Influence of Different Superplasticizers on Properties of Ready Mix Concrete (RMC)

TAHIR ABSAR MALLICK FAHIM

MOHAMMAD ABDUL MUNIM

MD. FARHAN SHAHRIAR

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

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Tahir Absar Mallick Fahim

Mohammad Abdul Munim

Md. Farhan Shahriar

(115434)
(115405)
(115421)

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The thesis titled "Influence of Different Superplasticizers on Properties of Ready Mix Concrete (RMC)" submitted by Tahir Absar Mallick Fahim, St. No. 115434, Mohammad Abdul Munim, St. No. 115405 & Md. Farhan Shahriar, St. No. 115421 has been found as satisfactory and accepted as partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering.

SUPERVISOR

Dr. Md. Tarek Uddin, PEng.

Professor and Head,
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT)
Board Bazar, Gazipur, Bangladesh.

DECLARATION OF CANDIDATE

We hereby declare that, undergraduate project work reported in this thesis has been performed by us and this has not been submitted elsewhere for any purpose except for publication.

Dr. Md. Tarek Uddin, PEng.

Professor and Head,
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT)
Board Bazar, Gazipur, Bangladesh.

Tahir Absar Mallick Fahim
Student No: 115434
Academic Year: 2014-2015
Date: _/11/2015

Mohammad Abdul Munim
Student No: 115405
Academic Year: 2014-2015
Date: _/11/2015

Md. Farhan Shahriar
Student No: 115421
Academic Year: 2014-2015
Date: _/11/2015

DEDICATION

We dedicate this to our parents, teachers, friends and fellow members without whom it was almost impossible for us to complete our thesis work.

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"***In the name of Allah, Most Gracious, Most Merciful***"

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ABSTRACT

An experimental study was conducted to understand the influence of some factors on workability and compressive strength of ready mix concrete (RMC). To conduct this study, different types of plasticizers and superplasticizers were collected from local market. Sylhet sand and boulder crushed stone chips were used as fine and coarse aggregates respectively. According to ASTM specification the test was conducted. Different concrete mixtures with different chemical admixtures and sand to total aggregate volume ratios were investigated. Slump test was carried out at 15 minutes interval till the slump is less than or equal to 3 cm after mixing of concrete. For measurement of workability in two stage admixture dosage, the second stage of admixture was added to the concrete when the slump was equal or less than 3 cm. After that the casting was done. Curing of the concrete specimen was done in two steps; primary curing and final curing. Cylindrical concrete specimens of 4 inch diameter and 8 inch in height were made to measure compressive strength at 7 days and 28 days. From the test results, it was found that plasticizers impart more compressive strength to concrete than most of the superplasticizers. However, superplasticizers give more workability than plasticizers. Concrete made with high range water reducing superplasticizer attains more strength than concrete made with retarding superplasticizer. But, retarding superplasticizers impart more workability to concrete. In this test w/c ratio was kept constant. There was variations in s/a ratio, cement content and admixture dosage. It was found that two stage dosage of admixture provide better and long-time workability. It is also found that with the increase of s/a ratio the workability of concrete decreases and with the increase of cement content the workability increases. Also the strength of the concrete increased with the addition of some of the chemical admixture compared to without admixture specimen.

Key words:

Plasticizer, Super plasticizer, Sand to Aggregate Ratio, Workability, Compressive Strength.

NOMENCLATURE

ASTM	American Society for Testing and Materials
SSD	Saturated Surface Dry
FA	Fine Aggregate
CA	Coarse Aggregate
UTM	Universal Testing Machine
UPV	Ultrasonic Pulse Velocity
PFA	Pulverized Fuel Ash
PCC	Portland Composite Cement
RMC	Ready Mix Concrete
FM	Fineness Modulus
SC	Stone Chips
OD	Oven Dry
SMF	Sulphonated Melamine Formaldehyde
SNF	Sulphonated Napthalene Formaldehyde
CEM	Cement
s/a	Sand to Aggregate Ratio
w/c	Water- Cement Ratio
γ	Unit Weight (kg/m^3)
SP	Superplasticizer
P	Plasticizer
WR	Water Reduce

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Chapter 1 Introduction

1.1 General

This chapter covers the background of the study and the importance of the project briefly. It also discusses the problem faced during construction projects and necessity to overcome this problems for sound construction of any civil engineering project. Objectives, thesis outline and scope of the study are also mentioned in this chapter.

1.2 Background

The demand of Ready Mix Concrete (RMC) is increasing exponentially in recent few years in many huge construction projects and also in small scale projects. The reasons behind the engineers tendency to use the Ready Mix Concrete are as follows: a) to properly maintain the ratio of cement, sand, aggregate; b) convenience of RMC in constructing high rise structures; c)construction time saving; d) to reduce the loss of concrete; e) shortage of space at construction site; f) better quality. As per available information up to 2010, there are 76 RMC plants in major cities with a total capacity of around 1200m^3/hr., producing 1.80 million cubic meter of concrete per year (Islam, 2014).

In the past few years the increase of using ready mix concrete (RMC) has been noticed dramatically. In a few years, we will notice a vast range of use of ready mix concrete and more and more ready mix plant will be established. Use of chemical admixtures, proper graded aggregates, maintaining proper ratio of cement, sand, aggregate, water and s/a ratio in those plants should be maintained with skilled supervision.

1.3 Rational

Due to convenience of working with concrete now-a-days Ready Mix Concrete (RMC) is being used in lion share of the construction works. If there is some inconvenience and Ready Mix Concrete cannot be reached to its destination within the usual setting time of concrete, we need to consider making the concrete workable for a longer period. Hence Ready Mix Concrete (RMC) plants are using chemical admixtures to lengthen the setting time of concrete. But we need to use admixtures in such a way that the strength of concrete is not affected. Therefore experimenting with a large variation of dosage of admixtures is necessary to ensure the workability without compromising the strength of concrete.

1.4 Problem Statement

The initial setting time of concrete is 45 minutes but it is not always possible to carry the Ready Mix Concrete (RMC) by this short period of time due to:

i) High traffic volume in the designated route

ii) Long travel distance

So it is necessary to increase the initial setting time thus the workability of the concrete for the prolonged travel period without compromising the desired strength. It is crucial to use a proper chemical admixtures & to maintain a suitable dosage, to maintain proper sand to aggregate ratio, w/c ratio, cement content and adequate amount of water.

1.5 Objectives

The major objective of this study is to create a comparative analysis of the workability and strength of concrete using variation of different admixtures and different dosages, and application time. The specific objectives are:

i. Different types of locally available chemical admixtures

ii. Different admixture dosages

iii. Application time of dosages

1.6 Scope

The primary focus of this study shall be identifying the best chemically composed admixture (Plasticizers or Super plasticizers). Finding out which combination of mixing the concrete will have maximum workability without compromising the strength of the concrete. Through analyzing the combination of s/a ratio, cement content, admixture type and admixture dosage variation, we will have a complete picture of the effect of admixture type and dosage on Ready Mix Concrete (RMC). The study excludes the further analysis of the less functioning admixtures but it will be adequate for ensuring the identification of the best functioning admixture in case of both workability and strength. In this study only the variation of locally available chemical admixtures is experimented. The effect of temperature over the workability & strength was not included in the study.

1.7 Thesis Outline

The rest of the thesis chapters will be organized as follows:

- ✓ Chapter 2: Literature Review; the chapter discusses about the past works on this subject, necessity and importance of the study, analysis of data on previous works.
- ✓ Chapter 3 – Methodology; discusses the procedural steps of the study.
- ✓ Chapter 4 – Comparative Data Analysis; it discusses the workability and strength of chemical admixture variation, combination and application period.
- ✓ Chapter 5 – Conclusion and Recommendation; discusses about the effectiveness of the study, and recommendations for future studies.

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Chapter 2 Literature Review

2.1 General

This chapter discusses about admixtures with different chemical compositions. The chapter also describes in brief effectiveness of different admixtures on the basis of past studies. It describes the effect of different dosage of admixtures and application of dosage in periods on the properties of concrete.

2.2 Types of Chemical Admixture

Two major types of chemical admixtures are available in the local market, such as plasticizers and superplasticizers. They may have water reducing or retarding or both characteristics. They can be used in concrete mixtures for three different purposes or in a combination of these (Collepardi, 1995): (i) to increase workability without changing the mix composition in order to enhance placing characteristics of concrete; (ii) to reduce the mixing water and the water-cement ratio (W/C) in order to increase strength and improve durability at a given workability; and (iii) 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.

The use of superplasticizers in concrete began in the 1960s and was a milestone in concrete technology and the field of construction (Malhotra, 1997). In this way the production of concrete of high performance and durability was achieved, because adding, superplasticizers high workability remained at a very low ratio of w/c. The superplasticizers are poly-electrolytes of organic origin, which function like the dispersing chemical media in heterogeneous systems. The naphthalene—formaldehyde sulphonate is the most well-known super plasticizer. There are other types having lignosulphonate base. Another group of reactive super plasticizers are based in sulfonated products of synthetic polymers (e.g. SNF, naphthalene or SMF, melamine). These materials result in a higher decrease of required water and so higher strengths are achieved. The family of super plasticizers which are based in polycarboxylic products are more recent (1980s). These materials are of higher reactivity, they do not contain the sulfonic group and they are totally ionized in alkaline environment (Papayianni, 2005).

2.3 Effectiveness of Types of Chemical Admixtures

Most of the studies that address the effect of chemical admixtures on the compressive strength of concrete were done either using plasticizers or superplasticizers. However, it is known that superplasticizers have more plasticizing ability (i.e. result more workability) than plasticizers. Superplasticizers are able to enhance the placing characteristics of concrete mixtures by increasing the workability level at a given w/c. Therefore they allow easier placement of concrete mixtures, even with low w/c when required for strength or durability reasons (Collepardi, 1998). Although superplasticizers do not react by a chemical action on hydrated products, they affect the microstructure of cement gel and concrete. The porosity and the bleeding decrease significantly and, on a second level, the drying shrinkage and creep deformations. Thus, beyond the increase of strength, there is also an increase of the durability of concrete with the use of superplasticizers (Whiting, 1987), (Mehtra, 1992). It is generally known that lignosulfonic superplasticizers in high dosages result delaying the curing of concrete (Papayianni, 2005). The superplasticizers of high reactivity (such as polycarboxylic products), which in high dosages do not have the side-effect of delaying the curing of concrete, made the production of concrete with a big volume of fly ash or slag possible (Langley, 1989). In case of plasticizers, it is found that retarding plasticizer or combination of retarding and water reducing plasticizers provides higher workability and strength of concrete than water reducing plasticizer (Baskoca, 1998).

2.4 Effects of Different Dosage of Chemical Admixture

Several studies concluded that the workability of concrete increases with the increase of the dosage of superplasticizer (Alsadey, 2012), (Muhit, 2013), (Rao, 2014); however, compressive strength of concrete initially increases with the increase of superplasticizer dosage but after a certain limit of dosage the strength starts to decrease (Alsadey, 2012), (Muhit, 2013).

2.5 Effects of Application of Dosage in Stages

Ş. Erdoğdu observed that in case of prolonged mixing, concrete re-tempered to initial slump level at the end of mixing period using superplasticizer attains more strength than the concrete re-tempered with water. Concrete with no retempering revealed a slightly higher strength. The reason for this is preferably attributed to the reduced air content in addition to the esteemed effect of proper placement and compaction of concrete (Erdoğdu, 2005).

Chapter 3 Methodology

3.1 General

In this experiment boulder crushed stone chips as coarse aggregate, Sylhet sand as fine aggregate, water, cement as binding material and different types of chemical admixtures were used to make cylindrical concrete specimen. The chapter describes the full experimental procedure, material properties of both coarse and fine aggregate, chemical structure or base of the chemical admixture. The tests of material in order to find their properties, mix designs, gradation of coarse aggregate. Casting were performed according to different codes of ASTM. Specific ASTM standards for carrying out different test methods and the results from the tests are mentioned in this chapter.

3.2 Background of the Work

The following procedures was followed in the field work before making concrete specimen:

- Selecting coarse aggregate and grading them according to ASTM **C33**.
- Sylhet sand is used as fine aggregate after sieving and grading them according to ASTM **C33**.
- Using cement as binding material.
- Using different types of chemicals as chemical admixtures at certain dosage limits.

3.3 Material Properties

This section describes the properties of coarse aggregate, fine aggregate, binding material, water and chemical admixture with their dosage limits. The test were performed according to the following ASTM codes.

Table 3.1 ASTM Test Methods Followed

Tested Parameters	Test Method
Specific Gravity	ASTM C127
Absorption Capacity	ASTM C127
Unit Weight and Voids in Aggregate	ASTM C29
Abrasion Test	ASTM C131
Fineness Modulus	ASTM C136

3.3.1 Binding Material

As a binding material Portland Composite Cement (PCC) has been used in this research. We used CEM type-II/B-M to make cylindrical specimen. This cement has about 65% -79% clinker, 21%-35% of fly ash, limestone and slag and 0.5% gypsum.

3.3.2 Aggregate

Recently in Bangladesh stone chips as coarse aggregate is used in most construction works. We used Sylhet sand as fine aggregate which is commonly used in our country for construction works.

Table 3.2 Abrasion of Coarse Aggregate, Bulk Specific Gravity, Absorption and Unit Weight of Fine and Coarse Aggregate

Material Type	Fineness Modulus (FM)	% Wear	Bulk Specific Gravity (SSD)	Absorption (%)	Unit Weight (kg/m^3)
Stone Chips (SC)	Was controlled according to ASTM C33	38.96	2.56	0.46	2342
Sylhet Sand	2.52	-	2.45	3.3	1527

3.3.2.1 Coarse Aggregate

Coarse aggregates were collected from the local markets. For the ASTM requirements various tests like specific gravity, absorption test, Los Angeles Abrasion test and sieve analysis were done. Los Angeles Abrasion test was done according to ASTM **C131** and other tests were done according to ASTM **C127.**

Table 3.3 Specific Gravity and Absorption of Stone Chips

Mass of oven dry test sample in air, A	Mass of saturated surface dry test sample in air, B	Apparent mass of saturated test sample in water, C	Specific Gravity (SSD)	Avg. Sp.Gr. (SSD)	Specific Gravity (Apparent)	Avg. Sp. Gr. (Apparent)
1600	1606	972	2.5	2.6	2.5	2.6
1700	1709	1004	2.4		2.4	
1700	1708	1080	2.7		2.7	

Mass of oven dry test sample in air, A	Mass of saturated surface dry test sample in air, B	Apparent mass of saturated test sample in water, C	Specific Gravity (OD)	Avg. Sp.Gr. (OD)	Absorption (%)	Avg. Absorption (%)
1600	1606	972	2.5	2.5	0.4	0.5
1700	1709	1004	2.4		0.5	
1700	1708	1080	2.7		0.5	

Table 3.4 % Abrasion Wear of Stone chips

Mass of sample before test (g)	Mass retained on sieve size 1.70 mm (g)	Mass passing on sieve size 1.70 mm (g)	% wear	Avg. % wear
5000	3052	1948	39.0	38.8
5000	3074	1928	38.6	

Photo 3.1 Los Angeles Abrasion Test

3.3.2.2 Gradation of Coarse Aggregate

Sieve analysis of coarse aggregate (stone chips) was within the upper and lower limit set by ASTM **C33** of shown in figure 3.2.

