

SUITABILITY OF SUGAR WASTE IN STRUCTURAL CONCRETE

A Dissertation Submitted
In Partial Fulfillment of the Requirements
for the degree of

**MASTERS OF ENGINEERING
IN
STRUCTURES**

Submitted by:

**BHUPENDER SINGH
(Roll No. 821122003)**

UNDER THE SUPERVISION OF

Dr. SHRUTI SHARMA
Associate Prof., CED
Thapar University, Patiala.



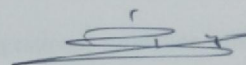
**DEPARTMENT OF CIVIL ENGINEERING
THAPAR UNIVERSITY,
PATIALA-147004
JULY 2016**

DECLARATION

I, Bhupender Singh, hereby declare that this thesis entitled "SUITABILITY OF SUGAR WASTE IN STRUCTURAL CONCRETE" in fulfillment of the requirement for the award of the Degree of **Master of Engineering in Structures** and submitted in the Civil Engineering Department, Thapar University, Patiala is an authentic record of my work carried out during a period from Jan 2016 to July 2016 under the supervision of **Dr. Shruti Sharma, Associate Prof.**, Department of Civil Engineering, Thapar University, Patiala.

This matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other University.

Date: 15-07-16

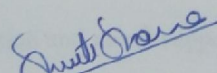


Bhupender Singh

Roll No.: 821122003

CERTIFICATE

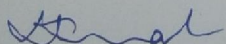
This is to certify that above statement made by the student concerned is correct and true to the best of my knowledge and belief.



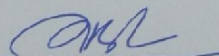
(SHRUTI SHARMA)

Associate Professor
Department of Civil Engineering
Thapar University, Patiala-147004

Countersigned by



(Dr. NAVEEN KWATRA)
Professor & Head
Department of Civil Engineering
Thapar University, Patiala- 147004



(Dr. S.S. BHATIA)
Dean of Academic Affairs
Thapar University, Patiala-147004

ACKNOWLEDGEMENT

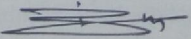
A thesis cannot be completed without the help of many people who contribute directly or indirectly through their constructive criticism in the evolution and preparation of this work. It would not be fair on my part, if I don't say a word of thanks to all those whose sincere advice made this period a real educative, enlightening, pleasurable and memorable one.

First of all, a special debt of gratitude is owned to my supervisor, **Dr. Shruti Sharma, Associate Prof.,** CED, Thapar University, Patiala for giving me the opportunity. I am also thankful to her for her constant supervision, valuable suggestions, guidance and advice throughout my work. Her dynamism and diligent enthusiasm has been highly instrumental in keeping my spirit high. Her flawless and forthright suggestions blended with an innate intelligent application have crowned my task a success.

I would also like to express my gratitude to my family, for their unconditional support and prayers at all time and constant encouragement during the entire course of my thesis work.

I also take this opportunity to thank to the entire faculty and staff of Civil Engineering Department, Thapar University, Patiala, for their help, inspiration and moral support, which went a long way in successfully completion of this report.

July, 2016.


Bhupender Singh
Roll No. 821122003

ABSTRACT

A major challenge for our society is the protection of the environment. Some of the important issues are the reduction in the consumption of energy and natural raw materials, as well as the increase in consumption of waste materials. The use of molasses from sugarcane industry in construction, as alternative to chemical admixtures (water reducing admixtures), has strong potential. The use of molasses preserves natural resources and reduces the space required for the disposal of sugarcane industry in other purposes. It is estimated that India alone contributes 5-8 million tons of sugarcane waste. A solution for excess waste production would be the utilization of molasses together with an improvement in the final quality of concrete. It might be an important breakthrough for our society in our attempt towards sustainable development. Much research on the uses of molasses has been performed during the last few decades. In fact, most of them showed that the molasses is adequate for use as structural concrete although volume changes in and durability performance of molasses in comparison with water retaining admixtures are still being debated and researched. The aim of this study is to determine the suitability of using molasses in structural concrete based on its strength, stiffness, dimensional stability and durability. Studies were carried out on a cement paste, three different types of mortar mixes and on the three different concrete mixes, with and without the use of molasses. In present work the molasses was collected from Sir ShadiLal Enterprises Limited' (SSEL), Shamli, Uttar Pradesh. The effects of different dosages level 0, 0.05, 0.1, 0.2, 0.50, 1.00, 2.00, 3.00, 4.00, 5.00 and 6.00 % of the molasses by weight of cement were studied for standard consistency, setting time, water reduction behaviour and workability in fresh concrete. The studies were also carried out for 3 day, 7 day and 28 day compressive strength of the mortar for the dosage level 0, 0.10, 0.30, 0.50 and 0.60 % of molasses by weight of cement. The effect of molasses on different concrete mix under same workability conditions was also carried out. The studies were carried out for 3 day, 7 day and 28 day compressive strength and split tensile strength of the concrete mix M20, M30 and M35 for the dosage level of 0, 0.10, 0.30, 0.50 and 0.60 % of molasses by weight of cement. The test result indicates that molasses acts as accelerator up to 0.50 % dose and then retarder. Also it is highly a water reducer agent. The early (3rd and 7th day) compressive and split tensile strength of the concrete and mortar mix with molasses showed considerable decline in strength as compared with the control sample. The compressive strength of mortar and concrete after 28th day gets increased using 0-0.50 % of dose of molasses but the most favorable is 0.30 % of molasses by weight of cement.

CONTENTS

Page No.

DECLARATION.....	Error! Bookmark not defined.
ACKNOWLEDGEMENT.....	Error! Bookmark not defined.
ABSTRACT.....	3
CONTENTS.....	4
LIST OF TABLES.....	6
LIST OF FIGURES.....	7
CHAPTER 1: INTRODUCTION.....	9
1.1 General.....	9
1.2 Blackstrap Molasses.....	9
1.3 Challenges and Scope of use of Molasses.....	10
1.4 Motivation and Objectives of Work.....	10
1.5 Organization of the Thesis.....	11
CHAPTER 2: MOLASSES- AN INTRODUCTION.....	12
2.1 General.....	12
2.1.1 Raw Sugar Process.....	13
2.1.2 Sugarcane.....	14
2.1.3 Definations.....	15
2.2 Sampling of Waste Molasses from Sugar Industry.....	16
2.3 Molasses- Composition and Specifications.....	16
2.3.1 General.....	16
2.3.2 Chemical composition.....	16
2.3.3 Types of Molasses.....	17
2.3.4 Miscellaneous uses:.....	18
2.4 Cement Concrete.....	19
2.4.1 General.....	19
2.4.2 Cement.....	19
2.4.3 Strength of Cement Concrete.....	20
2.4.4 Improved Concrete System.....	20
2.5. Admixture for Concrete.....	21
2.5.1 General.....	21
2.5.2 Molasses as Admixtures.....	22
CHAPTER 3: REVIEW OF LITERATURE.....	23
3.1 Introduction.....	23
3.2 Need of the Present Investigation.....	38
3.3 Closing Remarks.....	38
CHAPTER 4: EXPERIMENTAL PROGRAM.....	39
4.1 Introduction.....	39
4.2 Test Matrix & Experimental Program.....	39

4.3	Materials.....	41
4.3.1	Molasses.....	41
4.3.2	Cement	41
4.3.3	Fine Aggregates.....	42
4.3.4	Coarse Aggregate	43
4.3.5	Water	43
4.4	Testing for Standard Consistency and Setting Time of Cement	44
4.5	Testing For Mortar	44
4.5.1	Mixing mortar	44
4.5.2	Cube Moulds	44
4.5.3	Preparation of Mortar	44
4.5.4	Moulding, Curing and Testing	44
4.6	Testing for Workability of Concrete	44
4.7	Testing of Concrete	45
4.8	Testing for Air content for freshly mixed concrete.....	45
4.9	Testing For Splitting Tensile Strength Test	46
4.10	Testing for Flexural Strength Test	47
4.11	Non-Destructive Testing for monitoring initial setting.....	48
4.11.1	Excitation mode and frequency:	51
4.12	Closing Remarks	53
CHAPTER 5: RESULTS & DISCUSSIONS.....		54
5.1:	GENERAL	54
5.2	Effect of Molasses & Sugar on standard consistency and setting time.....	54
5.2	Effect of Molasses on cement sand mortar	57
5.3	Compressive Strength of Cement Sand Mortar at Different Dose of Molasses.....	61
5.4	Workability.....	63
5.5.	Air entrainment in fresh concrete due to the addition of molasses	65
5.6.	Compressive Strength	66
5.7	Flexural Strength of concrete mixes.....	71
5.8	Split Tensile strength of concrete mixes	75
5.9.	Ultrasonic Guided Wave	78
CHAPTER 6: CONCLUSIONS AND SCOPE FOR FURTHER RESEARCH		81
6.1	Conclusions	81
6.2	Scope of Further Study.....	82
REFERENCES.....		83
PHOTOGRAPHS		86

LIST OF TABLES

		Page No.
Table 1.1	Typical composition of Molasses	9
Table 2.1	General composition of Sugarcane	13
Table 2.2	Chemical composition of Molasses.....	17
Table 2.3	Types of Molasses.....	18
Table 3.1	Workability properties and air contents of fresh concretes.....	24
Table 3.2	Sorptivity of concretes	25
Table 3.3	Comparison tests of molasses modifications	28
Table 3.4	Mixing proportions of the concretes.	31
Table 3.5	Mix proportion for 1 Kg. of cement.....	33
Table 3.6	Oxide composition (%) of Control and Microbed cement paste.....	34
Table 3.7	Effect of Molasses on Split tensile strength of concrete	37
Table 3.8	Effect of Molasses on Flexural strength of concrete	38
Table 4.1	Physical properties and main Sugar constituents of Molasses.....	41
Table 4.2	Physical properties of Cement.....	42
Table 4.3	Sieve analysis of Fine Aggregates	42
Table 4.4	Sieve Analysis of Natural Coarse Aggregate.....	43
Table 4.5	Mix design proportions of Concrete.....	45
Table 4.6	Specifications of JSR Pulse-Receiver	50
Table 5.1	Effect of Molasses on Standard Consistency and Setting Time.....	54
Table 5.2	Effect of Sugar on Standard Consistency and Setting Time.....	55
Table 5.3 (A)	Flow Table Results for Mortar (Cement: Sand = 1:3)	57
Table 5.3 (B)	Flow Table Results for Mortar (Cement: Sand = 1:4)	58
Table 5.3 (C)	Flow Table Test for Mortar (Cement: Sand = 1:5)	59
Table 5.4	Compressive Strength of Cement Mortar (With Molasses).....	61
Table 5.5	Effect of Varying Dosage of Molasses on Slump Values.....	63
Table 5.6	Effect of Molasses on the Air Entrainment in Concrete	65
Table 5.7	Compressive Strength of Various Mixes at different dose of Molasses	66
Table 5.8	Flexural Strength of Various Mixes at Different Dose of Molasses.....	71
Table 5.9	Split Tensile Strength of Various Mixes at Different Dose of Molasses ...	75

LIST OF FIGURES

	Page No.
Fig. 2.1	Sugarcane Parts and Its By-products..... 14
Fig. 3.1	Total bleeding water obtained for the concretes with admixtures 24
Fig. 3.2	Compressive strength development of concretes for admixture content ... 25
Fig. 3.3	Monitoring drying shrinkage of concretes for admixture content..... 26
Fig. 3.4	Compressive strength development of concretes for admixture content ... 26
Fig. 3.5	Chemical structures of common monosaccharides and sucrose 30
Fig. 3.6	Chemical structures of common disaccharides others than sucrose..... 30
Fig. 3.7	The chemical structure of saccharin 31
Fig. 3.8	Coefficient of capillarity and setting times for 270 dosage concrete 32
Fig. 3.9	Coefficient of capillarity and setting times for 320 dosages concrete 32
Fig. 3.10	Compressive strength of Control and Microbed cement specimens..... 34
Fig. 3.11	Effect of Molasses on Compressive strength of concrete. 35
Fig. 3.12	Graph between Compressive strength of concretes 36
Fig. 3.13	Plot of Setting Time v/s Dosage rate for Molasses. 37
Fig. 4.1	Experimental program..... 40
Fig. 4.2	Testing of Splitting Tensile Strength 46
Fig. 4.3	Testing for Flexural Strength 47
Fig. 4.4	Experimental setup of UGW for cube Specimen 150x150x150mm..... 48
Fig. 4.5	Transducers -S24 HB 0.1 S and S 24 HB 0.1E (Karl Deutsch) 49
Fig. 4.6	JSR Ultrasonic DPR 300 Pulser/Receiver System 49
Fig. 4.7	Curves for 25mm dia bar 52
Fig. 5.1	Plot of Setting Time v/s Dosage Rate of Molasses 56
Fig. 5.2	Plot of Setting Time v/s Dosage of Sugar 56
Fig. 5.3	Effect of Molasses on Water Reduction (Cement: Sand = 1:3) 59
Fig. 5.4	Effect of Molasses on Water Reduction (Cement: Sand = 1:4) 60
Fig. 5.5	Effect of Molasses on Water Reduction (Cement: Sand = 1:5) 60
Fig. 5.6	7 day Strength variation of Mortar with varying dosage of Molasses 62
Fig. 5.7	28 day Strength variation of Mortar with varying dosage of Molasses 62
Fig. 5.8	Slump Value (Cm) 64
Fig. 5.9	3 day Strength variation with varying dosage of Molasses..... 67
Fig. 5.10	7 day Strength variation with varying dosage of Molasses..... 67
Fig. 5.11	28 day Strength variation with varying dosage of Molasses..... 68

Fig. 5.12	Strength variation with varying dosage of Molasses for M1 (20MPA).....	68
Fig. 5.13	Strength variation with varying dosage of Molasses for M2 (30 MPA)....	69
Fig. 5.14	Strength variation with varying dosage of Molasses for M3 (35 MPA)....	69
Fig. 5.15	Variation in Flexural strength with varying dosage of Molasses for Mix Design M1 (20 MPA).....	72
Fig. 5.16	Variation in Flexural strength with varying dosage of Molasses for Mix Design M2 (30MPA).....	72
Fig. 5.17	Variation in Flexural strength with varying dosage of Molasses for Mix Design M3 (35 MPA).....	73
Fig. 5.18	7 day Flexural Strength variation with varying dosage of Molasses	73
Fig. 5.19	28 day Flexural Strength variation with varying dosage of Molasses	74
Fig. 5.20	Variation in strength with varying dosage of Molasses for M1 (20MPA).	76
Fig. 5.21	Variation in strength with varying dosage of Molasses forM2 (M 30).....	76
Fig. 5.22	Variation in strength with varying dosage of Molasses forM3 (M35).....	77
Fig. 5.23	7 day Strength variation with varying dosage of Molasses.....	77
Fig. 5.24	28 day Strength variation with varying dosage of Molasses.....	78
Fig. 5.25	Ultrasonic Guided Waves.....	79

1.1 General

With a greater emphasis on reducing carbon footprint for construction, the use of waste materials from various industries is now coming into practice. It is estimated that close to 16 billion tons of waste materials that can be recycled or used in alternative form was produced in 2009. With the ever increasing urbanization and more emphasis has been laid on solid structures with high strength. For high strength structures, water cement ratio is usually low and for such mixes workability is low. To achieve high degree of workability, admixtures are used. Admixtures are mostly chemical compounds used to achieve high degree of workability without affecting the desired strength. An alternate to such admixtures may be available in the form of waste product in certain industries. One such waste material available is molasses which is a waste product generated from sugar mills.

1.2 Blackstrap Molasses

Molasses is the main by-product of the raw sugar process. It is a heavy viscous liquid from which no further sugar can be obtained by simple means. Per ton of cane, up to 8 gallons of molasses may be produced. Molasses contains about 50 to 60% total sugars, of which 16-17% is sucrose, the rest being glucose and fructose. The general composition of molasses is given in Table 1.1:

Table 1.1 Typical composition of Molasses (Source: ASI molasses survey (2000))

Dry matter	80%
Total sugar	52-58%
Sucrose	16-17%
Reducing sugars	34-38%
Total nitrogen	2-3%
Organic acids	3%
Gums (insoluble in alcohol)	2%
pH value	5-6
Ash	12-18%

1.3 Challenges and Scope of use of Molasses

The use of molasses in the concrete is relatively negligible. It may be attributed due to the following reasons:

- Lack of knowledge and standard guidelines
- Use of molasses in other industries
- Uncertainty in the behaviour of molasses from region to region
- Lack of proper research in the field of molasses

Technical problems may include

- Weak interfacial zones between cement paste and mortar due to molasses
- High level of sucrose
- High level of sulphates
- Impurity
- High variations in quality

1.4 Motivation and Objectives of Work

- There hasn't been significant research done on the use of molasses in the concrete.
- Molasses has numerous uses in many industries, but, by founding its use in concrete field can significantly help the industry.
- The aim of this study is divided into three parts. The first part is to determine the suitability of using molasses in cement. Its effect on cement alone is studied so as to understand how the dose of molasses affects the properties of the cement.
- The second part is to determine the suitability of molasses in cement mortar mix. Various tests are conducted to study its effect on various parameters.
- In last part, the effect of dosage of molasses on the various concrete mixes is studied so as to determine whether the molasses can be used as an alternate admixture without significantly affecting the mechanical integrity of the concrete.

1.5 Organization of the Thesis

Chapter 1. Introduction – a brief overview of the thesis and its objective

Chapter 2. Molasses- An Introduction - it presents various aspects of molasses

Chapter 3. Review of Literature - An effort has been made to briefly describe the maximum possible literature on the use of molasses as mineral admixtures in concrete and their contributions to the composite materials in terms of compressive strength, tensile strength, flexural strength.

Chapter 4. Experimental Program- It describes the material characteristics (physical/chemical), mixture proportions, specimen size, test methods and associated instruments.

Chapter 5. Test Results & Discussions- Deals with the presentation of different results in tabular or graphical form and analysis, discussion of different test results.

Chapter 6. Conclusion- Summarizes the main conclusions and recommendations for future scope of study is presented.

References are listed at the end for the convenience of the readers.

CHAPTER 2: MOLASSES- AN INTRODUCTION

2.1 General

The years of great engineering development and the anticipated demand of future societies have necessitated the need to utilise the industrial waste and by products in order to achieve high economy. Side by side one or another means of safe disposal of such a material which can cause environmental pollution is discovered.

Realising that the waste and by product of sugar industry may found a suitable admixture with cement and other binding material. It can prove itself in the field of construction material investigation particularly for the leading sugar producing nations of third world like India, Ghana, etc. In such countries sugar industries are widely distributed throughout the length and breadth making the raw material easily available.

Recognising the need, a series of experiments conducted to study the effect of molasses on concrete, which is one of the four types of waste of sugar industry.

There are four types of sugar waste coming out from the sugar industry. Among these two are liquids and other two are solids. They are as follows:

1. Molasses
2. Bagasse
3. Pressed mud
4. Discharging water contacting mud

Molasses will be discussed later. Solid Bagasse contains about 3% sugar content and is used in paper mill industry.

Pressed mud contains about 3% sugar content and creates a disposal problem. It can be used in the filling of depressed ground only.

Effluent water contains mud and negligible % of sugar content. The disposal of this water is also a problem for sugar industry.

This water can be used for the construction purposes if it contains acceptable amount of mud and molasses.

2.1.1 Raw Sugar Process

The initial steps in sugar manufacture are: (1) handling of cane including harvesting, weighing, dispatching, and washing (if required); (2) cane preparation and milling; (3) clarification of the juice; (4) evaporation and concentration; (5) sugar crystallization; (6) drying, storage, and packaging.

Table 2.1 General composition of Sugarcane (Chen and Chu, 1993)

Millable cane:

Water	73-76%
Solids	24-27%
• fiber	11-16%
• soluble solids	11-16%

Juice composition:

Sugars	75-92%
• Sucrose	70-88%
• Glucose	2-4%
• Fructose	2-4%
Salts	3.0-4.5%
• Inorganic acids	1.5-4.5%
• Organic acids	1-3.0%
• Carboxylic acids	1.1-3.0%
• Amino acids	0.5-2.5%

Other organic non-sugars

• Protein	0.5-0.6%
• Starch	0.001-0.1%
• Gums	0.30-0.60%
• Waxes, fats, phosphatides	0.05-0.15%
Other	3.0-5.0%

2.1.2 Sugarcane

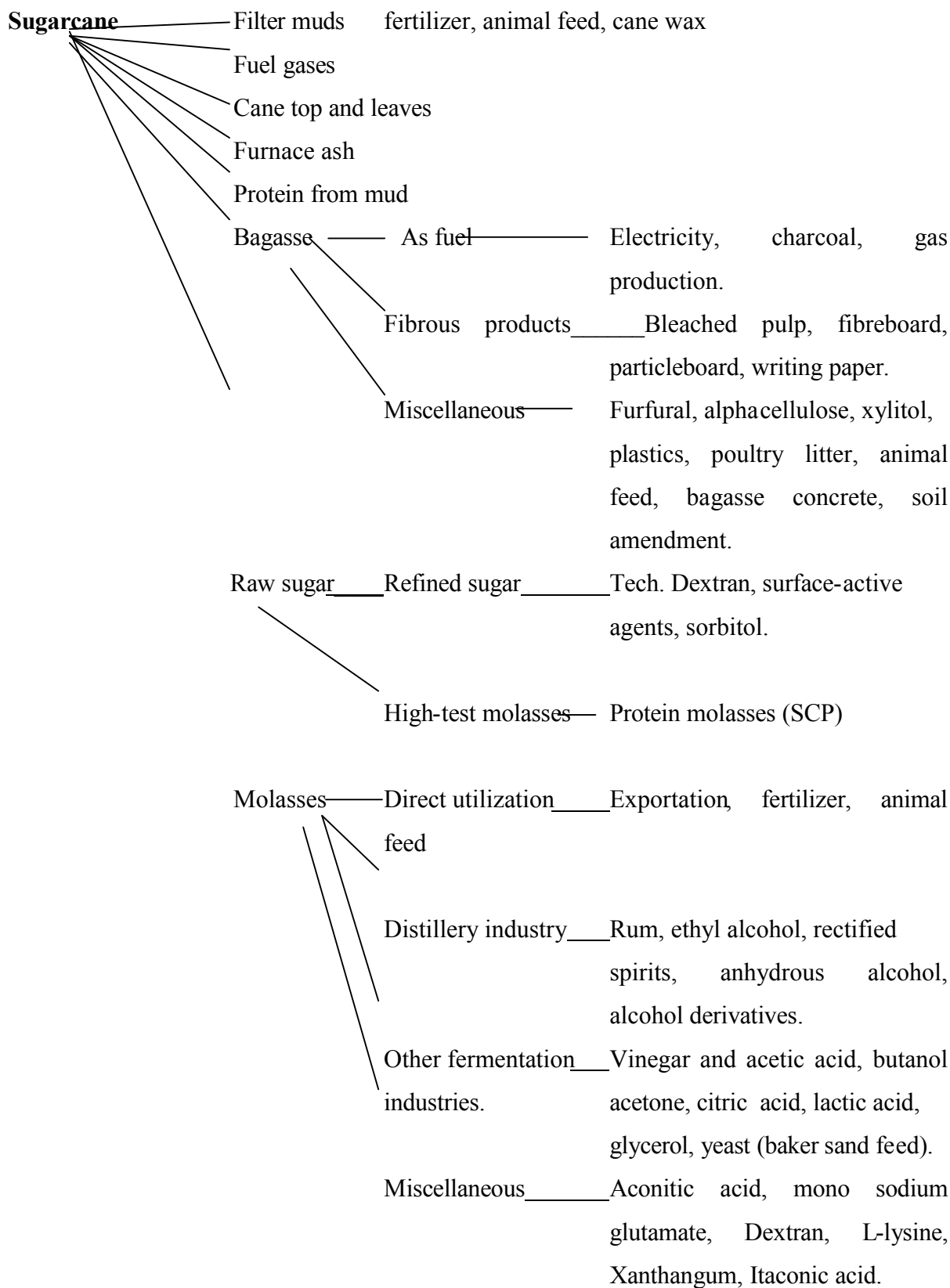


Fig. 2.1 Sugarcane Parts and Its By-products (Rao, 1997& Hunsigi, 1993)

2.1.3 DEFINATIONS

(1). **Admixtures**

The basic components of concrete are cement, aggregates and water. Any other material added at the time of mixing the concrete or just before mixing is called admixture.

(2). **Molasses**

It is the effluent obtained from the centrifugal on purging and spinning a massecuite and is distinguished as A, B and C. The discharge before washing begins, it is termed as heavy molasses and when diluted with water it is called light molasses. The molasses eventually removed from the process is called waste, exhausted or final molasses.

(3) **Degree brix (brix)**

Brix is the % by weight of the solids taken as sugar in the pure sugar solution. A material of no brix is of the same specific gravity as a solution containing 0% of the cane sugar, e.g. 80° Brix molasses means molasses contains 80 % soluble solids by weight of molasses.

(4). **Gravity solids (Brix)**

The solids are in the solution as determined from the specific gravity and referred to as the specific gravity of solution of cane sugar. Numerically gravity solids and degree brix are the same.

(5). **Absolute solid (Brix)**

The solid matter as determined after the removal of water.

