polymers containing sulfonic acid groups attached to the polymer backbone at regular intervals. Most of the commercial formulations belong to one of four families relating to their chemical composition [3].

1. Sulfonated melamine-formaldehyde condensates (*SMF*).
2. Sulfonated naphthalene-formaldehyde condensates (*SNF*).
3. Modified lignosulfonates (*MLS*).
4. Polycarboxylate derivatives such as sulfonic acid esters, or other carbohydrate esters.

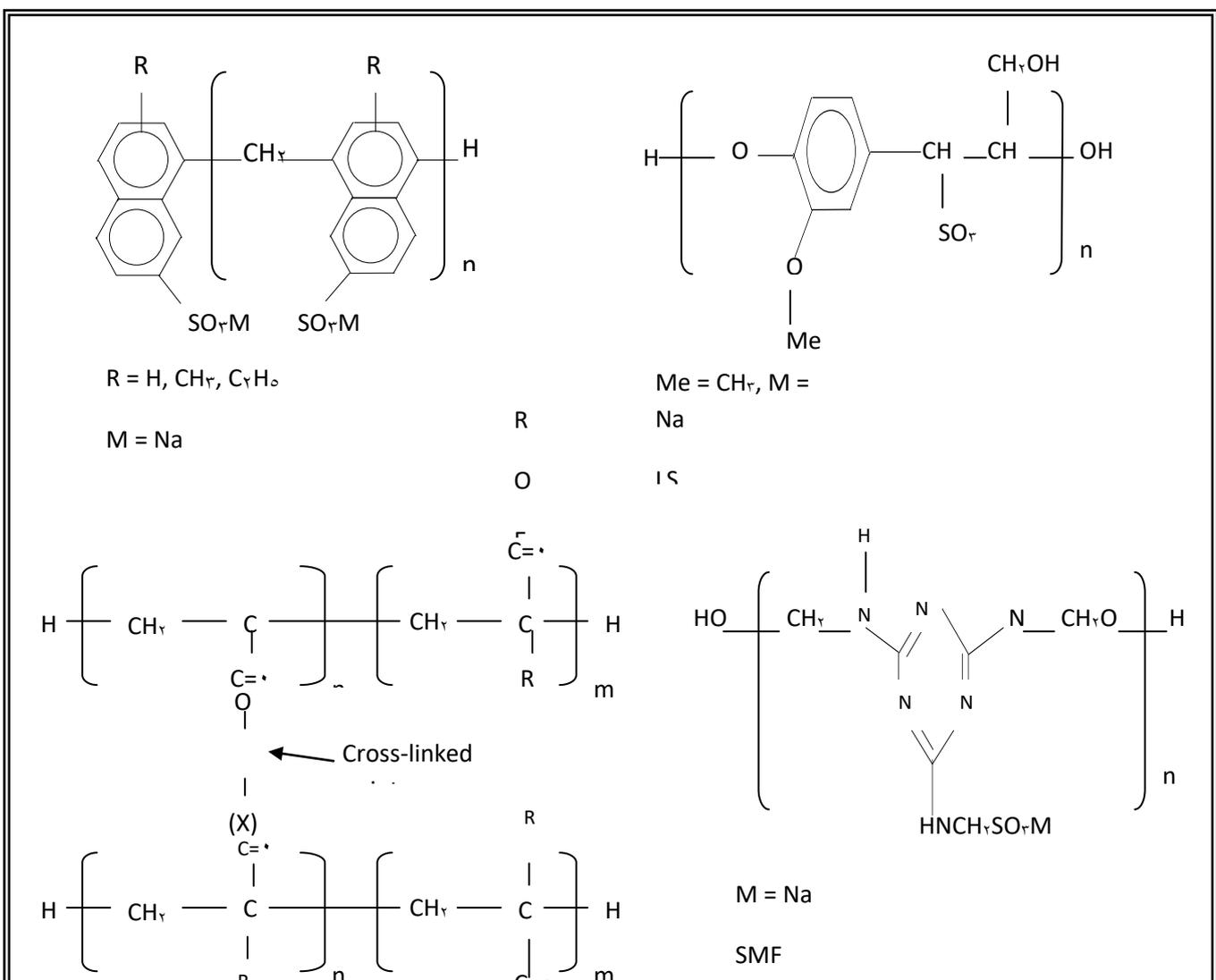
The first two are the most common ones. For brevity, they will be referred to as melamine based superplasticizers. And naphthalene based superplasticizers respectively [4].

The *SMF* or *SNF* based superplasticizers are available as 4-7% aqueous solution. The chemical structures of the most important types used as active ingredient of superplasticizers shown in figure (1-1).

Superplasticizers are water-soluble organic polymers, which have to be synthesized, using a complex polymerization process, to produce long

molecules of high molecular mass. On the other hand, because they are manufactured for a specific purpose, their characteristics can be optimized in terms of length of moleculars with minimum cross-linking. They also have a low content of impurities so that, even at high dosage, they do not exhibit unduly harmful side effects [17].

The main ingredients in the superplasticizer are synthetic water – soluble polymers such as sulfonated melamine formaldehyde condensate (SMF). Alternative water–soluble synthetic polymers have been recently proposed to reduce the slump–loss drawback, which can partly or completely cancel the initial technical advantage associated with the use of superplasticizer (low w/c ratio or high slump level) [18].



The copolymer is more active at higher temperatures, which is particularly beneficial in concreting in hot weather when high workability can be retained for up to one hour after mixing [11].

Tanaka et., al, [12] studied the effect of an acrylic polymers based superplasticizer on the slump-loss of a concrete mixture. This superplasticizer is partially cross-linked copolymer of acrylic acid and polyethylene glycol – alkyl ether.

In some cases, chloride – free inorganic salts are used as secondary ingredients to compensate for the retarding effect associated with heavily dosed superplasticizer system [13].

The main ingredients used in the manufacture of superplasticizers are organic products and can be divided into four groups. The first contains salts of lignosulfonic acid, which can also be used as an important ingredient of superplasticizers when available in a modified (LMS), and consist mainly of a de-sugarized product with reduced retarding effects. The second group contains salts of hydroxycarboxylic acids. The third group was carbohydrates and the fourth group contains miscellaneous compounds such as glycerol. The secondary ingredients in superplasticizers may be accelerating products such as triethanolamine, calcium and sodium of inorganic acids, as well as de-foaming agents, anti-bacterial and anti-fungal materials to avoid gas development caused by the transformation of the organic main ingredient [14].

It is worth noting that the concentration of solids in commercial superplasticizers varies so that any comparison of performance should be

made on the basis of the amounts of solids, and not on the total mass. For practical purposes comparison should be made on the basis of the price for a given effect [14].

2. 2. Superplasticizers Effect in Concrete:

Hydration of Portland cement starts when adding water to it, with time the volume of hydration products increases; giving denser paste. Setting phenomenon, caused by stiffening of the paste and its subsequent solidification, which gives the hydrating cement paste, with time a significant strength. The change in consistency (slump) may be quite rapid particularly in hot weather and causes difficulties in discharging, handling, and placing [15].

The main purpose of using superplasticizers is to produce flowing concrete with very high slump to be used in heavily reinforced structures and in placements where adequate vibration cannot be readily achieved. The other major application is the production of high-strength concrete at w/c ranging from 0.3 to 0.5 [16].

Superplasticizers behave much like conventional water reducing admixtures in that they reduce the inter-particle forces that exist between cement grains in the fresh paste, thereby increasing the paste fluidity. However, they differ from conventional admixtures in that they do not affect the surface tension of water significantly; therefore, they can be used at higher dosages without excessive air entrainment [17].

The influence of superplasticizer on the properties of fresh concrete was studied by Kishitani [18] who stated that the bleeding in high flowing concrete (produced from presence of superplasticizer) is higher than the bleeding in ordinary concrete that had no admixture. However, this bleeding

less than its counterpart obtained in concrete of high workability, which is produced by increase of water content.

The dosage of the superplasticizer should be found by trials and controlled carefully for each set of materials and mix proportions. An example for its importance: it has been confirmed that the addition of superplasticizer reduces the total air content of concrete significantly, however an inadvertent over dosage of superplasticizer can result in a very strong retardation and a high percentage of entrapped air and reducing ultimate strength [13].

The superplasticizer dosage control, for example, might not be adequate, and it requires ancillary equipment such as truck-mounted admixture tanks and dispensers. Adding admixtures at the batch plant, beside dosage control improvement, reduces wear of truck mixers and reduces the tendency to add water onsite. New admixtures now being marketed can be added at the batch plant and can hold the slump above (200 mm) for more than 2 hours [14].

For instance set retarder appear more effective with cement content, which has lower alkali and C₇A contents. The quantity of superplasticizer added must be accurately determined and measured because a heavy over dose can seriously damage the setting and hardening of concrete, particularly when an excess of air is entrained in the concrete by the over dosage [15].

Under moderate weather conditions, the use of superplasticizers in air-entrained concrete can produce coarser-than normal air-void systems. The maximum recommended spacing factor for air-entrained concrete to resist freezing and thawing is (0.7 mm) [16].

Mailvaganam & Rixom, [13] showed that the possibility to reduce the water content as (20 – 30)% for mixes has (300 – 600) Kg/m³ and normally initial slump (70 – 90) mm depends on the properties of aggregate and the type of cement and admixture with the increase in later compressive strength.

Ispas and Ionescu [14] stated that it could reduce the amount of cement in concrete by the use of [Sulfonated melamine-formaldehyde condensates and Sulfonated naphthalene-formaldehyde condensates] superplasticizers, while maintaining the same workability and strength with (10-20)% increase when using (370-380)kg cement for one cubic meter of concrete with 10% furnace slag and 2% superplasticizer by weight of cement.

For superplasticizers effect on volume change in high flowing concrete Kishitani [15] showed that the drying shrinkage approximately is equal for both high flowing and ordinary concrete. However, the shrinkage in a high flowing concrete is less by (20)% compared with shrinkage obtained in a high workability concrete because of the reduction in water content.

Dhir et al., [16] stated that drying shrinkage in a high flowing concrete is higher than in the ordinary concrete and it increase between (0-20)% when the amount of superplasticizer is increased. They suggested using high flowing concrete with aggregate of lower shrinkage to avoid increasing shrinkage. And they pointed that creep of the high flowing concrete is less than the ordinary concrete by about (1)% . But Brooks et al., [17] showed a decrease in creep for flowing concrete than ordinary concrete by about (30)%.

2. 1. 1. Cement savings when using superplasticizers

This concept of obtaining an economic advantage from the use of admixtures is probably the best known and widely practiced throughout the worldwide concrete industry [1]. The diagram shown in figure (2-3) is well known and shows how “corresponding mixes” containing different cement contents can have the same workability, strength, and durability characteristics by the use of the high range water reducing or water reducing admixtures in the lower cement content mix, which can have even improved properties in terms of drying shrinkage, creep, and thermal stresses [14].

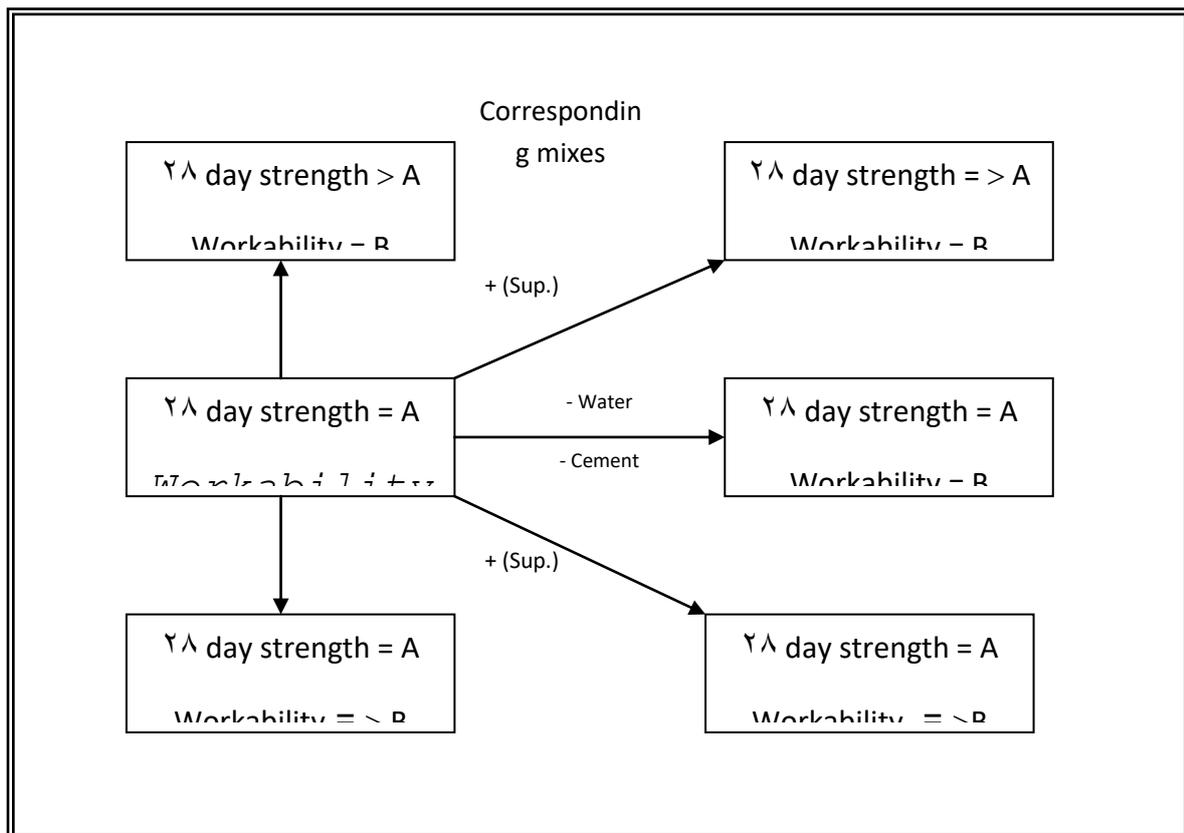


Figure (2): The concept of corresponding mixes [14].

However in practice, where the real cost savings come down to the difference between the cost of the admixture and the savings in the concrete ingredients, things are sometimes not so simple. A customer introduced the “three point” method of evaluating the effectiveness of superplasticizers, where two concrete mixes are selected with suitable properties, which designed at two different w/c ratios with and without the presence of some types of (Superplasticizers) at the same initial slump. The results that were shown in figure (٢-٤) taking corresponding mixes containing ٢٦٠ kg cement/m³ plus (٣% Sup.) by the weight of cement, and both having a same ٢٨ days compressive strength [٢٢].

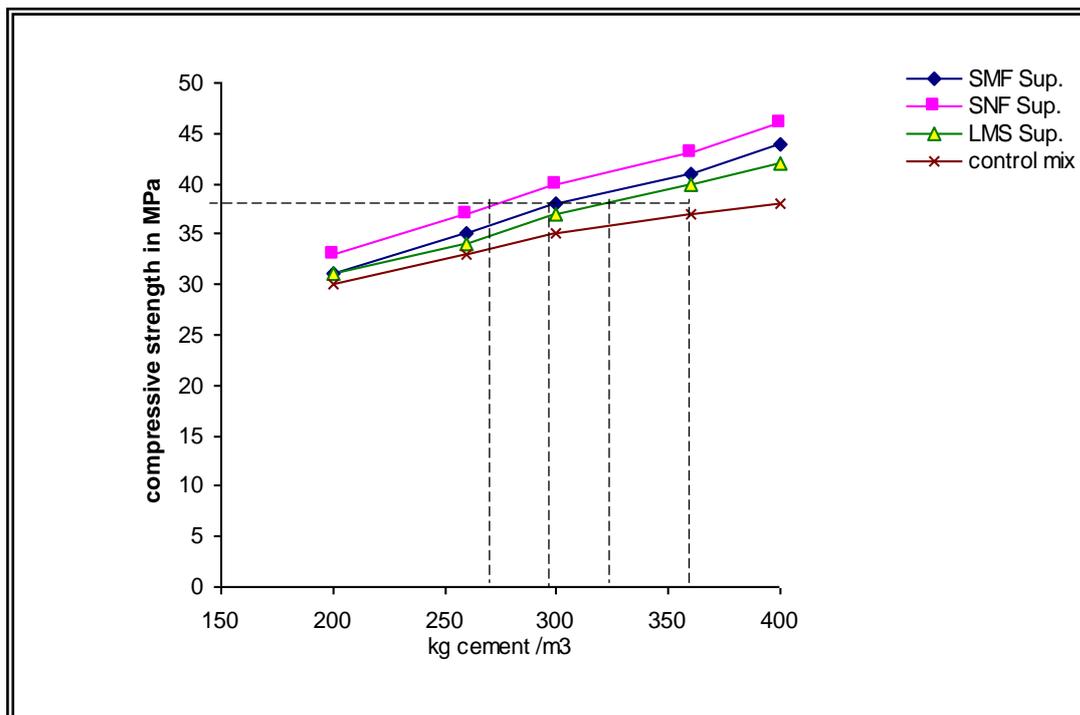


Figure (٢-٤): three-point curve for different Sup [٢٢].

From their results it can be indicated that there are no savings in the net cost. Thankfully, the price of cement has risen over the intervening years whilst that of admixtures has remained more or less the same, so an updated cost comparison looks better today [1].

So many products could have this sort of performance level. For a complete picture, the following points need to be considered.

a. Water reduction; the amount of water reduction obtained is influenced by the following main factors [1].

1. *Cement characteristics*; although a large difference in the performance of (Sup.) with different cements have been observed, to date there is no reliable way of forecasting behavior from cement composition, although a major project in this respect is planned. It has been noted, however, that higher C_vA levels reduce the effectiveness of superplasticizers, possibly by adsorbing part of the active material and preventing it from playing a role in the de-flocculation of the cement particles. And there is some information available on the role of SO₃ level and type, and fineness of cement [1].

2. *Superplasticizers Composition*; it is obviously true that a higher solid content will perform more effectively than a lower one, but it has

also been observed that the different chemical types of superplasticizers have different degrees of effectiveness, and this is also cement dependent [17,19].

γ. *Superplasticizers dosage*; the experience of the author and others is that there is curvature relationship between the dosage of superplasticizers and the water reduction obtained. This leads to the interesting conclusion that the higher dosage can be tolerated from a retardation point of view, the greater will be the cost savings [19,20]. Since the degree of retardation at the higher dosage would probably be unacceptable, but it is certainly worth going up in 1% of weight of cement increments to find the optimum level. Alternatively, in the past 5 years (2000-2005), the (Sup.) have been developed to allow higher dosages, and hence water reductions (3.0 to 12%), without dramatic increase in setting time [19,20].

b. (Sup.) price; this is clearly a factor as far as a specific type of (Sup.) is concerned. However, it is cost effectiveness that is important, as clearly illustrated, where the most expensive product at the highest dosage level has resulted in the lowest per meter cost [21].

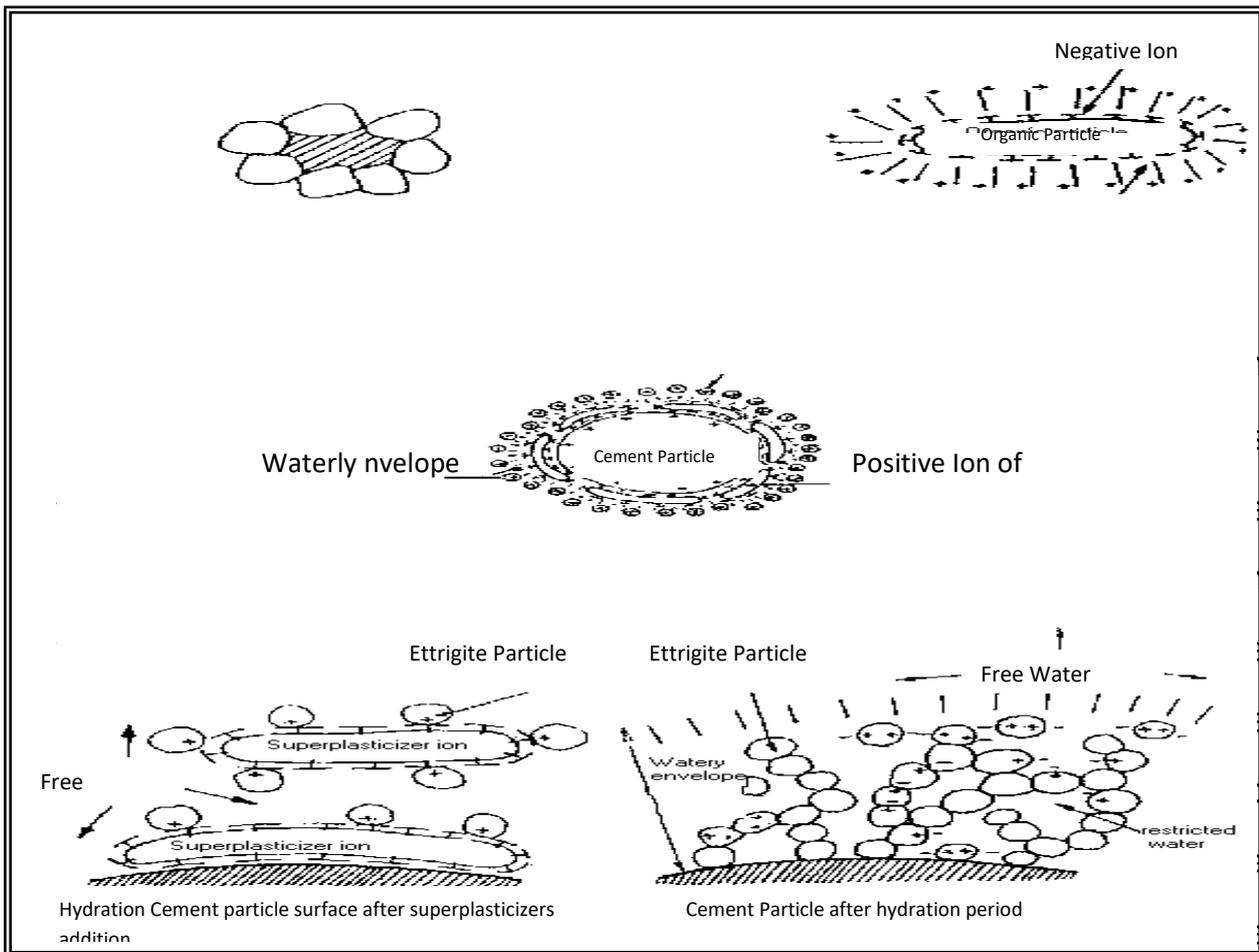
To summarize, the cost saving that can be affected using (Sup.) can be very significant. As long as care is taken in the selection of a cement that is compatible with (Sup.), that as high a dosage as possible is used, and that in negotiating a price for the (Sup.), solids content as well as per letter price should be considered.

2.2.1.2. Mechanical and Chemical Action

Conventional superplasticizers, such as those based on sulphonated melamine and naphthalene formaldehyde condensates, at the time of mixing, become absorbed onto the surface of the cement particles. This absorption takes place at a very early stage in the hydration process. The sulphonic groups of the polymer chains increase the negative charge on the surface of the cement particles and dispersion of the cement occurs by electrostatic repulsion [107] shown in figure (2-0).

The sulfonic acid groups are responsible for neutralizing the surface charges on the cement particles and causing dispersion, thus releasing the water tied up in the cement particle agglomerations and thereafter reducing the viscosity of the paste and concrete [107].

Superplasticizers cause dispersion into smaller agglomerates of cement particles, which are predominated in the cement paste of the concrete mix. Because of the dispersion effect, there is a fluidity increase in the cement mixture. In the paste, the dispersion effect was ascribed to the development of the electrostatic (negative) charge on the cement particles [108]. Attractive forces existing among cement particles that cause agglomerates would be neutralized by the adsorption of anionic polymer, by the presence of (SO_4^-) groups on the surface of cement particles. The dispersion of cement particles would be related to the electrical repulsion produced by the adsorption of negatively charged groups [109].



reacted materials and causes a delay in hydration. In the third stage (after 7 hours) and by the presence of admixture, the water presented in the capillary pores is changed to a solution and a change in the pores frame of cement particles takes place and the volume of the capillary pores becomes small. So, the admixture pellicle prevents the penetration of the water, thus, delaying the hydration of cement.

Popovice [5] described the mechanism of action of superplasticizer, which is depending on adsorption theory, where the big ions of the superplasticizer and their molecules period the reaction between the cement and water, consequently, retarding the setting time. After that, as a

result of reaction between (C₇A) and the organic salts, the resulted solution moves on the system, thus reducing the retardation.

Rixom ^[47] proved that the job of superplasticizer is to form a film layer around the cement particles, which prevents or retards the reaction between the cement and water. The degree of retardation depends on the film thickness, after a period of time, the film breaks and the hydration process continues.

Talib et al., ^[58] believed that these superplasticizers have high surfactant effects, which improve the workability of the mixture and the objective of these admixtures is to reduce the soluble alumina ability to combine with hydration products which form a sulpho aluminate instead of alumina silicate gel.

Young ^[59] studied the effect of lignosulphonate additives on the hydration of C₇A. It was found that the lignosulphonate modifies the hydration of C₇A and promotes the formation of acircular crystals at the expense of hexagonal plates, also in the presence of lime or gypsum, the sequence of reaction is not affected. He concluded that the increase in strength might be due to the circular crystals because of their ability to interlock.

Colleparidi et al., ^[60] and Hattori., ^[61] studied the combined effect of lignosulphonate and carbonate on the hydration of tetracalcium aluminoferrite C₄AF and the tricalcium aluminate C₇A. They found that the type of hydration products is not substantially changed by the simultaneous presence of the two admixtures.

It is logical to assume that the first dosage of the superplasticizer must be applied soon after the cement and water have come into contact with one another, otherwise, the initial reactions of hydration would make it impossible for the superplasticizer to effect adequate deflocculation of the cement particles. The supply of superplasticizer becomes entrapped in the inadequate water and the workability of the mix is rapidly lost [17].

Superplasticizers are exceptionally effective for dispersing cement particles in water in comparison with other existing surfactants (a surface – acting agent who reduces surface tension). This dispersing action takes place by decreasing the surface tension of water by equidirectional charging of cement particles and / or by producing a film at particle surface. The concrete produced with the use of superplasticizer has sufficient cohesiveness, and it dose not segregate [17].

Ramachandran et al., [17] mentioned that one of the possible causes for the slump decreases in superplasticized concrete may be the accelerated reaction of $C_7A + \text{gypsum} + H_2O$ to form ettringite, and they concluded that the addition of polymer to superplasticized concrete increases slump retention. The mechanism of slump retention with superplasticizer and polymer may involve retardation of ettringite formation by the reaction $C_7A + \text{Gypsum} + H_2O$.

Fujiu et al., [17, 18] have developed a polymer (with ester amides and acid anhydrides as functional groups), which by itself is not soluble in mixing water. But under the alkaline environment formed in the aqueous phase in contact with cement is slowly transformed into an aqueous soluble product that has a superplasticizing effect. The mechanism of this method is based

on the principle that the effectiveness of superplasticizers is significantly reduced by rapid adsorption in the early periods of cement hydration.

Mehat and Manmohan., believed that volume of the capillary pores in cement paste have significant role in definition the strength of concrete. They showed that the pores might be divided into harmful according to its influence on the strength (size is more than $1000A_0$) and non-harmful (size is less than $1000A_0$) [14].

2. 2. 2. **Effect of Superplasticizers on Fresh Concrete**

2. 2. 2. 1. **Workability**

Different definitions have been made for the term **(concrete workability)** such as: *workability is the property of concrete to determines the amount of the work that is needed to overcome the internal friction of the mixture “useful internal work” necessary to produce complete compaction* [15].

And workability is that property of fresh concrete or mortar that determines the ease with which it can be mixed, (transported, placed, compacted, and finished). Workability depends on [16]:

- a. Internal factors: *(mixture proportions, w/c, fines of cement, hydration rang)*
- b. External factors: *such as (type of construction, method of placing, compaction)*

Workability is a complex concept and it is difficult to evaluate on an objective basis because of the lack of a good test method. Workability problem can be apparent clearly in concrete placement [14].

Workability is improved when there is an excess of paste above that required to fill the space between sand particles and an excess of mortar above that required to fill the space between the coarse aggregate, so that the mixture will not be harsh [14].

The important factor of workability is the degree of wetness of concrete that called “consistency of concrete”. The test for measuring consistency is slump. Slump test used in practice and is highly sensitive to water content and this sensibility is more noticed for higher slump than for lower slump mixes [4].

A study indicated that high workability concrete containing superplasticizer can be made with a high freeze-thaw resistance, but air content must be increased relative to concrete without superplasticizer. This study also showed that the type of superplasticizer has nearly no influence on the air-void system [14].

The combination of high temperature and low relative humidity promotes rapid evaporation of the mix water, leading to rapid loss in workability and possibly insufficient water to hydrate the cement. The incorporation of superplasticizers or the application of auxiliaries to the concrete can help eradicate this problem. One of the main functions of superplasticizers in hot climatic conditions is to produce concrete of the desirable workability, at a specified water / cement ratio (water applicable),

and to retain that workability until the concrete can be transported from the place of manufacture to the location of placing [v1].

The adoption of superplasticizers to concrete mixes offers to the mix designer to obtain; higher workability while maintaining the same w/c ratio, or lower w/c ratio with the same workability, or concrete with a given properties with less cement content [v2].

2. 2. 2. 2 *Slump and slump-loss*

Prolonged mixing induces “thickening” of the mix, that is to say, consistency change or slump-loss, which constitutes of an early stage of stiffening of the mix, this should be clearly distinguished from the later stiffening and hardening, defined as initial and final set [v3].

As mentioned earlier, the stiffening of the fresh concrete, and the associated slump-loss are brought about mainly by the hydration of the cement. Some evaporation of the mixing water and, in some cases, also the absorption of water by dry aggregates may constitute additional causes. All these effects reduce the amount of free water in the fresh concrete mix. Consequently, the fluidity of the mix is decreased, i. e. stiffening takes place [v4].

The main problem associated with using a high range water reducer in concrete is slump-loss. In a study of the behavior of fresh concrete containing a high range water reducer found that slump-loss with time is very rapid in spite of the fact that high range water reducer is claimed not to

suffer as much from the slump-loss phenomenon as the conventional water reducers do [vs].

Use of superplasticizers slowing down the rate of hydration, would slow down the rate of slump-loss and thereby counteract the accelerating effect of temperature [v].

The ability of superplasticizers to increase the slump of concrete depends on such factors as the type, dose, and time of addition of superplasticizer; w/c; and the nature or amount of cement. It has been found that for most types of cement, superplasticizer improves the workability of concrete [v].

The slump-loss problem appears to be even more serious than that related to the different performances caused by superplasticizer addition. When concrete mix must be transported for a long period, practically in hot weather, it should be kept as moist as possible in the initial slump level to avoid reducing the concrete with water above and beyond that required in the mix design. Results of investigations of re-tempered concrete indicate that many of the properties of the hardened concrete (strength, durability, abrasion, resistance, etc.) are significantly affected, since re-tempered concrete does not perform as well as concrete that has not been re-tempered [v].

However, slump-loss is unavoidable because of the intrinsic requirement for cement mixed, which should set and harden in a relatively short time. Therefore, a right and proper compromise would be a zero slump-loss concrete mix for about (1 hour). By using traditional superplasticizer based on SNF or SMF polymers it is not easy to achieve this target, because in general, slump-loss is higher in superplasticized concrete

with respect to the corresponding plain mix at a given initial slump Figure (2-6). The lower the w/c, the higher the slump-loss for the same initial slump level. It seems that the lower w/c in superplasticized concrete and the consequent lower distance among cement particles causes a more significant slump-loss when the same amount of water is lost through evaporation or by reaction with cement during the transportation time Figure (2-7) [14].