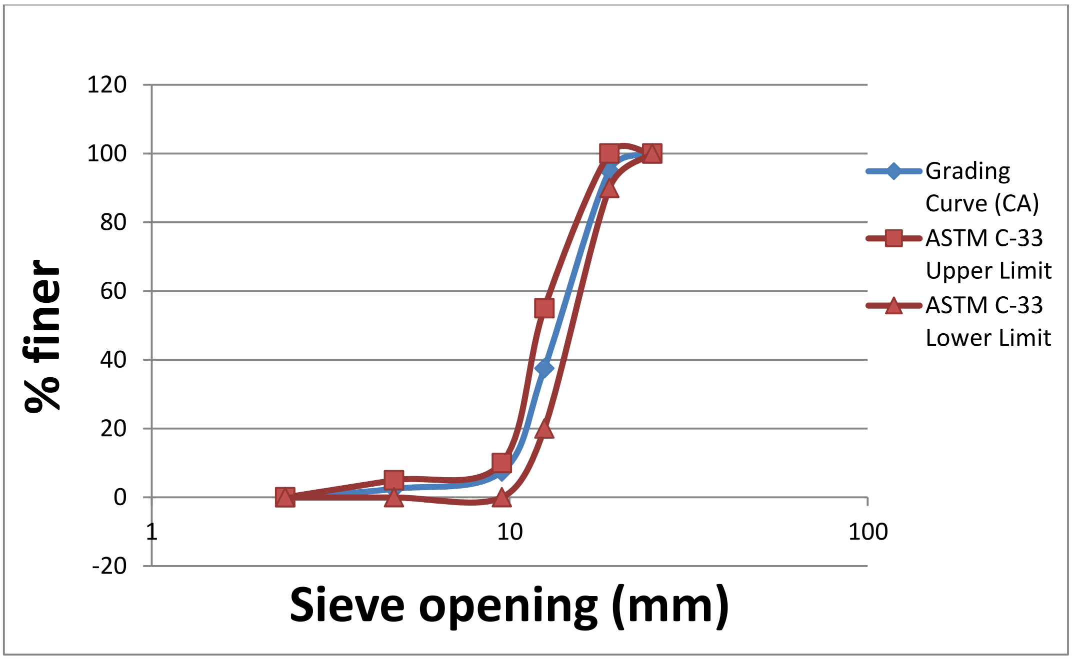

Figure: 3.1 Gradation Curve for Coarse Aggregate

3.3.2.3 Gradation of Fine Aggregate

Sieve analysis of fine aggregate (Sylhet sand) was within the upper and lower limit set by ASTM **C33** shown in figure 3.4.

Photo 3.2 Sieve Analysis of Sand for FM Calculation

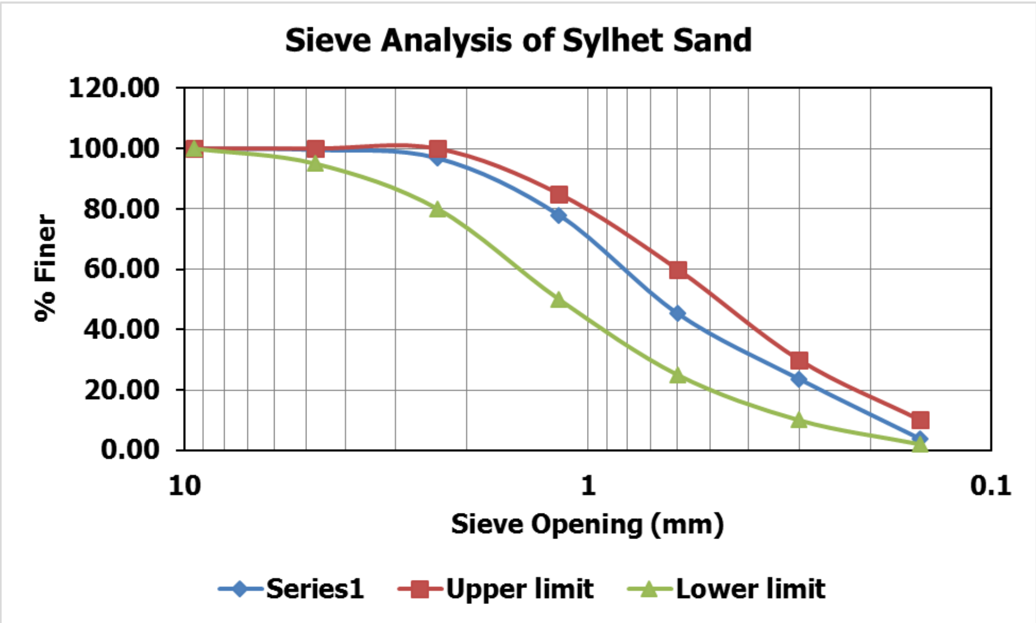

Figure: 3.4 Gradation Curve for Fine Aggregate

3.3.3 Chemical Admixture

In this analysis we used 9 types of admixtures. The tables below show the ASTM Types (Table 3.5) and chemical base and allowable maximum dosage and also the ASTM types (Table 3.6).

Table 3.5 ASTM Types of Chemical Admixture and Chemical Behavior

ASTM Types	Chemical Behavior
A	Water Reducing
B	Retarding
C	Accelerating
D	Water Reducing and Retarding
E	Water Reducing and Accelerating
F	High Range Water Reducing or Superplasticising
G	High Range Water Reducing and Retarding, or Superplasticising

Table 3.6 Admixture Name, ASTM Types, Limits and Chemical Composition

Admixture (Brand Name)	ASTM Type	Dosage Limit	Chemical Composition
SP 1	F and A	0.5-2.0liters /100kg container	naphthalene sulphonate based
SP 2	F	300-570 ml / bag of cement	organic polymers
SP 3	F	500ml-1200ml / 100kg cement	second generation polycarboxylic ether based
SP 4	B,D,G	400ml-1200ml / 100kg cement	modified polycarboxylic ether based
SP 5	B,D,G	400ml-1200ml / 100kg cement	modified polycarboxylic ether based
SP 6	G	600ml-1800ml / 100kg cement	naphthalene sulphonate based
WR	A and D	200ml-400ml / 100kg cement	lignosulphonate based
SP 7	B,D,G	400ml-1200ml / 100kg cement	naphthalene sulphonate based
SP 8	A, F	500ml-1500ml / 100kg cement	Synthetic polymers

3.4 EXPERIMENTAL SETUP

3.4.1 Preparation of Fine Aggregate

Fine aggregates was collected from local market. We used Sylhet sand for our experiment procedure. The aggregates were cleaned to avoid impurities. They were sieved by ASTM **C33-93** standard. The aggregates passing 4.75 mm sieve were selected for the test procedure. Before casting the aggregates were prepared in SSD condition.

Photo 3.3 Sand Before Sieved

Photo 3.4 Sand After Sieved And In SSD Condition

3.4.2 Preparation of Coarse Aggregate

Coarse aggregates were collected from the local markets. They were sieved and the particles retained on 19 mm sieve, 12.5 mm sieve, 9.5 mm sieve and 4.75 mm sieve were collected for the mix design. The aggregates were cleaned very carefully to avoid dust and any kind of harmful materials. Before casting the aggregates were prepared to SSD condition.

Photo 3.5 Coarse Aggregate Before After SSD Condition

Photo 3.6 Coarse Aggregate SSD Condition

3.4.3 Preparation of Cement

For casting we used CEM Type II B-M. This is a Portland Composite Cement and is manufactured by inter-grinding three major mineral components - Pulverized Fuel Ash (PFA), Blast Furnace Slag and Limestone with common raw materials - Clinker and Gypsum. The cement content for each test procedure was weighted very carefully.

3.4.4 Preparation of Water

Water that we used in the concrete casting and for the curing of the concrete specimen was normal tap water which unit weight was about 1000 kg/m^3.

3.4.5 Chemical Admixture

Chemical admixture were used with the concrete while mixing as our main purpose were to make the concrete workable for a long period of time without deteriorating the strength of the concrete. We used 9 types of chemical admixture for the experiment. Three steps were followed to mix the chemical admixture. They are:

- Using average dosage limit of the admixtures
- Using maximum dosage of admixtures
- Using maximum dosage of admixture in two steps

Photo 3.7 Preparation of Admixture

3.4.5.1 Average Admixture Dosage

In this process of adding chemical admixture we used to add the average dosage of minimum and maximum allowable dosage of chemical admixture. The minimum and the maximum dosage limits are stated in ASTM guideline.

3.4.5.2 Maximum Admixture Dosage

In application of maximum admixture dosage we applied the peak value of the admixture range stated in ASTM standards. It is done to evaluate the maximum effectiveness of each chemical admixture was used in the experiment.

3.4.5.3 Maximum Admixture Dosage in Two Steps

In this application process of chemical admixture maximum dosage of admixture were used in two steps. 70% admixture were used in first step and the rest of them were used in second step. The application of admixture in second step was done when the slump value of the concrete was less or equal to 3 cm.

3.5 Mix Design

3.5.1 Mix Design for Average Admixture Dosage (s/a=0.4, cc=340kg/m^3, w/c=0.4)

Table 3.7 Mix Design for Average Dosage Admixture

Cases	Admixture Name	Content (kg/m3 of Concrete)				Chemical Admixture (ml/100kg of cement)	w/c	s/a
		Cement	CA	FA	Water			
Average admixture dosage (Case 1)	SP1	340	1113.7	742.5	136	550	0.4	0.4
	SP2		1112.2	741.4		850		
	SP3		1113.9	742.6		500		
	SP4		1113.2	742.1		650		
	SP5		1112.9	741.9		700		
	SP6		1109.3	739.6		1400		
	WR		1114.9	743.3		300		
	SP7		1111.6	741.1		950		
	SP8		1110.4	740.2		1200		

3.5.2 Mix Design for Maximum Admixture Dosage (s/a=0.4, cc=340kg/m, w/c=0.4)

Table 3.8 Mix Design for Maximum Dosage Admixture

Cases	Admixture Name	Content (kg/m3 of Concrete)				Chemical Admixture (ml/100kg of cement)	w/c	s/a
		Cement	CA	FA	Water			
Maximum admixture dosage (Case 2)	SP1	340	1106.3	737.5	136	2000	0.4	0.4
	SP2		1113.6	742.4		570		
	SP3		1110.4	740.2		1200		
	SP4		1110.4	740.2		1200		
	SP5		1110.4	740.2		1200		
	SP6		1107.3	738.2		1800		
	WR		1114.4	742.9		400		
	SP7		1110.4	740.2		1200		
	SP8		1108.8	739.2		1500		

3.5.3 Mix Design for 2 Stages Admixture Dosage (s/a=0.4, cc=340kg/m^3, w/c=0.4)

Table 3.9 Mix Design for 2 Stages Admixture Dosage

Cases	Admixture Name	Content (kg/m3 of Concrete)				Chemical Admixture (ml/100kg of cement)	w/c	s/a
		Cement	CA	FA	Water			
2 Stages admixture dosage (Case 3)	SP3	340	1110.4	740.2	136	1200	0.4	0.4
	SP4		1110.4	740.2		1200		
	SP5		1110.4	740.2		1200		
	SP6		1107.3	738.2		1800		
	WR		1114.4	742.9		400		

3.5.4 Mix Design for 2 Stages Admixture Dosage (s/a=0.45 cc=340 kg/m^3 {case 4} and 380 kg/m^3, w/c=0.4{case 5})

Table 3.10 Mix Design for 2 Stages Admixture Dosage (Case 4 & Case 5)

Cases	Admixture name	Content (kg/m3 of Concrete)				Chemical Admixture (ml/100kg of cement)	w/c	s/a
		Cement	CA	FA	Water			
Case 4	SP6	340	1002.9	820.6	136	1800	0.4	0.45
Case 5	SP6	380	788.75	964	152	1800		

3.6 Workability Measurement

The mixing was done with the chemical admixture in a specific way. At 15 minute interval the workability of the concrete was tested by taking the slump value. When the concrete gave a slump of less or less equal to 3mm then the casting was done.

There was three criteria for applying chemical admixture.

1. Average Dosage Application
2. Maximum Dosage Application
3. 2 Stage Dosage Application

In two stage dosage application of Admixture, at first stage, when the slump was less or equal to 3 cm then the rest of the admixture was added to the concrete. For second stage dosage there was again increase in slump value. After that when the slump was again less or equal to 3 cm, casting was done.

Photo 3.8 Slump Test Procedure at 15 Minute Interval

3.7 Sample Making

3.7.1 Mold Preparation

The size of the cylindrical mold was 4 inch in diameter and 8 inch in height. The cylinder was prepared very carefully. They were tightened and the inside surface was polished with lubricant. For lubrication grease was used.

3.7.2 Casting

We used mixture machine for casting of cylindrical specimen. Here the mixing procedure was slightly different than the normal procedure followed in Bangladesh.

In Bangladesh all cement, sand and water put together in the mixing machine. But we followed the right procedure of mixing. At first 50% of the fine aggregate was poured in the mixing machine. Then all the cement was poured and then rest of the sand was poured for each case. After that they were mixed for about 30 second in the mixing machine. Then water mixed with the admixture was poured and again mixed for 30 second. After that coarse aggregate was poured in the mixing machine. The slump test


Photo 3.9 Mixing & Casting of Concrete

was carried out at 15 minutes interval. When we found that the slump was less or equal to 3 cm then the casting of the specimen was done.

3.7.3 Compaction of Specimens

The cylindrical specimen was properly compacted. Each of the specimen was compacted in two layers. In each layer we made 25 blows as per ASTM specification.

After the compaction hammering and scaling was done to attain void free specimens.

Photo 3.10 Concrete Pouring in Mold

Photo 3.11 Tamping of Concrete

Photo 3.12 Scaling

Photo 3.13 Hammering

Photo 3.14 Prepared Specimen Casted in Molds

3.7.4 Curing of the Specimen

Curing was done in two steps. After the casting when the surface was hardened we kept a wet cloth over the specimen.

After 24 hours the mold was opened and the specimens were put in bath for curing Normal tap water was used for the curing procedure. The curing was done for 7 days for 7^{th} day compressive strength and 28 days curing was done for the 28^{th} day compressive and tensile strength analysis. The temperature during curing period was maintained and kept 27° Celsius.

Photo 3.15 Primary Curing

Photo 3.16 Final Curing

3.8 Testing

3.8.1 Non Destructive Test

Ultrasonic Pulse Velocity (UPV) test was done on 7^{th} day and 28^{th} day. It is seen that with the increase of the strength the Velocity increases.

Photo 3.17 Ultrasonic Pulse Velocity Test (UPV)

3.8.2 Destructive Test

The Universal Testing Machine was used to carry on destructive test for the cylindrical specimen for measuring compressive strength of the samples for 7^{th} day and 28^{th} day. Before the destructive test of the cylindrical specimen capping was done.

Photo 3.18 Tensiometer

Photo 3.19 Compressive Strength Test

Photo 3.20 Tensile Strength Test

Chapter 4 Results and Discussion

4.1 General

As discussed before we have used 9 types of chemical admixtures in this study. Eight of them were Super Plasticizers and one of them is water reducer. The three criteria we selected for analyzing the results were- i) Average Dosage ii) Maximum Dosage & iii) Two Stage Dosage. In this chapter, the results obtained throughout the investigation are summarized and discussed. The effects of chemical admixtures type and dosage on compressive strength, splitting tensile strength, Young's modulus, and Ultrasonic Pulse Velocity are discussed. The effects of cement content, sand to total aggregate ratio on compressive strength of concrete are also discussed.

4.2 Effects of Chemical Admixture on Workability

Chemical admixtures are primarily used to increase the setting time of concrete to a certain desired level so the Ready Mix Concrete can be transported to the construction site without having it hardened before reaching the destination. To be able to determine the best possible way to increase the workability we worked with three types of concrete mixtures with variation of chemical admixture dosage.

