The Effective Nature of Admixtures on Properties of Concrete

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Abstract - In this study super plasticizers admixtures were used for the three grades of concrete 20, 25 and 35N/mm^2 to improve the properties of fresh and harden concrete in hot weather to achieve these properties in the summer season of Kashmir: Increase the workability, Increase the compressive strength by adoption super plasticizers admixtures which increase the workability and hence the strength is increased through the reduction of water content. Reduce the cement content and hence cost saving.

The experimental work was divided into two phases: Firstly, tests on basic materials (cement, aggregate, sand, water) and the effect of recommended dose of admixture on the properties of fresh and hardened concrete. The results of tests for the basic materials were carried to ensure that their results conforming to their standards and can be used. Secondly, Concrete testing program for the three grades which contain four mixes for each grade. Ordinary reference mix, Same mix with admixture to increase strength, Same mix with admixture to reduce water content and hence increase strength, Same mix with admixture to reduce the cement content keeping same workability and strength.

Keywords*: Admixtures, Concrete, Super Plasticizers, Portland Cement, workability and strength.*

I. INTRODUCTION

Concrete, in the broadest sense, is any product or mass made by the use of cementing medium. Generally, this medium is the product of reaction between hydraulic cement and water. Concrete is made with several types of cement and also containing pozzolana, fly ash, blast furnace slag, etc. The main components of concrete are a mixture of cement, water, aggregate (fine and coarse) and sometimes admixtures. The relation between the constituent of this mixture: Firstly, one can view the cementing medium as the essential building material, with the aggregate fulfilling the role of cheap, Or cheaper diluting. Secondly, one can view the coarse aggregate as assort of mini-

Masonry which is joined together by mortar i.e. by a mixture of hydrated cement and fine aggregate. Thirdly, is to recognize that, concrete consist of two phases hydrated cement paste and aggregate, and, as a result, the properties of concrete are governed by the properties of the two phases and also by the presence of interface between them. In its hardened state concrete is a rock_ like materials with a high compressive strength, by virtue of the ease with which fresh concrete in its plastic state may be molded into virtually any shape it may be used advantages architecturally or solely decorated purposes. Concrete is composed mainly of three materials, namely Cement, water, and aggregate and an additional material, known as an admixture, is sometimes added to modify certain of its properties.

The different cements used for making concrete are finely powder and all have the important property that when mixed with water a chemical reaction (hydration) takes place which in time produce a very hard and strong binding medium for the aggregate particles, in the early stage of hydration, while in its plastic stage, cement mortar gives to the fresh concrete its cohesive properties.

Admixtures are substances introduced into concrete mixes in order to alter or improve the properties of the fresh or hardened concrete or both. In general, these changes are effected through the influence of the admixture on hydration, liberation of heat, formation of pores and the development of the gel structure. Concrete admixtures should only be considered for use when the required modification cannot be made by varying the composition and proportions of the basic constituents' materials, or when the admixtures can produce the required effect more economically. The specific effects of an admixture generally vary with: Type of cement, Cement-water ratio, Ambient conditions (particularly temperature) and its dosage.

Types of admixtures:

Several hundred proprietary admixtures are available and since a great many usually contain several chemicals intend simultaneously to change several properties of concrete.

Of the different types of admixtures, the: Air entraining, Retarders, Water reducing admixtures, Accelerators, Superplasticizers and special admixtures are most commonly used.

1. Air-entraining agents: These are probably the most important group of admixtures. They improve the durability of concrete. The entrainment of air in the form of very small and stable bubble can be achieved by using foaming agents based on natural resins, animals or vegetable fats and synthetic detergent which promote the formation of air bubbles during mixing or by using gas- producing chemicals such as zinc or alumina powder which react with cement to produce gas bubbles. Air entrain agents also improve the workability and cohesiveness of fresh concrete and tend to reduce bleeding and segregation, prevent the loss in strength. The amount of entrained air is dependent on the:

- Type of the cement
- Mix proportions
- Ambient temperature

2. Retarders: Most admixtures in this group are based on lignosulphonate or hydroxylated carboxylic acids and their salts with cellulose or starch. A delay in the setting of the cement paste can be achieved by the addition to the mix of a retarder admixture (ASTM type B), for brevity refer to as a retarder. They are used mainly in hot weather countries where high temperature can reduce the normal setting and hardening time. Slightly reduced water content may be used when using these retarder agents, with corresponding increase in final concrete strength. The lignin's -based retarders results in some air-entrainment and tend to increase cohesiveness and reduce bleeding although drying shrinkage may be increased. The hydroxyl_ carboxylic retarders, however, tend to increase bleeding. In general, they prolong the time during which concrete can be transported, placed, and compacted.

3. Water-reducing admixtures: According to ASTM C 494-92, admixtures which are only water- reducing are called Type A, but if the properties are associated with retardation, the admixture is classified as Type- D. There exist also water-reducing and accelerating admixtures (Type E) but these are of little interest. As their name implies, the function of water reducing admixtures is to reduce the water content of the mix by 5 or 10 per cent, sometimes (in concrete of very high workability) up to 20 per cent. Thus, the purpose of using water reducing admixtures in a concrete mix is to allow a reduction in the water/cement ratio while retaining the desired workability or,

alternatively, to improve its workability at a given
water/cement ratio. Water reducing admixtures improve the properties of fresh concrete made with poorly graded aggregate, e.g. a harsh mix. Concrete containing a water reducing admixture generally exhibits low segregation and good "flow ability". Water reducing admixtures can also be used in pumped concrete or in concrete placed by term. These admixtures are also based on lignosulphonic and hydroxylated - carboxylic acids. Their effect is thought to be due to an increased dispersion of cement particles causing a reduction in the viscosity of the concrete.

4. Accelerating agents: These can be divided into two groups, namely setting accelerators and setting and hardening accelerators. The first of these are alkali solution which can considerably reduce the setting time and are particularly suitable for repair working involve water leakage. Because of their adverse effect on subsequent strength development these admixtures should not be used where the final concrete strength is an important consideration. Setting and hardening accelerators increase the rate of both setting and early strength development. The most common admixtures for this purpose is "$CaCl_2$" which should comply with BS 3587.It may usefully be employed for concrete in winter conditions, for emergency repair work where early removal of formwork is required

5. Superplasticizers: Superplasticizers are admixtures which are water reducing but significantly and distinctly more so than water reducing admixtures. ASTM C494-92 refers to superplasticizers as "water-reducing high range admixtures" Type F admixtures, when the superplasticizers are also retarding they are called Type G admixtures. *There exist four main categories of superplasticizers:*

- Sulfonated melamine-formaldehyde condensates
- Sulfonated naphthalene- formaldehyde condensates
- Modified lignosulfonates
- Others such as sulfonic- acids esters and carbohydrate esters.

The first two are the most common ones, for brevity, they will be referring to as:

- Melamine - based superplasticizers
- Naphthalene-based superplasticizers

The main action of the long molecules is to wrap themselves around the cement particles and give them a high negative charge so that they repel each other. These results in deflocculating and dispersion of cement particles. *The resulting improvement in workability can be exploited in two ways:*

- by producing concrete with a very high workability
- or concrete with a very high strength

At a given water/cement ratio and water content in the mix, the dispersing action of superplasticizers increase the workability of concrete "flowing concrete" and is useful very heavily reinforced sections. The second use of superplasticizers is in the production of concrete of normal workability but with an extremely high strength owing to a very substantial reduction in the water /cement ratio. Most superplasticizers do not produce appreciable set retardation, but there exist also asset-retarding superplasticizers classified by ASTM C 494-92 as Type G. Superplasticizers do not influence shrinkage, creep, modulus of elasticity or resistance to freezing and thawing. They have no effect on the durability of concrete; specifically, durability on exposure to sulfate is unaffected.

