The Effect of Admixtures on Concrete Properties

A thesis submitted to the University of Khartoum in partial fulfillment of the requirements for the degree of M.Sc in (Structural Engineering)

By

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Abstract

In this study super plasticizers admixtures were used for the three grades of concrete 15, 25 and 40N/mm^2 to improve the properties of fresh and harden concrete in hot weather to achieve these properties in the summer season of Sudan:

- 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:

1. 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.

2. 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.

The results of the second phase for the three grades indicate that admixtures can be used to:

- Increase the workability of the concrete for the three grades by:

  Slump from 55 to 160 for grade 15.
  Slump from 60 to 200 for grade 25.
  Slump from 60 to 160 for grade 40.
- Increase the compressive strength of the three grades at 28 days by:
  (28 – 33)% for grade15.
  (32 – 55)% for grade 25.
  (19 – 28)% for grade 40.
- Reduce the cement content by 23% compared with reference mixes without reducing the compressive strength and keeping same (w/c).

الخلاصة

تم في هذه الدراسة استخدام الإضافات الخراسانية (الملدنات الفائقة) إلي الخرسانة بدرجاتها الثلاثة (15, 25 و 40 نيوتن ملم$^{-2}$) وذلك للأستفاده من تحسينها لخواص الخرسانة الطازجة والمتصلدة في الأجواء الحارة بتحقيق الخواص التالية في فصل الصيف في السودان:

- زيادة قابلية التشغيل
- زيادة مقاومة الضغط بتخفيض كمية الماء وإضافة الملدنات الفائقة إليها للاحتفاظ بالتشغيلية وزيادة المقاومة
- نقصان كمية الأسمنت المستخدم وذلك لتخفيض التكلفة

تم تقسيم برنامج الاختبارات إلي قسين:

أولا: الاختبارات ألأولية علي المواد ألأساسية المستخدمة(ألأسمنت,الركام الناعم,الركام الخشن والماء) واختيار الجرعة المناسبة من ألإضافات (حسب مدي الجرعة المحددة من المصنع) وذلك للتأكد من ان نتائجها تتوافق مع مواصفاتها القياسية.

ثانيا: تم عمل برنامج الاختبارات الخراسانية للثلاثة درجات من الخرسانة وذلك بعمل أربعة خلطات خراسانية لكل درجة خراسانية وهى:

- الخلطة المرجعية
- الخلطة المرجعية مع استخدام الإضافات لزيادة قابلية التشغيل
- الخلطة المرجعية مع استخدام الإضافات وتقليل كمية الماء لزيادة مقاومة الضغط
- الخلطة المرجعية مع استخدام الإضافات والاحتفاظ بالتشغيلية لنقصان كمية الأسمنت

نتائج برنامج الاختبارات في القسم الثاني تشير إلى انه يمكن استخدام الإضافات الخراسانية للحصول علي:

- زيادة قابلية التشغيل (الهبوط) للثلاثة درجات من الخرسانة بالأتي:
  الهبوط من 55 ملم إلي 160ملم لدرجة 15
  الهبوط من 60 ملم إلي 200ملم لدرجة 25
  الهبوط من 60 ملم إلي 160 ملم لدرجة 40

- زيادة مقاومة الضغط للثلاثة درجات من الخرسانة في عمر 28 يوم بالأتي:
  (28 إلي 33) % لخرسانة درجة 15
  (32 إلي 55) % لخرسانة درجة 25
  (19 إلي 28) % لخرسانة درجة 40

- نقصان كمية الأسمنت المستخدم بنسبة لا تقل عن 23% بالمقارنة مع الخلطة المرجعية للثلاثة درجات من الخرسانة بدون نقصان مقاومة الضغط مع الاحتفاظ بنسبة الماء إلي الأسمنت كما هي.

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CHAPTER ONE

INTRODUCTION

INTRODUCTION

1.1 Concrete Constituents and Properties

1.1.1 General

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, blastfurnace 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 moulded 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.

Concrete as a construction material has the following advantages:

1. concrete is economical in the long run as compared to other engineering materials, except cement , it can be made from locally available coarse and fine aggregate.
2. Concrete possesses a high compressive strength, and the corrosive and weathering effects are minimum. When properly prepared its strength is equal to that of a hard natural stone.
3. The green concrete can be easily handle and moulded into any shape or size according to specification.
4. It is strong in compression and has unlimited structural applications in combination with steel reinforcement, the concrete and steel have approximately equal coefficients of thermal expansion. The concrete is extensively used in the construction of foundations, walls roads, airfields, buildings, water retaining structures, docks and harbours, dams' bridges, silos, etc.
5. Concrete can even be sprayed on and filled into fine cracks for repairs by the guniting process.
6. The concrete can be pumped and hence it can be laid in the difficult positions also.
7. It is durable and fire resistance and requires very little maintenance.

The disadvantages of concrete can be as follow:

1. Concrete has low tensile strength and hence cracks easily. Therefore it is to be reinforced with the steel bars or meshes
2. Fresh concrete shrink on drying, and hardened concrete expands on wetting.
3. Concrete under sustained loading undergoes creep resulting in reduction of prestress of the prestressed concrete construction.
4. Concrete is liable to disintegrate by alkali and sulphate attack.
5. The lack of ductility inherent in concrete is disadvantages with respect to earthquake resistance.

1.1.2 Cement

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.

The different types of cement and the related British standards in which certain physical and chemical requirement are specified are given in Table (1.1).

Table (1.1)

Main Types of Portland cement

Traditional British description	ASTM description
Ordinary Portland	Type 1
Rapid hardening Portland	Type 111
Extra rapid –hardening Portland	
Ultra high early strength Portland	Regulated set
Low heat Portland	Type IV
Modified cement	Type II
Sulphate-resisting Portland	Type V
Portland blastfurnace	Type I (SM)
White Portland	-
Portland - pozzolana	Type IP &Type I (SM)
Slag cement	Type S

Of these, ordinary Portland cement is the most widely used; the others being used where concrete with especial properties are required.

Types of Portland cements

1. Ordinary Portland cement

Ordinary Portland (Type 1) cement is admirably suitable for use in general concrete construction when there is no exposure to sulphates in the soil or groundwater.

British standards BS 12:1991classifies Portland cements according to their compressive strength as shown in Table (1.2).

Table (1.2)

Compressive strength requirements of cements according to BS 12:1991

class	Minimum strength, MPa At the age of			Maximum strength MPa, at the age 28dayes
	2 days	7 days	28 days	
32.5 N 32.5 R	- 10	16 -	32.5	52.5
42.5 N 42.5 R	10 20	- -	42.5	62.5
52.5 N	20	-	52.5	-
62.5 N	20	-	62.5	-

The 28 days minimum strength in MPa gives the name of the classes, moreover, cement of class32.5 and 42.5 are each subdivided into two subclasses, one with an ordinary early strength, and the other with a high early strength.

The two subclasses with a high early strength, denoted by the letter R, are rapid hardening cements.

2. Rapid-hardening Portland cement

This cement comprises Portland cement subclasses of 32.5 and 42.5 MPa as prescribed by BS 12:1991.rapid hardening Portland cement (Type 111), as its name implies, develops strength more rapidly, and should, therefore, be correctly describe as high early strength cement.

The use of it is indicated where a rapid strength development is desired, e.g. when the formwork is to be removed early for re-use, or where sufficient strength for further construction is wanted quickly as practicable.

Rapid-hardening Portland cement should not be used in mass construction or in a large structural section.

3. Low heat Portland cement

Cement having such a low rate of heat development was first produced for use in large gravity dams in the United States, and is known as low heat Portland cement (Type IV).

This cement has a low heat of hydration accompanied by a much slower rate of increase in strength than for ordinary cement, although its final strength is similar and its resistance to a chemical attack is greater than that of Portland cement.

4. Sulphate resisting Portland cement

Except for its high resistance to sulphate attack, have principal properties similar to those of ordinary Portland cement.

Calcium chloride should not be used with this cement as it reduces its resistance to sulphate attack.

5. White and coloured Portland cements

Are similar in basic properties to ordinary Portland cement White cement required special manufacturing methods, using raw materials containing less than 1 per cent iron oxide.

Coloured cements are produced by intergrinding a chemically pigment with ordinary clinker.

Because of its inert characteristics, the presence of a pigment slightly reduces the concrete strength.

These cements are used for architectural purposes.

6. **Slag cements**

Different types of slag cements can be produced by intergrinding varying portions of granulated blastfurnace slag with activators such as ordinary Portland cement and gypsum.

The chemical composition of the granulated slag is similar to that of Portland cement but the properties are different.

One general requirement that the slag used must have high lime content.

7. **Portland blastfurnace cement**

   It is produced by mixing up to 65 per cent granulated blastfurnace slag with ordinary Portland cement.
   The basic characteristics are similar to those of ordinary Portland cement although the rate of hydration is lower.
   It is particularly suited for structures involving large masses of concrete. Its resistance to chemical attack, particularly seawater, is somewhat better than that of ordinary Portland cement

8. **High-alumina cement**

This cement, which is manufactured by melting a mixture of limestone, chalk and bauxite (aluminium ore) at about 1450 C and then the cold mass, has different composition and properties from those of Portland cements.

The high proportion of alumina, about 40 per cent, brings about a very high early strength and consequently it often becomes necessary to keep concrete, in which this cement is used, continuously wet for at least 24 hours to avoid damage from the associated heat of hydration.

The cement can be beneficially employed for concreting in winter conditions. It has a wide application in refractory concrete.

Manufacture

Cement is prepared by first intimately grinding and mixing the raw constituents in certain proportions, burning this mixture at Avery high temperature to produce clinker, and then grinding it into powder form. Since the clinker is formed by diffusion between the solid particles, intimate mixing of the ingredients is essential if uniform cement is to produced. This mixing may be in dry or wet state depending on the hardness of the available rock.

The wet process is used in general, for the softer materials such as chalks or clay. Water is added to the proportioned mixture of crush chalk and clay to produce slurry which is eventually led off to a kiln. This is steel cylinder, with a refractory lining, which is slightly inclined to the horizontal and rotates continuously about its own axis. It is usually fired by pulverised coal, although or oil may also be used .it may be as large as 3.5 m in diameter and 150m long and handle up to 700 t of cement in a day.

The slurry is fed in at the upper end of the kiln and the clinker is discharge at the lower end where fuel is injected. With its temperature increasing progressively, the slurry undergoes a number of changes as it travels down the kiln. At 100 C the water is driven off, at about 850 C carbon dioxide is given off and at about 1400 c incipient fusion takes place in the firing zone where calcium silicate and calcium aluminates are formed in the resulting clinker. The clinker is allowed to cool and then ground, with 1 to 5 per cent gypsum, to the required fineness.

Different types of Portland cements are obtained by varying the proportions of the raw materials, the temperatures of burning and the fineness of grinding. Gypsum is added to control the setting of the cement, which would otherwise set much too quickly for general use.

Certain additives may also be introduced for producing special cements; e .g. calcium chloride is added in the manufacture of extra rapid hardening cement.

The dry or semi-dry process is used for the harder rocks such as limestone and shale and shale. The constituent materials are crushed into powder form, and with a minimum amount of water, passed into an inclined rotate nodulising pan where nodules are formed. These are known as *raw meal*. This is fed into a kiln and thereafter the manufacturing process is similar to the wet process although much shorter length of kiln is used.

The grinding of the clinker produces a cement powder which is still hot and this hot cement is usually allowed to cool before it leaves the cement works.

Basic characteristic of Portland cement

Differences in the behaviour of the various Portland cements are determined by their chemical composition and fineness. The effect of theses on the physical properties of cement mortar and concrete are considered here.

A. Chemical composition

As a result of the chemical of the chemical changes which take place within the kiln several compounds are formed in the resulting cement although only four are generally considered to be important (see Table 1.3).

Table (1.3)

Main chemical compounds of Portland cements

Name of compounds	**Chemical composition**	**Usual abbreviation**
Tricalcium silicate	$3\ CaO.SiO_2$	C_3S
Dicalcium silicate	$2\ CaO.SiO_2$	C_2S
Tricalcium aluminates	$3CaO.Al_2O_3$	C_3A
Tetra calcium aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF

The two silicates C_3S and C_2S which are the most stable of these compounds, together from 70 to 80 per cent of the constituents in the cement and contribute most to the physical properties of concrete.

When cement comes into contact with water, C_3S beings to hydrate rapidly, generating a considerable amount of heat and making a significant contribution to the development of the early strength, particularly during the first 14 days. In contrast C2S which hydrate slowly and is mainly responsible for the development in strength after about 7 days may be active for a considerable period of time.

It is generally believed that cements riche in C_2S result in a greater resistance to chemical attack and smaller drying shrinkage than do other Portland cements.

The hydration of C3A is extremely exothermic and takes place very quickly, producing a little increase in the strength after 24 hrs.

C_3A, is the least stable and cement containing more than 10 per cent of this compound produces concrete which particularly susceptible to sulphate attack.

Tetra calcium aluminoferrite, C_4AF, is of less importance than the other three compounds when considering the properties of hardened cement mortars or concrete.

B. Fineness

The reaction between the water and cement starts on the surface of the cement particles and in consequence the grater the surface area of a given volume of cement the greater the hydration.

It follows that for a given composition; affine cement will develop strength and generate heat more quickly than coarse cement.

Fine cements, in general, improve the cohesiveness of fresh concrete and can be effective in reducing the risk of bleeding, but they increase the tendency for shrinkage cracking.

Several methods are available for measuring the fineness of cement, e.g. BS 12 prescribes a permeable method which is a measure of the resistance of a layer of cement to the passage of air.

The measured fineness is an over –all value known as specific surface and is expressed in square centimetres per gram.

C. **Hydration**

The chemical combination of cement and water, known as hydration, produces a very hard and strong binding medium, for the aggregate particles in concrete and is accompanied by the liberation of heat, normally expressed as calories per gram.

The rate of hydration depends on the relative properties of silicate and aluminates compounds, the cement fineness and the ambient conditions.

Factors affecting the rate of hydration have a similar affect on the liberation of heat.

Concrete is poor conductor of heat and the heat generated during hydration can have undesirable effects on the properties of the hardened concrete as a result of micro cracking on the binding medium .

The possible advantages associated with the increased rate of hydration may in the circumstances be outweighed by the loss in durability of the concrete resulting from the micro cracking. The heat characteristic must be considered when determining the suitability of cement for a given job.

D. Setting and hardening

Setting and hardening of the cement paste are the main physical characteristics associated with the hydration of the cement.

Hydration results in the formation of a gel around each of the cement particle and in time these layers of gel grow to the extent that they come into contact with each other.

At this stage the cement paste being to loss its fluidity. The begging of noticeable stiffening in the cement paste is known as the *initial* setting. Further stiffening occurs as the volume as the volume of gel increases and the stage at which this is complete and the final hardening process, responsible for its strength, commences is known as the *final* set. The time from the addition of the water to the initial and final set are known as the setting times.

Setting time is affected by cement composition and fineness, and also, through its influence on the rate of hydration, by the ambient temperature.

Two further phenomena are *flash set* and a *false set*.

A false set also produces a rapid stiffening of the paste but is not accompanied by excessive heat. In this case remixing the paste without further addition of water causes it to regain its plasticity and its subsequent setting and hardening characteristics are quiet normal. False set is thought to be the result of intergrinding gypsum with very hot clinker in the final stage in the manufacture of cement.

E. Soundness

An excessive change in volume, particularly expansion of cement paste after setting indicates that the cement is unsound and not suitable for the manufacture of concrete.

In general, the effects of using unsound cement may not be apparent for some considerable period of time, but usually manifest themselves in cracking and disintegration of the surface of concrete.

1.1.3 Aggregate

Aggregate is much cheaper than cement and maximum economy is obtained by using much aggregate as possible in concrete. It’s also considerably improves both the volume and the durability of the resulting concrete.

Natural aggregate are formed by the process of weathering and abrasion, or by artificially crushing a large parent mass.

Basic characteristics of aggregate

The criterion for a good aggregate is that it should produce the desired properties in both the fresh and hardened concrete.

A. Physical properties

The properties of the aggregate known to have a significant effect on concrete behaviour are:

1. Strength

The strength of an aggregate limits the attainable strength of concrete only when its compressive strength is less than or of the same order as the design strength of concrete. In practice the majority of rock aggregates used are usually considerably stronger than concrete. While the strength does not normally exceed 80 N/mm^2 and is generally between 30 to 50 N/mm^2 the strength of aggregate commonly used is in the range 70 to 350 N/mm^2.

In general 1gnious rocks are very much stronger than sedimentary and metamorphic rocks. Because of irregular size and shape of aggregate particles a direct measurement of their strength properties is not possible.

These are normally assessed from compressive strength tests on cylindrical specimen taken from the parent rock and from crushing value tests on the bulk aggregate. For weaker material, that is, those with crushing values greater than 30, the crushing value may be unreliable and the load required to produce 10 per cent fines in the crushing value test should be used.

2. Deformation

The deformation characteristic of an aggregate are seldom considered in assessing its suitability for concrete work although they can easily

Be determined from compression tests on specimens from the parent rock.