(6). **Sucrose or Saccharose**

It is carbohydrate and its chemical composition is $C_{12}H_{22}O_{11}$

(7) **Reducing sugar**

It is glucose type of carbohydrate

2.2 Sampling of Waste Molasses from Sugar Industry

Sample must be taken from the discharge pipe leading to the weighing or measuring tanks and not from the gutter behind the centrifugal pump. The samples taken should be referred to each pan strike. A sample may be taken from the storage water tank by hand at every 4 hours and composited for analysis. A small sub-sample i.e. 100 gm of every daily sample is weighed out and transferred into a second collecting bottle. These sub samples are mixed and served for the total analysis which is made once a week or a fortnight.

2.3 Molasses- Composition and Specifications

2.3.1 General

The history of the molasses ('Melasse' in German and Dutch) is not mentioned in etymological dictionaries since it is quite definitely and clearly derived from the roman language.

The term 'molasses' is applied to the final effluent obtained in the preparation of sugar by repeated crystallisation. The amount of molasses obtained and its quality provides information about the nature of the sugarcane and the processing in the sugar factor, such as the efficiency of the juice clarification, the method of crystallisation during boiling and the separation of the sugar crystals from the low grade massecuite.

2.3.2 Chemical composition

Theoretically the final molasses is a mixture of sugar, non-sugars and water, from which no sucrose crystallizes under any conceivable physical and technically optimum conditions, with no regard to time. The objective of sugar industry is to produce molasses whose purity is as low as possible.

The average composition of cane molasses is presented in table 2.2

Table 2.2 Chemical composition of Molasses. (Gmbh, 2006)

S.NO	CONSTITUENT	PERCENTAGE
1.	Water	20.0
2.	Sugars (a) Sucrose (b) Glucose (c) Fructose (d) Raffinose	32.0 14.0 16.0 - 62.0
3.	Non Sugars- nitrogenous materials, free and bound acids, soluble gummy substances	10.0
4.	Inorganic constituents (ash) (a) SiO ₂ (b) K ₂ O (c) CaO (d) MgO (e) P ₂ O ₅ (f) Na ₂ O,Fe ₂ O ₃ ,Al ₂ O ₃ (g) Sulphate residue (h) Chlorides	0.5 3.5 1.5 0.1 0.2 0.2 1.6 0.4 8.0
Total		100.0

2.3.3 Types of Molasses

Molasses is effluent obtained from the centrifugals on purging or spinning a massecuite and also distinguished as A, B and C etc. The discharge, before washing begins, is termed as heavy molasses and when diluted with wash water it is called as light molasses. This molasses eventually removed from the process is called waste or final molasses.

Although the main objective of the sugar industry is to produce a final molasses, whose purity and total sugar content is as low as possible, yet the final molasses comes out as waste from the sugar industry having no uniform brix and total sugar content. So depending upon brix and total sugar content the final molasses are divided into three grades as shown in table 2.3.

Table 2.3 Types of Molasses. (Gmbh, 2006)

S.No.	Grade of final molasses	Degree Brix	Total sugar Content (%)
1.	A	100° to 110°	55 - 60
2.	B	90° to 100°	45 – 55
3.	C	80° to 90°	40 – 45

2.3.4 Miscellaneous uses:

Molasses can be used for purposes other than its use in cement mortar and cement concrete. These are following:

- (1) Production of alcohol from molasses.
- (2) Production of glycerine from molasses in which 3 % weight of sugar content is converted to glycerine.
- (3) Preparation of rum from the beet molasses.
- (4) Production of citric acid from the molasses.
- (5) Production of Itaconic acid.
- (6) Production of butane, acetone and dextran.
- (7) Production of Butanediol.
- (8) Production of distillation of gases by carbonization.
- (9) Biological utilisation of molasses as Vinasse.
- (10) Use of molasses as cattle feed and other feed products. It is very rich in carbohydrates and minerals. When feeding horse, the molasses exhibits a particularly favourable effect on the general health of horse.

2.4 Cement Concrete

2.4.3 General

Cement concrete is the most widely used construction material now-a-days and is being extensively used in greater quantities than any other man made material of construction in the field of civil engineering. Due to its property that it can be cast into any desired shape, it has not only replaced the old construction techniques of stone and brick masonry construction, but also has made it possible to cast intricate structures. The annual rate of production of cement is nearly constant but its demand increases day by day. That's why there is greater demand to save cement and the cost. By slightly changing the composition of concrete e.g. adding admixture, we can improve much the quality of concrete and at the same time can save cement, other constructional material and the total cost of structure. Thus the use of controlled cement concrete definitely results in an improved quality job and that also at lower cost. Quality control thus aims at reducing the above variations inherent in the mixing of cement concrete and in producing a uniform material with requisite properties. The actual work in situ production of cement concrete requires very careful attention in their proportioning, mixing, placing, compacting finishing and other required operations.

2.4.4 Cement

There is a large variety of cements available now a days and is used under certain conditions due to its special properties. But for ordinary construction, ordinary Portland cement is used.

Portland cement is produced by burning together in definite proportion, a mixture of siliceous, argillaceous and calcareous materials at a temperature about 1400C. Thus clinker is cooled and ground to the required fineness, that powder is cement. It is a good binding material and possesses strong hydraulic properties.

By changing the proportion of three raw materials lightly and adding some small amount of required chemicals a large variety of cements are produced now -a- days. Among these, ordinary Portland cement (O.P.C) is the most important and widely used cement.

2.4.5 Strength of Cement Concrete

Strength of concrete is commonly considered as the most valuable property, although other characteristics such as durability and impermeability also play an equally important and significant role in overall performance of this material. No doubt, the strength normally gives an overall picture of the quality of concrete.

As a structural material the primary requirement of cement concrete may be its compressive strength, but its capacity to overcome the tensile stresses is also of significance. To design a material which finds commercial acceptance, its properties such as durability, resistance to abrasion, resistance to acids and other chemical attacks, bond strength density, direct tensile strength, split tensile strength and flexural strength plays dominant role. Although cement concrete has numerous advantages but there are certain limitations associated with this material. The major one being, its deficiency in tension and brittle behaviour.

Some important factors which affect the strength of concrete are as under-

- (1) Type of cement – after 2 years almost all types of cements give the same strength except high alumina cement.
- (2) Type and characteristics of aggregate.
- (3) Richness of the mix or aggregate/cement ratio.
- (4) Mixing and compaction procedure.
- (5) Type of curing
- (6) Water/cement ratio
- (7) Age of concrete.
- (8) Temperature of concrete
- (9) Effects of lateral stresses
- (10) Types of loading
- (11) Testing procedure

2.4.6 Improved Concrete System

Although cement concrete is the most widely used construction material, but it has number of drawbacks in its manufacture which limit its use as a construction material under certain conditions. Since ancient times, efforts have been made in one form or the other to improve upon the low capacity of cement concrete and to obtain cement concrete of exceptionally

high strength. Now- a days from improved concreting system a concrete of compressive strength 350N/mm^2 at 28 days can be produced.

A number of variations in quantities of cement and aggregate characteristics have been tried to bring out their effects on concrete strength. It was found that the variation in cement composition has a definite effect on the ultimate strength of cement concrete. Similarly the variations in aggregate, size and aggregate grading have result to develop high strength cement concrete. several other techniques such as decreasing the porosity of concrete, applying greater comp active effect and combination of certain new types of reinforcing materials have been tried and the results have indicated that a cement concrete of exceptionally high strength can be produced. Polymer concrete, fibre reinforced concrete etc. are few examples of improved concreting system.

A large variety of concretes have been produced now-a-days. Some of these have been shown a considerable increase in strength in which have been found to be very much useful as a construction material or more as a special purpose concrete. Some of this new development may be listed as prestressed concrete, ready mix concrete, rolled concrete, granolithic concrete, terrazzo concrete, structurally light weight concrete, expensive concrete, epoxy concrete, polymer concrete, etc. Among the various recent developments the polymer impregnated concrete is the most recent development in the field of concrete technology improving upon the properties of concrete. But the basic cost of monomers restricts the use of this form of concrete for general purposes. Thus there is a great demand for a cheaper admixture which could replace this form of concrete and produce a concrete of similar strength with a considerable lower cost of manufacture. That's why resent study deals with a new type of admixture i.e. Molasses has been undertaken.

2.5 Admixture for Concrete

2.5.1 General

All materials other than the cement, aggregate and water that are added to concrete, mortar or grout immediately before or during mixing to attain special properties are called admixtures. According to A.C.I committee 212, admixtures are classified in 15 groups according to the type of material constituting the admixture or to characteristic effects of their use. These are following

- (1) Accelerating admixtures
- (2) Water reducing admixture and set controlling admixtures
- (3) Grouting admixtures
- (4) Air entraining admixtures
- (5) Air detraining admixtures
- (6) Gas forming admixtures
- (7) Expansion producing admixtures
- (8) Finely divided mineral admixtures
- (9) Damp proofing mineral admixtures
- (10) Bonding admixtures
- (11) Chemical admixtures to reduce alkali aggregate reaction
- (12) Corrosion inhibiting reaction
- (13) Fungicidal , germicidal admixtures
- (14) Flocculating admixtures
- (15) Colouring admixture

Admixtures are recommended to be used when the desired effects in concrete cannot be produced effectively and economically produced by other means such as by using special cement or by changing mix proportions, etc.

2.5.2 Molasses as Admixtures

Molasses is waste product of sugar industry, which contains too much sugar content as compared to other waste products in the industry. Molasses from the Sir ShadiLal Enterprises Limited (SSEL) Shamli, Uttar Pradesh, has been undertaken as an admixture for cement mortar and cement concrete in the present study. There are three types of molasses depending upon the degree of brix and total sugar content. Normally from a sugar factor lowest grade molasses (Grade C) comes as an effluent, which is available in the market for commercial purposes. This grade molasses contains 40 to 45 % total sugar content. It contains about 20 % water and rest of other chemicals, so its effect on the concrete is very complicated.

CHAPTER 3: REVIEW OF LITERATURE

3.1 Introduction

It is proposed in this work to study the effect of molasses on the properties of cement, cement mortar and cement concrete. This chapter presents the review of literature on application of molasses on cement concrete by monitoring the fresh stage properties and hardened properties of the specimen. This gives an idea of study carried out in this area since last few years.

Jumadurdiyev et al. (2004) compared the effect of molasses, determined from three different sugar factories, and a normal water reducing agent, based on lignosulphonate in the production of concrete. The fresh concrete properties i.e. setting time, workability and bleeding were studied. The compressive strength and flexural strength were also compared. For comparison of durability properties, tests like capillary test, freeze thaw cycle test, carbonation test, drying shrinkage test, and sulphate resistance test was carried out on all the test specimens for each property investigated at different age.

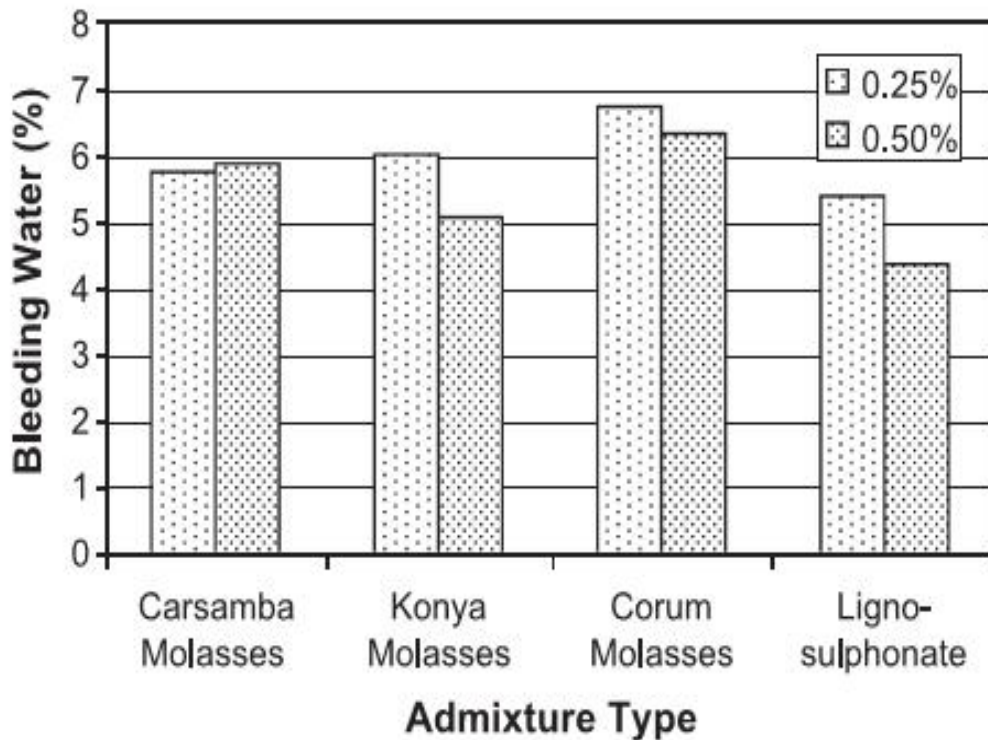
The test results showed that the molasses-added cement pastes show expanded setting times even in 0.2% dosage, and the higher the molasses dosage, the longer the setting time. Further, the molasses obtained from three sugar factories show similar behaviour as the lignosulphonate-based admixture with respect to the workability of concrete as shown in table 3.1. The bleeding of the molasses concretes was higher than that of the lignosulphonate one, probably due to the higher air content of the latter shown in figure 3.1. The concretes prepared with molasses show a slight increase in compressive strength at all ages except early age compared with those of the lignosulphonate based admixture shown in figure 3.2. The sorptivity of the lignosulphonate-added concrete was 15% lower than that of molasses-added concretes shown in table 3.2.

Three molasses and lignosulphonate concretes showed similar shrinkage behaviour shown in figure 3.3. The deterioration effect of freezing and thawing was slight on all molasses and lignosulphonate-added concretes for 140 cycles as shown in figure 3.4. The molasses- and lignosulphonate-added concretes show similar performance with respect to carbonation. The entire molasses sample and the lignosulphonate concrete behaved almost similarly in the Na-

sulphate solution. Nevertheless, they all remained under the limit of expansion given in the standard.

**Table 3.1 Workability properties and air contents of fresh concretes
(Jumadurdiyev et al. (2004))**

Admixture Content (%)	Carsamba molasses	Konya molasses	Corum molasses	Lignosulphonate
Slump of fresh concrete (cm)				
0.25	14	14.5	15.5	17.5
0.50	16	18	19	20
Air content (%)				
0.25	0.3	0.3	0.3	1.6
0.50	0.2	0.6	0.2	2.0



**Fig. 3.1 Total bleeding water obtained for the concretes with admixtures tested
(Jumadurdiyev et al. (2004))**

Table 3.2 Sorptivity of concretes (Jumadurdiyev et al. (2004))

Curing condition	Age of concrete (days)	Sorptivity (mm/min)			
			Carsamba molasses	Konya molasses	Corum molasses
					Lignosulphonate
28 days in water	180	0.241	0.231	0.207	0.186
No water curing	900	0.296	0.285	0.283	0.257

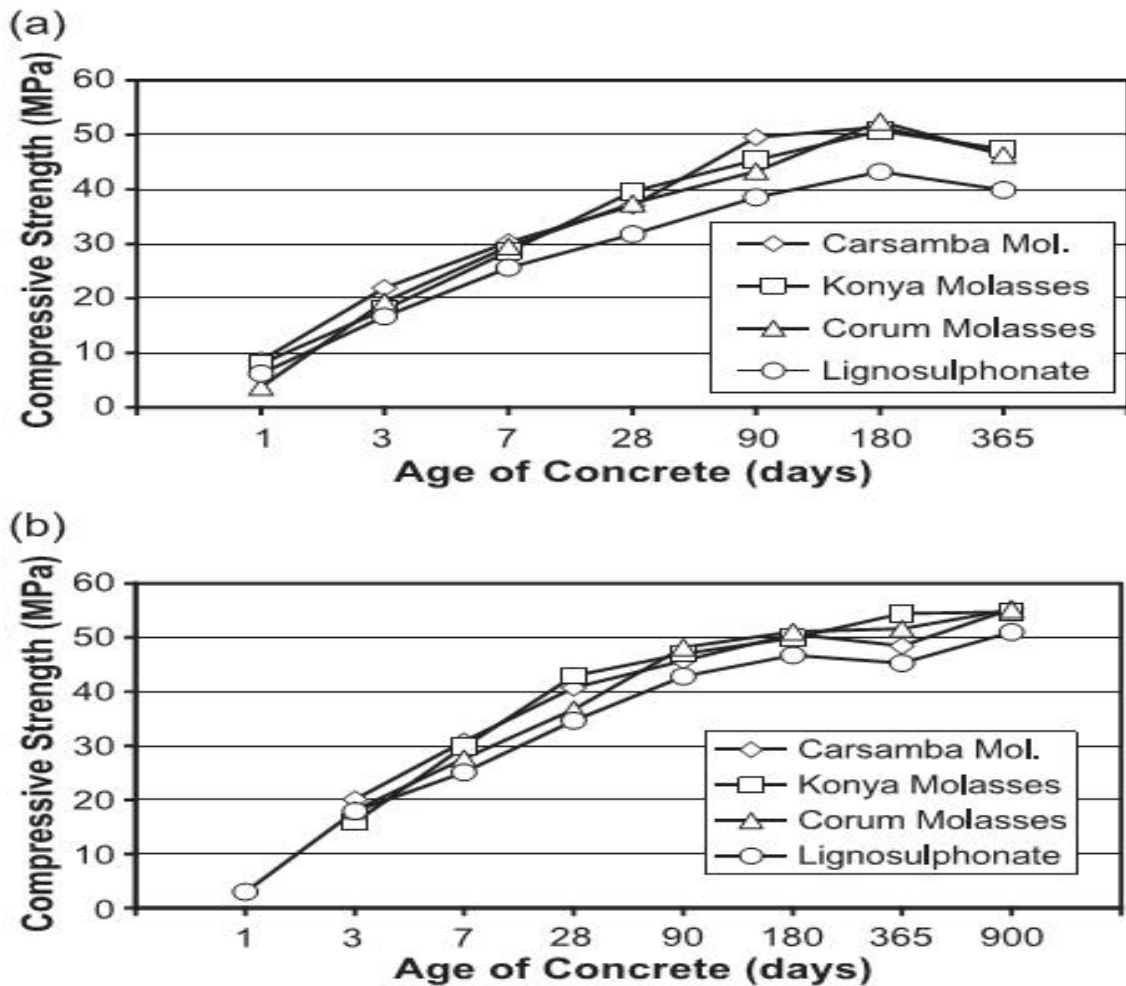


Fig. 3.2 Compressive strength development of concretes for admixture content of (a) 0.25 % and (b) 0.50 % (Jumadurdiyev et al. (2004))

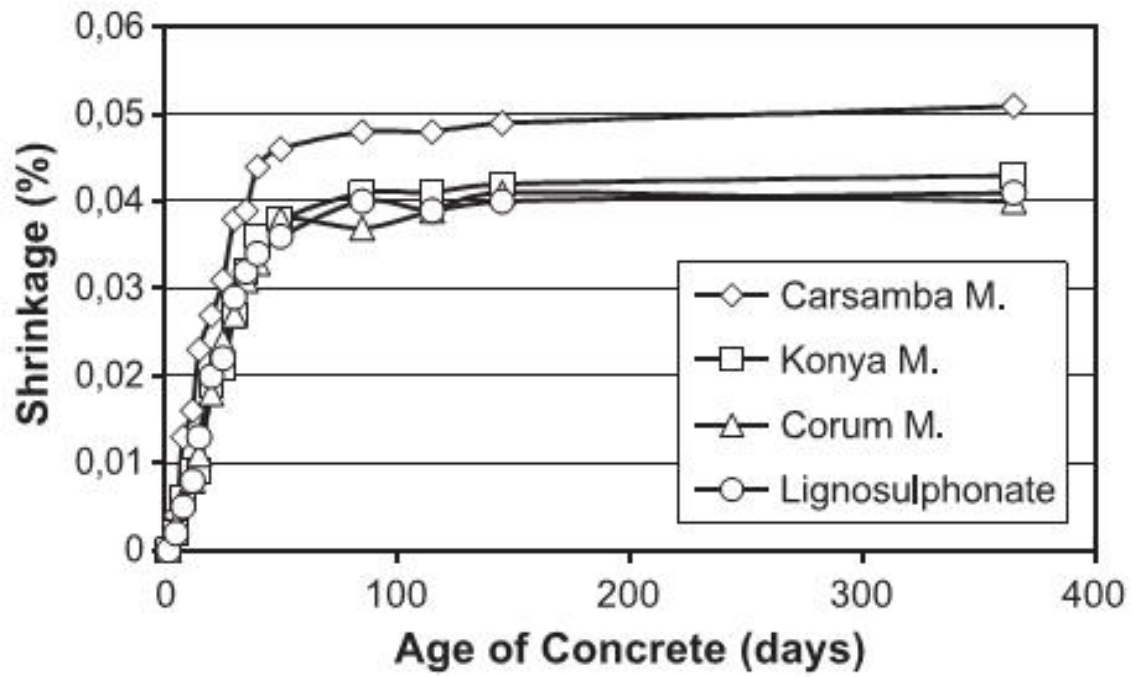


Fig. 3.3 Monitoring drying shrinkage of concretes for admixture content of 0.50% (Jumadurdiyev et al. (2004))

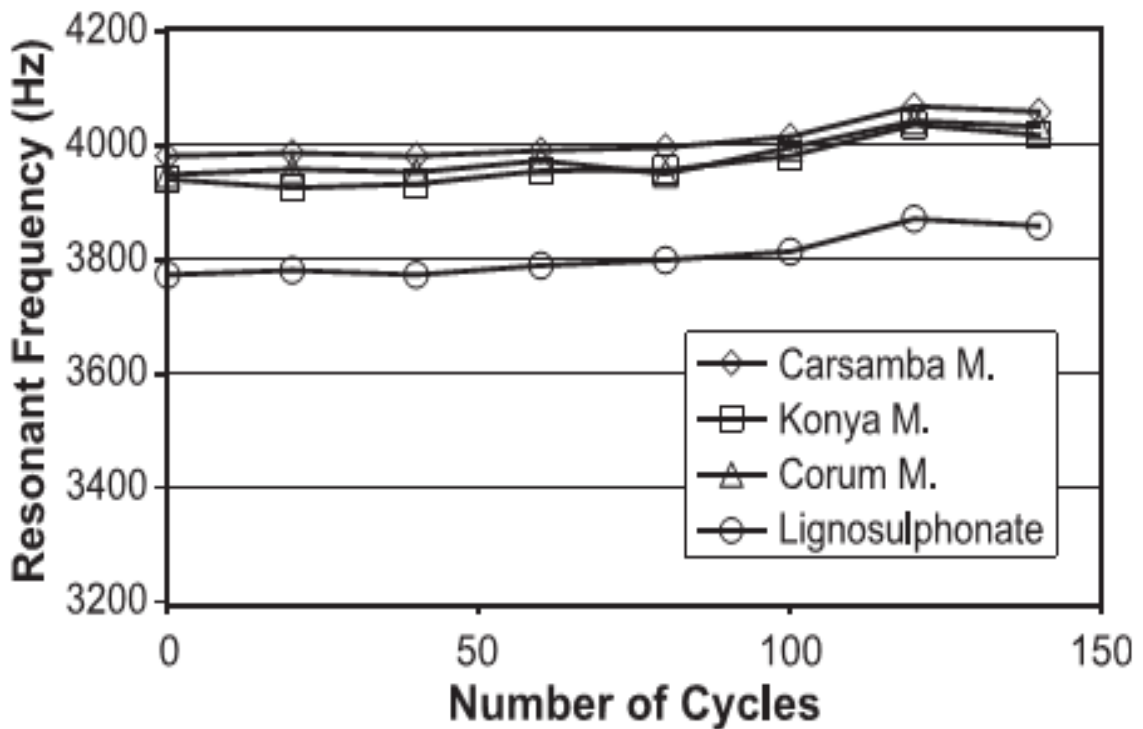


Fig. 3.4 Compressive strength development of concretes for admixture content of (a) 0.25 % and (b) 0.50 % (Jumadurdiyev et al. (2004))

Gorman et al., 2005 in their study discussed a method of treating in which molasses was modified to yield surfactants with plasticizer (water reducing) and dispersant properties. The essence of the treatment was that molasses in the series was treated in acid and alkali environment at temperature higher than the ambient.

It was found that the ingredients of the molasses were exposed to acid and alkali hydrolysis. The acid treatment provided the production of monosaccharides (reducing sugar), aldonic and aminocarbonic acids. The alkali treatment provided for the formation of saccharinic acid and their salts, and soluble soap of wax ethers. The molasses modifications were effectively used for concrete plasticizers (water reducing admixtures) and cement clinker grinding additives application.

The modified molasses showed that the salts of saccharinic and aldonic surfactants are quite strong anionic surfactants with high dispersion properties. The salts of aminocarbonic acids and wax soaps were effective wetting agents. The produced complex of the surfactants provides a relatively high effectiveness of the treated molasses as concrete plasticizers (water reducing admixtures) and clinker grinding additives.