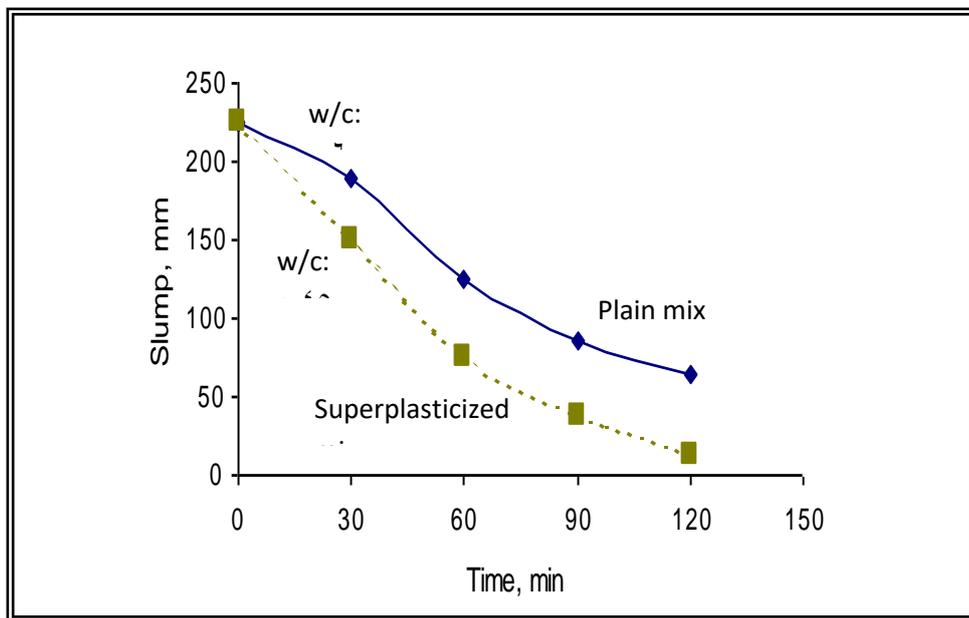


Figure (2-6). Slump-loss for plain and superplasticized mix at the same initial slump. [14]

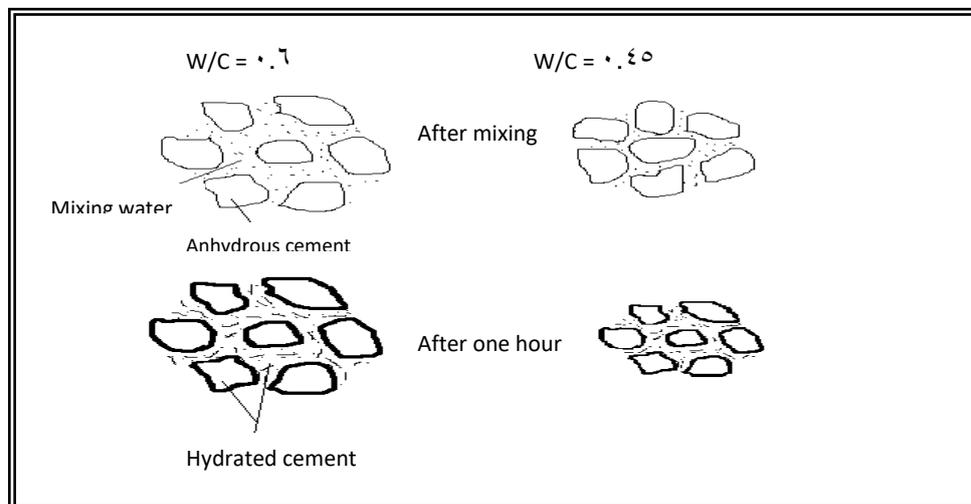


Figure (2-7). Schematic picture of cement paste in a plain and superplasticizer concrete. [14]

Several methods have been adopted to control the rate of slump-loss [1,2].

1. Adding superplasticizer at the point of discharge of mix.
2. Adding a higher than normal dosage of superplasticizer or using some type of retarding admixture in the formulation.

In the first method some practical problems may occur. For instance, the concrete in the truck- mixer before the superplasticizer addition would be too stiff at the placement when high – quality concrete (with low w/c) is produced.

In the second method there are some limitations, because sometimes the final effect produce concrete with an unacceptably low early strength or to aggravate slump-loss more seriously. For instance, slump-loss accompanied by a surprisingly quick set may be recorded by using retarders such as sugar, sucrose, corn syrup or calcium lignosulfonate.

Ramachandran et al., [1,2] concluded that the rate of slump-loss can be decreased by adding a higher than normal dosage of superplasticizer, by adding the superplasticizer at different times, or by including some type of retarder in the formulation. Inclusion of a retarder in a small amount seems to offer advantages such as economy and better control at the point of mixing.

In the hot climate it has a very high temperatures and very low humidity. For a long period in the year the variation in temperatures needs a necessary measure to avoid this problem by compensation for

slump–loss with time by using initial slump more than the required slump in cast place. This compensation can be applied by using additional water or using a superplasticizer. Using additional water executes reduction in compressive strength. But when using higher or normal doses of superplasticizers the water in mix can be reduced [17].

Ravina, has concluded a general conclusion that is related to the use of retarding water–reducing admixture to increase the initial workability. It was found that the initial rate of slump–loss could be compensated for, and would prolong the time available for the transporting, placing of concrete [17].

It is well known that slump–loss takes place, in the absence of any superplasticizer, during the first twenty minutes. Such a situation may encourage the addition of water, accompanied by a loss of control of the water / cement ratio of the mix and its strength. To overcome this, a suitable superplasticizer for 2 min. after starting mixing may solve the problem in the field. The mentioned conclusion and recommendation were given by, hersy [17].

A study made by Malivagan has dealt with the effect of various temperatures on the rate of slump–loss of concrete with sulphonated melamine formaldehyde superplasticizer. This is shown in Figure (7-8) [18].

Sukhvaish and Lindsay, [19] studied the slump–loss of superplasticized concrete. The slump readings were taken at 10-min intervals for a total period of 90 min after mixing. He concluded that the greatest loss of slump

occurs in the first 30 min after mixing, and the superplasticized concrete retains its workability for longer period than the control mix.

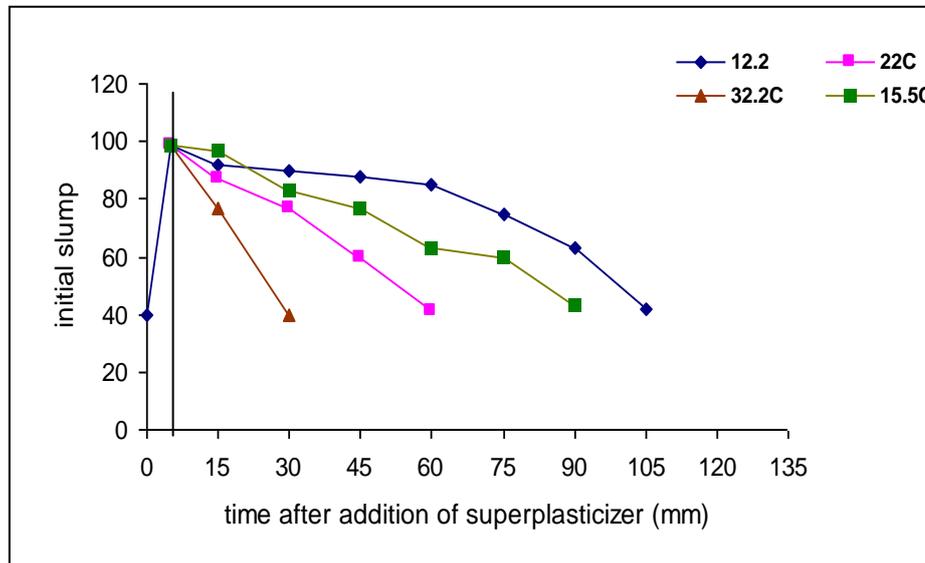


Fig (2-8): Effect of various temperatures on rate of slump – loss of concrete with sulphonated melamine formaldehyde superplasticizer. [14]

2.2.3. Effect of Superplasticizers on hardened Concrete

2.2.3.1. Compressive strength

The concrete is a composite material and can be described as a very complex material with complex multiphase materials composed of seven components, (i. e. coarse and fine aggregate, cement gel and unhydrated

particles of cement, capillary and gel pores, pore water and accidentally entrapped air voids) [10].

The compressive strength test is one of the most important properties of concrete and most other properties are related to it [11].

Influences of superplasticizer are directly affected on compressive strength. Where, it is generally increased when a superplasticizer is used to reduce water content, and this increase depends on dose and type of admixture. Figure (2-9) shows that compressive strength increase depends on dosage of superplasticizer [12].

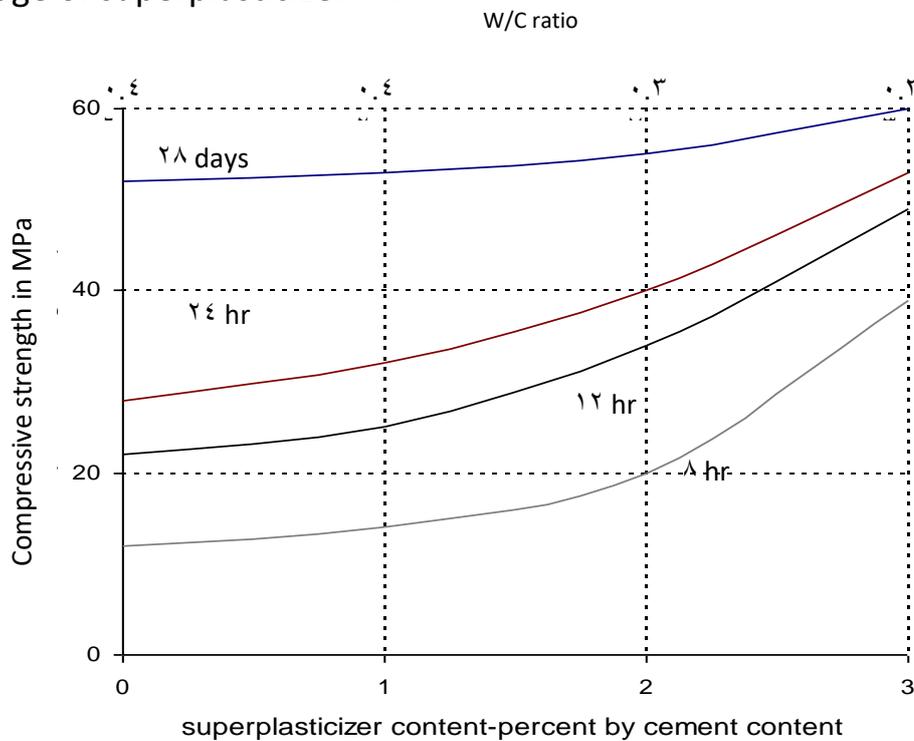


Figure (2-9). The influence of the added of superplasticizer on the early strength of concrete. [12]

Ispas and Ionescu [133] stated that compressive strength when using superplasticizer with a proportion of between (1.0-3)% by the weight of cement was increased by proportions of between (30-80)% at age of (24)hr, between (20-40)% at age of (28)days and between (14-32)% at age of (360)days. Also they added that this increase in strength is accompanied by increases in modulus of elasticity, tensile strength and bond resistance between concrete with reinforcing steel.

Aignesberger et al., [134] concluded that the compressive strength increases with increase in proportion of superplasticizer (type SMF sulphonated melamine formaldehyde) up to (1)%, after that the increase is little.

On other hand, the apparent increase in compressive and flexural strength and modulus of elasticity of concrete in which admixture was employed, it may be due to reducing the water content and a high hydration that resulted from a good distribution of cement particles with superplasticizer that leads to complete hydration [135].

2. 2. Retempering Concrete Mix:

2. 2. 1. Retempering Concrete Mix without Superplasticizer

There are two reasons for the loss of slump with time. First from the instant that cement powder and water come into contact with one another, chemical reaction of hydration of cement takes place. As these reactions

involve fixing of water, less water is left to lubricate the movement of individual particles in the mix. Second in ambient conditions, some of the mix water evaporates into the atmosphere and dose so the more rapidly the higher the temperature and the lower the ambient relative humidity ^[44].

if a specified workability is required at the point of delivery of the concrete after a certain passage of time, this has to be ensured by the use of appropriate mix proportions and transport arrangements. Occasionally, however, delays occur in transport or other accidents prevent a timely discharge of the concrete. If, in the meantime, a loss of slump occurs, the question arises as to whether the slump can be restored by means of addition of water coupled with re-mixing. Such an operation is referred to as re-tempering ^[44].

As re-tempering increase, the original water / cement ratio of the mix, it is arguable that it should not be permitted where the original water / cement ratio was directly or indirectly specified. This is an appropriate stance under some circumstances but, at other times, a more flexible and sensible solution may be appropriate as long as the consequences of re-tempering are understood and appreciated.

The starting point to be considered is the overall water / cement ratio on the basis both of the original mix water and the re-tempering water. There is a considerable evidence, that not all the re-tempering water should be counted as a part of the free water for the purpose of calculating the water / cement ratio. The reason for this behavior probably lies in the fact that water replacing that lost by evaporation should not be included in the

effective water / cement ratio, only the water replacing that used in early hydration constitutes part of the effective mix water ^[33].

It follows from the above that the relation between strength and overall free water / cement ratio for re-tempered concrete is slightly more advantageous than the usual ratio between strength and the free water / cement ratio ^[34].

Nevertheless, re-tempering inevitably results in some loss of strength compared with the original concrete. A loss of 5 to 10 percent was reported, but it can mix. Some empirical relationships have been suggested but in practice the precise amount of re-tempering water may not be known, if only because partial discharge from the mixer and occurred prior to the realization of the slump loss ^[35].

The amount of water needed to raise the slump depends on the original slump level, being higher at low slump ^[36]. Another way of viewing the preceding data is to say that the lower the water / cement ratio the more re-tempering water is needed. The amount of water also rises steeply with an increase in temperature ^[37].

2. 2. 2. Retempering Concrete Mix with Suprplasticizer

Because the effectiveness of superplasticizers is limited in duration, it may be advantageous to add the superplasticizer to the mix in two, or even three, operations. Such repeated addition, or re-dosage, is possible if an agitator truck is used to deliver the concrete to site. If the workability is to be restored by the re-dosage some time after the original mixing, the

amount of superplasticizer has to be adequate to act both on the cement particles and on the products of hydration. Therefore, a high re-dosage of superplasticizer is necessary, a small re-dosage is ineffective [44].

Whereas repeated addition of the superplasticizer to the mix is beneficial from the standpoint of the workability, it may increase bleeding and segregation. Other possible side effects are set retardation and a change (up or down) in the amount of entrained air. Also the workability restored by the second dosage may decrease at a fast rate so that the re-dosage should preferably be applied immediately prior to placing and compaction of the concrete [44].

The quantity of superplasticizer which needs to be added to restore the workability increase with temperature, and is much higher at a water /cement ratio of about 0.4 than at higher water/cement ratios. Even through the original workability is restored by the second or even the third dosage of a superplasticizer, the subsequent loss of workability becomes more rapid. However, the rate of the loss is not increased at higher temperature [44].

Nowadays, there exist superplasticizers with a long period of effectiveness so that re-dosage immediately prior to placing of concrete can be avoided. The use of such superplasticizers offers a better control of the mix proportions and is, therefore, preferable [44].

2. 3. 3. Retempering Concrete Mix with Mixing

It is essential that the mix ingredients, properly so as to product fresh concrete in which the surface of all aggregate particles is coated with

cement paste and which is homogeneous on the macro-scale and therefore possessing uniform properties.

On site, there is often a tendency to mix concrete as rapidly as possible, and, therefore, it is important to know what is the minimum mixing time necessary to produce a uniform concrete in composition as a result of satisfactory strength. There may be rare occasions when small quantities of concrete have to be mixed by hand and, particular care and effort are necessary. In order to make sure that the relevant art be not forgotten.

Intermittent re-mixing up to about three hours, and in some cases up to six hours, is harmless as far as strength and durability are concerned, but the workability falls off with time unless loss of moisture from the mixer is prevented [3,4].

Chapter Three

Experimental work

3. 1. General:

This chapter describes the experimental work, which was performed during the summer season. The investigation includes measuring of the initial slump and slump loss of various concrete mixes. These mixes differ from each other in w/c ratio, percentage of superplasticizer and the type of superplasticizer used. The also investigation includes the measuring of the compressive strength, for hardened concrete. All specimens were cured in water. The aim of this experimental work is to study the properties of plasticized concrete that is produced at different mix proportions from the available and commercial superplasticizers. At the same time investigating

the effect of adding different types of superplasticizers on the properties of fresh and hardened concrete.

۳. ۲. *Materials:*

۳. ۲. ۱. *Cement*

Ordinary Portland cement manufactured by Kufa cement factory was used throughout this study which is conforming to Iraqi specification (IQS No. ۵ : ۱۹۸۴)^[۱,۲]. The chemical and physical analyses are shown in table (۳-۱) and table (۳-۲) respectively. These analysis were accomplished in “New Kufa Cement Factory Laboratories”. To avoid any differences between different batches, the needed quantity of cement was delivered at one time and stored in a dry place.

Table (۳-۱A). Chemical composition of the cement

| Oxide composition | Oxide content % by weight | Limit of Iraqi specification No. ۵ / ۱۹۸۴ |
|--------------------------------|------------------------------|--|
| CaO | ۶۱.۷۴ | - |
| SiO _۲ | ۲۰.۶۰ | - |
| Al _۲ O _۳ | ۶.۲۰ | - |
| Fe _۲ O _۳ | ۳.۲۴ | - |
| MgO | ۴.۴۰ | ≤ ۵ |
| SO _۳ | ۲.۵۱ | ≤ ۲.۸ |
| Na _۲ O | - | - |
| K _۲ O | - | - |
| Loss on ignition | ۱.۴۰ | ≤ ۴ |
| Insoluble residue | ۰.۹۰-۱ | ≤ ۱.۵ |

Table (r-B). Main compounds of the cement

| Oxide composition | Oxide content % by weight | Limit of Iraqi specification No. ٥ / ١٩٨٤ |
|-----------------------|------------------------------|--|
| Main compounds | | |
| C ₃ S | ٣٨.٥٣ | - |
| C ₂ S | ٣٠.٠٠ | - |
| C ₄ A | ١٠.٩٥ | - |
| C ₃ AF | ٩.٣٤ | - |

Table (r-r). Physical properties of cement

| Physical properties | Test result | Limit of Iraqi specification No. ٥ / ١٩٨٤ |
|---|----------------|--|
| Specific surface area, Blaine method, m ² /kg | ٣١٠ | ≥ ٢٣٠ |
| Setting time, Vicat's method | | |
| Initial setting time, hrs.:min. | ٢ : ٠ | ≥ ٠ : ٤٥ |
| Final setting time, hrs.:min. | ٣ : ٢٠ | ≤ ١٠ : ٠٠ |
| Compressive strength: | | |
| ٣-days, MPa | ٢٢ MPa | ≥ ١٥ |
| ٧-days, MPa | ٣٠ MPa | ≥ ٢٣ |
| Soundness autoclave method, % | ٠.٥٠ | ≤ ٠.٨ |

2.2.2. Water

Ordinary drinking water was used throughout this work for both mixing and curing.

2.2.3. Fine aggregate

Sand brought from Al – Tahreer Company site plant was used as fine aggregate in this research. Its grading and other characteristics are conformed to (ISO 450-1988) [1]. Its grading is shown in table (2-2) and other characteristics are shown in Table (2-0).

2.2.4. Coarse aggregate

River gravel with (19mm) maximum size obtained from Al-Nibae area was used as coarse aggregate in this research. Its grading is shown in Table (2-3), that grading and other characteristics are conformed to (IOS 450-1988) and (ASTM C33-1986) [1], shown in Table (2-1). The gravel was washed from dust and fine particles, then left in air to dry.

Table (2-2). Grading of the fine aggregate.

| Sieve size (mm) | Percentage passing for fine aggregate % | Limit of Iraqi specification No. 450/1988 Zone 1 | ASTM limits C33-1986 |
|-----------------|---|--|----------------------|
| 4.75 | 100 | 100 | 100 |
| 7.5 | 100 | 100 | 100 |
| 15 | 100 | 100 | 100 |
| 30 | 100 | 100 | 100 |
| 60 | 100 | 100 | 100 |
| 125 | 100 | 100 | 100 |
| 250 | 100 | 100 | 100 |
| 500 | 100 | 100 | 100 |

Table (2-3). Grading of the coarse aggregate.

| Sieve size, mm | % passing | The grading according to ASTM limits C33-1986 % | Limit of Iraqi specification No. 450-1988 zone 1 |
|----------------|-----------|---|--|
| 75 | 100 | 100 | 100 |
| 150 | 100 | 100 | 100 |
| 300 | 100 | 100 | 100 |
| 600 | 100 | 100 | 100 |
| 125 | 100 | 100 | 100 |
| 30 | 100 | 100 | 100 |
| 15 | 100 | 100 | 100 |
| 7.5 | 100 | 100 | 100 |
| 4.75 | 100 | 100 | 100 |

| | | | |
|------|-----|---------|---------|
| 37.0 | 1.0 | 1.0 | 1.0 |
| 19 | 97 | 90-100 | 90-100 |
| 1.0 | 0.4 | 2.0-0.0 | 3.0-7.0 |
| 0 | 2 | 0-1.0 | 0-1.0 |

Table (r-0). Characteristics of Fine aggregate.

| Properties | Value | Limit of Iraqi specification No. 40 - 1984 zone 1 |
|-------------------|-------|---|
| Specific gravity | 1.83 | - |
| Absorption % | 1 | - |
| SO _r % | 0.1 | ≤ 0.5 |
| Cl% | 0.20 | - |

Table (r-1). Characteristics of Coarse aggregate.

| Properties | Value | Limit of Iraqi specification No. 40 - 1984 zone 1 |
|------------------------------|-------|---|
| Specific gravity | 2.7 | - |
| Absorption % | 1.0 | - |
| Sulfate content, % | 0.9 | ≤ 1.1 |
| Cl % | 0.18 | - |
| Materials finer than 75μm, % | 1.0 | ≤ 3 |

r. 2. 0. Superplasticizers

Three types of superplasticizers were used. The first one is Glenium-01 (G-01) chemically naming is (Sulfonated melamine-formaldehyde condensates) SMF, the second type is Conplast SP-122 chemically naming is (Sulfonated naphthalene-formaldehyde condensates) SNF, and the third type is modified lignosulfonates MLS with commercial name Daracem SP-1. Their commercial description is shown in table (r-5), all types conformed to ASTM C-494, F&G. The materials were prepared as a solution according to the technical description shown in table (r-6). Figure (r-1) presented a chemical structure for these groups of superplasticizers. All superplasticizers were

added as a liquid material as a percent from weight of cement to the concrete at different dosages.

Table (r-v). The Commercial description of superplasticizers used

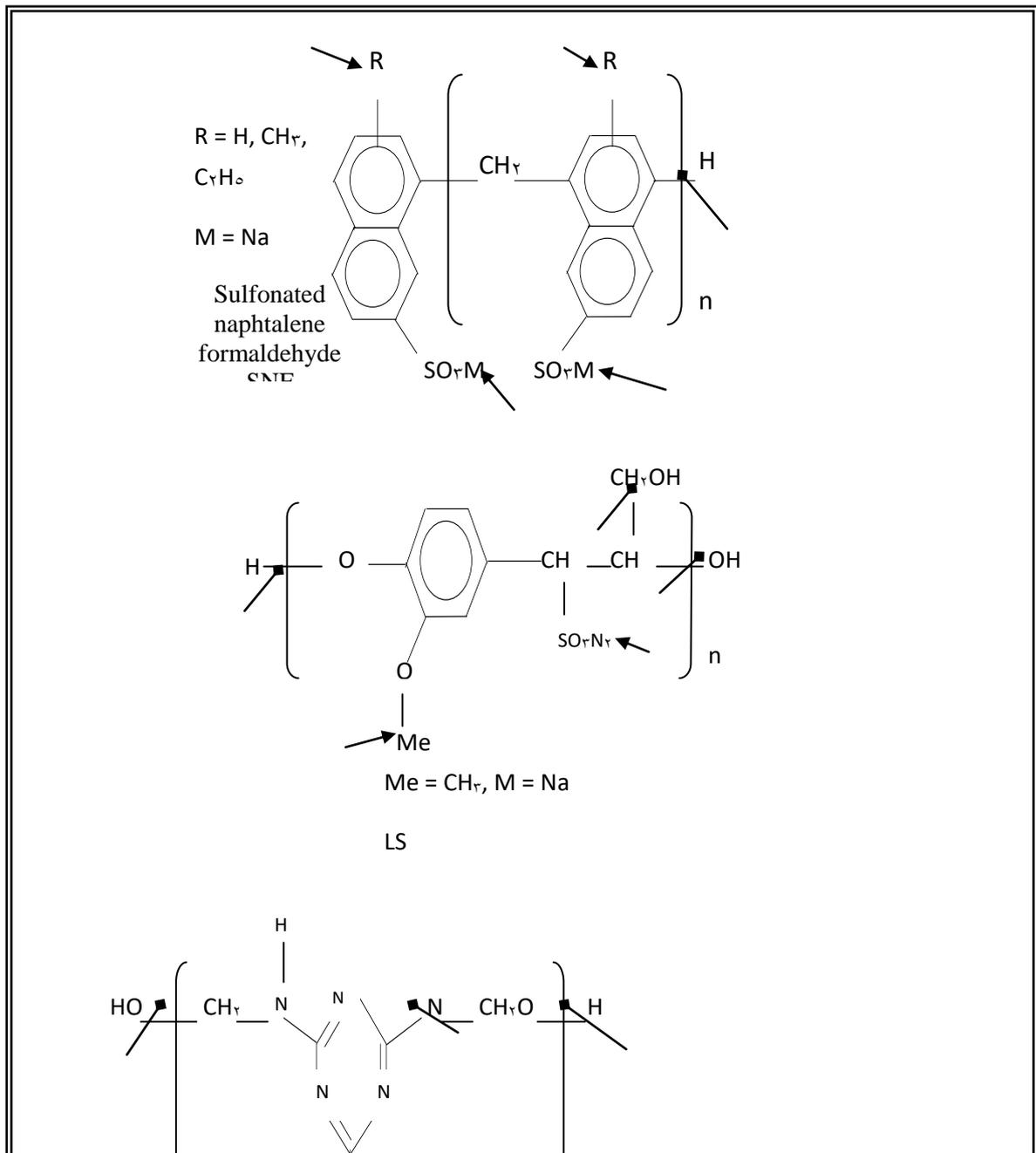
| Superplasticizer designation | Commercial name | Chemical group |
|------------------------------|------------------------------|-------------------------------------|
| SMF | Glenium 01 (G01) | Sulfonated Melamine formaldehyde |
| SNF | Conplast SP02 | Sulfonated Naphthalene formaldehyde |
| MLS | Daracem SP0 (Batch No. 1010) | Modify Lignosulfonates |

* The chemical analysis executes in collage of science / chemical department laboratory and their commercial name takes from data sheet of buying.

Table (r-λ). The technical description of superplasticizers used^[1,2]

| NO | Property | Type of Superplasticizer | | |
|----|------------------------------|--------------------------|----------------|-------------|
| | | Glenium 01 (G01) | Conplast SP 02 | Daracem SP0 |
| 1. | Form | Viscous liquid | Viscous liquid | Liquid |
| 2. | Color | Light brown | Dark brown | Brown |
| 3. | pH | 6.6 | 7.6 | 4.0 |
| 4. | Soluble powder concentration | 20% | 22% | 33% |
| 5. | Specific gravity | 1.18 (+/- 0.1) at 20°C | Same | Same |
| 6. | Viscosity | 128+ / -30 cps @ 20°C | Same | Same |
| 7. | Chloride content | <0.005% | Nil to BS 0.70 | Traces |

| | | | | |
|----|------------------|--|---------------|---------------|
| λ. | Alkali content | Typically less than 12.0g. Na ₂ O equivalent/liter of admixture | Same | Same |
| ρ. | Transport | Not classified as dangerous | Not dangerous | Not dangerous |
| γ. | Relative density | 1.1 @ 20°C | 1.19 @ 20°C | 1.7 @ 20°C |



3.3. Details of mixes

3.3.1. Normal concrete mixes:

Five types of normal mixes are used, which have five different w/c ratios and same cement content. The w/c ratios used were (0.3, 0.4, 0.5, 0.6 and 0.7). The variation in w/c ratios was made as an effective factor in the concrete mixes. Figure (3-1) shows the Factors affecting properties of concrete

3.3.2. Plasticized concrete mixes:

Superplasticizers were used as admixtures to ordinary Portland cement concrete mixes. Three types of superplasticizers were used (Glenium-31/SMF, Daracem/MLS, Conplast SP-17/SNF). Five percentages of superplasticizer were used (1, 1.5, 2, 3 and 3.5 %) by weight of cement, these percentages were used with each types of superplasticizers. The addition time of superplasticizers was (3-5) minutes after the completion of mixing constituents.

3.3.3. Moulds

- For compressive strength test the moulds used are:

(100 × 100 × 100) mm cubes

- For initial slump and slump loss test the mould used is:

Steel frustum cone (300) mm high placed on smooth surface w

ith the smaller opening at the top, according to ASTM C 143 - 1987 [1,4].

These moulds were cleaned and tightened strongly, to avoid flow of mix through the joints during compaction.

3.4. Mixing. Casting. Curing.

All the materials were weighted separately. The American Concrete Institute method for mix design (ACI 211.1-91)^[1,5] was followed, the mixes proportion was (1: 1.5: 2). The concrete constituents were mixed by hand. The dry constituents were initially mixed for (2-3) minutes, then the required amount of water was added, and the whole mix constituents were mixed for another (2-3) minutes. To avoid adhesion between moulds and concrete, all the moulds were lightly coated with engine oil before casting.

- *Mixing:*

Half weight of the coarse aggregate was put in the container then the fine aggregate, cement and the remaining half weight of the coarse aggregate were added subsequently to the mixture. The dry materials were mixed until the mix appears uniform, then the water was added and mixing continued for a period of (2-3 minutes). The addition of the superplasticizer was accomplished by stirring it thorough (2-3) minutes after mixing. The superplasticizer was added to the concrete mixture in different proportions (liquid material by weight of cement). After that, the concrete was cast in the moulds in three equal layers. Finally compaction was done using compaction rod, the excess concrete was cut and removed with a trowel from the top of the specimens, then the surface of concrete was leveled and attempting to have a good smooth finished surface.

- *Casting:*

For the compressive strength specimens, the concrete mixture was put in cube moulds with three equal layers and each layer is compacted by using rod compaction. The surface of cubes was leveled and trowled to obtain a good smooth finished surface.

- Curing:

The time that concrete remains in cubes was (24 ± 2 hours) for unsuperplasticized concrete and (28 - 32 hours) for superplasticized concrete.

The moulds of all specimens were covered with nylon bags to prevent water evaporation. The specimens were taken out from moulds (demoulded) carefully and stored in water tanks until testing; the range of the water temperature was normal laboratory temperature.

r. r. 2. Testing:

For fresh concrete (slump and slump-loss) was determined. Slump test was conducted according to ASTM C 137 - 1987 Procedure.

Slump loss is a measure of loss of consistency over time, which simply means that the slump measured after a period of time is less than the slump initially measured. Slump loss is measured by repeated slump test with intervals of (10, 30, 60, and 90) minutes.

A slump test was conducted by using frustum of a cone, filled with concrete in four layers. Each layer is tamped (20) times with a standard (10mm) diameter steel rod, and the top surface is struck off by mean of a sawing and rolling motion of the tamping rod. The mould must be firmly held against its base during the entire operation, therefore, the handles facilitate this.

For hardened concrete the compressive strength was determined. This test was done according to (B. S. 1881: part 10.8: 1983)^[1]. The cube mould is filled with three layers. Each layer of concrete compacted with vibrating by using steel rod (20mm diameter) of. The investigation achieve for specimens with ages (7, 28 and 90 days). The load was applied until failure and the failure load

was recorded for each specimen. Before the cube specimens were tested, they were taken out from the water tank. Their surface was dried from excess water and kept in the laboratory for few minutes to obtain saturated dry surface specimens. The weight of concrete cubes was taken after drying to determine the density of specimen. For each test age, three cubes of concrete were tested.

2.4. Evaluation procedure for superplasticized concrete performance:

Number of investigations applied for concrete with superplasticizers to evaluate their performance and their effect on properties of fresh and hardened concrete.

Three suitable mixes were chosen, which have suitable workability (high initial slump, low slump loss) and acceptable compressive strengths, (0.4, 0.45 and 0.5) w/c ratios were selected. The superplasticizer was added to the concrete mixture as a liquid material by weight of cement, to to continuity slump with medium range (80-100) mm. These applications summarized in case one through case four, (making & trials) procedure was using in these applications.

2.4.1. Case one:

Using superplasticizers in concrete mixes with (0.2, 0.4, 0.45, 0.5, 0.6) w/c ratio.