In general, the modulus of elasticity of concrete increases with increasing aggregate modulus. The deformation characteristics of the aggregate also play an important part in the creep and shrinkage properties of concrete as the restraint afforded by the aggregate to the creep and shrinkage of the cement paste depends on their relative modulus of elasticity.

3. Toughness

Is its resistance to failure by impact and this is normally determined from the aggregate impact test (BS 812). Since the apparatus is portable, cheap, simply to operate and rapid in application it can be used in the field for quality control purposes.

4. Hardness

Is the resistance of an aggregate to wear and is normally determined by an abrasion test (BS 812). Toughness and hardness properties of an aggregate are particularly important for concrete used in road pavements.

5. Volume change

Is due to moisture movements in aggregate derived from sand stones, greywacke and some basalts may results in considerable shrinkage of the concrete. If the concrete is restrained this produces internal tensile stresses, possible tensile cracking and subsequent deterioration of the concrete. If the coefficient of thermal expansion of an aggregate differs considerably from that of the cement paste this too may adversely affect the concrete performance.

6. Porosity

Is an important property since it affects the behaviour of both freshly mixed and hardened concrete through its effect on the strength, water absorption and permeability of the aggregate? An aggregate with high porosity will tend to produce a less durable concrete, particularly when subjected to freezing and thawing, than an aggregate with low porosity.

Direct measurement of porosity is difficult and in practice a related property, namely, water absorption, is measured. The water absorption is defined as the weight of water absorbed by a dry aggregate in reaching a saturated surface- dry state and is expressed as a percentage of the weight of the dry aggregate.

In general, sedimentary rock materials have the highest absorption value.

The total moisture content, that is, the absorbed moisture plus the free or surface water, of aggregate used for making concrete varies considerably. The water added at the mixer must be adjusted to take the account of this if the free water content is to be kept constant and the required workability and strength maintained.

7. The specific gravity

Is the ratio of its unit weight to that of water? Since aggregates incorporated pores, the value of specific gravity varies depending on the extent to which the pores contain (absorbed) water when the value is determined.

For the purposes of mix design the specific gravity on a "saturated and surface – dry ". This is given by

$$(A/(A-B))$$

Where

A is the weight of the saturated surface-dry sample in air

B is the weight of the saturated sample in water.

The specific gravity of most natural aggregate falls within the range (2.5 to 3) .

Aggregate is the major constituent of concrete and as such its specific gravity is an important factor affecting the density of the resulting concrete.

B. **Shape and surface texture**

Aggregate shape and surface texture can be affected the properties of concrete in both its plastic and hardened state.

These external characteristics may be assessed by observation of the aggregate particles and classifications of their particle shape and texture in accordance with Table (1.4) and Table (1.5) from BS 812.

Table (1.4)

Shape of Aggregates, BS 812

classification	Description
Rounded	Fully water-worn or completely shaped by attrition
Irregular	Naturally irregular, or partly shaped by attrition and having rounded edge.
Angular	Possessing well-defined edges formed at the intersection of the roughly planar faces
Flaky	Materials of which the thickness is small relative to the other two dimensions
Elongated	Materials, usually angular, in which the length is considerably larger than the two dimensions
Flaky &elongated	Materials having the length considerably larger than the width, and the width considerably larger than the thickness.

Table (1.5)

Surface texture of the aggregate

Surface texture	Characteristics
Glassy	Conchoidal fracture
Smooth	Water-worn, or smooth due to fracture of laminated or fine-grained rocks
Granular	Fracture showing more or less uniform rounded grains
Rough	Rough fracture of fine or medium –grained rock containing no easily visible crystalline constituent
Crystalline	Containing easily visible crystalline constituent
Honeycombed	With visible pores and cavities

The classification is somewhat subjective, however and the particle shape may also be assessed by direct measurement of the aggregate particle to determine the:

(1) Flakiness
(2) Elongation
(3) Angularity

C. Grading

The grading of an aggregate defines the proportions of particle of different size in the aggregate. The size of aggregate particles normally used in concrete varies from 37.5 to .15 mm.

BS 882 places aggregate in three main categories**.**

(1) ***Fine aggregate or sand***.

Smaller than 5mm

(2) ***Coarse aggregate***.

Larger than 5mm.

(3) ***-all_ in aggregate.***

Comprising both fine and coarse aggregate.

Types of aggregate

The general classification of aggregate and the related British standards are shown in Fig (3).

1. **Heavy weight aggregate**

It provides an effective and economical use of concrete for radiation shielding by giving the necessary protection against X- rays, gamma-rays and neutron.

2. **Normal weight aggregate**

These aggregates are suitable for most purposes and produces concrete with density in the range 2300 to 2500 kg/m3.

3. **Light weight aggregate**.

Light weight aggregate find application in a wide variety of concrete products ranging from insulation screed to reinforce or priestesses concrete, although their greatest use has been in the manufacture of precast concrete blocks.

Concrete made with light weight aggregate have good fire resistance properties.

Their bulk density normally ranges from 350 to 850 kg/m3 for coarse aggregate and from 750 to 1100 kg/m3 for fine aggregate.

1.1.4 Water

Water is used in concrete making for three different purposes:

- As mixing water.
- For curing of concrete.
- For washing aggregate.

The quality and requirements for the water depend on the type of the Summaries of the physical and physicochemical use.

1. Mixing water

The mixing water, that is, the free water encountered in freshly mixed concrete, has three main functions:

(1) it reacts with the cement powder thus producing hydration
(2) it acts as a lubricant, contributing to the workability of the fresh mixture
(3) it secures the necessary space in the paste for the development of hydration products

The amount of water needed for adequate workability is practically always greater than that needed for complete hydration of the cement.

2. Water for curing of concrete

The requirements for curing water are less stringent than those discussed above, mainly because curing water is in contact with the concrete for only a relatively short time.

Such water may contain more inorganic and organic materials, sulphuric anhydride acids, chlorides, and so on, than an acceptable mixing water, especially when slight discoloration of the concrete surface is not objectionable. Nevertheless, the permissible amounts of the impurities are still restricted, In cases of any doubt, water samples should be sent to a laboratory for testing.

3. Water for washing aggregate

Water for washing aggregate should not contain materials in quantities large enough to produce harmful films or coatings on the surface of aggregate particles.

Essentially the same requirement holds when the water is used for mixing and cleaning concrete . other concreting Chemical limitations for the impurities equipment in wash water are specified in ASTM C 94-8913.

1.2 Objectives of this study

The objective of this research is to study the effect of using concrete admixtures to improve concrete properties both in its fresh and hardened stages in the extremely hot and dry weather of the Sudan.

This can be achieved through experimental work on:

1. Improvement of workability.
2. Increasing of strength.
3. Reducing cement content, hence cost saving.

CHAPTER TWO

LITERATURE REVIEW

LITRETURE REVIEW

2-1 Concreting In Hot Weather

Concrete is defined as hot weather concrete when it is mixed, transported, and placed under conditions of:

- High ambient temperature
- High concrete temperature
- Low relative humidity
- Wind velocity
- Solar radiation

Hot weather is any combination of the above which impair quality of fresh or hardened concrete or causes detrimental results.

There are some special problems involved in concreting in hot weather, arising both from a higher temperature of the concrete and, in many cases, from an increased rate of evaporation from the fresh mix.

These problems concern the mixing, placing and curing of the concrete are:

1- a higher temperature speed up the setting time of concrete, as defined in ASTM C 403-92.(testing on 1:2 cement sand mortar showed that the initial setting time was approximately halved by a change in temperature of the concrete from 28 to 40 c).

2- A higher ambient temperature causes a higher water demand of the concrete and increase the temperature of the fresh concrete. This results in an increased rate of slump losses and in a more rapid hydration, this leads to accelerate setting and to a lower long –term strength of concrete.
Furthermore, rapid evaporation may causes plastic shrinkage cracking and crazing, and subsequent cooling of the hardened concrete can introduce tensile stresses.

3-There are further complication in hot- weather concreting, air entraining is more difficult, although this can be remedied by using large quantities of the entraining agent.
A related problem is that, if relatively cool concrete is allowed to expand when placed at a higher temperature, the air voids expand and the strength reduces.

This would occur, for instance with horizontal panels but not with vertical ones_ in steel mould where expansion is prevented *(A.M. Neville 2000)*.

Here in Sudan all these problems are existing because of the high ambient temperature and low relative humidity.

precautions measurements to be taken.

1. The cement content should keep as low as possible so that the heat of hydration does not unduly aggravate the effect of high ambient temperature.
2. The temperature of the fresh concrete can be lowered by pre_ cooling one or more of the ingredient of the mix.
3. A useful reduction in the placing temperature of concrete can be achieved by simply and cheaply by shading the aggregate stockpiles from the direct rays of the sun.
4. To avoid workability problems, the aggregate type and grading should be chosen so those high absorption rates are avoided.
5. To reduce the loss of workability and also the increase in the setting time asset _ retarding admixtures can be used.
6. After placing, evaporation of water from the mix has to be prevented.
7. In dry weather, wetting the concrete and allowing evaporation to be takes place results in effective cooling as well as effective curing.
8. Schedule concrete placement to limit exposure to atmospheric conditions, such as at night or during favorable weather conditions.
9. Use materials and mix proportions that have a good record in hot weather conditions *(A.M. Neville 2000)*.

2-2 Concrete Admixtures

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)
- Its dosage.

Admixtures should comply with specifications of the British standards *(N.Jackson1980).*

2-2-1 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
- Special admixtures

are most commonly used *(N.Jackson1980).*

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

(*N.Jackson1980)*

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 lignins –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.

ASTM C 494-92 requires Type B admixtures to retard the initial set by at least 1 hour but not more than 3.5 hours, as compared with a control mix.

The compressive strength from the age of 3 days onwards is allowed to be 10 per cent less than the strength of the control concrete. The requirements of BS 5075 are broadly similar*(N.Jackson1980).*

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 15 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 “flowability”.

Water reducing admixtures can also be used in pumped concrete or in concrete placed by termie.

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.

They can also be used to increase strength and durability, since for a given workability less water is necessary *(A.M. Neville 2000)*.

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 “CaCl2” 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 *(N.Jackson1980)*.

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 *(A.M. Neville 2000)*.

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.

a) Water proofing admixtures

Water proofing admixtures aims at preventing penetration of water into concrete. Their performance is very much dependant 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 *(A.M. Neville 2000).*

b) Pigments

Colorings pigments are normally used for architectural purposes and the best effect is produced when they are interground with the cement clinker rather than when added during mixing *(N.Jackson1980).*

c) Pozzolanas

The most commonly used Pozzolanas are pumicit 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.

Pulverized fuel ash can also is used as a replacement for sand (up to 20 per cent) in harsh mixes to improve workability *(N.Jackson1980).*

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 *(N.Jackson1980).*

2-3 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 constituents 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 its:

- Consistency.
- Mobility.
- Compactability.

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 *(N.Jackson 1980).*

2-3-1 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 three 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.
Compatibility: the ease with which a given mix can be fully compacted , all trapped air should be removed *(N.Jackson 1980).*

2-3-2 Measurement of workability

There is no acceptable test which will measure directly the workability. Three tests widely used for measuring workability are the slump, compacting factor and V-B consistometer test.

Slump test

This is a test used extensively in site work all over the world .the slump test does not measure the workability of concrete, although ACI 116R-90 prescribe it as a measure of consistency. but the test is very useful in detecting variation in the uniformity of a mix of a given nominal properties.

The slump test is prescribed by ASTM C 143-90a and BS 1881:part 102:1983.

The mould for the slump testis a frustum of a cone, 300mm height. it is placed on smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer should be tamped 25 times with standard 16mm diameter steel rod, rounded at the end, and the top surface is struck off by means of sawing and rolling motion of the tamping rod. the mould must be firmly held against its base during the entire operation; this is facilitated by handles or foot-rests brazed to the mould.

Immediately after filling, the cone is slowly lifted, and the unsupported concrete will now slump—hence the name of the test.

The decrease in the height of the slumped concrete is called *slump*, and is measured to the nearest 5mm. the decrease is measured to the highest point according to BS 1881:part 102:1983 but to the "displaced original center "according to ASTM C 143-90a. *(A.M. Neville 2000)*.

The test is not suitable for very dry or wet mixes.

<u>Three types of slump usually observed:</u>

1. ***True slump***

is observed with cohesive and rich mixes for which the slump is generally sensitive to variation in workability.

2. ***Shear slump***

Shear slump occurs more often in leaner mixes than harsh mixes .whenever shear slump is obtained the test should be repeated and, if persistent, this fact should recorded together with test result.

3. ***Collapse slump***

Is usually associated with very wet mixes and is generally indicative of poor quality concrete and most frequently result from segregation of its constituents materials.

The standard slump apparatus is only suitable for concretes in which the maximum aggregate size does not exceed 37.5mm *(N.Jackson 1980)*.

Compacting factor test

This test measures the degree of compaction for standard amount of work and thus offers a direct and reasonably reliable assessment of the workability of concrete.

The apparatus is relatively simple machine contrivance and is fully described in BS 1881: part 2.the test requires measurement of the weights of the partially and fully compacted concrete and the ratio of the partially compacted weight to the fully compacted weight, which is always less than 1, is known as the compacting factor.

For the normal range of concretes the compacting factor lies between 0.8 and 0.92.the test is particularly useful for drier mixes for which the slump test is not satisfactory,

And is appropriate for concrete with a maximum size of aggregate up to 40mm.

The apparatus consist essentially of two hopers, each in the shape of a frustum of a cone and one cylinder, the three being above one another. The hopers have hinged doors at the bottom, all inside surfaces are polished to reduce friction.

The upper hoper is filled with concrete, this being placed gently so that at this stage no work is done on the concrete to produce compaction. The bottom door of the hopper is then released and the concrete falls into the lower hopper. This is similar than the upper one and is therefore filled to over flowing, and thus always contains approximately the same amount of concrete in a standard state; this reduces the influence of the personal factor in filling the top hopper. The bottom door of the lower hopper is then released and the concrete falls into the cylinder. Excess concrete is cut by two floats slide across the top of the mould, and the net mass of concrete in the known volume of the cylinder is determined.

The density of the concrete in the cylinder is now calculated, and this density divided by the density of full compacted concrete is defined as the *compacting factor.*

$$\text{The compacting factor} = \frac{\text{weight of partially compacting concrete}}{\text{weight of fully compacting concrete}}$$

(A.M. Neville 2000)& (N.Jackson 1980).

V- B Consistometer test

The name "vebe" is derived from the initial of V. Bahrner of Sweden who developed the test. The test is covered by BS 1881: PART 104: 1983; it is referred to also in

ACI 211.3-75.

Compaction is achieved using a vibrating table with an eccentric mass rotating at 50 Hz and a maximum acceleration of 3g to 4g. it is assumed that the input of energy required for compaction of workability of the mix, and this is expressed as the time in seconds, called *vebe time,* required for the remolding to be complete.

Vebe is a good laboratory test, particularly for very dry mixes .the vebe test also has the additional advantages that the treatment of concrete during the test is comparatively closely related to the method of placing in practice. *(A.M. Neville 2000).*

2-3-3 Factors affecting workability

Various factors known to influence the workability of freshly mixed concrete, and it will be apparent that a change in workability associated with the constituents materials is mainly affected by water content and specific surface of cement and aggregate .

- Cement and water
- Admixtures
- Aggregate type and grading
- Ambient conditions(temperature, humidity, wind velocity)
- Time

(N.Jackson 1980).

Properties of hardened concrete

The properties of fresh concrete are important only in the first few hours of its history whereas the properties of harden concrete assume an important which is retained the remainder of the life of concrete.

The important properties of hardened concrete are:

- Strength
- Deformation under load
- Durability
- Permeability
- Shrinkage

In general, strength is considered to be the most important property and the quality of concrete is often judged by its strength *(N.Jackson1980).*

2-4-1 Strength

The strength of concrete is defined as the maximum load (stress) it can carry. As the strength of concrete increases its other properties usually improve and since the test for strength, particularly in compression, are relatively simple to perform concrete compressive strength is commonly used in the construction industry for the purpose of specification and quality control. Concrete is comparatively brittle material which is relatively weak in tension. *(N. Jackson 1981).*

2-4-1-1 compressive strength

The compressive strength of concrete is taken as the maximum compressive load it can carry per unit area. Concrete strength up to 80 N/mm^2 can be achieved by selective use of the type of cement, mix proportion, method of curing conditions.

Concrete structures, except for road pavements, are normally designed on the basis that concrete is capable of resisting only compression, the tension being carried by steel reinforcement.

The standard method described in BS 1881:Part 3 requires that the test specimen should be cured in water at 20 ^0C and crushed immediately after it has been removed from the curing tank. *(N. Jackson 1981).*

2-4-1-2 Tensile strength

The tensile strength of concrete is of importance in the design of concrete roads and runways. Concrete members are also required to withstand tensile stresses resulting from any restraint to contraction due to drying or temperature variation.