They also carried out further testing to prove the effectiveness of modified or treated molasses (Molassperse). The modifications were labelled as Molassperse P-1, Molassperse P-2 and Molassperse P-3. The Na and Ca lignosulphonates (typical middle range water reducers and retarders) were taken as control samples. The dose of both molassperse and lignosulphonates were 0.1, 0.2 and 0.3% of cement mass with different consumption levels as low 0.1%, medium 0.2% and high 0.3%.

The results tabulated in table 3.3 showed that compressive strength of all cement mortars with all cement mortars with all the molasses modifications were slightly higher in comparison with the mortar with lignosulphonates. So it was concluded that the molasses modifications were compatible with the standards to be classified as middle range water reducers with a low air entrapment.

Table 3.3 Comparison tests of molasses modifications Molassperse P-1, Molassperse P-2 and Molassperse P-3 with NA and CA lignosulphonates (Gorman et al. (2005))

N	Name of admixture	Fluidity of cement paste (mm)		Air entrainment (%)	Compressive strength (MPa)		
		5 Min	60 Min		1 day	7 days	28 days
1	Plain molasses (consumption 0.2% of cement mass)	155	150	2	21.4	31.7	40.9
Admixture consumption of cement mass= 0.1 %							
2	Molassperse P-1	182	158	2	20.3	32.1	43.3
3	Molassperse P-2	182	160	2	21.3	33.2	44.1
4	Molassperse P-3	183	159	2	21.4	33.5	44.4
5	NA Lignosulphonate	178	148	3	21.5	29.4	40.4
6	CA Lignosulphonate	179	162	3	20.5	30.1	41.1
Admixture consumption of cement mass= 0.2 %							
7	Molassperse P-1	181	162	3	20.2	33.9	45.0
8	Molassperse P-2	186	163	3	20.6	34.3	45.1
9	Molassperse P-3	188	169	3	20.9	34.7	45.3
10	NA Lignosulphonate	186	164	7	20.3	32.6	43.2
11	CA Lignosulphonate	188	168	7	19.6	32.8	43.9
Admixture consumption of cement mass= 0.3 %							
12	Molassperse P-1	193	162	3	20.3	34.1	44.9
13	Molassperse P-2	190	160	3	20.1	33.1	43.5
14	Molassperse P-3	198	168	3	20.5	33.6	43.9
15	NA Lignosulphonate	200	170	7	19.5	31.2	41.4
16	CA Lignosulphonate	195	168	7	19.3	31.5	41.9

Roar Myrdal (2007) in his report gave a theoretical background of working of molasses and sugars in the concrete. Molasses is a form of sugars or saccharides are carbohydrates, i.e. aldehydes or ketones with many hydroxyl groups added, usually one on each carbon atom that is not part of the aldehyde or ketone functional group. These materials are characterized by functional groups in which oxygen atoms are attached to adjacent carbon atoms, like the α -hydroxyl carbonyl group $\text{HO}-\text{C}-\text{C}=\text{O}$.

The most common sugar is 'table sugar' or sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$, which is a disaccharide, composed of the two monosaccharides glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, and fructose (fruit sugar), $\text{C}_6\text{H}_{12}\text{O}_6$. Figures 3.5 and 3.6 shows the chemical structures of common sugars. Not all sugars retard cement hydration to the same extent. The so-called 'reducing' sugars are moderate retarders, while 'non-reducing' sugars are either very efficient or very inefficient retarders depending on their chemical structures. A reducing sugar is any sugar that, in basic solution, forms some aldehyde or ketone. This allows the sugar to act as a reducing agent. Sugar without this reducing capability are called non-reducing sugars.

Examples of reducing and non-reducing sugars:

Reducing sugars

- Glucose
- Fructose
- Lactose (milk sugar)
- Maltose (malt sugar)

Non-reducing sugars

- Sucrose (composed of glucose and fructose)
- Trehalose (composed of two glucose units)
- Raffinose

Sucrose (table sugar) is a very efficient retarder, but impractical due to extreme dosage sensitivity. In a typical case, the addition of 0.1 % sucrose on the weight of cement might increase the time of initial setting from 4 hours to 14 hours, while a 0.25 % addition might delay it to 6 days. The retarding effect of different sugars can be divided into three categories:

Very efficient retarders: Non-reducing sugars containing both 5- and 6-membered rings.
Examples: Sucrose and raffinose

Moderate retarders: Reducing sugars containing only 6-membered rings.
Examples: Glucose, lactose and maltose

Inefficient retarders: Non-reducing sugars contain only 6-membered rings.
 Example: Trehalose

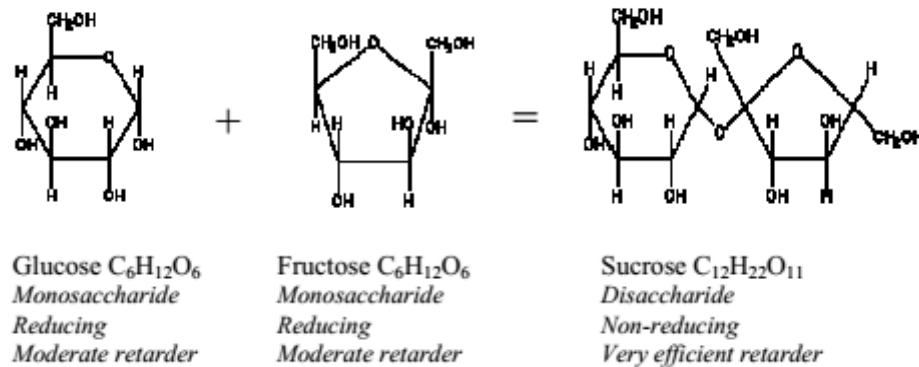


Fig. 3.5 Chemical structures of common monosaccharides and sucrose (table sugar), and their chemical relationship (Roar Myrdal, 2007)

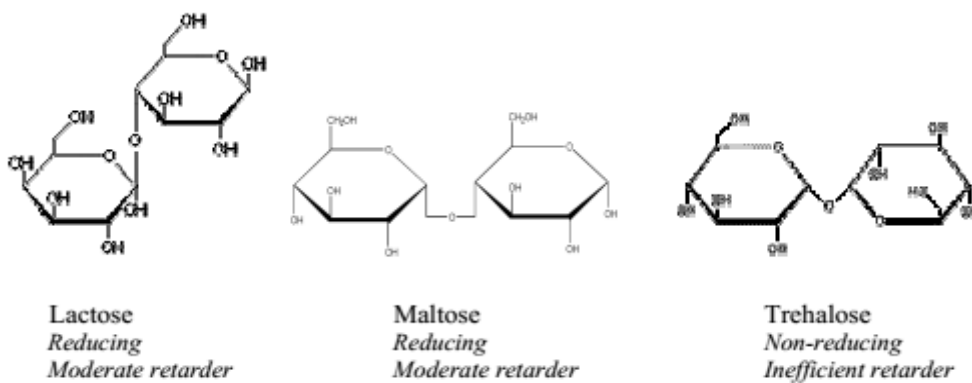


Fig. 3.6 Chemical structures of common disaccharides others than sucrose (table sugar) (Roar Myrdal, 2007)

A plausible mechanism of retardation by sugars has been summarized by Taylor:

- The retardation arises from the adsorption of sugar molecules on to the surfaces of growing particles of hydrating products.
- The ability to complex calcium seems to decide the retarding affiance. Sucrose complexes calcium very well, while the ability of trehalose to complex calcium is very weak. The sugar-calcium complex incorporates into the surface of a growing particle of CH or CSH, thereby inhibiting growth.

Also saccharin, an artificial sweetener (see Figure 3.7), is used as retarder for concrete, but studies reporting its mode of action in OPC is not found.

The hydrogen atom on the nitrogen atom is quite acidic (pKa ~2). The sweetener is usually sold as the sodium salt.

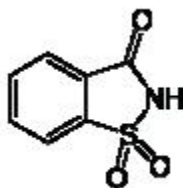


Fig. 3.7 The chemical structure of saccharin (also called benzosulfamide). (Roar Myrdal, 2007)

Yildirim & Altun (2012) compared the water reducing and retarding effect of molasses along with the lignosulphonate based water reducer admixture. For this study, a lignosulphonate based water reducer admixture (ASTM C 494 Type A) and three different types of molasses (Konya, Susurluk & Bor) were used as plasticizer admixture. In total fourteen designs were prepared shown in table 3.4.

Table 3.4 Mixing proportions of the concretes. (Yildirim & Altun (2012))

Concrete Code	Cement (Kg/m ³)	Water (Kg/m ³)	Aggregate (Kg/m ³)	Water reducing capacity (%)	Admixture (%)	Admixture (Kg)	Slump (cm)	Base of admixture
270C00	277	245	1804	0	0.0	0.00	16	Control
270L04	269	235	1801	4	0.4	1.08	14	Lignosulphonate
270K04	276	224	1835	9	0.4	1.10	15	Konya Mol.
270L07	269	218	1846	11	0.7	1.89	15	Lignosulphonate
270K07	272	214	1827	13	0.7	1.9	17	Konya Mol.
320C00	325	241	1766	0	0.0	1	13	Control
320L04	323	215	1791	11	0.4	1.29	15	Lignosulphonate
320K04	325	229	1784	5	0.4	1.30	15	Konya Mol.
320B04	324	228	1791	5	0.4	1.30	15	Bor Mol.
320S04	323	224	1790	7	0.4	1.29	14	Susurluk Mol.
320L07	323	209	1815	13	0.7	2.26	16	Lignosulphonate
320K07	324	222	1788	8	0.7	2.27	15	Konya Mol.
320B07	325	216	1791	10	0.7	2.27	16	Bor Mol.
320S07	321	223	1791	7	0.7	2.25	14	Susurluk Mol.

The test results showed that the usage of molasses as a plasticizer satisfied the ASTM C 494-98 admixture standard for water reduction criteria. It was also found that molasses could be used as a type D and by reducing the dosage of molasses it can be used as Type-A in concrete with accordance with ASTM C 494 standard. With the usage of lignosulphonate and

molasses based plasticizers caused a reduction of the coefficient of capillary due to increase in setting time as well as water cement ratio as shown in figures 3.8 & 3.9. Molasses based admixtures were found to be more effective on reducing of capillary coefficient than lignosulphonate based plasticizers. Molasses were effective on retarding of setting times. The high retarding effect should be taken into account for molasses concrete. Molasses added concrete did not showed any different behaviour than lignosulphonate concrete in sulphate solution for 125 days storing time. According to all the test results, it was clear that molasses has water reducing and retarding effect on the concrete.



Fig. 3.8 Coefficient of capillarity and setting times for 270 dosage concrete. (Yildirim & Altun (2012))

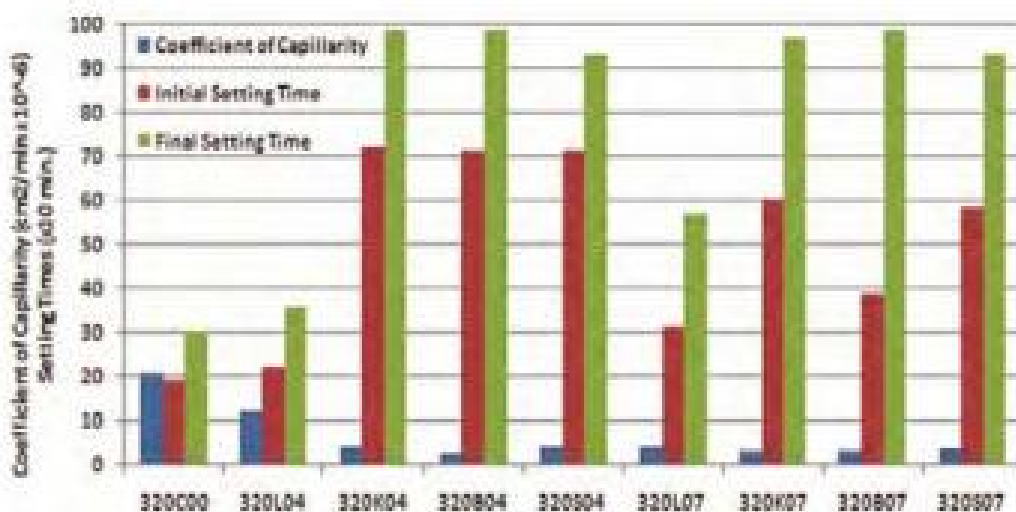


Fig. 3.9 Coefficient of capillarity and setting times for 320 dosages concrete. (Yildirim & Altun (2012))

Giridhar et al. (2013) compared the effect of sugar and molasses on properties of the cement concrete. The target mix design strength was M20. Three different proportions (0%, 0.05% and 0.1%) were used for each molasses and sugar respectively. The test results showed that there was increase in slump value for both molasses and sugar. But in case of sugar, the slump value was relatively higher than that of molasses. Compressive strength of concrete enhanced when dosage of admixture was increased. Concrete with molasses as admixture, had better strength values than the Sugar. Segregation and bleeding was very less due to the usage of these admixtures. Setting time of the concrete increased more rapidly as the dosage of sugar was increased.

Ismail et al. (2014) utilized the molasses in the Effective Microorganism (EM) cement paste. Effective Microorganism (EM) is a branch of horticulture in which beneficial micro organisms are developed to enhance the soil quality and crop yield. In this study, five (5) ratios of molasses were introduced and it was blended with constant contents of EM.No-1 (5%) as shown in table 3.5. Furthermore, consistency, setting time and soundness test contains different molasses content in microbed EM.No-1 cement paste were carried out. The investigation of chemical phases of oxide composition of microbed cement containing with and without molasses using X-Ray Fluorescence (XRF) was also reported.

Table 3.5 Mix proportion for 1 Kg. of cement. (Ismail et al. (2014))

Designation	E (ml)	M (ml)	DW (ml)
Control	0	0	280
M2	15	6	279
M5	15	15	270
M10	15.5	31	263.50
M15	16	48	256
M20	17	68	255

The results showed that with increase in molasses content in microbed cement paste, the setting time prolonged with respect to control cement paste without molasses and EM. Inclusion of molasses into the microbed EM.No-1 cement paste increased the cement expansion. It was reported that the incorporation of two (2) percent molasses of total

volume of water with 5% EM.No-1 into cement paste produced higher compressive strength at the age of 28 days with respect to control without EM and molasses as shown in figure 3.10. Furthermore, the addition of molasses between 5% and 20% reduce the compressive strength. X-Ray Fluorescence (XRF) showed that there was no much different oxide compositions of microbed cement paste containing molasses compared to control at 1 day and 28 of age after curing. However, there was slightly small increment recorded in amount of silica oxide and aluminium oxide in microbed cement paste as shown in table 3.6.

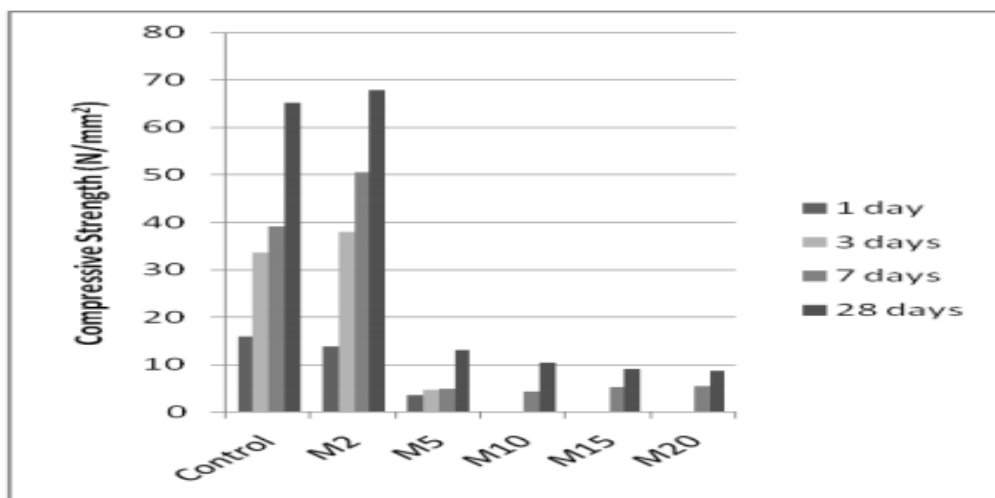


Fig. 3.10 Compressive strength of Control and Microbed cement specimens. (Ismail et al. (2014))

Table 3.6 Oxide composition (%) of Control and Microbed cement paste for 28 days after curing. (Ismail et al. (2014))

Designation	Day 28			
	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃
Control	61.948	22.755	5.275	3.251
M2	62.872	21.597	5.264	3.174
M5	61.944	19.075	7.183	2.609
M10	61.798	20.977	6.091	2.993
M15	60.502	21.557	7.172	2.976
M20	63.261	20.159	5.467	3.169

Karthik et al. (2015) studied the effect of molasses on setting time, workability and strength of the concrete. The target mix design of the concrete was 20 MPa. The molasses was added in the proportion of 0.2, 0.4, 0.6, 0.8 and 1.0 percent by weight of the cement content.

The results showed that both initial and final setting times were increased up to a greater extent when molasses was added in the mix. The workability was also enhanced as the compacting factor and slump value increases with increase in molasses content. The target strength was achieved for all the samples of the concrete in figure 3.11. The results showed that molasses could be used as time retarding plasticizer.

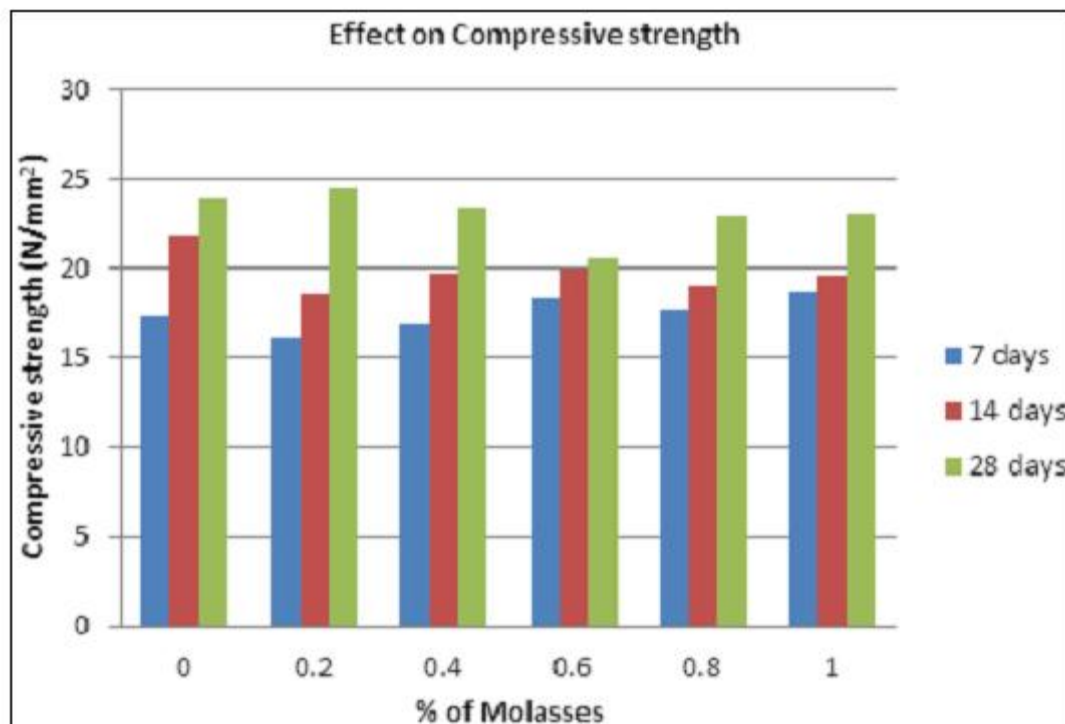


Fig. 3.11 Effect of Molasses on Compressive strength of concrete.(Karthik et al. (2015))

Kashyap et al. (2015) studied the effect rice husk ash along with molasses on the compressive strength of the concrete. The grade of concrete adopted was the mix design M30 with water cement ratio 0.45. Two different sets of specimens were prepared using design mix. In the first set, the specimen was casted by varying percentage of replacement of cement by Rice husk ash starting from 0 to 20% with increment of 5% by weight of cement and they represented as 5%, 10%, 15%, 20% respectively. In second set, the former procedure was followed, I have selected one of the above sample which gave the optimum strength and then vary the sugar molasses at 0.4%, 0.8%, 1.2%, 1.6%, 2% by weight of cementitious material was added.

The test results in Figure 3.12 showed that optimum compressive strength at 28 days was obtained at 10% replacement of cement by Rice Husk Ash. It was observed that at 28 days in 10% replacement of OPC by rice husk ash and addition of sugar molasses at 0.8% by the weight of cementitious material increased the strength. As the amount of Rice Husk Ash and the amount of admixture was changed, the strength of concrete also changed accordingly. Sugar Molasses as an admixture worked satisfactorily to enhance the strength of concrete with RHA.

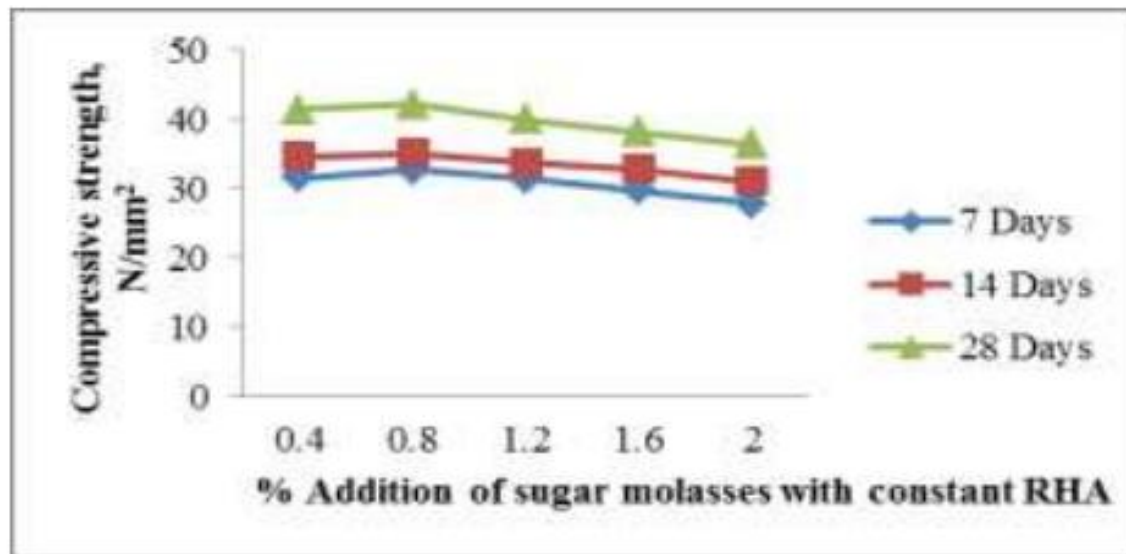


Fig. 3.12 Graph between Compressive strength of concrete with RHA and Sugar Molasses.(Kashyap et al. (2015))

Aalm and Singh (2016) studied the effect of molasses on the properties of cement and concrete. The effects of different dosage of the molasses by weight of cement were studied for standard consistency, setting time in fresh concrete. The studies were also carried out for 28-day tensile strength and flexural strength of concrete for the dosage levels 0, 0.10, 0.25, and 0.50 percent of molasses by weight of cement. This test results as shown in figure 3.13 indicates that molasses acts as accelerator up to 0.50 percent dose and then becomes retarder. The flexural strength and tensile strength of concrete get increased on using 0- 0.50 percent dose of molasses as shown in tables 3.7 & 3.8.

