

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction:

The feasibility of structures has always depended on the available materials, the level of construction technology, and the state of development of the services necessary for the use of the building. The most widely used construction material is concrete, commonly made by mixing cement with sand, aggregate, water, and sometimes admixture. In recent time concrete made in manufactures (ready mix) to control concrete materials and its quality which depends on the workmanship and placing. Concrete has to be satisfactory in its fresh state while being transported from the mixer and placed in the formwork of structural element and in its hardened state that usual requirement satisfactory in compressive strength. In this chapter concrete materials: cement, aggregate, mix water, and admixture were presented. Also fresh and hardened properties, tests in fresh and hardened states, and mix design were presented. [2]

2.2 Cement:

Cement in the general sense of the word, can be described as a material with adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact whole. This definition embraces a large variety of cementing materials.

For construction purposes the meaning of the term, cement is restricted to the bonding materials used with stones, sand, bricks and building blocks. The principal constituents of cement are compounds of lime, so that in building and civil engineering are concerned with calcareous cement. The cements of interest in the making of concrete have the property of setting and hardening underwater by virtue of a chemical action with it. [2]

2.2.1 Portland cement:

Definition:

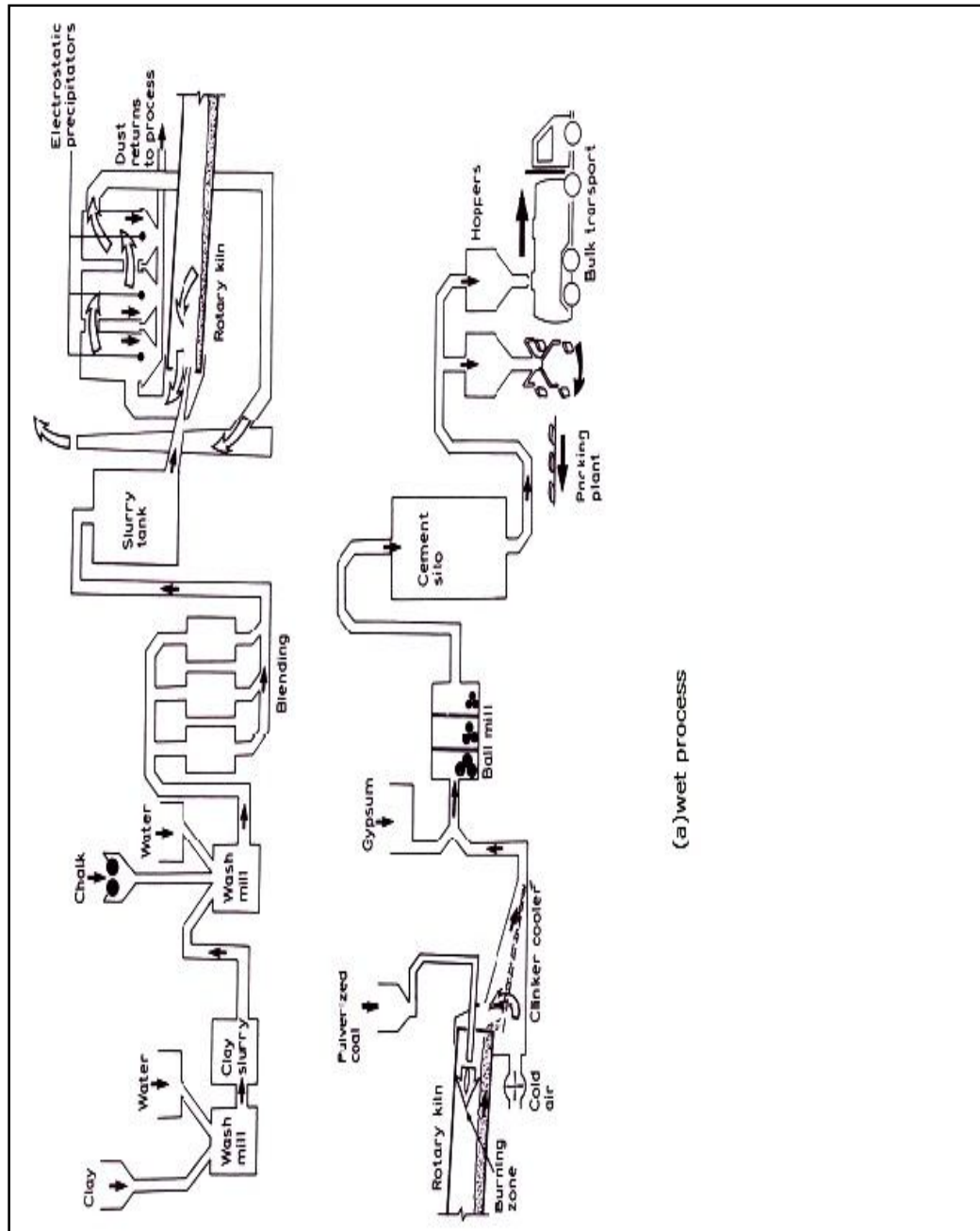
Portland cement has become one of the most important construction materials during the last 150 years or so, primarily because concretes can be used advantageously for so many different purposes. It is produced from an appropriate combination of a lime-containing material, such as limestone, and clayey materials by burning this mixture, then grinding the resulting clinker along with a small amount of gypsum. A typical tiny Portland cement grain consists of numerous microscopic crystals called clinker minerals, also called cement compounds. [1]