Unlike metals, it is difficult to measure concrete strength in direct tension and indirect methods have been developed for assessing this property. Of these :

Split cylinder test

is the simplest and most widely used. This test is fully described in BS 1881 Part 4 and entails diametrically loading a cylinder in compression along its entire length. This form of loading induces tensile stresses over the loaded diametrical plane and the cylinder split along the loaded diameter. The magnitude of the induced tensile stress

f_{ct} at failure is given by:

$$f_{ct} = \frac{2F}{\pi l d}$$

where:

F = the maximum applied load

l = the cylinder length

d = the diameter of the cylinder

(N. Jackson 1981).

Flexure strength

The flexure strength of concrete is another indirect tensile value which is also commonly used (BS 1881:Part 4). In this test a simple supported plain concrete

Beam is loaded at is third points, the resulting bending moments inducing compressive and tensile stresses in the top and bottom of the beam respectively. The beam fails in tension and the flexure strength (modulus of rupture) f_{cr} is defined by:

$$f_{cr} = \frac{FL}{bd^2}$$

where:

F = the maximum applied load

L = the distance between the supports

b&d are the beam breadth and depth respectively at the section which failure occurs.

The tensile strength of concrete is usually taken to be about one- tenth of its compressive strength. This may vary, however, depending on the methods used for measuring tensile strength and the type of concrete.

In general the direct tensile strength and the splitting strength vary from 5 to 13 per cent and the flexure strength from 11 to 23 per cent of the concrete cube compressive strength. In each case, as the strength increases the percentage decrease *(N. Jackson 1981).*

2-4-2 Factors influencing strength

Several factors which affect the strength of concrete are listed below:

1. Influence of the constituent materials (cement, water, aggregate, admixtures).
2. Influence of the methods of preparation.
3. Influence of curing
4. Influence of test conditions.

(N. Jackson 1980)

CHAPTER THREE
EXPERMENTAL WORK

EXPERMENTAL WORK

3-1 Concrete Mix Design

Concrete mix design can be defined as the procedure by which, for any given set of conditions, the proportion of the constituent materials are chosen so as to produce a concrete with all the required properties for the minimum cost. The cost of the mix design includes

- The materials
- The cost of the mix design, of batching, mixing and placing the concrete and of side supervision

  Two types of concrete mixes are available

a) Prescribe mix

It is given in least form included:

- Proportion of cement
- Fine and coarse aggregate
- Workability

Minimum compressive strength is very important to produce proper mix.

b) Designed mix

The basic requirements for concrete are conveniently considered at two stages in its life.

In its hardened state the concrete should have adequate durability, the required strength and also the desired surface finish.

In its plastic state, or the stage during which it is to be handle, placed and compacted in its final form, it should be sufficiently workable for the required properties in its hardened state to be achieved with the facilities available on site.

This means that:

1. The concrete should be sufficiently fluid for it to be able to flow into and fill all parts of the formwork, or mould into which it is placed.
2. It should be so without segregation or separation, of the constituents' materials while being handled from the mixer or during placing.
3. It must be possible to fully compact the concrete when placed in position.

4. It must be possible to obtain the required surface finish.

If concrete does not have the required workability in its plastic state, it will not be possible to produce concrete with the required properties in its hardened state *(N.Jackson1980)*.

3-1-1 Factors governing the selection of mix proportion

1. Durability

Adequate durability of exposed concrete can frequently be obtained by ensuring full compaction, an adequate cement content and low water – cement ratio, all of which contribute to producing a dense, impermeable concrete.

The choice of aggregate is also important particularly for concrete wearing surfaces or where improved fire resistance is required.

Aggregate having high shrinkage properties should be used with caution in exposed concrete. Durability is not a readily measured property of the hardened concrete. However, for a correctly design concrete mix any increase in the water – cement ratio on site with the associated reduction in durability, will be a companied by a reduction in concrete strength *(A.M.Neville 2000).*

2. Strength

The strength of the concrete is frequently an important design consideration particularly in structural application where the load –carrying capacity of a structural member may be closely related to the concrete strength. This will usually be the compressive strength although occasionally the flexure or indirect tensile strength may be more relevant.

The strength requirement is generally specified in terms of a characteristic strength coupled with a requirement that the probability of the strength falling below this shall not exceed a certain value. Typically this may be 5 per cent or 1 in 20 chances in strength falling below the specific characteristic strength, this generally be the 28 – day strength.

An understanding of the factors affecting concrete strength on site, and of the probable variation in strength, is essential if such specifications are to have any real meaning at the design stage.

If the proportion of the aggregate and cement and also the quality of the aggregate are maintained constant, the water – cement ratio can be controlled very effectively at the mixer by adding just sufficient water to give the required workability. Once a suitable mix has been obtained the workability can be assessed quite satisfactorily by an experienced mixer operator, with periodic control tests of the workability *(A.M.Neville 2000).*

Any variation in mix proportions or significant change in the aggregate grading will affect the quantity of water needed to maintain the required workability and this too results in variations in the water – cement ratio and hence in concrete strength.

All these factors tend to give water – cement ratios which are as likely greater as they are to be less than the target value. The actual water – cement ratios tend therefore to have normal or Gaussian distribution about the mean, or target, value.

The relationship between the water – cement ratio and concrete strength is non – linear. Nevertheless over a limit range the relationship will be approximately linear and it might be expected that the concrete strengths will also tend to have a normal distribution. This can be seen in fig (3.1) in which atypical bell – shape normal distribution curve is shown.

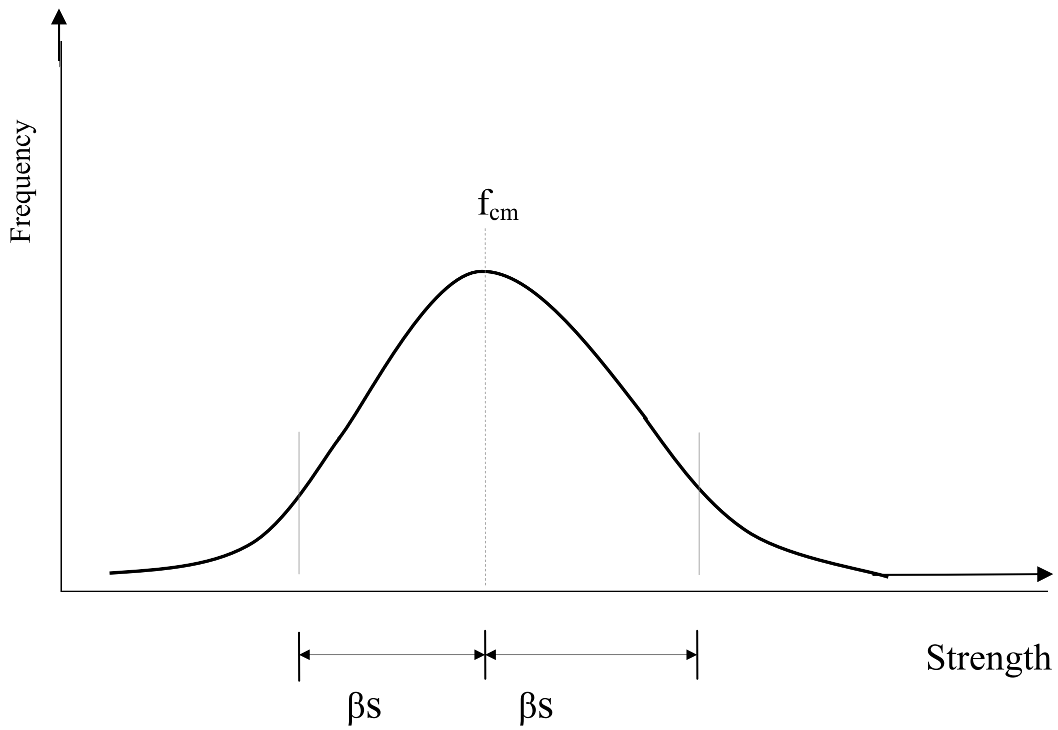

Fig (3.1) Normal distribution curve *(A.M.Neville 2000).*

Design mean strength

The assumption of a normal distribution of concrete strengths forms the basis of mix design and statistical quality control procedures to satisfying the strength requirement.

For a normal distribution, the probability of strength lying outside the specified limits either side of the mean strength can be determined.

These limits (fig 3.1) are usually expressed in terms of the standard deviation *s* defined by

$$s = \left[\frac{\sum (f_c - f_{cm})^2}{n-1}\right]^{\frac{1}{2}} = \left[\frac{\sum (f_c)^2 - (\sum f_c)^2 / n}{n-1}\right]^{\frac{1}{2}} N/mm^2 \quad \textit{(N.Jackson1980).}$$

Where

f_c = The observed strength.

f_{cm} = The best estimate of the means strength.

The probabilities of a strength lying outside the range $(f_{cm} \pm \beta s)$ for different values of are given in Table (3.1) in which the probabilities of strengths falling below the lower limit $(f_{cm} - \beta s)$ are also given.

Table (3.1)

Probability values

Probability of an observed strength lying outside the range $(f_{cm} \pm \beta \times s)$	β	Probability of an observed strength being less than $(f_{cm} - \beta \times s)$
1 in 50	2.33	1 in 100
1 in 20	1.96	1 in 40
1 in 10	1.64	1 in 20

If the specified characteristic strength f_{cu} is the strength below which not more than 5% of the population of strengths shall fall, it follows that

$$f_{cu} = f_{cm} - 1.64s$$

Hence if the standard deviation can be obtained on site, the mean strength for which the concrete must be designed can be determined. Otherwise the mean cube strength is obtained by adding 15 N/mm^2.

3. Workability

Beside the requirements for the concrete to be satisfactory in the hardened state, properties when being transported, possibly pumped, and placed are equally important. One essential at this stage is a satisfactory workability. Selection of mix proportions which do not permit the achievement of appropriate workability totally defeats the purpose of rational mix proportioning.

The workability that is considered desirable depends on two factors:

- The minimum size of the section to be concrete and the amount and spacing of reinforcement.
- The method of compaction to be used.

It is clear that when the section is narrow and complicated, the concrete must have a high workability so that the full compaction can be achieved with a reasonable amount of effort. The same applied when embedded steel sections or fixtures are present.

Because these features of the structure are determined during its design, the necessary workability must be ensured in the selection of mix proportions.

For given water – cement ratio, the principal factors affecting workability are:

1. The shape and grading of the coarse and fine aggregate
2. The aggregate – cement ratio

The choice of suitable concrete mix proportions must take all these factors into account *(A.M.Neville 2000)*.

4. Maximum size of aggregate

In reinforced concrete, the maximum size of aggregate which can be used is governed by the width of the section and the spacing of the reinforcement. It now seems that the improvement in the properties of concrete with an increase in the size of aggregate does not extend beyond about 40mm so that the use of larger size may not be advantageous. In particular, in high performance concrete, the use of aggregate larger than 10 to 15 mm is counter – productive. Furthermore, the use of a larger maximum size means that a great number of stockpiles have to be maintained and the batching operations become correspondingly more complicated. This may be uneconomical on small sites but, where larger quantities of concrete are to be placed, the extra handling cost may be offset by a reduction in the cement content of the mix. The choice of the maximum size may also be governed by the availability of the materials and by their cost*(A.M.Neville 2000)*.

5. Grading and type of aggregate

The grading influences the mix proportions for a desired workability and the water/cement ratio: the coarser the grading the leaner the mix which can be used, but this is true within certain limits only because a very lean mix will not be cohesive without a sufficient amount of fine material.

The influence of the type of aggregate should also be considered because its surface texture, shape and allied properties influence the aggregate – cement ratio for a desired workability and given water – cement ratio. In selection a mix, it is essential, therefore, to know at the outset what type of aggregate is available.

An important feature of satisfactory aggregate is the uniformity of its grading. In the case of coarse aggregate, this is achieved comparatively easily by the use of separate stockpiles for each size fraction. However, considerable care is required in maintaining the uniformity of grading of fine aggregate and this is especially important when the water content of the mix is controlled by the mixer operator on the basis of a constant workability*(A.M.Neville 2000)*.

6. Cement content

The choice of cement is made either on the basis of experience or alternatively from charts and tables prepared from comprehensive laboratory tests. Such tables are no more than a guide to the mix proportion required because they apply fully only to the actual aggregates used in their derivation.

Moreover, recommended proportions are usually based on aggregate grading which have been found to be satisfactory*(A.M.Neville 2000)*.

3-2 Mix proportions

For the three grades (15, 25, and 40) N/mm^2 we used:

Cement type: ordinary Portland cement.

Coarse aggregate type: crushed.

Fine aggregate type: uncrushed.

Maximum aggregate size: 20 mm.

Workability: medium (30 – 60) mm.

Concrete density: $2400kg/m^3$

Mix (A)

Characteristic compressive strength = 15 N/mm^2 at 28 days.
Target mean compressive strength = 28 N/mm^2.
Water/ cement ratio = 0.70.
Total aggregate content = 1890kg/ m^3

Quantities per m^3

Cement (kg)	**Water(kg)**	**Fine aggregate(kg)**	**Coarse aggregate (kg)**
300	**210**	**700**	**1190**

Mix (B)

Characteristic compressive strength = 25 N/mm^2 at 28 days.
Target mean compressive strength = 38 N/mm^2.
Water/ cement ratio = 0.58.
Maximum aggregate size =20 mm.
Total aggregate content = 1828 kg/ m^3

Quantities per m^3

Cement (kg)	Water(kg)	Fine aggregate(kg)	Coarse aggregate (kg)
360	210	640	1190

Mix (C)

Characteristic compressive strength = 40 N/mm^2 at 28 days.
Target mean compressive strength = 53 N/mm^2.
Workability: medium (30 – 60 mm).
Water/ cement ratio = 0.46.
Maximum aggregate size =20 mm.
Total aggregate content = 1734kg/ m^3

Quantities per m^3

Cement (kg)	Water(kg)	Fine aggregate(kg)	Coarse aggregate (kg)
455	210	570	1165

3-2 Experimental Work

Where the main requirement is to:

1. improve workability
2. Increase strength.
3. reduce cement content, hence cost saving

A concrete mix design or trial mixes should be made with normal concrete mix design.
In this study three grades of concrete are to be used:

1. grade 15
2. grade 25
3. grade 40

Beside the ordinary reference mixes, chemical admixtures should be used. These admixtures are:

High performance superplasticising admixture *(conplast sp432ms*)

The study will be divided to theses phases:

3- 2-1 Materials test

1. Test of base materials, i.e. cement , aggregate , water and admixture
2. the effect of recommended doses of admixture on the properties of fresh and hardened concrete , i.e. (workability & strengths)
3.

3- 2- 2 Testing program

A. Grade 15

1. Ordinary reference mix (RM).
   (12 cubes+3cylinder+3beams)
   - 3 cubes will be crushed on 7 days
   - 3 cubes will be crushed on 14 days
   - 3 cubes will be crushed on 28 days
   - 3 cubes will be crushed on 90 days
   - 3 cylinder will be tested on 28 days
   - 3 beams will be tested on 28 days

2. Reference mix admixture to increase workability (WrM).
   (12 cubes+3cylinder+3beams)
3. Mix with admixture and same workability to increase strength (StM).
   (12 cubes+3cylinder+3beams)
4. Mix with admixture to reduce cement content keeping same strength and workability (CrM).
   (12 cubes+3cylinder+3beams)

B. Grade 25

1. Ordinary reference mix (RM)
   (12 cubes+3cylinder+3beams)
   - 3 cubes will be crushed on 7 days
   - 3 cubes will be crushed on 14 days
   - 3 cubes will be crushed on 28 days
   - 3 cubes will be crushed on 90 days
   - 3 cylinder will be tested on 28 days
   - 3 beams will be tested on 28 days

2. Reference mix admixture to increase workability (WrM).
   (12 cubes+3cylinder+3beams)
3. Mix with admixture and same workability to increase strength (StM).
   (12 cubes+3cylinder+3beams)
4. Mix with admixture to reduce cement content keeping same strength and workability (CrM).
   (12 cubes+3cylinder+3beams)

C. Grade 40

1. Ordinary reference mix (RM).
   (12 cubes+3cylinder+3beams)
   - 3 cubes will be crushed on 3 days
   - 3 cubes will be crushed on 6 days
   - 3 cubes will be crushed on 28 days
   - 3 cubes will be crushed on 90 days
   - 3 cylinder will be tested on 28 days
   - 3 beams will be tested on 28 days
2. Reference mix admixture to increase workability (WrM).

(12 cubes+3cylinder+3beams)

3. Mix with admixture and same workability to increase strength (StM).
   (12 cubes+3cylinder+3beams)
4. Mix with admixture to reduce cement content keeping same strength and workability (CrM).
   (12 cubes+3cylinder+3beams)

Notice

- All specimens will be cured on the laboratory room temperature up to the date of test.
- Ordinary Portland cement will be used.
- Medium workability (30___60).
- Crushed stone aggregate will be used so as to get the strength 40N/mm^2 easily.