2.4.2. Case one:

Using superplasticizers with the concrete mix lowering w/c ratio by decreasing water content and keeping cement content constant to obtain similar workability (slump).

r. 4. r. Case two:

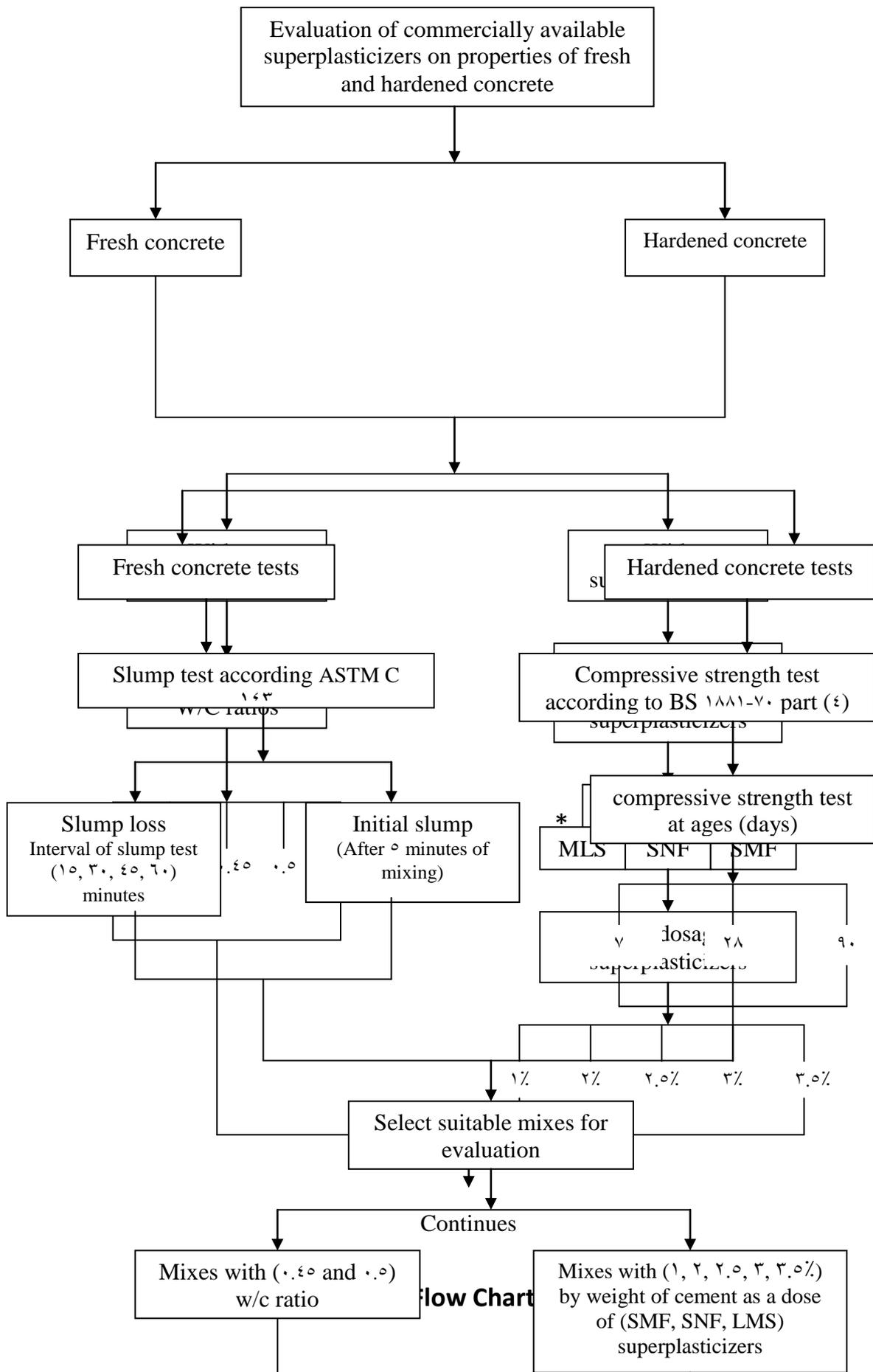
Using superplasticizers with the concrete mix keeping w/c ratio constant by decreasing both cement and water contents to obtain similar workability (slump).

r. 4. 4. Case three:

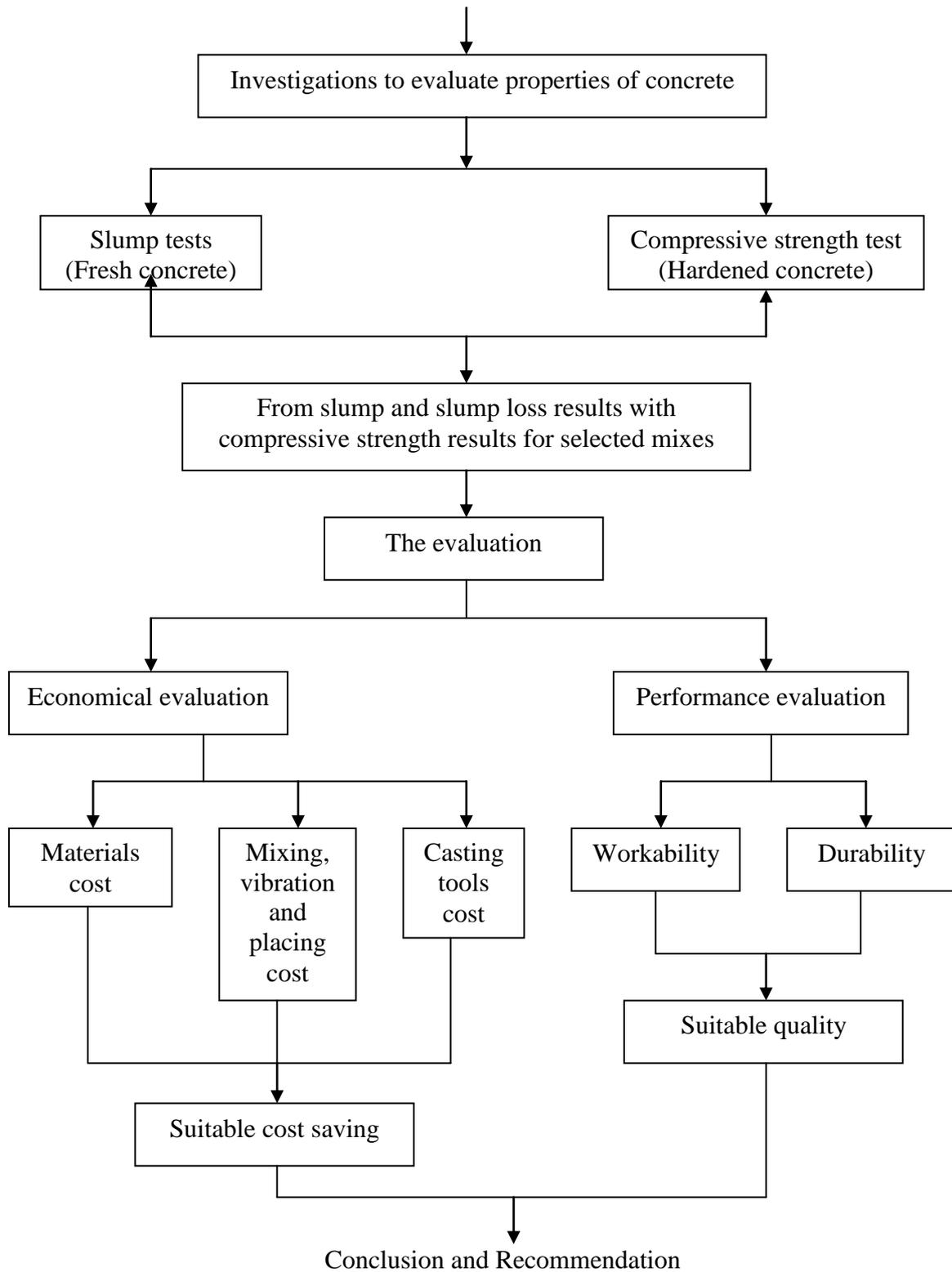
Re-tempering concrete mixes by adding water to regain slump. The original additional water was added after 7-10 minutes from mixing, when the slump reaches approximately (50mm).

r. 4. 4. Case Four:

Using re- dosing superplasticizers to the concrete mix for regaining slump. Re-dosing practice should be explored with trial mix with close similarity of field condition as rapid slump loss occurrence is detected.



Flow Chart



*: MLS = Modify Lignosulfonate.

SMF = Sulfonated melamine formaldehyde.

SNF = Sulfonated Naphtalene formaldehyde.

Chapter Four

Experimental Results and discussion

4. 1. General:

The results of slump and slump loss were obtained according to ASTM. C143^[1,2]. The results of compressive strength were obtained from specimens according to B.S. 1881: part 108: 1983^[3,4]. Each result represents the average of three test specimens. In this chapter, the results of tests described in chapter three are presented and discussed.

Fresh concrete

4. 2. Workability test results:

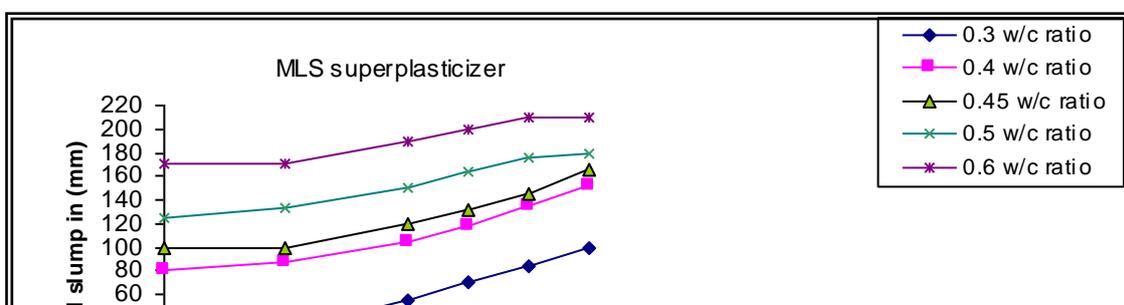
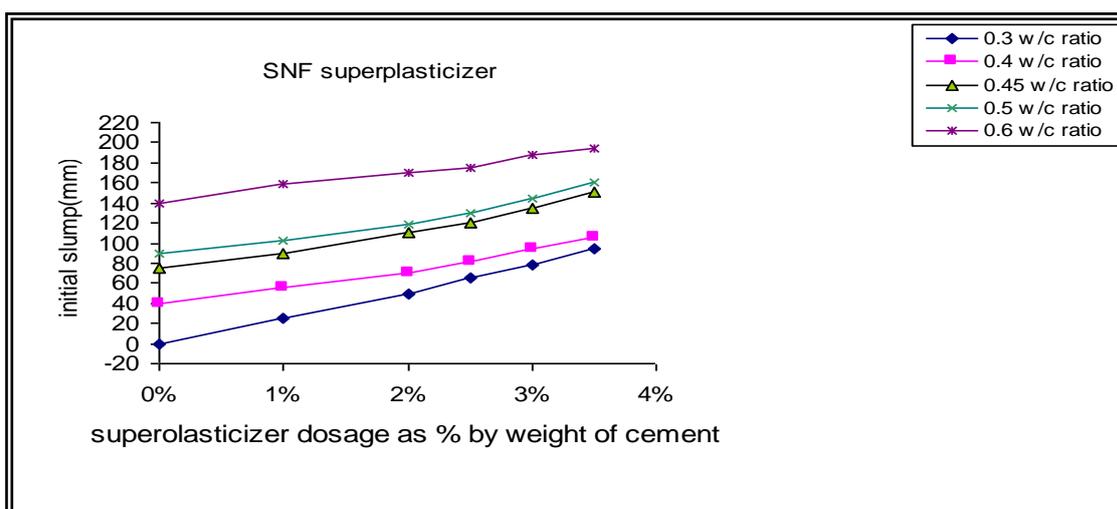
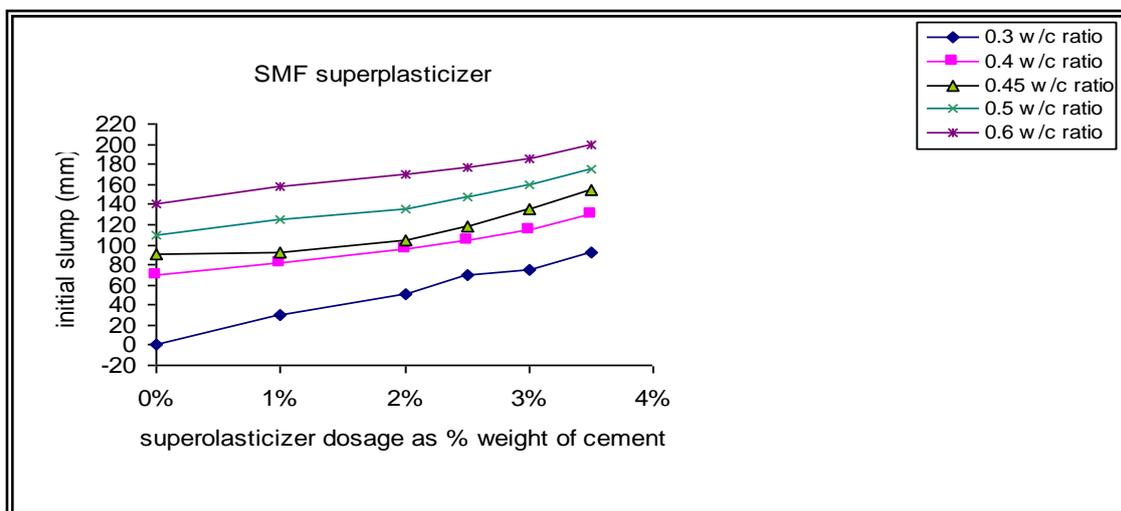
Unfortunately, there is no accurate test, which measures directly the workability. Numerous attempts have been made, however, to correlate workability with some easily determinable physical measurement, but none of these is fully satisfactory although they may provide useful information within a range of variation in workability^[5,6].

4. 2. 1. Slump test:

This test is used extensively in field all over the world. The test is very useful in detecting variations in the uniformity of concrete mixes.

4. 2. 1. 1. **Initial slump with various w/c ratios:**

In general a high amount of initial slump was evident with high w/c ratio. Effect of w/c ratio on initial slump for normal and superplasticized concrete is shown in figure (4-1).



Large amount of water present in case of high w/c ratio makes cement particles move freely and disperse quickly, which leads the mixture to be more workable and increases initial slump. For ordinary concrete mix with w/c ratio (0.4, 0.45, 0.5, 0.6) the increase in initial slump approach to (0, 20, 30, 36)% compared with 0.3 w/c ratio, which has no slump (0 mm).

When mixing water be more than demand the bleeding and segregation appear in mixture^[11].

4. 2. 1. 2. **Initial slump with plasticized concrete:**

In General the average values of initial slump increase when using various types and dosages of superplasticizers with different w/c ratios. From figure (4-1), it can be seen that the initial slump of concrete mixes containing (SMF, SNF, MLS) superplasticizers is strongly affected. Results indicate also that the increase in average percentage of initial slump compared with reference mix for (0.3, 0.4, 0.45, 0.5, 0.6) w/c ratio approach (118, 50.5, 49, 30.23, 27)% for SMF, (100, 103.5, 71, 40.56, 26.4)% for SNF and (131, 70.7, 55, 54, 40)% for MLS respectively. The details of slump results are shown in table (4-1). The increase in initial slump could be due to dispersion theory of superplasticizers. In this theory superplasticizers cause dispersion into smaller agglomerates of cement particles and this dispersion related to the electrical repulsion produced by the adsorption of negative charged groups. Dispersion effect is ascribed to the adsorption of (SMF, SNF, and MLS) by the presence of SO_4^- groups on the surface of cement particle^[12]. Because of this dispersion effect, there is a fluidity increase in cement paste.

Higher dosage of superplasticizers causes high retarding in setting time that lead to stop and deform the cement component interaction, which give side effect for final form of mixture. The results of these trials are represented in table (ε-۲): Similar behavior was obtained by (Ahmed. K & Wassem. A)^[۱۳, ۱۳]

With all types of superplasticizers, low and medium dosages of superplasticizer have high effect on initial slump especially with low and medium w/c ratio mixes, while the effect of high superplasticizer dosage is lower. Table (ε-۱) shows these results previously with all details were the average increase in initial slump for mixes (۰.۳, ۰.۴, ۰.۴۵, ۰.۵, ۰.۶) w/c ratio approach to (۱۸.۶, ۱۲, ۱۴, ۱۳, ۱۲) mm, (۲۰, ۱۳, ۱۳, ۱۴, ۱۱) mm and (۲۰, ۱۵.۴, ۱۵, ۱۶, ۱۴)mm with (SMF, SNF, and MLS) respectively.

Table (ε-۱): Variations in initial slump for superplasticized concrete mixes.

| Sup. Type | W/C | Initial slump (mm) | | | | | | % Increase in Initial slump | | | | | Increase in Initial slump (mm) | | | | |
|-----------|------|--------------------|-----|-----|------|-----|------|-----------------------------|----|------|------|------|--------------------------------|----|------|----|------|
| | | ۰% | ۱% | ۲% | ۲.۵% | ۳% | ۳.۵% | ۱% | ۲% | ۲.۵% | ۳% | ۳.۵% | ۱% | ۲% | ۲.۵% | ۳% | ۳.۵% |
| SMF | ۰.۳ | ۰ | ۳۰ | ۵۰ | ۷۰ | ۸۳ | ۹ | ۳۰ | ۶۶ | ۱۳۳ | ۱۶۷ | ۲۱۰ | ۳۰ | ۲۰ | ۲۰ | ۱۳ | ۱۰ |
| | ۰.۴ | ۷۰ | ۸۲ | ۹۵ | ۱۰۵ | ۱۱۵ | ۱ | ۱۷ | ۳۵ | ۵۰ | ۶۴ | ۸۵.۷ | ۱۲ | ۱۳ | ۱۰ | ۱۰ | ۱۵ |
| | ۰.۴۵ | ۸۵ | ۱۰۰ | ۱۱۵ | ۱۲۵ | ۱۴۰ | ۱ | ۱۷ | ۳۵ | ۴۷ | ۶۴ | ۸۲ | ۱۵ | ۱۵ | ۱۰ | ۱۵ | ۱۵ |
| | ۰.۵ | ۱۱۰ | ۱۲۵ | ۱۳۶ | ۱۴۸ | ۱۶۰ | ۱ | ۱۳ | ۲۳ | ۳۴ | ۴۵.۴ | ۵۰ | ۱۵ | ۱۱ | ۱۲ | ۱۲ | ۱۵ |
| | ۰.۶ | ۱۴۰ | ۱۵۸ | ۱۷۰ | ۱۸۰ | ۱۹۰ | ۲ | ۱۲.۸ | ۲۱ | ۲۵ | ۳۲ | ۴۲.۸ | ۱۸ | ۱۲ | ۱۰ | ۱۰ | ۱۰ |
| SNF | ۰.۳ | ۰ | ۲۵ | ۵۰ | ۶۵ | ۷۸ | ۹ | ۲۵ | ۱۰ | ۱۶ | ۲۱۲ | ۲۸۰ | ۲۵ | ۲۵ | ۱۵ | ۱۷ | ۱۷ |
| | ۰.۴ | ۴۰ | ۵۵ | ۷۰ | ۸۲ | ۹۵ | ۱ | ۳۷ | ۷۵ | ۱۰۵ | ۱۳۷ | ۱۶۲ | ۱۵ | ۱۵ | ۱۲ | ۱۳ | ۱۰ |
| | ۰.۴۵ | ۷۵ | ۹۰ | ۱۱۰ | ۱۲۰ | ۱۳۵ | ۱ | ۲۰ | ۴۶ | ۶۰ | ۸۰ | ۱۰۰ | ۱۵ | ۲۰ | ۱۰ | ۱۵ | ۱۵ |
| | ۰.۵ | ۹۰ | ۱۰۳ | ۱۱۸ | ۱۳۰ | ۱۴۵ | ۱ | ۱۴ | ۳۱ | ۴۴ | ۶۱ | ۷۷.۸ | ۱۳ | ۱۵ | ۱۲ | ۱۵ | ۱۵ |
| | ۰.۶ | ۱۴۰ | ۱۵۸ | ۱۷۰ | ۱۸۰ | ۱۸۸ | ۱ | ۱۲ | ۲۱ | ۲۵ | ۳۴ | ۳۹ | ۱۸ | ۱۲ | ۱۰ | ۸ | ۷ |
| MLS | ۰.۳ | ۰ | ۳۰ | ۵۵ | ۷۰ | ۸۳ | ۱ | ۳۰ | ۸۳ | ۱۳۳ | ۱۷۶ | ۲۳۳ | ۳۰ | ۲۵ | ۱۵ | ۱۳ | ۱۷ |

| | | | | | | | | | | | | | | | | | |
|--|------|-----|-----|-----|-----|-----|---|----|----|----|----|------|----|----|----|----|----|
| | ٠.٤ | ٧٥ | ٩٣ | ١٠٥ | ١١٨ | ١٣٥ | ١ | ٢٤ | ٤٠ | ٥٧ | ٨٠ | ١٠٢ | ١٨ | ١٢ | ١٣ | ١٧ | ١٧ |
| | ٠.٤٥ | ٩٠ | ١١٠ | ١٣٠ | ١٣٨ | ١٥٣ | ١ | ٢٢ | ٤٤ | ٥٣ | ٧٠ | ٨٦.٦ | ٢٠ | ١٥ | ١٣ | ١٥ | ١٢ |
| | ٠.٥ | ١٠٠ | ١٢٣ | ١٤٠ | ١٥٨ | ١٧٠ | ١ | ٢٣ | ٤٠ | ٥٨ | ٧٠ | ٨٠ | ٣٣ | ١٥ | ١٢ | ١٠ | ١٠ |
| | ٠.٦ | ١٤٠ | ١٧٠ | ١٩٠ | ٢٠٠ | ٢١٠ | ٢ | ٢١ | ٣٥ | ٤٢ | ٥٠ | ٥٠ | ٣٠ | ٢٠ | ١٠ | ٠ | ١٠ |

Table (٤-٢): Effect of excessive superplasticizer dosage on concrete mixes.

| Sup. Type | W/C | Sup. Dosage (% by weight of cement) | Initial Setting time | Final forms of mix |
|-----------|-----|-------------------------------------|----------------------|---------------------------|
| SNF | ٠.٦ | ٣.٥ | ٦٠ minutes | Normal |
| | | ٣.٧٥ | ٧٢ hours | Normal with little deform |
| | | ٤ | No setting | Deform |
| SMF | | ٣.٥ | ٥٠ minutes | Normal |
| | | ٣.٧٥ | No setting | Deform |
| MLS | | ٣.٥ | No setting | Deform |

٤. ٢. ٢. Slump loss:

Loss of water by hydration, absorption (by the aggregate or by the forms), or evaporation leads to slump loss. Slump loss is a measure of loss of consistency over time. Simply means that the slump loss measured after a period of time is less than the slump initially measured.

٤. ٢. ٢. ١. Slump loss with various w/c ratios:

Slump loss in normal concrete mixes is evident with high initial slump range, during the forty-five minutes from mixing time. Because large amount of water present in case of high w/c ratio rapidly allows more cement particles to hydrate rapidly. And this rapid hydration process leads to rapid slump loss. Concrete mixes were used with (0.3, 0.4, 0.45, 0.5, 0.6) w/c ratios to get low/ medium/ and high initial slump, the average percentage of slump loss during the first (10) minutes approach to (24.9, 27.28, 30.78, 30.70)% respectively. Figure (ε-2) and table (ε-3) show the effect of initial slump on rate of slump loss.

Table (ε-3): Effect of (w/c ratio) on rate of slump loss

| Mix No. | W/C | Initial slump in (mm) | Slump with each interval 10 | | | | | % average Loss of Initial slump during 10 min. |
|----------------|------|-----------------------|-----------------------------|--------|--------|--------|--------|--|
| | | | 0 min | 10 min | 20 min | 30 min | 40 min | |
| M ₁ | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| M ₂ | 0.4 | 80 | 51 | 40 | 31 | 20 | | 24.9 |
| M ₃ | 0.45 | 100 | 72 | 52 | 38 | 28 | | 27.28 |
| M ₄ | 0.5 | 130 | 93 | 64 | 44 | 31 | | 30.78 |

| | | | | | | | |
|----------------|-----|-----|-----|----|----|----|-------|
| M _o | ٠.٦ | ١٦٥ | ١١٥ | ٨٠ | ٥٥ | ٣٨ | ٣٠.٧٥ |
|----------------|-----|-----|-----|----|----|----|-------|

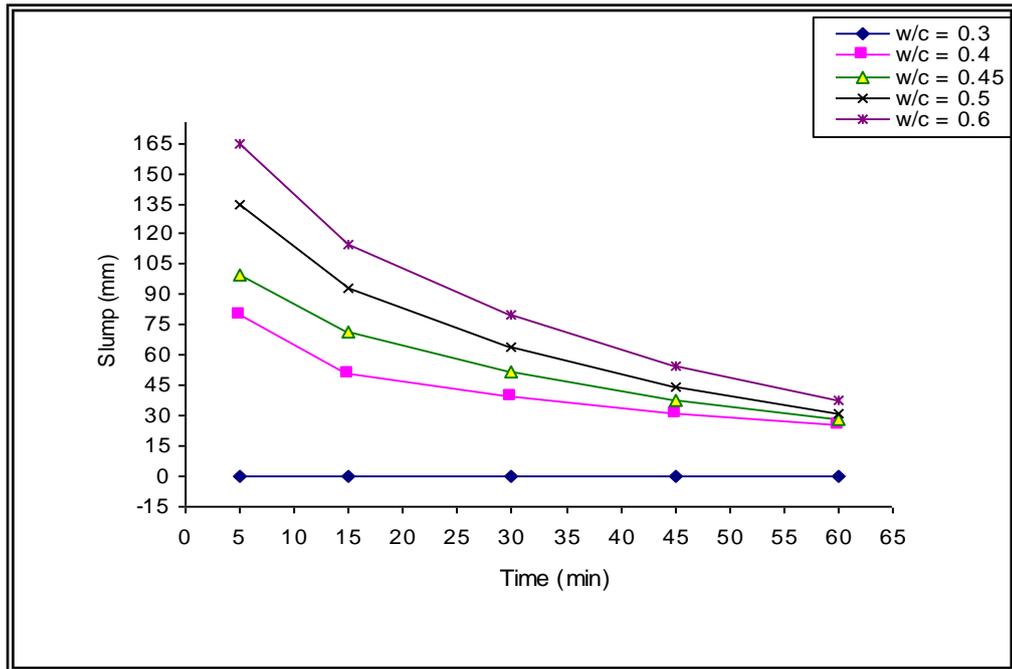


Figure (٤-٢): Variation of slump with time for different w/c ratios

٤. ٢. ٢. ٢. Slump loss with Superplasticized concrete:

Three types of superplasticizers were used. The first one is Glenium-٥١ (G٥١) chemically classified as (Sulfonated melamine-formaldehyde

condensates, SMF), second type is Conplast SP^{ε₂₃} chemically classified as (Sulfonated naphthalene-formaldehyde condensates, SNF). The third type is modified lignosulfonates MLS with commercial name Daracem. Slump loss was measured in intervals of (0, 10, 30, 40 and 60) minutes after mixing.

In figures (ε-3) through (ε-7) it can be seen that the rate of slump loss in concrete mixes with (SMF) superplasticizer was faster when compared with unsuperplasticized concrete (reference concrete mix) during the forty-five minutes. However, after that the rate of slump loss became slower, at later interval the rate of slump loss was less than in the reference mix. These results were (ε, ε.6, 0.0, 6, 6)%, (2.0, 2.2, 3, 3, 3.6)%, (0, 0.10, 0.7, 1.7, 2.2)%, (0, 2.2, 2.2, 2.3, 2.6)% higher in rate of slump loss with (1, 2, 2.0, 3 and 3.0)% by weight of cement for SMF dosages and (0.ε, 0.ε0, 0.0, 0.6) w/c ratio. The later interval results were (1.ε, -0.8, -0.8, -1, -1)%, (0, 0, 0, -1, 0)%, (0, 0, -0.ε, -1, -1)%, (0, -1, -1, -2, -2)% and all their details are indicated in table (ε-ε).

The (SMF) effect on slump loss may be due to that (SMF) is more effective in dispersing the cement particles. Dispersing effect is mainly promoted by absorption of sulphonic acid from surface of cement particles and causing them to become negatively charged which leads to repulsion between cement particles, and this increases the workability. This behavior makes the cement to react rapidly, and thus slumps will be lost faster [1,7].

Table (4-4): Variation slump at various periods after mixing with various dosages of SMF superplasticizer

| W/C | Sup. Dosage | Slump after different periods in (mm) | | | | | % increase in average rate of slump loss compared with reference mix | |
|------|-------------|---------------------------------------|--------|--------|--------|--------|--|-------------------------------|
| | | 0 min | 10 min | 30 min | 50 min | 70 min | First interval from 0-30 min | Later interval from 30-70 min |
| 0.4 | 0 | 70 | 00 | 40 | 30 | 23 | - | - |
| | 1 | 80 | 70 | 40 | 32 | 20 | 4 | 1.4 |
| | 2 | 90 | 70 | 40 | 33 | 20 | 4.7 | -0.8 |
| | 2.0 | 110 | 83 | 00 | 38 | 29 | 0.0 | -0.8 |
| | | 130 | 93 | 70 | 43 | 33 | 7 | -1 |
| | 3.0 | 130 | 88 | 70 | 40 | 34 | 7 | -1 |
| 0.40 | 0 | 90 | 70 | 00 | 40 | 28 | - | - |
| | 1 | 100 | 80 | 70 | 40 | 28 | 2.0 | 0 |
| | 2 | 113 | 83 | 08 | 43 | 30 | 2.2 | 0 |
| | 2.0 | 130 | 90 | 70 | 00 | 38 | 3 | 0 |
| | 3 | 140 | 103 | 70 | 02 | 40 | 3 | -1 |
| | | 140 | 100 | 70 | 00 | 40 | 3.7 | -1 |
| 0.0 | | 130 | 100 | 80 | 70 | 40 | - | - |
| | 1 | 140 | 110 | 90 | 70 | 40 | 0 | 0 |
| | 2 | 130 | 110 | 80 | 70 | 47 | 0.10 | 0 |
| | 2.0 | 170 | 120 | 100 | 70 | 03 | 0.7 | -0.4 |

| | | | | | | | | |
|-----|-----|-----|-----|-----|----|----|-----|----|
| | ۲ | ۱۶۰ | ۱۲۸ | ۹۰ | ۶۸ | ۵۱ | ۱.۷ | -۱ |
| | ۲.۵ | ۱۶۳ | ۱۲۳ | ۹۵ | ۶۷ | ۵۰ | ۲.۲ | -۱ |
| ۰.۶ | . | ۱۶۰ | ۱۳۰ | ۱۱۰ | ۸۵ | ۵۵ | - | - |
| | ۱ | ۱۶۰ | ۱۳۰ | ۱۰۰ | ۸۵ | ۵۵ | . | . |
| | ۲ | ۱۶۵ | ۱۳۵ | ۱۱۰ | ۸۰ | ۵۱ | ۲.۲ | -۱ |
| | ۲.۵ | ۱۶۵ | ۱۳۳ | ۱۰۰ | ۸۰ | ۵۱ | ۲.۲ | -۱ |
| | ۳ | ۱۸۰ | ۱۵۰ | ۱۱۸ | ۸۶ | ۵۵ | ۲.۳ | -۲ |
| | ۳.۵ | ۱۹۰ | ۱۵۰ | ۱۲۰ | ۹۰ | ۷۰ | ۲.۶ | -۲ |

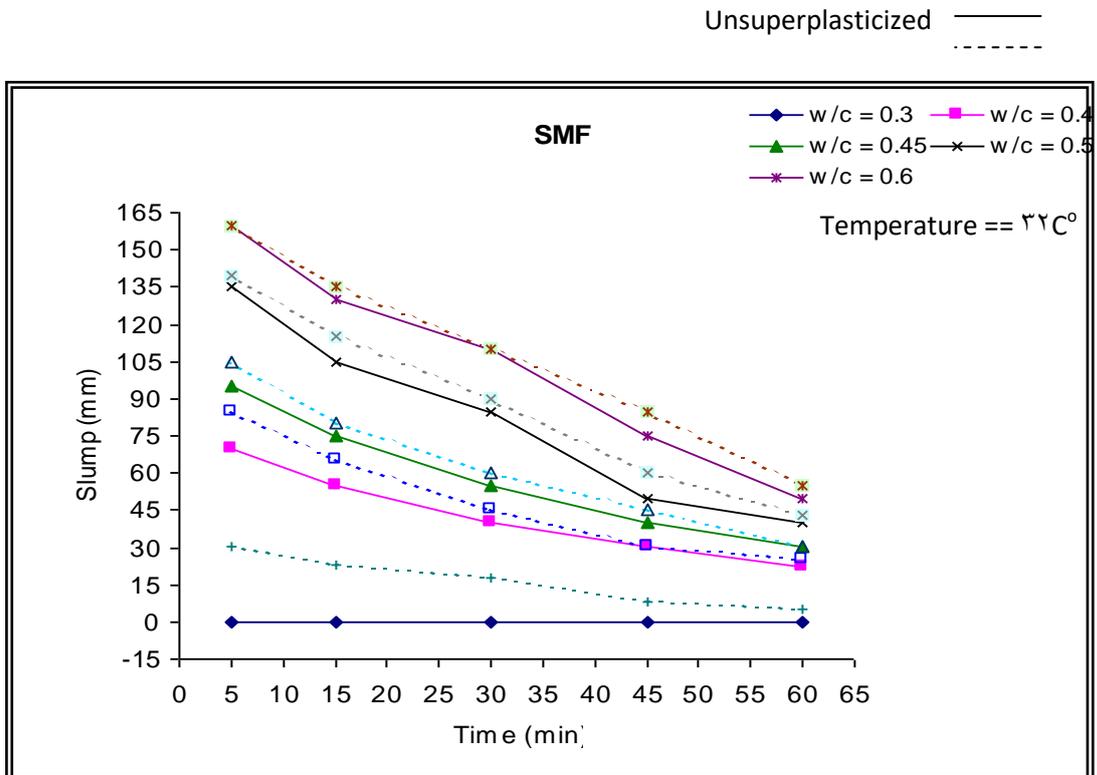


Figure (4-۳): Effect of (%) SMF Sulfonated melamine formaldehyde condensates [Glenium-۵۱, G۵۱] superplasticizer) on slump loss in concrete mixes with various w/c