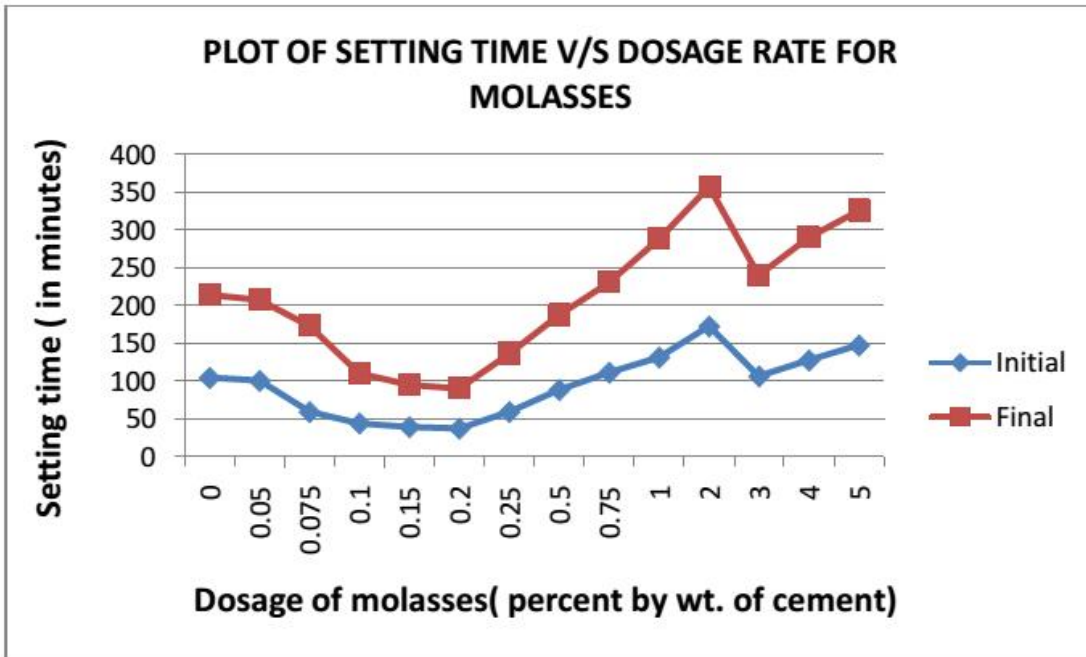


Fig. 1 Plot of Setting Time v/s Dosage Rate for Molasses

Fig. 3.13 Plot of Setting Time v/s Dosage rate for Molasses.(Aalm and Singh (2016))

Table 3.7 Effect of Molasses on Split tensile strength of concrete for 28 days. (Aalm and Singh (2016))

S.No	Dose (% by wt. of cement)	W/C ratio	Average Load (t) (P)	Split tensile strength	Increase in strength (%)
1	0.00	0.550	7.75	1.096	0.00
2	0.10	0.550	8.75	1.238	12.96
3	0.25	0.547	10.75	1.521	38.78
4	0.50	0.543	9.75	1.379	25.82
Cylinder specimen size dia =150 mm		Length = 300 mm	Aggregate/Cement =6.0		

**Table 3.8 Effect of Molasses on Flexural strength of concrete for 28 days.
(Aalm and Singh (2016))**

S.No	Dose (% by wt. of cement)	W/C ratio	Average deflection Load (t) mm		Flexural strength	Increase Flexural strength (%)
1	0.00	0.550	0.076	0.671	2.686	0.00
2	0.10	0.550	0.087	0.769	3.074	14.48
3	0.25	0.550	0.098	0.869	3.463	28.94
4	0.50	0.540	0.079	0.698	2.792	3.950
Beam specimen size =100x100x500 mm		Aggregate/Cement =6.0				

3.2 Need of the Present Investigation

A review of literature presented shows that the use of molasses is being investigated for proper use in concrete. The use of molasses as a water reducing admixture in concrete with positive results has been done in very few studies. Moreover the uses of this natural admixture have not been examined completely on all properties of concrete.

3.3 Closing Remarks

A review of recent literature on behaviour of molasses as an admixture in concrete has been presented on the basis of which the need of the present investigation has been identified.

CHAPTER 4: EXPERIMENTAL PROGRAM

4.1 Introduction

Experimentation was made as intensive and broad based as possible considering the various objectives of the study consistent with the available facilities. Testing of materials, casting and curing of specimens and conducting tests at the prescribed age formed a major part of the study.

The aim of the present investigation was to study the effect of sugar molasses on the various properties of cement, cement mortar and cement concrete. The molasses was taken from SSEL (Sir ShadiLal Enterprises Limited) Shamli, whose main constituents are listed below in the table. By varying dosage level of molasses the tests are conducted on cement and different mixes of the cement mortar and the cement concrete.

4.2 Test Matrix & Experimental Program

The test matrix for the proposed work can be briefed as below:

- (1) The standard consistency, initial setting time and final setting time was compared with and without the use of molasses. The effect of molasses on these properties of cement was compared with effect of sugar on these properties of cement.
- (2) The water reducing effect in different mixes of cement sand mortar (1:3, 1:4, 1:5) has been worked out for different dosages of molasses. The workability of the cement mortar was set the same. Using 50 mm size cubes specimens the 7 day and 28 day compressive strength were determined
- (3) The workability of fresh concrete is determined by slump cone method.
- (4) Water reducing effect in three different concrete mixes have been worked out for different dosages of molasses. The compaction factor was kept the same. Using 150 mm cube specimens, the 3day, 7 day and 28 day compressive strength were determined.
- (5) The split tensile strength and flexural strength of the above three concrete mixes have been determined for different doses of molasses. For split tensile strength using 150 mm dia cylinder specimen and for flexural strength 150x150x600 mm beam specimens have been used.

The experimental program for the proposed work is detailed in Figure 4.1 below:

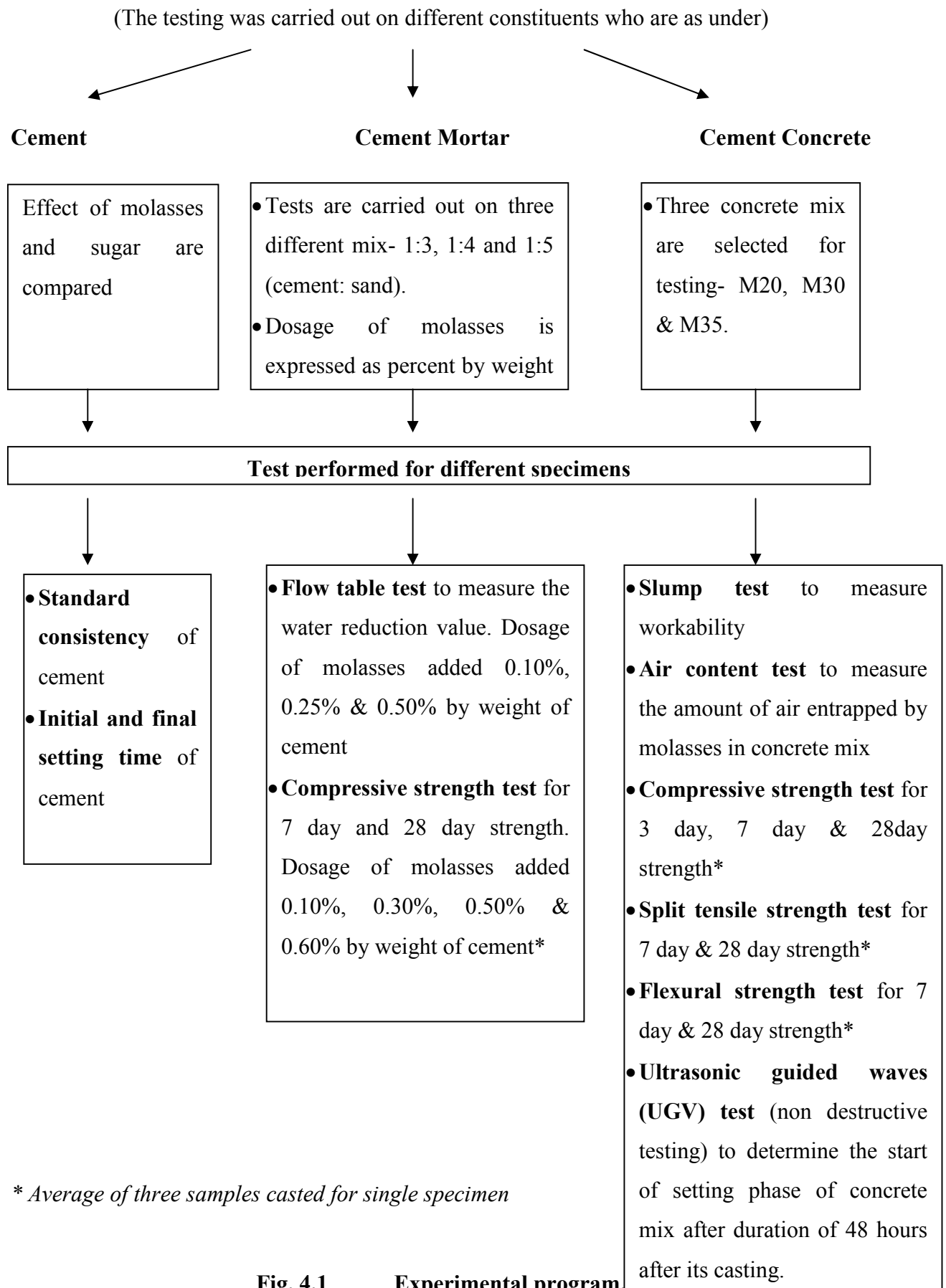


Fig. 4.1 Experimental program.

4.3 Materials

4.3.1 Molasses

The molasses were collected from SSEL Shamli. This type of molasses can be obtained for commercial purposes. Its commercial designation and main constituents are listed in table below. The molasses samples were mixed homogeneously in specific quantity of water and that water was used for the work. The properties of the molasses used in the experimental work are summarized in Table 4.1 below:

Table 4.1 Physical properties and main Sugar constituents of Molasses (SSEL Shamli)

<u>1. Physical properties of Molasses</u>	
(i) Colour	Dark Brown
(ii) State	Liquid
(iii) Brix	80°
(iv) Specific Gravity	1.333
<u>2. Main sugar constituents</u>	
(i) Reducing Sugar (Glucose)	19%
(ii) Sugar content (Sucrose)	24-26%
(iii) Total sugar content	43-45%

4.3.2 Cement

The cement used for the project was ordinary Portland cement with trade name JK. The cement as tested as per IS: 4031-1968 and satisfied the requirements of IS: 269-1976. The properties of cement are shown in the table 4.2 below.

Table 4.2 Physical properties of Cement

S.No.	Characteristics	Test Results	IS:269-1976(9) Requirements
1.	Colour of cement	Deep grey	-
2.	Standard consistency	29.0 %	-
3.	Specific gravity	3.043	3.14- 3.15
4.	Setting time (minutes) (a) Initial setting time (b) Final setting time	112 218	Less than 30 min. Not more than 600 min.
5.	Compressive strength (MPa) on 1:3 cement-Standard sand mortar (a) 3 day (b) 7 day	20.6 MPa 35.1 MPa	Less than 16 MPa Less than 22 MPa
6.	Soundness –by Lechatliers Method	2.0 mm	Not more than 10 mm
7.	Fineness (by sieve analysis) residue on IS sieve No.9	6.5 %	Mot more than 10 %

4.3.3 Fine Aggregates

Fine aggregate occupies approximately 30% of the total volume of conventional concrete, and the quality of fine aggregate affects the properties of concrete. Locally available Ghaggar sand was used as a fine aggregate in the mix. The properties of the sand are given in table 4.3 below:

Table 4.3 Sieve analysis of Fine Aggregates

Weight of sample = 1000 gms

Sieve size (mm)	Weight retained (g)	Cumulative % weight retained	% passing
4.75	0	0	100
2.36	49	4.9	95.1

Sieve size (mm)	Weight retained (g)	Cumulative % weight retained	% passing
1.18	115	16.4	83.6
600 μ	215	37.9	62.1
300 μ	308	68.7	31.3
150 μ	221	90.8	9.2
PAN	92	100	0
TOTAL		218.70	

(i) Fineness modulus = $218.7/100 = 2.19$

(ii) Specific gravity = 2.69

4.3.4 Coarse Aggregate

Locally available crushed coarse aggregate were used in the mix. The sieve analysis of coarse aggregate is given in the table below

Table 4.4 Sieve Analysis of Natural Coarse Aggregate

Weight of sample = 10000 gms

Sieve size (mm)	Weight retained (g)	Cumulative % weight retained	% passing	% passing required (IS:383-1970)
20	0	0	100	95-100
12.5	1040	12.4	87.6	-
10	3700	50.4	49.6	30-50
4.75	4570	99.48	0.52	-

(i) Specific gravity = 2.65

4.3.5 Water

Tap water, used for drinking purposes available in the laboratory was used for mixing and curing purposes.

4.4 Testing for Standard Consistency and Setting Time of Cement

The investigations were done with the help of Vicat apparatus confirming to “IS: 5513-1969”. All the tests followed Clause 7 of the “IS: 4031-1968”, Indian standard methods for hydraulic cement”. Same procedure was adopted for different dosage levels of molasses.

4.5 Testing For Mortar

4.5.1 Mixing mortar

The mixing of mortar was done according to Clause 9 of IS: 4031-1969, “Indian standard methods of physical tests for hydraulic cement”

4.5.2 Cube Moulds

The 50 mm size moulds were used according to the specifications in Clause 9.3.2 of IS: 4031-1969 for the testing

4.5.3 Preparation of Mortar

Maintaining the room temperature as per laboratory conditions, the mix was prepared. Three different proportions of cement and sand were taken 1:3, 1:4 and 1:5 by weight. The amount of water was adjusted to get the flow of 110 %. The flow value was determined according to Clause 9.5.3 of IS: 4031-1969.

4.5.4 Moulding, Curing and Testing

Moulding, storage, curing and testing of specimens were done according to the Clause 9.6, 9.7 and 9.8 respectively of IS: 4031-1969. Similar tests were repeated for different the dosages of molasses.

4.6 Testing for Workability of Concrete

Control specimen was prepared with cement content 375 kg/m^3 , keeping water cement ratio at 0.48. Water content was taken as 180 kg/m^3 . Slump value for this mix was found. Molasses are added in 0.2, 0.4, 0.6, 0.8 and 1.0 %age by weight of concrete. Workability was measured by conducting slump test on each fresh concrete mix.

4.7 Testing of Concrete

Three mix designs M1, M2, and M3 with mix design of 20 MPa, 30 MPa and 35 MPa respectively were prepared as per Indian standard specifications and presented in Table 4.5 below. The test specimens were 150 mm size cube moulds which were tested for 3day, 7 day, and 28 day compressive strength.

Table 4.5 Mix design proportions of Concrete

MIX	Notation	Water (Kg/m³)	Cement (Kg/m³)	Sand (Kg/m³)	C.A. (Kg/m³)	Water Cement Ratio
M20	M20	201.00	372.00	666	1179	0.50
M30	M30	201.00	438.00	628	1153	0.45
M35	M35	201.00	465.00	673	1094	0.40

4.8 Testing for Air content for freshly mixed concrete

Air content in fresh concrete was measured by the pressure method according to IS 1199-1959. Boyle's law is the foundation of Pressure Method. The law states that the applied pressure is proportional to the volume occupied by air. Two types of meters designated by A and B are covered by the standard. The A type meter is used infrequently. The type B meter consists of a separate air chamber connected through a valve to the test bowl that is filled with concrete. With the valve closed, the separate air chamber is pressurized to a predetermined operating pressure. When the valve is opened, the air expands into the test chamber and the pressure drops in proportion to the air contained within the concrete sample. The pressure gauge is read in units of air content. Over-vibration, leaks in the meter, error in the pressure gauge and incomplete sample consolidation etc., can cause an incorrect value of the measured air content in the concrete. For light-weight concrete the pressure meter should not be used but the volumetric method should be used instead.

4.9 Testing For Splitting Tensile Strength Test

The cylinders were tested by placing them uniformly in the compression testing machine of capacity 5000 kN. Specimen were taken out from curing tank at the age of 7 and 28 days of standard curing and tested after surface water dipped down from specimens. This test was performed on Compression Testing Machine (CTM) as shown in Figure 4.2. The test is carried out at the loading rate of 1 kN/s specified IS: 5816 -1999. The magnitude of tensile stress acting uniformly to the line of action of applied loading is given by formula 4.1 below:

$$f_{ct} = \frac{2P}{\pi l D} \quad \dots\dots\dots(4.1)$$

where

f_{ct} = split tensile strength, (N/mm²)

P = maximum applied load to the specimen, (N)

l = length of the specimen (mm)

D = cross sectional dimension of the specimen, (mm)



Fig. 4.2 Testing of Splitting Tensile Strength

4.10 Testing for Flexural Strength Test

The beams were tested by placing them uniformly in the universal testing machine of capacity 1000 kN. Specimen were taken out from curing tank at the age of 28 days of standard curing and tested after surface water dipped down from specimens. This test was performed on universal testing machine (UTM) as shown in figure 4.3. The test is carried out at the loading rate of 70 kN/min. The magnitude of flexural stress acting uniformly to the line of action of applied loading is given by formula 4.2 below:

$$f_b = p \times l / b \times d^2 \quad \dots\dots\dots(4.2)$$

Where

f_b = flexural strength in N/mm²

p = maximum applied load to specimen in Newton

l = length of the span on which the specimen was supported

b = measured width of the specimen

d = measured depth of the specimen at point failure



Fig. 4.3 Testing for Flexural Strength

4.11 Non-Destructive Testing for monitoring initial setting

Ultrasonic Guided Waves

From the above testing we selected the specimen with optimum test result in order to monitor the effect of molasses on the setting phase of the concrete, we selected **2 specimens**, namely **M30 grade with molasses dosage 0.30 % by mass of cement** (result for this specimen is discussed in chapter 5 ahead) and the control sample **M30 grade with 0% molasses**. The detail of this ultrasonic guided waves test has been discussed below:

In all cubes of size 150 cm x 150 cm x 150cm were cast. A mild steel bar of diameter 25mm was embedded in each cube at the centre position(7.5cm,7.5cm,7.5cm in global coordinates).The testing apparatus consisted of a DPR 300 pulser/receiver which generates pulses for a specified time interval. This pulse after generation is sent to a transducer which converts the signal to an ultrasonic wave. Figure 4.4 shows the experimental setup.

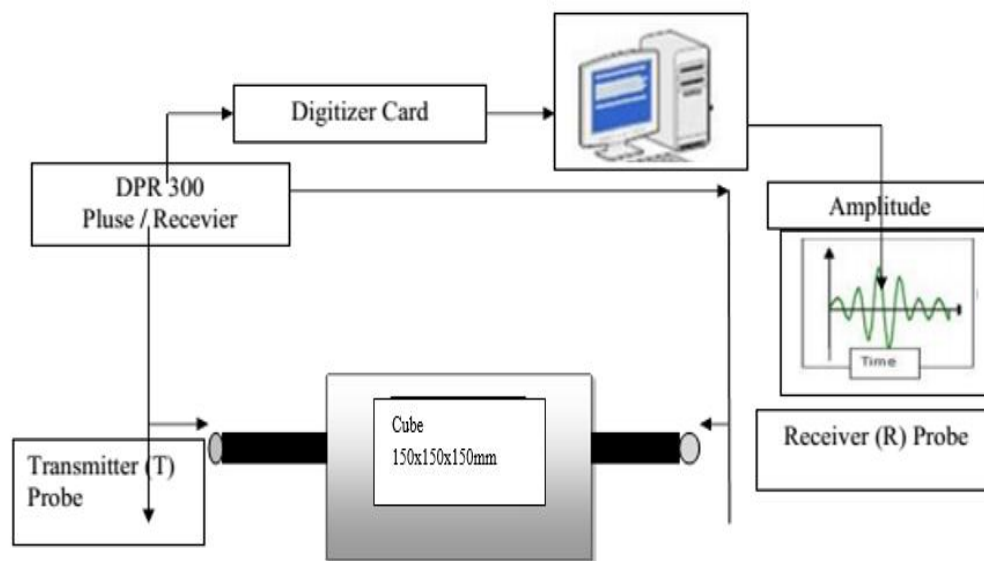


Fig. 4.4 Experimental setup of UGW for cube Specimen 150x150x150mm

The ultrasonic pulse propagates through the mild steel bar in form of guided waves. After the concrete setting process starts, the concrete surrounding the mild steel bar begins to bond with the bar thus resulting in attenuation, that is, loss of wave energy. This wave energy loss is due to the absorption of the wave energy by the material and energy leakage into surrounding concrete. Finally, the receiver transducer picks up the wave signal after

attenuation and converts it to an electrical signal to be processed by software. Figure 4.4 gives the work flow diagram of the UGW test method.

The key elements of the apparatus were:

a) Transducers: S24 HB 0.1 S and S 24 HB 0.1E (Karl Deutsch) were the standard transducers of 0.1 MHz frequency and 24 mm diameter used in this experiment. The transducers are given in Fig 4.5.



Fig. 4.5 Transducers -S24 HB 0.1 S and S 24 HB 0.1E (Karl Deutsch)

b) JSR Ultrasonic DPR 300 Pulser/receiver system:

This device can produce a high voltage electrical excitation pulse upto 475V and transfers this pulse to the instrument's T/R connector. Figure 4.6 shows a sample of the slab while testing.



Fig. 4.6 JSR Ultrasonic DPR 300 Pulser/Receiver System

This device can be configured for both pulse echo and through operations using the computer software. During the echo mode, signals reflected from interfaces or defects within the specimen are converted into electrical signals. The DPR 300 amplifies the signals before these are passed through adjustable high pass and low pass filters. Figure 4.5 shows the pulser-receiver system used in the study and Table 4.6 shows the specifications of the same.

Table 4.6 Specifications of JSR Pulse-Receiver

Pulser	
Pulse Type	Negative Spike Pulse
High Voltage Supply	100Vto475V
Initial Transition (Fall Time)	<5ns (10-90%)typical for 475 V pulsars
Pulse Amplitude	-475Vpeak. Amplitude depends on Energy, Impedance, Damping control settings, and pulser type
Pulse Energy	1.55 μ Joules minimum, 304 μ Joules maximum for 475V pulsars. Dependent upon energy and voltage setting
Pulse Duration	Typically10-70ns FWHM for 50 Ω load. Function of the Energy, Impedance, and Damping controls
Damping	16 Damping values :331,198,142,110,92,77,67,59,52,47, 43, 39,37,34,32, and 30 Ω
Mode	Pulse-echo or through transmission
Through Mode Isolation	Typically 80 dBat 10MHz
Pulser Repetition rate	Internal: 100 Hz -5 kHz for 475V pulsars. External: 0-5 kHz for 475 V pulsars.
Sync Output	Maximum +5V, t_r <30ns, t_w =50ns.min. TTL and CMOS compatible. Minimum value of load impedances 50 Ω
Pulser Trigger Source	Selectable by computer between internal oscillator and external source
External Trigger Input	2-5Vpositive going pulse. Triggering will occur synchronously with leading edge of trigger signal.
Receiver	
Gain	-13to66dBin 1dB steps controlled by the host computer

Phase	0°(non-inverting)
Input Impedance	500Ω (through transmission)
Bandwidth	.001-35MHz (-3dB) or .001-50 MHZ
High Pass Filter	DC,1,2.5,5,7.5 and 12.5 MHz
Low Pass Filter	3,7.5,10,15,22.5 (35MHz BW) or 5,10,15,22.5,35(50MHzBW)
Pulse Energy	1.55 μ Joules minimum, 304 μ Joules maximum for 475V pulsers. Dependent upon energy and voltage setting
Pulse Duration	Typically10-70ns FWHM for 50 Ω load. Function of the Energy, Impedance, and Damping controls
Damping	16Damping values:331,198,142,110,92,77,67,59,52,47, 43, 39,37,34,32, and30Ω
Mode	Pulse-echo or through transmission
Through Mode Isolation	Typically80dBat10MHz
Pulsar Repetition rate	Internal: 100 Hz -5 kHz for 475V pulsers. External: 0-5kHz for 475 Vpulsers.
Sync Output	Maximum+5V, tr<30ns, tw=50ns.min. TTL and CMOS compatible. Minimum value of load impedanceis 50Ω
Receiver Noise	Typically 49μV pk-pk input referred (measured at 60dB, 35MHz bandwidth)
Output Impedance	50Ω
Output Voltage	±0.5Vinto50Ω
Receiver Noise	Typically 49μV pk-pk input referred (measured at 60dB,35MHz bandwidth)
Output Impedance	50Ω
<u>Output Voltage</u>	<u>±0.5Vinto50Ω</u>

4.11.1 Excitation mode and frequency:

The selection of a suitable test mode and frequency is done after analyzing the dispersion curves using the software Disperse. According to Sharma and Mukherjee (2010), modes that have lowest signal attenuation and at the same time are easily distinguishable are selected.

Generally, modes at low attenuation are used to maximize the inspection range and at the same time to minimize the effects of dispersion and also minimize the interference of other modes in the received signal. Curves for a mild steel bar of 25mm diameter are shown in figure 4.7.

Testing procedure:

Another contributing factor to the selection of mode is the relative sensitivity of ultrasonic waves to setting of concrete. A mode that has significant surface component would be sensitive to bonding effect of concrete on the bar. Such mode is L (0, 1) mode at a low frequency of 100 kHz (0.1 MHz) having negligible amount of signal loss due to material absorption. This mode shows significant axial displacement at the interface and is a surface seeking mode) and hence, is chosen to monitor the bond development at 100 kHz. .

KARL DEUTSCH contact transducers with a central frequency of 0.1 MHz was chosen and its surface was applied with an ultrasonic gel. This gel helps to make the surface smooth and remove the air gap. The transducers are then connected to the ends of the mild steel bar embedded in the concrete slab. One transducer acts as a transmitter and the other as a receiver. The transducers used had longer wave form duration and a relatively narrow frequency bandwidth with central frequency of 0.1 megahertz as the objective was to monitor bonding between the mild steel bar and the surrounding concrete in the slab.