CHAPTER FOUR

TEST ERSULTS AND DISSCUSION

TEST RESULTS AND DISSCUSION

4-1 Preliminary Tests:

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

Table (4.1) results of cement test

Test	**Results**	**Requirements of BS12 1996**
Consistency	30%	
Setting time		
1) Initial	1 hrs : 40min	Not less than 60 min (-15 min)
2) Final	2 hrs : 40 min	Not more than 10 hrs
Compressive strength		
1) 2 days		
1	25.5 N/mm^2	Average Equal or greater than 10 N/mm^2(-2 N/mm^2)
2	27.4 N/mm^2	
3	27.5 N/mm^2	
2) 28 days		
1	46.4 N/mm^2	
2	45.2 N/mm^2	Average Equal or greater than 42.5 N/mm^2 (-2.5 N/mm^2)
3	47.6 N/mm^2	

Table (4.2) fine aggregate sieve analysis

Sieve size (mm)	Percentage retain	Percentage passing	BS 882 1992
10	0	100	100
5	2.33	97.7	90 – 100
2.36	5.5	94.5	75 – 100
1.18	19.47	80.5	55 – 90
0.6	46	54	35 – 59
0.3	79.5	20.5	8 – 30
0.15	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
50	0	100	100
37.5	0	100	100
20	0	100	100
14	0	100	100
10	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
50	0	100	100
37.5	0	100	100
20	0	100	100
14	40.34	53.7	0 – 70
10	93.58	6.4	0 – 25
5	99.98	.02	0 – 5
2.36	_	_	_

<u>Coarse aggregate crushing value (ACV)</u>

ACV $=M_2/M_1 \times 100$

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.

4-2 Test Results of The Specimens

Table(4.5): Results of compressive cube strength grade 15

(RM) Reference mix (without admixture)
slump = 55mm w/c = 0.7
(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (days)	Weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
22/05/2008	29/05/2008	7	8.50	610	27.11	
22/05/2008	29/05/2008	7	9.07	600	26.66	26.52
22/05/2008	29/05/2008	7	8.70	580	25.78	
22/05/2008	05/06/2008	14	8.42	700	31.11	
22/05/2008	05/06/2008	14	8.62	700	31.11	31.33
22/05/2008	05/06/2008	14	8.49	715	31.77	
22/05/2008	19/06/2008	28	9.02	810	36.00	
22/05/2008	19/06/2008	28	8.47	765	34.00	34.89
22/05/2008	19/06/2008	28	8.44	780	34.67	
22/05/2008	20/08/2008	90	8.60	870	38.67	
22/05/2008	20/08/2008	90	8.57	900	40.00	37.63
22/05/2008	20/08/2008	90	8.59	770	34.22	

Table(4.6): Results of compressive cube strength grade 15

(WrM) (mix +1LIT/100kg cementious material)

slump = 160mm W/C = 0.7

to improve workability

(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
05/06/2008	12/06/2008	7	9.11	760	33.78	
05/06/2008	12/06/2008	7	9.01	745	33.11	34.00
05/06/2008	12/06/2008	7	9.11	790	35.11	
05/06/2008	19/06/2008	14	8.51	740	32.89	
05/06/2008	19/06/2008	14	8.26	800	35.56	34.00
05/06/2008	19/06/2008	14	8.76	755	33.56	
05/06/2008	03/07/2008	28	8.75	950	42.22	
05/06/2008	03/07/2008	28	9.18	960	42.67	42.22
05/06/2008	03/07/2008	28	8.69	940	41.78	
05/06/2008	03/09/2008	90	8.80	1120	49.78	
05/06/2008	03/09/2008	90	8.77	1140	50.67	50.30
05/06/2008	03/09/2008	90	8.89	1135	50.44	

Table(4.7): Results of compressive cube strength grade15 (StM) (mix +1.5lt/100kg cementious material) decrease the water content from 210 to 160 kg/lt slump = 60mm w/c=.0.53 to increase strength (Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (days)	weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
6/19/2008	6/26/2008	7	8.82	750	33.33	
6/19/2008	6/26/2008	7	8.67	720	32.00	33.19
6/19/2008	6/26/2008	7	8.76	770	34.22	
6/19/2008	7/3/2008	14	8.32	1025	45.56	
6/19/2008	7/3/2008	14	8.77	895	39.77	43.26
6/19/2008	7/3/2008	14	8.75	1000	44.44	
6/19/2008	7/17/2008	28	8.575	1000	44.44	
6/19/2008	7/17/2008	28	8.63	1090	48.44	45.11
6/19/2008	7/17/2008	28	8.46	955	42.44	
6/19/2008	9/17/2008	90	8.64	1185	52.67	
6/19/2008	9/17/2008	90	8.40	1090	48.44	50.96
6/19/2008	9/17/2008	90	8.78	1165	51.78	

Table(4.8): Results of compressive cube strength grade15 (CrM) (mix +1.5lt/100kg cementious material) decrease the water content from 210 to 160 kg/lt slump = 50mm w/c=.0.70 To reduce the cement content from 300kg to 228.57kg (Cr ratio=23.3%) (Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
7/24/2008	7/31/2008	7	8.64	480	21.33	
7/24/2008	7/31/2008	7	8.70	480	21.33	21.63
7/24/2008	7/31/2008	7	8.51	500	22.22	
7/24/2008	8/7/2008	14	8.42	660	29.33	
7/24/2008	8/7/2008	14	8.62	6350	28.22	27.93
7/24/2008	8/7/2008	14	8.65	590	26.22	
7/24/2008	8/21/2008	28	8.80	645	28.67	
7/24/2008	8/21/2008	28	8.54	785	34.89	31.70
7/24/2008	8/21/2008	28	8.81	710	31.56	
7/24/2008	10/22/2008	90	8.77	870	38.67	
7/24/2008	10/22/2008	90	8.80	850	37.78	38.07
7/24/2008	10/22/2008	90	8.60	850	37.78	

Table(4.9) Results of cubes compressive strength Grade 15

Mix specification	Slump (mm)	Age (days)	Mean strength (N/mm^2)
(RM) Reference mix	55	7	26.52
		14	31.33
		28	34.89
		90	37.63
(WrM) same mix with admixture to increase workability	160	7	28.19
		14	36.00
		28	42.22
		90	50.30
(StM) Mix with admixture and same workability to increase strength	60	7	34.00
		14	41.26
		28	45.11
		90	50.96
(CrM) Mix with admixture to reduce cement content keeping same strength& workability	50	7	21.63
		14	27.92
		28	31.70
		90	38.07

Figure (4.1) compressive strength development for different mixes grade15

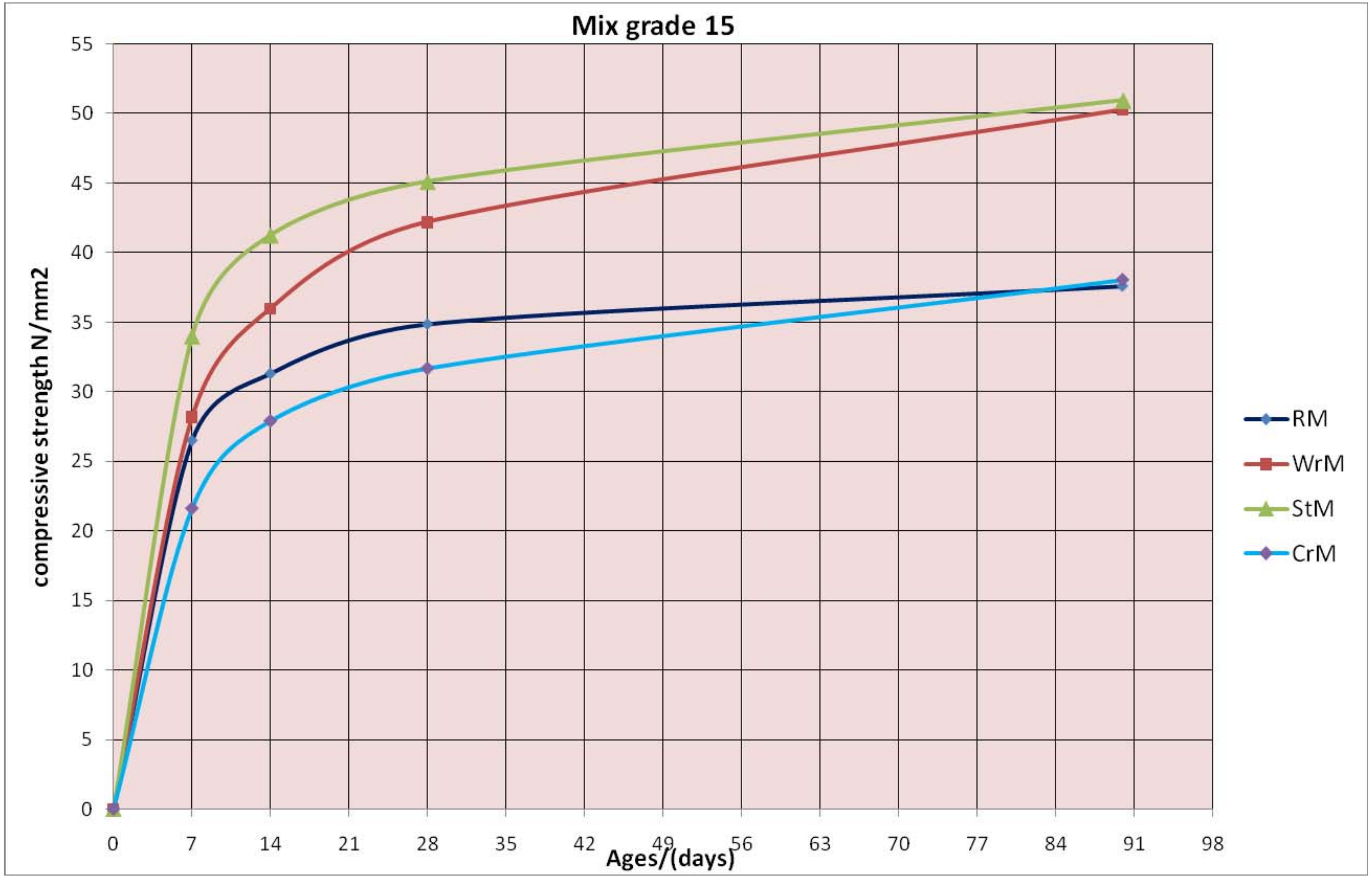

Figure (4.1) compressive strength development for different mixes grade1

Table (4.10) Results of compressive cube strength grade 25
(RM) Reference mix (without admixture)
slump = 60mm w/c =0.58
(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Strength (N/mm²)	Mean strength (N/mm²)
21/05/2008	28/05/2008	7	8.58	585	26.00	
21/05/2008	28/05/2008	7	8.46	655	29.11	27.85
21/05/2008	28/05/2008	7	9.00	640	28.44	
21/05/2008	04/06/2008	14	8.82	755	33.55	
21/05/2008	04/06/2008	14	8.85	700	31.11	33.55
21/05/2008	04/06/2008	14	9.04	810	36.00	
21/05/2008	18/06/2008	28	9.05	820	36.44	
21/05/2008	18/06/2008	28	8.91	850	37.77	37.26
21/05/2008	18/06/2008	28	8.81	845	37.55	
21/05/2008	19/08/2008	90	8.65	970	43.11	
21/05/2008	19/08/2008	90	8.64	980	43.55	42.00
21/05/2008	19/08/2008	90	8.86	885	39.33	

Table (4.11) Results of compressive cube strength grade25

(WrM) (mix +minimum dose of sp 432 ms 1 Lit/100kg Cementious Material)

slump = 185mm w/c =0.58

to improve workability

(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
03/06/2008	10/06/2008	7	9.20	830	36.89	
03/06/2008	10/06/2008	7	9.22	895	39.79	39.04
03/06/2008	10/06/2008	7	9.25	910	40.44	
03/06/2008	17/06/2008	14	8.78	940	41.78	
03/06/2008	17/06/2008	14	9..00	975	43.33	42.81
03/06/2008	17/06/2008	14	8.915	975	43.33	
03/06/2008	01/07/2008	28	9.18	1100	48.89	
03/06/2008	01/07/2008	28	9.03	1080	48.00	47.48
03/06/2008	01/07/2008	28	8.8	1025	45.55	
03/06/2008	01/09/2008	90	9.02	1185	52.67	
03/06/2008	01/09/2008	90	9.41	1230	54.66	52.81
03/06/2008	01/09/2008	90	9.02	1150	51.11	

Table(4.12) Results of compressive cube strength grade 25

(StM) (Mix +1.25lit dose of sp 432 ms)

decrease the water content from 210 to 160 kg/lt

slump =40mm w/c=.44

to increase strength

(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
15/06/2008	22/06/2008	7	9.33	970	43.11	43.25
15/06/2008	22/06/2008	7	9.15	975	43.33	
15/06/2008	22/06/2008	7	8.95	975	43.33	
15/06/2008	29/06/2008	14	9.00	1040	46.22	47.63
15/06/2008	29/06/2008	14	8.90	1070	47.55	
15/06/2008	29/06/2008	14	9.25	1105	49.11	
15/06/2008	13/07/2008	28	8.79	1175	46.22	49.33
15/06/2008	13/07/2008	28	8.68	1145	50.88	
15/06/2008	13/07/2008	28	9.06	1145	50.88	
15/06/2008	13/09/2008	90	8.74	1040	52.22	52.07
15/06/2008	13/09/2008	90	9.14	1060	47.11	
15/06/2008	13/09/2008	90	8.93	1280	56.88	

Table(4.13) : Results of compressive cube strength grade25 (CrM) (mix +1.5lt/100kg cementious material)

decrease the water content from210 to 160 kg/lt

slump = 80mm w/c=.0.58

Reduce the cement content from 360kg to 275.86kg (Cr ratio=23.3%)

(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
03/08/2008	10/08/2008	7	8.65	640	28.44	
03/08/2008	10/08/2008	7	8.85	585	26.00	27.04
03/08/2008	10/08/2008	7	8.8	600	26.67	
03/08/2008	17/08/2008	14	8.66	670	29.78	
03/08/2008	17/08/2008	14	9.26	710	31.56	30.22
03/08/2008	17/08/2008	14	8.68	660	29.33	
03/08/2008	31/08/2008	28	8.97	790	35.11	
03/08/2008	31/08/2008	28	8.96	810	36.00	35.56
03/08/2008	31/08/2008	28	8.88	800	35.55	
03/08/2008	01/11/2008	90	8.845	860	38.22	
03/08/2008	01/11/2008	90	9.14	1010	44.89	42.07
03/08/2008	01/11/2008	90	9.18	970	43.11	

Table(4.14): Results of cubes compressive strength
Grade 25

Mix specification	Slump (mm)	Age (days)	mean compressive strength N/mm^2
(RM) Reference mix	60	7	27.85
		14	33.56
		28	37.26
		90	42.00
(WrM) same mix with admixture to increase workability	185	7	36.04
		14	42.81
		28	47.48
		90	52.07
(StM) Mix with admixture and same workability to increase strength	40	7	43.26
		14	47.63
		28	49.33
		90	52.89
(CrM) Mix with admixture to reduce cement content keeping same strength& workability	80	7	25.03
		14	31.22
		28	35.56
		90	42.07