4.2.1 Workability of Type 1 Concrete (cc = 340 kg/m3, w/c = 0.4, s/a = 0.4)

Slump values of different type 1 concrete mixtures are presented in figure 4.1. The result shows that slump values of the concrete mixtures made with - lignosulphonate based water reducer WR, synthetic polymer based superplasticizer SP8 and organic polymer based superplasticizer SP2 reduced drastically within half an hour. Modified polycarboxylic ether based SP4 and naphthalene sulphonate based SP1 gave comparatively better result than WR, SP2 and SP8; but as per JIS A 5308 specification the dosages are still not sufficient to meet the requirement of being used in ready mix concrete that will be hauled for casting. Modified polycarboxylic ether based SP5 and naphthalene sulphonate based SP6 gave slump values of 18.25 cm and 18 cm respectively. At the end of 90 minutes mixture produced by SP5 gave slump of 2 cm and at the end of 75 minutes mixture produced by SP6 gave slump of 2.5 cm. The best result is found for second generation polycarboxylic ether based superplasticizer SP3. The mixture prepared with this admixture resulted satisfactory workability at a temperature higher than 25°C even after 1.5 hours, which meets the requirement of JIS A 5308.

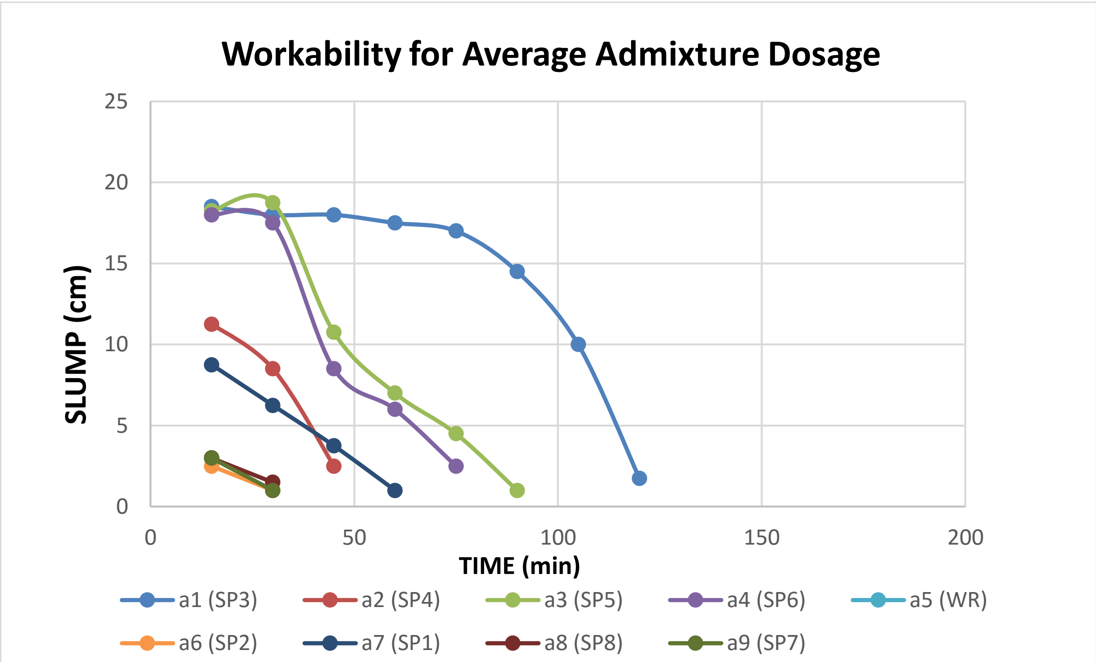

Figure 4.1 Workability of Type 1 Concrete

4.2.2 Workability of Type 2 Concrete (cc = 340 kg/m3, w/c = 0.4, s/a = 0.4)

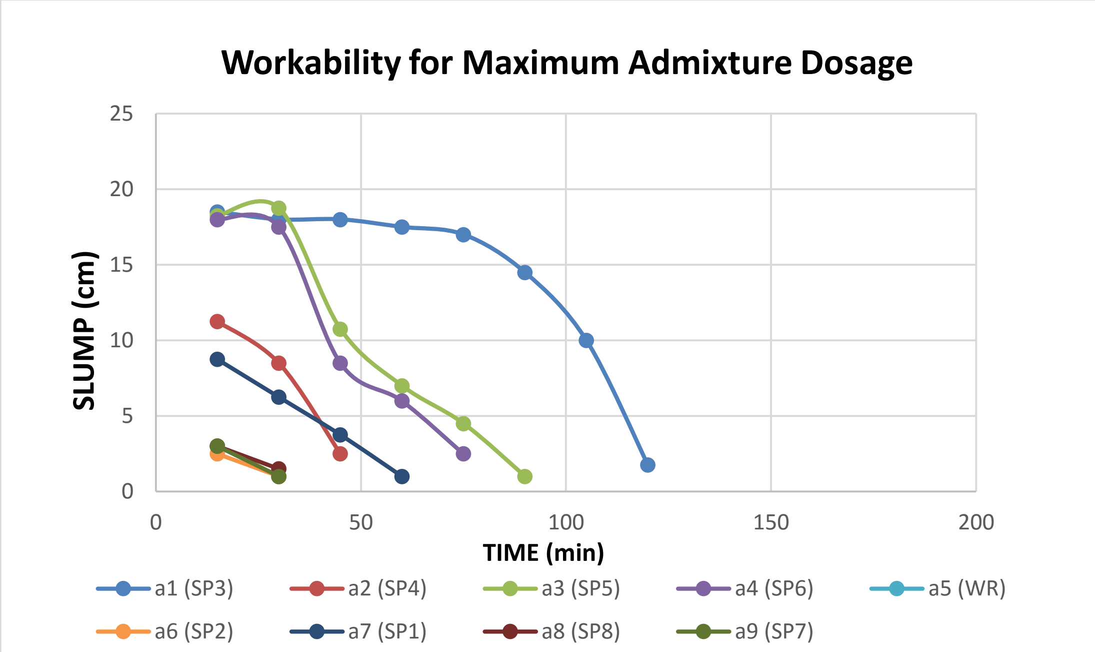

Figure 4.2 Workability of Type 2 Concrete

During the preparation of type 2 concrete the recommended maximum dosages of admixtures have been used. It can be seen from figure 4.2 that the initial slump values of mixtures prepared with WR and SP2 increased with the increase of admixture dosage but the final slump values at the end of 30 minutes didn't change much. In case of SP4, SP7 and SP8 the initial and final slump values are greater than those of type 1 concrete mixture. In case of SP1, SP3, SP5 and SP6 the initial slump values are smaller in comparison to those of type 1 concrete; but after 30-50 minutes the slump values increased and the values became greater than those of type 1 concrete. SP1, SP3, SP5 and SP6 remained workable more than 1.5 hours which is satisfactory according to JIS A 5308. Amongst all the admixtures used in type 2 concrete best result is found for naphthalene sulphonate based SP6 with a final slump of 3 cm after 150 minutes.

4.2.3 Workability of Type 3 Concrete (cc = 340 kg/m^3, w/c = 0.4, s/a = 0.4)

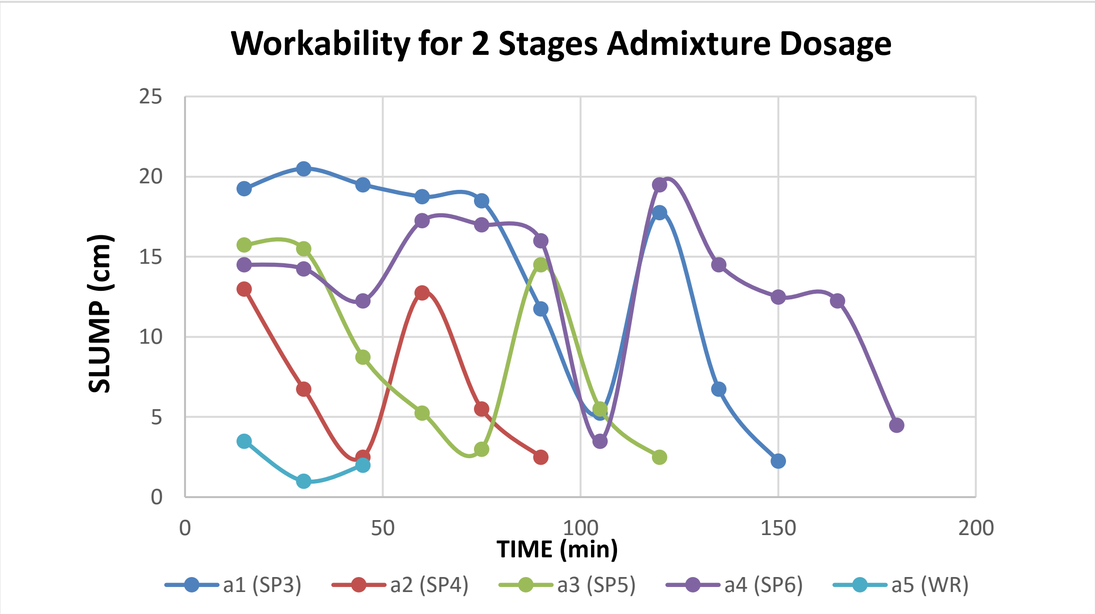

Figure 4.3 Workability of Type 3 Concrete

In case of Type 3 concrete the maximum recommended dosage of each admixture was applied in two stages. At first stage one half of the total admixture was applied and then when the slump value became less than or equal to 3 cm then another half was applied. Figure 4.3 shows, when the second half of the dosage was applied the slump values again increased for almost all the admixtures. The slump values attained after the application of second dosage were very close to the initial slump values. The best results were found for naphthalene sulphonate based superplasticizer SP6 and polycarboxylic ether based superplasticizer SP3. 4.4 and 4.5 show the workability performances of SP6 and SP3 respectively in case of type 1, 2 and 3 concrete.

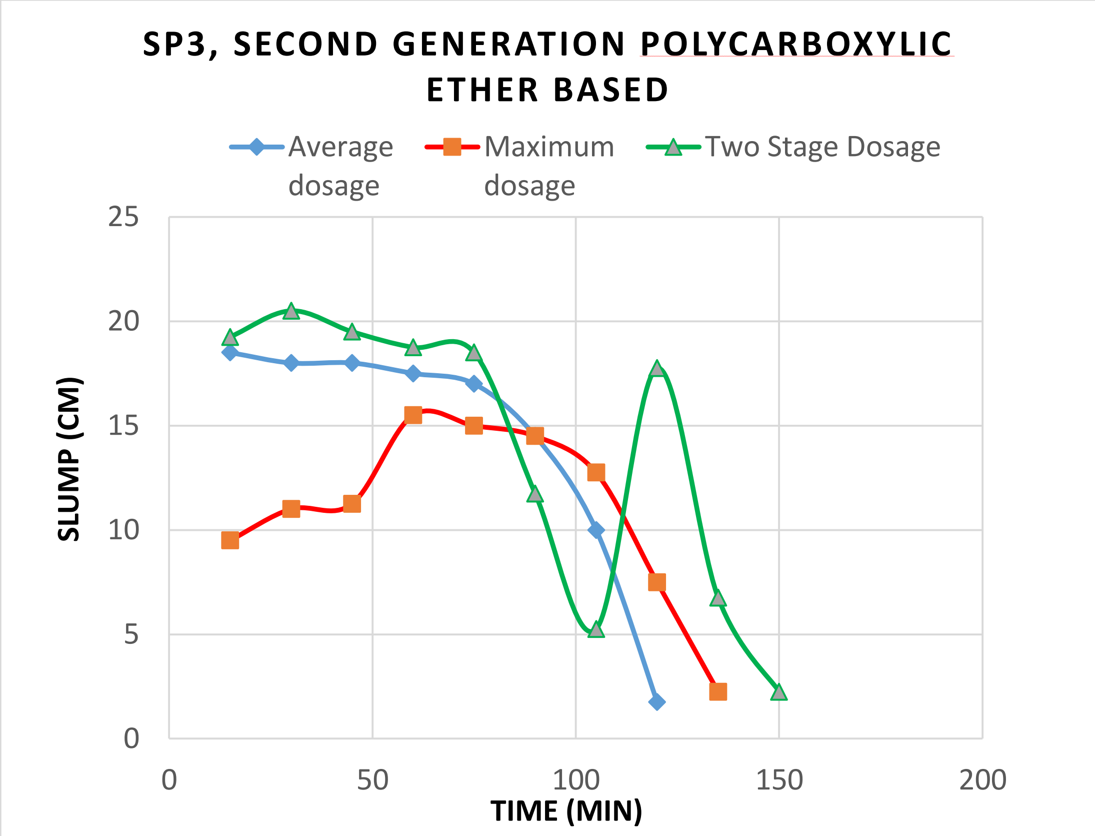

Figure 4.4 Workability Due to the Use of SP3 Admixture

Figure shows the results of slump test for SP3, 2nd generation Polycarboxylic ether base Super plasticizers having high range water reducing properties. It shows in all three dosage variation the slump have a value of 2 to 3 cm even after 120 to 150 minutes.

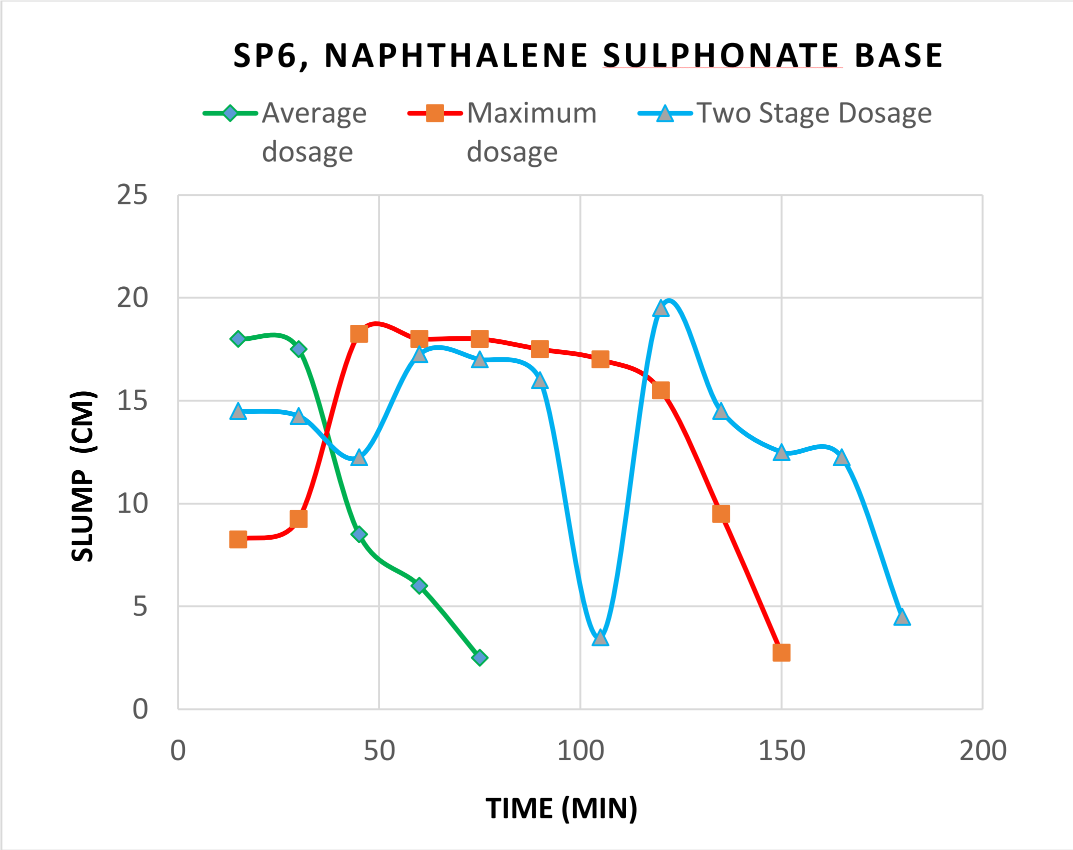

Figure 4.5 Workability Due to the Use of SP6 Admixture

Effect on workability of Admixture type SP6, a super plasticizer with both high range water reducing and retarding properties with chemical composition of Naphthalene sulphonate base is shown in figure. Other than average dosage the workability is quite better with a slump value of 3 to 4.5 even after 150 to 180 minutes.