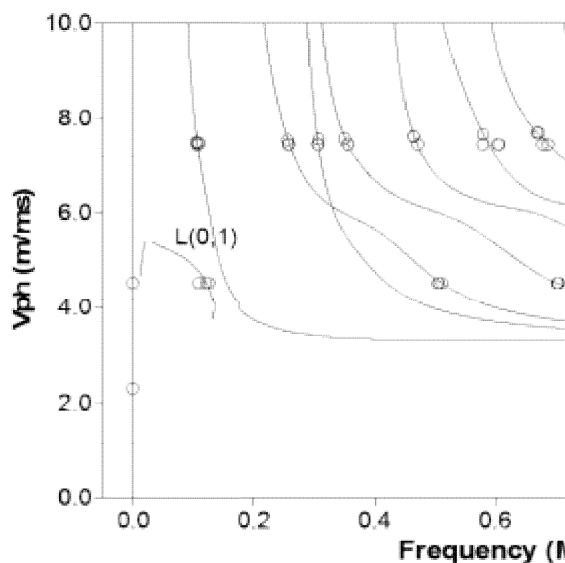


Fig. 4.7 Curves for 25mm dia bar (Sharma & Mukherjee, 2010)

Figure 4.8 shows the specimen details for UGW tests.

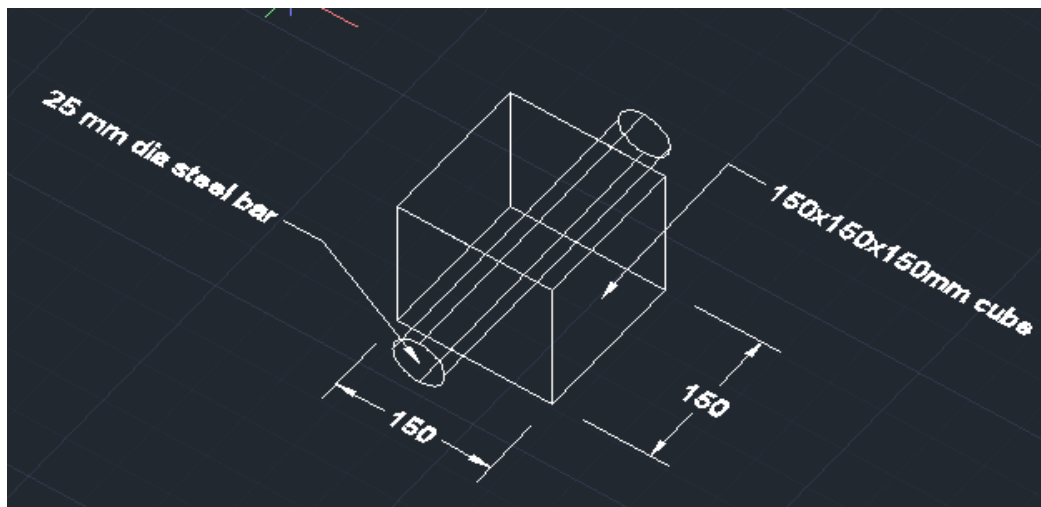


Fig. 4.8 **Cube specimen for UGW testing**

4.12 **Closing Remarks**

The experimental programme described in this chapter includes the significant material properties and specifications of the ingredients of concrete and the testing procedure. The specimen details and the test set-up have been discussed.

CHAPTER 5: RESULTS & DISCUSSIONS

5.1: GENERAL

The compressive strength, flexural strength and splitting strength are relatively important mechanical properties of any hardened concrete. To benefit from the vast experience and knowledge base, concrete produced with molasses should have similar properties as provided for in existing standards and must adopt the same conventional concreting practices in accordance with code specification. In this chapter results of mechanical tests on the specified range of specimens are reported, with the purpose of establishing whether the strength of concretes produced with molasses meet the standardized structural concrete criteria. Several series of tests were carried out on concrete cylinders, cubes and beams for the above purpose. In addition, this chapter compares the performance of molasses on cement, cement mortar and concrete is studied. For cement, standard consistency test, and setting time test were conducted. For cement sand mortar, flow table test and compressive strength were conducted. For concrete, slump test, air content test, the compressive strength, flexural strength and splitting strength were performed for both concretes (with and without molasses) as a basis for the comparison of their performances in the hardened state. For durability state, ultrasonic guided waves were also performed.

The observations based on the experimental program are discussed in sections below:

5.2 Effect of Molasses & Sugar on standard consistency and setting time

The results obtained for setting time and standard consistency on cement on addition of molasses and sugar are presented in table 5.1 and table 5.2 and plotted in figure 5.1 and figure 5.2 respectively.

Table 5.1 Effect of Molasses on Standard Consistency and Setting Time

Composition Of Molasses (% Of Cement)	Standard Consistency	Setting Time	
		Initial (Minutes)	Final (Minutes)
NIL	29.00	112	218
0.050	29	108	203

Composition Of Molasses (% Of Cement)	Standard Consistency	Setting Time	
		Initial (Minutes)	Final (Minutes)
0.100	29	62	128
0.200	27	45	98
0.500	26	52	199
1.000	25	120	272
2.000	23.50	162	332
3.0	23.50	125	262
4.0	23.50	132	272
5.0	23.50	152	312
6.0	23.00	158	322

Table 5.2 Effect of Sugar on Standard Consistency and Setting Time

Composition Of Sugar (% Of Cement)	Standard Consistency	Setting Time	
		Initial (Minutes)	Final (Minutes)
NIL	27.00	108	215
0.050	27	37	150
0.075	27	45	158
0.100	27	58	168
0.150	29	80	207
0.200	29	160	266
0.250	28.25	208	309
0.300	28.25	202	267
0.400	28.25	178	241
0.500	28.00	160	237
0.750	27.85	145	229
1.000	27.85	120	218
1.125	27.85	142	226

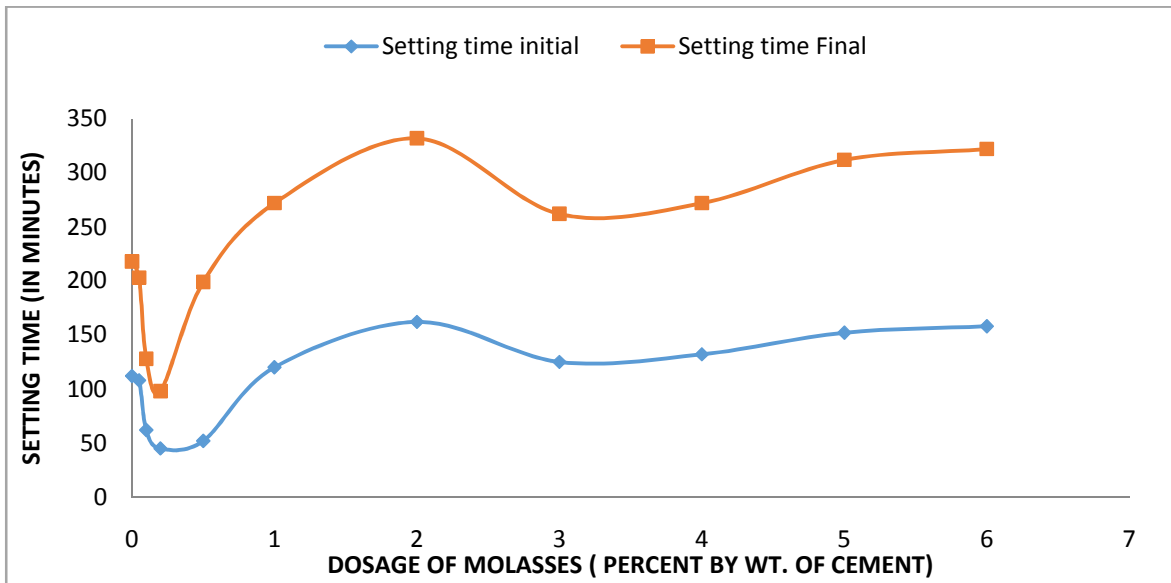


Fig. 5.1 Plot of Setting Time v/s Dosage Rate of Molasses

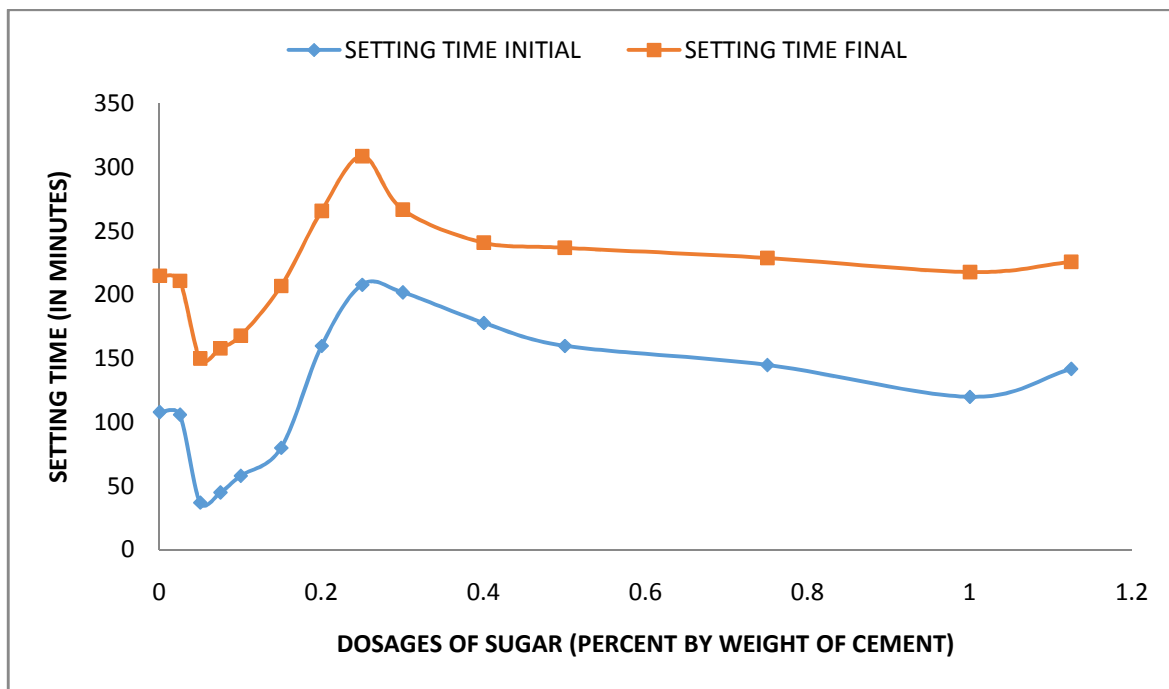


Fig. 5.2 Plot of Setting Time v/s Dosage of Sugar

The observed results of the standard consistency, initial and final setting time of cement paste with varying dosage of molasses are presented in the Table 5.1. From the data, a graph of setting time Vs dosage of molasses is plotted. From the testing following observations are made and following inferences are drawn:

- Molasses contain 20-25 % sugar (i.e. sucrose) and 20 -25 % of that dose of sugar gives the similar trend of graph of (setting time vs dosage) of molasses as that of sugar.
- Standard consistency of cement decreases with an increase in dosage level, which shows, it is a water reducing agent.
- Initial setting time and final setting time first decrease up to 0.2 % dose of molasses and then increase up to the dose of 2.0 %. Thus at some particular %age of dosage level it acts as an accelerating agent and whereas at dosage level, it acts as retarding agent. This behaviour may be due to the large amount of chemicals and chemical compounds in molasses. Due to carbohydrates it is acting as retarding agent and due to chlorides and hydroxides it is acting as accelerating agent. Up to 0.50 % dose it acts as accelerating agent and later as retarding agent upto 2%

5.2 Effect of Molasses on cement sand mortar

The flow table test was conducted on different cement sand mortar composition and the results are presented in the table 5.3 (a), 5.3 (b) and 5.3 (c). The results are also plotted in the figure 5.3, figure 5.4 and figure 5.5 below. In order to perform the flow table test, flow value of 110 ± 5 mm (workability value for mortar) was fixed as a base value. As the dosage of molasses is increased, the water cement ratio decreases which is clear from the table 5.3 (a).

Table 5.3 (A) Flow Table Results for Mortar (Cement: Sand = 1:3)

Flow table = 110 ± 5 mm

Original base diameter = 100 mm

Dosage Of Molasses (Percent By Weight Of Cement)	Water/ Cement Ratio	Increase In Diameter(mm)	Flow Value (Percent)	Water Reduction (Percent)
0.00	0.70	110	110	0.00
0.10	0.70	107	111	0.00
0.25	0.70	101	114	0.00
0.50	0.69	96	108	1.4

Dosage Of Molasses (Percent By Weight Of Cement)	Water/ Cement Ratio	Increase In Diameter(mm)	Flow Value (Percent)	Water Reduction (Percent)
1.00	0.68	111	111	2.4
2.00	0.67	114	114	4.8
3.00	0.65	108	108	7.2
4.00	0.63	109	109	9.6
5.00	0.62	107	107	12.0

From table 5.3 (a), it is clear that to maintain the constant workability value of cement mortar mix, the value of water cement ratio reduced as the value of molasses is increased. It is clear that molasses serves the purpose of water reducing agent.

Table 5.3 (B) Flow Table Results for Mortar (Cement: Sand = 1:4)

Flow table = 110±5 mm

Original base diameter = 100 mm

Dosage Of Molasses (Percent By Weight Of Cement)	Water/ Cement Ratio	Increase In Diameter(mm)	Flow Value (Percent)	Water Reduction (Percent)
0.00	0.93	111	111	-
0.10	0.93	113	113	-
0.25	0.923	108	108	0.746
0.50	0.915	109	109	1.386

From table 5.3 (b), it is clear that to maintain the constant workability value of cement mortar mix, the value of water cement ratio reduced as the value of molasses is increased. It is clear that molasses serves the purpose of water reducing agent.

Table 5.3 (C) Flow Table Test for Mortar (Cement: Sand = 1:5)

Flow table = 110±5 mm

Original base diameter = 100 mm

Dosage of molasses (% by weight of cement)	Water/ cement ratio	Increase in diameter(mm)	Flow value (%)	Water reduction (%)
0.00	1.20	1140	110	-
0.10	1.20	112	112	-
0.25	1.19	108	108	0.667
0.50	1.18	110	110	1.25

From table 5.3(c) it is clear that molasses is water reducing agent.

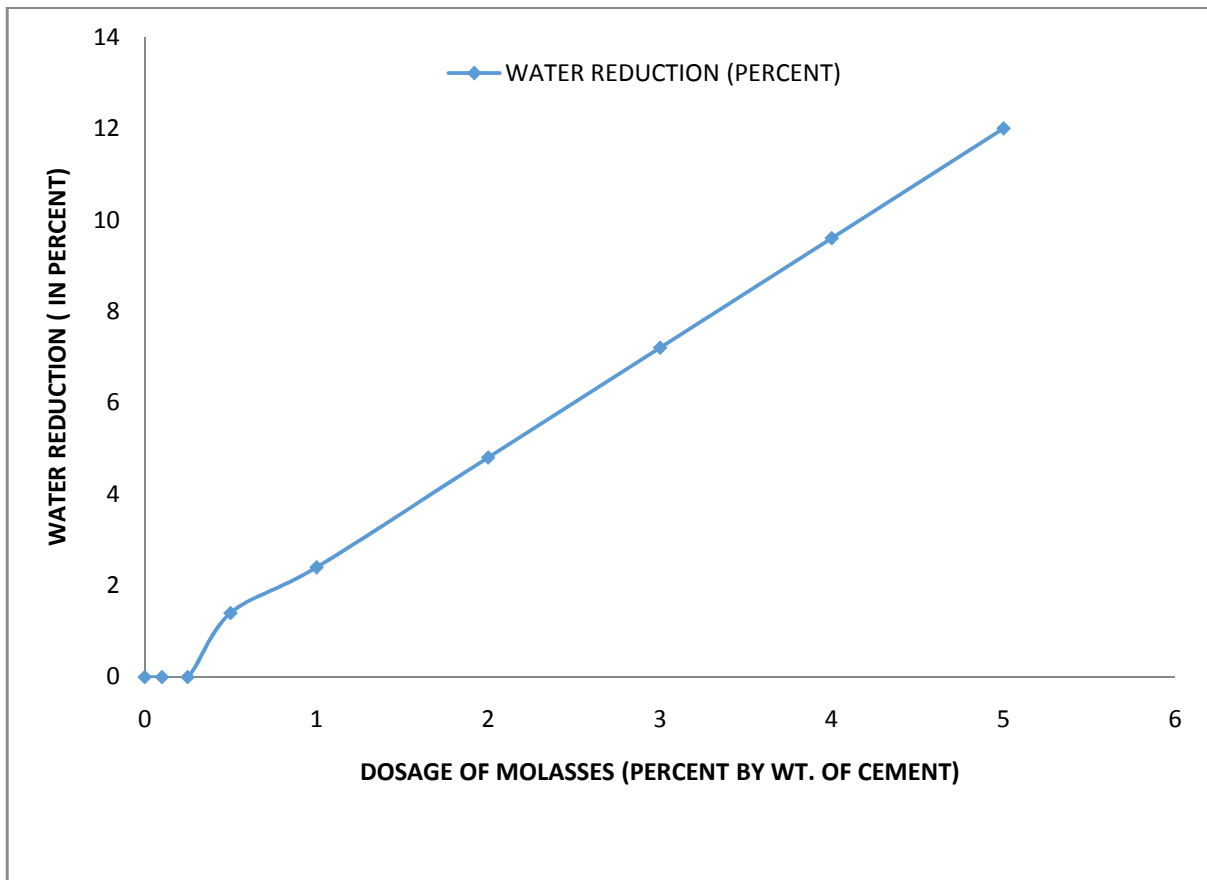


Fig. 5.3 Effect of Molasses on Water Reduction (Cement: Sand = 1:3)

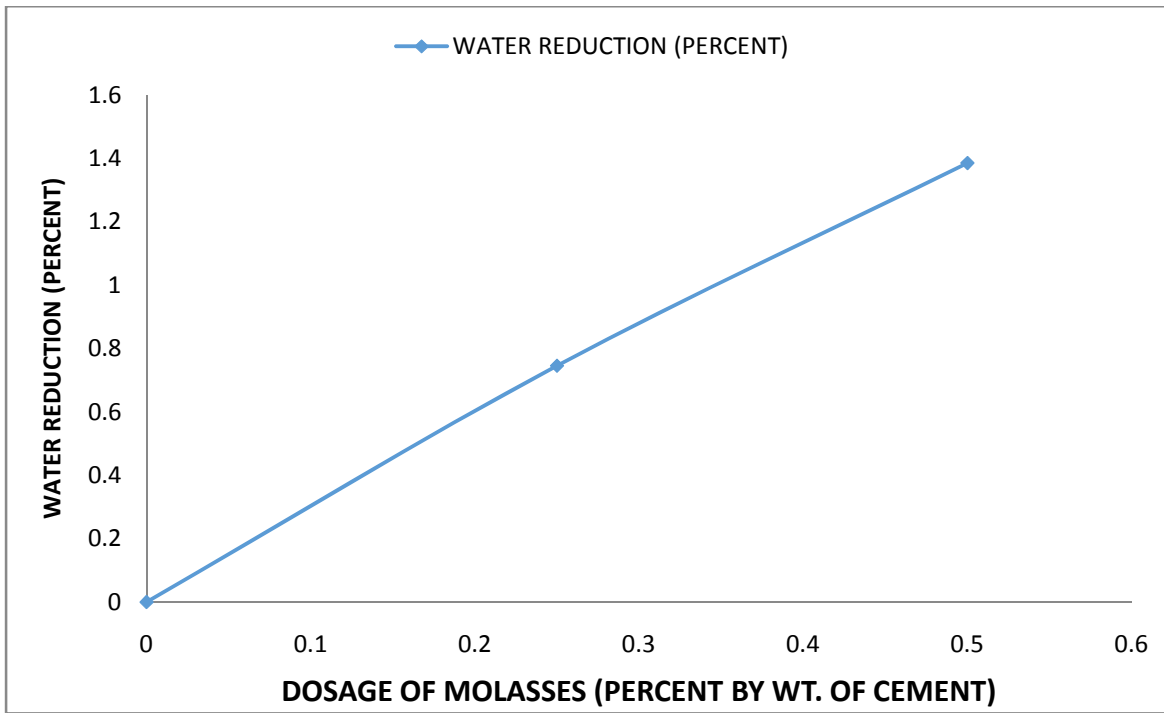


Fig. 5.4 Effect of Molasses on Water Reduction (Cement: Sand = 1:4)

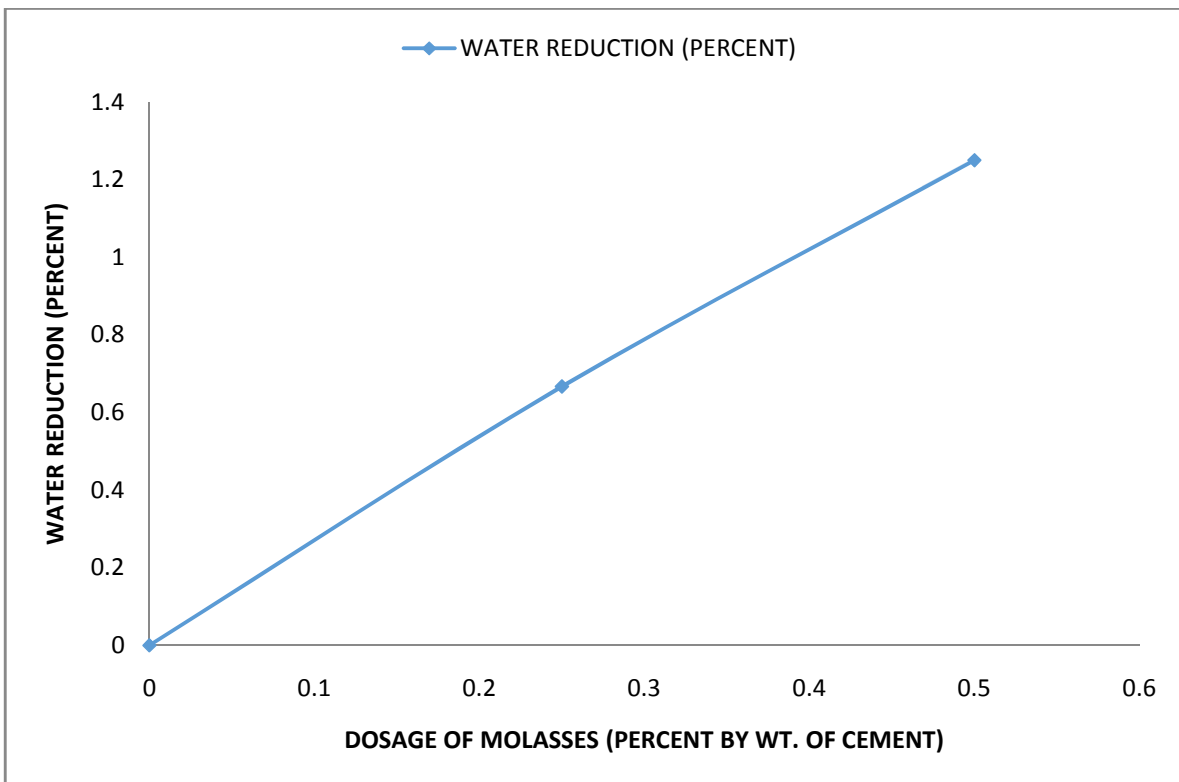


Fig. 5.5 Effect of Molasses on Water Reduction (Cement: Sand = 1:5)

From the results and discussion for each of the cement mortar mix obtained, following final observations are made:

- For each of cement mortar mix, the molasses showed a water reducing behaviour.

- From all the graphs of all mixes, the graphs between water reduction and dose of molasses is linear for all mixes indicating that water reduction is directly proportional to the dose of molasses
- It is clear from the data above that molasses is a water-reducing agent. It is observed that as the cement sand mortar mix is increased, the percentage of water reduction decreases marginally. For example, for a 0.50% dosage level of molasses, the value of water reduction is 1.4% for 1:3 mix, 1.386% for 1:4 mix and 1.25% for 1:5 mix respectively.

5.3 Compressive Strength of Cement Sand Mortar at Different Dose of Molasses

The compressive strength test was carried out on cement sand mortar for 7 days and 28 days and the results are shown in table 5.4 and figure 5.6.