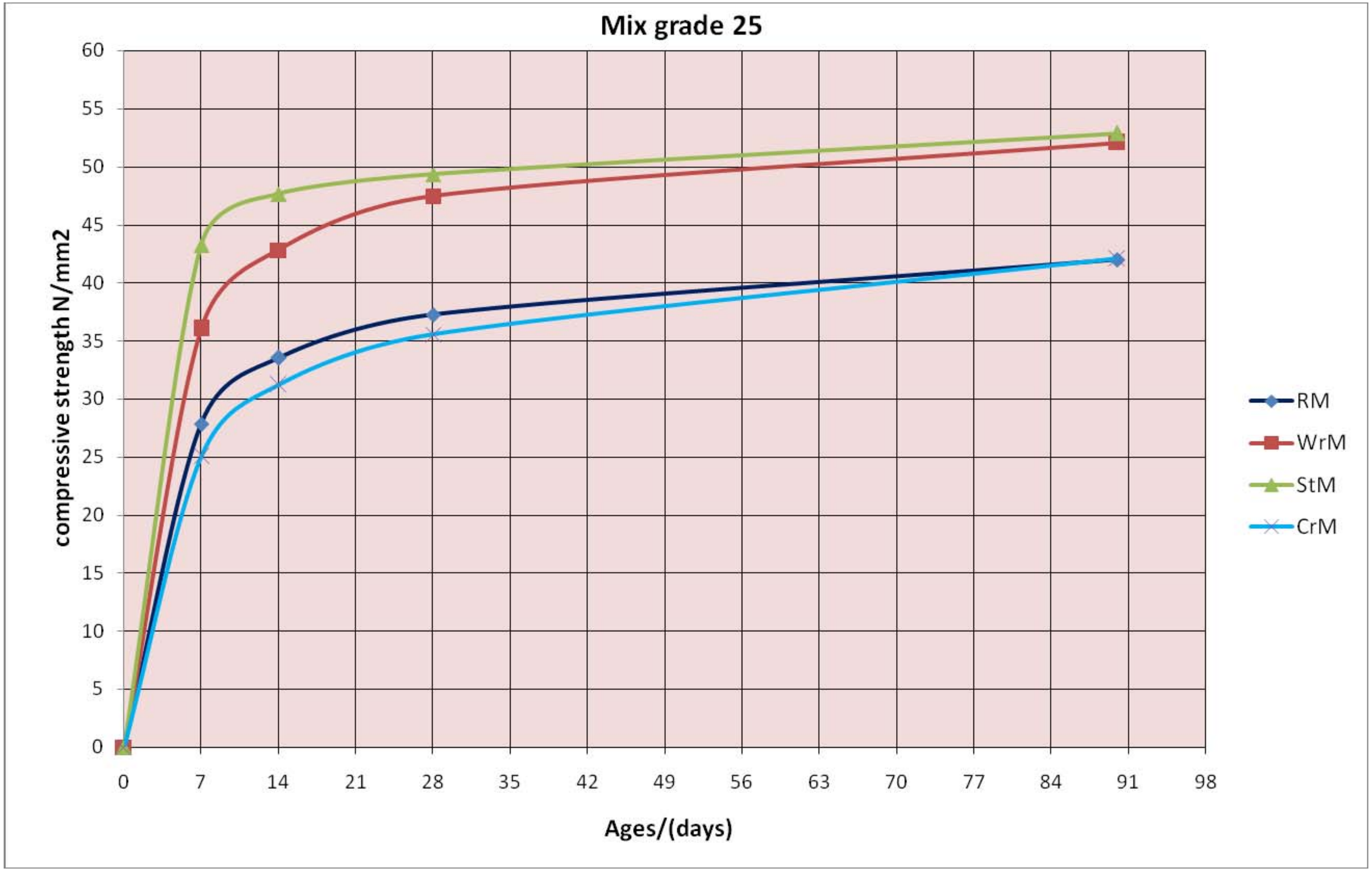

Figure (4.2) compressive strength development for different mixes grade25

Table(4.15): Results of compressive cube strength grade 40

(RM) Reference mix (without admixture)
slump = 60mm w/c = 0.46
(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
26/05/2008	02/06/2008	7	8.565	895	39.78	
26/05/2008	02/06/2008	7	8.56	865	38.44	38.74
26/05/2008	02/06/2008	7	8.67	855	38.00	
26/05/2008	09/06/2008	14	8.69	950	42.22	
26/05/2008	09/06/2008	14	8.80	910	40.44	40.74
26/05/2008	09/06/2008	14	8.50	890	39.56	
26/05/2008	23/06/2008	28	8.60	1060	47.11	
26/05/2008	23/06/2008	28	8.71	1010	44.88	46.96
26/05/2008	23/06/2008	28	8.625	1100	48.89	
26/05/2008	24/08/2008	90	8.62	1100	48.89	
26/05/2008	24/08/2008	90	8.64	1100	48.88	47.70
26/05/2008	24/08/2008	90	8.60	1020	45.33	

Table(4.16): Results of compressive cube strength grade 40 (WrM) (Mix +1lit/100kg cementious material)

slump = 160mm w/c = 0.46
to improve workability
(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (days)	weight (kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
28/05/2008	04/06/2008	7	8.65	880	39.11	
28/05/2008	04/06/2008	7	9.16	1020	45.33	42.37
28/05/2008	04/06/2008	7	8.76	960	42.67	
28/05/2008	11/06/2008	14	8.76	1050	46.67	
28/05/2008	11/06/2008	14	8.90	1060	47.11	46.67
28/05/2008	11/06/2008	14	9.22	1040	46.22	
28/05/2008	25/06/2008	28	9.60	1170	52.00	
28/05/2008	25/06/2008	28	8.70	1095	48.66	49.85
28/05/2008	25/06/2008	28	8.80	1100	48.89	
28/05/2008	26/08/2008	90	8.86	1210	53.78	
28/05/2008	26/08/2008	90	8.81	1160	51.56	53.48
28/05/2008	26/08/2008	90	9.42	1240	55.11	

Table(4.17): Results of compressive cube strength grade 40

(StM) (mix + 1 lit /100kg cementious materials)

decrease the water content from 210 to 160 kg/lt

slump = 50mm w/c=.35
To increase strength
(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (days)	weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
10/06/2008	17/06/2008	7	8.70	1150	51.11	50.89
10/06/2008	17/06/2008	7	9.11	1150	51.11	
10/06/2008	17/06/2008	7	8.46	1135	50.44	
10/06/2008	24/06/2008	14	8.71	1165	51.78	51.63
10/06/2008	24/06/2008	14	8.80	1175	52.22	
10/06/2008	24/06/2008	14	8.57	1145	50.89	
10/06/2008	08/07/2008	28	8.87	1230	54.67	56.14
10/06/2008	08/07/2008	28	8.88	1280	56.89	
10/06/2008	08/07/2008	28	9.13	1280	56.89	
10/06/2008	08/09/2008	90	8.78	1360	60.44	61.11
10/06/2008	08/09/2008	90	8.68	1380	61.33	
10/06/2008	08/09/2008	90	8.85	1385	61.56	

Table(4.18) : Results of compressive cube strength grade40
(CrM) (mix +2lt/100kg cementious material dose of sp 432 ms)
decrease the water content from 210 to 160 kg/lt
slump = 60mm w/c=.0.46
To reduce the cement content from 455kg to 347kg
(Cube dimension 150*150*150mm)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Strength (N/mm^2)	Mean strength (N/mm^2)
7/2/2008	7/9/2008	7	8.92	740	32.88	
7/2/2008	7/9/2008	7	9.03	925	41.11	39.85
7/2/2008	7/9/2008	7	9.08	1025	45.56	
7/2/2008	7/16/2008	14	9.51	1040	46.22	
7/2/2008	7/16/2008	14	8.88	860	38.22	42.07
7/2/2008	7/16/2008	14	8.83	940	41.78	
7/2/2008	7/30/2008	28	8.75	1030	45.78	
7/2/2008	7/30/2008	28	9.16	980	43.55	44.15
7/2/2008	7/30/2008	28	8.91	970	43.11	
7/2/2008	9/30/2008	90	9.4	1170	52.00	
7/2/2008	9/30/2008	90	8.57	1180	52.44	52.89
7/2/2008	9/30/2008	90	9.25	1220	54.22	

Table (4.19): Results of cubes compressive strength Grade40

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	56.15
		90	61.11
(CrM) Mix with admixture to reduce cement content keeping same strength &workability	60	7	37.85
		14	42.07
		28	44.15
		90	52.89

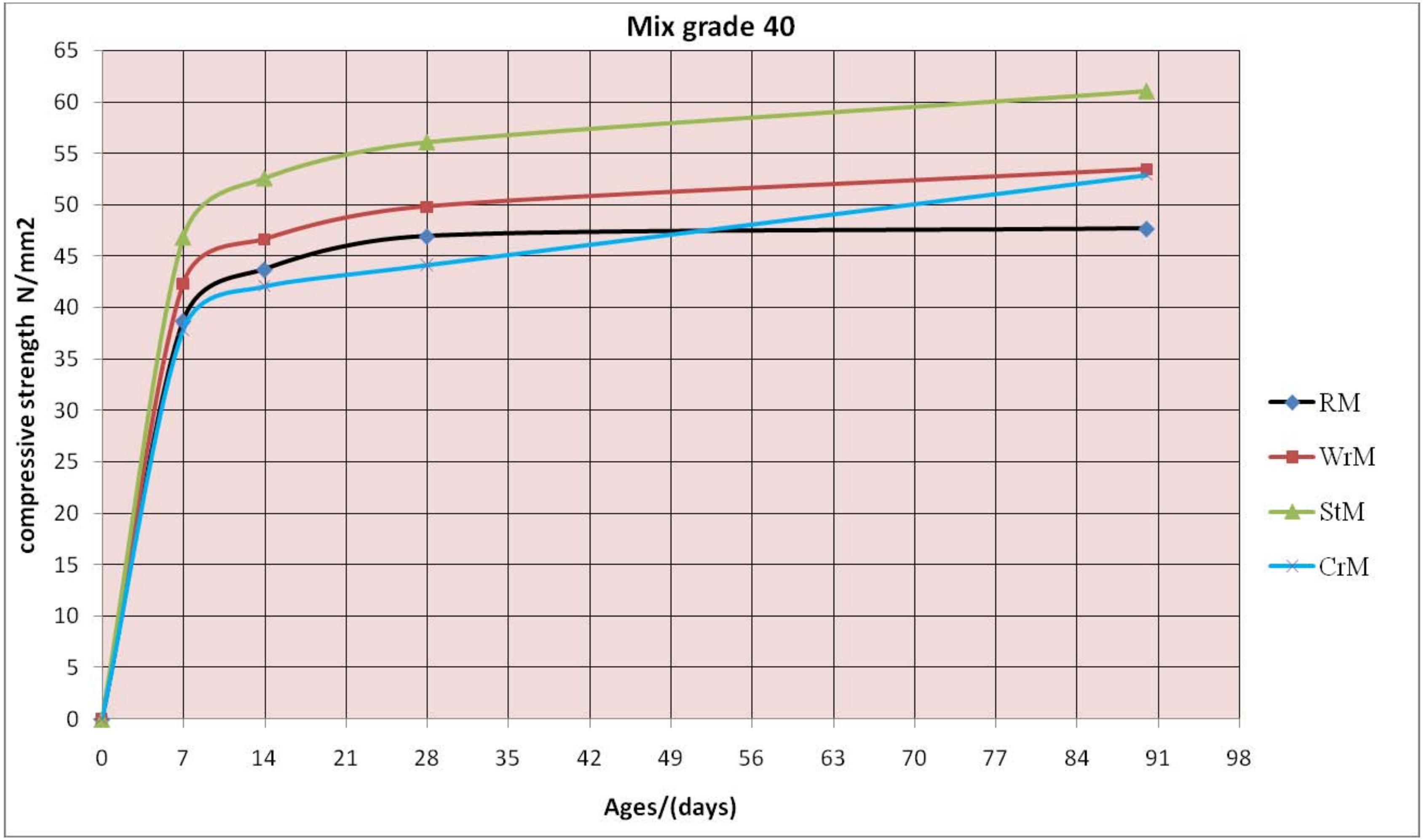

Figure (4.3) compressive strength development for different mixes grade40

Table(4.20) Results of flexure strength grade15 : Reference mix (RM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm^2)	Mean strength (N/mm^2)
22/05/2008	19/06/2008	28		13.14	6.57	
22/05/2008	19/06/2008	28		10.38	5.19	6.11
22/05/2008	19/06/2008	28		13.14	6.57	

Table(4.21) Results of splitting strength grade 15 : 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)
22/05/2008	19/06/2008	28	14.24	209.10	2.96	
22/05/2008	19/06/2008	28	14.12	198.00	2.80	2.91
22/05/2008	19/06/2008	28	14.20	209.40	2.96	

Table(4.22) Results of flexure strength grade 15: 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)
05/06/2008	03/07/2008	28		10.14	5.07	
05/06/2008	03/07/2008	28		11.30	5.65	5.38
05/06/2008	03/07/2008	28		10.84	5.42	

Table(4.23) Results of splitting strength grade 15 : 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
05/06/2008	03/07/2008	28	14.41	190	2.69	2.69
05/06/2008	03/07/2008	28	14.36	185	2.62	
05/06/2008	03/07/2008	28	14.34	194	2.75	

Table(4.24) Results of flexure strength grade 15 : 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)
19/06/2008	17/07/2008	28		11.53	5.77	6.65
19/06/2008	17/07/2008	28		14.75	7.38	
19/06/2008	17/07/2008	28		13.61	6.81	

Table(4.25) Results of splitting strength grade 15 : 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)
19/06/2008	17/07/2008	28	14.45	245.00	3.47	3.41
19/06/2008	17/07/2008	28	14.38	236.40	3.35	
19/06/2008	17/07/2008	28	14.52	241.40	3.42	

Table(4.26) Results of flexure strength grade 15: Mix with admixture to reduce cement content (CrM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load kn (KN)	Flexural strength (N/mm^2)	Mean strength (N/mm^2)
24/07/2008	21/08/2008	28		13.84	6.92	5.92
02/07/2008	21/08/2008	28		10.38	5.19	
02/07/2008	21/08/2008	28		11.30	5.65	

Table(4.27) Results of splitting strength grade15 : 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)
24/07/2008	21/08/2008	28	14.60	146.00	2.07	2.11
02/07/2008	21/08/2008	28	13.11	138.00	1.95	
02/07/2008	21/08/2008	28	14.20	163.00	2.31	

Table(4.28): Results of tensile strength for grade 15 @28dayes

Test specification	Mix type			
	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