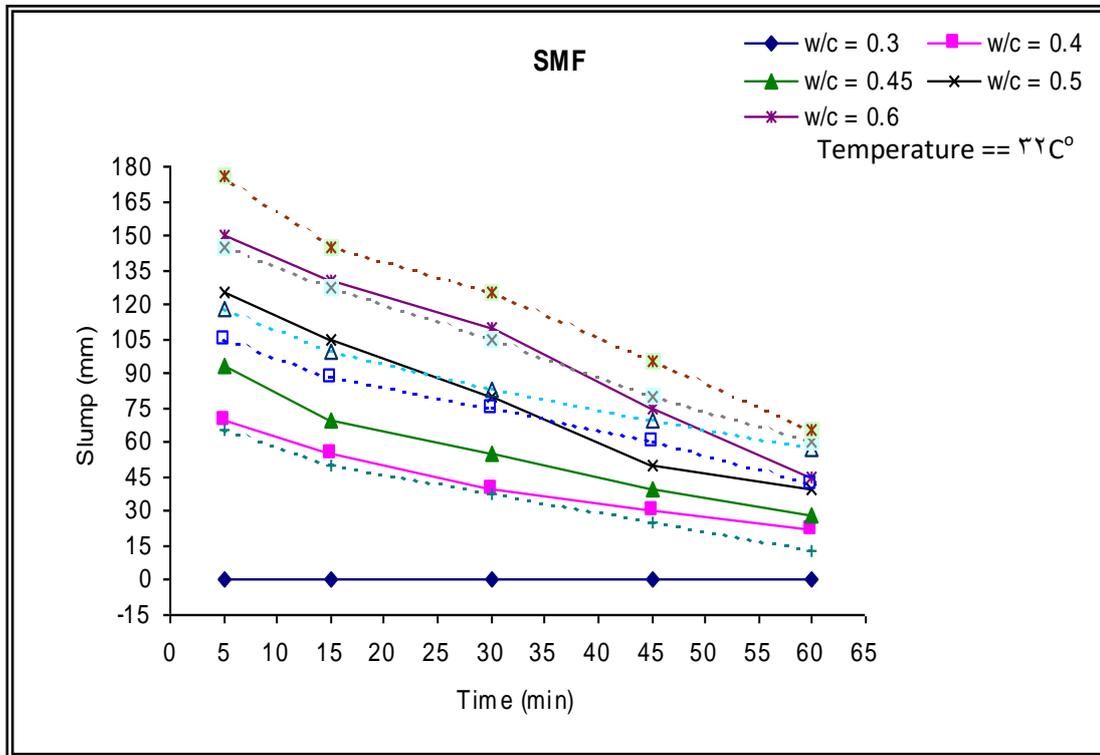


Figure (4-5): Effect of (1.5% SMF Sulfonated melamine formaldehyde condensates [Glenium-01, G01] superplasticizer) on slump loss in concrete mixes with various w/c ratios

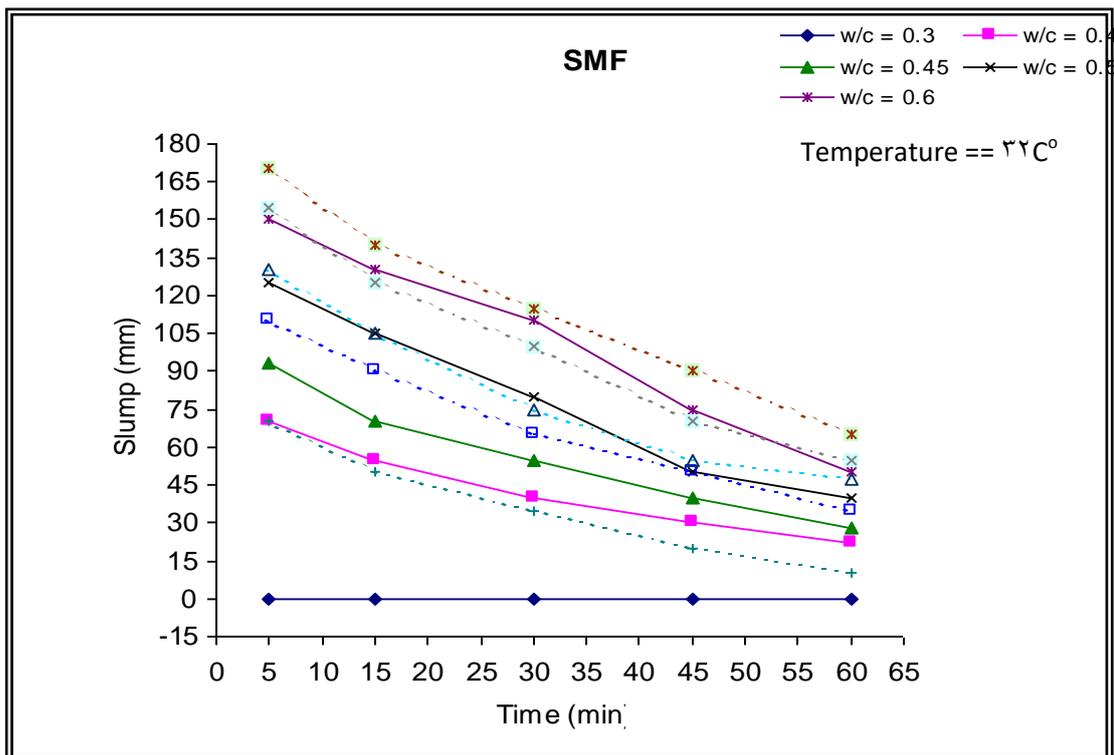


Figure (4-6): Effect of (1% SMF Sulfonated melamine formaldehyde condensates [Glenium-01, G01] superplasticizer) on slump loss in concrete mixes with various w/c ratios

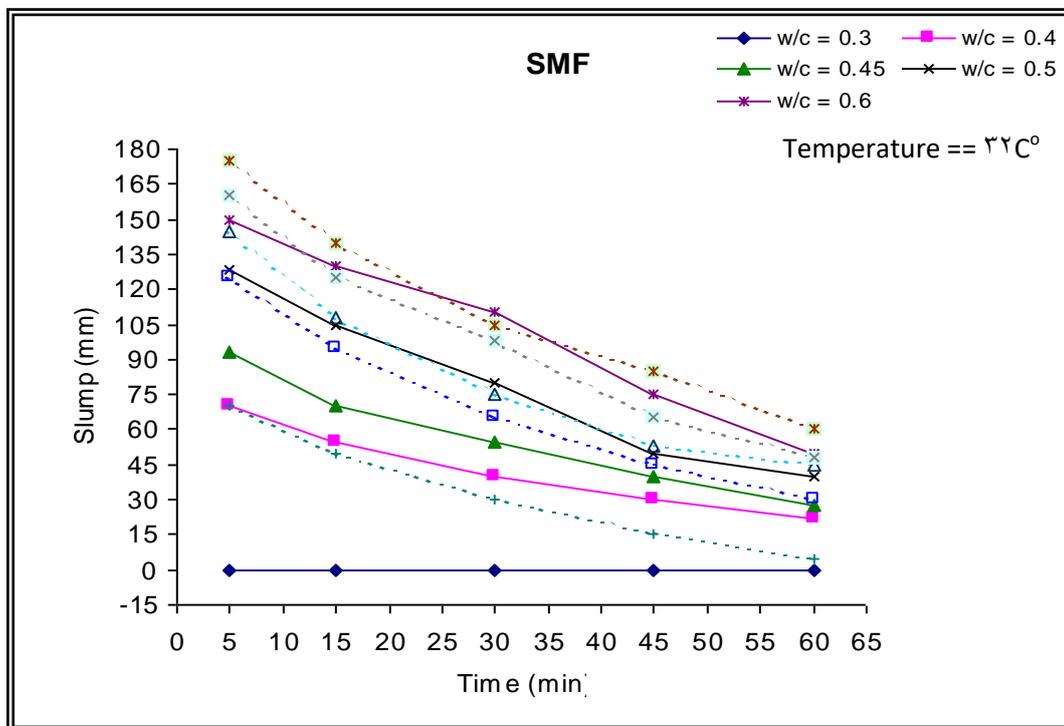


Figure (ε-ν): Effect of (2.5% SMF Sulfonated melamine formaldehyde condensates [Glenium-01, G01]superplasticizer) on slump loss in concrete mixes with various w/c ratios

Figures (ε-λ) through (ε-12) presented that the rate of slump loss when using (SNF) superplasticizer in concrete mixes is less than in the reference mix during the forty five minutes after mixing, after this time the slump loss of mixes with (SNF) is higher than in the reference mix. For the concrete mixes with (1, 2, 2.5, 3 and 3.5)% by weight of cement of (SNF) superplasticizer and different initial slump mixes, the average percentage of

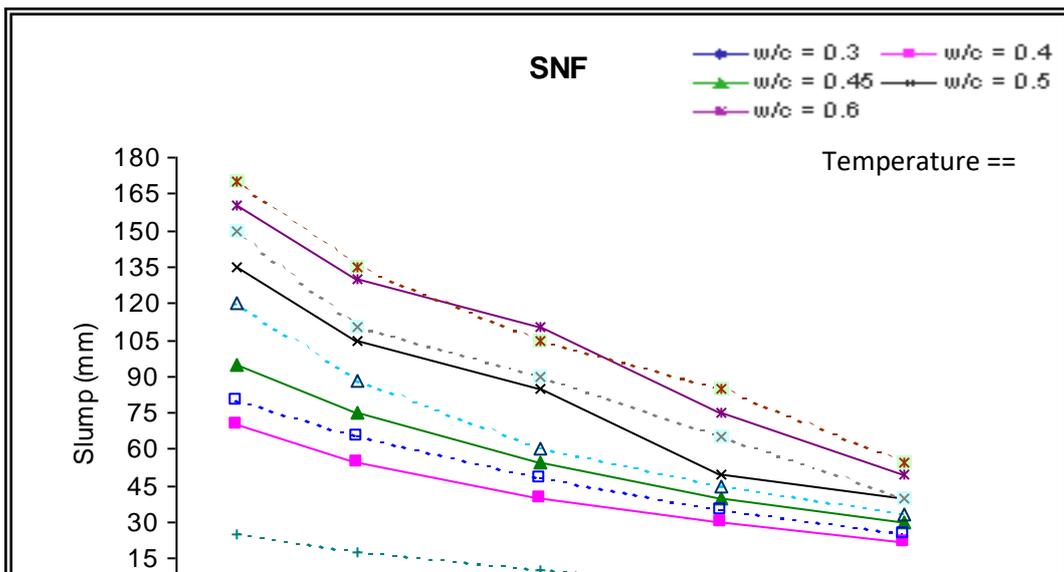
slump loss were (0, -1, -1, -1.3, -2)%, (-1, -1, -2, -2, -2)%, (-1.8, -2.0, -2.0, 3.2, 3.0)%, (-2, -2, -3, -3.3, -3.3)%. And for later time the results are (0, 1, 2, 2, 2)%, (0.0, 1, 1.4, 2, 2.6)%, (1, 1, 2.3, 2.4, 2.8)%, (1.6, 2.7, 2.3, 3, 3.6)% that may be attributed to the nature of (sulfonated naphthalene formaldehyde). (SNF) is polymer components have an organic nature with ability to replace ions and bonds. Interaction between (SNF) and cement components makes a strong net overlap with hydrate products, which gives concrete more workability and decreases slump loss. The increase in volume of these chains with continuation of interaction leads to fill the free spaces in mixes. After stability of interaction the products be more flocculation to take place and that increases slump loss^[1,5]. These results are represented in table (4-0).

Table (4-0): variation in rate of slump loss with various dosages of SNF superplasticizers

| W/C | Sup. Dosage | Slump after different periods in (mm) | | | | | % increase in average rate of slump loss compared with reference mix | |
|-----|-------------|---------------------------------------|--------|-------|--------|-------|--|-------------------------------|
| | | 0 min | 10 min | 0 min | 10 min | 0 min | First interval from 0-10 min | Later interval from 10-30 min |
| 0.4 | 0 | 70 | 00 | 40 | 30 | 20 | - | - |
| | 1 | 83 | 60 | 00 | 30 | 29 | 0 | 0 |
| | 2 | 90 | 70 | 02 | 39 | 33 | -1 | 1 |
| | 2.0 | 110 | 90 | 60 | 40 | 38 | -1 | 2 |
| | 3 | 110 | 80 | 60 | 46 | 39 | -1.3 | 2 |
| | 3.0 | 120 | 88 | 64 | 47 | 40 | -2 | 2 |

| | | | | | | | | |
|------|-----|-----|-----|-----|----|----|------|-----|
| 0.45 | . | 90 | 70 | 00 | 40 | 30 | - | - |
| | 1 | 120 | 88 | 70 | 49 | 37 | -1 | 0.0 |
| | 2 | 128 | 90 | 70 | 00 | 38 | -1 | 1 |
| | 2.0 | 140 | 102 | 70 | 00 | 40 | -2 | 1.4 |
| | 3 | 140 | 100 | 77 | 07 | 43 | -2 | 2 |
| | 3.0 | 100 | 110 | 80 | 08 | 40 | -2 | 2.7 |
| 0.5 | . | 130 | 100 | 80 | 00 | 40 | - | - |
| | 1 | 130 | 100 | 73 | 04 | 39 | -1.8 | 1 |
| | 2 | 140 | 103 | 70 | 00 | 41 | -2.0 | 1 |
| | 2.0 | 160 | 120 | 90 | 70 | 49 | -2.0 | 2.3 |
| | 3 | 170 | 123 | 90 | 70 | 47 | -3.2 | 2.4 |
| | 3.0 | 170 | 122 | 88 | 73 | 00 | -3.0 | 2.8 |
| 0.6 | . | 160 | 130 | 110 | 70 | 00 | - | - |
| | 1 | 100 | 110 | 90 | 77 | 00 | -2 | 1.7 |
| | 2 | 160 | 120 | 90 | 70 | 03 | -2 | 2.7 |
| | 2.0 | 170 | 132 | 98 | 73 | 00 | -3 | 2.3 |
| | 3 | 180 | 130 | 100 | 70 | 07 | -3.3 | 3 |
| | 3.0 | 180 | 138 | 103 | 77 | 08 | -3.3 | 3.7 |

Unsuperplasticized



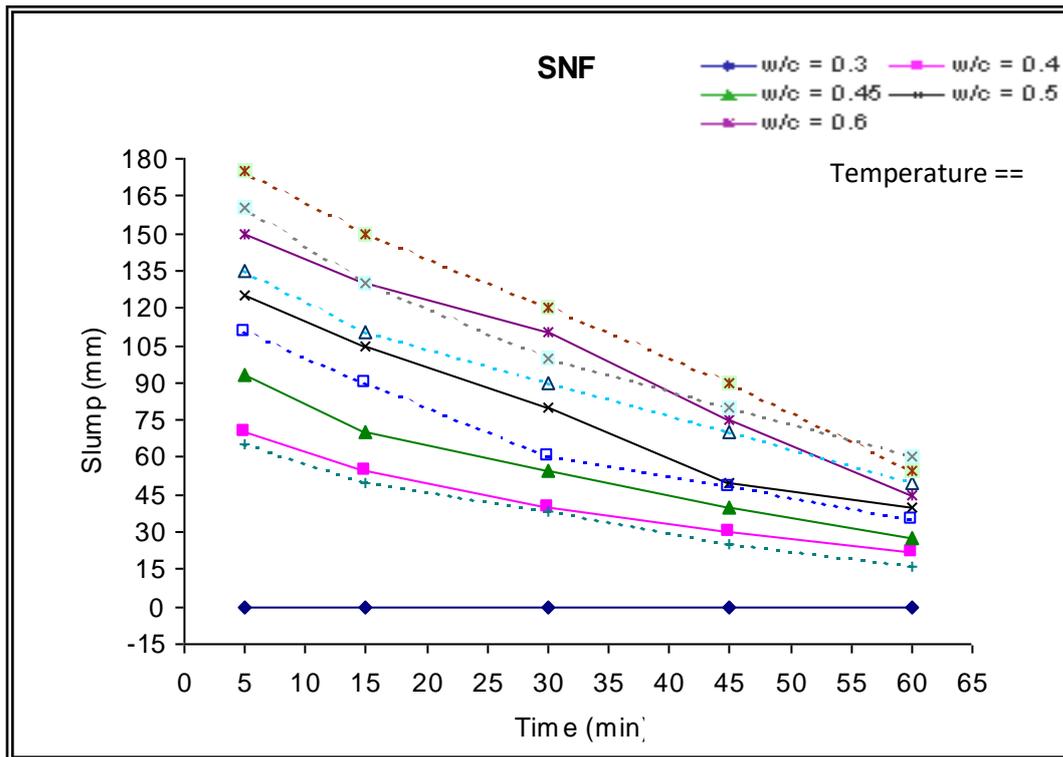


Figure (4-10): Effect of (1.0% SNF Sulfonated naphthalene formaldehyde condensates [Conplast SP(10)] superplasticizer) on slump loss in concrete mixes with various w/c ratios

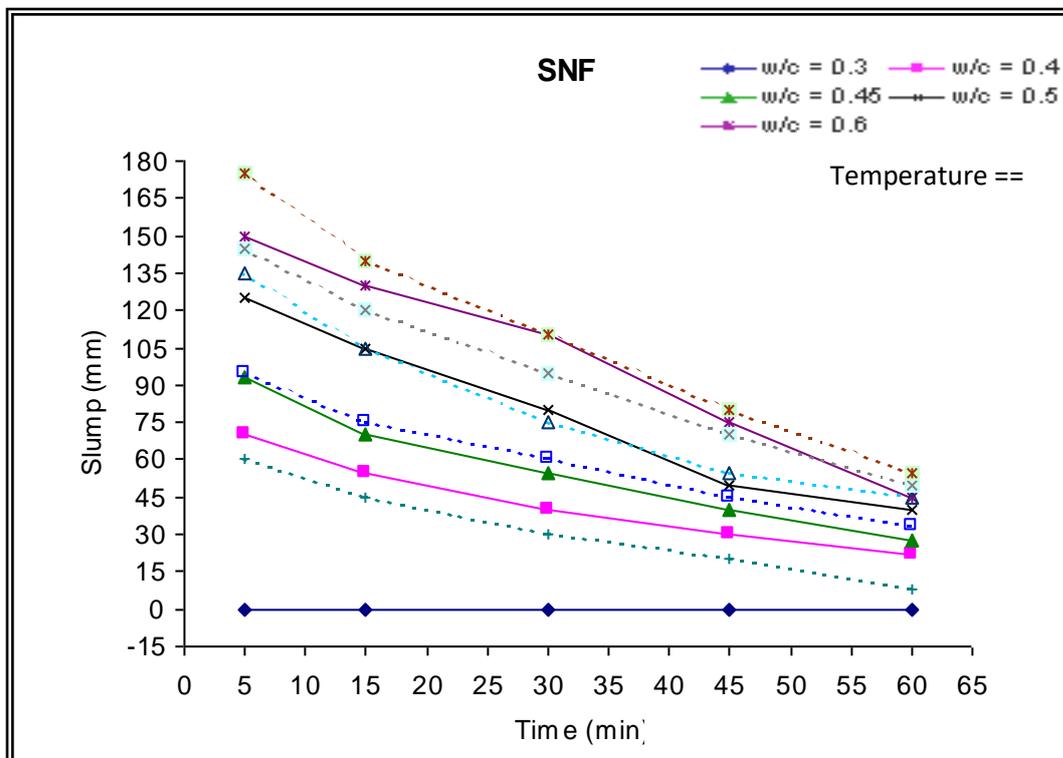


Figure (4-11): Effect of (3% SNF Sulfonated naphthalene formaldehyde condensates [Conplast SP(3)] superplasticizer) on slump loss in concrete mixes with various w/c

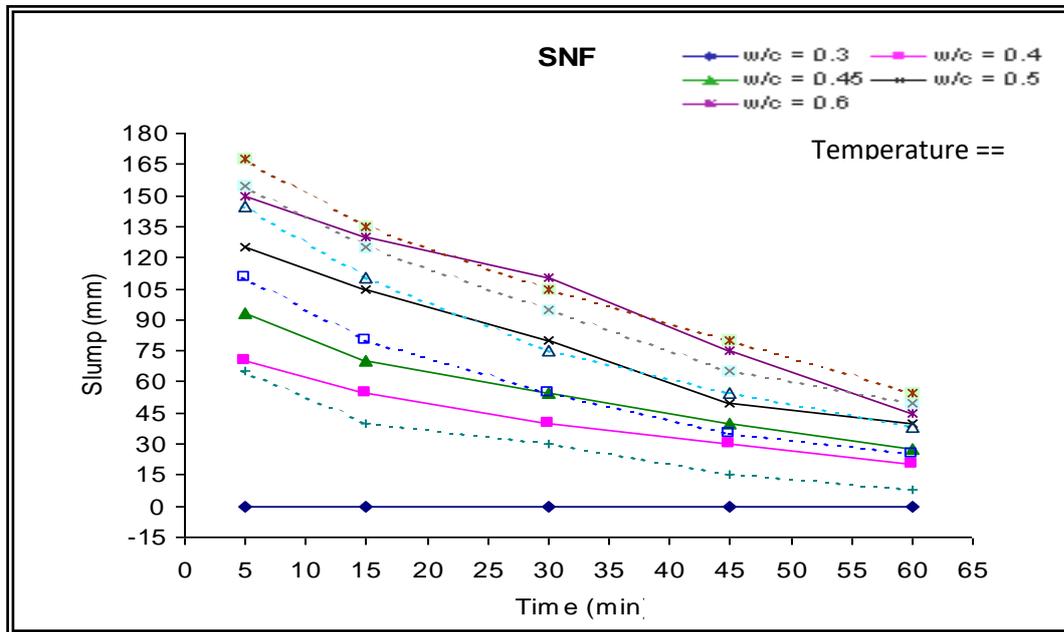


Figure (4-12): Effect of (0.5% SNF Sulfonated naphthalene formaldehyde condensates [Conplast SP43] superplasticizer) on slump loss in concrete mixes with various w/c ratios

Figures (ε-13) through (ε-17) show the rate of slump loss when using (MLS) superplasticizer in concrete mixes compared with the reference mix during sixty minutes after mixing. It can be seen that the rate of slump loss increases with higher (MLS) dosages especially in mixes with high initial slump. After forty-five minutes from mixing the rate of slump loss was approximately similar to the slump loss in the reference mix. Table (ε-6) showed percentage increase in slump loss through sixty minutes after mixing were (0.0, 1.1, 1.0, 2.1, 2.0)%, (1, 2, 2.7, 2.0, 2.7)%, (1.4, 2.2, 3, 3.4, 3.4)%, (2, 3, 3.0, 4)%, with (1, 2, 2.0, 3 and 3.0)% as weight of cement (MLS) dosages and different (w/c ratio).

Table (ε-6): Variation in rate of slump loss with various dosages of MLS superplasticizers

| W/C | Sup. Dosage | Slump after different periods in (mm) | | | | | % increase in average rate of slump loss compared with reference mix |
|------|-------------|---------------------------------------|--------|--------|--------|--------|--|
| | | 0 min | 10 min | 30 min | 45 min | 60 min | |
| 0.4 | . | 70 | 50 | 40 | 30 | 20 | - |
| | 1 | 90 | 78 | 53 | 38 | 29 | 0.0 |
| | 2 | 100 | 77 | 60 | 40 | 34 | 1.1 |
| | 2.0 | 120 | 92 | 71 | 50 | 41 | 1.0 |
| | 3 | 130 | 100 | 77 | 60 | 40 | 2.1 |
| | 3.0 | 130 | 100 | 82 | 64 | 48 | 2.0 |
| 0.40 | . | 90 | 70 | 50 | 40 | 30 | - |
| | 1 | 110 | 87 | 66 | 50 | 37 | 1 |
| | 2 | 120 | 92 | 71 | 50 | 41 | 2 |
| | 2.0 | 140 | 112 | 87 | 68 | 51 | 2.7 |
| | 3 | 150 | 120 | 93 | 72 | 54 | 2.0 |
| | 3.0 | 160 | 124 | 96 | 75 | 56 | 2.7 |
| 0.5 | . | 130 | 100 | 80 | 50 | 40 | - |
| | 1 | 140 | 110 | 80 | 63 | 47 | 1.4 |
| | 2 | 150 | 110 | 88 | 68 | 51 | 2.2 |
| | 2.0 | 160 | 128 | 99 | 77 | 58 | 3 |
| | 3 | 170 | 133 | 103 | 80 | 60 | 3.4 |
| | 3.0 | 170 | 136 | 107 | 83 | 62 | 3.4 |

| | | | | | | | |
|-----|-----|-----|-----|-----|-----|----|-----|
| 0.7 | . | 160 | 130 | 100 | 70 | 00 | - |
| | 1 | 160 | 120 | 90 | 72 | 06 | 2 |
| | 2 | 160 | 133 | 107 | 88 | 69 | 3 |
| | 2.0 | 180 | 140 | 118 | 96 | 70 | 3 |
| | 3 | 180 | 100 | 122 | 100 | 78 | 3.0 |
| | 3.0 | 190 | 160 | 127 | 100 | 82 | 4 |

Unsuperplasticized ———
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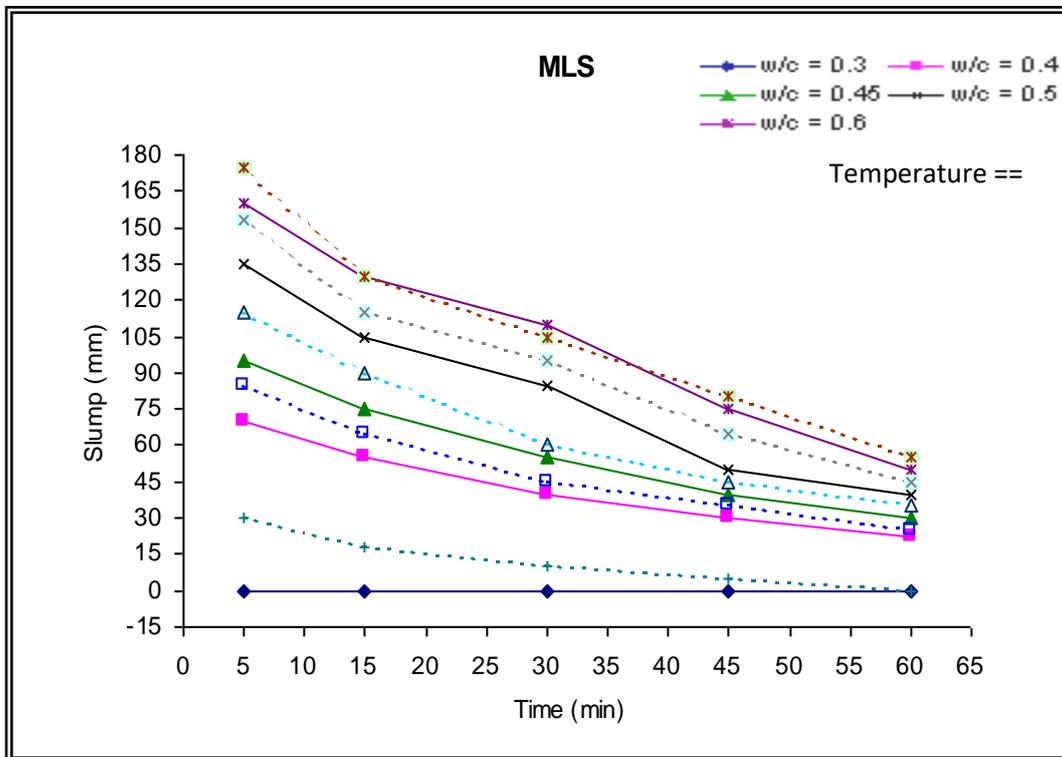
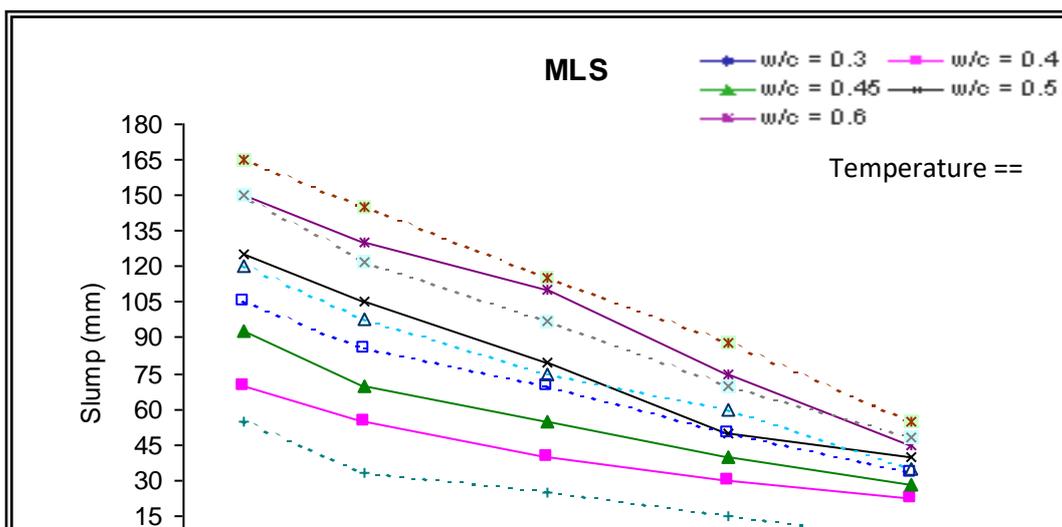


Figure (4-13): Effect of (1% MLS Lignosulfonates [Daracem] superplasticizer) on slump loss in concrete mixes with various w/c ratios



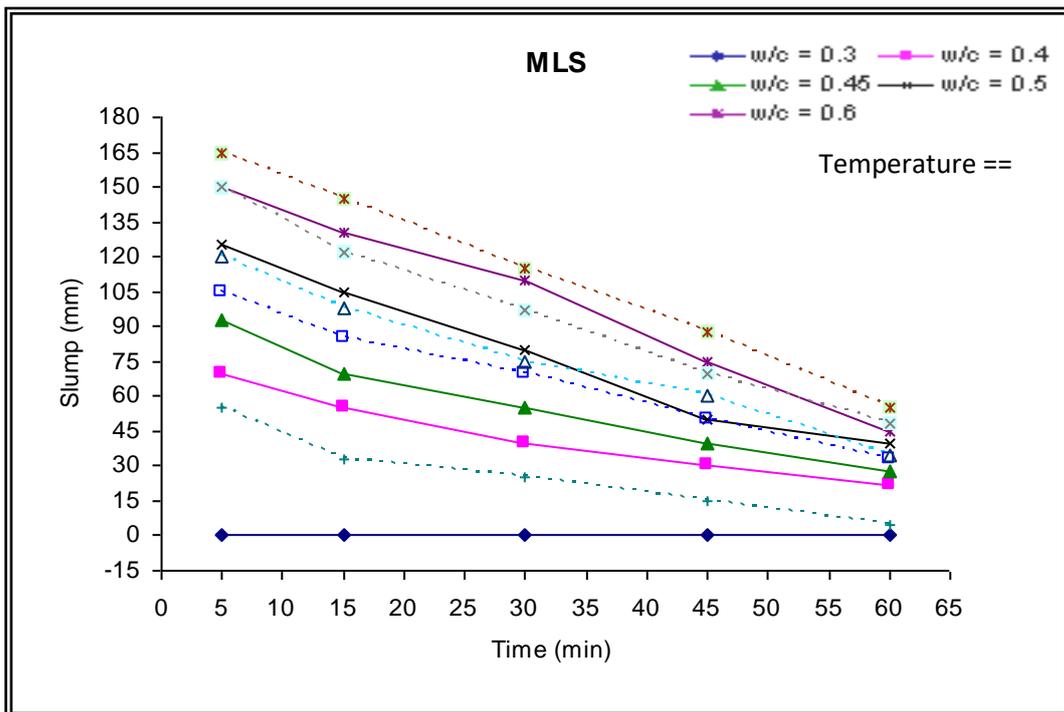
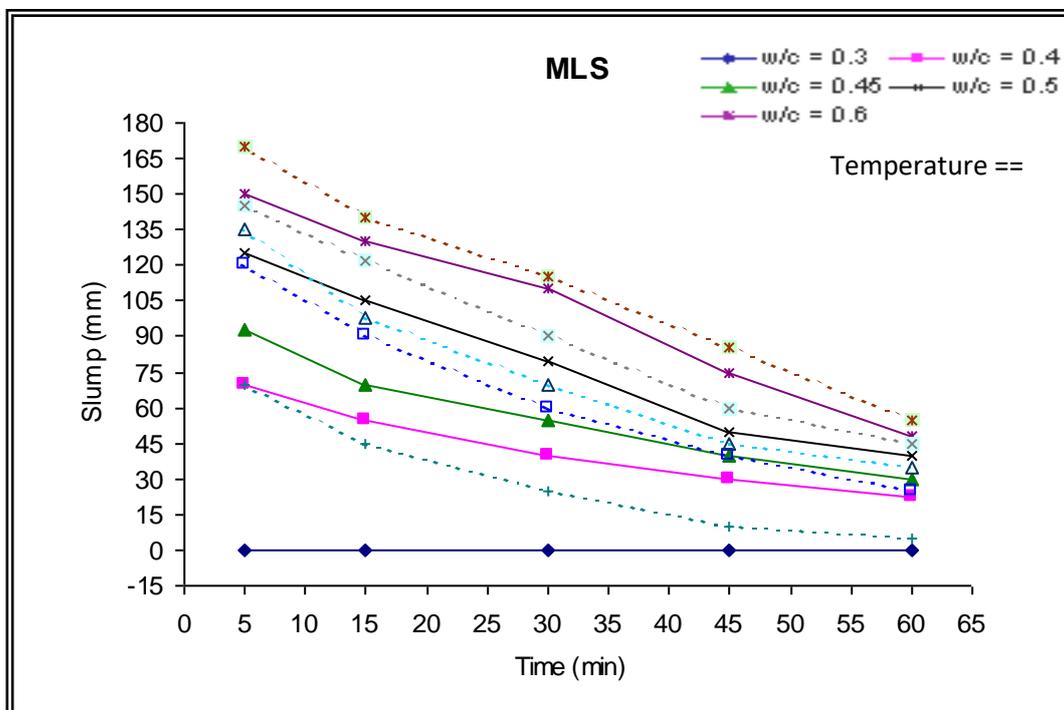


Figure (4-10): Effect of (1.0% MLS Lignosulfonates [Daracem] superplasticizer) on slump loss in concrete mixes with various w/c ratios



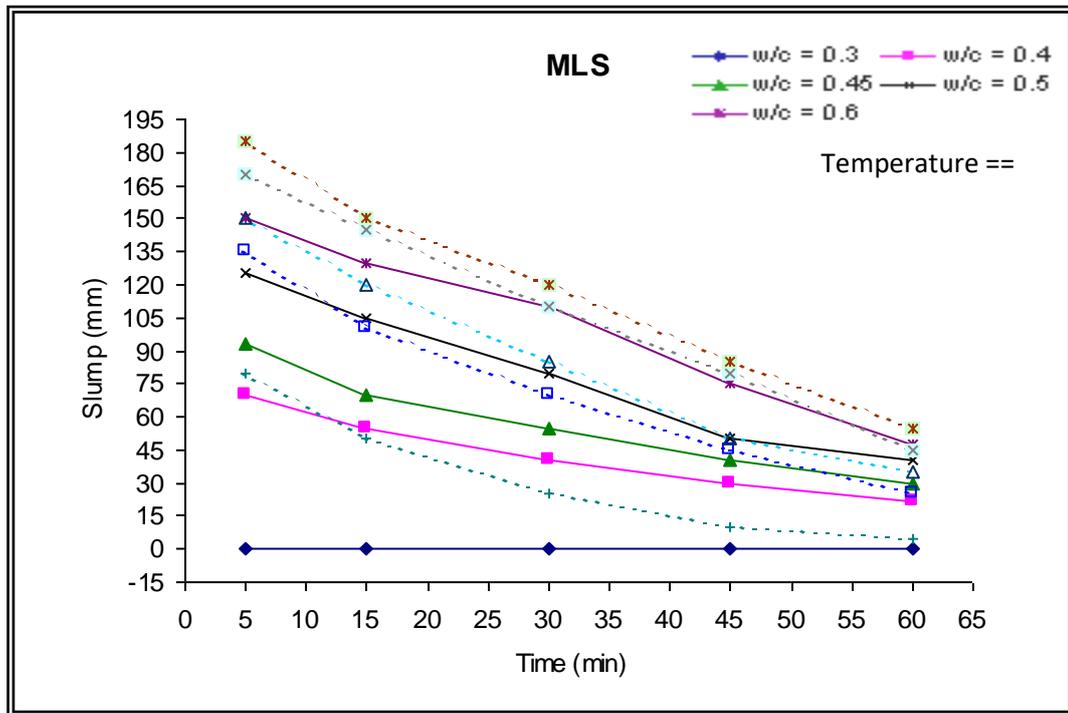


Figure (4-17): Effect of (3.0% MLS Lignosulfonates [Daracem] superplasticizer) on slump loss in concrete mixes with various w/c ratios

4.2.3. Use of superplasticizers for reducing a amount of water content

When (SMF, SNF, MLS) superplasticizers were used as water reducers by proportion shown previously in table (4-7) through (4-9), it might reduce the water content by (10-20)%. Figure (4-18) shows the percentage of reduction in water content with the addition of superplasticizer to obtain similar slumps. Table (4-10) gives details of these variations. Therefore when using (1, 2, 2.5, 3, 3.5)% (SMF) by weight of cement the increase in rate of slump loss was (4.0, 4.7, 4.7, 0.7, 0.7)%, (2.4, 2.6, 2.8, 3, 3)%, (1.7, 2, 2.6, 2.6, 2.6)%

for (0.4, 0.45, 0.5) w/c ratios respectively compared with unsuperplasticized concrete mix.