ASTM C 150 defines Portland cement as a hydraulic cement produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, and a small amount of one or more forms of calcium sulfate as an inter ground addition. Clinkers are 5- to 25-mm-diameter nodules of a sintered material that is produced when a raw mixture of predetermined composition is heated to high temperatures. [1]

- History of Portland cement manufacture:

Portland cement is essentially calcium silicate cement. The process of manufacture of cement consists essentially of grinding the raw materials, mixing them intimately in certain proportions and burning in a large rotary kiln at a temperature of up to about 1450°C when the material sinters and partially fuses in to balls known as clinker. The clinker is

cooled and ground to a fine powder, with some gypsum added, and the resulting product is the commercial Portland cement so widely used throughout the world. Some details of the manufacture of cement will now be given, and these can be best followed with reference to the diagrammatic representation of the process shown in (Figure 2.1). [2]



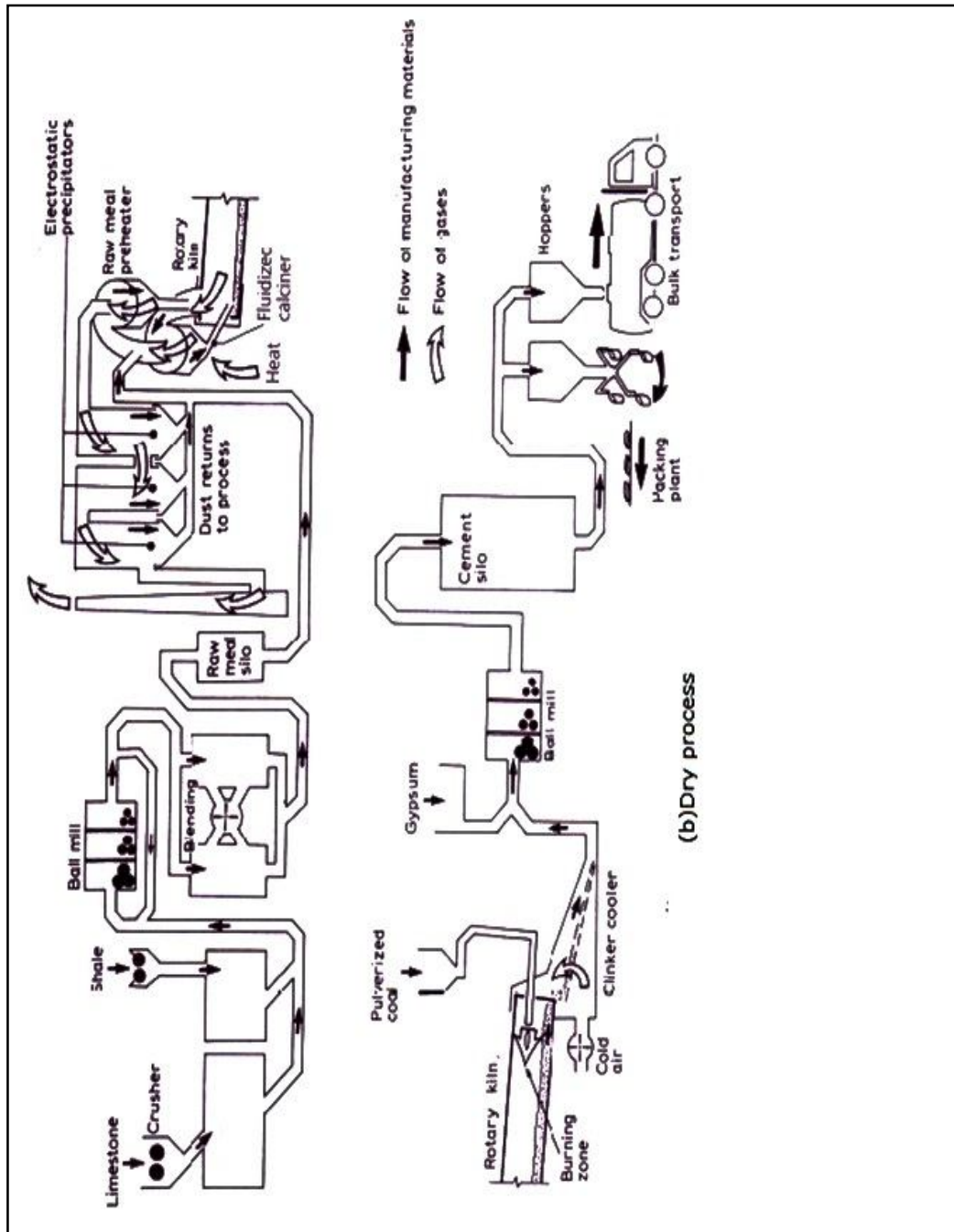


Figure 2.1 Diagrammatic representation of: (a) the wet process and (b) the dry process of manufacture of cement.[2]

2.2.2 Hydraulic and non hydraulic cements:

Cements that not only harden by reacting with water but also form a water resistant product are called hydraulic cements such as Special Portland cements (white Portland cement, colored cements, oil-well cements, rapid setting, regulated set, waterproof cements, hydrophobic cement). Compared to gypsum and lime cements, Portland cement and its various modifications are the principal cements used today for making structural concrete. [3]

Portland cement and modified Portland cements are hydraulic cements because they do not require the addition of a pozzolanic material to develop water-resisting properties. [5]

Other cements have compositions such that they cannot be considered as Portland cement:

- High-alumina cement.
- Expansive cement.
- Hydraulic lime.
- Natural cement.
- Masonry cement.
- Super sulfated cement.
- Slag cement.
- Fly ash and silica fume.

2.2.3 Cement components:

The raw materials for the manufacture of Portland cement contain, in suitable proportions;

- Silica.
- Aluminum oxide.
- Calcium oxide.
- Ferric oxide.

The source of lime is calcareous ingredients such as limestone or chalk and the source of silica and aluminum oxide are shales, clays or slates. The iron bearing materials are iron and pyrites. The cement clinker is produced by feeding the crushed, ground and screened raw mix into a rotary kiln and heating to a temperature of about 1300-1450°C.[3]

2.2.4 Major types of Portland cement:

There are two main cement types:

1. Generic types :

National (and regional) standards have specific limits for the contents of constituents and there may be several different ‘sub-types’ of cement with different levels of power station fly ash and blast furnace slag and even mixtures of slag, fly ash and limestone. In this chapter the term composite is applied to all cements containing clinker replacement materials (other than a minor additional constituent). [3]

Six major types of cement are sold in Australia:

1. Type GP (General Purpose Portland cement).
2. Type GB (General Purpose Blended cement).
3. Type HE (High Early Strength cement).
4. Type LH (Low Heat cement).
5. Type SR (Sulfate Resisting cement).
6. Type SL (Shrinkage Limited cement).

Each type of cement will produce concrete with different properties.

The most commonly used are Type GP and Type GB. Blended cements contain Portland cement and more than 5% of either fly ash, ground slag, amorphous silica (e.g. silica fume), or a combination of these. [3]

2. Other European cement standards :

The CEN committee responsible for the development of standards for cements and building limes (CEN TC 51) has produced a number of

standards for construction binders, which are close to finalization and adoption by member countries these are:

1. PrEN 413-1: Masonry cement.
2. PrEN 645: Calcium aluminates cement.
3. EN 197-1: prA1: Amendment to EN 197-1 to include low heat common cements.
4. PrEN 197-X: Low early strength blast furnace cements.
5. PrEN 14216: Very low-heat special cements.
6. EN 459-1: Building lime (published).
7. EN 13282: Hydraulic road binders (published).