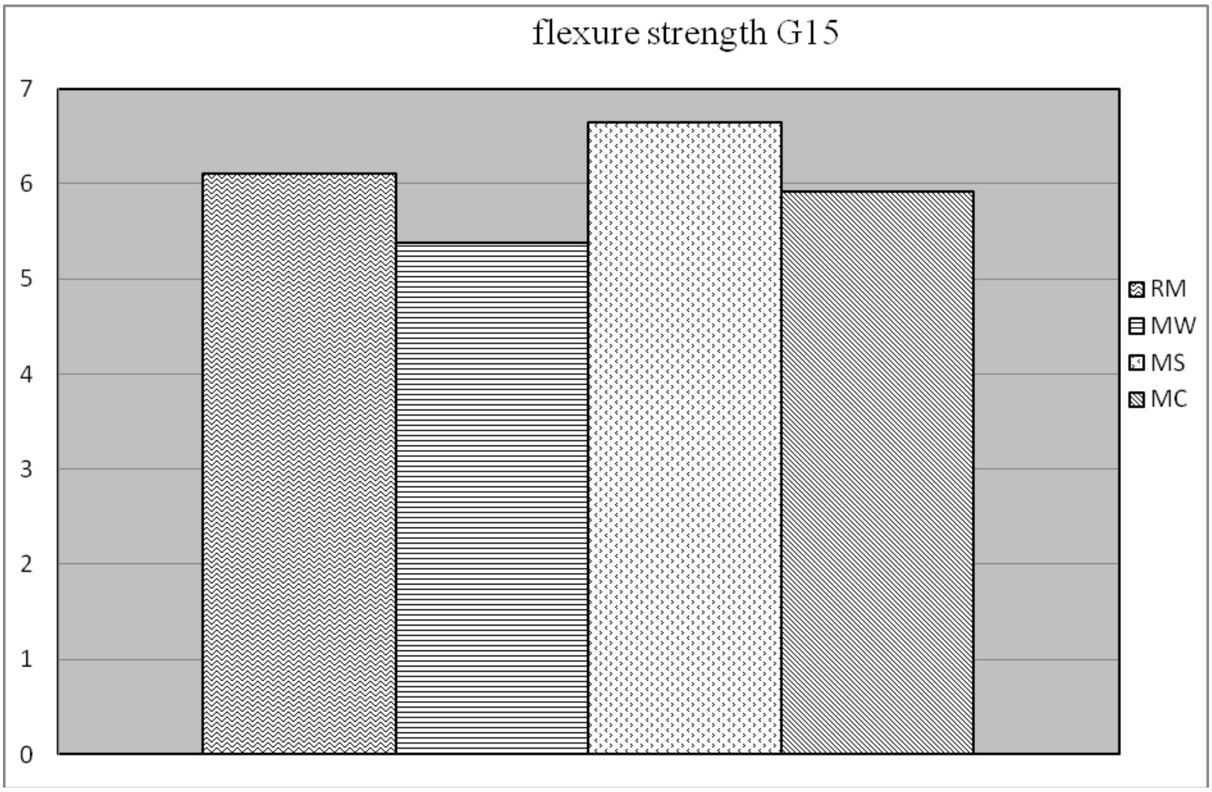

Fig (4.4) flexure strength Development for different mixes grade 15

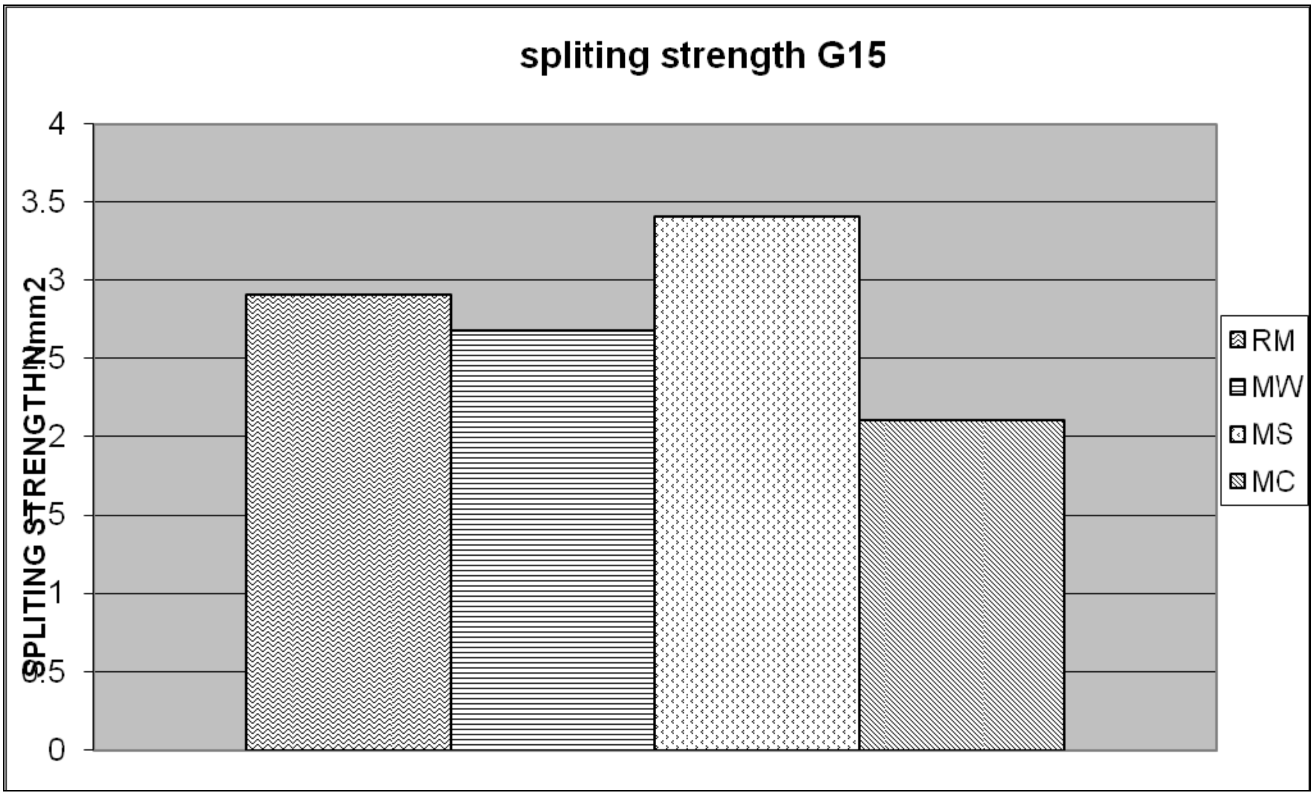

Fig (4.5) splitting strength Development for different mixes grade 15

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 (N/mm^2)
21/05/2008	18/06/2008	28		13.83	6.92	7.19
21/05/2008	18/06/2008	28		16.14	8.07	
21/05/2008	18/06/2008	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)
21/05/2008	18/05/2008	28	14.24	167.80	2.38	2.40
21/05/2008	18/05/2008	28	14.12	173.00	2.45	
21/05/2008	18/05/2008	28	14.20	169.00	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)
22/05/2008	19/06/2008	28		12.68	6.34	6.26
22/05/2008	19/06/2008	28		12.68	6.34	
22/05/2008	19/06/2008	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)
22/05/2008	19/06/2008	28	14.24	164	2.32	2.33
22/05/2008	19/06/2008	28	14.12	151	2.13	
22/05/2008	19/06/2008	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)
15/06/2008	13/07/2008	28		15.91	7.95	8.34
15/06/2008	13/07/2008	28		17.06	8.53	
15/06/2008	13/07/2008	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)
15/06/2008	13/07/2008	28	14.44	295.80	4.18	3.86
15/06/2008	13/07/2008	28	14.48	244.90	3.46	
15/06/2008	13/07/2008	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)
03/08/2008	31/08/2008	28		13.84	7.95	8.33
03/08/2008	31/08/2008	28		10.38	8.53	
03/08/2008	31/08/2008	28		11.30	8.53	

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

Date of cast	Date of test	Age (days)	weight (Kg)	Load (KN)	Splitting strength (N/mm^2)	Mean strength (N/mm^2)
03/08/2008	31/08/2008	28	14.44	294.00	4.18	3.86
03/08/2008	31/08/2008	28	14.48	244.90	3.46	
03/08/2008	31/08/2008	28	14.7	277.60	3.93	

Table(4.37): Results of tensile strength for grade 25@28days

Test specification	Mix type			
	Ref mix	mix to increase workability	mix to increase strength	mix to reduce cement content
Flexure strength (N/mm^2)	7.19	6.26	8.34	8.34
Splitting strength (N/mm^2)	2.41	2.34	3.86	3.86

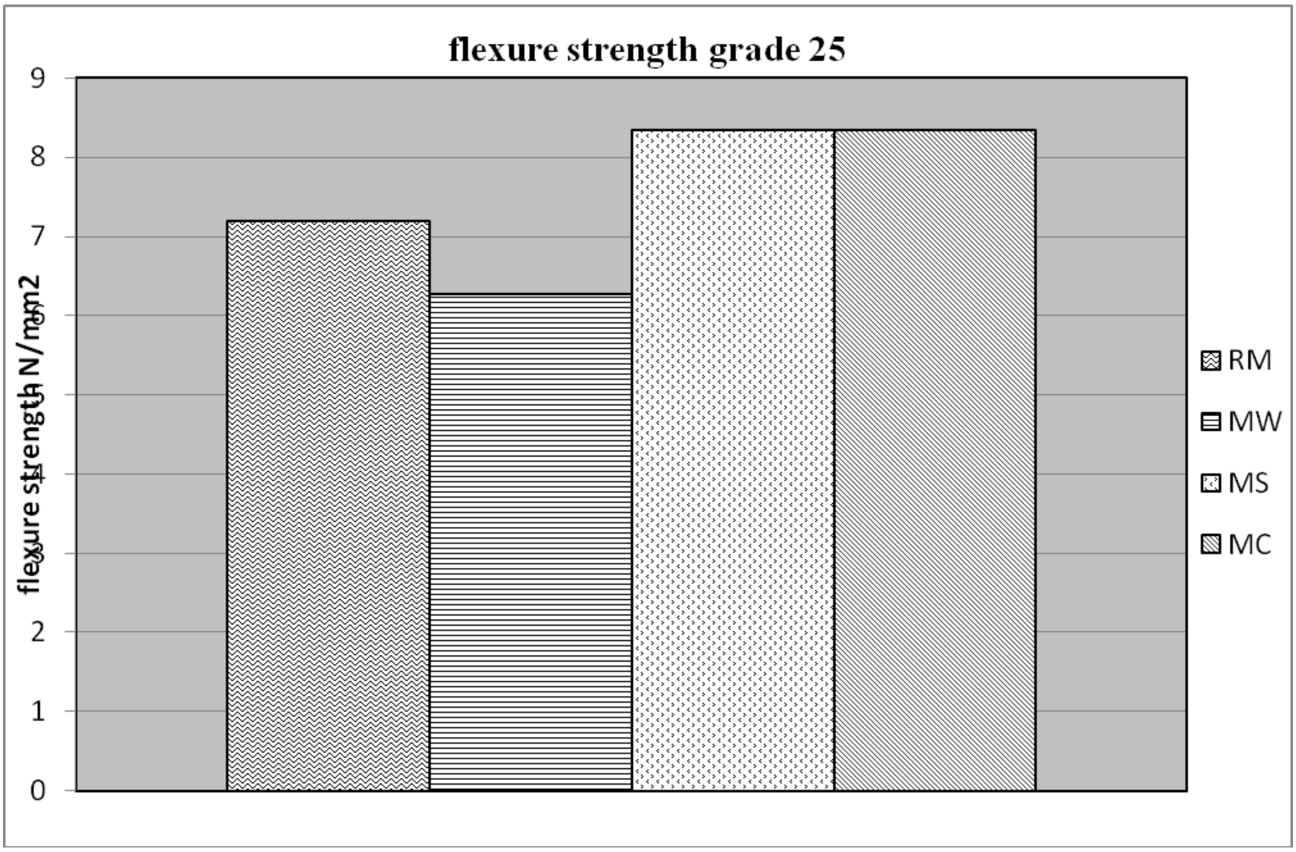

Fig (4.6) flexure strength Development for different mixes grade 25

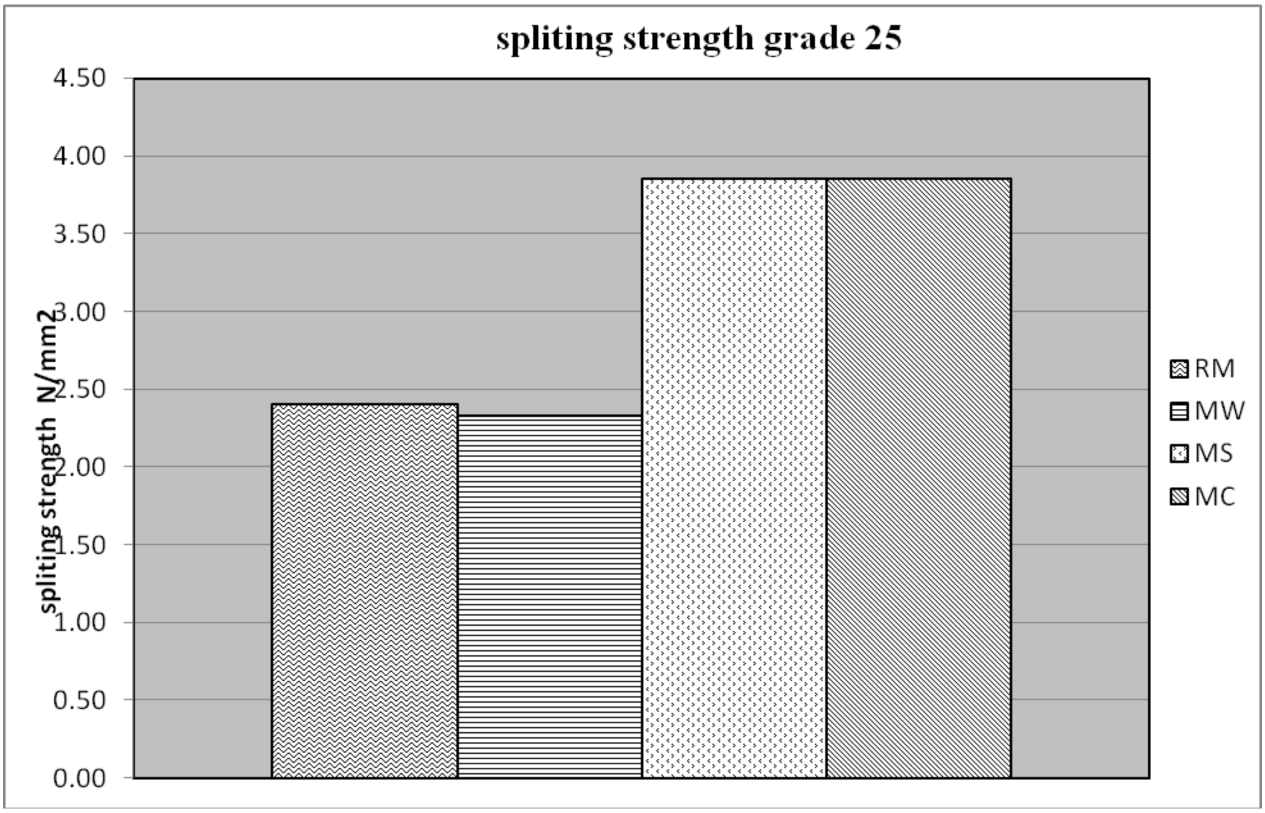

Fig (4.7) splitting strength Development for different mixes grade 25

Table(4.38) Results of flexure strength grade40 : Reference mix (RM)

Date of cast	Date of test	Age (days)	Weight (Kg)	Load (KN)	Flexural strength (N/mm^2)	Mean strength (N/mm^2)
26/05/2008	23/06/2008	28		18.00	9.00	8.77
26/05/2008	23/06/2008	28		16.83	8.41	
26/05/2008	23/06/2008	28		17.76	8.88	

Table(4.39) Results of splitting strength grade 40 : 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)
26/05/2008	23/06/2008	28	14.38	243.10	3.44	3.43
26/05/2008	23/06/2008	28	14.41	256.40	3.63	
26/05/2008	23/06/2008	28	14.40	227.80	3.22	

Table(4.40) Results of flexure strength grade 40: 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)
28/05/2008	25/06/2008	28		14.98	7.49	8.07
28/05/2008	25/06/2008	28		16.14	8.07	
28/05/2008	25/06/2008	28		17.29	8.64	

Table(4.41) Results of splitting strength grade 40 : 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)
28/05/2008	25/06/2008	28	14.52	290	4.11	3.54
28/05/2008	25/06/2008	28	14.26	230	3.26	
28/05/2008	25/06/2008	28	14.25	230	3.26	

Table(4.42) Results of flexure strength grade 40 : 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)
10/06/2008	08/07/2008	28		19.83	9.92	9.76
10/06/2008	08/07/2008	28		19.37	9.69	
10/06/2008	08/07/2008	28		19.37	9.69	

Table(4.43) Results of splitting strength grade 40 :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)
10/06/2008	08/07/2008	28	14.60	296.20	4.19	4.07
10/06/2008	08/07/2008	28	14.32	285.30	4.03	
10/06/2008	08/07/2008	28	14.59	281.70	3.98	

Table(4.44) Results of flexure strength grade40: Mix with admixture to reduce cement content (CrM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Flexural strength N/mm^2	Mean strength (N/mm^2)
02/07/2008	30/07/2008	28		13.84	6.92	5.92
02/07/2008	30/07/2008	28		10.38	5.19	
02/07/2008	30/07/2008	28		11.30	5.65	

table(4.45) Results of splitting strength grade40 : Mix with admixture To reduce cement content (CrM)

Date of cast	Date of test	Age (Days)	Weight (Kg)	Load (KN)	Splitting strength N/mm^2	Mean strength (N/mm^2)
02/07/2008	30/07/2008	28	14.60	294.00	4.16	3.85
02/07/2008	30/07/2008	28	13.11	244.90	3.47	
02/07/2008	30/07/2008	28	14.20	277.60	3.92	

Table(4.46): Results of tensile strength for grade 40 @28days

Test specification	Mix type			
	Ref mix	mix to increase workability	mix to increase strength	mix to reduce cement content
Flexure strength (N/mm^2)	8.77	8.07	9.76	5.96
Splitting strength (N/mm^2)	3.43	3.54	4.07	3.85