6. Special admixtures: There exist also admixtures for other purposes, such as air detrainment, anti -bacteria action, and water proofing, but these are not sufficiently standardized to make reliable generalizations possible.

Moreover, some of the names under which certain admixtures are sold give an exaggerate impression of their performance are:

a) Water proofing admixtures: Water proofing admixtures aims at preventing penetration of water into concrete. Their performance is very much dependent on whether the applied water pressure is low, as in the case of rain or capillary rise, or whether a hydrostatic pressure is applied, as in the case of water retaining structures. Water proofing admixtures may act in several ways but their effect is mainly to concrete hydrophobic. One action of waterproofing admixtures is through reaction with the calcium hydroxide in hydrate cement paste; examples of products are stearic acid and some vegetable and animal fats. The effect is to make the concrete hydrophobic. Another action of water proofing admixtures is through coalescence on contact with the hydrate cement paste which, because of its alkalinity, breaks down the 'waterproofing' emulsion; an example is an emulsion of very finely divided wax. The effect here, too, is to make concrete hydrophobic. The type of waterproofing admixture is in the form of very fine material containing calcium stearate or some hydrocarbon resin or coal tar pitches which produce hydrophobic surfaces. Some waterproofing admixtures, in addition to their hydrophobic action, also effect pore blocking through coalescent component. Aside effect of some water proofing admixtures is to improve the workability of the mix owing to the presence of finely divided wax or bituminous emulsions.

b) Pigments: Colorings pigments are normally used for architectural purposes and the best effect is produced when they are underground with the cement clinker rather than when added during mixing.

c) Pozzolanas: The most commonly used Pozzolanas are pumice and pulverized fuel ash. Because of their reaction with lime, which is liberated during the hydration of cement, these materials can improve the durability of concrete. Since they retard the rate of setting and hardening but have no long term effect on strength, they can be used in mass concrete work.

d) Water-repelling agents: These are the least effective of all admixtures and are based on metallic soaps or vegetable or mineral oils. Their use gives a slight temporary reduction in concrete permeability.

II. PROPERTIES OF FRESH CONCRETE

Fresh concrete is a mixture of water, cement, aggregate and admixture. After mixing, operation such as transporting, placing, compacting and finishing of fresh concrete can all considerably affect the properties of harden concrete. It is important that the constituent materials remain uniformly distributed within the concrete mass during the various stages of its handling and that full compaction is achieved.

The characteristics of fresh concrete which affect full compaction are:

- Consistency.
- Mobility.
- Compatibility.

In concrete practice these are often collectively as workability. The ability of concrete to maintain its uniformity is governed by its stability, which depends on its consistency and its cohesiveness.

III. WORKABILITY

Workability of concrete has never been precisely defined. For practice purposes it generally implies the ease with which concrete mix can be handled from the mixer to its finally compacted shape. The main characteristics of the property are:

Consistency: is a measure of wetness or fluidity.

Mobility: the ease with which a mix can flow into and completely fill the formwork or mould.

IV. TEST RESULTS

A. Preliminary Tests

The results of cement test are shown in table (4.1)

Test	Results	Requirements of BS12 1996
Consistency	30%	
Setting time 1) Initial	1 hrs : 35min	Not less than 60 min (-20 min)
Compressive strength 1) 2 days I. 1 II. 2 III. 3	 25.5 N/mm^2 27.4 N/mm^2 27.5 N/mm^2	Average Equal or greater than 10 N/mm^2(-2 N/mm^2)
2) 28 days I. 1 II. 2 III. 3	 46.4 N/mm^2 45.2 N/mm^2 47.6 N/mm^2	Average Equal or greater than 42.5 N/mm^2 (-2.5 N/mm^2)

Table (4.2) Fine aggregate sieve analysis (Site Lasgen Srinagar, Kashmir)

Sieve size (mm)	Percentage retain	Percentage passing	BS 882 1992
20	0	100	100
06	1.33	97.7	90 - 100
1.36	6.5	94.5	75 - 100
1.18	18.47	80.5	55 - 90
0.6	47	54	35 - 59
0.3	79.5	20.5	8 - 30
0.20	96	4	0 - 10
Total weight	100	0	0