Progress in developing a standard for sulfate-resisting cement is difficult as a result of national differences of view concerning the maximum level of C3A in CEM I cements and the effectiveness of fly ash in preventing concrete deterioration. The solution may be a laboratory performance test but difficulties have been experienced in achieving a satisfactory level of reproducibility. Table 2.1 lists the main type of Portland cement as classified by BS, ASTM.[3]

ASTM C-150 describes five major types of Portland cement. They are:

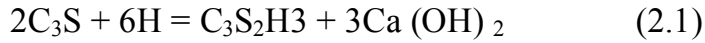
1. Normal Type I: (when special properties specified for any other type are not required), Moderate Sulfate Resistant or Moderate Heat of Hydration.
2. Type II: High Early Strength.
3. Type III: Low Heat-Type N-Sulfate Resisting.
4. Type V : The general composition, fineness and compressive Strength characteristics.

Table 2.1 Main type of Portland cement. [1]

Traditional classification		European classification BS 8500 – 1 :2006	
British	American		
Ordinary Portland [BS12]	Type I [ASTM C 150]	Type (CEM) I	Portland
Rapid –hardening Portland [BS12]	Type III [ASTM C 150]	Type II A	Portland with 6 to 20% fly ash, ggbs, limestone or 6 to 10% Silica fume
Low-heat Portland [BS 1370]	Type IV [ASTM C 150]		
Modified cement	Type II [ASTM C 150]	Type IIB-S	Portland with 21 to 35% ggbs
Sulfate-resistance Portland (SRPC) [BS4027]	Type V [ASTM C 150]		
Portland blast-furnace (slag cement) [BS 146]	Type Is Type S Type (SM) [ASTM C 595]	Type IIIB-V	Portland with 21 to 35% fly ash
High-slag blast-furnace [BS 4246]	-	Type IIIB-SR	Portland with 25 to 35% fly ash with enhanced sulfate resistance
White Portland [BS 12]	-	Type IIIA	Portland with 36 to 65 ggbs
Portland-pozzolana [BS6588; BS 3892]	Type IP Type P Type I (PM) [ASTM C 595]	Type IIIA + SR	Portland with 36 to 65 % ggbs with enhanced sulfate resistance
		Type IIIB	Portland with 66 to 80 ggbs
		Type IIIB + SR	Portland with 66 to 80 Ggbs with enhanced sulfate resistance
		Type IIIC	Portland with 81 to 95 % ggbs
		Type IVB-V	Portland with 36 to 55% fly ash

2.2.5 Hydration of cement:

Hydration process is the chemical reaction that occur to cement compounds after the addition of water, which gives hydride compounds have binding property and stick property, are as follows[1] :



2.2.6 Influence of cement quality control parameters on properties:

The cement properties of water demand (workability), setting behavior and strength development are largely determined by the following ‘key’ cement quality control parameters:

1. Cement fineness (SA and 45 micron residue).
2. Loss on ignition (LOI).
3. Clinker alkalis and SO_3 .
4. Clinker-free lime.
5. Clinker compound composition (mainly calculated C_3S and C_3A levels) Cement SO_3 and the forms of SO_3 present.
6. Water demand (workability).

The initial hydration reactions and the importance of matching the supply of readily soluble calcium sulfate to clinker reactivity. In order to ensure satisfactory workability characteristics the cement producer should:

- Maintain an appropriate ratio of SO_3 to alkalis in the clinker.

- Achieve a uniform and appropriate level of dehydrated gypsum by a combination of controlling the level of natural anhydrite in the 'calcium sulfate' used and the cement milling conditions.
- The slag is uncreative during initial hydration and generally has a neutral influence on water demand.
- Limestone can have a positive influence on water demand particularly when compared to a more coarsely ground pure Portland cement of the same strength class. [2]

2.2.7 Tests on properties of cement:

The manufacture of cement requires stringent control, and a number of tests are performed in the cement plant laboratory to ensure that the cement is of the desired quality and that it conforms to the requirements of the relevant national standards. [2]

(a)Fineness:

On cement plants, cement fineness is normally determined with reference to surface area (SA) and 45-micron residue. While surface area is a good guide to the early rate of hydration of cement and thus early strengths, it is a less reliable guide to late strengths and, in particular, to 28-day strengths. This is because under standard curing conditions clinker particles which are coarser than approximately 30 microns are incompletely hydrated at 28 days.