The (SMF) effect on slump loss may be due to that (SMF) is more effective in dispersing the cement particles. Dispersing effect is mainly promoted by absorption of sulphonic acid from surface of cement particles and causing them to become negatively charged which leads to repulsion between cement particles, and this increases the workability. This behavior makes the cement to react rapidly, and thus slumps will be lost faster [10].

When (SNF) is used the increase in rate of slump loss was (0, 0, 4.7, 3.9, 3.8)%, (2.8, 2, 2, 1.9, 0.8)%, (2, 1.45, 1.25, 0.8, 0.6)%. The increase in rate of slump loss when using (MLS) is (4.6, 4.7, 4.8, 0, 0.7)%, (2, 2.3, 2.8, 3, 3.0)%, (2, 2.8, 3, 3, 3.4)% for (0.4, 0.45, 0.5) w/c ratios respectively. These results are shown in Figure (4-19) through (4-21).

(MLS) is a surface-active agent which is concentrated at the interface between two immiscible phases which alters the physical and chemical forces at this interface. This agent is absorbed by cement particles and giving them negative charge, that causes repulsion between cement particles. Negative charge causes development of sheath of oriented water molecules around each particle, thus separating cement particles. More air-bubbles can be generated by (MLS) without attach to cement particles, which lead to more separating of cement particles, and that increase workability of concrete mix. Continuous mixing gives reduction in air bubbles with more water free that can help to reduce mix temperature and give suitable slump loss. Using high dosage of (MLS) superplasticizer (beyond saturation) may lead to segregation problem with break-down

protective layer by osmotic pressure which improve particles mobility and more water free from the restraining influence of flocculated system that cause segregation and bleeding. Normally saturated high percentage of (MLS) lead to acceleration of hydrate action to cement particles during the first fifteen minutes, which gives the mix high slump loss. After this time more air is coming in and cause high dispersion to agglomerate of hydrate products and disruption of the hydrate protective layer by physico-chemical transformation of the hydrates (change in composition or structure)^[1,2].

Table (4-7): percentage reduction in water content when using SMF Superplasticizer

| (SMF) superplasticizer % weight of cement | (SMF) superplasticizer in (l/m ³) | W/C ratio | % Reduction in water content |
|--|---|-----------|---------------------------------|
| Mix with 0.45 w/c ratio and cement content (360 Kg/m ³) with slump (80-110) mm | | | |
| 0 | 0 | 0.45 | 0 |
| 1 | 3.27 | 0.368 | 8 |
| 2 | 6.50 | 0.340 | 13.60 |
| 2.5 | 8.18 | 0.332 | 17 |
| 3 | 9.8 | 0.324 | 19 |
| 3.5 | 11.40 | 0.32 | 20 |
| Mix with 0.40 w/c ratio and cement content (360 Kg/m ³) with slump (90-120) mm | | | |
| 0 | 0 | 0.40 | 0 |
| 1 | 3.27 | 0.340 | 10 |
| 2 | 6.50 | 0.328 | 16 |
| 2.5 | 8.18 | 0.320 | 19 |
| 3 | 9.8 | 0.300 | 21 |
| 3.5 | 11.40 | 0.298 | 22.0 |
| Mix with 0.35 w/c ratio and cement content (360 Kg/m ³) with slump (90-130) mm | | | |

| | | | |
|-----|-------|-------|-------|
| 0 | 0 | 0.0 | 0 |
| 1 | 3.27 | 0.44 | 12 |
| 2 | 6.00 | 0.41 | 18 |
| 2.0 | 8.18 | 0.390 | 21 |
| 3 | 9.8 | 0.38 | 23.0 |
| 3.0 | 11.40 | 0.378 | 24.20 |

Table (4-8): percentage reduction in water content when using SNF Superplasticizer

| (SNF) superplasticizer % weight of cement | (SNF) superplasticizer in (L/m ³) | W/C ratio | % Reduction in water content |
|--|---|-----------|---------------------------------|
| Mix with 0.4 w/c ratio and cement content (370 Kg/m ³) with slump (80-110) mm | | | |
| 0 | 0 | 0.4 | 0 |
| 1 | 3 | 0.372 | 7 |
| 2 | 6 | 0.344 | 14 |
| 2.0 | 7.06 | 0.332 | 17 |
| 3 | 9 | 0.32 | 19.0 |
| 3.0 | 10.6 | 0.3 | 21 |
| Mix with 0.40 w/c ratio and cement content (370 Kg/m ³) with slump (90-120) mm | | | |
| 0 | 0 | 0.40 | 0 |
| 1 | 3 | 0.407 | 9.00 |
| 2 | 6 | 0.378 | 16 |
| 2.0 | 7.06 | 0.37 | 19 |
| 3 | 9 | 0.300 | 21 |
| 3.0 | 10.6 | 0.34 | 24.20 |
| Mix with 0.5 w/c ratio and cement content (370 Kg/m ³) with slump (90-130) mm | | | |
| 0 | 0 | 0.5 | 0 |
| 1 | 3 | 0.442 | 11.0 |
| 2 | 6 | 0.41 | 17.70 |
| 2.0 | 7.06 | 0.4 | 20 |

| | | | |
|-----|------|-------|-------|
| 3 | 9 | 0.39 | 22 |
| 3.0 | 10.6 | 0.377 | 24.40 |

Table (4-9): percentage reduction in water content when using MLS Superplasticizer

| (MLS) superplasticizer % weight of cement | (MLS) superplasticizer kg (L/m ³) | W/C ratio | % Reduction in water content |
|--|---|-----------|---------------------------------|
| Mix with 0.45 w/c ratio and cement content (360 Kg/m ³) with slump (80-110) mm | | | |
| 0 | 0 | 0.45 | 0 |
| 1 | 2.20 | 0.364 | 9 |
| 2 | 4.0 | 0.336 | 16 |
| 2.0 | 0.620 | 0.326 | 18.30 |
| 3 | 6.70 | 0.32 | 20 |
| 3.0 | 7.870 | 0.3 | 21.30 |
| Mix with 0.50 w/c ratio and cement content (360 Kg/m ³) with slump (90-120) mm | | | |
| 0 | 0 | 0.50 | 0 |
| 1 | 2.20 | 0.390 | 12.20 |
| 2 | 4.0 | 0.369 | 18 |
| 2.0 | 0.620 | 0.350 | 21 |
| 3 | 6.70 | 0.347 | 22.8 |
| 3.0 | 7.870 | 0.34 | 23.0 |
| Mix with 0.60 w/c ratio and cement content (360 Kg/m ³) with slump (90-130) mm | | | |
| 0 | 0 | 0.60 | 0 |
| 1 | 2.20 | 0.43 | 13.0 |
| 2 | 4.0 | 0.41 | 19.0 |
| 2.0 | 0.620 | 0.390 | 21.8 |
| 3 | 6.70 | 0.387 | 23.70 |
| 3.0 | 7.870 | 0.378 | 24.0 |

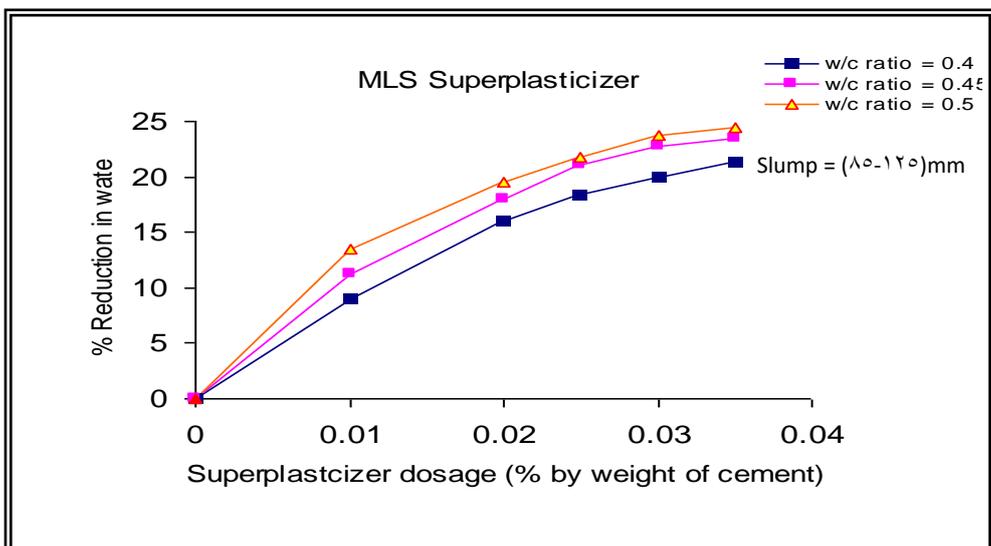
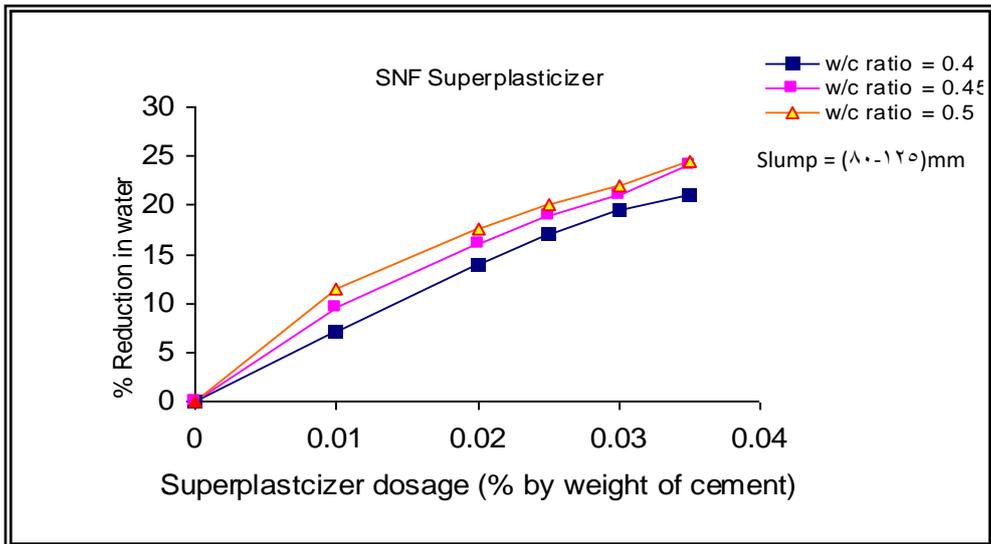
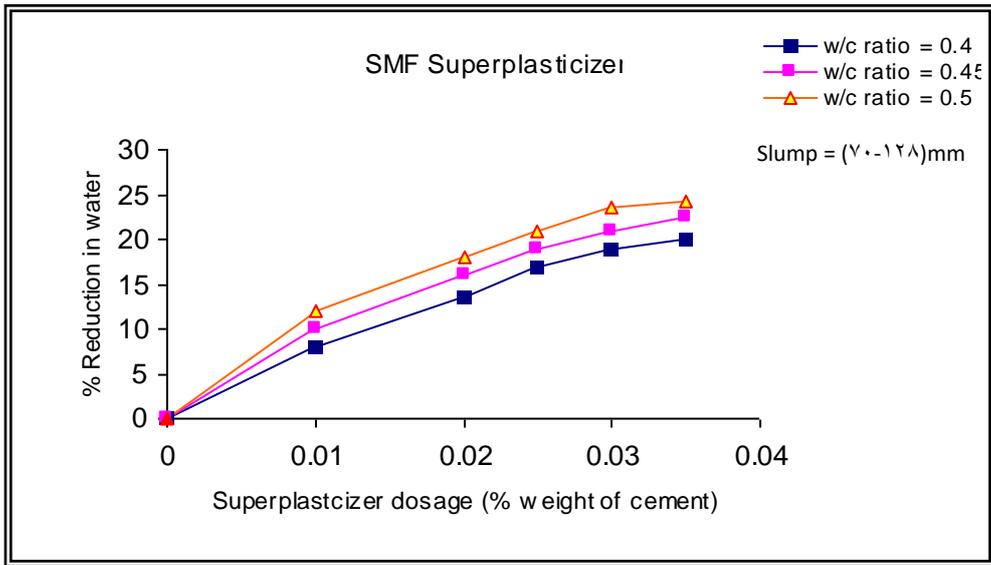


Figure (4-11): Using superplasticizers for reducing water content

Table (4-10): Variation in rate of slump loss with various types and dosages of superplasticizers when used as water reducer

| Sup. Type | W/C | Sup. Dosage | Slump loss in (mm) | | | | | % increase in rate of slump loss |
|-----------|------|-------------|--------------------|--------|--------|--------|--------|----------------------------------|
| | | | 0 min | 10 min | 30 min | 40 min | 60 min | |
| SMF | 0.4 | | 80 | 70 | 50 | 35 | 20 | 4.0 |
| | | | 93 | 70 | 52 | 39 | 29 | 4.7 |
| | | | 100 | 70 | 56 | 42 | 31 | 4.7 |
| | | | 100 | 78 | 58 | 43 | 32 | 0.7 |
| SMF | 0.45 | | 110 | 82 | 71 | 40 | 33 | 0.7 |
| | | | 90 | 72 | 54 | 41 | 31 | 2.4 |
| | | | 108 | 82 | 72 | 47 | 30 | 2.7 |
| | | | 110 | 87 | 77 | 50 | 37 | 2.8 |
| SMF | 0.5 | | 120 | 91 | 79 | 52 | 38 | 3 |
| | | | 120 | 90 | 72 | 54 | 40 | 3 |
| | | | 100 | 80 | 71 | 40 | 36 | 1.7 |
| | | | 112 | 87 | 77 | 51 | 38 | 2 |
| SMF | 0.5 | | 120 | 92 | 71 | 54 | 40 | 2.7 |
| | | | 120 | 97 | 74 | 57 | 42 | 2.7 |
| | | | 128 | 98 | 70 | 57 | 43 | 2.7 |
| | | | 120 | 98 | 70 | 57 | 43 | 2.7 |
| SNF | 0.4 | | 80 | 73 | 47 | 30 | 27 | 0 |
| | | | 90 | 71 | 53 | 39 | 29 | 0 |
| | | | 100 | 70 | 56 | 42 | 31 | 4.7 |
| | | | 110 | 82 | 71 | 40 | 30 | 3.9 |
| SNF | 0.45 | | 113 | 84 | 73 | 47 | 37 | 3.8 |
| | | | 90 | 78 | 51 | 39 | 29 | 2.8 |
| | | | 100 | 77 | 58 | 44 | 33 | 2 |
| | | | 110 | 83 | 73 | 48 | 37 | 2 |
| SNF | 0.5 | | 110 | 87 | 77 | 50 | 38 | 1.9 |
| | | | 120 | 91 | 70 | 53 | 41 | 0.8 |
| | | | 100 | 77 | 59 | 40 | 34 | 2 |
| | | | 110 | 84 | 70 | 50 | 38 | 1.40 |
| SNF | 0.5 | | 118 | 90 | 79 | 53 | 41 | 1.20 |
| | | | 120 | 97 | 74 | 57 | 44 | 0.8 |
| | | | 130 | 100 | 77 | 59 | 40 | 0.7 |
| | | | 120 | 97 | 74 | 57 | 44 | 0.8 |
| MLS | 0.4 | | 130 | 100 | 77 | 59 | 40 | 0.7 |
| | | | 90 | 77 | 50 | 37 | 28 | 4.7 |
| | | | 100 | 70 | 50 | 43 | 31 | 4.7 |
| | | | 110 | 82 | 70 | 47 | 34 | 4.8 |
| MLS | 0.45 | | 118 | 88 | 77 | 49 | 37 | 0 |
| | | | 120 | 90 | 77 | 50 | 37 | 0.7 |
| | | | 100 | 77 | 50 | 37 | 28 | 4.7 |
| | | | 110 | 83 | 73 | 48 | 37 | 2.3 |
| MLS | 0.45 | | 110 | 87 | 77 | 50 | 39 | 2.8 |
| | | | 123 | 93 | 70 | 53 | 39 | 3 |
| | | | 127 | 97 | 73 | 50 | 40 | 3.0 |
| | | | 120 | 97 | 74 | 57 | 44 | 0.8 |
| MLS | 0.5 | | 112 | 87 | 77 | 50 | 38 | 2 |
| | | | 120 | 92 | 70 | 50 | 40 | 2.7 |
| | | | 128 | 98 | 70 | 58 | 42 | 3 |
| | | | 130 | 100 | 77 | 60 | 43 | 3 |

Unsuperplasticized

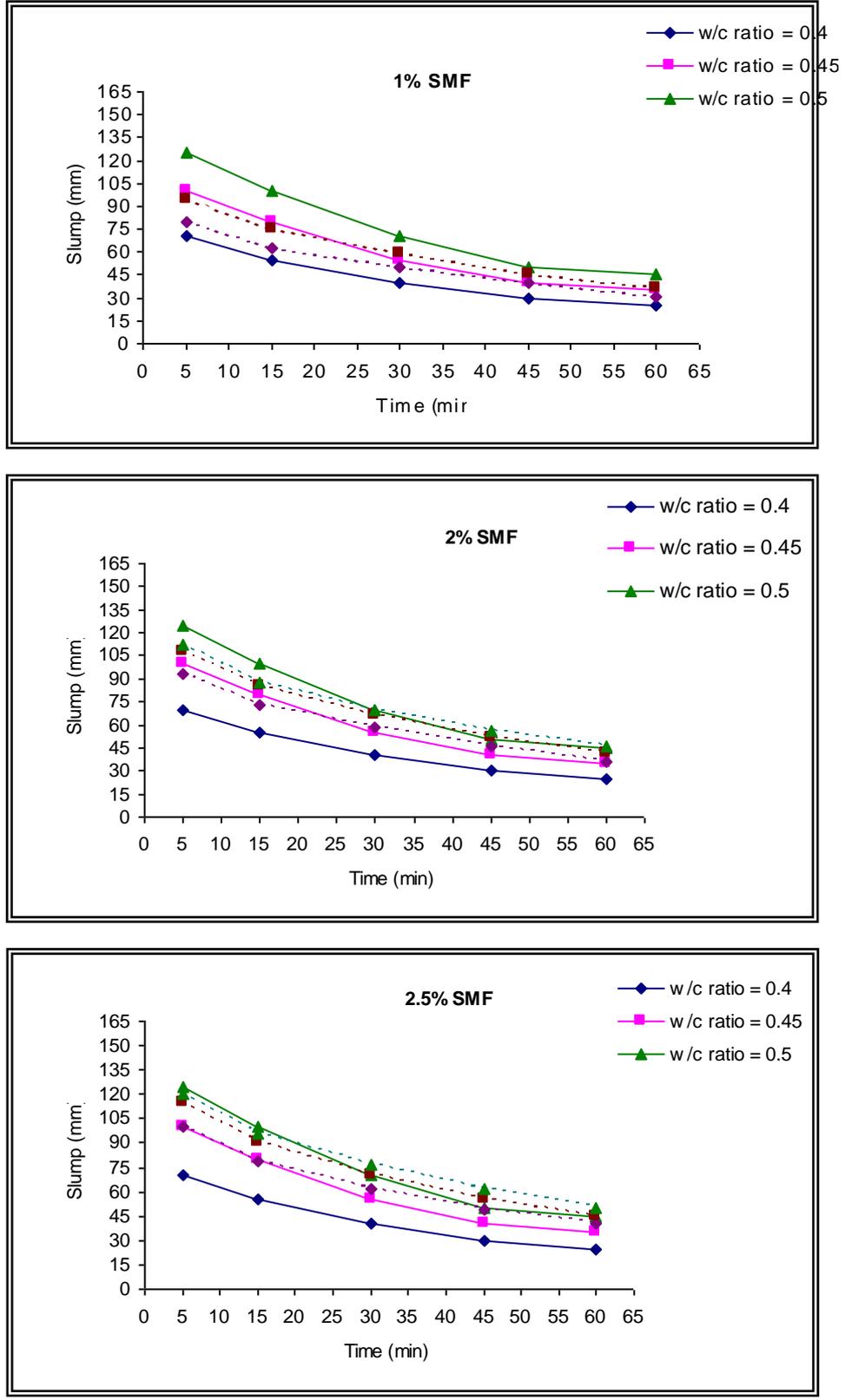


Figure (4-14): Effect of using Sulfonated melamine-formaldehyde superplasticizer as water reducer on slump loss of concrete mixes with various w/c ratios

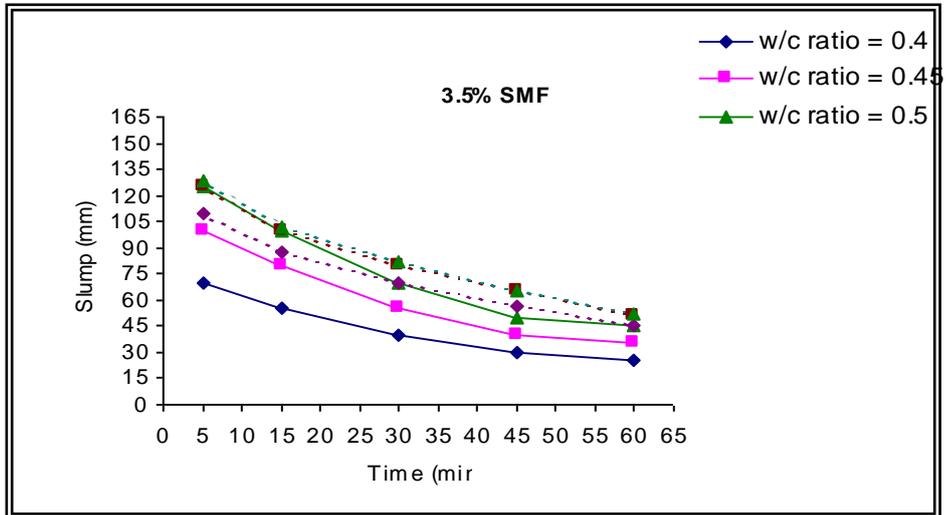
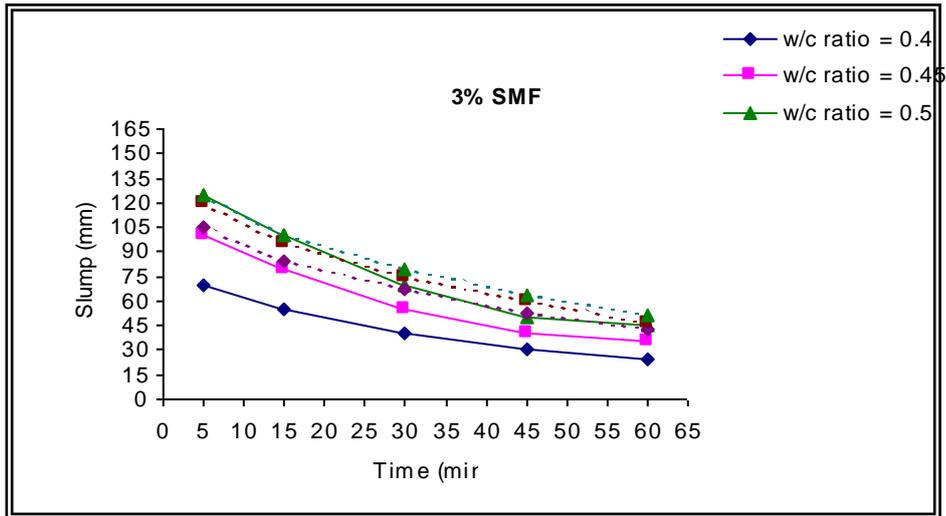
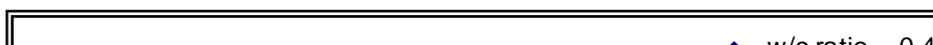
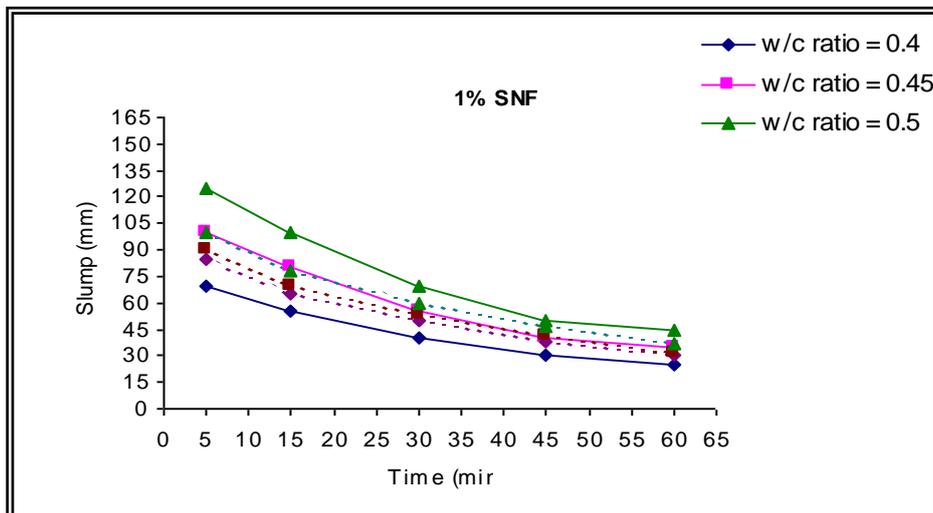


Figure (4-14): Effect of using Sulfonated melamine-formaldehyde superplasticizer as water reducer on slump loss of concrete mixes with various w/c ratios



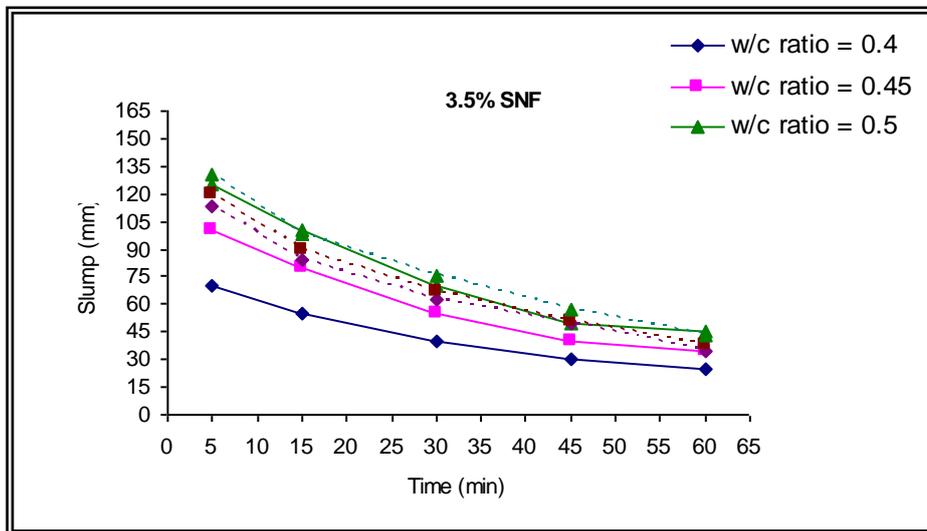
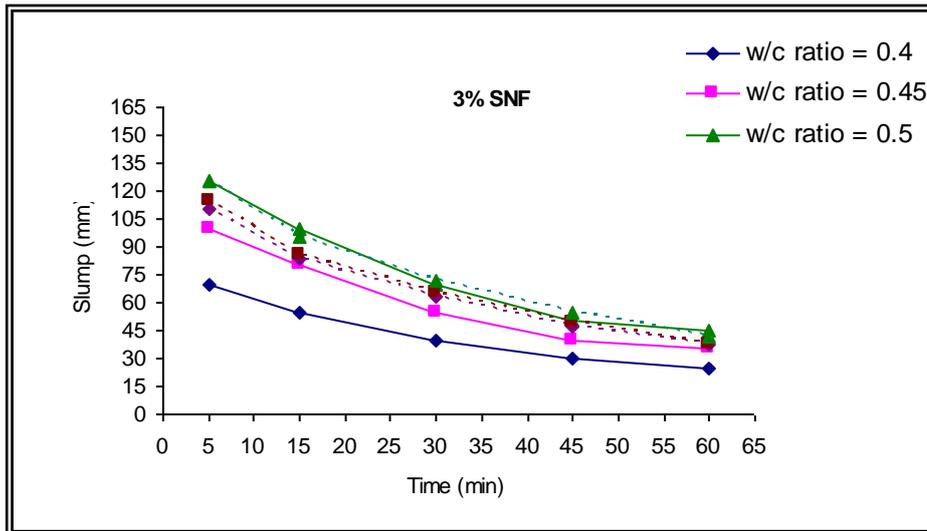


Figure (4-20): **Effect of using Sulfonated naphthalene-formaldehyde superplasticizer as water reducer on slump loss of concrete mixes with various w/c ratios**

Figure (4-21): **Effect of superplasticizer using as water reducer on slump loss in concrete mix with various w/c ratio**