Table (4.3) Coarse aggregate single size (10mm) sieve analyses

Sieve size(mm)	Percentage retain	Percentage passing	BS 882 1992
55	0	100	100

37.5	0	100	100
15	0	100	100
10	0	100	100
14	3.9	96.1	85 - 100
5	79.4	20.6	0 - 25
2.36	100	0	0 - 5

Table (4.4) Coarse aggregate single size (20mm) sieve analyses

Sieve size(mm)	Percentage retain	Percentage passing	BS 882 1992
40	0	100	100
37.5	0	100	100
24	0	100	100
10	35.34	53.7	0 - 70
10	93.58	6.4	0 - 25
5	99.98	.02	0 - 5
2.36	_	_	_

Coarse aggregate crushing value (ACV)

$ACV = M_2/M_1$ 100
Where:
M_1 is the mass of the test specimen (in gm) =21.25gm
M_2 is the mass of the material passing the 2.36mm test sieve (in gm) = 457 gm
ACV = 457/21.25 = 21.5% is satisfactory because < 25% according to BS 812: Part 110:1990.

Table (4.19): Results of cubes compressive strength Grade35

Mix specification	slump (mm)	Age (days)	Mean strength (N/mm^2)
(RM) Reference mix	60	7	38.74
		14	43.74
		28	46.96
		90	47.70
(WrM) same mix with admixture to increase workability	160	7	42.37
		14	46.67
		28	49.85
		90	53.48

(StM) Mix with admixture and same workability to increase strength	50	7	46.89
		14	52.63
		28	56.20
		90	61.11
(CrM) Mix with admixture to reduce cement content keeping	60	7	37.85
		14	42.07
		28	44.20
		90	52.89

Figure (4.3) compressive strength development for different mixes grade35

Table (4.20) Results of flexure strength grade20 : Reference mix (RM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm²)	Mean strength (N/mm²)
22/01/2018	19/02/2018	28		13.14	6.57	6.11
22/01/2018	19/02/2018	28		10.38	5.19	
22/01/2018	19/02/2018	28		13.14	6.57	

Table (4.21) Results of splitting strength grade 20: Reference mix (RM)

Date of cast	Date of test	Age	Weight	Load	Splitting strength	Mean strength (N/mm²)
22/01/2018	19/02/201	28	14.24	209.10	2.96	2.91
22/01/2018	19/02/201	28	14.12	198.00	2.80	
22/01/2018	19/02/201	28	14.20	209.35	2.96	

Table (4.22) Results of flexure strength grade 20: Mix with admixture to improve workability (WrM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm²)	Mean strength (N/mm²)
05/02/2018	03/03/2018	28		10.14	5.07	5.38
05/02/2018	03/03/2018	28		11.30	5.65	
05/02/2018	03/03/2018	28		10.84	5.42	

Table (4.23) Results of splitting strength grade 20: Mix with admixture to improve workability (WrM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Splitting strength N/mm^2	Mean strength N/mm^2
05/02/2018	03/03/2018	28	14.41	190	2.69	2.69
05/02/2018	03/03/2018	28	14.36	185	2.62	
05/02/2018	03/03/2018	28	14.34	194	2.75	

Table (4.24) Results of flexure strength grade 20: Mix with admixture to increase strength(StM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm^2)	Mean strength (N/mm^2)
19/02/2018	17/03/2018	28		11.53	5.77	6.65
19/02/2018	17/03/2018	28		14.75	7.38	
19/02/2018	17/03/2018	28		13.61	6.81	

Table (4.25) Results of splitting strength grade 20: Mix with admixture To increase strength (StM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Splitting strength (N/mm^2)	Mean strength (N/mm^2)
19/02/2018	17/03/2018	28	14.45	245.00	3.47	3.41
19/02/2018	17/03/2018	28	14.38	236.35	3.35	
19/02/2018	17/03/2018	28	14.52	241.35	3.42	