Table 5.4 Compressive Strength of Cement Mortar (With Molasses)

Mortar Ratio (Cement : Sand)	Dosage Of Molasses (% By Wt. of Cement)	w/c Ratio	Compressive Strength (MPa)	
			7 days	28 days
1:3	0.00	0.65	8.90	21.67
	0.10	0.65	8.75	21.92
	0.30	0.64	6.75	22.84
	0.50	0.62	4.50	20.15
	0.60	0.60	4.25	18.25
1:4	0.00	0.95	6.62	15.23
	0.10	0.94	6.50	17.50
	0.30	0.92	5.80	19.70
	0.50	0.90	3.80	18.20
	0.60	0.88	2.98	16.90
1:5	0.00	1.250	4.80	10.28
	0.10	1.240	4.02	12.24
	0.30	1.190	3.80	15.80
	0.50	1.115	2.98	14.64
	0.60	1.002	2.02	12.80

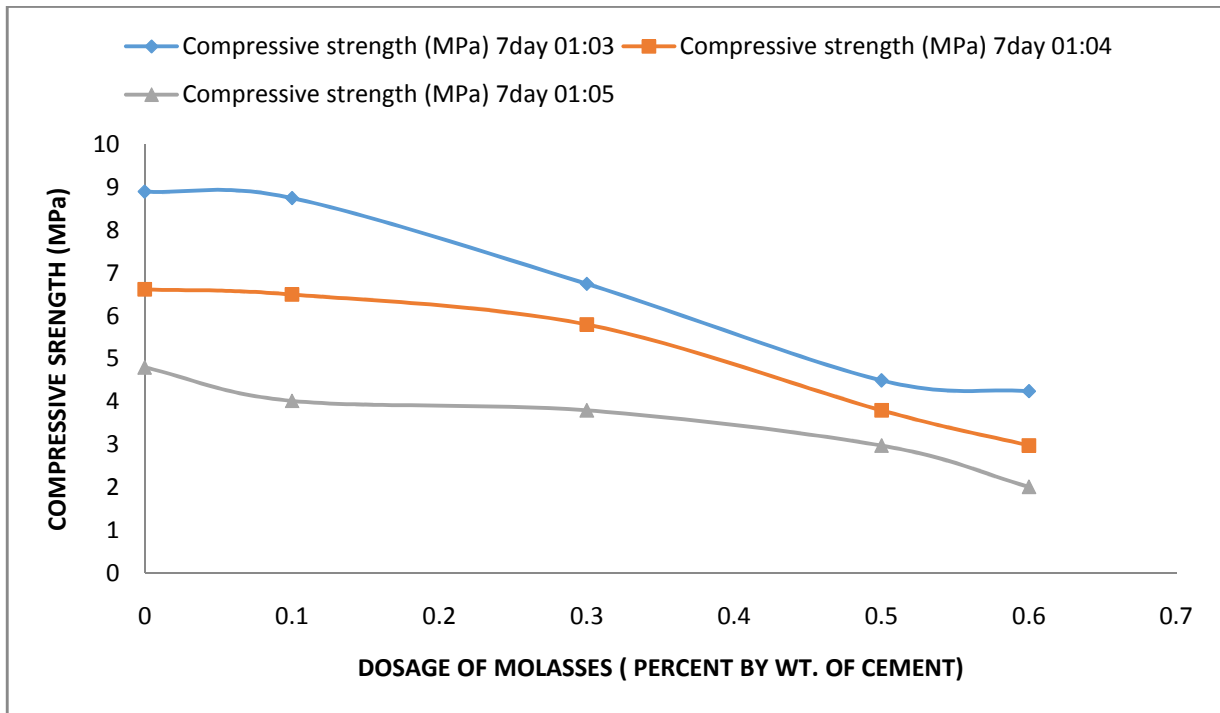


Fig. 5.6 7 day Strength variation of Mortar with varying dosage of Molasses

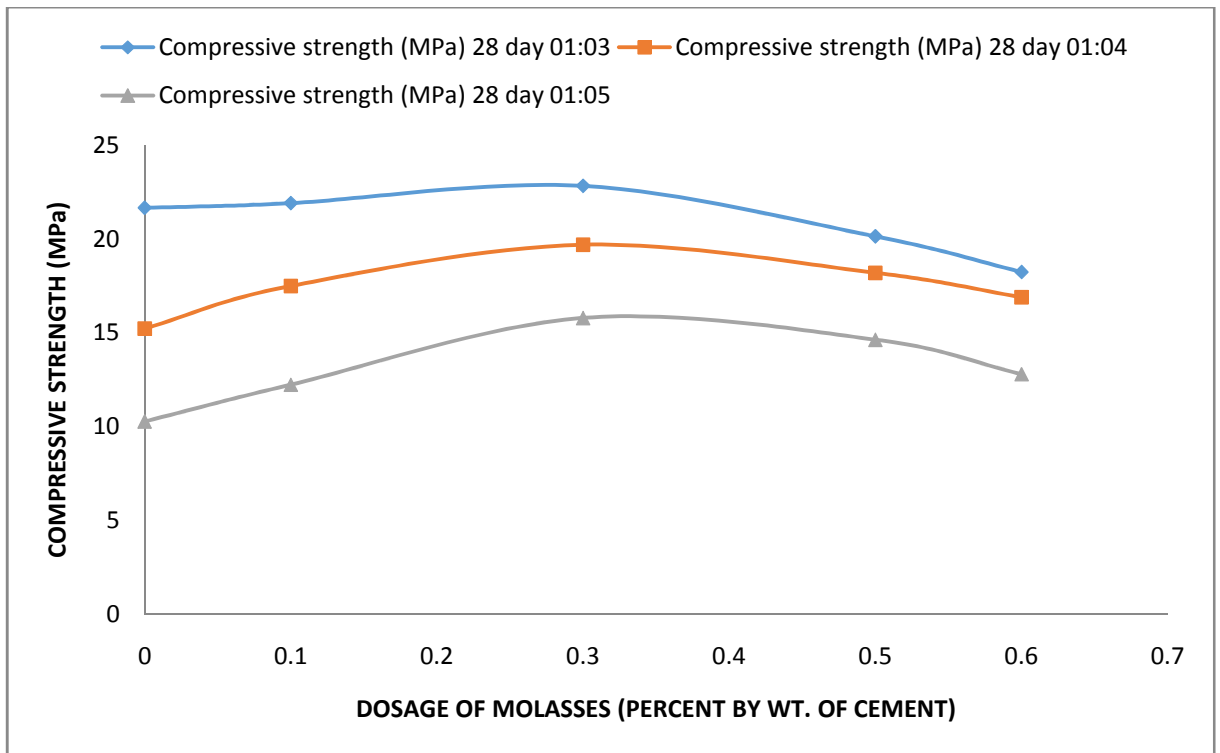


Fig. 5.7 28 day Strength variation of Mortar with varying dosage of Molasses

From the compressive strength results for all different cement mortar mixes prepared, following observations can be made:

- In general, it is seen that the 7 day compressive strength of every mortar mix decreases with the increase in the dosage levels of molasses. This is due to the fact that molasses acts as retarding agent.
- In general it is seen that the 28 day compressive strength of every mortar mix increases slightly up to dosage of 0.30 % by weight of cement and then decreases slightly at a lower rate such that at 0.50 % dose, the compressive strength is more than the reference strength.
- It is also seen that during the experiment that at higher dose of molasses the cement mortar is not setting within 24hoursIt is also seen that the proper bond between cement and sand is not developing at higher doses because the cement mortar mix did not hardened in cube moulds even after 24 hours of casting.

5.4 Workability

Workability is the easiness with which the concrete can be pumped, placed, transported and compacted without any segregation losses. The degree of workability is measured by slump value for a concrete. The effect of varying dosage of molasses is given in table 5.5 and figure 5.8 given below:

Table 5.5 Effect of Varying Dosage of Molasses on Slump Values

S.No.	% of molasses	Slump Value (cm)
1	0	5.4
2	0.2	6.3
3	0.4	8.6
4	0.6	15.2
5	0.8	16.4
6	1.0	19.6

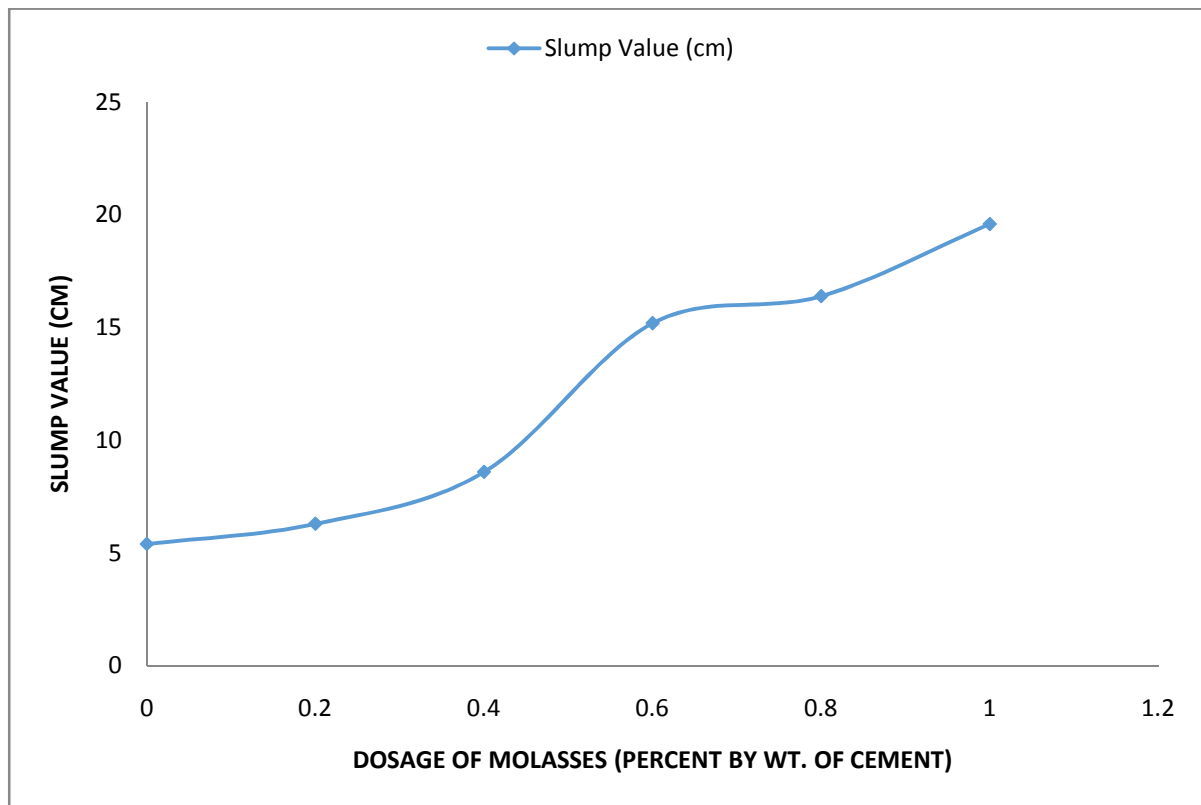


Fig. 5.8 Slump Value (Cm)

From the close observations made it found that:

- The dosage of molasses increases the slump values of the concrete. It means that the workability increases significantly for a concrete mix.
- Since in this study, the behaviour of concrete with the dosage of molasses is studied which lead to significant increase in workability.
- It may be attributed to the fact that the sucrose present in the molasses forms a dense gel which entraps the air inside the concrete mix which acts as a lubricant increasing the workability value. To support this fact, air entrainment test is carried out later.
- If we take particular value of workability as a controlling factor, the water cement ratio required may decrease with increase in dosage of level of molasses on controlled manner.

5.5. Air entrainment in fresh concrete due to the addition of molasses

The freshly mixed concrete at different dosage of molasses was prepared and air entrainment was determined. The results are shown in table 5.6 as below:

Air content for freshly mixed concrete by pressure method

Volume of measuring bowl = 6640ml

Table 5.6 Effect of Molasses on the Air Entrainment in Concrete

Dose of molasses (% by wt. of cement)	Pressure head difference (ml)		Air content (%)	Increase in air content (%)
	(h1-h2)	Average value		
0	68.5	66.55	1	
	65.8			
	68.8			
	63.1			
1	71.2	69.175	1.04	4
	71.2			
	68.5			
	65.8			
3	76.6	73.9	1.11	11
	73.9			
	73.9			
	71.2			
5	82	78.63	1.18	18
	79.3			
	76.6			
	76.6			

- The test result clearly shows that the air content increases with increase in the dosage of molasses.
- The air content of freshly mixed concrete and dosage are almost directly proportional to each other.
- It may be attributed to the fact that the sucrose present in the molasses forms a dense gel which entraps the air inside the concrete mix which acts as a lubricant. As the value of molasses increases, the air entrained in concrete mix also increases.

5.6. Compressive Strength

The summarized results of various concrete mixes are presented in the table 5.7 and graphs 5.9 to 5.14 have been plotted for the above results.

Table 5.7 Compressive Strength of Various Mixes at different dose of Molasses

S.No.	Mix Design	Dosage (% by weight of cement)	Average compressive strength(MPa)		
			3 days	7 days	28 days
1	M1 (20)	0	13.43	19.31	25.98
		0.1	13.01	18.04	26.14
		0.3	13.24	19.93	27.98
		0.5	9.84	16.64	25.45
		0.6	7.78	14.88	20.12
2	M2 (30)	0	18.70	26.88	38.96
		0.1	17.32	24.25	36.45
		0.3	18.70	27.10	38.12
		0.5	13.85	22.35	34.54
		0.6	11.25	17.85	32.69
3	M3 (35)	0	20.23	29.08	42.15
		0.1	19.10	27.48	41.28
		0.3	20.15	29.45	44.26
		0.5	15.98	25.02	39.14
		0.6	12.01	21.54	37.45

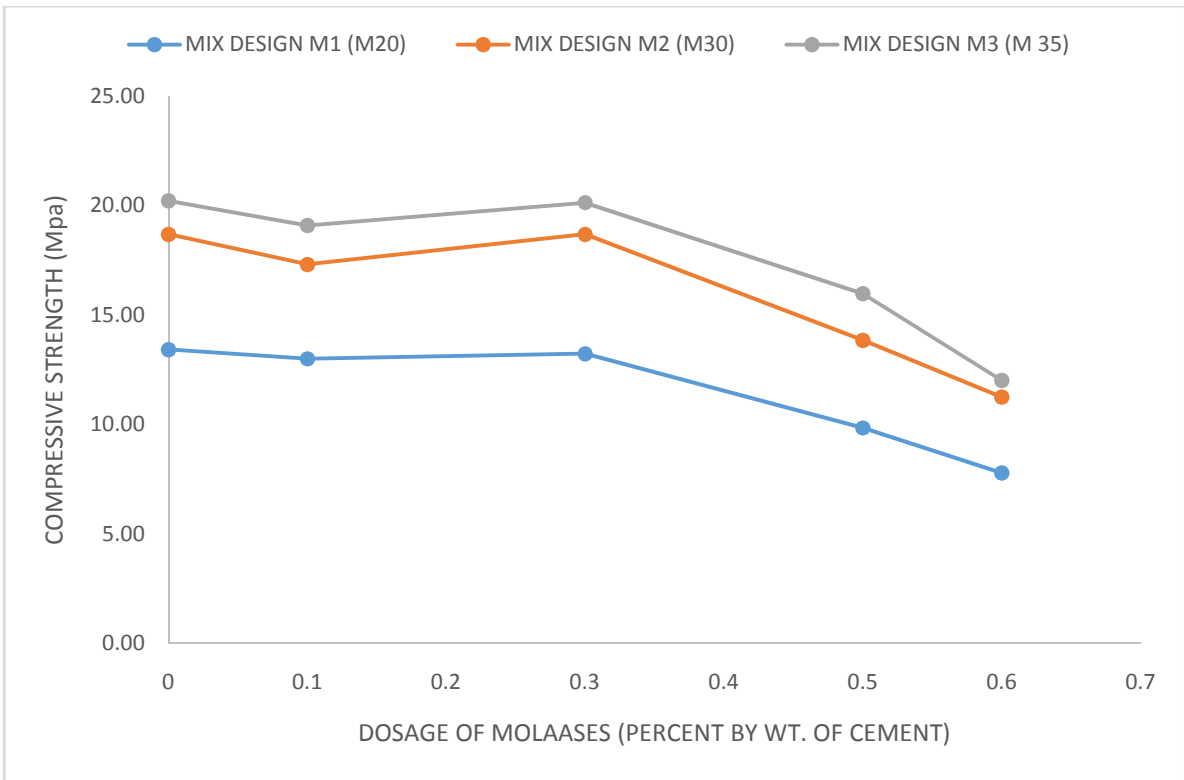


Fig. 5.9 3 day Strength variation with varying dosage of Molasses

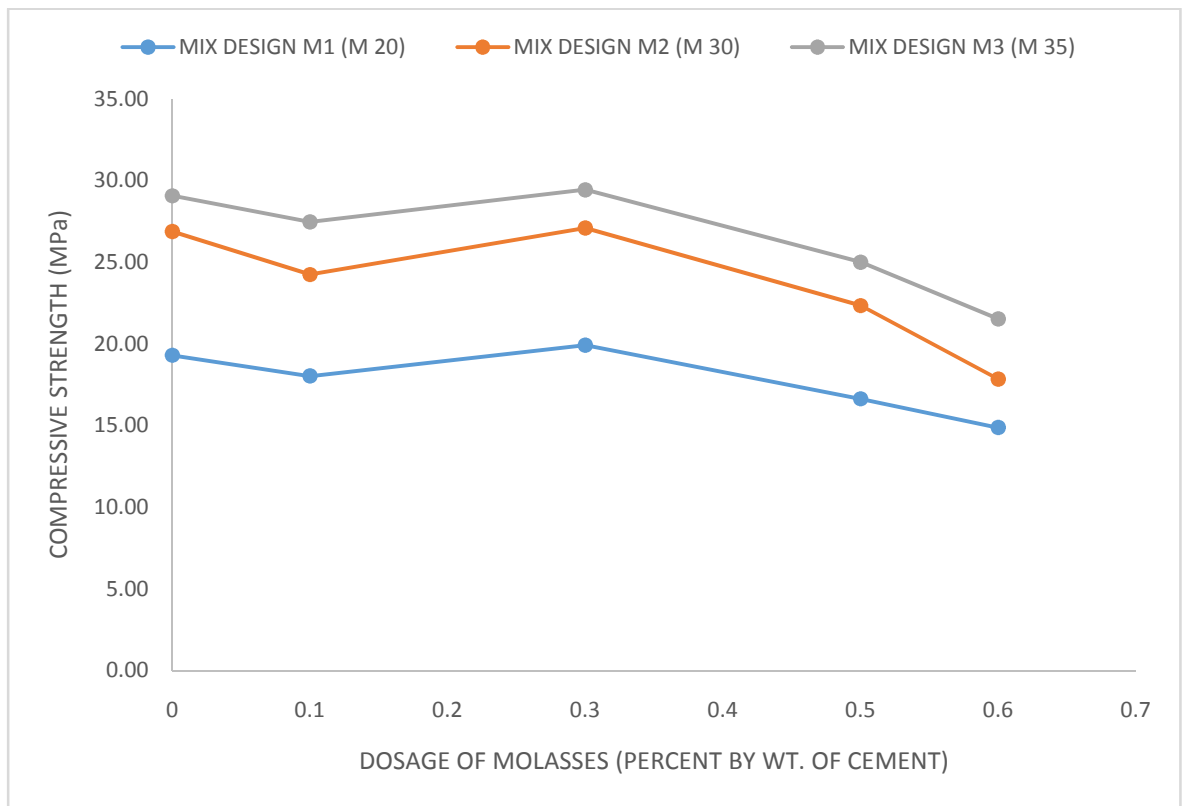


Fig. 5.10 7 day Strength variation with varying dosage of Molasses

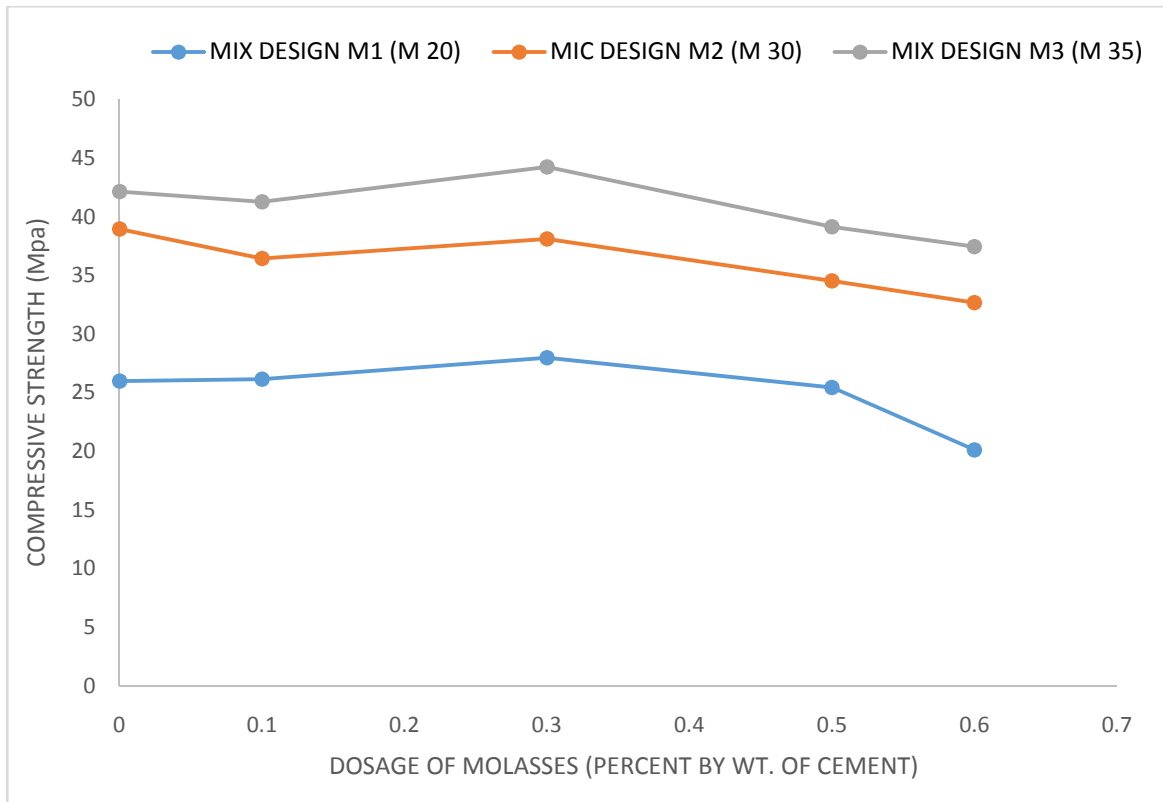


Fig. 5.11 28 day Strength variation with varying dosage of Molasses

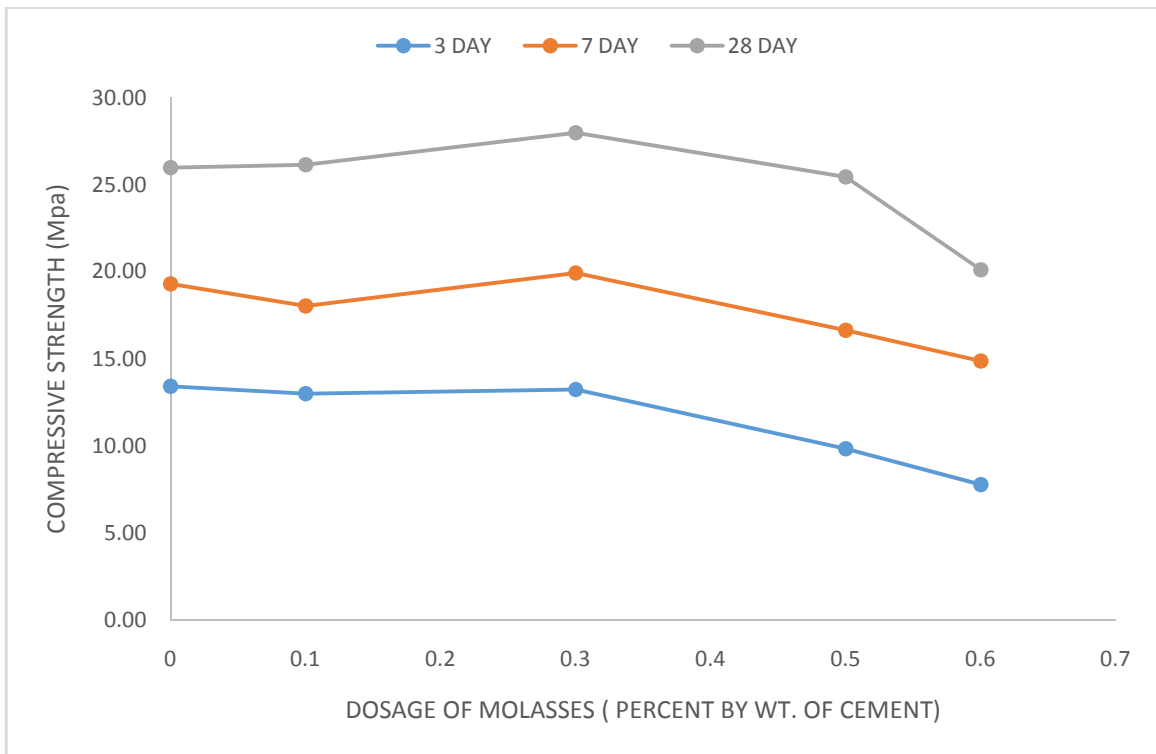


Fig. 5.12 Strength variation with varying dosage of Molasses for Mix Design M1 (20MPa)