4.2.4 Workability of Type 4 Concrete (cc = 340 kg/m3, w/c = 0.4, s/a = 0.45)

Type 4 concrete was prepared with naphthalene sulphonate based superplasticizer SP6. In this type of concrete only the s/a value was increased to 0.45 from 0.4 but the cement content and water to cement ratio were kept similar to those of type 3 concrete. Figure 4.6 shows type 4 concrete mixture gave smaller slump than type 3 concrete mixture prepared with SP6.

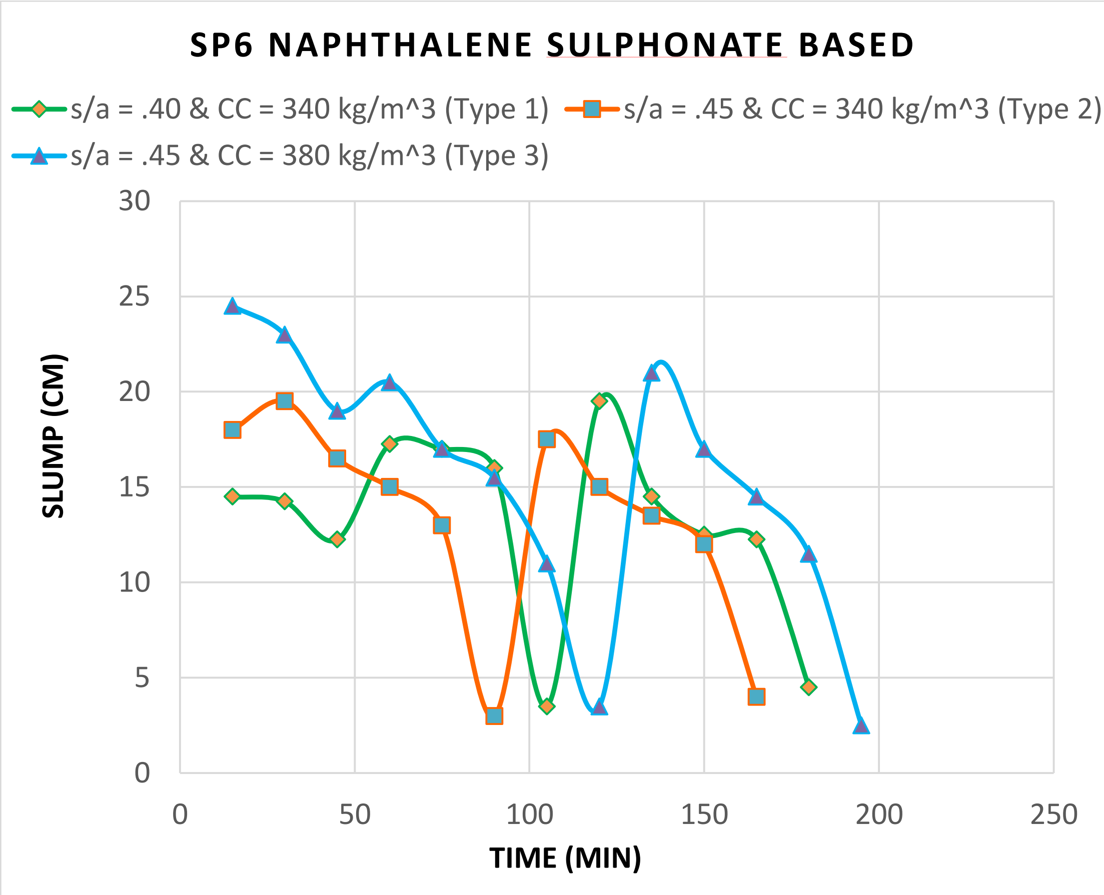

Figure 4.6 Workability of Type 3, 4 &5 Concrete (SP6)

4.2.5 Workability of Type 5 Concrete (cc = 380 kg/m3, w/c = 0.4, s/a = 0.45)

In type 5 concrete, cement content was also increased to 380 kg/m^3. It can be seen from Figure z that type 5 concrete mixture gave better slump value than both type 3 and 4 concrete mixtures.

4.3 Hardened Properties of Concrete

4.3.1 Effects of Chemical Admixture on Ultrasonic Pulse Velocity

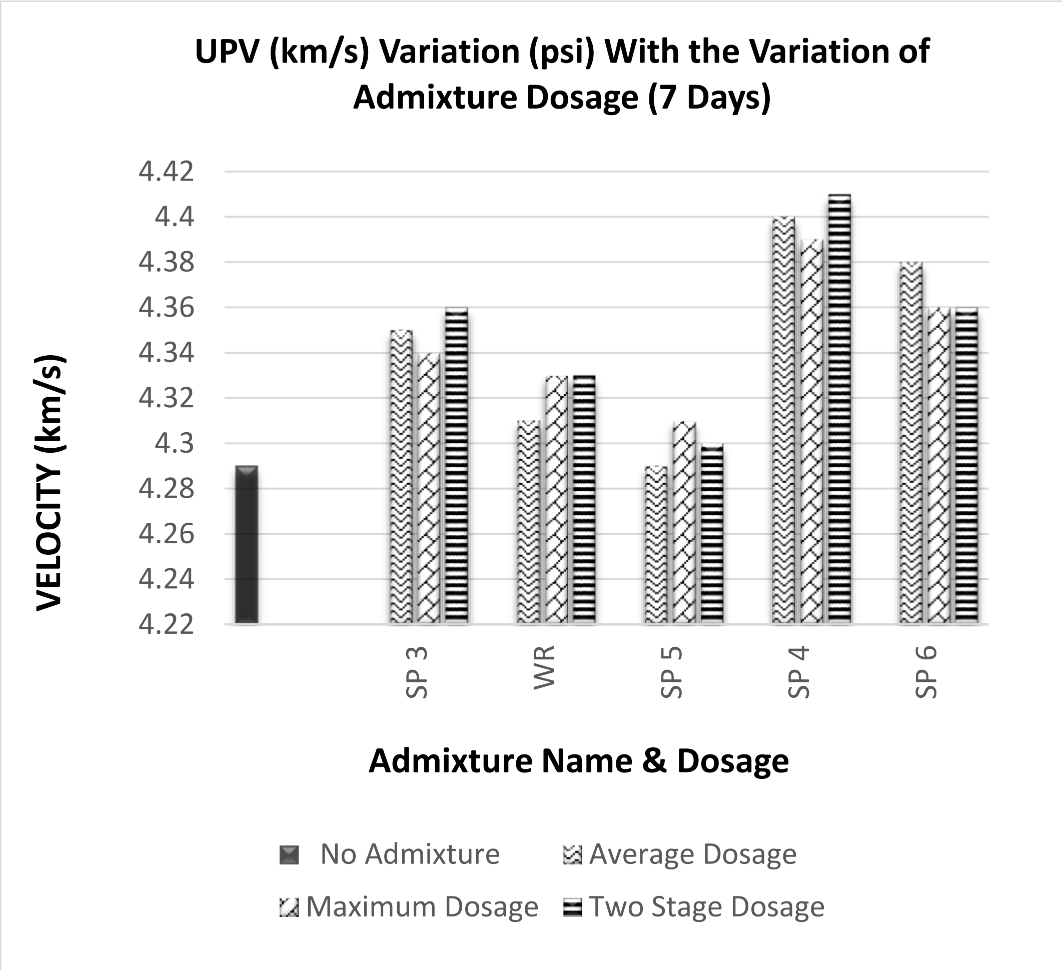

Figure 4.7 UPV Variation of 7 Days

7 days and 28 days UPV test results for type 1, 2 and 3 concrete cylinders prepared with different admixtures are shown in figure 4.7 and figure 4.8 respectively. Both the figures show that in most of the cases UPV through concrete made with chemical admixtures is higher than UPV through concrete made without admixture. The figures also show that, when the dosage is within the recommended range, for a

particular admixture UPV don't vary much in case of type 1, 2 and 3 concrete. UPV through concrete prepared with naphthalene sulphonate based superplasticizer SP6 is higher in comparison to most of the admixtures. Past studies (Yang et al 2010, Ravindrarajah 1997, Bogas et al 2013) suggest that UPV through concrete increases with the increase of compressive strength. In this study similar finding has been obtained. Concrete made with SP6 imparted both higher compressive strength and higher UPV compared to other admixtures.

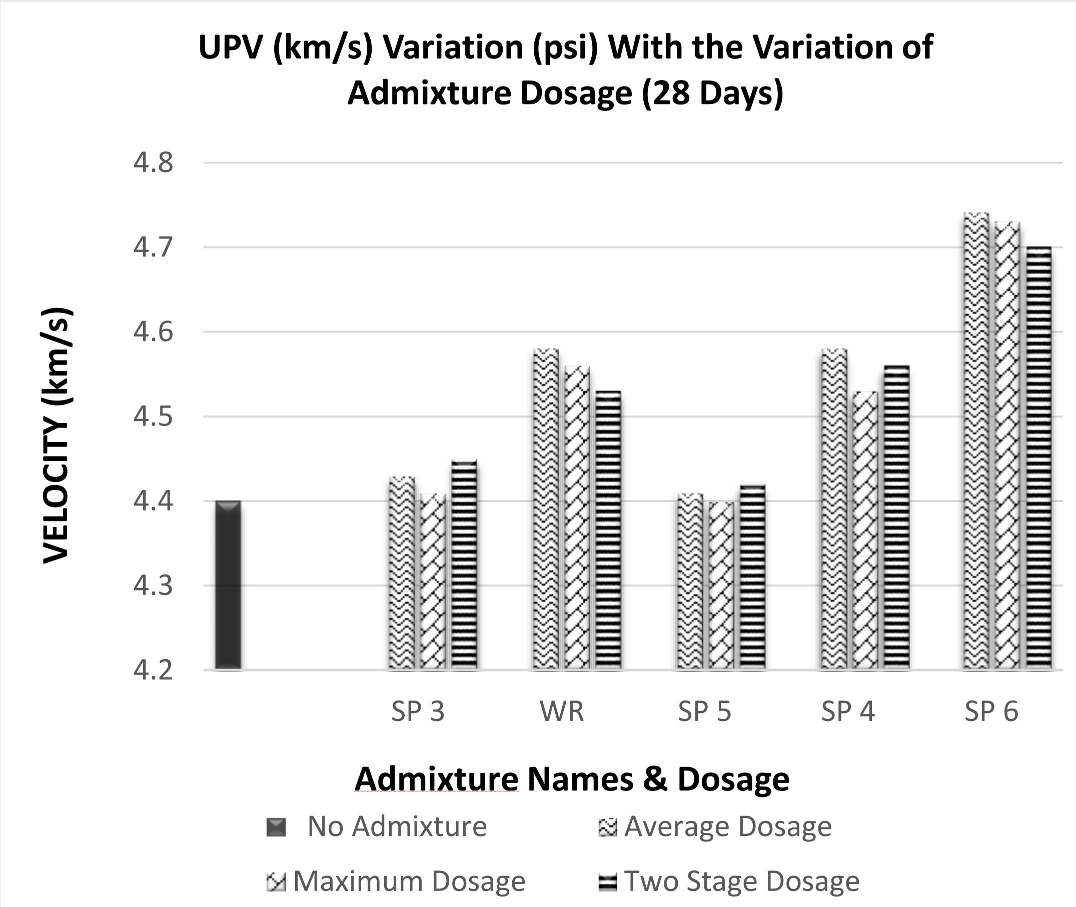

Figure 4.8 UPV Variation of 28 Days

4.3.2 Effects of Chemical Admixture on Compressive Strength

4.3.2.1 Compressive Strength of Type 1, 2 & 3 Concrete

Table 4.1 Effects on 7 Days Compressive Strength (psi) Due to Using of Different Dosage of Admixture

Admixture Type	Compressive Strength (psi)		
	Average Dosage	Maximum Dosage	Two Stage Dosage
SP 3	4359	4461	4464
SP 5	2989	3650	3417
SP 4	3747	3369	3835
WR	3485	3421	3328
SP 6	4476	3950	3898
SP 8	4286	4018	-
SP 7	3707	4503	-
SP 1	3269	3578	-
SP 2	3069	3541	-

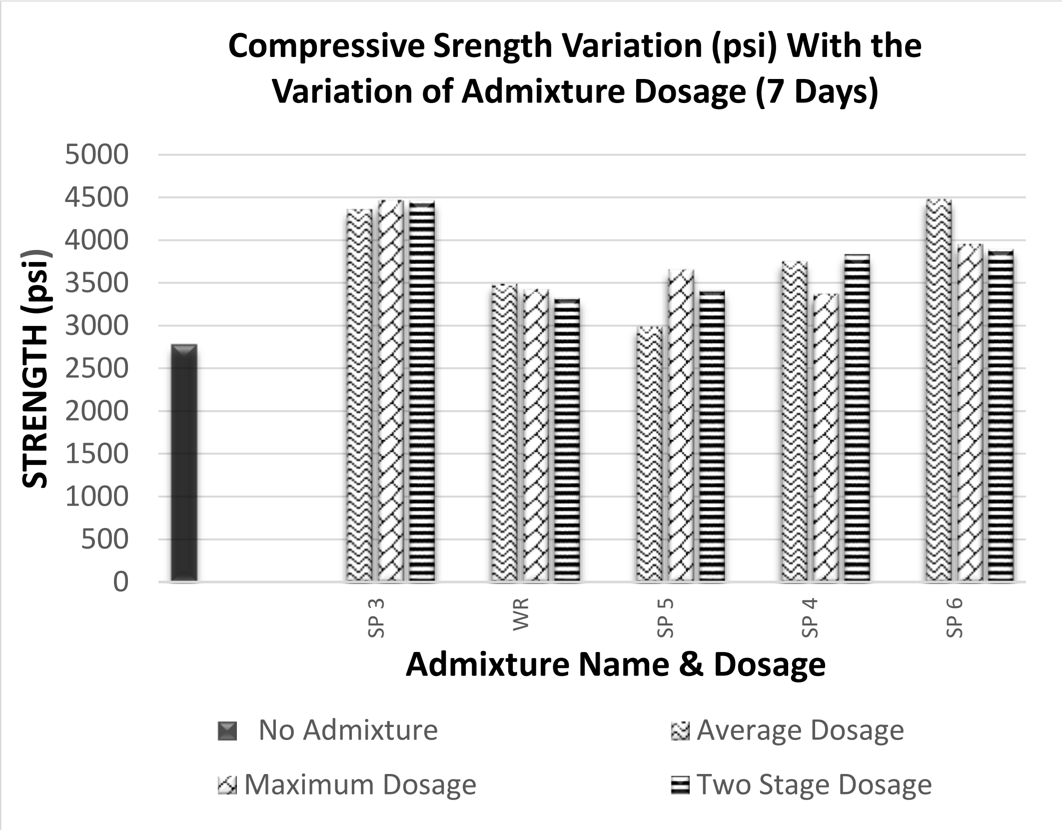

Figure 4.9 Compressive Strength Variation of 7 Days

Figure 4.9 and figure 4.10 show 7 days and 28 days compressive strengths respectively for type 1, 2 and 3 concrete cylinders prepared with different admixtures. Both the figures show that concrete cylinders made with chemical admixtures give much better compressive strength than concrete cylinder made without admixture. The figures also show that, when the dosage is within the recommended range, for a particular admixture compressive strength values don't vary much in case of type 1, 2 and 3 concrete. But compressive strength tends to vary a little with the variation of admixture type. Previous studies on effect of chemical admixtures on strength of concrete (Alsadey, 2012) Vol. 1, No. 3, 2012 ISSN 2277 – 4378) shows that continuous strength gain for chemical admixture is observed by the increase in compressive strength with increase dosage of super plasticizer, but when we observe the effect of dosage of the admixture, the admixture present different behaviors on the compressive strength of concrete. Addition of super plasticizer not able to increase the compressive strength of concrete, on the other hand, it reduces the strength significantly, and become worse when the dosages increase. The super plasticizer (SP), increase in dosage will increase the compressive strength. Since addition of SP will provide more water for concrete mixing, not only the hydration process will not be disturbed, but, it is accelerated by the additional water from de flocculation of cement particles. Hence, increase in dosage will increase the entrapped water and promote hydration of cement. Though increment in dosage of admixture will enhance the compressive strength, there is still an optimum limit for the usage of admixture. When the dosages go beyond this limit, increase in dosage will only reduce the compressive strength. This phenomenon occur since over dosage of SP will cause bleeding and segregation, which will affect the cohesiveness and uniformity of the concrete. As a result, compressive strength will reduce if the used dosage is beyond the optimum dosage. In comparison to other admixtures naphthalene sulphonate based super plasticizer SP6 and polycarboxylic ether based super plasticizer SP3 imparted higher 7 days and 28 days compressive strengths. All the admixtures imparted satisfactory compressive strengths which meet the requirement of normal concrete as per JIS A 5308.