Since the process of rehydration begins at the surface of the particles of cement, the surface area of the total cement is representing the material available to the smoothness of granulated cement, as it is for growth of early resistance should be granulated cement with smoothness high. [2]

In addition to the compound composition, the fineness of cement also affects its reactivity with water. Generally, the finer the cement, the more rapidly it will react. For a given compound composition the rate of reactivity and hence the strength development can be enhanced by finer

grinding of cement; however, the cost of grinding and the heat evolved on hydration set some limits on the fineness. [3]

(b) Consistency of standard paste:

For the determination of the initial setting time, the final setting, and for Le Chatelier soundness tests, neat cement paste of a standard consistence has to be used. It is necessary to determine for any given cement the water content which will produce a paste of standard consistence. Consistence is determined by the Vicat apparatus, which measures the depth of penetration of a 10mm diameter plunger under its own weight. When the depth of penetration reaches a certain value, the water content required gives the standard consistence of between 26 and 33 (expressed as a percentage by mass of dry cement). [1]

(c) Setting time:

Cement paste setting behavior is strongly influenced by clinker reactivity and by cement fineness. The main factors, which tend to shorten setting time, are increases in the levels of:

1. Clinker-free lime.
2. Cement fineness (surface area SA).
3. C_3S content.
4. C_3A content.

Because the setting time test is carried out on a sample of cement paste, which is gauged with water to give a standard consistency, any change in cement properties, which increases the water required. The effects of a steeper size distribution are much more apparent in paste than in concrete and concretes made from the same cement may not exhibit the same magnitude of extension in setting time. Setting time may also be extended by the presence of certain minor constituents.[1]

Initial and final sets should be distinguished from false sets which sometimes occur within a few minutes of mixing with water (ASTM C 451 – 05). [3]

Vicat apparatus used to determine setting time with 1mm diameter for initial set and 5mm diameter for final set. British standards prescribe the final setting time as maximum of 10 hours for Portland cements which is the same as that of the American standards. [1]

The initial and final setting times are approximately related:

$$\text{Final time (min.)} = 90 + 1.2 [\text{initial time (min.)}]$$

(d)Soundness:

Expansion may occur due to reaction of free lime, magnesia, and calcium sulfate, and cements exhibiting this type of expansion are classified as unsound.

Le Chatelier accelerated test is prescribed by BS EN 196 – 3:1995 for detecting unsoundness due to free lime only. ASTM C 151 – 05 specified autoclave test to both free magnesia and free lime.[1]

(e)Strength:

Strength tests are not made on neat cement paste because of difficulties in obtaining good specimens and in testing with a consequent large variability of test results. The minimum strength requirements of the British and ASTM standards for the different cements are shown in table 2.2. [1]

Table 2.2 BS EN 197 – 1: 2000 and ASTM C 150 – 05 requirements for minimum strength of cement (MPa).[2]

Age (days)	BS EN 197 – 1 : 2000 (mortar prism), strength class					
	32.5N	32.5R	42.5N	42.5R	52.5N	62.5R
2	-	10	10	20	20	20
7	16	-	-	-	-	-
28	32.5*	32.5*	42.5	42.5**	52.5	62.5

Age (days)	ASTM C 150 – 05 (mortar cube), cement type							
	I	IA	II [#]	IIA [#]	III	IIIA	IV	V
1	-	-	-	-	12.0	10.0	-	-
3	12.0	10.0	10.0	8.0	24.0	19.0	-	8.0
7	19.0	16.0	17.0	14.0	-	-	7.0	15.0
28	28.0 ^a	22.0 ^a	28 ^a	22.0 ^a	-	-	17.0	21.0

* and not more than 52.5 ; and not more than 62.5
[#] strength value depend on specified heat of hydration or chemical limit of tricalcium silica and tricalcium aluminate
^a optional

[ASTM C 595]	
Type II B	Portland with 66 to 80% ggbs
Type III B+ SR	Portland with 66 to 80% Ggbs with enhanced sulfate resistance
Type III C	Portland with 81 to 95% ggbs
Type IVB	Portland with 36 to 55% fly ash

2.3 Aggregates:

Aggregate are one of the most important common bulk materials in general used in the building industry, it was originally viewed as an inert, inexpensive material dispersed throughout the cement paste to produce a large volume of concrete. Natural sand, gravel and crushed rock undoubtedly form a major and fundamental part of concrete and mortars. Natural rock in the form of aggregate particles typically makes up

between 70 per cent and 80 per cent of the volume of a normal concrete.[3]