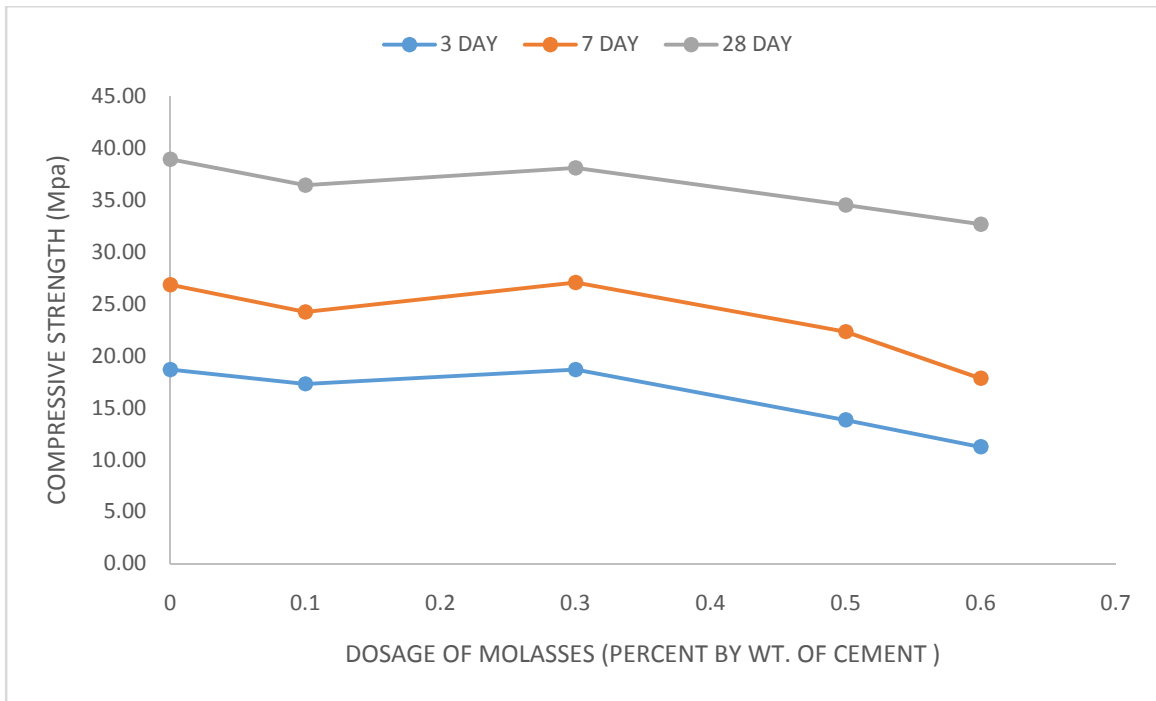


Fig. 5.13 Strength variation with varying dosage of Molasses for Mix Design M2 (30 MPA)

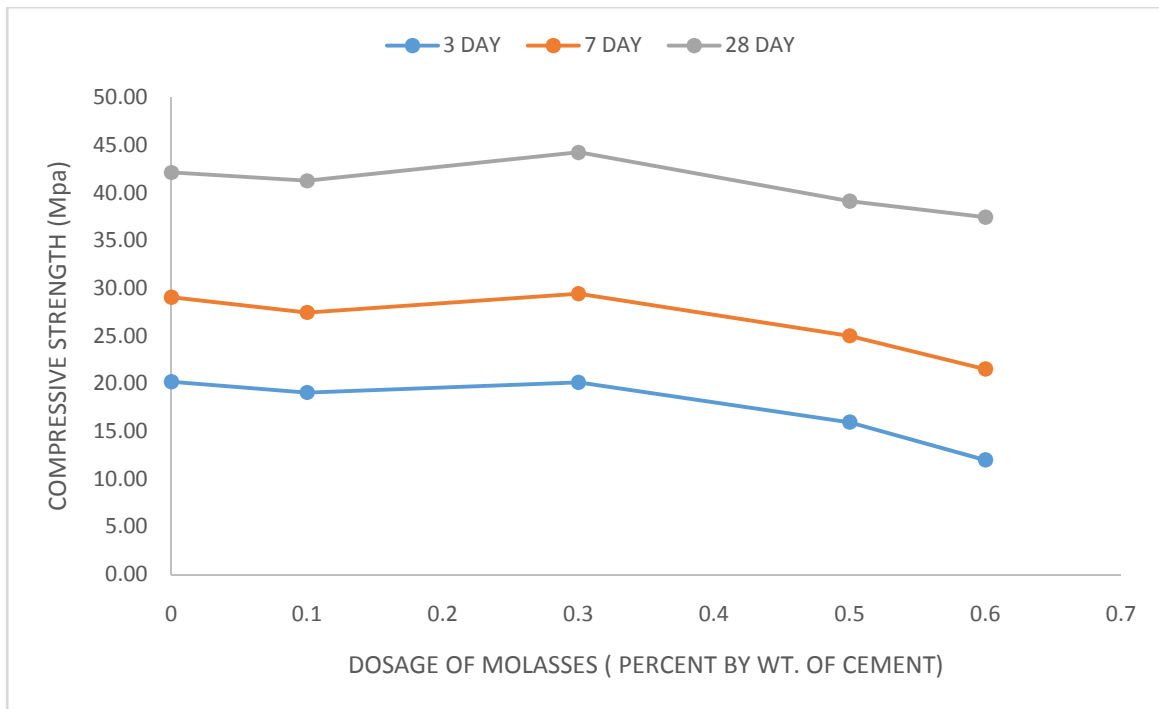


Fig. 5.14 Strength variation with varying dosage of Molasses for Mix Design M3 (35 MPA)

The following observations are made:

- For 3 day strength, all the three mixes showed decrease in the value of compressive strength. It may be due to the starting of formation of sucrose gel with water in concrete mix.
- For 7 day strength value, the value of strength decreased except at 0.30 percent dosage level of molasses. It points to the fact that the increased level of molasses delays the hardening process of concrete mix. Optimum results obtained at 0.30 percent dosage level of molasses for each mix.
- For 28 day compressive strength value, it was observed that up to 0.30 dosage levels of molasses showed increase in the compressive strength value of concrete for each mix. But at further increase in dosage level of molasses beyond 0.30, it was observed that there was decrease in the compressive strength as compared with the control sample.
- For each mix, the trend was almost similar. At 3 days, there was decrease in the compressive strength value for each mix. At 7 days, there was decrease in value of the compressive strength. After 28 days, there was increase in the compressive strength value at 0.30 percent dosage level of molasses, beyond that there was decrease in the compressive strength.

5.7 Flexural Strength of concrete mixes

The flexure test was conducted on the different concrete mixes and the results are shown in table 5.8 and plotted in figure 5.15 to figure 5.19 below:

Table 5.8 Flexural Strength of Various Mixes at Different Dose of Molasses at indicated age (Day)

S.No.	Mix Design	Dosage (% by weight of cement)	Average flexural strength	
			7 day	28 day
1	M1 (20)	0	2.44	3.21
		0.1	2.26	3.12
		0.3	2.51	3.23
		0.5	1.87	3.05
		0.6	1.52	2.89
2	M2 (30)	0	2.97	3.98
		0.1	2.62	3.79
		0.3	2.49	3.92
		0.5	1.73	3.17
		0.6	1.74	3.03
3	M3 (35)	0	3.26	4.25
		0.1	3.03	4.12
		0.3	2.88	4.39
		0.5	2.33	3.93
		0.6	2.03	3.77

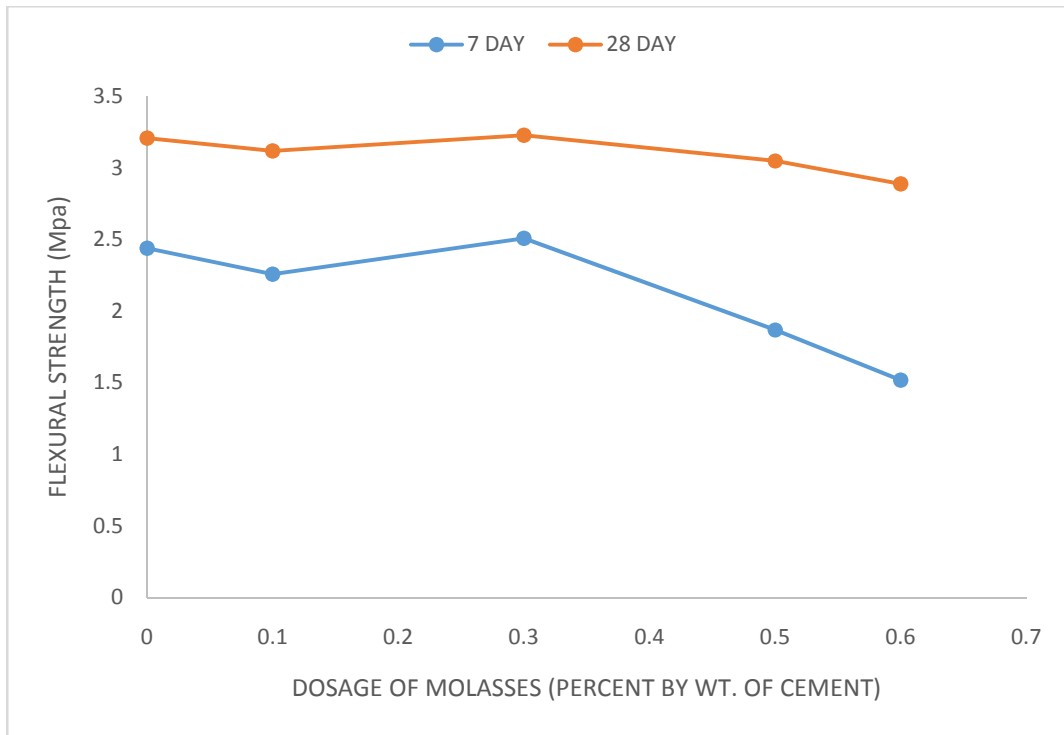


Fig. 5.15 Variation in Flexural strength with varying dosage of Molasses for Mix Design M1 (20 MPA)

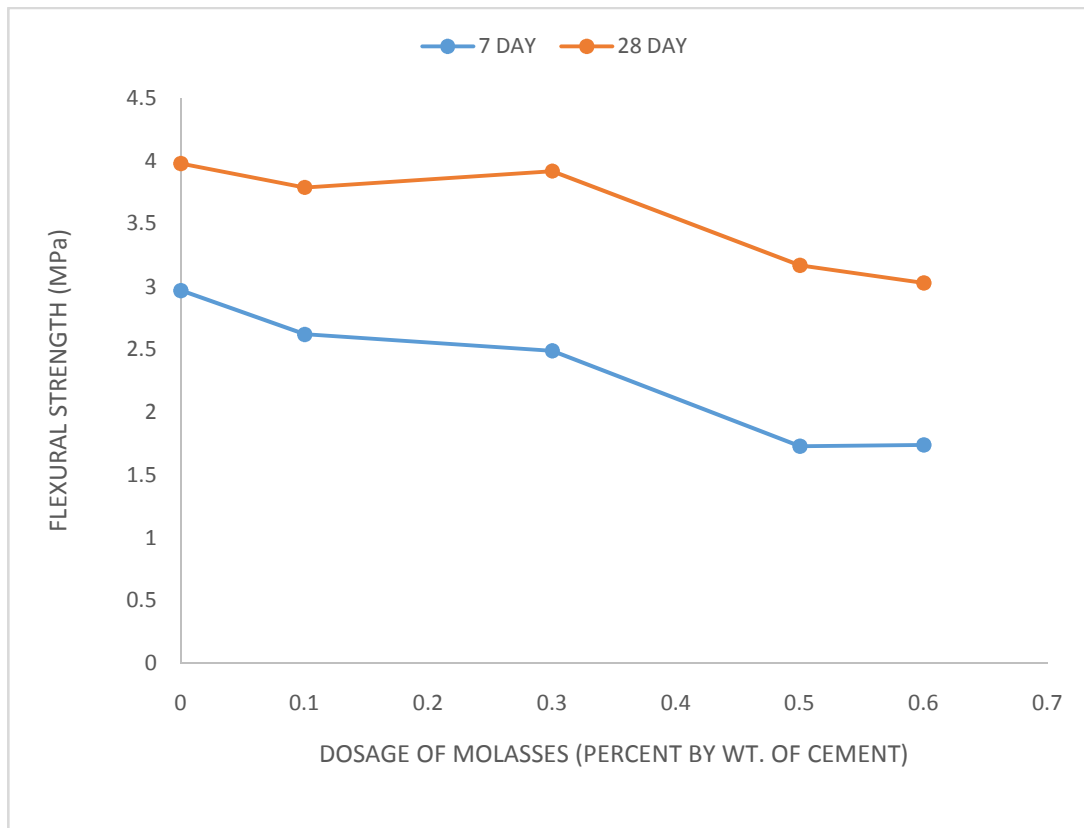


Fig. 5.16 Variation in Flexural strength with varying dosage of Molasses for Mix Design M2 (30MPA)

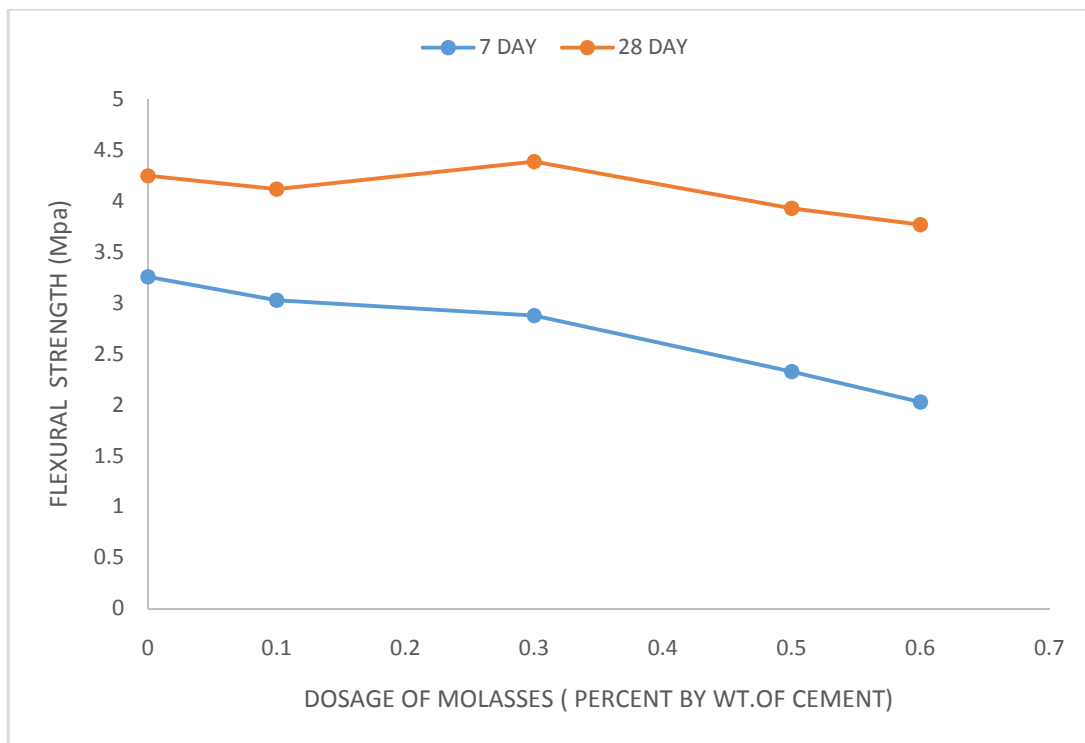


Fig. 5.17 Variation in Flexural strength with varying dosage of Molasses for Mix Design M3 (35 MPA)

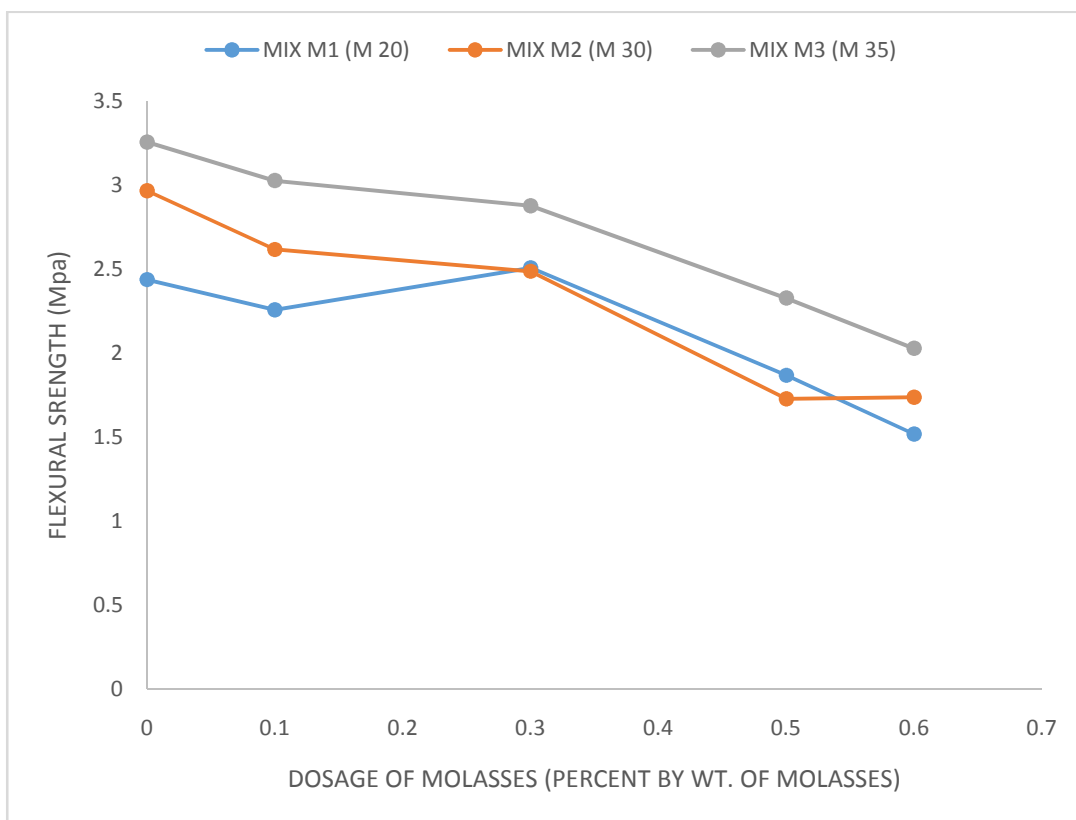


Fig. 5.18 7 day Flexural Strength variation with varying dosage of Molasses

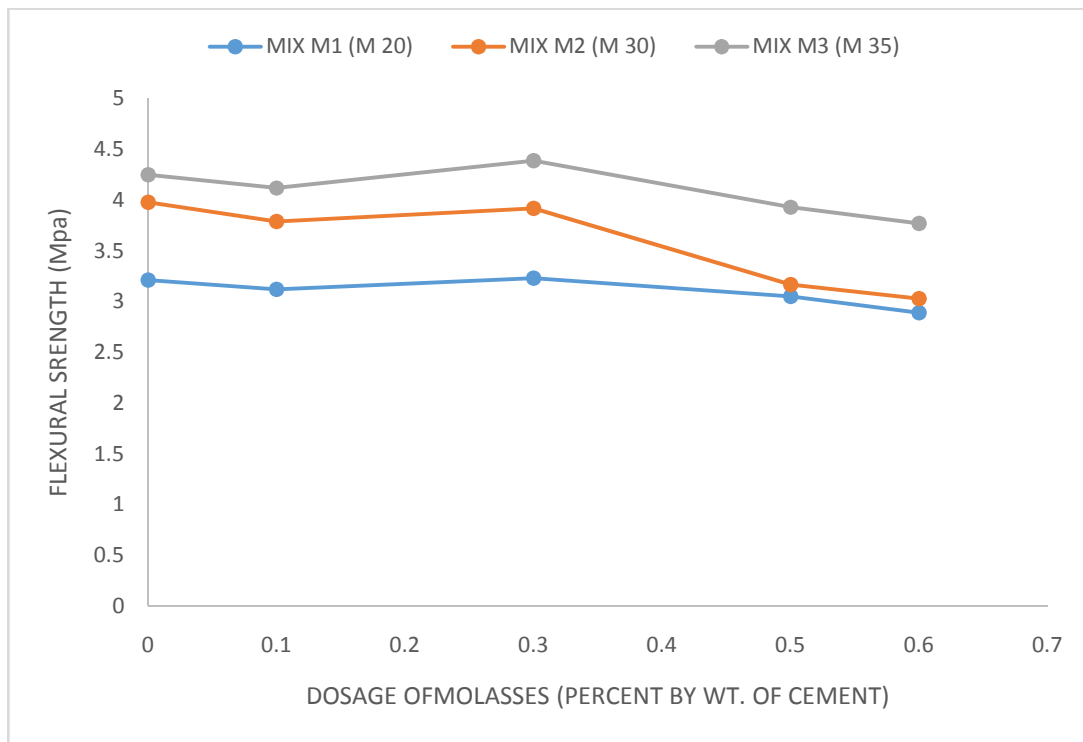


Fig. 5.19 28 day Flexural Strength variation with varying dosage of Molasses

The following points may be noted from the result plotted on the graphs:

- The test results for flexural were shown in the concerned graph in previous chapter. The following points may be remarked:
- The flexural strength increases with an increase in the dosage level upto 0.30 % dose and then decreases and then decreases.
- The flexural strength is maximum at 0.30 % dose of molasses.

5.8 Split Tensile strength of concrete mixes

The result for split tensile strength is shown in figure 5.9 and plotted in figure 5.20 to 5.24.

Table 5.9 Split Tensile Strength of Various Mixes at Different Dose of Molasses at indicated Age (Day)

S.No.	Mix Design	Dosage (% by weight of cement)	Average Split tensile strength	
			7 day	28 day
1	M1 (20)	0	1.98	2.68
		0.1	1.78	2.58
		0.3	2.13	2.79
		0.5	1.60	2.21
		0.6	1.21	2.05
2	M2 (30)	0	2.45	3.12
		0.1	2.40	2.98
		0.3	2.43	3.16
		0.5	2.01	2.75
		0.6	1.98	2.31
3	M3 (35)	0	2.71	3.85
		0.1	2.64	3.68
		0.3	2.78	3.91
		0.5	2.02	3.14
		0.6	1.78	2.87

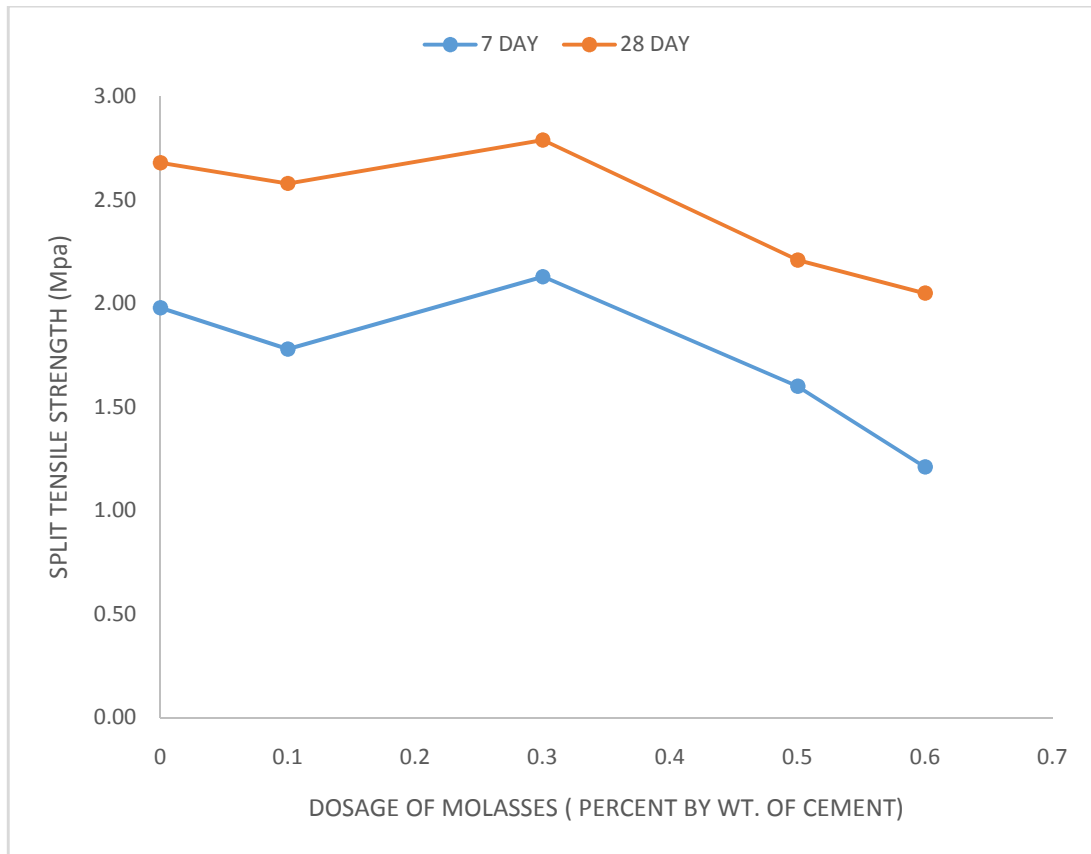


Fig. 5.20 Variation in strength with varying dosage of Molasses for M1 (20MPa)