Table (4.26) Results of flexure strength grade 20: Mix with admixture to reduce cement content (CrM)

Date of cast	Date of test	Ag	Weight	Load kn	Flexural strength	Mean strength (N/mm^2)
24/02/201	21/03/201	28		13.84	6.92	5.92
24/02/201	21/03/201	28		10.38	5.19	
24/02/201	21/03/201	28		11.30	5.65	

Table (4.27) Results of splitting strength grade 20: Mix with admixture To reduce cement content (CrM)

Date of cast	Date of test	Ages (Days	Weight (Kg)	Load (KN)	Splitting strength (N/mm^2)	Mean strength (N/mm^2)
24/02/2018	21/03/2018	28	14.60	146.00	2.07	2.11
24/02/2018	21/03/2018	28	13.11	138.00	1.95	
24/02/2018	21/03/2018	28	14.20	163.00	2.31	

Table (4.28): Results of tensile strength for grade 20 @28dayes

Mix Cell				
Test specification	Ref mix	Mix to increase workability	Mix to increase strength	Mix to reduce cement content
Flexure strength N/mm^2	6.11	5.38	6.65	5.92
Splitting strength N/mm^2	2.91	2.68	3.41	2.11

Table (4.29) Results of flexure strength grade 25 :Reference mix (RM)

Date of cast	Date of test	Age (days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm^2)	Mean strength
21/02/2018	18/03/2018	28		13.83	6.92	7.19
21/02/2018	18/03/2018	28		16.14	8.07	
21/02/2018	18/03/2018	28		13.14	6.57	

Table(4.30) Results of splitting strength grade 25 :Reference mix (RM)

Date of cast	Date of test	Age (days)	Weight (Kg)	Load (KN)	Splitting strength (N/mm^2)	Mean strength (N/mm^2)
21/02/2018	18/03/201	28	14.24	167.8	2.38	2.35
21/02/2018	18/03/201	28	14.12	173.0	2.45	
21/02/2018	18/03/201	28	14.20	169.0	2.39	

Table(4.31) Results of flexure strength grade 25 : Mix with admixture to improve workability (WrM)

Date of cast	Date of test	Age (days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm^2)	Mean strength (N/mm^2)
22/01/2018	19/02/2018	28		12.68	6.34	6.26
22/01/2018	19/02/2018	28		12.68	6.34	
22/01/2018	19/02/2018	28		12.22	6.11	

Table (4.32) Results of splitting strength grade 25: Mix with admixture to improve workability (WrM)

Date of cast	Date of test	Age (days)	Weight (Kg)	Load (KN)	Splitting strength (N/mm^2)	Mean strength (N/mm^2)
22/01/2018	19/02/2018	28	14.24	164	2.32	2.33
22/01/2018	19/02/2018	28	14.12	201	2.13	
22/01/2018	19/02/2018	28	14.20	180	2.54	

Table (4.33) Results of flexure strength grade 25: Mix with admixture to increase strength(StM)

Date of cast	Date of test	Age (days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm^2)	Mean strength (N/mm^2)
20/02/2018	13/03/2018	28		20.91	7.95	8.34
20/02/2018	13/03/2018	28		17.06	8.53	
20/02/2018	13/03/2018	28		17.06	8.53	

Table(4.34) Results of splitting strength grade 25 : Mix with admixture To increase strength (StM)

Date of cast	Date of test	Age (days)	weight (kg)	Load (KN)	Splitting strength (N/mm^2)	Mean strength (N/mm^2)
20/02/2018	13/03/2018	28	14.44	295.80	4.18	3.86
20/02/2018	13/03/2018	28	14.48	244.90	3.46	
20/02/2018	13/03/2018	28	14.70	277.60	3.92	

Table(4.35) Results of flexure strength grade 25 : Mix with admixture to reduce cement content (CrM)

Date of cast	Date of test	ages (days)	weight (Kg)	Load (KN)	Flexural strength (N/mm^2)	Mean strength (N/mm^2)
03/02/2018	31/03/2018	28		13.84	7.95	8.33

Table(4.36) Results of splitting strength grade 25 : Mix with admixture To reduce cement content (CrM)

V. DISCUSSION

I. *Preliminary results and observation:*

Tests for basic materials were done to ensure that the main constituents of concrete (cement, aggregate, admixture) are adequate and satisfying the requirement of the standards.