Table 4.2 Effects on 28 Days Compressive Strength (psi) Due to Using of Different Dosage of Admixture

Admixture Type	Compressive Strength (psi)		
	Average Dosage	Maximum Dosage	Two Stage Dosage
SP 3	5632	5776	4861
SP 5	3871	4139	4319
SP 4	4912	4921	5007
WR	4079	4606	4171
SP 6	5809	5175	5383
SP 8	5596	5438	-

Admixture Type	Compressive Strength (psi)		
	Average Dosage	Maximum Dosage	Two Stage Dosage
SP 7	5606	5418	-
SP 1	4944	4894	-
SP 2	4195	5284	-

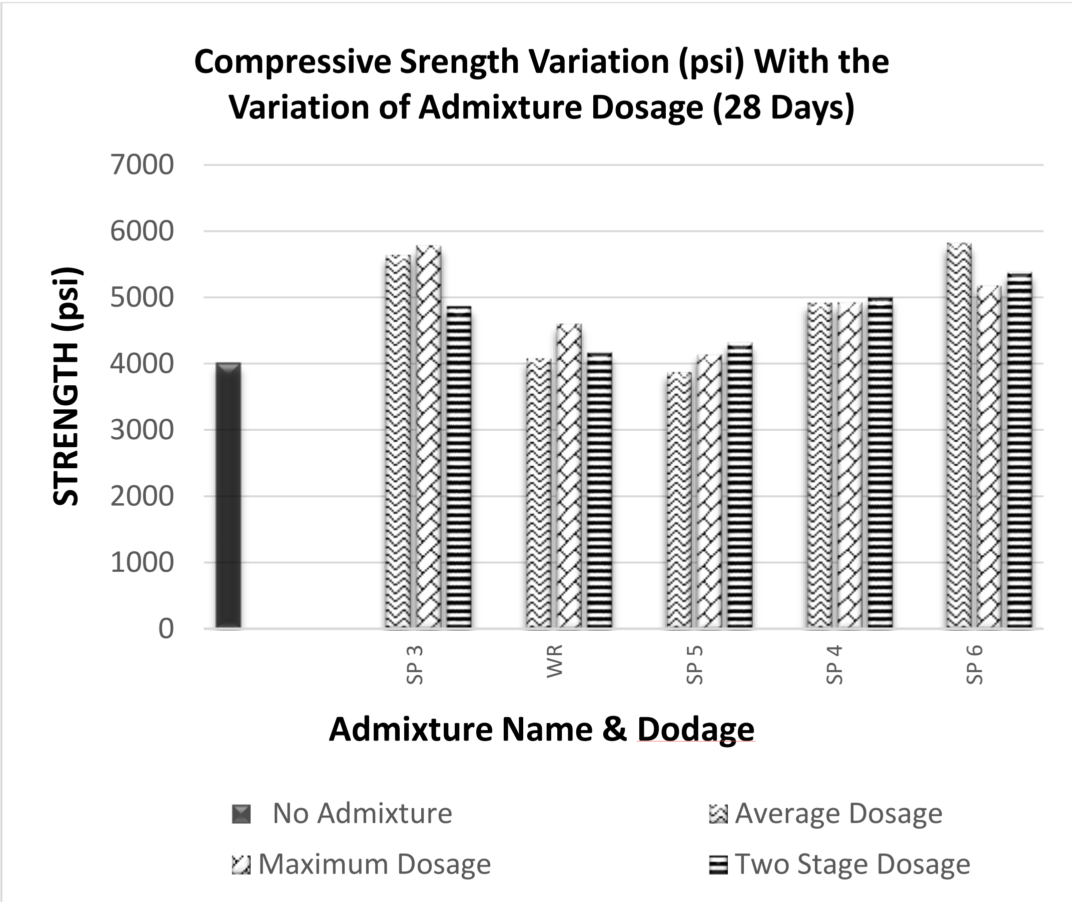

Figure 4.10 Compressive Strength Variation of 28 Days

4.3.2.2 Compressive Strength of Type 4 & 5 Concrete

From Figure we can see the variation of compressive strength for concrete with super plasticizer SP6 with the variation of s/a ratio and cement content per unit volume and here admixture was added in two stages as well. As we can see from figure, concrete mixed with higher s/a ratio with rest of the content constant the compressive strength falls significantly and when concrete is mixed with higher s/a ratio and higher cement content per unit volume at the same time, it gives a better compressive strength even a little better than original concrete mixture of s/a ratio 0.40 and cement content 340 kg/m^{3}.

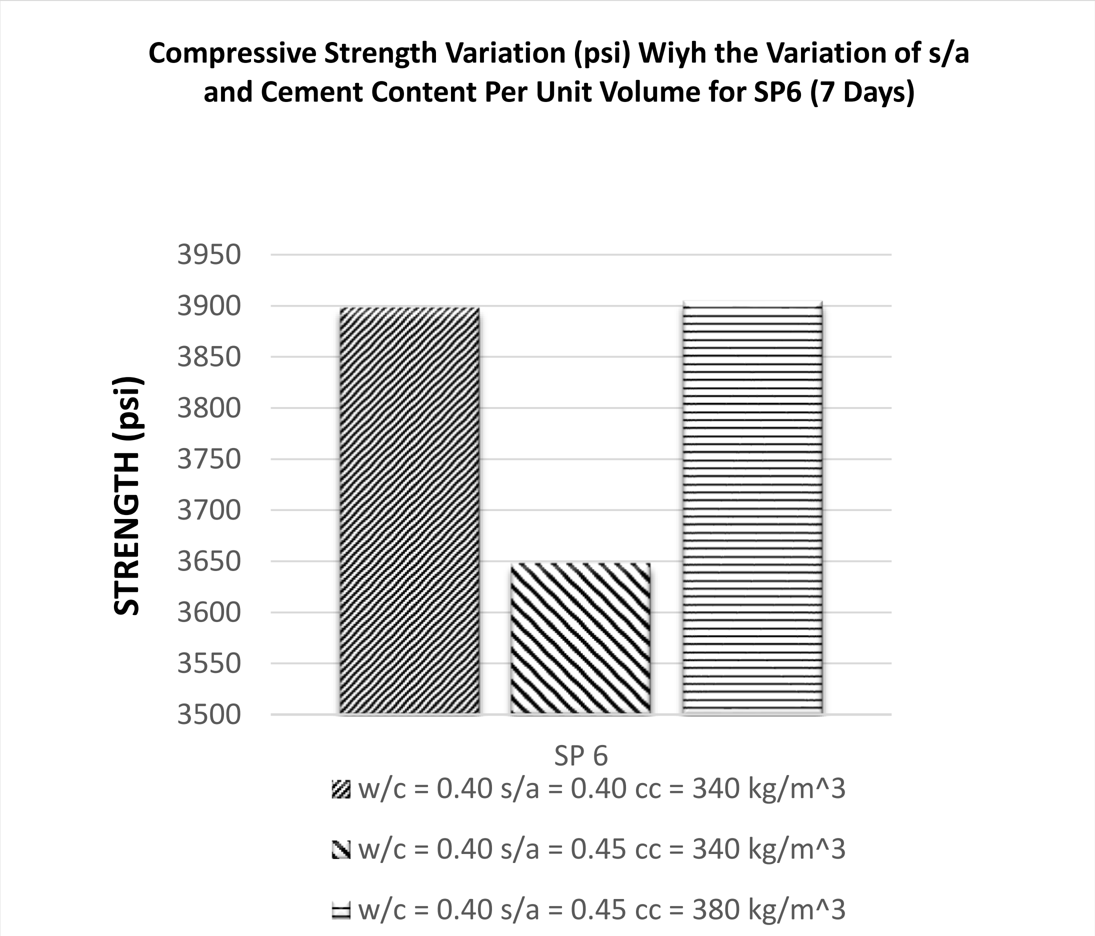

Figure 4.11 Variation in Compressive Strength (7 Days) Due to Change in s/a and Cement Content

4.3.3 Effects of Chemical Admixture on Splitting Tensile Strength (28th day)

Table 4.3 Effects of Chemical Admixture on Splitting Tensile Strength (psi)

Admixture Type	Splitting Tensile Strength (psi)		
	Average Dosage	Maximum Dosage	Two Stage Dosage
SP 3	110.31	89.33	89.88
SP 5	93.56	90.2	91.86
SP 4	87.15	88.38	99.83
WR	101.09	91.08	94.38
SP 6	101.16	89.27	100.47
SP 8	109.6	83.33	-
SP 7	100.83	101.71	-
SP 1	85.91	87.43	-
SP 2	95.53	94.84	-

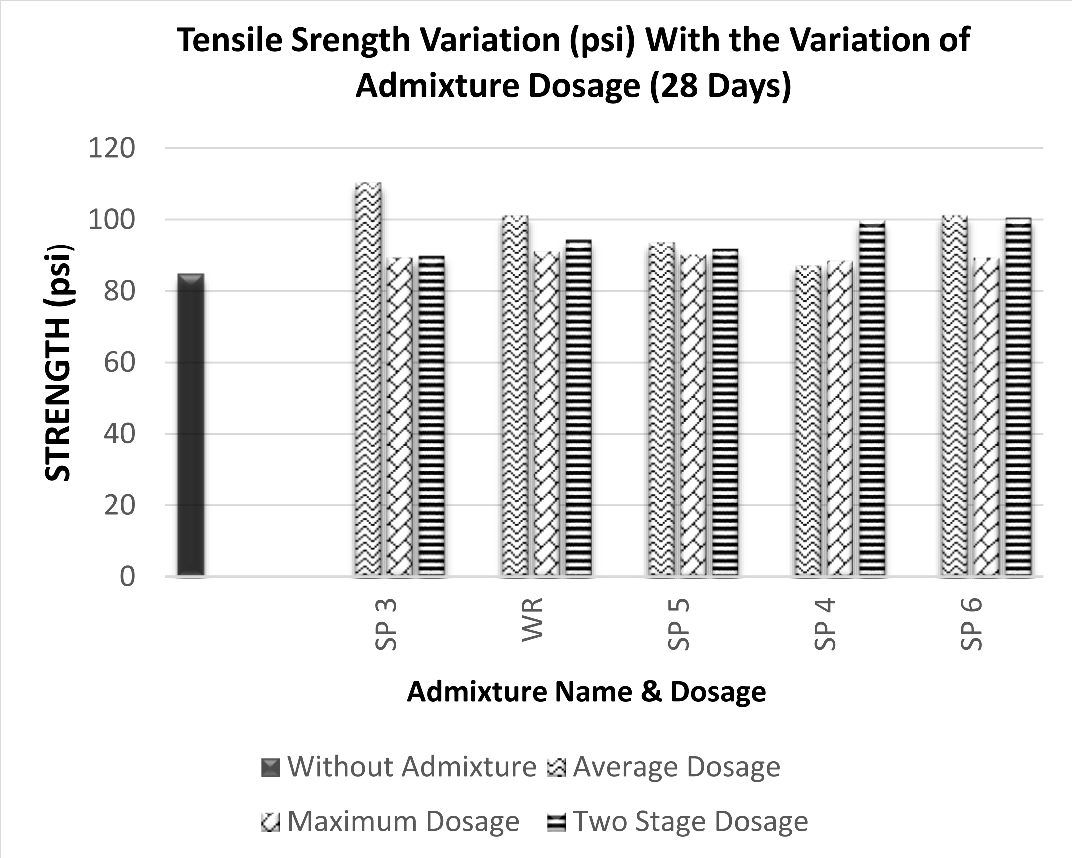

Figure 4.12 Tensile Strength Variation

A clear comparison is shown in the figure with the variation of admixture type and dosage type and without admixture. As we can see from the figure splitting tensile strength tends to increase with addition of chemical admixture. Splitting tensile strength also varies with the variation of admixture type as well as dosage.

4.3.4 Young's Modulus of Concrete

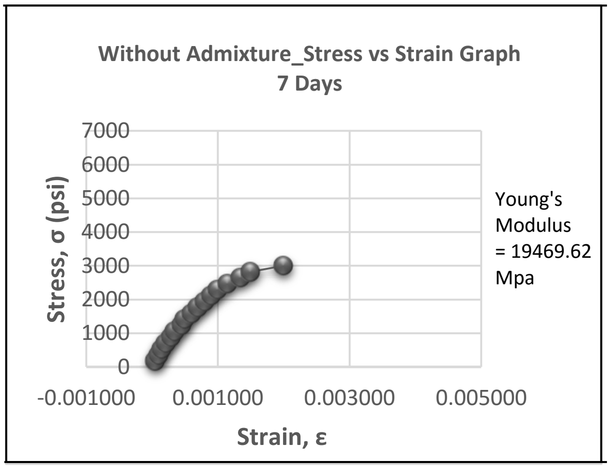

Figure 4.13 Stress vs Strain Graph Without Admixture (7 Days)

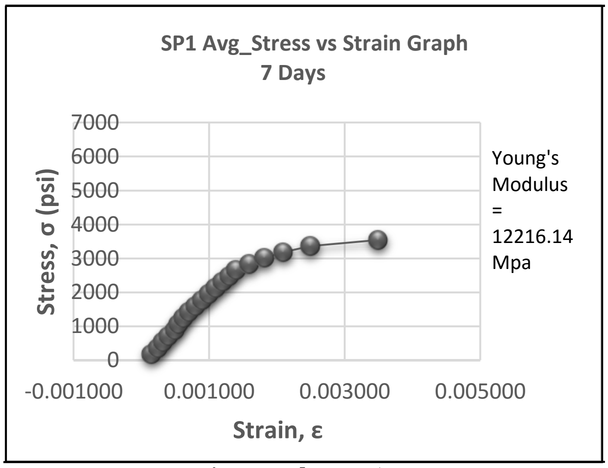

Figure 4.14 Stress vs Strain Graph SP1 (Average Dosage-7 Days)

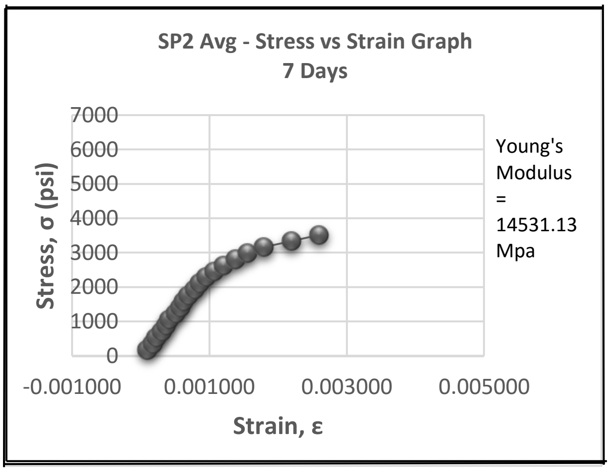

Figure 4.15 Stress vs Strain Graph SP2 (Average Dosage-7 Days)