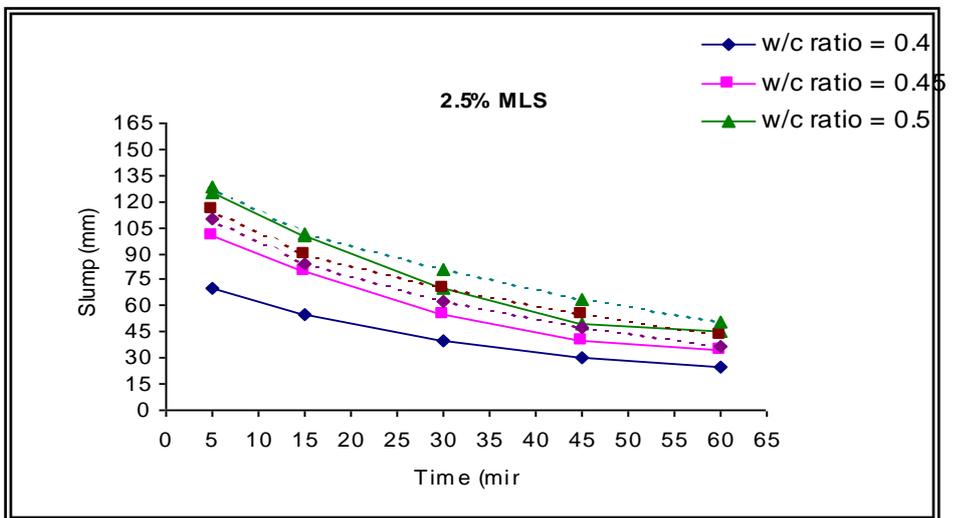
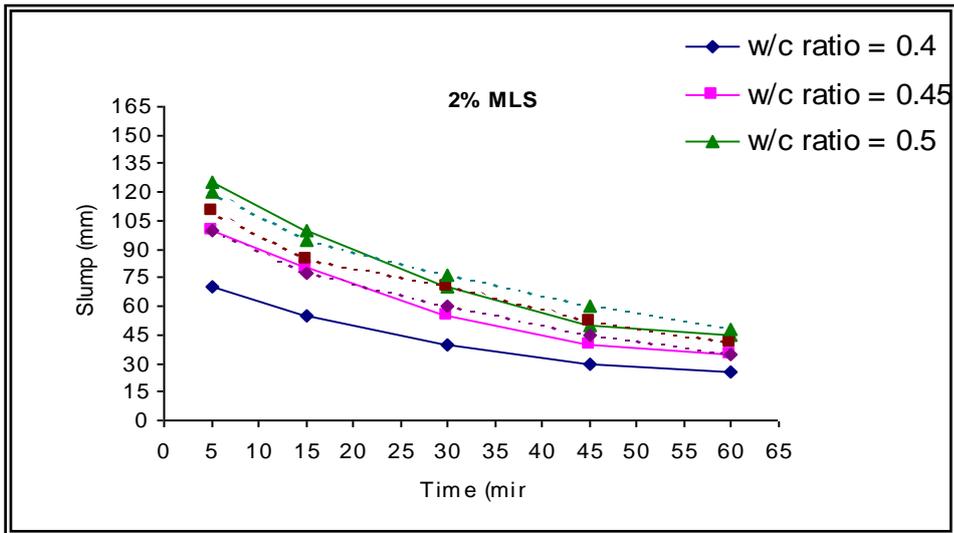
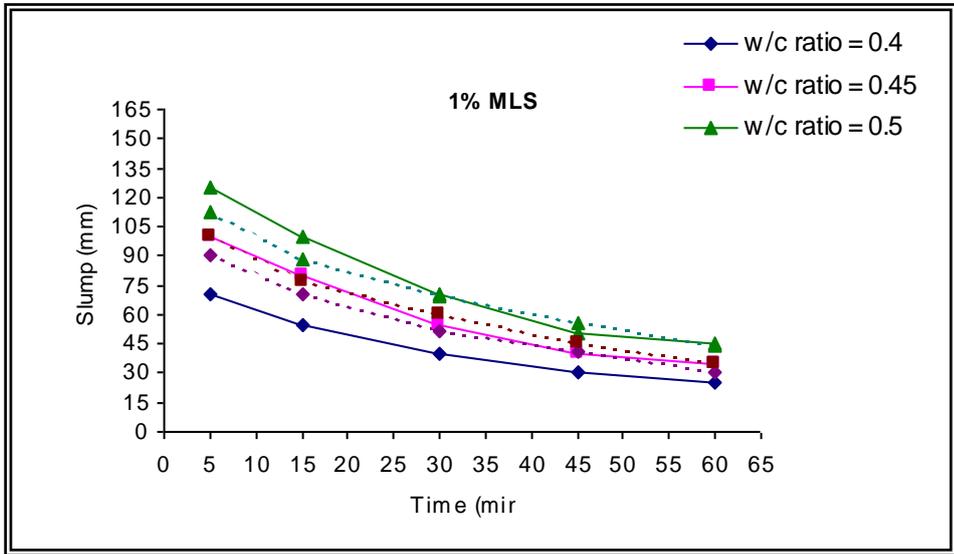


Figure (٤-٢١): Effect of using Lignosulfonates superplasticizer as water reducer on slump loss of concrete mixes with various w/c ratios

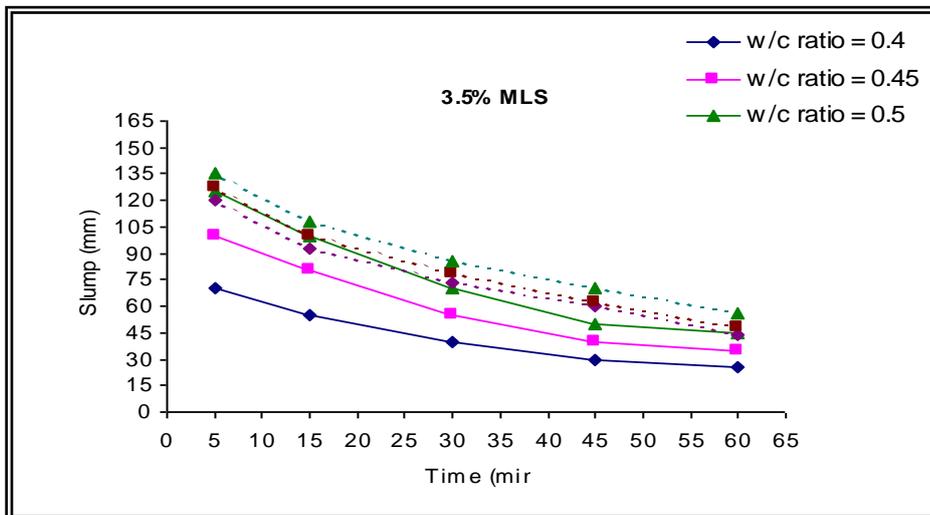
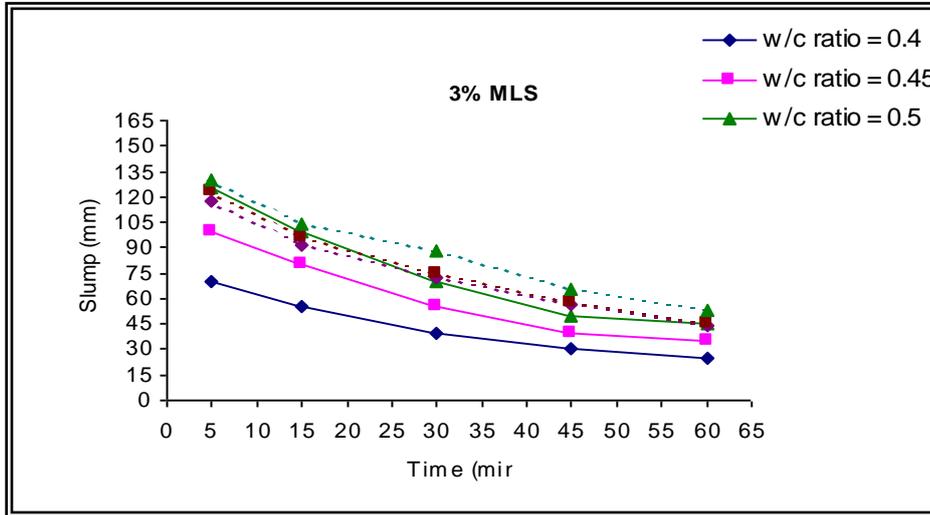


Figure (٤-٢١): Effect of using Lignosulfonates superplasticizer as water reducer on slump loss of concrete mixes with various w/c ratios

4. 2. 3. Use of superplasticizers for reducing a mount of cement content

Mixes with different cement contents and with same initial slump range have approximately the same rate of slump loss in room temperature after forty-five minutes from mixing. The rate of slump loss increases with the increase in cement content, and this was noticed early within first fifteen minutes. High proportion of cement content in the concrete mix caused increase in total heat of hydration, which leads to more evaporation rate of mixing water that causes high slump loss.

Tables (4-11) through (4-13) show that the percentage reduction in cement content from original cement weight with SMF superplasticizers dosage (1, 2, 3, 4, 5)% by weight of cement and (0.4, 0.45, 0.5) w/c ratios are (6, 12.5, 16, 19, 20)%, (8, 15, 18, 21, 21.8) %, (12, 17, 19.5, 21, 22)%. with SNF superplasticizer (7.8, 13.2, 17.6, 20, 22.2)%, (9, 14.5, 19.4, 22.2, 22.33)%, (13.5, 17.8, 21.7, 22, 22.2)% respectively, For MLS superplasticizer with same dosage and w/c ratios was (8.33, 13.2, 16, 20, 21.53)%, (10, 15.5, 19.3, 22.8, 21.2)%, (13.33, 17.64, 19.6, 20.6, 21.2)%, respectively. Figure (4-22) shows these details.

Table (٤-١١): Reduction in cement content when using (SMF) superplasticizer

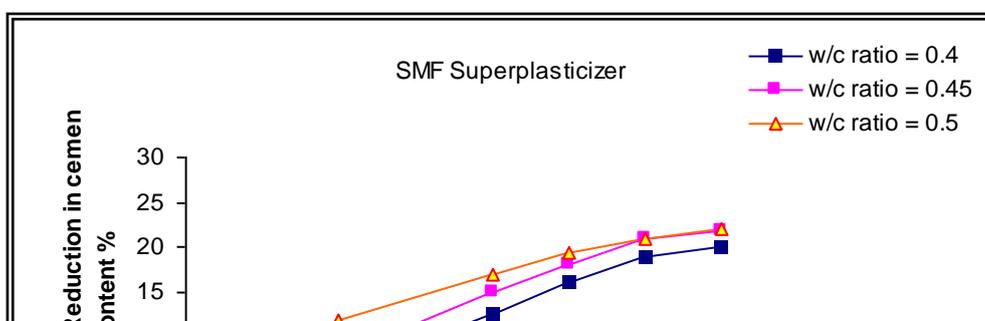
| Mix No. | W/C ratio | SMF dosage % weight of cement | Water content kg/m ³ | Cement content kg/m ³ | % Cement Reduction |
|---|-----------|-------------------------------|---------------------------------|----------------------------------|--------------------|
| Mix with constant w/c ratio = ٠.٤ with slump (٨٠-١١٠) mm | | | | | |
| ١ | ٠.٤ | ٠ | ١٤٤ | ٣٦٠ | ٠ |
| | ٠.٤ | ١ | ١٣٥.٣٦ | ٣٣٨.٤ | ٦ |
| | ٠.٤ | ٢ | ١٢٦ | ٣١٥ | ١٢.٥ |
| | ٠.٤ | ٢.٥ | ١٢١ | ٣٠٢.٥ | ١٦ |
| | ٠.٤ | ٣ | ١١٦.٦٤ | ٢٩١.٦ | ١٩ |
| | ٠.٤ | ٣.٥ | ١١٥ | ٢٨٨ | ٢٠ |
| Mix with constant w/c ratio = ٠.٤٥ with slump (٩٠-١٢٠) mm | | | | | |
| ١ | ٠.٤٥ | ٠ | ١٦٢ | ٣٦٠ | ٠ |
| | ٠.٤٥ | ١ | ١٤٩.٠٤ | ٣٣١.٢ | ٨ |
| | ٠.٤٥ | ٢ | ١٣٧.٨٨ | ٣٠٦.٤ | ١٥ |
| | ٠.٤٥ | ٢.٥ | ١٣٢.٨٤ | ٢٩٥.٢ | ١٨ |
| | ٠.٤٥ | ٣ | ١٢٧.٨ | ٢٨٤ | ٢١ |
| | ٠.٤٥ | ٣.٥ | ١٢٦.٧٢ | ٢٨١.٦ | ٢١.٨ |
| Mix with constant w/c ratio = ٠.٥ with slump (١٠٠-١٣٠) mm | | | | | |
| ٢ | ٠.٥ | ٠ | ١٨٠ | ٣٦٠ | ٠ |
| | ٠.٥ | ١ | ١٥٨.٤ | ٣١٦.٨ | ١٢ |
| | ٠.٥ | ٢ | ١٤٩.٤ | ٢٩٨.٨ | ١٧ |
| | ٠.٥ | ٢.٥ | ١٤٤.٩ | ٢٨٩.٨ | ١٩.٥ |
| | ٠.٥ | ٣ | ١٤٢.٢ | ٢٨٤.٤ | ٢١ |
| | ٠.٥ | ٣.٥ | ١٤٠.٤ | ٢٨٠.٨ | ٢٢ |

**Table (٤-١٢): Reduction in cement content when using (SNF)
superplasticizer**

| Mix No. | W/C ratio | SMF dosage % weight of cement | Water content kg/m ^٣ | Cement content kg/m ^٣ | % Cement Reduction |
|---|-----------|-------------------------------|---------------------------------|----------------------------------|--------------------|
| Mix with constant w/c ratio = ٠.٤ with slump (٨٠-١١٠) mm | | | | | |
| ١ | ٠.٤ | ٠ | ١٤٤ | ٣٦٠ | ٠ |
| | ٠.٤ | ١ | ١٣٢.٨ | ٣٣٢ | ٧.٨ |
| | ٠.٤ | ٢ | ١٢٥ | ٣١٢.٥ | ١٣.٢ |
| | ٠.٤ | ٢.٥ | ١١٨.٧ | ٢٩٦.٧٥ | ١٧.٦ |
| | ٠.٤ | ٣ | ١١٥ | ٢٨٧.٥ | ٢٠ |
| | ٠.٤ | ٣.٥ | ١١٢ | ٢٨٠ | ٢٢.٢ |
| Mix with constant w/c ratio = ٠.٤٥ with slump (٩٠-١٢٠) mm | | | | | |
| ١ | ٠.٤٥ | ٠ | ١٦٢ | ٣٦٠ | ٠ |
| | ٠.٤٥ | ١ | ١٤٧.٤٥ | ٣٢٧.٦٦ | ٩ |
| | ٠.٤٥ | ٢ | ١٣٨.٥٨ | ٣٠٧.٩٥ | ١٤.٥ |
| | ٠.٤٥ | ٢.٥ | ١٣٠.٦٤ | ٢٩٠.٣ | ١٩.٤ |
| | ٠.٤٥ | ٣ | ١٢٦ | ٢٨٠ | ٢٢.٢ |
| | ٠.٤٥ | ٣.٥ | ١٢٥.٨ | ٢٧٩.٦ | ٢٢.٣٣ |
| Mix with constant w/c ratio = ٠.٥ with slump (١٠٠-١٣٠) mm | | | | | |
| ٢ | ٠.٥ | ٠ | ١٨٠ | ٣٦٠ | ٠ |
| | ٠.٥ | ١ | ١٥٥.٧٥ | ٣١١.٥ | ١٣.٥ |
| | ٠.٥ | ٢ | ١٤٨ | ٢٩٦ | ١٧.٨ |
| | ٠.٥ | ٢.٥ | ١٤٥.٣٣ | ٢٩٠.٦٦ | ٢١.٧ |
| | ٠.٥ | ٣ | ١٤٠.٩٢ | ٢٨١.٨٤ | ٢٢ |
| | ٠.٥ | ٣.٥ | ١٤٠ | ٢٨٠ | ٢٢.٢ |

Table (٤-١٣): Reduction in cement content when using (MLS) superplasticizer

| Mix No. | W/C ratio | SMF dosage % weight of cement | Water content kg/m ³ | Cement content kg/m ³ | % Cement Reduction |
|---|-----------|-------------------------------|---------------------------------|----------------------------------|--------------------|
| Mix with constant w/c ratio = ٠.٤ with slump (٨٠-١١٠) mm | | | | | |
| ١ | ٠.٤ | ٠ | ١٤٤ | ٣٦٠ | ٠ |
| | ٠.٤ | ١ | ١٣٢ | ٣٣٠ | ٨.٣٣ |
| | ٠.٤ | ٢ | ١٢٥ | ٣١٢.٥ | ١٣.٢ |
| | ٠.٤ | ٢.٥ | ١٢١ | ٣٠٢.٥ | ١٦ |
| | ٠.٤ | ٣ | ١١٥ | ٢٨٧.٥ | ٢٠ |
| | ٠.٤ | ٣.٥ | ١١٣ | ٢٨٢.٥ | ٢١.٥٣ |
| Mix with constant w/c ratio = ٠.٤٥ with slump (٩٠-١٢٠) mm | | | | | |
| ١ | ٠.٤٥ | ٠ | ١٦٢ | ٣٦٠ | ٠ |
| | ٠.٤٥ | ١ | ١٤٥.٨ | ٣٢٤ | ١٠ |
| | ٠.٤٥ | ٢ | ١٣٦.٩٨ | ٣٠٤.٤ | ١٥.٥ |
| | ٠.٤٥ | ٢.٥ | ١٣٠.٧٥ | ٢٩٠.٥٥ | ١٩.٣ |
| | ٠.٤٥ | ٣ | ١٢٥ | ٢٧٧.٧٨ | ٢٢.٨ |
| | ٠.٤٥ | ٣.٥ | ١٢٤.٧٣ | ٢٧٧.١٨ | ٢٣ |
| Mix with constant w/c ratio = ٠.٥ with slump (١٠٠-١٣٠) mm | | | | | |
| ٢ | ٠.٥ | ٠ | ١٨٠ | ٣٦٠ | ٠ |
| | ٠.٥ | ١ | ١٥٦ | ٣١٢ | ١٣.٣٣ |
| | ٠.٥ | ٢ | ١٤٨.٢٥ | ٢٩٦.٥ | ١٧.٦٤ |
| | ٠.٥ | ٢.٥ | ١٤٤.٧٥ | ٢٨٩.٥ | ١٩.٦ |
| | ٠.٥ | ٣ | ١٤٣ | ٢٨٦ | ٢٠.٦ |
| | ٠.٥ | ٣.٥ | ١٤١.٩٨ | ٢٨٣.٧٦ | ٢١.٢ |



2.4. Use of superplasticizers for re-tempering concrete mixes

If the workability is to be restored for a period higher than (60 minutes), the re-dosage of superplasticizers is used as a practical method to raise the workability after 60 minutes of mixing. The amount of re-dosage of superplasticizer must be adequate to act on the cement particles and on hydration products. Therefore re-dosage of superplasticizer is higher than normal dosage. Table (4-14) shows details of re-dosing. The experimental results show that the effect of re-dosage of (MLS) is higher than that of (SNF) and in turn this is higher than that of (SMF). Table (4-15) shows that the percentages of recover of-slump compared with the original slump with (0.4, 0.45, 0.5) w/c ratio, were (88, 90, 92)%, (77, 86, 90)%, (70, 80, 88)% for (MLS, SNF, SMF) respectively. And for the second dosage the percentages were (80, 82, 83.3)%, (73, 70, 77)%, (60, 70, 72)%. In the other hand from table (4-16) it can indicated that the slump loss with re-dosing higher than in original dosage, the increase rate of slump loss with re-dosage was (12, 6, 0)%, (9, 6, 0)%, (0, 4, 4) for first dosage, and (3.0, 2, -4)%, (-2, 2, 0)%, (-1, 1, 6))% for second dosage with (SMF, SNF, MLS) superplasticizers and (0.3, 0.45, 0.5) w/c ratios respectively . Figure (4-26) shows the superplasticized concrete behavior with re-dosage. From number of re-dosing trails it can be seen that re-dosing more than two steps gives the concrete mix harmful properties such as retarding setting time, segregation and decrease in compressive strength.

4.2.5. Using water for re-tempering superplasticized concrete mix

Added amount of water to superplasticized concrete leads to standpoint workability as shown in table (٤-١٧). The results in figure (٤-٢٣) show the effect of adding water on slump loss in only one step of water addition. More steps of water addition are not recommended because lead to deform the concrete mix properties.

Table (٤-١٤): Re-dosing concrete mixes with various types of superplasticizers

| Original w/c | Original Initial slump (mm) | Original final slump | Re-dosage after ١ hour in (% weight of cement) | Slump in mm | Re-dosage after ١.٥ hour in (% weight of cement) | Slump in mm |
|----------------------|-----------------------------|----------------------|--|-------------|--|-------------|
| SMF Superplasticizer | | | | | | |
| ٠.٤ | ١٠٠ | ٣٣ | ٠.٣٢ | ١٢٠ | ٠.٣ | ٩٠ |
| ٠.٤٥ | ١١٠ | ٤٦ | ٠.٢٩ | ١٣٥ | ٠.٢٩ | ١٠٥ |
| ٠.٥ | ١٣٥ | ٦٠ | ٠.٢٧ | ١٤٠ | ٠.٢٦ | ١٢٠ |
| SNF Superplasticizer | | | | | | |
| ٠.٤ | ٩٥ | ٣٣ | ٠.٣٥ | ١٣٠ | ٠.٣ | ١٠٠ |
| ٠.٤٥ | ١١٠ | ٤٠ | ٠.٣ | ١٤٠ | ٠.٢٧ | ١٠٥ |
| ٠.٥ | ١٤٠ | ٦٠ | ٠.٢٨ | ١٤٠ | ٠.٢٧ | ١٢٢ |
| MLS Superplasticizer | | | | | | |
| ٠.٤ | ١٠٥ | ٤٣ | ٠.٣ | ١٢٠ | ٠.٣ | ١١٠ |
| ٠.٤٥ | ١٢٠ | ٥٥ | ٠.٢٥ | ١٤٠ | ٠.٢٧ | ١٢٠ |
| ٠.٥ | ١٥٠ | ٦٥ | ٠.٢٥ | ١٤٠ | ٠.٢٦ | ١٢٥ |

Table (٤-١٥): Variation in slump for re-dosing superplasticized concrete mixes

| Sup. Type | W/C ratios | Slump in (mm) | | | | | Slump with re-dosage in (mm) | | | Slump with re-dosage in (mm) | | |
|-----------|------------|---------------|-----|-----|-----|-----|------------------------------|-------|-------|------------------------------|---------|---------|
| | | *٥ | ١٥ | ٣٠ | ٤٥ | ٦٠ | First dosage (٦٠-٩٠) min | | | second dosage (٩٠-١٢٠) min | | |
| | | min | min | min | min | min | ٦٥ | ٧٥ mi | ٩٠ mi | ٩٥ min | ١١٥ min | ١٢٠ min |
| SMF | ٠.٤ | ١٠٠ | ٧٥ | ٥٥ | ٤٥ | ٣٣ | ٧٥ | ٤٠ | ٣٠ | ٩٠ | ٤٣ | ٢٠ |
| | ٠.٤٥ | ١١٠ | ٨٥ | ٧٠ | ٥٣ | ٤٦ | ٩٤ | ٥٠ | ٣٣ | ١٠٥ | ٥٥ | ٢٨ |
| | ٠.٥ | ١٣٥ | ١٠٠ | ٨٠ | ٧٠ | ٦٠ | ١١٩ | ٦٠ | ٤٢ | ١٢٠ | ٦٠ | ٣٢ |
| SNF | ٠.٤ | ٩٥ | ٧٠ | ٥٥ | ٤٣ | ٣٣ | ٧٥ | ٣٥ | ٢٨ | ١٠٠ | ٤٠ | ٢٢ |
| | ٠.٤٥ | ١١٠ | ٨٠ | ٦٥ | ٥٠ | ٤٠ | ٩٥ | ٥٠ | ٣٥ | ١٠٥ | ٥٥ | ٢٥ |

| | | | | | | | | | | | | |
|-----|------|-----|-----|-----|-----|-----|-----|----|----|-----|----|----|
| | 0.5 | 1.4 | 1.0 | 1.0 | 7.0 | 7.0 | 126 | 77 | 44 | 122 | 70 | 33 |
| MLS | 0.4 | 1.0 | 1.0 | 73 | 0.0 | 43 | 93 | 00 | 33 | 110 | 40 | 18 |
| | 0.45 | 1.2 | 1.0 | 70 | 7.0 | 00 | 108 | 70 | 38 | 120 | 48 | 23 |
| | 0.5 | 1.0 | 1.1 | 1.0 | 7.0 | 70 | 138 | 70 | 40 | 120 | 00 | 20 |

Table (4-16): Slump loss in re-dosing and original superplasticized concrete mixes

| Sup. Type | W/C ratios | Slump in (mm) | | | | | % Variation in slump for re-dosing mix compared with original slump | | % Increase in slump loss for re-dosing mixes compared with original slump | |
|-----------|------------|---------------|--------|--------|--------|--------|---|----------------------------|---|----------------------------|
| | | 0 min | 10 min | 30 min | 40 min | 60 min | First dosage (10-90) min | second dosage (90-120) min | First dosage (10-90) min | second dosage (90-120) min |
| | | SMF | 0.4 | 100 | 70 | 00 | 40 | 33 | 70 | 70 |
| | 0.45 | 110 | 80 | 70 | 03 | 47 | 80 | 70 | 7 | 2 |
| | 0.5 | 130 | 100 | 80 | 70 | 70 | 88 | 72 | 0 | -4 |
| SNF | 0.4 | 90 | 70 | 00 | 43 | 33 | 77 | 73 | 9 | -2 |
| | 0.45 | 110 | 80 | 70 | 00 | 40 | 87 | 70 | 7 | 2 |
| | 0.5 | 140 | 100 | 80 | 70 | 70 | 90 | 77 | 0 | 0 |
| MLS | 0.4 | 100 | 80 | 73 | 00 | 43 | 88 | 80 | 0 | -1 |
| | 0.45 | 120 | 90 | 70 | 70 | 00 | 90 | 82 | 4 | 1 |
| | 0.5 | 100 | 110 | 80 | 70 | 70 | 92 | 83.3 | 4 | 7 |

Table (4-17): Re-watering superplasticized concrete.

| Original w/c | Original Water content in Kg/m ³ | Original slump in (mm) | Additional water after 1 hour in Kg/m ³ | % Added water | Re-slump in (mm) | Final slump after 90 min in (mm) |
|-----------------------------|---|------------------------|--|---------------|------------------|----------------------------------|
| (2.7%) SMF Superplasticizer | | | | | | |
| 0.4 | 144 | 120 | 101 | 70 | 100 | 20 |
| 0.45 | 172 | 130 | 93 | 57.4 | 120 | 30 |
| 0.5 | 180 | 140 | 80 | 47 | 130 | 40 |
| (2.7%) SNF Superplasticizer | | | | | | |

| | | | | | | |
|-----------------------------|-----|-----|-----|-------|-----|----|
| 0.4 | 144 | 130 | 110 | 76.4 | 110 | 27 |
| 0.45 | 162 | 140 | 100 | 61.73 | 130 | 30 |
| 0.5 | 180 | 140 | 90 | 00 | 130 | 48 |
| (2.0%) MLS Superplasticizer | | | | | | |
| 0.4 | 144 | 120 | 110 | 76.4 | 110 | 20 |
| 0.45 | 162 | 140 | 90 | 08.6 | 120 | 30 |
| 0.5 | 180 | 140 | 90 | 00 | 133 | 37 |

Unsuperplasticized

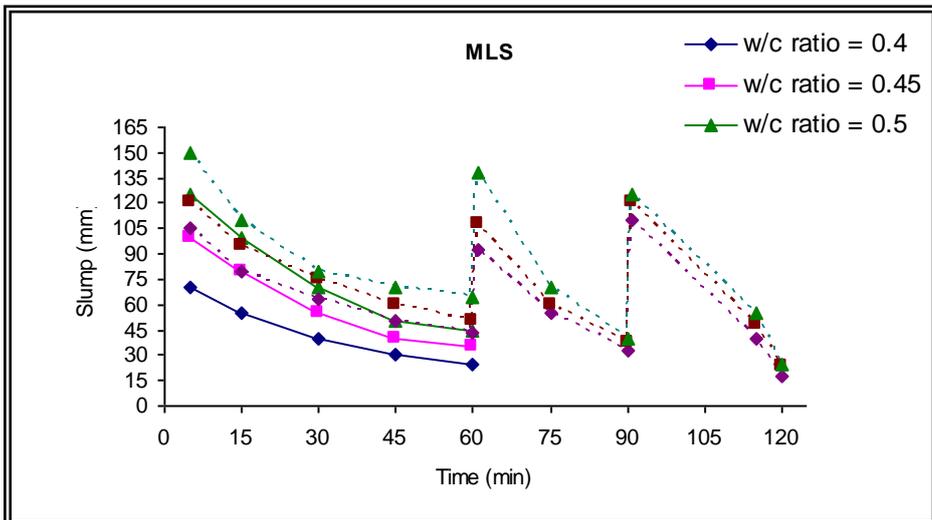
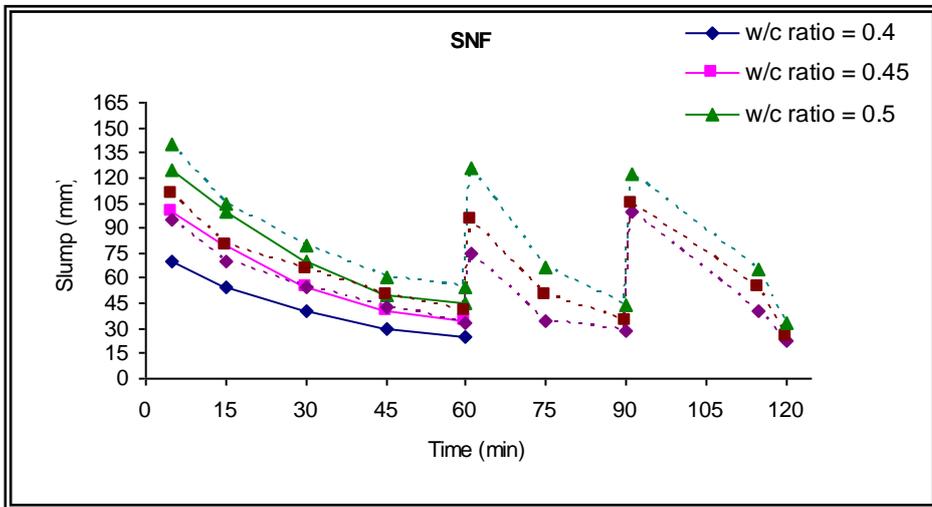
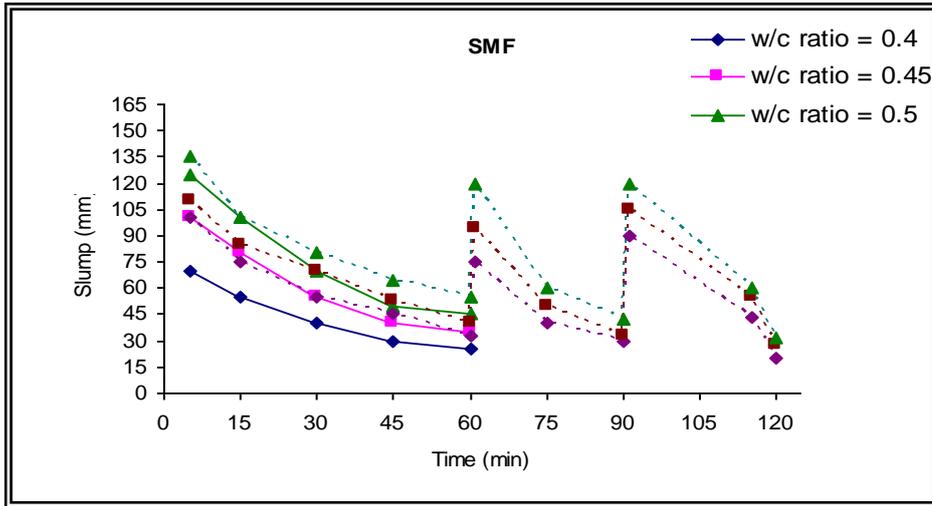


Figure (4-23): Variation in effect of re-dosing superplasticized concrete mixes in various types of superplasticizers with different w/c ratios

Unsuperplasticized ———

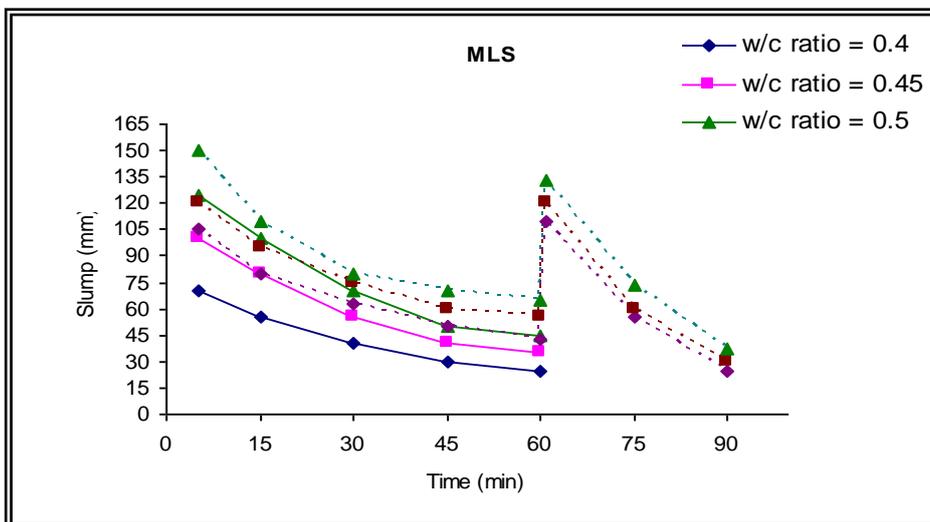
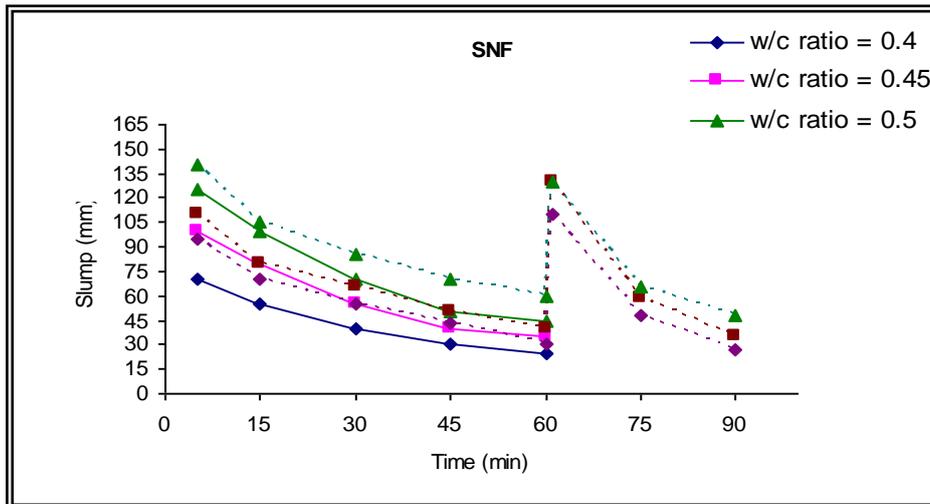
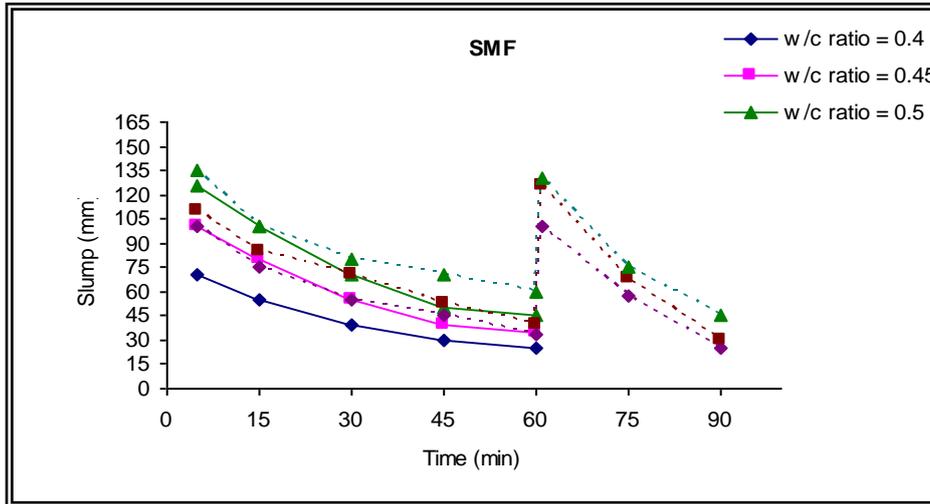


Figure (4-14): Effect of re-tampering with added water for superplasticized concrete mixes with different w/c ratios

4. 3. Compressive Strength test results:

4. 3. 1. Compressive strength of unsuperplasticized concrete:

The influence of the water/cement ratio on strength does not truly constitute a law because the water/cement ratio rule does not include many qualifications necessary for its validity. In particular, strength at any water/cement ratio depends on the degree of hydration of cement and its chemical and physical properties, the temperature at which hydration takes place, the air content of the concrete and also the change in the effective water/cement ratio^[110].