(a) Cement:

The results of testing cement for:

- Consistency
- Initial and final setting time
- Compressive strength

Were done and shown in Table (4.1) and all results are adequate and conforming with BS12 1996 specifications.

(b) Aggregate:

Sieve analysis was done according to BS 882 1992, results for both fine and coarse aggregate were presented in Table(4.2) for fine aggregate and Table(4.3)&Table(4.4) coarse aggregate single size 10&20mm , and they are all conform with the requirements.

Aggregate crushing value is also done to determine the crushing strength of aggregate and it gave ACV 21.5% which is satisfactory.

(c) Admixture:

The admixture used for this study was high performance superplasticising admixture *(conplast sp432ms*) which is used after determining its effects on concrete mixes for the three grades by doing trials mixes for each grade, also under the conditions of use given by the manufacturer before using it with the concrete mixes.

Ordinary reference mix was designed for each grade with medium workability which gave slump lies in the range of medium workability. In the admixture mixes where the main purpose is to increase strength the quantities of cement and aggregate were kept constant while the quantity of water was adjusted to ensure increase in the compressive strength for each grade.

The doses of the admixture were determined according to the manufacturer guidance and by doing trials mixes taken into account the cost of the admixture to save cost.

In the admixture mixes where the main purpose is to reduce cement content the quantity of aggregate was kept constant while the quantities of water and cement was adjusted so as to maintain

- Slump in the range of medium workability.
- Compressive strength not to be reduced.
- Same w/c ratio.

4-3-2 Workability

Slump test have been used as a measure of workability for the four mixes for each grade and the results are as follow:

Grade 20

Mix type	(RM)	(WrM)	(StM)	(CrM)
SLUMP/mm	55	160	60	50

Grade 25

Mix type	(RM)	(WrM)	(StM)	(CrM)
SLUMP/mm	60	185	35	80

Grade 35

Mix type	(RM)	(WrM)	(StM)	(CrM)
SLUMP/mm	60	160	50	60

For the three grades the observation on slump are as follow:

- The observed workability of mixes containing admixture (WrM) (reference mix with admixture to increase workability) was much higher than that of the ordinary reference mixes satisfying the first object of the research to increase workability.
- As a result the concrete workability has been increased without adding water to the mix keeping same strength.
- The amount of mixing water can be reduced when using admixture with concrete mixes designed for a given workability to improve specific properties (StM) & (CrM).

4-3-3 Compressive strength

Compressive strength results for the three grades (20, 25, and 35) were obtained from the average of three cubes under the normal laboratory temperature and same curing conditions for 7, 14, 28 and 90 days.
The ratio between the mixes containing admixtures and the reference mix are shown bellow for each grade.
Table (4.47): Grade 20:
Crushing strength of concrete containing
Admixtures as compared to ordinary concrete

	Strength as percentage of reference mix			
Ages/days Mix type	7	14	28	90
(WrM)	106	116	121	133
(StM)	128	131	129	133
(CrM)	82	90	93	100

Table (4.48): Grade 25:
Crushing strength of concrete containing
Admixtures as compared to ordinary concrete

	Strength as percentage of reference mix			
Ages/da ys	7	14	28	90
(WrM)	133	128	127	123
(StM)	205	142	132	126
(CrM)	90	93	95	102

Table (4.49): Grade 35:
Crushing strength of concrete containing
Admixtures as compared to ordinary concrete

	Strength as percentage of reference mix			
Ages/da ys	7	14	28	90
(WrM)	109	107	106	112
(StM)	121	120	119	128
(CrM)	98	96	94	110

- For the three grades increased ratio of strength in mixes (WrM) was in the range of :
  - a) (6 - 23) % for grade 20.
  - b) (23 – 33) % for grade 25.
  - c) (9 - 12) % for grade 35.