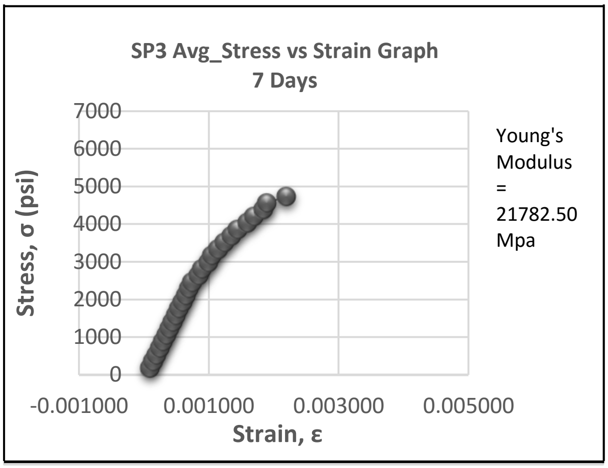

Figure 4.16 Stress vs Strain Graph SP3 (Average Dosage-7 Days)

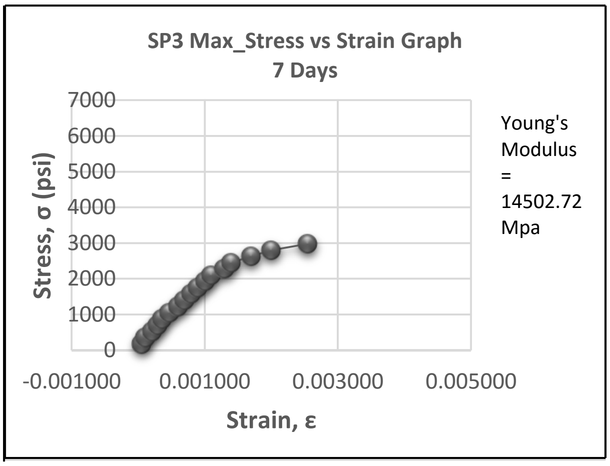

Figure 4.17 Stress vs Strain Graph SP3 (Maximum Dosage-7 Days)

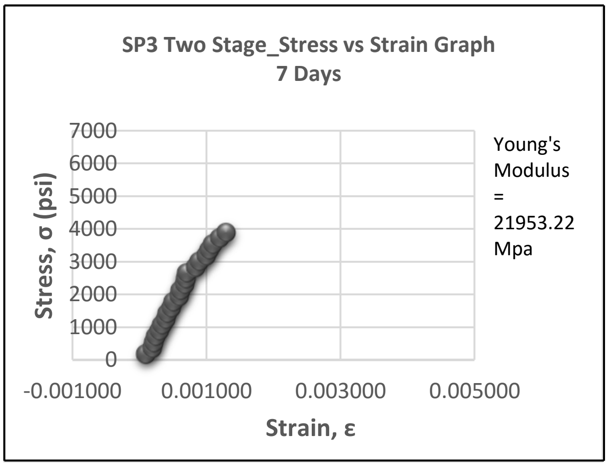

Figure 4.18 Stress vs Strain Graph SP3 (Two Stage Dosage-7 Days)

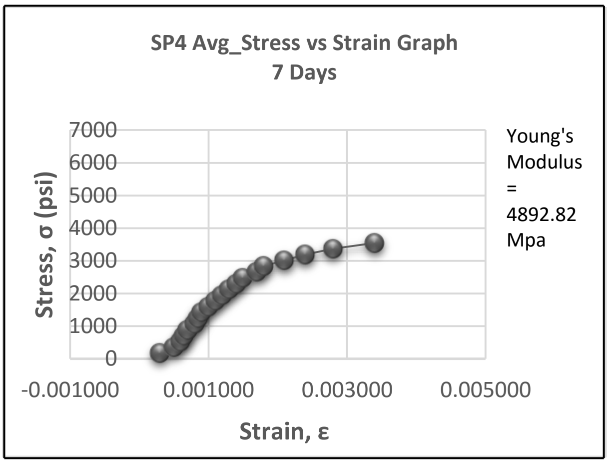

Figure 4.19 Stress vs Strain Graph SP4 (Average Dosage-7 Days)

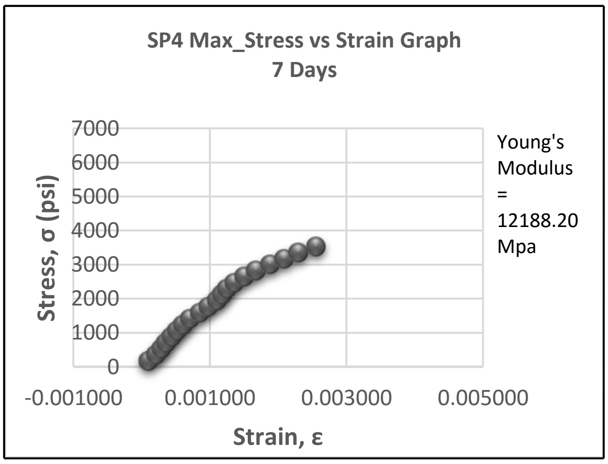

Figure 4.20 Stress vs Strain Graph SP4 (Maximum Dosage-7 Days)

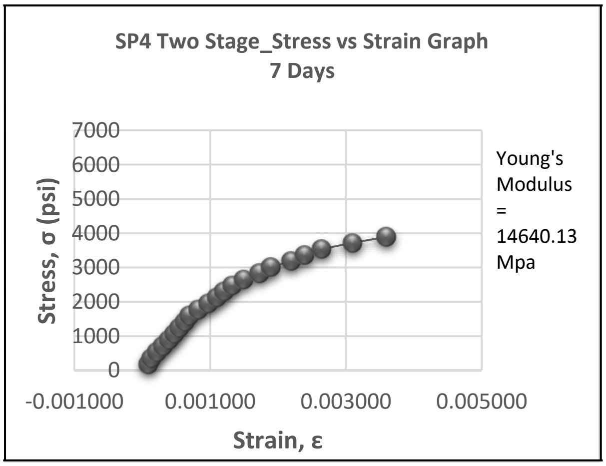

Figure 4.21 Stress vs Strain Graph SP4 (Two Stage Dosage-7 Days)

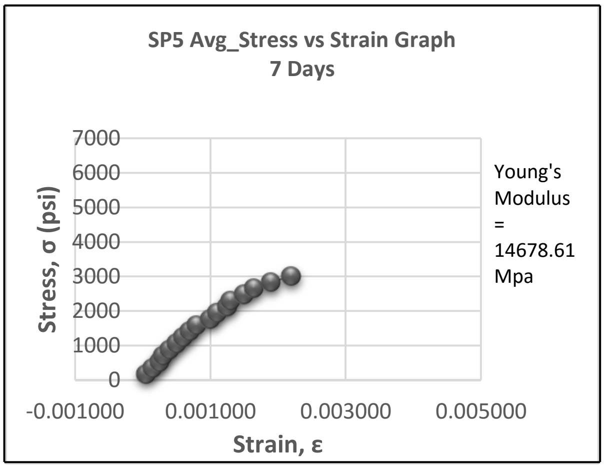

Figure 4.22 Stress vs Strain Graph SP5 (Average Dosage-7 Days)

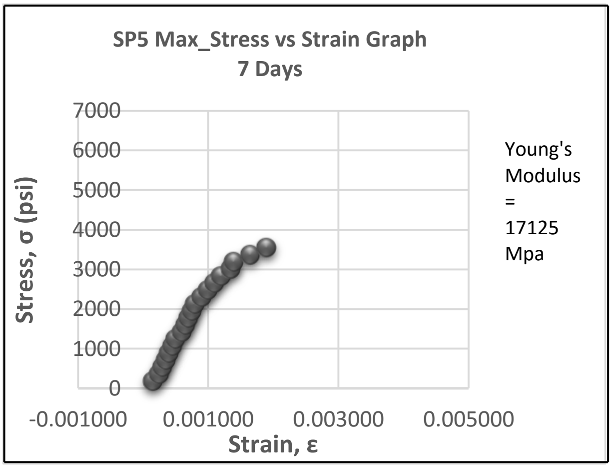

Figure 4.23 Stress vs Strain Graph SP5 (Maximum Dosage-7 Days)

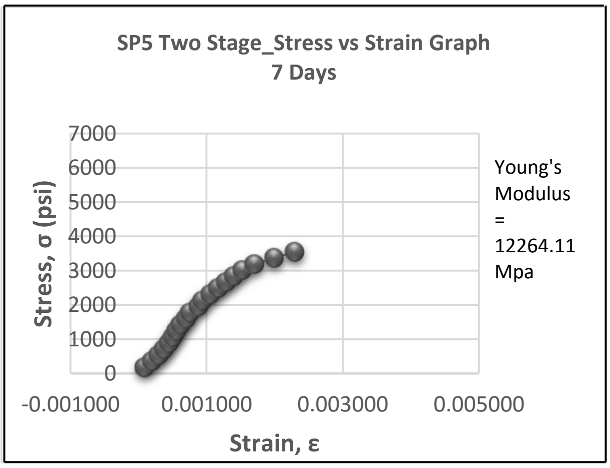

Figure 4.24 Stress vs Strain Graph SP5 (Two Stage Dosage-7 Days)

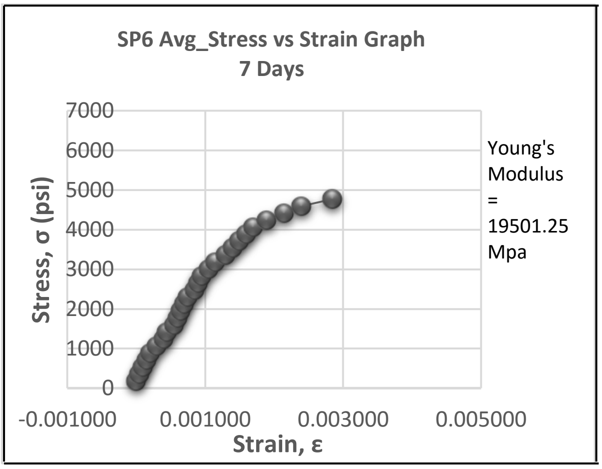

Figure 4.25 Stress vs Strain Graph SP6 (Average Dosage-7 Days)

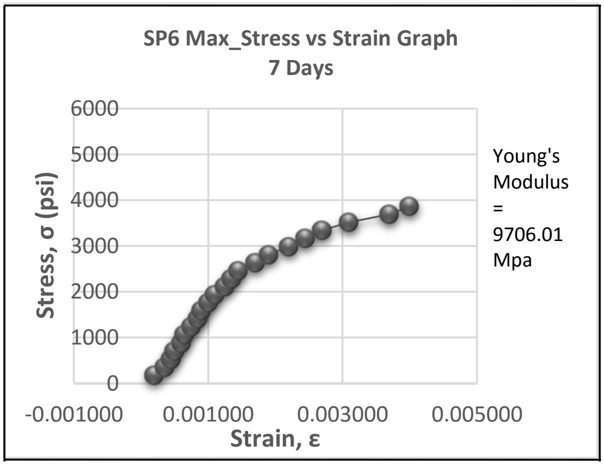

Figure 4.26 Stress vs Strain Graph SP6 (Maximum Dosage-7 Days)

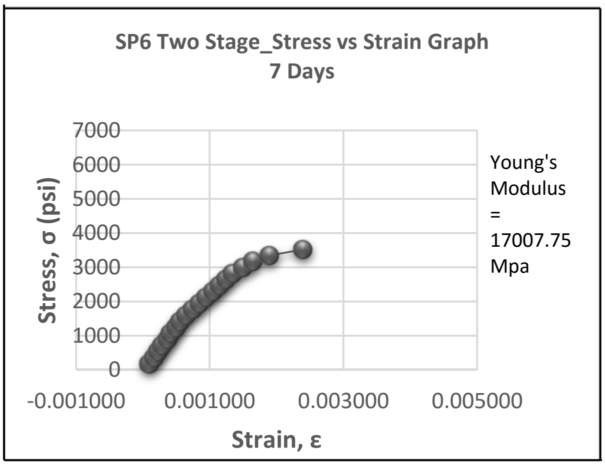

Figure 4.27 Stress vs Strain Graph SP6 (Two Stage Dosage-7 Days)

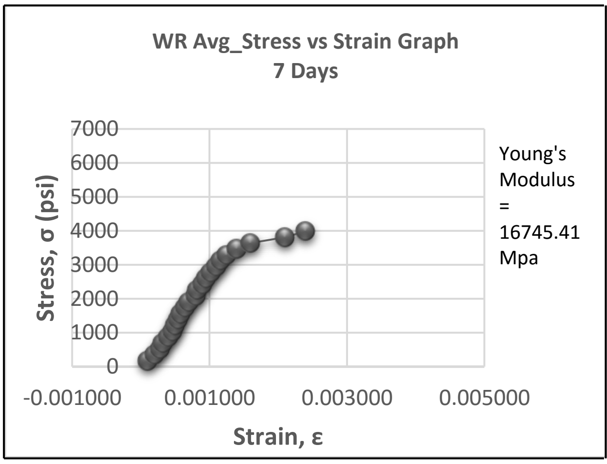

Figure 4.28 Stress vs Strain Graph WR (Average Dosage-7 Days)

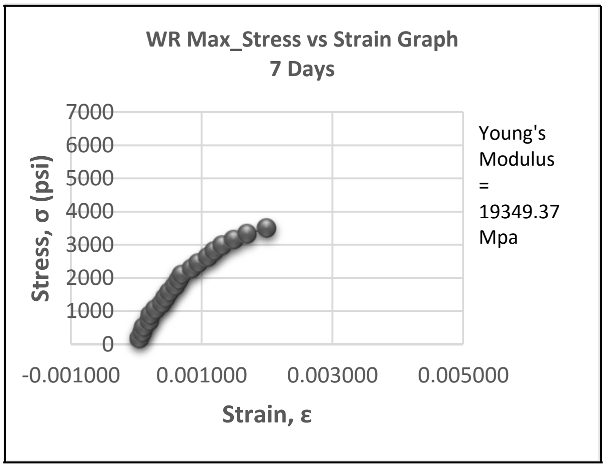

Figure 4.29 Stress vs Strain Graph WR (Maximum Dosage-7 Days)

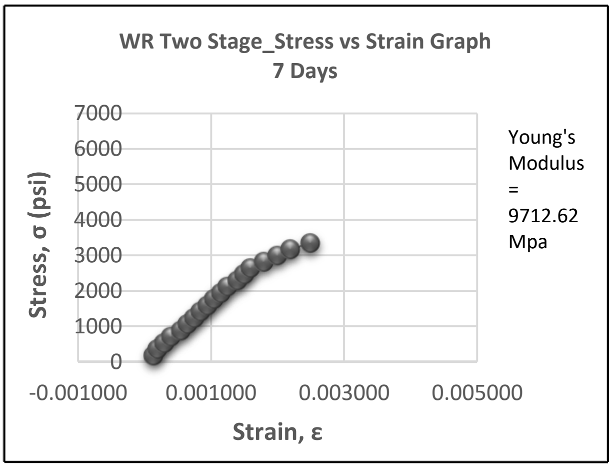

Figure 4.30 Stress vs Strain Graph WR (Two Stage Dosage-7 Days)