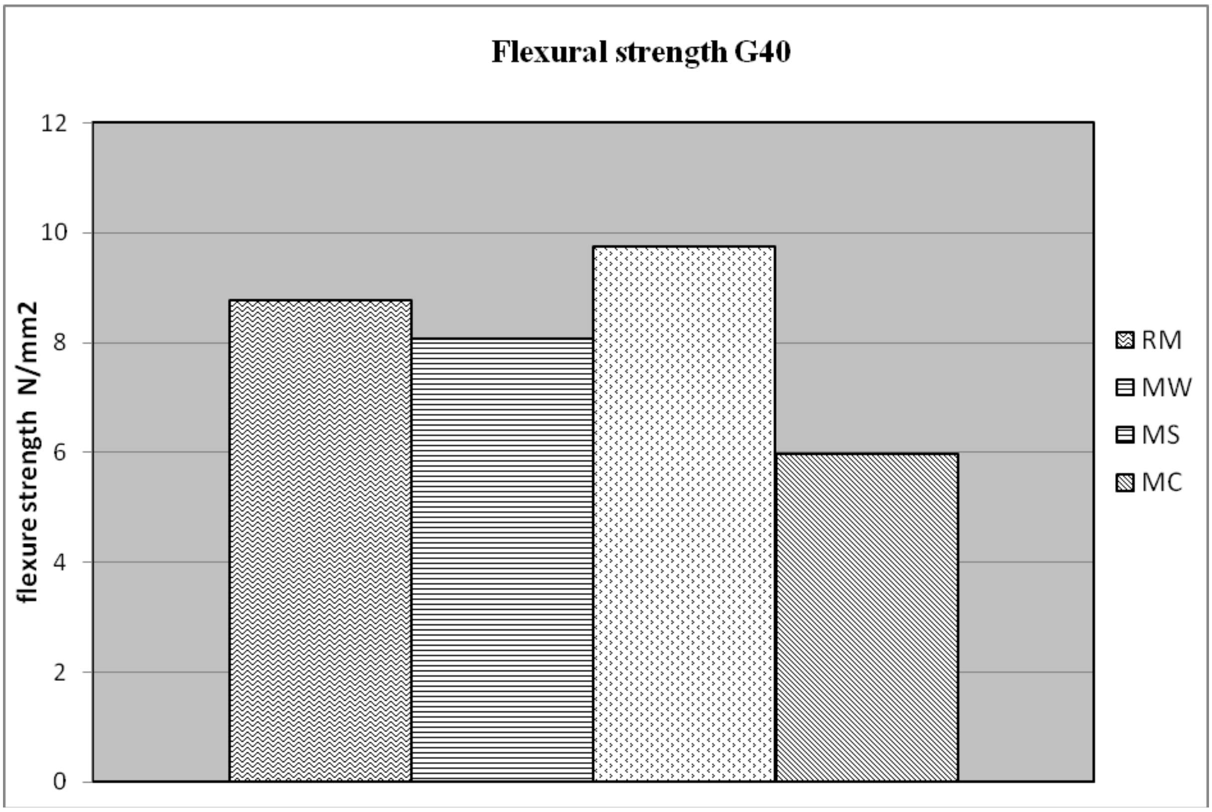

Fig (4.8) flexure strength Development for different mixes grade 40

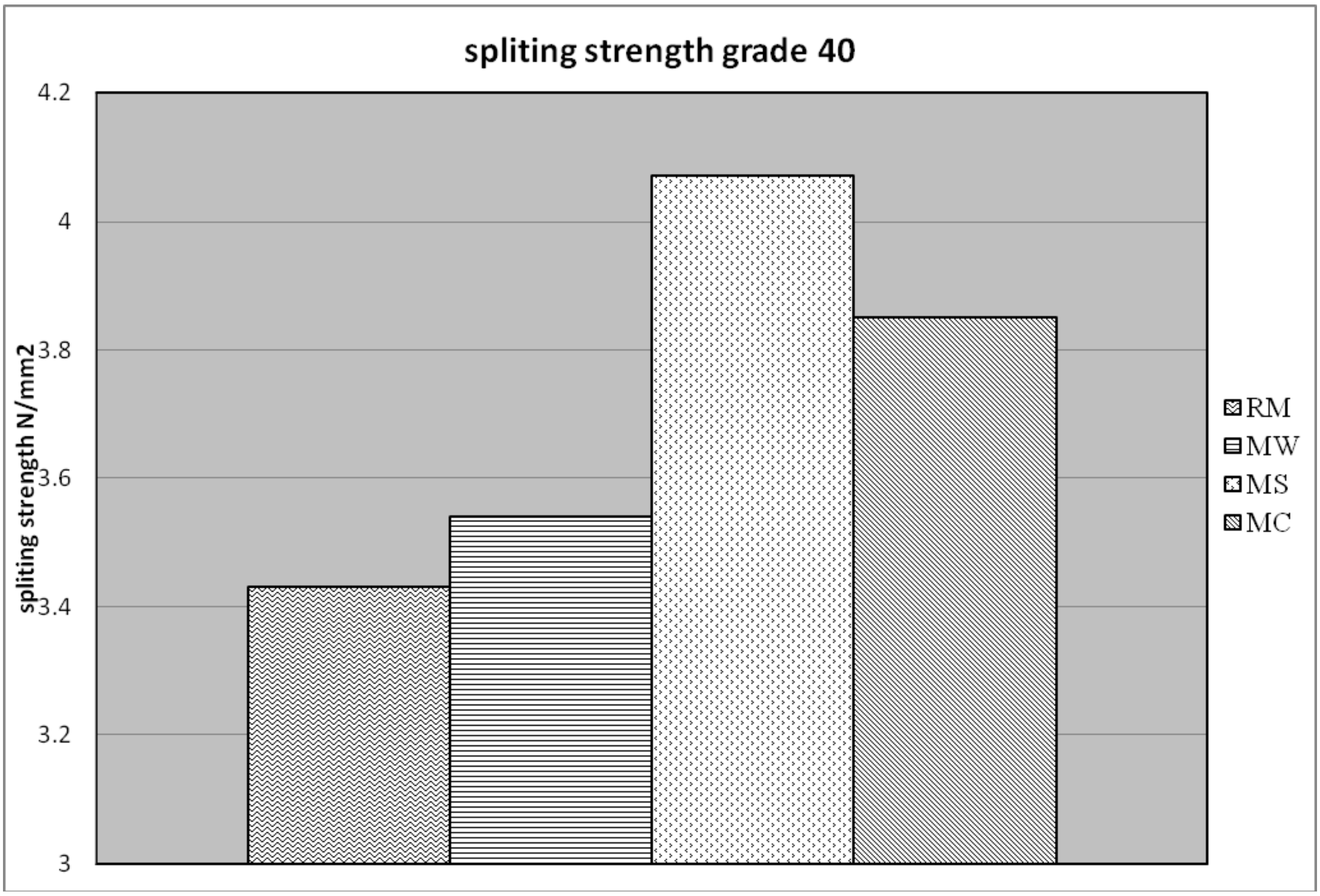

Fig (4.9) splitting strength Development for different mixes grade 40

4 -3 Test results discussion:

4-3-1 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.

4-3-1-1 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.

4-3-1-2 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.

4-3-1-3 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 15

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

Grade 25

Mix type	(RM)	(WrM)	(StM)	(CrM)
SLUMP/mm	60	185	40	80

Grade 40

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 (15, 25, and 40) 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 15:
<u>Crushing strength of concrete containing</u>
<u>Admixtures as compared to ordinary concrete</u>

	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:
<u>Crushing strength of concrete containing</u>
<u>Admixtures as compared to ordinary concrete</u>

	Strength as percentage of reference mix			
Ages/days Mix type	7	14	28	90
(WrM)	133	128	127	123
(StM)	155	142	132	126
(CrM)	90	93	95	102

Table (4.49): Grade 40:
<u>Crushing strength of concrete containing</u>
<u>Admixtures as compared to ordinary concrete</u>

	Strength as percentage of reference mix			
Ages/days / Mix type	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 15.
    b) (23 – 33)% for grade 25.
    c) (9 – 12)% for grade 40.

- For the three grades increased ratio of strength in mixes (StM) was in the range of :
    a) (28 – 33)% for grade 15.
    b) (32 – 55)% for grade 25.
    c) (19 – 28)% for grade 40.

- For the three grades ratio of strength in mixes (CrM) was in the range of :
    a) (.8 – .92)% for grade 15.
    b) (.9 – .95)% for grade 25.
    c) (.94 – 10)% for grade 40.

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 15 and last grade 40 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 15

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 40:

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 (15 x 30) cylinders for the four concrete mixes of each grade and the observations are as follow:

I. Grade 15:

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 40:

(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 (15,25, and 40) 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 (15&25) and (2lt/100kg cemntious material) for grade 40 .

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

To the total cost of the cement content Per cubic meter for each grade

Concrete grade No	Cost of reduced cement per cubic meter (SDG)	Cost of super plasticizer admixture per cubic meter (SDG)	Percentage saved of the reduced cement
15	37	22.5	8.9%
25	44.5	27	8.9%
40	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 = (cost of reduced cement- cost of admixture) / (Cost of the total cement content)

CHAPTER FIVE

CONCLUSIONS AND RECOMONDATIONS

5-1 CONCLUSIONS

The results from the various testes for the three grades (15, 25, and 40) conducted on the fresh and hardened state of concrete mixes lead to the following observations:

Super plasticizers admixtures improve the workability without increasing water demand, for the three grades of concrete no decreasing in compressive strength was observed.

Super plasticizers admixtures provide an increasing in ultimate strength gain by significantly reducing water demand in a concrete mix for the three grades, without affecting workability.

Super plasticizers admixtures reduce cement content up to 23%for the three grades without reducing the compressive strength and no effect on workability.

Super plasticizers admixtures provide improved durability by increasing ultimate strength and reducing w/c ratio.

Super plasticizers admixtures save cost of the reduced cement of about (4.5 – 8.9)% per cubic meter for the three grades of concrete.

5-2 Recommendations

1. Further researches using admixtures should be conducted on concrete mixes with low and high workability.
2. Further researches should be conducted on grades above 40N/mm^2.
3. More studies have to be carried on the effect of using super plasticizers admixtures on the percentage reduced of cement content on the concrete mixes .
4. More studies has to be carried on the effect of using admixtures in concrete mixes in the aggressive environment of Sudan to improve concrete properties such as strength, workability, durability, shrinkage, creep,…..etc.
5. Further researches has to carried here in Sudan to determine how concrete companies accept using concrete admixtures as a material to improves many properties of concrete especially those concern with the hot weather of Sudan.

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APPENDICES

Concrete mix design form

Stage	item	Reference or calculation	values
1.	1.1 characteristic strength	Specified	**25** N/mm^2 at **28** days Proportion defective **5** percent
	1.1 standard deviation	Fig 3	**8** N/mm^2 or no data N/mm^2
	1.2 margin	C1	**(k= 1.64)** × **8** = **13** N/mm^2
	1.3 target mean strength	C2	**25 + 13** = **38** N/mm^2
	1.4 cement type	Specified	**OPC**
	1.5 aggregate type: coarse aggregate type: fine		**Crushed** **Uncrushed**
	1.6 free-water/cement ratio	Table2 fig4	**0.58** use the lower value
	1.7 maximum free- water /cement ratio	specified	______
2.	2.1 slump or V- B	Specified	Slump **30- 60mm** or **medium**
	2.2 maximum aggregate size	Specified	**20** mm
	2.3 free water content	Table 3	**210** kg/m^3
3.	3.1 cement content	C3	**210 ÷ 0.58 = 362** kg/m^3
	3.2 maximum cement content	Specified	= kg/m^3
	3.3 minimum cement content	Specified	kg/m^3 use if greater than item 3.1 and calculate item 3.4
	3.4 modified free- water/cement ratio		
4.			
	4.1 relative density of aggregate (SSD)		**2.7** known/assume
	4.2 concrete density		
	4.3 total aggregate content	Fig 5 C4	**2400** kg/m^3 **2400 – 362 – 210 = 1828** kg/m^3
5	5.1 Grading of fine aggregate	BS882	Zone **3**
	5.2 Proportion of fine aggregate	Fig 6	**35** per cent
	5.3 Fine aggregate content	C5	**1828 × 0.35 = 640** kg/m^3
	5.4 Coarse aggregate content		**1828– 6402 = 1188** kg/m^3

	Quantities	Cement (kg)	Water (kg)	fine aggregate (kg)	coarse aggregate (kg)
	Per m^3 **(**to nearest 5 kg)	**360**	**210**	**640**	**1190**

Concrete mix design form

Stage	item	Reference or calculation	values
1.	1.1 characteristic strength	Specified	**40** N/mm² at **28** days Proportion defective **5** percent
	1.2 standard deviation	Fig 3	8 N/mm² or no data N/mm²
	1.3 margin	C1	**(k= 1.64)** × **8** = **13** N/mm²
	1.4 target mean strength	C2	**40 + 13 = 53** N/mm²
	1.5 cement type	Specified	**OPC**
	1.6 aggregate type: coarse aggregate type: fine		**Crushed** **Uncrushed**
	1.7 free-water/cement ratio	Table2 fig4	**0.46** use the lower value
	1.8 maximum free- water /cement ratio	specified	_____
2	2.1 slump or V- B	Specified	Slump **30- 60mm** or **medium**
	2.2 maximum aggregate size	Specified	**20** mm
	2.3 free water content	Table 3	**210** kg/m³
	3.1 cement content	C3	**210 ÷ 0.46 = 456** kg/m³
	3.2 maximum cement content	Specified	= kg/m³
	3.3 minimum cement content	Specified	kg/m³ use if greater than item 3.1 and calculate item 3.4
	3.4 modified free- water/cement ratio		
4	4.1 relative density of aggregate (SSD)		**2.7** known/assume
	4.2 concrete density		
	4.3 total aggregate content	Fig 5	**2400** kg/m³
		C4	**2400 – 456 – 210 = 1734** kg/m³
5	5.1 Grading of fine aggregate	BS882	Zone **3**
	5.2 Proportion of fine aggregate	Fig 6	**33** per cent
	5.3 Fine aggregate content	C5	**1734 × 0.33 = 572** kg/m³
	5.4 Coarse aggregate content	C5	**1734 – 572 = 1162** kg/m³

	Quantities	Cement (kg)	Water (kg)	fine aggregate (kg)	coarse aggregate (kg)
	Per m³ (to nearest 5 kg)	**455**	**210**	**570**	**1162**

Concrete mix design form

Stage	item	Reference or calculation	values
1	1.1 characteristic strength	Specified	**15** N/mm^2 at **28** days Proportion defective **5** percent
	1.1 standard deviation	Fig 3	**8** N/mm^{2}or no data N/mm^2
	1.2 margin	C1	**(k= 1.64) × 8 = 13** N/mm^2
	1.3 target mean strength	C2	**15 + 13 = 38** N/mm^2
	1.4 cement type	Specified	**OPC**
	1.5 aggregate type: coarse aggregate type: fine		**Crushed** **Uncrushed**
	1.6 free-water/cement ratio	Table2 fig4	**0.7** use the lower value
	1.7 maximum free- water /cement ratio	specified	_____
2	2.1 slump or V- B	Specified	Slump **30- 60mm** or **medium**
	2.2 maximum aggregate size	Specified	**20** mm
	2.3 free water content	Table 3	**210** kg/m^3
3	3.1 cement content	C3	**210 ÷ 0.7 = 300** kg/m^3
	3.2 maximum cement content	Specified	= kg/m^3
	3.2 minimum cement content	Specified	kg/m^3 use if greater than item 3.1 and calculate item 3.4
	3.3 modified free- water/cement ratio		
4	4.1 relative density of aggregate (SSD)		**2.7** known/assume
	4.2 concrete density	Fig 5	**2400** kg/m^3
	4.3 total aggregate content	C4	**2400 – 300 – 210 = 1890** kg/m^3
5	5.1 Grading of fine aggregate	BS882	Zone **3**
	5.2 Proportion of fine aggregate	Fig 6	**37** per cent
	5.3 Fine aggregate content	C5	**1890 × 0.37 = 699** kg/m^3
	5.4 Coarse aggregate content		**1890 – 699 = 1191** kg/m^3

	Quantities	Cement (kg)	Water (kg)	fine aggregate (kg)	coarse aggregate (kg)
	Per m^3(to nearest 5 kg)	**360**	**210**	**640**	**1190**