Mixes having the same cement richness and converging w/c ratio approximately have the same development of compressive strength during (7, 28, and 90) days age, and different for different w/c ratios.

Compressive strength increases with age but with different rates of strength development, The practical relations between water in concrete mix and its strength discussed so far involve the quantity of water in the mix. Consider as effective that water, which occupies space outside the aggregate particles when the gross volume of concrete becomes stabilized.

For mixes with (0.4, 0.45, 0.5) w/c ratio, compressive strength results are shown in figure (4-24) and table (4-18). It can be seen that a reduction in compressive strength with the increase in w / c ratio has taken place.

Table (٤-١٨): Compressive strength results for concrete mixes with out superplasticizers.

* Compressive strength results = average result of three specimens

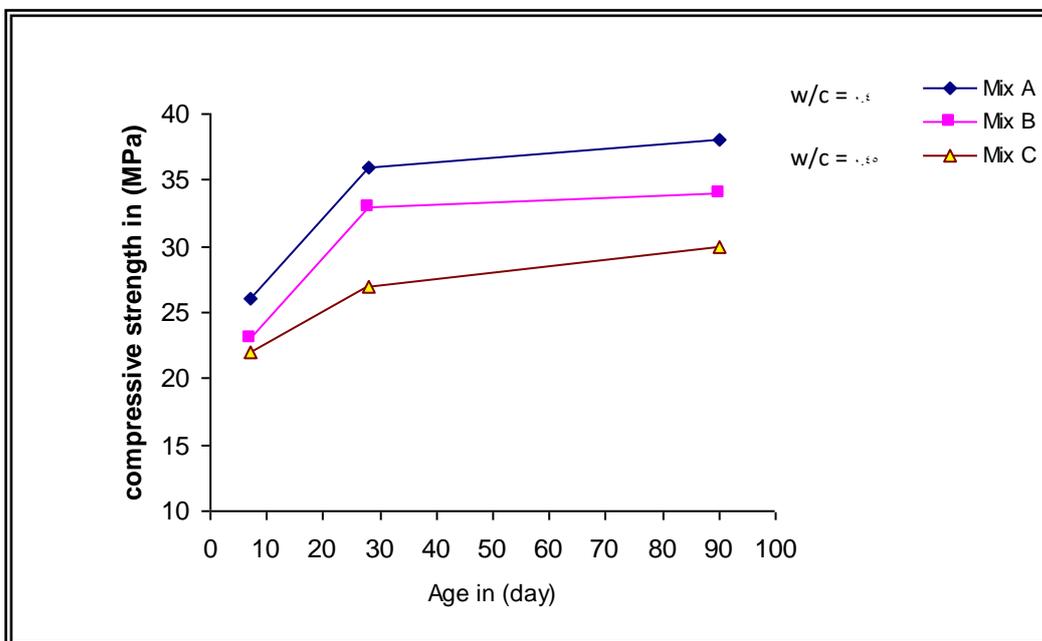


Figure (٤-٢٤): Development of compressive strength with different w/c ratios.

٤. ٣. ٣. Compressive strength of concrete mixes with superplasticizers:

For superplasticized concrete mixes with (SMF, SNF, MLS) and (0.4, 0.5, 0.6) w/c ratio, compressive strength results are shown in figure (4-26) through (4-27). It can be seen a reduction in compressive strength for these mixes with increase in dosage of superplasticizers, because added water comes from the activity and interaction of superplasticizers with concrete components that leads to presence more water in concrete mixes higher than that concrete hydration needs, which lead to reduction in compressive strength.

4. 2. 2. Compressive strength of concrete mixes with superplasticizers

when used as water reducer:

Generally using superplasticizers in concrete mix makes significant reduction in the w/c ratio possible leading to a considerable increase in compressive strength compared with unsuperplasticized concrete.

From figure (4-28) it can be seen the effect of using (SMF) superplasticizer in concrete mixes with different (dosages, w/c) on compressive strength for ages (7, 28, 90) days.

From figure (4-29) it is noticed that the compressive strength of superplasticized concrete with (SNF) is higher than that of unsuperplasticized concrete.

Superplasticized concrete with (MLS) produces concrete mixes with development in compressive strength less than in mixes with other superplasticizers. Figure (4-30) shows these results.

For concrete mixes with (SMF, SNF, MLS) when these admixtures have a behavior of high water reducing so water content will decrease more than

with low initial slump mix and the compressive strength will improve higher than compressive strength of reference mixes. The higher compressive strength obtained for superplasticized concrete are due to significantly reduced in w/c ratios. That leading to a considerable reduction in total porosity. Use superplasticizer in concrete mix ensures a more uniform dispersion of cement agglomerates into individual particles and deflocculating the watery ettringite shell around the cement grains and help to complete hydrate action. Which help concrete mixes to have higher development in compressive strength [1,9]. (SNF) associated (SMF) that they have lower air content than in (MLS) so their development in compressive strength is better than (MLS) [1]. From the previous discussion superplasticizers as (SMF and SNF) are copolymer or polymer components, which have an organic nature. And that gives ability to build long polymer chains with cement components. These results make a strong net overlap with concrete components and work as reinforcement inside concrete mix. So that the increases in volume of these chains with continuation of interaction leads to fill the spaces between hydration products and build new physical and chemical bonds that cause to increase cohesive of mixture [1,9].

4. 3. 4. Compressive strength of re-tamped concrete mixes:

Compressive strength for re-tempered superplasticized concrete with re-dosing or re-watering is better, that comes from compensation water evaporators from mixes which help to complete cement hydration and increase gel /space ratio [1,9] that leads to little increase in compressive strength.

١. Figure (٤-٣١) shows effect of re-tempering by using re-dosage superplasticizers on compressive strength.

٢. Figure (٤-٣٢) shows effect of re-tempering by using re-watering. on compressive strength.

Table (٤-١٩): Compressive strength of normally superplasticized concrete mixes with SMF

| W/C ratios | Superplasticizers type | Sup. dosage % weight of cement | Compressive Strength (mpa) | | |
|------------|------------------------|--------------------------------|----------------------------|---------|---------|
| | | | ٧ days | ٢٨ days | ٩٠ days |
| ٠.٤ | SMF | ٠ | ٢٦ | ٣٦ | ٣٨ |
| | | ١ | ٢٥ | ٣٣ | ٣٦ |
| | | ٢ | ٢٣ | ٣٠ | ٣٣ |
| | | ٢.٥ | ٢٣ | ٢٩ | ٣١ |
| | | ٣ | ٢١ | ٢٨ | ٣١ |
| | | ٣.٥ | ٢٠ | ٢٧ | ٣٠ |
| ٠.٤٥ | SMF | ٠ | ٢٣ | ٣٣ | ٣٤ |

| | | | | | |
|-----|-----|-----|------|------|----|
| | | 1 | 23 | 29 | 33 |
| | | 2 | 21 | 28 | 30 |
| | | 2.0 | 20.0 | 26 | 28 |
| | | 3 | 19 | 24 | 20 |
| | | 3.0 | 17.0 | 23 | 20 |
| 1.0 | SMF | 0 | 22 | 27 | 30 |
| | | 1 | 20 | 20 | 28 |
| | | 2 | 18 | 22.0 | 28 |
| | | 2.0 | 18 | 20 | 20 |
| | | 3 | 17 | 20 | 23 |
| | | 3.0 | 17 | 18 | 20 |

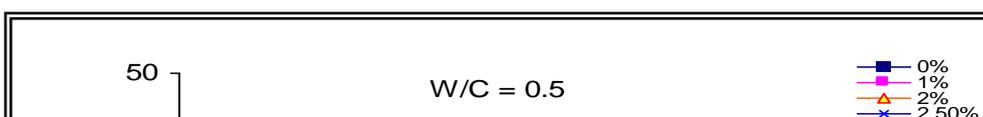
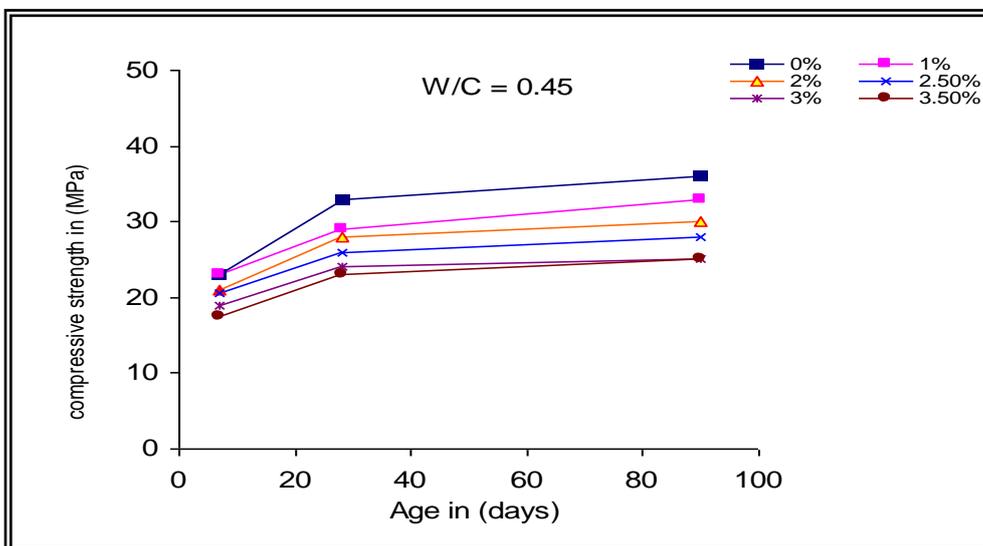
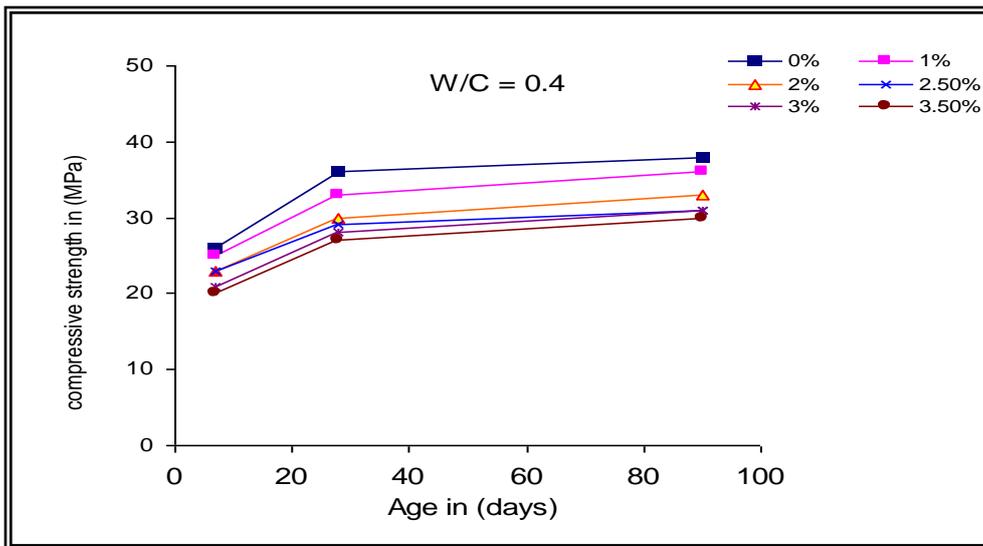


Table (٤-٢٠): Compressive strength of normally superplasticized concrete mixes with SNF

| W/C ratios | Superplasticizers type | Sup. dosage % weight of cement | Compressive Strength (Mpa) | | |
|------------|------------------------|--------------------------------|----------------------------|---------|---------|
| | | | ٧ days | ٢٨ days | ٩٠ days |
| ٠.٤ | SNF | ٠ | ٢٦ | ٣٦ | ٣٨ |
| | | ١ | ٢٦ | ٣٥ | ٣٤ |
| | | ٢ | ٢٣ | ٣٠ | ٣٠ |
| | | ٢.٥ | ٢١ | ٢٧ | ٣٠ |
| | | ٣ | ٢٠ | ٢٧ | ٢٨ |
| | | ٣.٥ | ٢٠ | ٢٥ | ٢٦ |
| ٠.٤٥ | SNF | ٠ | ٢٣ | ٣٣ | ٣٤ |
| | | ١ | ٢١ | ٢٨ | ٣١ |
| | | ٢ | ٢٠.٥ | ٢٦ | ٣٠ |
| | | ٢.٥ | ١٩ | ٢٣ | ٢٧ |
| | | ٣ | ١٩ | ٢٣ | ٢٥ |
| | | ٣.٥ | ١٧.٤ | ٢١.٧ | ٢٥ |
| ٠.٥ | SNF | ٠ | ٢٢ | ٢٧ | ٣٠ |

| | | | | | |
|--|--|-----|----|----|----|
| | | ۱ | ۲۲ | ۳۰ | ۳۳ |
| | | ۲ | ۲۰ | ۲۸ | ۲۹ |
| | | ۲.۰ | ۲۰ | ۲۰ | ۲۰ |
| | | ۳ | ۱۸ | ۲۴ | ۲۰ |
| | | ۳.۰ | ۱۷ | ۲۰ | ۲۳ |

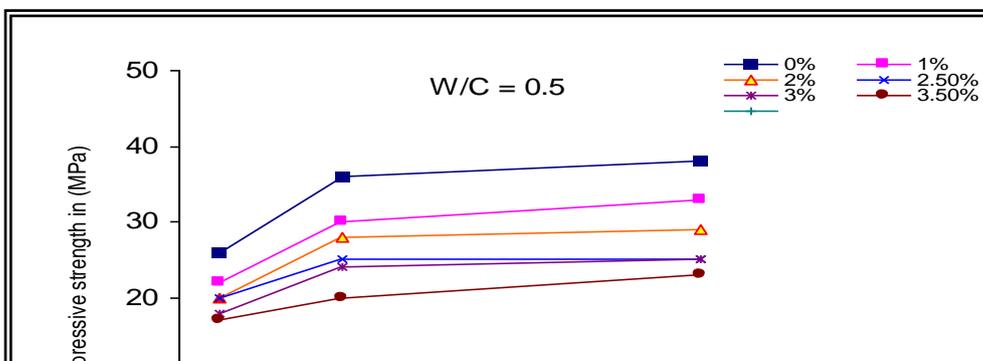
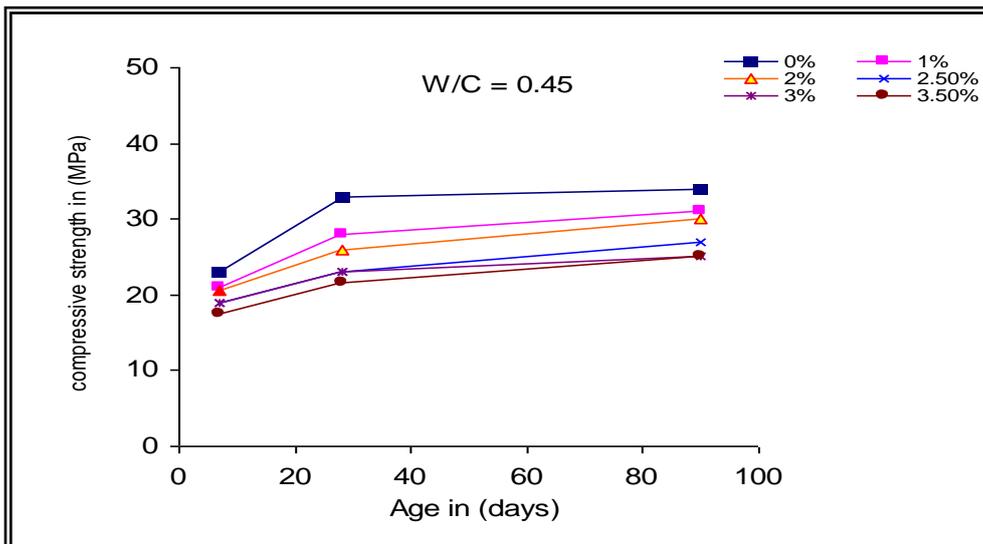
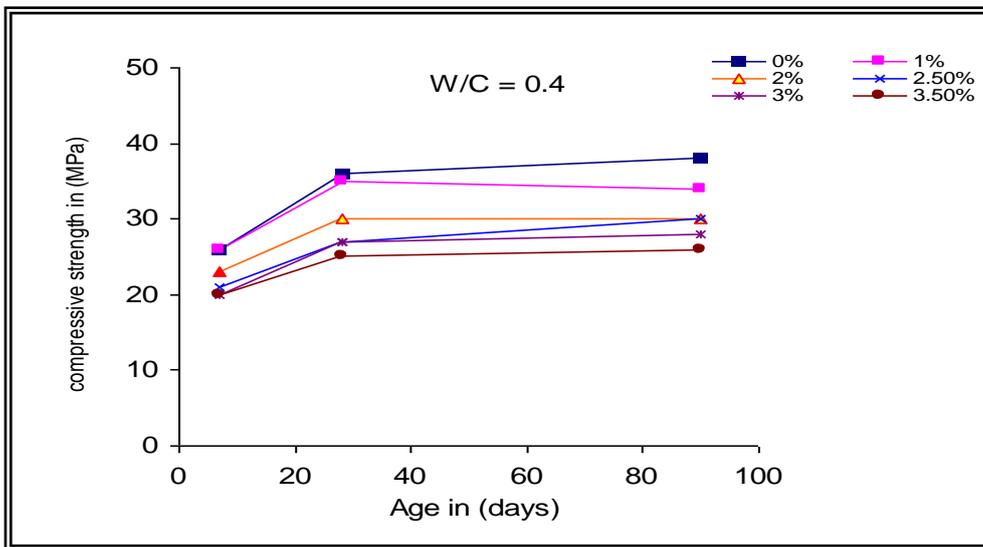


Table (٤-٢١): Compressive strength of normally superplasticized concrete mixes with MLS

| W/C ratios | Superplasticizers type | Sup. dosage % weight of cement | Compressive Strength (Mpa) | | |
|------------|------------------------|--------------------------------|----------------------------|---------|---------|
| | | | ٧ days | ٢٨ days | ٩٠ days |
| ٠.٤ | MLS | ٠ | ٢٦ | ٣٦ | ٣٨ |
| | | ١ | ٢٣.٨ | ٣٢ | ٣٣ |
| | | ٢ | ٢١ | ٢٩ | ٢٩ |
| | | ٢.٥ | ٢٠ | ٢٤.٣ | ٢٥ |
| | | ٣ | ١٨.٥ | ٢١ | ٢٣ |
| | | ٣.٥ | ١٧ | ١٩ | ٢٠ |
| ٠.٤٥ | MLS | ٠ | ٢٣ | ٣٣ | ٣٤ |
| | | ١ | ٢١ | ٢٩ | ٣٠ |
| | | ٢ | ١٩ | ٢٥ | ٢٧.٢٥ |
| | | ٢.٥ | ١٨ | ٢٣ | ٢٣.٥ |
| | | ٣ | ١٧.٣٥ | ٢٠ | ٢٣ |
| | | ٣.٥ | ١٦ | ١٨ | ١٩.١٥ |
| ٠.٥ | MLS | ٠ | ٢٢ | ٢٧ | ٣٠ |
| | | ١ | ٢٠ | ٢٤.٤٥ | ٢٨.٥ |
| | | ٢ | ١٨ | ٢١ | ٢٤.٦ |
| | | ٢.٥ | ١٧ | ٢٠ | ٢٣ |

| | | | | | |
|--|--|-----|-------|----|------|
| | | ۳ | ۱۰,۲۰ | ۲۰ | ۲۰ |
| | | ۳,۰ | ۱۰ | ۱۸ | ۱۸,۳ |

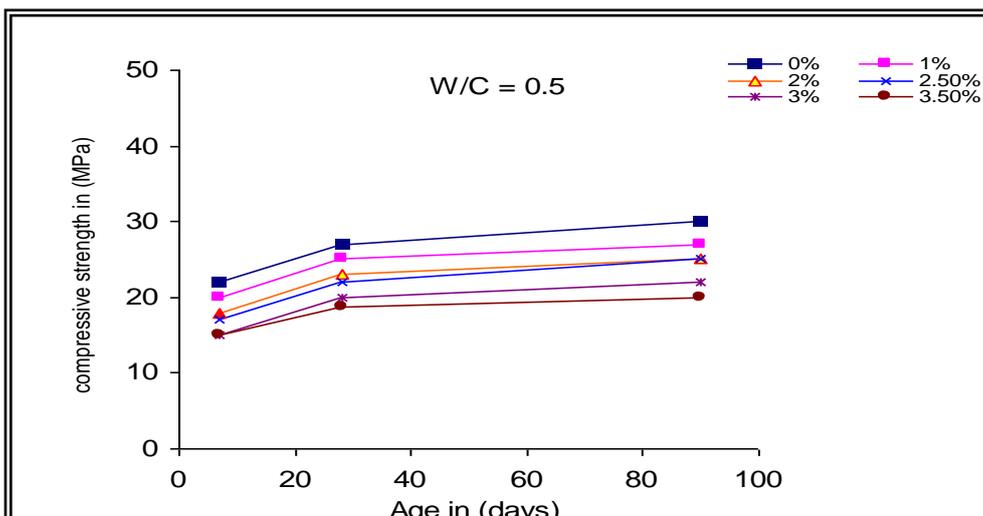
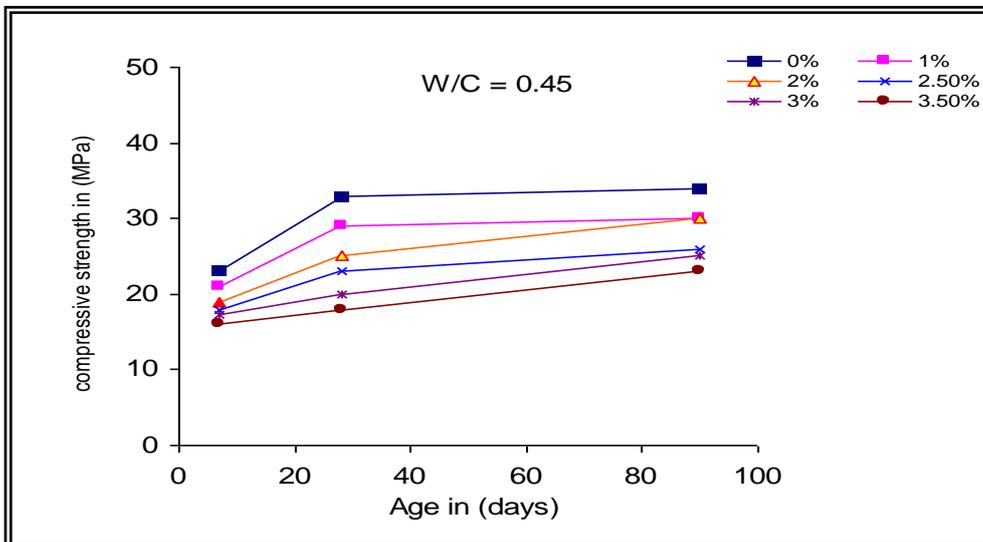
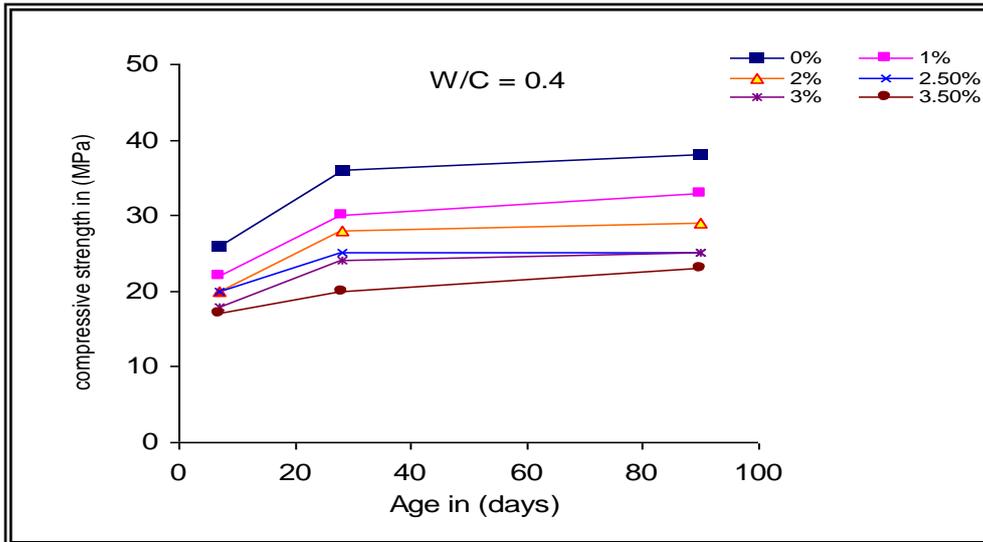


Table (4-22): Compressive strength of superplasticized concrete mixes with superplasticizers (SMF) used as water reducers

| W/C ratio | Superplasticizer type | Final W/C ratio | Sup. Dosage % weight of cement | Compressive Strength (mpa) | | |
|-----------|-----------------------|-----------------|--------------------------------|----------------------------|---------|---------|
| | | | | 7 days | 28 days | 90 days |
| 0.4 | SMF | 0.4 | 0 | 26 | 36 | 38 |
| | | 0.38 | 1 | 30 | 36 | 38 |
| | | 0.36 | 2 | 33 | 38 | 40 |
| | | 0.34 | 2.0 | 36 | 40.0 | 42.6 |
| | | 0.32 | 3 | 38 | 40.8 | 42 |
| | | 0.3 | 3.0 | 38 | 40 | 41.0 |
| 0.45 | SMF | 0.45 | 0 | 23 | 33 | 34 |
| | | 0.44 | 1 | 27 | 30 | 30 |
| | | 0.43 | 2 | 32 | 39 | 39.4 |
| | | 0.42 | 2.0 | 33 | 40.8 | 41 |
| | | 0.41 | 3 | 33.0 | 40 | 41 |
| | | 0.4 | 3.0 | 33 | 39 | 40.40 |
| 0.5 | SMF | 0.5 | 0 | 22 | 27 | 30 |
| | | 0.49 | 1 | 20 | 30 | 33 |
| | | 0.48 | 2 | 28 | 34 | 37 |
| | | 0.47 | 2.0 | 30 | 38.6 | 40 |
| | | 0.46 | 3 | 30 | 38 | 40 |
| | | 0.45 | 3.0 | 29 | 37.60 | 39 |

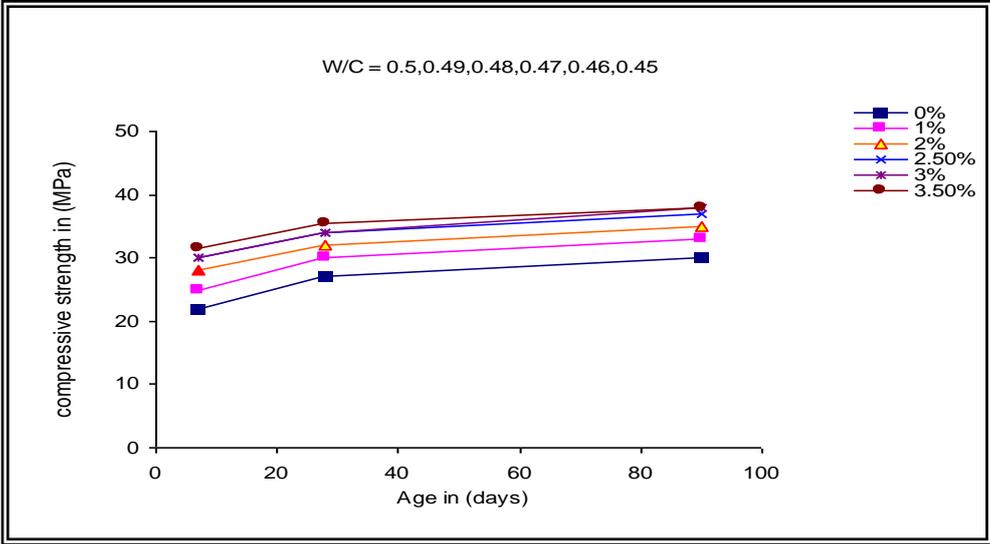
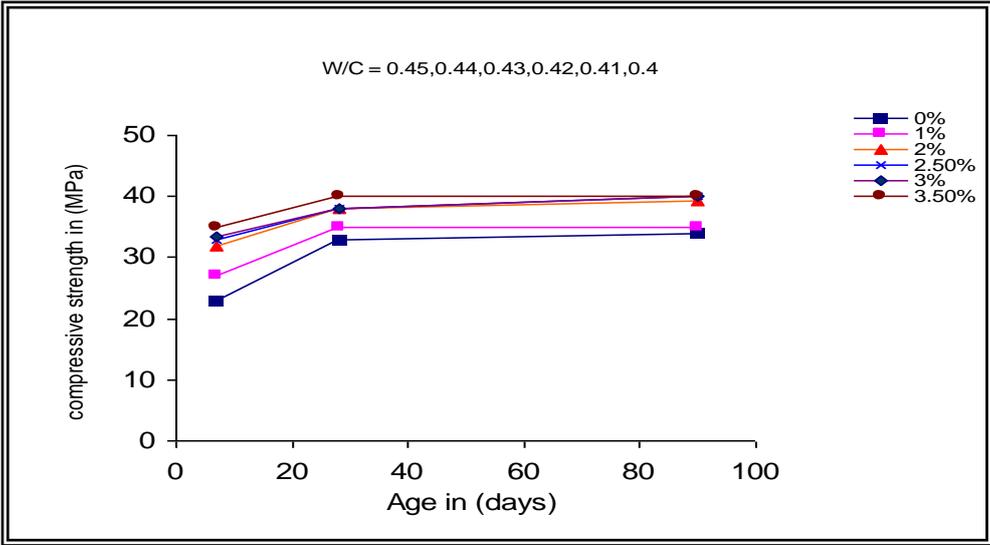
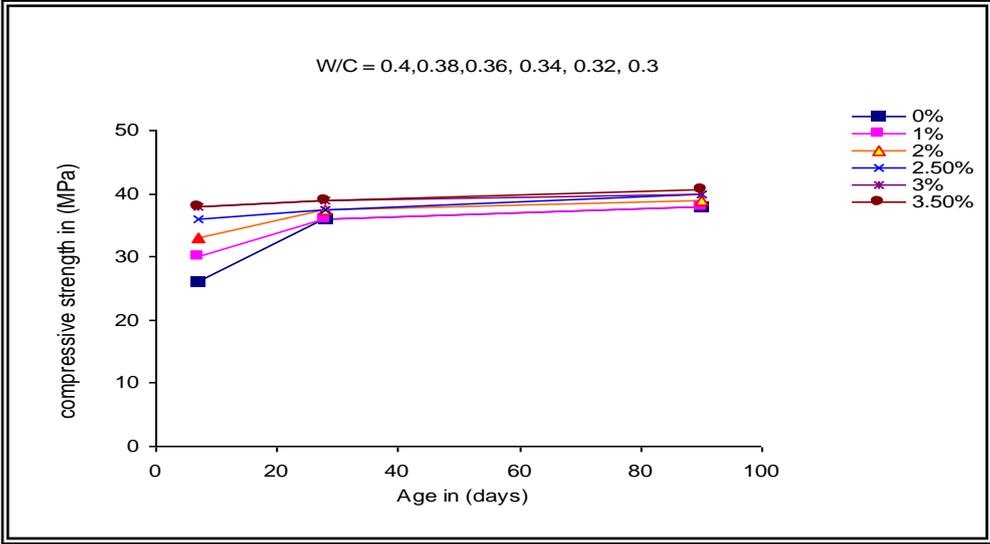