• For the three grades increased ratio of strength in mixes (StM) was in the range of:
a) (28 - 33) % for grade 20.
b) (32 - 55) % for grade 25.
c) (19 - 28) % for grade 35.

• For the three grades ratio of strength in mixes (CrM) was in the range of :
a) (.8 - .92)% for grade 20.
b) (.9 - .95) % for grade 25.
c) (.94 - 10) % for grade 35.

The higher rate of increased strength was in (StM) which is the main scope of the research and is higher in grade 25 then grade 20 and last grade 35 because of the difference doses of the admixture.

There is an increased rate of strength in mixes type (WrM) which is good because the scope of this mixes is to increase the workability and this is also an additional benefit. In mixes type (CrM) there is slight reduction in the compressive strength comparing with reference mixes but not less than the designed strength for each grade and this is because the amount of reduced cement which is equal to 23% for the three mixes and this can be avoided by reducing the reduction ratio.

4-3-4 Flexural strength:

Flexural strength tests are indirect tests to determine the tensile strength of concrete; tests were carried out on (100 x 100 x 500mm) beams loaded at third point.

The theoretical maximum tensile stress reached at the bottom fibres of the tested beam is known as the modulus of rupture, the results are presented in tables showed that:

I.Grade 20

An increase of about 8% for mix (StM) from the reference mixes while the other mixes were less than the reference mix and this is showed in fig (4.4).

II.Grade 25:

(StM) and (CrM) mixes gave approximately equal results, and they were increased about 16% from the reference mix, while (WrM) have a reduction of about 13% from the reference mix and this is shown in fig (4.6).

III. Grade 35:

An increase of about 11% for mix (StM) from the reference mix, where (WrM) and (CrM) had a reduction ratio of about 1% and 32% respectively shown in fig (4.8).

4-2-5 Tensile splitting strength:

Testes were made on (20 x 30) cylinders for the four concrete mixes of each grade and the observations are as follow:

I.Grade 20:

An increase of about 17% for (StM) mix compared with reference mix while (WrM) and (CrM) have a decrease of about 8% and 37% respectively from the reference mix shown in fig (4.5).

II. Grade 25:

(StM) and (CrM) mixes gave approximately equal results, and they were increased about 60% from the reference mix, while (WrM) have a reduction of about 3% from the reference mix and this is shown in fig (4.7).

III.Grade 35:

(WrM), (StM) and (CrM) mixes gave an increase of about 3%, 16% and 12% respectively from the reference mix, and this is shown in Fig (4.9).

4-3-5 Cement reduction and Cost saving

For the three grades of concrete mixes (20,25, and 35) cement content was reduced up to 23.3% without reducing compressive strength and no effect on workability should be noticed.

The doses of super plasticizer admixture (*conplast 432 ms*) added to the three mixes was (1.5lt/100kg cementious material) for grade (20&25) and (2lt/100kg cemntious material) for grade 35 .

Table (4.50) illustrate the percentage of cost saving of the (difference between the cost of the reduced cement and the cost of super plasticizer admixture) to the total cost of the cement content per cubic meter for each grade.

Table (4.50)

The percentage of cost saving of the reduced cement

Total cost per cubic meter of cement	Cost of reduced cement per cubic meter (SDG)	Cost of super plasticizer admixture per cubic meter (SDG)	Percentage saved of the reduced cement
20	37	22.5	8.9%
25	44.5	27	8.9%
35	56	45	4.5%

- The cost of super plasticizer admixture (*conplast 432 ms*) depending on the price of one litre equal to 5 SDG.
- The cost of the cement depending on the price of one kg equal to 0.53 SDG.

The percentage saved of the reduced cement per m^3 = $\frac{\text{(cost of reduced cement- cost of admixture)}}{\text{(Cost of the total cement content)}}$

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