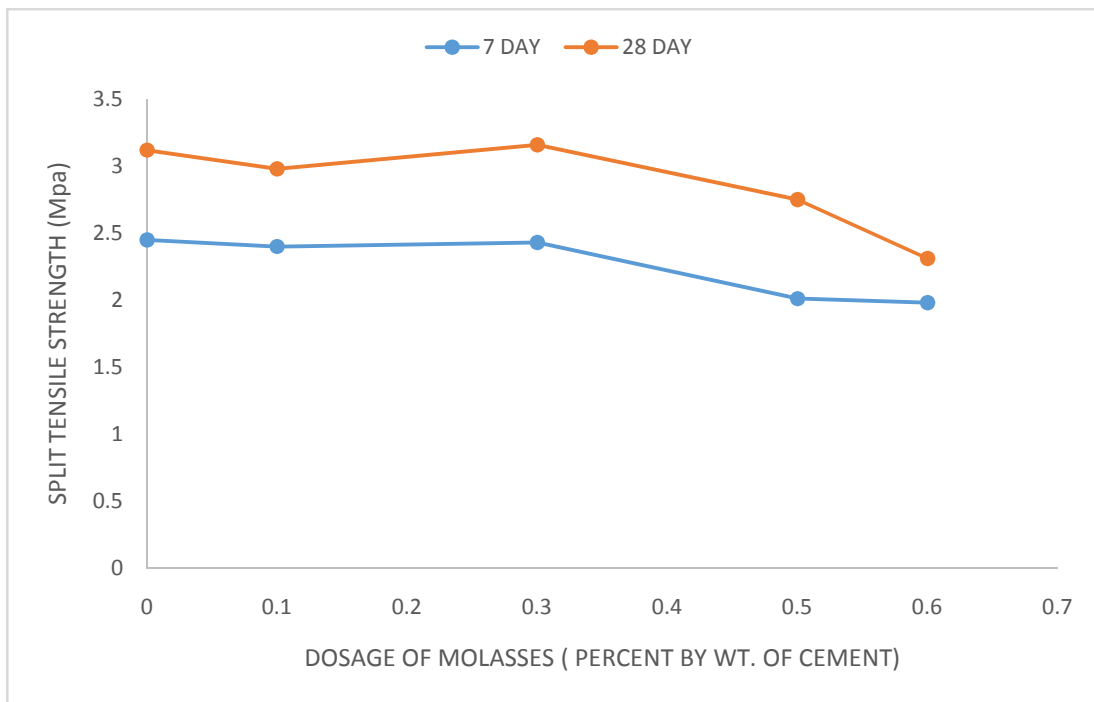


Fig. 5.21 Variation in strength with varying dosage of Molasses for M2 (M 30)

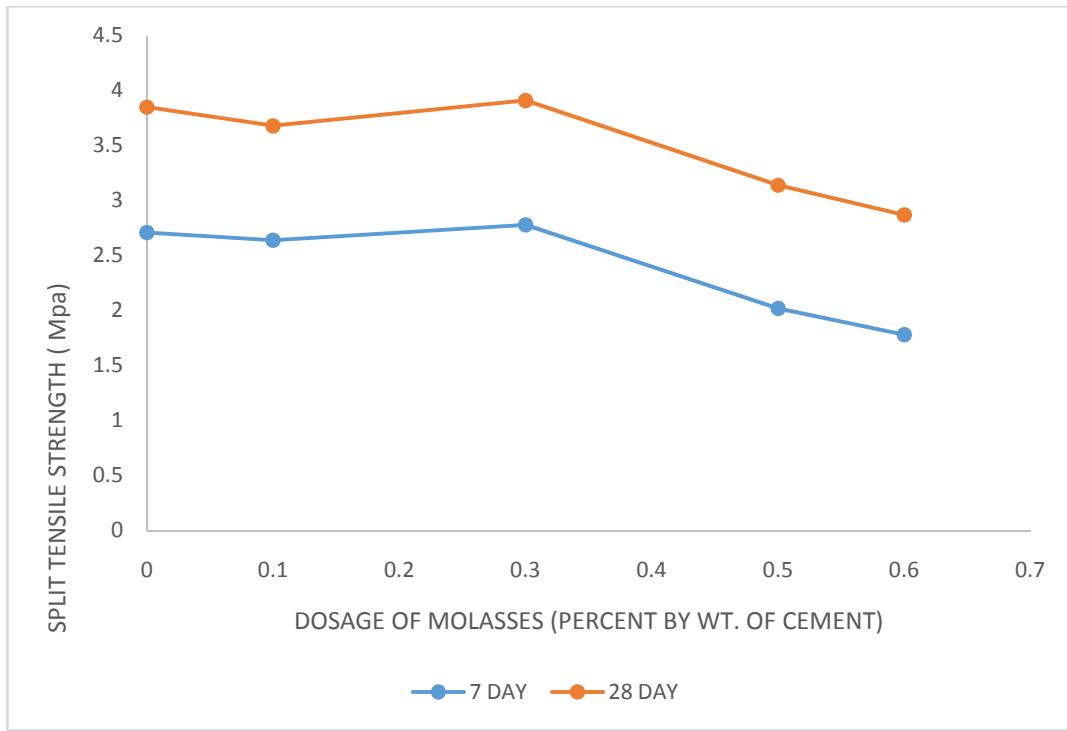


Fig. 5.22 Variation in strength with varying dosage of Molasses for M3 (M35)

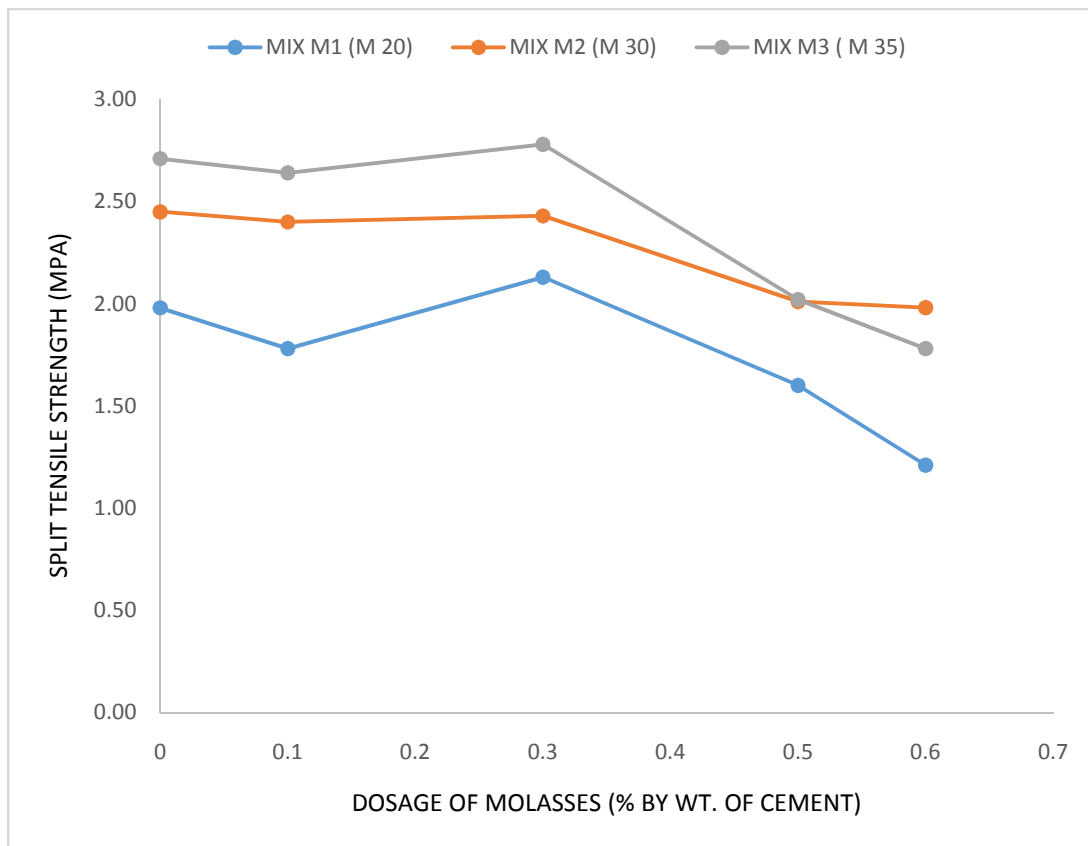


Fig. 5.23 7 day Strength variation with varying dosage of Molasses

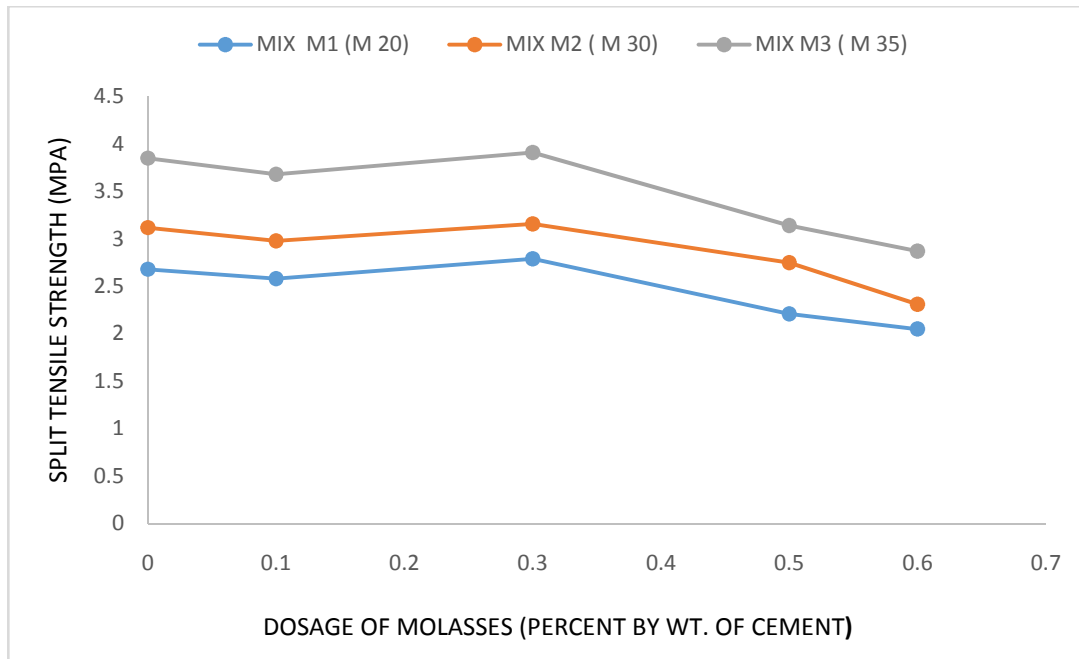


Fig. 5.24 28 day Strength variation with varying dosage of Molasses

The following point may be noted from the result obtained in table 5.9 and plotted on the Figure 5.20 to 5.24:

- The split tensile strength was maximum at 0.30 % dose and after that it decreases with increase in the dosage level of molasses.
- The flexural strength, split tensile strength and the compressive strength shows almost same pattern at 28 days.

5.9. Ultrasonic Guided Wave

Ultrasonic Guided Wave (UGV) readings are taken throughout 48 hrs of setting of concrete at regular time intervals. The ultrasonic measurements are made for concretes of control sample and sample with molasses (M35).

This test was conducted on a beam specimen of size 150 mm x 150 mm x 300 mm with an embedded mild steel rod of 25 mm diameter and 600 mm length (Fig 4.7). First a healthy signature i.e. voltage vs time graph is captured and then compared with results signatures taken at different time intervals. Finally pk-pk voltage is measured and results are plotted as V-T (Voltage vs Time) graphs.

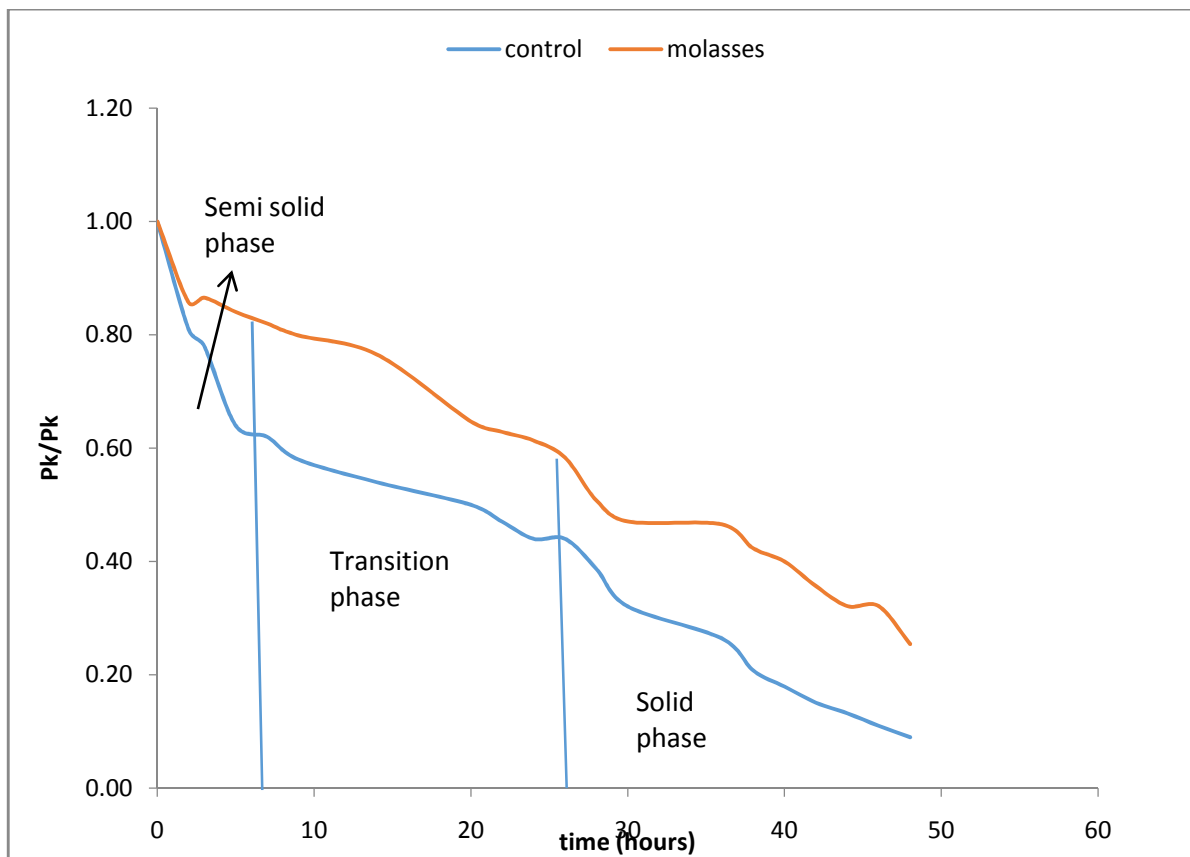


Fig. 5.25 Ultrasonic Guided Waves

- As concrete sets and hardens, Pk-Pk Voltage drops and hence the signature also drops. This is because of the surface seeking nature of the mode selected. This mode picks up the bond development between the reinforcing embedded mild steel and surrounding concrete.
- As the concrete sets, bond develops between steel and surrounding concrete indicating more energy leakage into the surrounding concrete thus causing drop in signal strength. Hence the fall in signal strength is a measure of development of bond and hence setting of concrete.
- It is clear after seeing the UGV result graph that concrete was undergoing through three phases i.e. Semi-Solid, Transition & Solid Phase (Fig 5.25).
- In Semi-solid Phase i.e. first 5 ½ hrs, the concrete is still in semi-liquid phase & there is heavy fall in Pk-Pk voltage while in molasses sample the fall is slight. Thus indicating there is significant difference between the two samples of molasses. In molasses sample, molasses starts to form a dense gel which delays the setting process of cement till 5 ½ hrs when concrete is in semi-solid phase.

- In Transition Phase i.e. 5½ to 25hrs, the concrete is undergoing a change from semisolid to solid state or in other words we can say that the concrete is starting to set or making bond with the embedded mild steel bar. The max fall in Pk-Pk Voltage is observed in this phase in case of control sample and molasses sample. The main difference between the two samples is that the pk-pk voltage is high in case of molasses sample indicating that the gel formed in molasses sample is delaying the setting time of the cement.
- Lastly in Solid Phase i.e. 25hrs to 48 hrs, there is very marginal fall in Pk-Pk voltage in case of both samples indicating the concrete has become almost solid. The main difference is again the pk- pk value of molasses sample which indicates that the action of molasses acts as an admixture is reducing considerably as it is entering solid phase. There is hardly any setting or bonding occurring in this phase which shows that the max setting or bonding occur up to 24 hrs after casting.

CHAPTER 6: CONCLUSIONS AND SCOPE FOR FURTHER RESEARCH

6.1 Conclusions

Based on the experimental results obtained in the present study, the following conclusions can be drawn indicating the effect of molasses on cement, cement mortar and cement concrete at different dosage levels of molasses:

1. The molasses contains about 20 to 25 % of sugar.
2. Molasses acts as accelerating agent at lower dosage level and as retarding agent at higher dosage level. Thus initial setting time and final setting time of cement paste with varying %ages of molasses shows too much variation. Up to 0.5 % dose, it acts as accelerating agent and later at higher %ages of dosage, it acts as a retarding agent.
3. Molasses is a water reducing admixture and is capable of reducing water by 12 % at 5 % molasses by weight of cement.
4. The relationship between dosage levels of the molasses and the %age of water reduction for the same workability is almost linear in the range of 0 to 5 % of dosage levels.
5. The rate of water reduction is different for the different mixes. It is maximum for poor mix and minimum for richer mixes.
6. There was increase in slump value with increase in dosage level of molasses indicating the increase in workability of concrete.
7. For different cement mortar mixes, 7 day compressive strength decreases with an increased level in the dosage. But at 28 day compressive strength of mortar is favourable in the range of 0 to 0.50 % of dose level.
8. For compressive strength, an optimum result for each mix was obtained at 0.30 percent (by weight of cement) dosage level of molasses.
9. From UGV test, it was confirmed that molasses delayed the setting time of the concrete.

6.2 Scope of Further Study

The present investigation had its own limitations. Keeping in view and on the basis of conclusions drawn, the following studies are suggested to supplement the available information.

1. A study to check the validity of the conclusions arrived at in the present investigations within range of variables used and to extend it to cover for wider ranges.
2. Molasses from other sugar mills should be studied for further research.
3. The long term effects on strength and durability of the concrete and mortar with the various levels of molasses can be studied.
4. Dosage level of molasses with various types of cement should be studied.
5. Variation in setting time of cement paste with molasses under different temperature ranges should be studied.

REFERENCES

1. ASTM: Standard C-494-79, "Specifications for chemical Admixtures for Concrete", Philadelphia, U.S.A.
2. BS: 5075 Part-I, 1974, "Water-reducing Admixtures for Concrete", London, U.K.
3. Ganguly K.K., "Superplasticized concrete", National Seminar on special concretes, ICI, Sept.13-14, 1989, Roorkee, India.
4. Honing Pieter, "PRINCIPLES OF Sugar Technology" Volume-III.
5. IS: 10262-1982, "Recommended Guidelines for Concrete Mix Designs", ISI, Mank Bhavan, New Delhi.
6. IS: 1199-1959, "Indian Standard, Methods of sampling and analysis of concrete (Second reprint March 1971)", ISI, Mank Bhavan, New Delhi.
7. IS: 269-1975, "Specification for Ordinary Rapid Hardening and Low heat Portland cement", ISI, Mank Bhavan, New Delhi.
8. IS: 383-1963, "Specification for coarse and fine aggregate from natural sources for concrete", ISI, Mank Bhavan, New Delhi.
9. IS: 4031-1969, "Indian Standard, Methods of Physical tests for Hydraulic Cement", ISI, Mank Bhavan, New Delhi.
10. IS: 456-1978, "Indian Standard, Code of practice for Plain and Reinforced Concrete", ISI, Mank Bhavan, New Delhi.
11. IS: 516-1959, "Method of test for strength of concrete", ISI, Mank Bhavan, New Delhi.
12. IS: 5816-1970, "Method of test for splitting tensile strength of concrete cylinders", ISI, Mank Bhavan, New Delhi.
13. IS: 9103-1979, "Specifications for Admixtures in Concrete", BIS, Manak Bhavan, New Delhi.
14. Kahan, M., "Concretes with increased workability by additions of plasticizers", Rev. Constr. Mater. Contr.21 (1): 33-7 (1976); Rome; CA 68:A42849.
15. Khalil S.M. and Ward M.A., "Influence of a Lignin based admixture on the hydration of Portland cements", Cement and Concrete Research, 3, No. 6, pp 677-88(Nov.1973).
16. LEA F.M., "The chemistry of Cement and concrete", London, Arnold 1970.
17. LEA F.M., "The chemistry of Cement and concrete", Third Edition, Edward Arnold (Publishers) Ltd., London.

18. Lothia, R.P. and Jain, O.P., “ Accelerated curing Techniques of Concrete”, Seminar on Speed and Economy in Building Construction in Defence Services, April 1970, C.M.E. Depodi, Poona, India.
19. Lothia, R.P., “Admixtures for concrete”, Specialist course on concrete Technology, July 1984 at University of Roorkee, India.
20. Lothia, R.P., “The effect of Sugar Solutions on Cement Concrete”, Cement and Concrete, April-June 1972, Vol.12, No. 5 (International). On Speed and Economy in Building Construction in Defence Services, April 1970, C.M.E. Depodi, Poona, India.
21. Lothia, R.P., “The use of Indigenous Admixtures in Cement Concrete”, Cement and Concrete. Jan.-March 1972, Vol. 12, No. 4, pp. 324-337 (International).
22. Malhotra V.M., “New Concretes: Properties, Production and applications proceedings”, Volume -I, International and Exhibition on Modernisation of concrete Construction, January 1982, Madras, India.
23. Mathur Ram BihariLal, “Handbook of cane sugar Technology”, India.
24. Niville A.M., “Properties of Concrete”, ELBS, England.
25. P. Hewlett and R. Rixom, “ Current Practice sheet no. 33-Super-Plasticized Concrete, concrete 10”, No. 9, London, Sept. 1976.
26. Prior M.E. and Adams A.B., “Introduction to Producers”, Papers on Water-Reducing Admixtures and Set-retarding admixtures for concrete, ASTM, SP.Tech. Publcn. No.266, Philadelphia, U.S.A.
27. RangaRoa M.V., “Investigation of Admixtures for High early strength in Concrete”, Indian concrete journal, 50, No. 9, pp. 279-89 (Sept. 1976).
28. RIXOM M.R. and Mailvagnam N.P., “Chemical admixtures for concrete”, E and F.N. Spon Ltd., London 1986, U.K.
29. RIXOM, M.R., “Concrete Admixtures – Use and application”, Lancaster, Construction Press, (1977).
30. SP23 (S and T)-1982,“Handbook on Concrete Mixes”, ISI, Mank Bhavan, New Delhi.
31. Aftab Aalm, Parveen Singh (2016); *Experimental Study on Strength Characteristics of Cement Concrete by Adding Sugar Waste*; International Journal of Enhanced Research in Science, Technology & Engineering ISSN: 2319-7463, Vol. 5 Issue 7, July-2016
32. Amanmyrat Jumadurdiyev, M. Hulusi Ozkul, Ali R. Saglam, Nazmiye Parlaka (2005) *The utilization of beet molasses as a retarding and water-reducing admixture for concrete* Cement and Concrete Research 35 (2005) 874 – 882

33. Giridhar.V, Gnaneswar . K and Kishore Kumar Reddy. P (2013); *Effect of Sugar and Molasses on Strength Properties of Concrete*, The International Journal Of Engineering And Science (IJES),Volume 2, Issue 10, Pages 01-06, 2013, ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805
34. Hasan Yildirim, Baris Altin (2012); *Usage of molasses in concrete as a water reducing and retarding admixture*; Indian Journal of engineering & Material Sciences, Vol. 19,, December 2012, pp. 421- 426.
35. Noorli Ismail, Hamidah Mohd.Saman, Hanis Jelani, Hasyidah Mansor and Mohd Faizal Md Jaafar (2014) *The Studies on the Effect of Molasses in Effective Microbed Cement Paste* International Conference on Agriculture, Environment and Biological Sciences (ICFAE'14) June 4-5, 2014 Antalya (Turkey)
36. Rishabh Kashyap, R.D.Patel (2015); *Studies on Compressive Strength of Cement Concrete by use of Rice Husk Ash with Sugar Molasses Waste*; IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 06, 2015 | ISSN (online): 2321-0613
37. Roar Myrdal (2007) A Report on *Advanced cementing materials SP 1.2 F Controlling hydration development Retarding admixtures for concrete State of the art*, SINTEF Building and Infrastructure COIN – Concrete Innovation Centre
38. S. Karthik, T. Suresh, E. Ashok kumar, N. Bharath kumar, R. Umashankar, K. Muthu kumar (2015). *Experimental Study on Strength and Setting Time of Concrete After Modifying Workability by Using Molasses as Time Retarding and Plasticizing Agent*; Journal of Structural Engineering and Management ISSN: 2393-8773(online)Volume 2, Issue 2 www.stmjournals.com
39. William James Gorman, Victor Vyrodov (2005) *Molasses treatment for the “molassperse” surfactant production for concrete plasticizers (water reducing admixtures) and cement clinker grinding additives applications*; <https://www.google.com/patents/WO2005110941A1?cl=en>

PHOTOGRAPHS



P1- Molasses Sample



P2 – Slump Cone Test for Workability for Fresh Concrete



P3- Casting of Concrete Cubes



P4 – Curing of Specimens



P5 – Mortar Cubes after Casting



P6 – Compression Testing Machine



P7 – Molasses Storage Tank



P8 – Cube for Guided Wave Testing