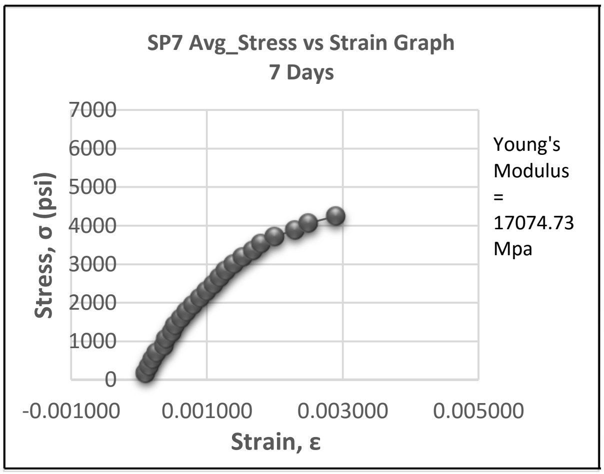

Figure 4.31 Stress vs Strain Graph SP7 (Average Dosage-7 Days)

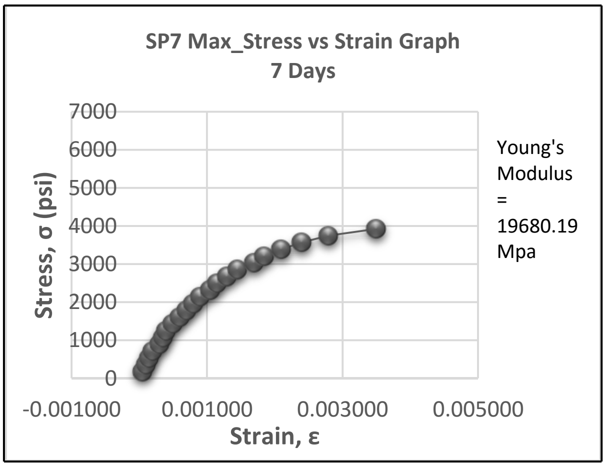

Figure 4.32 Stress vs Strain Graph SP7 (Maximum Dosage-7 Days)

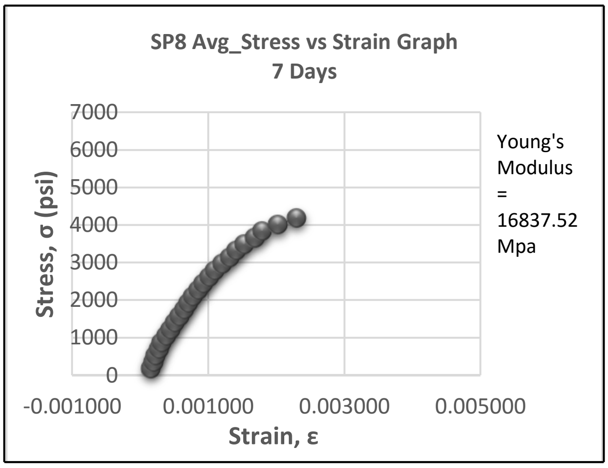

Figure 4.33 Stress vs Strain Graph SP8 (Average Dosage-7 Days)

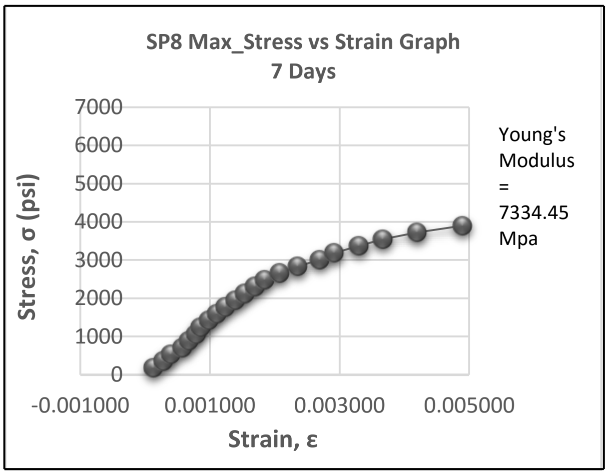

Figure 4.34 Stress vs Strain Graph SP8 (Maximum Dosage-7 Days)

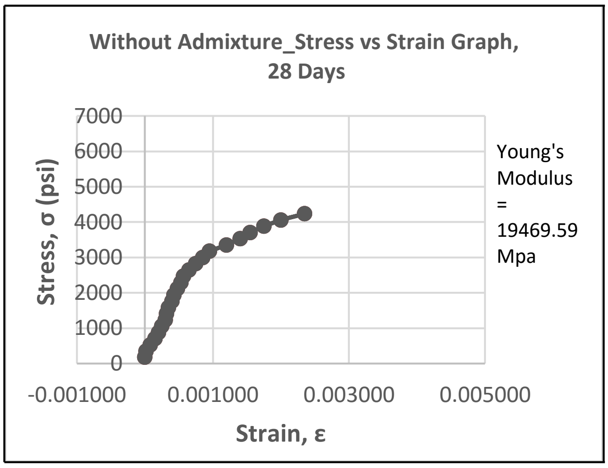

Figure 4.35 Stress vs Strain Graph Without Admixture (28 Days)

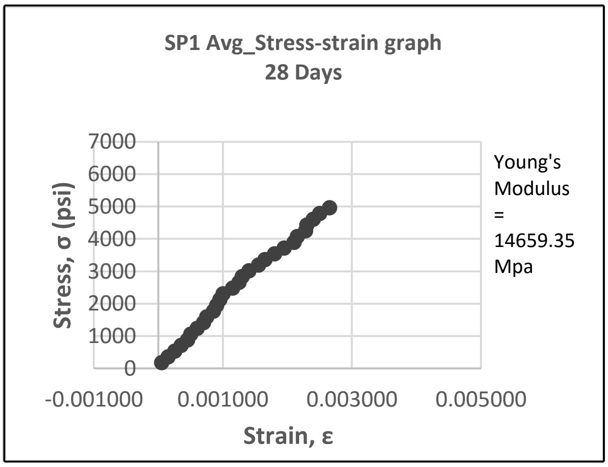

Figure 4.36 Stress vs Strain Graph SP1 (Average Dosage-28 Days)

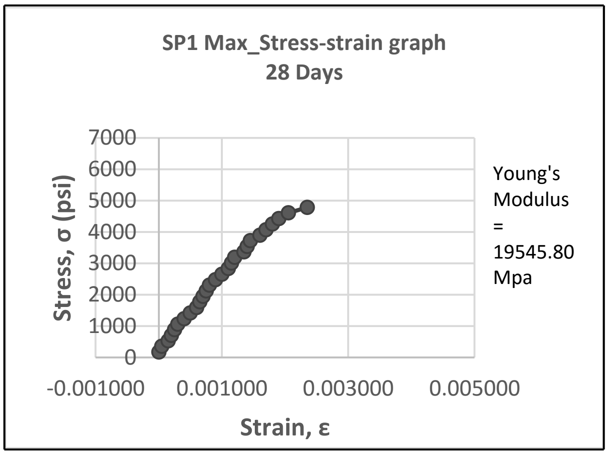

Figure 4.37 Stress vs Strain Graph SP1 (Maximum Dosage-28 Days)

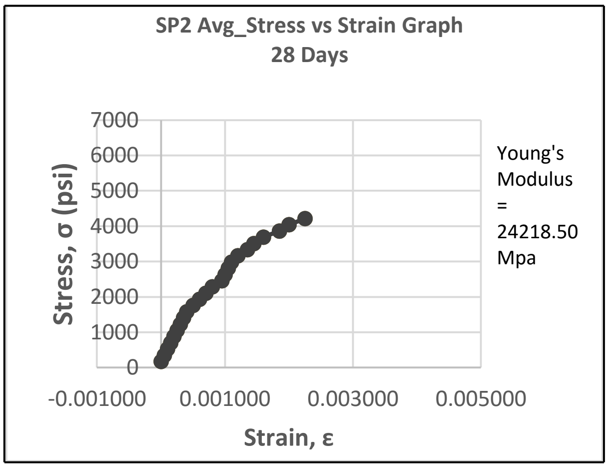

Figure 4.38 Stress vs Strain Graph SP2 (Average Dosage-28 Days)

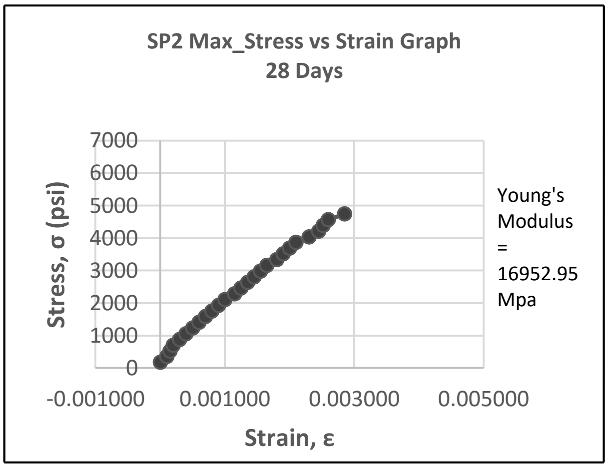

Figure 4.39 Stress vs Strain Graph SP2 (Maximum Dosage-28 Days)

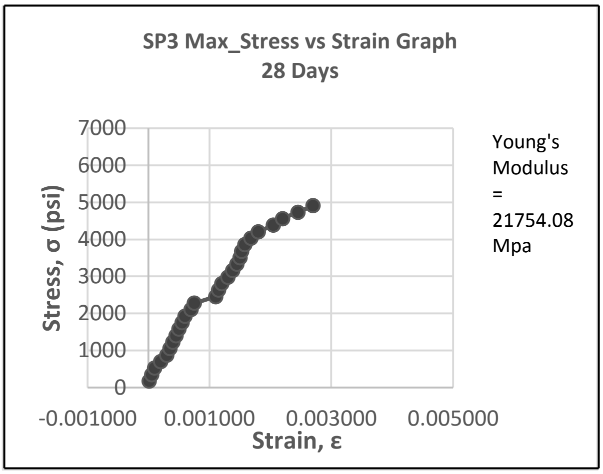

Figure 4.40 Stress vs Strain Graph SP3 (Maximum Dosage-28 Days)

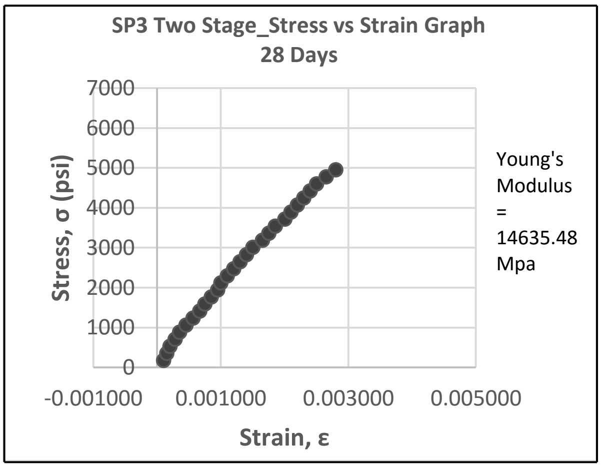

Figure 4.41 Stress vs Strain Graph SP3 (Two Stage Dosage-28 Days)

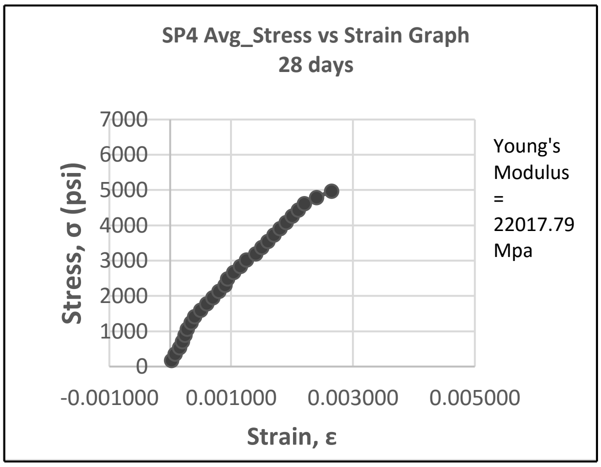

Figure 4.42 Stress vs Strain Graph SP4 (Average Dosage-28 Days)

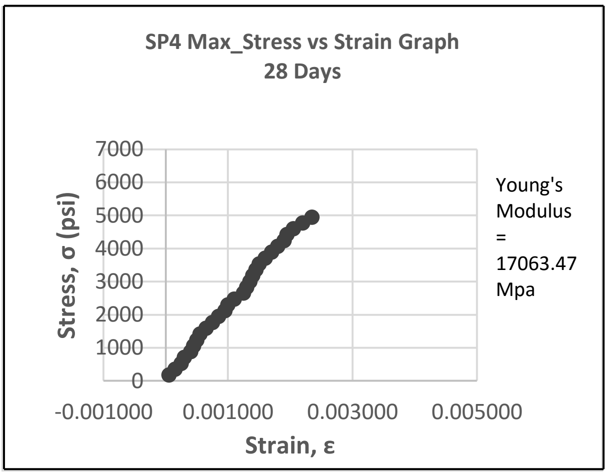

Figure 4.43 Stress vs Strain Graph SP4 (Maximum Dosage-28 Days)

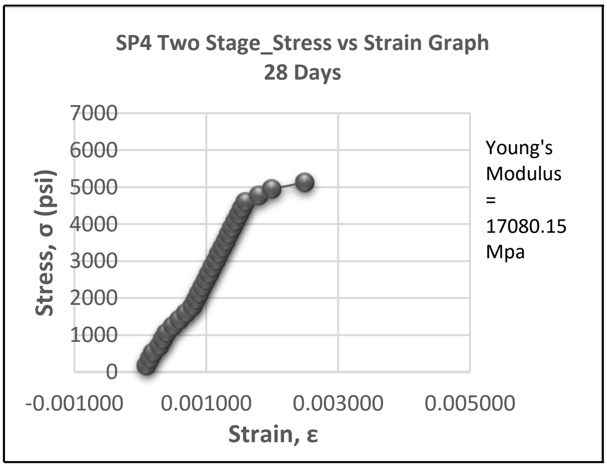

Figure 4.44 Stress vs Strain Graph SP4 (Two Stage Dosage-28 Days)

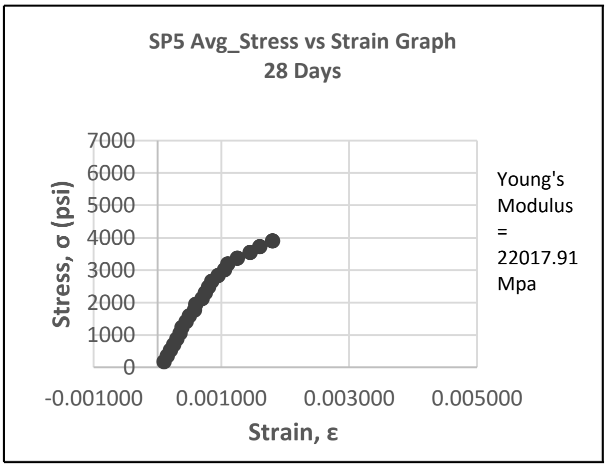

Figure 4.45 Stress vs Strain Graph SP5 (Average Dosage-28 Days)

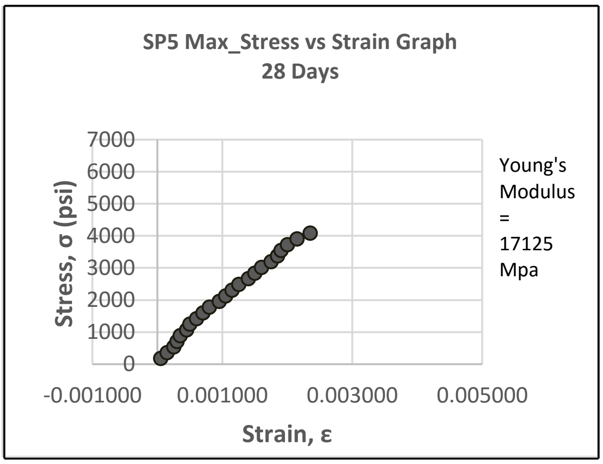

Figure 4.46 Stress vs Strain Graph SP5 (Maximum Dosage-28 Days)