Figure (4-28): Development compressive strength for superplasticized

Table (٤-٢٣): Compressive strength of superplasticized concrete mixes with superplasticizers (SNF) used as water reducers

| W/C ratio | Superplasticizer type | Final W/C ratio | Sup. Dosage % weight of cement | Compressive Strength (mpa) | | |
|-----------|-----------------------|-----------------|--------------------------------|----------------------------|---------|---------|
| | | | | ٧ days | ٢٨ days | ٩٠ days |
| ٠.٤ | SNF | ٠.٤ | ٠ | ٢٦ | ٣٦ | ٣٨ |
| | | ٠.٣٨ | ١ | ٣٠ | ٣٦ | ٣٨ |
| | | ٠.٣٦ | ٢ | ٣٣ | ٣٨ | ٣٩ |
| | | ٠.٣٤ | ٢.٥ | ٣٥ | ٤٠ | ٤٣ |
| | | ٠.٣٢ | ٣ | ٣٨ | ٤١ | ٤٣.٦ |
| | | ٠.٣ | ٣.٥ | ٣٨ | ٤٠ | ٤١ |
| ٠.٤٥ | SNF | ٠.٤٥ | ٠ | ٢٣ | ٣٣ | ٣٤ |
| | | ٠.٤٤ | ١ | ٢٥ | ٣٦ | ٣٦.٨ |
| | | ٠.٤٣ | ٢ | ٢٧ | ٣٨ | ٣٩.٤ |
| | | ٠.٤٢ | ٢.٥ | ٣٠ | ٤١ | ٤٢.٨ |
| | | ٠.٤١ | ٣ | ٣١ | ٤١ | ٤١.٥ |
| | | ٠.٤ | ٣.٥ | ٢٩ | ٣٩ | ٤٠ |
| ٠.٥ | SNF | ٠.٥ | ٠ | ٢٢ | ٢٧ | ٣٠ |
| | | ٠.٤٩ | ١ | ٢٥ | ٣٠ | ٣٢ |
| | | ٠.٤٨ | ٢ | ٢٩.٧٥ | ٣٣ | ٣٤ |
| | | ٠.٤٧ | ٢.٥ | ٣٣ | ٣٨ | ٣٨ |
| | | ٠.٤٦ | ٣ | ٣٣ | ٣٧.٨ | ٣٨ |
| | | ٠.٤٥ | ٣.٥ | ٣١ | ٣٥ | ٣٦.٧٥ |

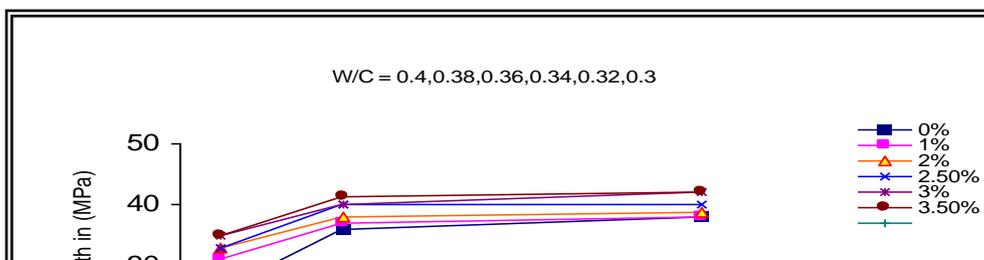


Table (٤-٢٥): Superplasticizers dosage for Re-dosing superplasticized concrete mixes

| W/C Ratio | Superplasticizer dosage for Re-dosage in (% weight of cement) |
|----------------------|---|
| SMF Superplasticizer | |
| ٠.٤ | ٠.٣٢ |
| ٠.٤٥ | ٠.٢٩ |
| ٠.٥ | ٠.٢٧ |
| SNF Superplasticizer | |
| ٠.٤ | ٠.٣٥ |
| ٠.٤٥ | ٠.٣ |
| ٠.٥ | ٠.٢٨ |
| MLS Superplasticizer | |
| ٠.٤ | ٠.٣ |
| ٠.٤٥ | ٠.٢٥ |
| ٠.٥ | ٠.٢٥ |

Table (٤-٢٦): Compressive strength of Re-dosing superplasticized concrete.

| Superplasticizers type | W/C Ratio | Compressive Strength (Mpa) | | |
|------------------------|-----------|----------------------------|--------|---------|
| | | ٧ days | ٢٨days | ٩٠ days |
| SMF | ٠.٥ | ٢٥ | ٢٨ | ٣١ |
| | ٠.٤٥ | ٢٨.٨ | ٣٢ | ٣٤.٣ |
| | ٠.٤ | ٣١ | ٣٥ | ٣٥.٧٥ |
| SNF | ٠.٥ | ٢٥.٦٥ | ٢٨ | ٣٢.٢٥ |
| | ٠.٤٥ | ٣٠ | ٣٢ | ٣٥ |

| | | | | |
|-----|------|----|-------|-------|
| | ۰.۴ | ۳۲ | ۳۴ | ۳۶ |
| MLS | ۰.۵ | ۲۳ | ۲۶ | ۲۶.۷۵ |
| | ۰.۴۵ | ۲۵ | ۲۸.۴۵ | ۳۱.۵ |
| | ۰.۴ | ۲۸ | ۳۱ | ۳۳ |

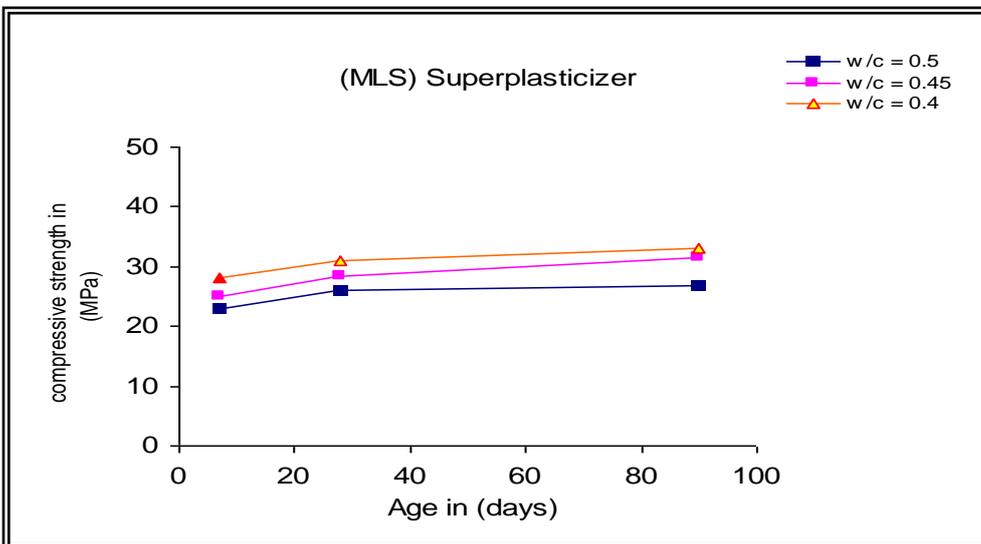
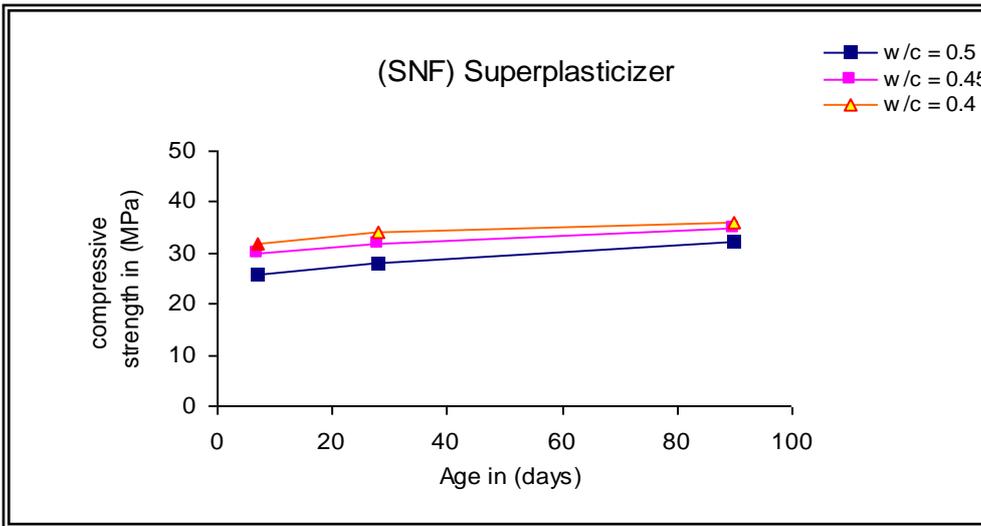
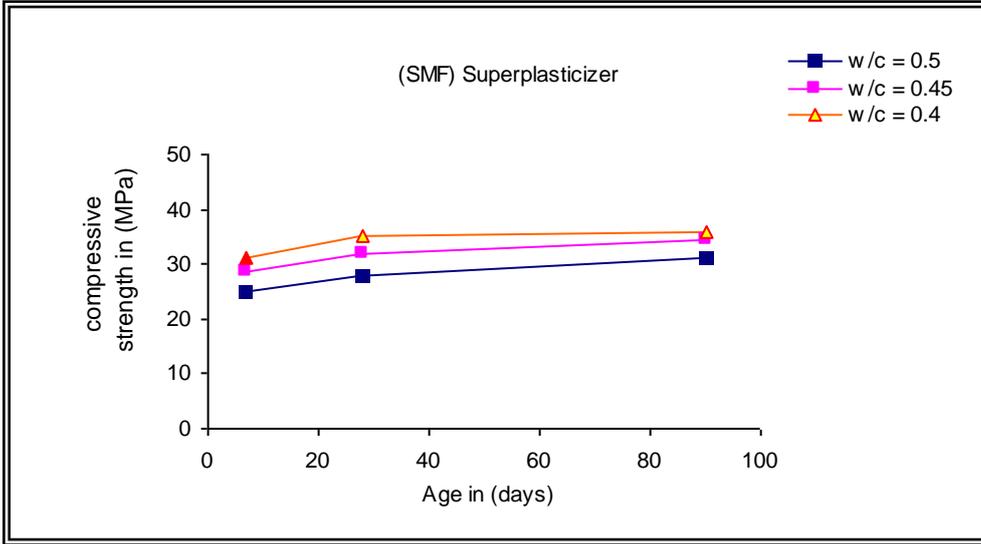


Figure (۴-۳۱): Development of compressive strength for re-dosing

Table (٤-٢٧): Re-Watering superplasticized concrete mixes with different types of superplasticizers

| Original W/C Ratio | % Added water | W/C ratio before re-watering | Water content before Re-Watering superplasticized concrete mix in Kg/m ³ | W/C ratio after re-watering |
|------------------------------|---------------|------------------------------|---|-----------------------------|
| (٢.٧%) SMF Superplasticizer | | | | |
| ٠.٤ | ٧٠ | ٠.٣٧ | ١٠١ | ٠.٦٥ |
| ٠.٤٥ | ٥٧.٤ | ٠.٤ | ٩٣ | ٠.٦٥٨ |
| ٠.٥ | ٤٧ | ٠.٤٧ | ٨٥ | ٠.٧ |
| (٢.٧٥%) SNF Superplasticizer | | | | |
| ٠.٤ | ٧٦.٤ | ٠.٣٧ | ١١٠ | ٠.٦٧٥ |
| ٠.٤٥ | ٦١.٧٣ | ٠.٤ | ١٠٠ | ٠.٦٧٧ |
| ٠.٥ | ٥٠ | ٠.٤٧ | ٩٠ | ٠.٧٢ |
| (٢.٥%) MLS Superplasticizer | | | | |
| ٠.٤ | ٧٦.٤ | ٠.٣٧٥ | ١١٠ | ٠.٦٨ |
| ٠.٤٥ | ٥٨.٦ | ٠.٤ | ٩٥ | ٠.٦٦ |
| ٠.٥ | ٥٠ | ٠.٤٧٥ | ٩٠ | ٠.٧٢٥ |

Table (٤-٢٧): Compressive strength for Re-Watering superplasticized concrete.

| Superplasticizers type | W/C Ratio | Compressive Strength (Mpa) | | |
|------------------------|-----------|----------------------------|---------|---------|
| | | ٧ days | ٢٨ days | ٩٠ days |
| SMF | ٠.٥ | ٢٢.٤٥ | ٢٦.٥ | ٢٧ |
| | ٠.٤٥ | ٢٤.٥ | ٢٨.٧ | ٢٩ |
| | ٠.٤ | ٢٦ | ٣٠ | ٣٢ |
| SNF | ٠.٥ | ٢٤ | ٢٧ | ٣٠ |
| | ٠.٤٥ | ٢٧ | ٢٩ | ٣١.٥ |

| | | | | |
|-----|------|-------|-------|------|
| | ٠.٤ | ٢٨ | ٣٠ | ٣٣ |
| MLS | ٠.٥ | ٢١ | ٢٤,٢٥ | ٢٥.٥ |
| | ٠.٤٥ | ٢٥ | ٢٧ | ٢٨ |
| | ٠.٤ | ٢٦,٤٥ | ٢٨ | ٣٠ |

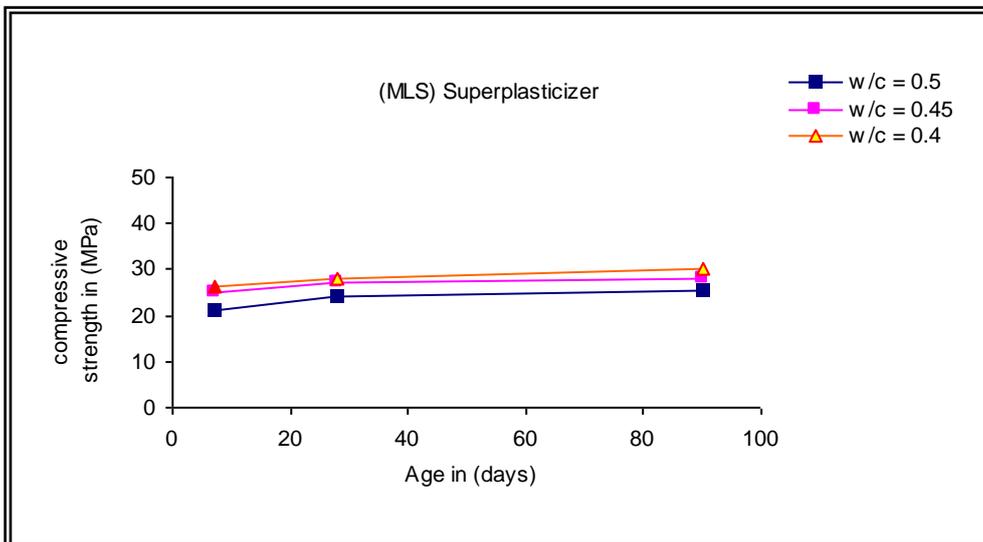
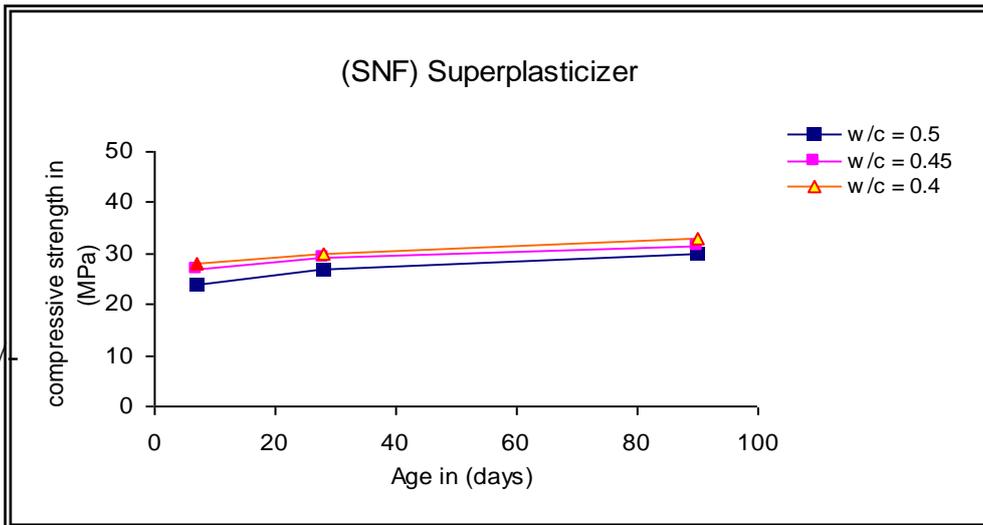
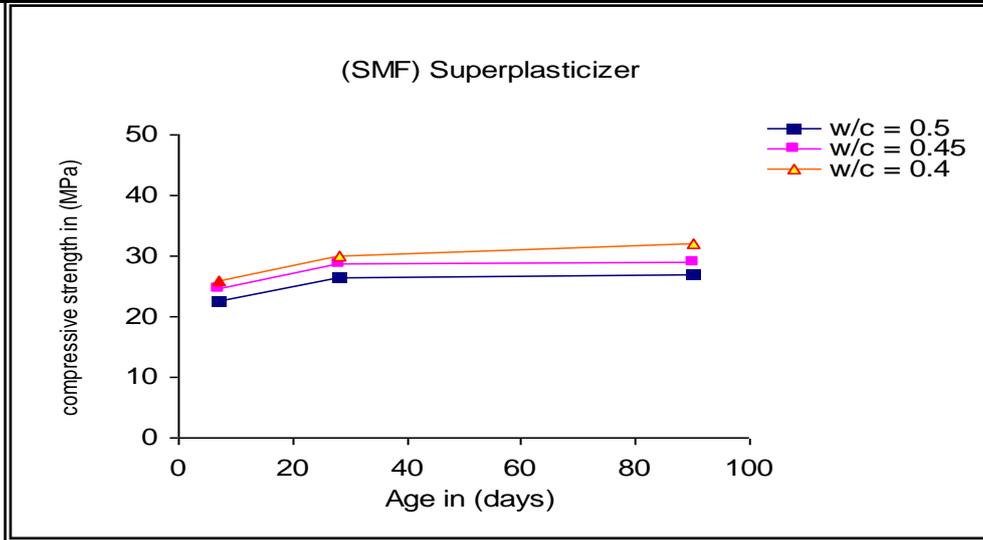


Figure (٤-٣٢): Development of compressive strength for re- watering

4.4. Density test results:

The influence of (Three types of superplasticizers, 1- Glenium-01 (G01) Sulfonated melamine-formaldehyde condensates SMF, 2- Conplast SP423 Sulfonated naphthalene-formaldehyde condensates SNF, 3- Daracem modified lignosulfonates MLS) on the density of concrete mixes is presented in the following sections.

4.4.1. Influence of superplasticizer on the density

- a. Superplasticized concrete mixes with (SMF and SNF) as an admixture in concrete mix has slight decrease in the density; presence of (SMF and SNF) as a water reducer admixture in concrete mix has no clear change in the density.
- b. Superplasticized concrete mixes with (MLS) as an admixture in concrete mix has clear reduction in the density of mixes, using (MLS) as a water reducer admixture in concrete mix has slight reduction in the density of mixes. Table (4-20) shows these results.

Table (4-20): Variation in concrete mix density with various types of superplasticizers

| * Mix No. | ** Weight of mix in (kg) | | | | *** Mix density in (kg/m ³) | | | |
|-----------|--------------------------|-------|-------|-------|---|--------|--------|---------|
| | - | SMF | SNF | MLS | - | SMF | SNF | MLS |
| A1 | 7.720 | 7.720 | 7.990 | 7.700 | 2209.26 | 2287.4 | 2367.4 | 2283 |
| A2 | 7.708 | 7.730 | 7.770 | 7.003 | 2204 | 2262 | 2274 | 2070 |
| A3 | 7.443 | 7.018 | 7.700 | 7.400 | 2200.3 | 2227.0 | 2203.3 | 2208.88 |

| | | | | | | | | |
|----------------|-------|-------|-------|-------|---------|---------|---------|--------|
| B ¹ | ٧.٦٣٨ | ٧.٦٢٠ | ٧.٥٩٠ | ٧.٧٠٠ | ٢٢٦٣ | ٢٢٥٧.٧٧ | ٢٢٤٨.٨٨ | ٢٢٨١.٥ |
| B ^٢ | ٧.٦١٨ | ٧.٥٩٥ | ٧.٦٦٠ | ٧.٥٨٥ | ٢٢٥٧.١٨ | ٢٢٥٠.٣ | ٢٢٦٩.٦ | ٢٢٤٧.٤ |
| B ^٣ | ٧.٥٦٣ | ٧.٥٦٠ | ٧.٥٩٧ | ٧.٤٨٠ | ٢٢٤٠.٨٨ | ٢٢٤٠ | ٢٢٥١ | ٢٢١٦.٣ |

*(A¹). Means concrete mix with superplasticizers and w/c ratio = ٠.٤

(A^٢). Means concrete mix with superplasticizers and w/c ratio = ٠.٤٥

(A^٣). Means concrete mix with superplasticizers and w/c ratio = ٠.٥

(B¹). Means concrete mix with a superplasticizer used as water reducer and w/c ratio = ٠.٤

(B^٢). Means concrete mix with a superplasticizer used as water reducer and w/c ratio = ٠.٤٥

(B^٣). Means concrete mix with a superplasticizer used as water reducer and w/c ratio = ٠.٥

** : Weight of mix = weight of concrete cube after curing.

*** : The density of concrete mixes was calculated from the following formula:

$$D = W / V$$

D = hardened concrete density, (kg/m^٣).

W = dry weight of specimen, (kg).

V = volume of the cube specimen, m^٣.

٤.٥. Cost saving.

Using superplasticizers to improve workability with reduction in water content in the same time improves compressive strength and has ability to keep the cost in the same range by decrease cement content without

effecting on properties of mixes and keep it a suitable case. Reduction cement content lead to savings in cost of concrete, as shown in table (ε-۲۱) through (ε-۲۳).

Table (ε-۲۱): Cost savings with using (SMF) Superplasticizer.

| Details | Cost in ID | * M ^۱ | | ** M ^۲ | | *** M ^۳ | |
|----------------------------|---------------|------------------------|-----------|-------------------|-----------|--------------------|-----------|
| | | Without t Sup. | With Sup. | Without t Sup. | With Sup. | Without t Sup. | With Sup. |
| Water in Kg/m ^۳ | - | ۱۴۴ | ۱۱۰ | ۱۶۲ | ۱۲۶ | ۱۸۰ | ۱۴۰ |
| Cement kg/m ^۳ | ۲۰۰ ID for kg | ۳۶۰ | ۲۸۸ | ۳۶۰ | ۲۸۱.۶ | ۳۶۰ | ۲۷۹.۸ |
| Cost in ID | | ۷۲۰۰۰ | ۵۷۶۰۰ | ۷۲۰۰۰ | ۵۶۳۲۰ | ۷۲۰۰۰ | ۵۵۹۶۰ |
| Cost saving in ID | | ۱۴۴۰۰ | | ۱۵۶۸۰ | | ۱۶۰۴۰ | |
| % cost savings | - | ۲۰ | | ۲۱.۸ | | ۲۲.۲۸ | |
| Sup. quantity | | ۱۱.۴۵ L/m ^۳ | | | | | |
| Sup. cost | ۱.۸۰۰ | ۲۰.۶ ID | | | | | |

Table (ε-۲۲): Cost savings with using (SNF) Superplasticizer.

| Details | Cost | M ^۱ | M ^۲ | M ^۳ |
|---------|------|----------------|----------------|----------------|
|---------|------|----------------|----------------|----------------|

| | in ID | Without Sup. | With Sup. | Without t Sup. | With Sup. | Without t Sup. | With Sup. |
|----------------------------|-----------------------|--------------|-----------|----------------|-----------|----------------|-----------|
| Water in Kg/m ³ | - | 144 | 112 | 162 | 120.8 | 180 | 140 |
| Cement Kg/m ³ | 200 ID for Kg | 36. | 28. | 36. | 279.6 | 36. | 28. |
| Cost in ID | | 72000 | 56000 | 72000 | 50920 | 72000 | 56000 |
| Cost saving in ID | | 16000 | | 16.80 | | 16000 | |
| % cost savings | | 22.22 | | 22.22 | | 22.22 | |
| Sup. quantity | 10.6 L/m ³ | | | | | | |
| Sup. cost | 1.800 | 19 ID | | | | | |

Table (4-23): Cost savings with using (MLS) Superplasticizer.

| Details | Cost in ID | M1 | | M2 | | M3 | |
|----------------------------|---------------|--------------|-----------|----------------|-----------|----------------|-----------|
| | | Without Sup. | With Sup. | Without t Sup. | With Sup. | Without t Sup. | With Sup. |
| Water in Kg/m ³ | - | 144 | 113 | 162 | 124.73 | 180 | 141.98 |
| Cement Kg/m ³ | 200 ID for Kg | 36. | 282.0 | 36. | 277.18 | 36. | 283.76 |
| Cost in ID | | 72000 | 56000 | 72000 | 50436 | 72000 | 56702 |
| Cost savings in ID | | 10000 | | 16064 | | 10248 | |
| % Cost saving | | 21.027 | | 22 | | 21.177 | |

| | | |
|---------------|------------------------|--------|
| Sup. quantity | 7.870 L/m ³ | |
| Sup. cost | 1.800 | 1 £ ID |

* M₁ means concrete mixes with 0.45 w/c ratio.

** M₂ means concrete mixes with 0.40 w/c ratio.

*** M₃ means concrete mixes with 0.35 w/c ratio.

Note: Cost of superplasticizers is constant approach to (2-3)% cost of cement.

Chapter five

Conclusions and Recommendations

5. 1. Conclusions:

Based on the results of the experimental work of this study the following conclusions were found. It should be kept in mind that the results obtained from the tests are for the types of materials used and conditions of the experimental work.

5. 1. 1. Workability:

1. The optimum dosage of the superplasticizer used to get suitable workability with the highest decrease in water content for different concrete mixes is (2-3%) as a liquid by the weight of cement, such as with (SMF) 11.0 L/m³, (SNF) 10.6 L/m³ and (MLS) 7.8 L/m³.

2. The percentage increases in the initial slump with (0.4, 0.45, 0.5, 0.6) w/c ratio is (0, 20, 30, 36)% compared with reference mix.
3. Using superplasticizers gives significant increase in the initial slump for concrete mixes with saving the original properties of concrete mixes, since percentage increase in the initial slump with Glenium-01 (Sulfonated melamine-formaldehyde condensates, SMF), and Conplast SP423 (Sulfonated naphthalene-formaldehyde condensates, SNF), modified lignosulfonates MLS Daracem are (118-27)%, (100-26)%, (131-40)% respectively, and (18.7-12)mm, (20-11)mm, (20-14)mm for (0.3-0.6) w/c ratios.
4. Using the highest dosage of superplasticizer especially with high w/c ratio causes a high retarding in setting time, segregation that leads to deform cement component interaction. This effect is more pronounced with (MLS, SNF, SMF) respectively.
5. The slump loss of unsuperplasticized concrete mixes increases with the increase in w/c ratio, the percentage increase are (24.8, 28, 30, 31)% with (0.4, 0.45, 0.5, 0.6) w/c ratio respectively.
6. The slump loss for superplasticized concrete mixes with (SMF) and (0.4, 0.45, 0.5, 0.6) w/c ratio respectively is higher than unsuperplasticized concrete through 40 minutes after mixing. The percentage increases are (0-1)% with (SMF) dosages (1, 2, 2.5, 3, 3.5)% by the weight of cement respectively. But after 40 minutes from mixing the slump loss is lower. The percentage decreases in rate of slump loss are (0-0.8) for the same dosage respectively.
7. The slump loss for superplasticized concrete mixes with (SNF) is lower than unsuperplasticized mixes. The percentage decreases are (0-3.5),

with (SMF) dosages (1, 2, 2.5, 3, 3.5)% by the weight of cement respectively. But after 30 minutes from mixing the slump loss is higher, since the percentage increases are (1-3.6)%, for the same dosage respectively.

8. The slump loss for superplasticized concrete mixes with (MLS) is higher than unsuperplasticized concrete. The percentage increase are (1.5-3.5)%, with (MLS) dosages (1, 2, 2.5, 3, 3.5)% by weight of cement respectively. But after 60 minutes from mixing the slump loss is similar to the slump loss in unsuperplasticized concrete.
9. Using superplasticizers causes significant reduction in water content, for mixes with (0.4, 0.45, 0.5) w/c ratio the reduction reaches to (1-24.25)%, with (1, 2, 2.5, 3, 3.5)% by the weight of cement from (SMF) respectively. For the same mixes but with (SNF) the reduction reaches to (7-24.45)% for the same dosage respectively. The percentage reduction for same mixes with (MLS) reaches to (9-24.5)% for the same dosage respectively.
10. Using superplasticizers as a water reducer causes significant reduction in cement content, approaches to (8.33-21.2)% with (0.4, 0.45, 0.5) w/c ratio and (MLS) dosages are (1, 2, 2.5, 3, 3.5)% by the weight of cement. For the same dosage respectively the reduction in cement content with (SMF) are (6-22)% and with (SNF) be (7.8-22.33)%.
11. The slump loss of superplasticized concrete with reduction in water content is approximately more than slump loss in superplasticized concrete without reduction in water content but in less percent.

12. Workability can be recovered for superplasticized concrete after 60-90 minutes by re-tempering with re-dosing superplasticizers or re-watering.
13. Re-tempering by re-dosing gives a re-slump approaches to (88, 90, 92)%, (77, 86, 90)%, (70, 80, 88)%, for first dosing and (80, 82, 83.3)%, (73, 70, 77)%, (60, 70, 72)% for second dosing with (MLS, SNF, SMF) respectively.
14. Re-tempering by re-watering gives a re-slump approaches to (83, 92, 93)%, (84, 93, 93)%, (91, 80, 90)% with (MLS, SNF, and SMF) respectively.
15. Re-dosing superplasticizers more than twice dosing is not favorable because of their harmful effect in the final form of concrete mixes, because they cause a high retarding in setting time of concrete mixes and stopping cement interaction.
16. Re-watering must be with one step because more than one step deforms concrete mixes, because the more presence water causes segregation and bleeding in concrete mixes .
17. The slump loss for re-tempering superplasticized concrete mixes are approximately higher than in normal superplasticized concrete mixes, the percentage increase is (12, 6, 0)%, (9, 6, 0)%, (0, 4, 4)% for first interval and (3.0, 2, -4)%, (-2, 2, 0)%, (-1, 1, 6)% for second interval.
18. The addition of superplasticizers (SMF, SNF and MLS) at a delay time (2-3) minutes after mixing is more useful and practical than the addition with mixing water.

e. 1. 2. Compressive strength:

1. The compressive strength for superplasticized concrete mixes without reduction in water content is less than in normal concrete mixes. The percentage reduction is (10, 22, 18)%, (22, 19, 10)%, (32, 28, 24)% for (SMF, SNF, MLS) superplasticizers and (0.4, 0.45, 0.5) w/c ratio respectively.
2. The compressive strength for superplasticized concrete mixes with reduction in water content is higher than in normally concrete mixes. The percentage increase is (7, 16, 26)%, (8, 18, 19)%, (0, 8, 10)% for (SMF, SNF, MLS) superplasticizers and (0.4, 0.45, 0.5) w/c ratio respectively.
3. The compressive strength for superplasticized concrete mixes with reduction in water content is higher with (SMF and SNF) than with (MLS).
4. The compressive strength of superplasticized concrete mixes with reduction in cement content is nearly the same original compressive strength.
5. The compressive strength of re-tempered superplasticized concrete mixes with reduction in water content is little higher than the original compressive strength when using re-dosing but approximately similar or lower than compressive strength of original mix with re-watering.
6. The density of superplasticized concrete mixes with (SMF, SNF) without reduction in water content is slightly higher than the original density, but with (MLS) is lower than in original mixes. When superplasticizers are used as water reducer in concrete

mixes the density of these mixes is similar density of the original mixes.

4. 1. Recommendations for Future Work:

As there are limited data available for using superplasticizers in concrete mixes, further investigations in the following field are suggested.

1. Effect of these types of superplasticizers on the permeability of concrete mixes.
2. Effect of using fine materials with superplasticized concrete mixes on final properties of concrete mix .
3. Studying the effect of using superplasticizers on drying shrinkage, strain capacity for a longer time and when using them to reduce cement content or water content.
4. Effect of these types of superplasticizers with high temperatures on the properties of fresh and hardened concrete.
5. Effect of these types of superplasticizers on the properties of fresh and hardened lightweight concrete.
6. Effect of exposed superplasticized concrete members for direct heat or fires.
7. Effect of exposed superplasticized concrete members to organic environment (farms, organic and chemical materials stores, organic and chemical materials tanks), or aggressive solutions.

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