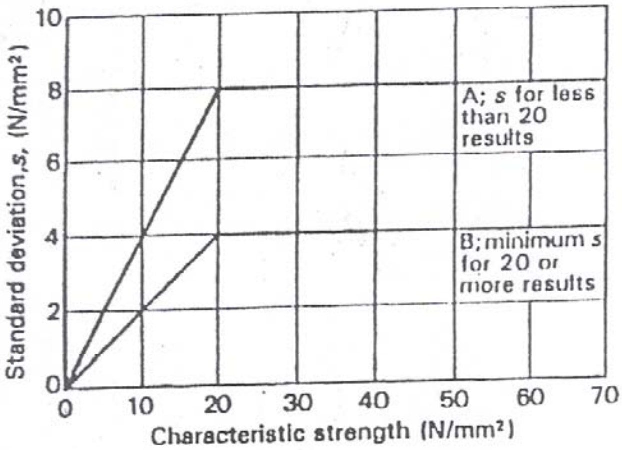


Figure 3
Relationship between standard deviation and characteristic strength

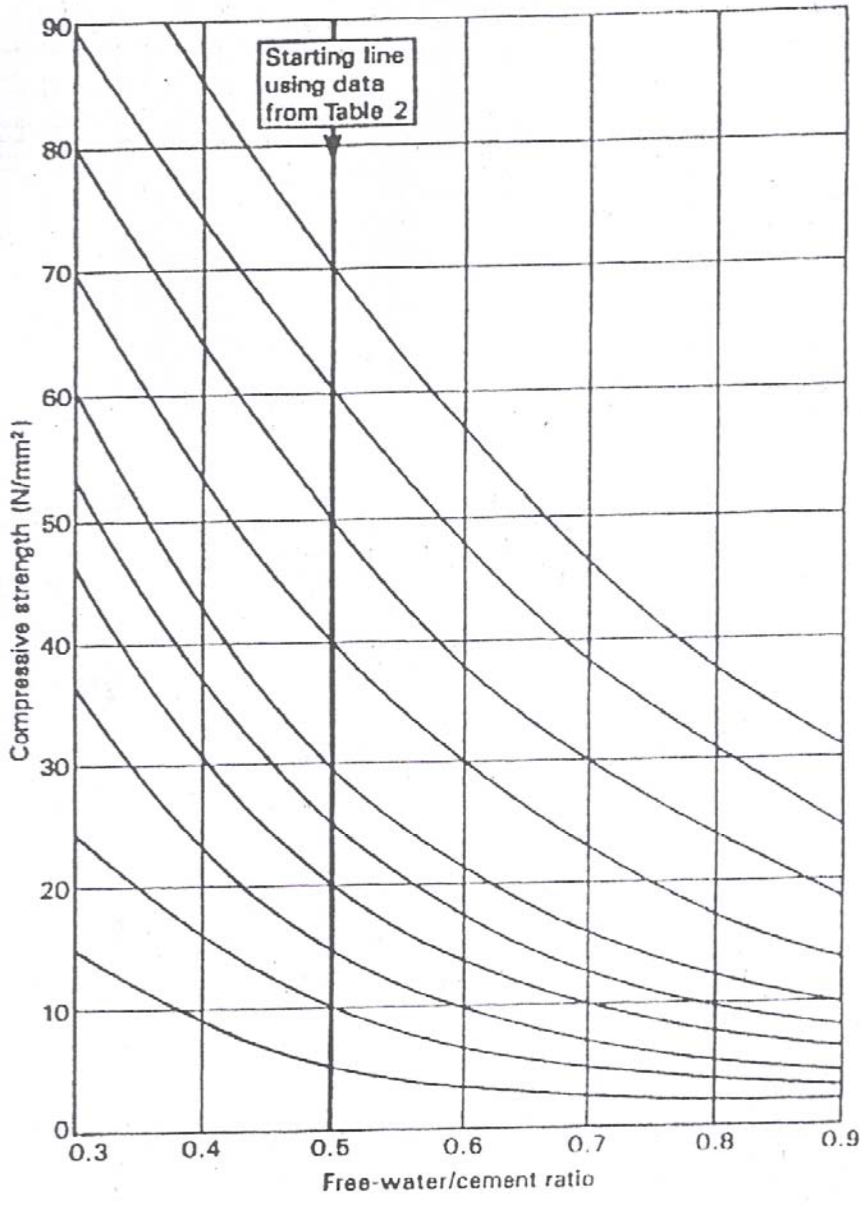


Figure 4
Relationship between compressive strength and free-water/cement ratio

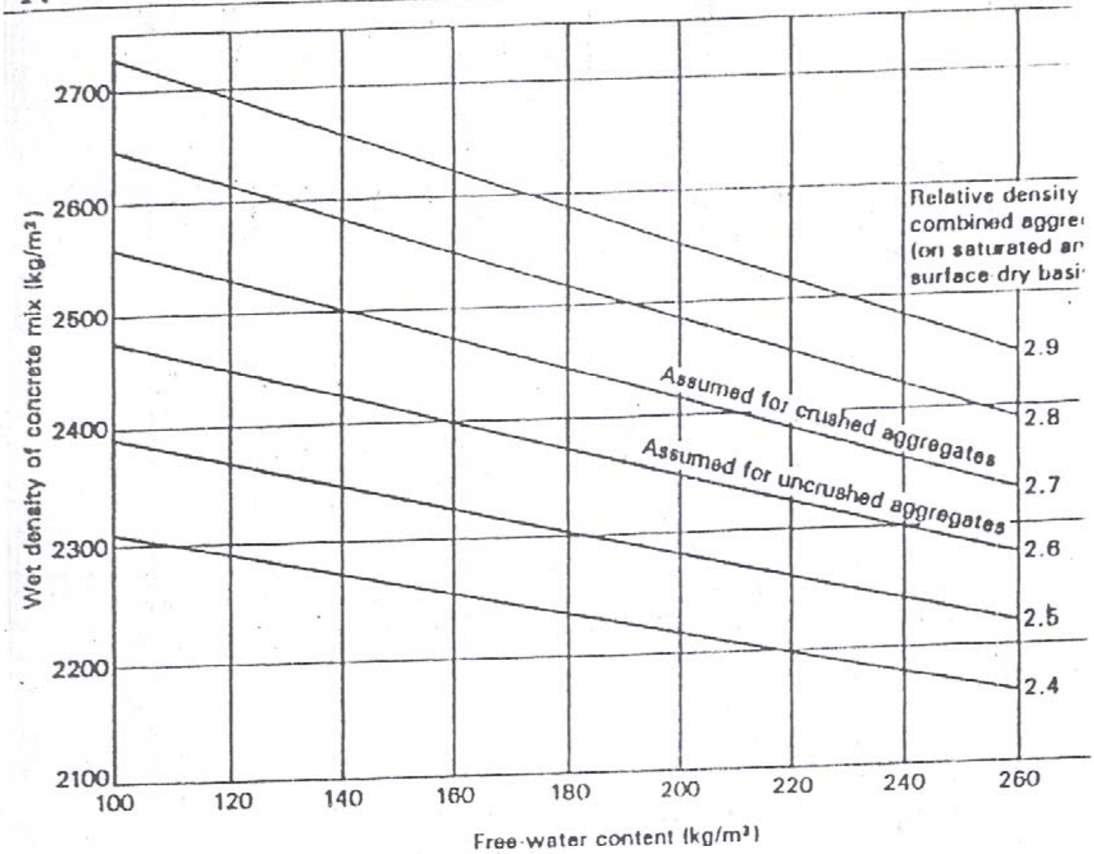


Figure 5 Estimated wet density of fully compacted concrete

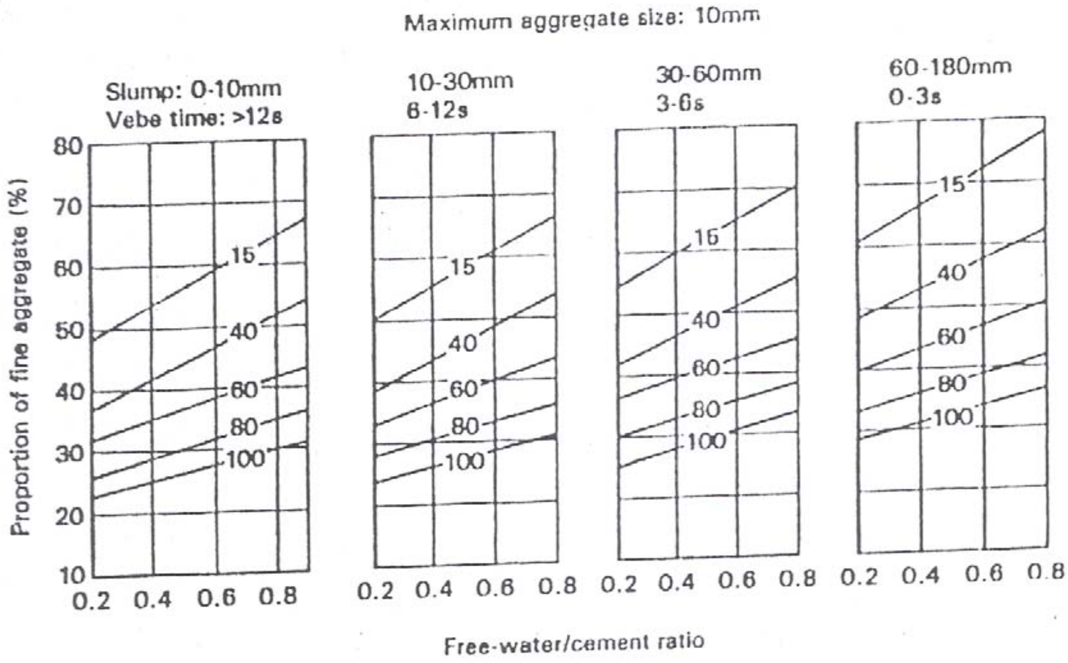
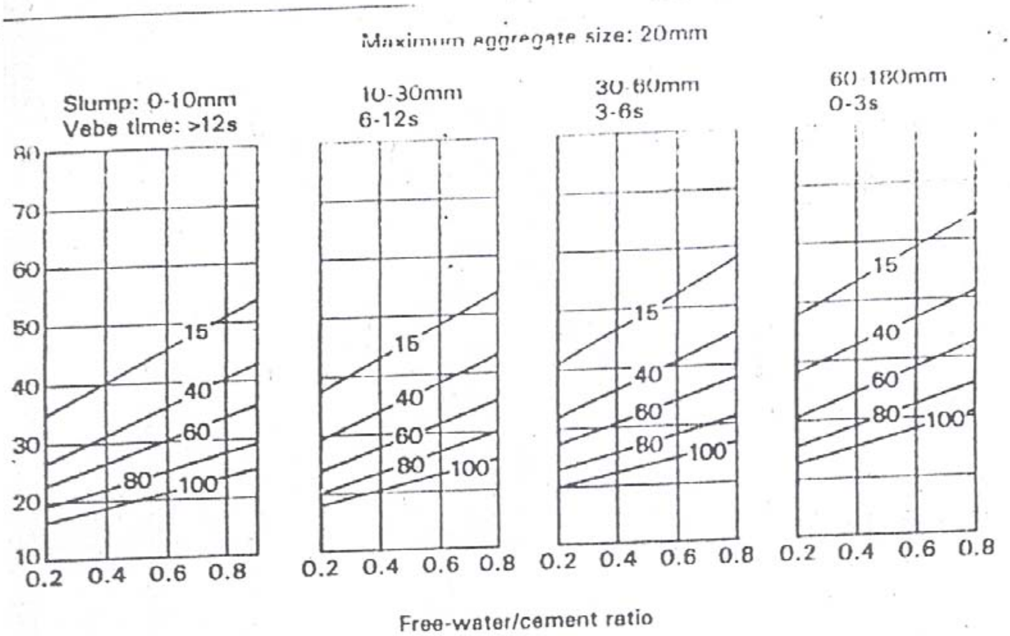


Figure 6 Recommended proportions of fine aggregate according to percentage passing a 600 μm sieve



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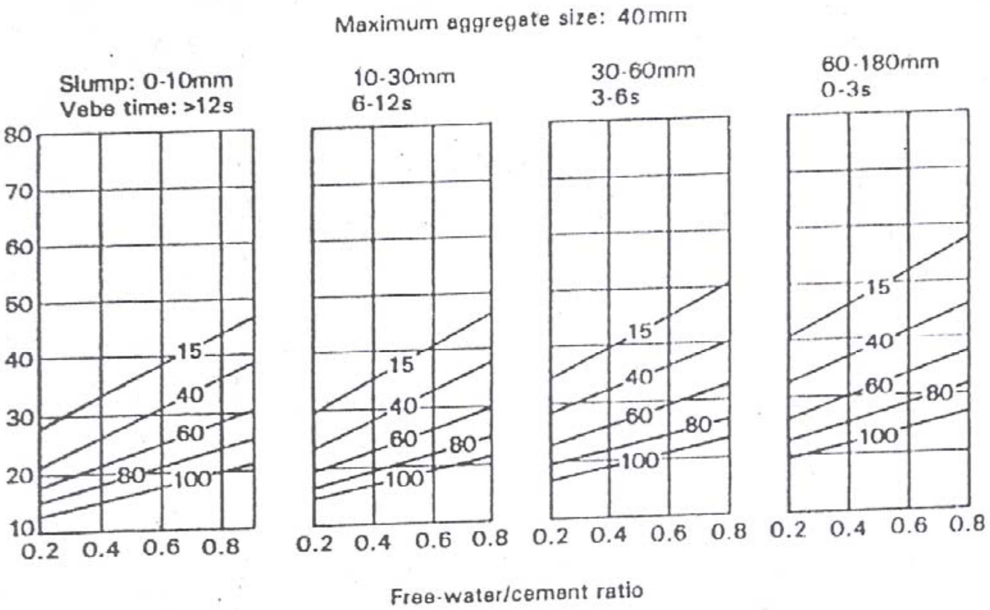

e 6 (continued)

Table 19.3: **Approximate compressive strengths of concrete mixes made with a free water/cement ratio of 0.5 according to the 1986 British method**

Type of cement	Type of coarse aggregate	Compressive strength* (MPa (psi)) at an age of (days):			
		3	7	28	91
Ordinary Portland (Type I) Sulphate-resisting Portland (Type V)	Uncrushed	22 (3200)	30 (4400)	42 (6100)	49 (7100)
	Crushed	27 (3900)	36 (5200)	49 (7100)	56 (8100)
Rapid-hardening Portland (Type III)	Uncrushed	29 (4200)	37 (5400)	48 (7000)	54 (7800)
	Crushed	34 (4900)	43 (6200)	55 (8000)	61 (8900)

* Measured on cubes.
Building Research Establishment, Crown copyright

Aggregate		Water content kg/m³; (lb/yd³) for:				
Max. size mm (in.)	Type	Slump mm (in.)	0–10 (0–½)	10–30 (½–1)	30–60 (1–2½)	60–180 (2½–7)
		Vebe s	>12	6–12	3–6	0–3
10 (⅜)	Uncrushed		150 (255)	180 (305)	205 (345)	225 (380)
	Crushed		180 (305)	205 (345)	230 (390)	250 (420)
20 (¾)	Uncrushed		135 (230)	160 (270)	180 (305)	195 (330)
	Crushed		170 (285)	190 (320)	210 (355)	225 (380)
40 (1½)	Uncrushed		115 (195)	140 (235)	160 (270)	175 (295)
	Crushed		155 (260)	175 (295)	190 (320)	205 (345)

Conplast SP432MS*

constructive solutions

High performance superplasticising admixture

Uses

- To provide increased ultimate strength gain by significantly reducing water demand in a concrete mix
- To significantly improve the workability and retention of site mixed concrete without increasing water demand.
- To provide improved durability by increasing ultimate strengths and reducing concrete permeability.
- Specifically developed for use in high quality concrete mixes utilising cement replacements.

Advantages

- Makes possible major reductions in water:cement ratio which allows the production of high strength concrete without excessive cement contents.
- Increased workability levels are maintained for longer than with ordinary sulphonated melamine and napthalene admixtures.
- Improved cohesion and particle dispersion minimises segregation and bleeding and improves pumpability.
- Chloride free, safe for use in prestressed and reinforced concrete.

Standards compliance

Conplast SP432MS conforms with BSEN 934-2 & ASTM C494 Type B, D and G, depending on dosage used.

Description

Conplast SP432MS is a chloride free, superplasticising admixture based on selected sulphonated napthalene polymers. It is supplied as a brown solution which instantly disperses in water.

Conplast SP432MS disperses the fine particles in the concrete mix, enabling the water content of the concrete to perform more effectively. The very high levels of water reduction possible allow major increases in strength to be obtained.

Technical support

Fosroc offers a comprehensive technical support service to specifiers, end users and contractors. It is also able to offer on-site technical assistance, an AutoCAD facility and dedicated specification assistance in locations all over the world.

Dosage

The optimum dosage of Conplast SP432MS to meet specific requirements should always be determined by trial mixes using the materials and conditions that will be experienced in use.

For high strength, water reduced concrete, the normal dosage range is from 1.0 to 2.5 litres/100kg of cementitious material, including PFA, GGBFS and microsilica.

Use at other dosages

Dosages outside the typical ranges quoted above can be used to meet particular requirements, Contact Fosroc for advice.

Effects of overdosing

An overdose of double the amount of Conplast SP432MS will result in an increase in retardation as compared to that normally obtained. Provided that adequate curing is maintained, the ultimate strength of the concrete will not be impaired by increased retardation and will generally be increased. The effects of overdosing will be further increased if sulphate resisting cement or cement replacement materials are used.

Properties

Appearance	:	Brown liquid
Specific gravity (BSEN 934-2)	:	1.19 @ 22°C + 2°C
Water soluble chlorides (BSEN 934-2)	:	Nil
Alkali content (BSEN 934-2)	:	Typically less than 50g. Na_2O equivalent/litre of admixture

Instructions for use

Mix design

Where the main requirement is to improve strengths, initial trials should be made with normal concrete mix designs. The addition of the admixture will allow the removal of water from the mix whilst maintaining workability. After initial trials, minor modifications to the overall mix design may be made to optimise performance.

Where the main requirement is to provide high workability concrete, the mix design should be one suitable for use as a pump mix. Advice on mix design for flowing concrete is available from Fosroc.

Conplast SP432MS*

Compatibility

Conplast SP432MS is compatible with other Fosroc admixtures used in the same concrete mix. All admixtures should be added to the concrete separately and must not be premixed together prior to addition. The resultant properties of concrete containing more than one admixture should be assessed by trial mixes.

Conplast SP432MS is suitable for use with all types of Portland cements, SRC cements and cement replacement materials such as PFA, GGBFS and microsilica.

The use of a combination of admixtures in the same concrete mix and or cement replacements may alter the setting time. Trials should always be conducted to determine such setting times.

Dispensing

The correct quantity of Conplast SP432MS should be measured by means of a recommended dispenser. Normally, the admixture should then be added to the concrete with the mixing water to obtain the best results. Where high workability concrete is required from normal workability concrete delivered to site, Conplast SP432MS may also be added to concrete direct into a readymix truck. Full blending of the admixture and the concrete should be ensured by mixing at high speed for a period of at least two minutes.

Contact Fosroc for advice regarding suitable equipment and its installation.

Estimating - packaging

Conplast SP432MS is available in 210 litre drums or bulk supply. For larger users, storage tanks can be supplied.

Storage

Conplast SP432MS has a minimum shelf life of 12 months provided the temperature is kept within the range of 2°C to 50°C. Should the temperature of the product fall outside this range contact Fosroc for advice.

Freezing point: Approximately -2°C

Precautions

Health and safety

Conplast SP432MS does not fall into the hazard classifications of current regulations. However, it should not be swallowed or allowed to come into contact with skin and eyes.

Suitable protective gloves and goggles should be worn.

Splashes on the skin should be removed with water. In case of contact with eyes rinse immediately with plenty of water and seek medical advice. If swallowed seek medical attention immediately - **do not** induce vomiting.

For further information consult the Material Safety Data Sheet available for this product.

Fire

Conplast SP432MS is water based and non-flammable.

Cleaning and disposal

Spillages of Conplast SP432MS should be absorbed onto sand, earth or vermiculite and transferred to suitable containers. Remnants should be hosed down with large quantities of water.

The disposal of excess or waste material should be carried out in accordance with local legislation under the guidance of the local waste regulatory authority.

Additional information

Conplast SP432MS is a retarded version of Conplast SP430*†

*** Denotes the trademark of Fosroc International Limited**

† See separate data sheet

Important note

Fosroc products are guaranteed against defective materials and manufacture and are sold subject to its standard Conditions for the Supply of Goods and Service

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