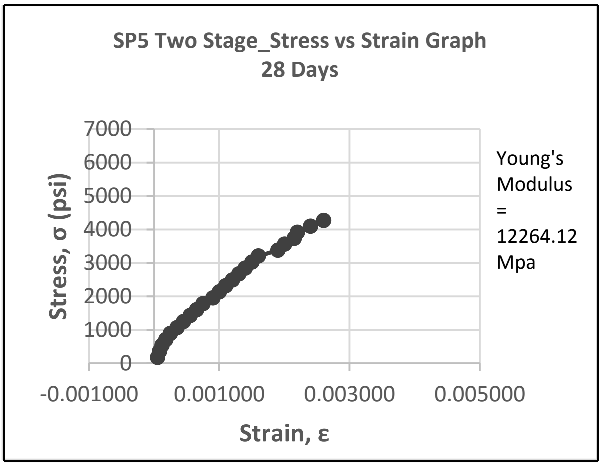

Figure 4.47 Stress vs Strain Graph SP5 (Two Stage Dosage-28 Days)

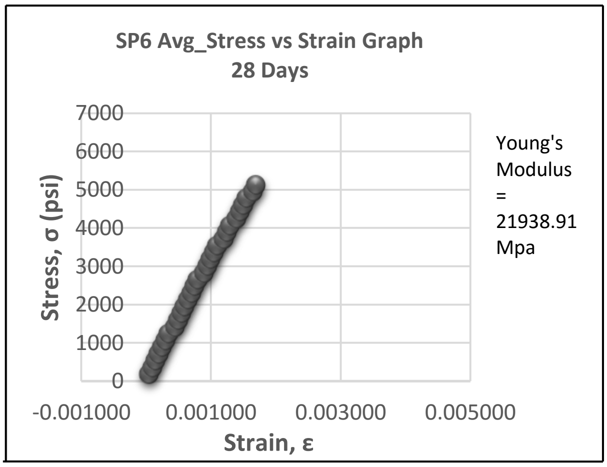

Figure 4.48 Stress vs Strain Graph SP6 (Average Dosage-28 Days)

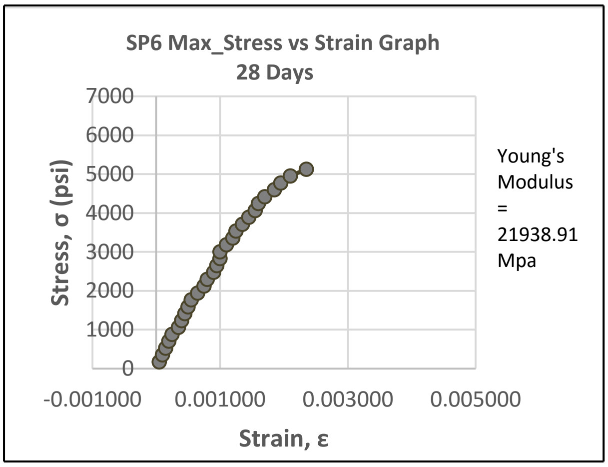

Figure 4.49 Stress vs Strain Graph SP6 (Maximum Dosage-28 Days)

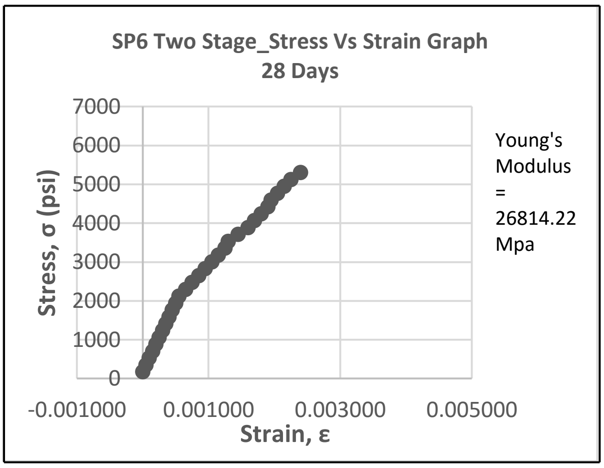

Figure 4.50 Stress vs Strain Graph SP6 (Two Stage Dosage-28 Days)

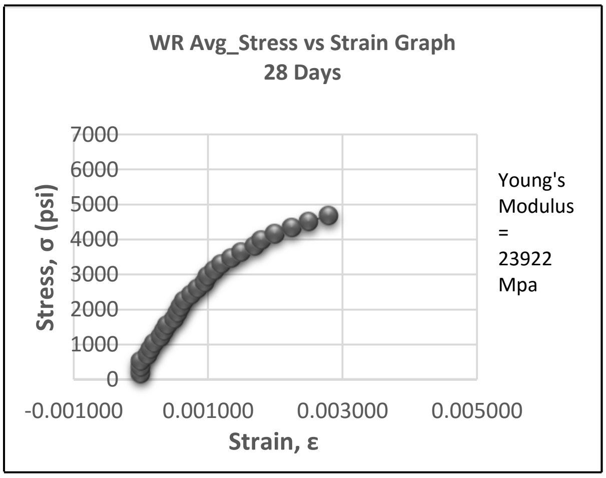

Figure 4.51 Stress vs Strain Graph WR (Average Dosage-28 Days)

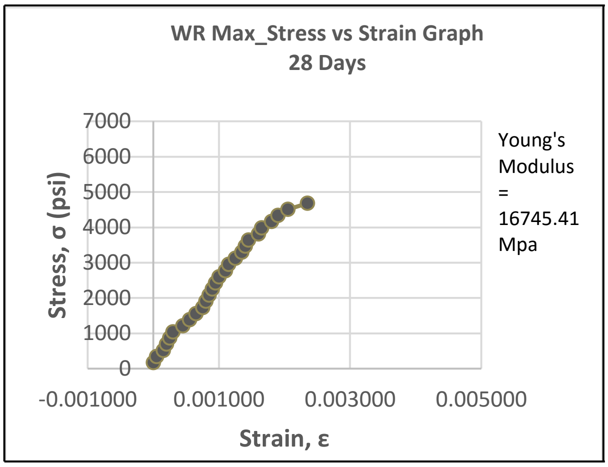

Figure 4.52 Stress vs Strain Graph WR (Maximum Dosage-28 Days)

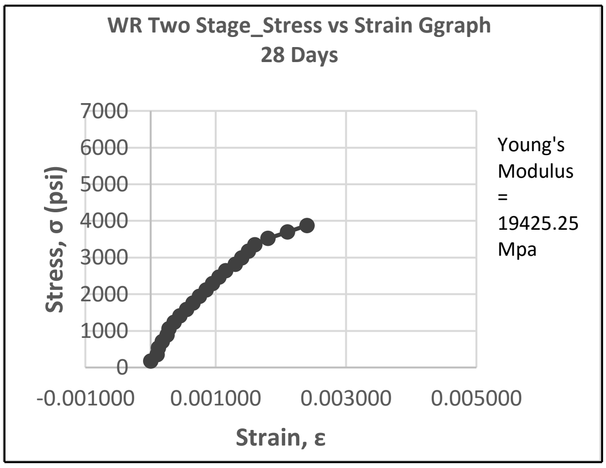

Figure 4.53 Stress vs Strain Graph WR (Two Stage Dosage-28 Days)

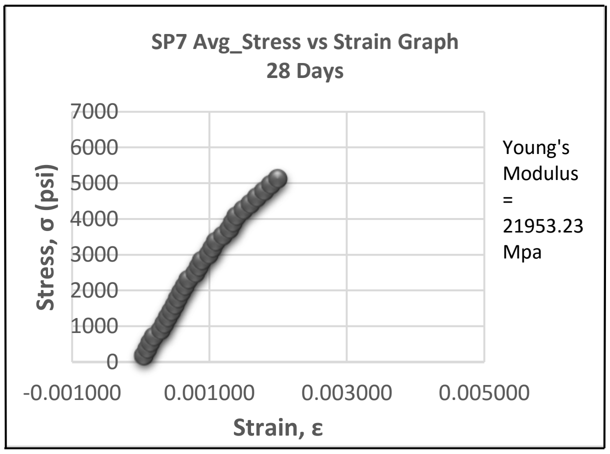

Figure 4.54 Stress vs Strain Graph SP7 (Average Dosage-28 Days)

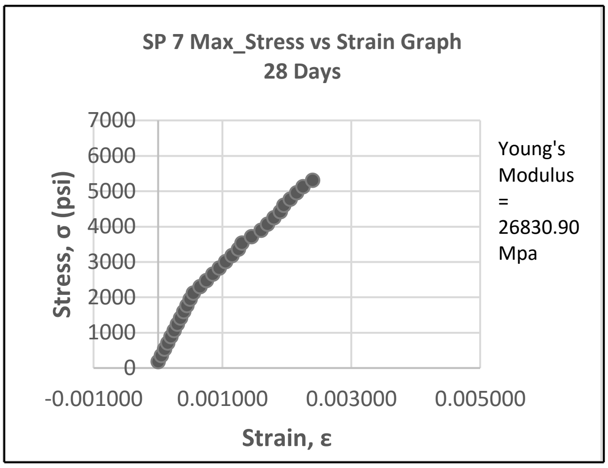

Figure 4.55 Stress vs Strain Graph SP7 (Maximum Dosage-28 Days)

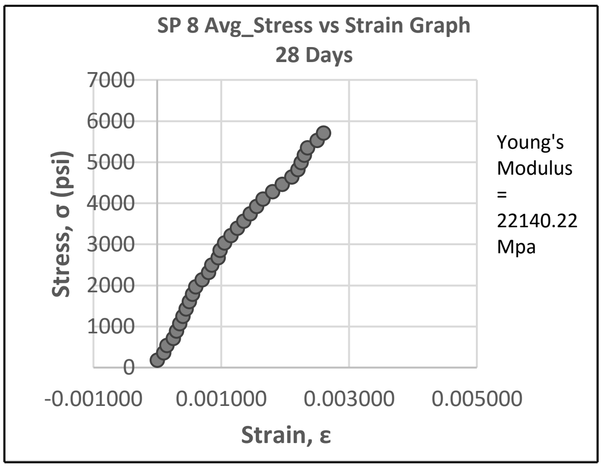

Figure 4.56 Stress vs Strain Graph SP8 (Average Dosage-28 Days)

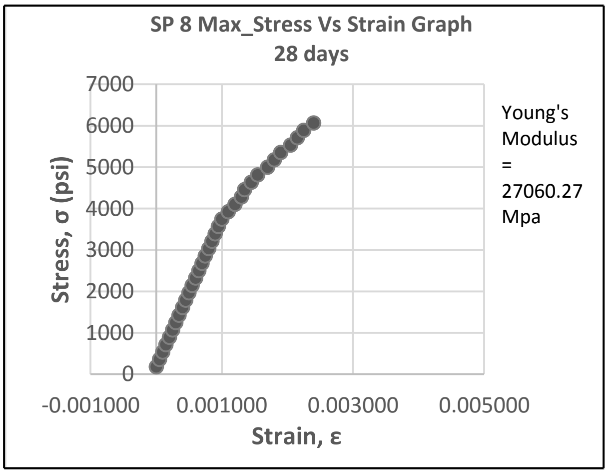

Figure 4.57 Stress vs Strain Graph SP8 (Maximum Dosage-28 Days)

Young's modulus of elasticity is a mechanical property of linear elastic solid materials. It defines the relationship between stress (force per unit area) and strain (proportional deformation) in a material. From Stress vs. Strain graph, stress corresponding to 0.005 Strain (ε) is measured as young's modulus of elasticity. Figure 4.13 through Figure 4.34 and Figure 4.35 through Figure 4.57 show 7 days and 28 days young's modulus of type 1, 2 and 3 concrete made with super plasticizers and water reducer. The Figures indicate that the young's modulus of concrete increases with the increase of compressive strength. Neville (1997) proposed similar behavior of concrete in his study.

Photo 4.1 Destructive Test (Tensile & Compressive Strength)

Chapter 5 Conclusion and Future Possibilities

5.1 General

The main goal of this study was to estimate the workability of concrete by using different types of chemical admixtures and choose the best admixture among them. In our study we increased the workability of concrete using various chemical admixture dosages (Average, Maximum & Two stage) without compromising the necessary strength of concrete.

5.2 Summary of Main Findings

In this experiment 9 types of chemical admixtures were used. Three criteria were used in application of chemical admixture.

Among them for average admixture dosage, 2nd Generation Polycarboxylic Ether Based admixture gave the best result. In this case the concrete was workable for about 120 minutes and the slump value after 120 minutes was 3 cm. In this case we also saw that for using chemical admixture the 7th day and 28th day compressive strength of the concrete increased than the 7th day and 28th compressive strength of without admixture case.

For maximum admixture dosage we found that Naptahlene Sulphonate Based admixture gave the best result for workability. In this case the concrete was workable for 150 minutes and the slump value then was about 3 cm. Also in this case the strength was more than without admixture case.

In application of 2 stage dosage of chemical admixture we found more workable concrete than other two criteria of application of chemical admixture. And in this case also Napthalene Sulphonate Based admixture gave the best result. At first stage dosage the concrete was workable for about 100 minutes and the slump was 4 cm.

Then the second dosage was applied and the slump increased to 20 cm. Gradually the slump reduced with time interval. The concrete was in total workable for 180 minutes and the slump was 4.5 cm then.

Among the three criteria of application of chemical admixture, the application of admixture in 2 stages gave the best result. So further analysis was carried out. Before further analysis, there was only change in admixture dosage in the mix design, but the w/c and s/a was kept 0.4 and cement content was kept 340 kg/m^3. And for further analysis with Napthalene Sulphonate Based admixture with two stages dosage, there were variation in s/a and cement content.

When we used w/c = 0.4, s/a = 0.45 and Cement Content = 340 kg/m^3 with Napthalene Sulphonate Based admixture the concrete was workable for around 165 minutes and the slump was 3.5 cm. That means for higher s/a ratio the workability decreases.

Again when we used w/c = 0.4, s/a = 0.45 and Cement Content = 380 kg/m^3 with Napthalene Sulphonate Based admixture it gave the best result among the all criteria and variations. The concrete in this case was workable for 195 minutes and the slump was 2.5 cm. So, we can gather a conclusion that for higher cement content the workability of the concrete increases when mixed with Chemical Admixtures.

5.3 Conclusion

From the test results, it was found that plasticizers impart more compressive strength to concrete than most of the superplasticizers. However, superplasticizers give more workability than plasticizers. Concrete made with high range water reducing superplasticizer attains more strength than concrete made with retarding superplasticizer. But, retarding superplasticizers impart more workability to concrete. With the reduction of W/C and increase of superplasticizer dosage (within a certain limit), the compressive strength of concrete is increased. Concrete mixtures with a lower sand to total aggregate volume ratio (s/a) gives more workability than those with a higher s/a. Again concrete mixtures with higher cement content gives more workability than those with a lower cement content.

5.4 Recommendation for Future Studies

Current research focuses on the applicability of chemical admixtures in concrete mixture to increase workability without compromising the compressive strength. Future research should continue

- For more research on mechanical properties (Compressive Strength, Tensile Strength) of concrete.
- For more research on more chemical admixtures.
- For more variations of admixture dosages.
- For more variations of

  -w/c ratio

  -s/a ratio &

  -Cement Content
- For more variations of aggregate sizes.
- For more types of coarse aggregates (Brick Chips, Slag etc.)
- For more seasonal variations of casting.

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