Natural aggregates are formed by the process of weathering and abrasion, or by artificially crushing a larger parent mass. Many properties of the aggregate depend on properties of the parent rock, e.g. chemical and mineral composition, petro graphic classification, specific gravity, hardness, strength, physical and chemical stability, pore structure, etc. In addition, there are other properties of aggregate which are absent in the parent rock: particle shape and size, surface texture and absorption. All these properties have to be considered on the quality of fresh and hardened concrete. [1]

2.3.1 Size classification:

Concrete is made with aggregate particles covering a range of sizes up to a maximum size which usually lies between 10 mm to 50 mm. The particle size distribution is called grading. In making low-grade concrete, aggregate from deposits containing a whole range of sizes, from the largest to the smallest, is sometimes. [2]

In the manufacture of good quality concrete is obtain aggregate in at least two separate lots, the main division being at a size of 5 mm or No.4 ASTM sieve. This divides fine aggregate (sand) from coarse aggregate (Table 2.3). [1]

Table 2.3 BS, ASTM and BS EN sieve sizes normally used for grading of aggregate.[1]

Coarse aggregate				
BS		ASTM		BS EN
Aperture	Previous	Aperture	Previous	Aperture
-	-	125 mm (5 in)	5 in	125 mm (5 in)
-	-	100 mm (4 in)	4 in	-
75 mm (3 in)	3 in	75 mm (3 in)	3 in	-
63 mm (2.5 in)	$2\frac{1}{2}$ in	63 mm (2.5 in)	$2\frac{1}{2}$ in	63 mm (2.5 in)
50 mm (2 in)	2 in	50 mm (2 in)	2 in	-
37.5 mm (1.5 in)	$1\frac{1}{2}$ in	37.5 mm (1.5 in)	$1\frac{1}{2}$ in	31.5 mm (1.24 in)
28 mm (1.1 in)	1 in	25 mm (1 in)	1 in	-
20 mm (0.876 in)	$\frac{3}{4}$ in	19 mm (0.75 in)	$\frac{3}{4}$ in	-
14 mm (0.51 in)	$\frac{1}{2}$ in	12.5 mm (0.50 in)	$\frac{1}{2}$ in	16mm (0.63 in)
10 mm (0.393 in)	$\frac{3}{8}$ in	9.5 mm (0.374 in)	$\frac{3}{8}$ in	-
6.3 mm (0.248 in)	$\frac{1}{4}$ in	6.3 mm (0.248 in)	$\frac{1}{4}$ in	8 mm (0.315 in)
Fine aggregate				
BS		ASTM		BS EN
Aperture	Previous	Aperture	Previous	Aperture
	us		us	
5 mm (0.197 in)	$\frac{3}{16}$ in	4.75 mm (0.187 in)	No.4	4 mm (0.157 in)
2.36 mm (0.0937 in)	No. 7	2.36 mm (0.0937 in)	No. 8	2 mm (0.0787 in)
1.18 mm (0.0496 in)	No. 14	1.18 mm (0.0496 in)	No. 16	1 mm (0.0394 in)
600 μ m (0.0234 in)	No. 26	600 μ m (0.0234 in)	No. 30	0.5 mm (0.0197 in)
300 μ m (0.0117 in)	No. 52	300 μ m (0.0117 in)	No. 50	0.25 mm (0.0098 in)
150 μ m (0.0059 in)	No. 100	150 μ m (0.0059 in)	No. 100	0.125 mm (0.0049 in)
-	-	-	-	0.063 mm (0.0025 in)

2.3.2 Petrographic classification:

From petro graphic standpoint, aggregates can be divided into several groups of rocks having common characteristics (Table 2.4).The group classification does not imply suitability of any aggregate for concrete making; unsuitable material can be found in any group, although some groups tend to have a better record than others. [1]

Table 2.4 Classification of natural aggregates according to Rock type (BS812:part1:1975). [2]

Basalt Group	Flint Group	Gabbro Group
Andesite	Chert	Basic diorite
Basalt	Flint	Basic gneiss
Basic porphyrites		Gabbro
Diabase		Hornblende-rock
Dolerites of all kind including theralite and teschenite		Norite
Epidiorite		Periodotite
lamprophyre		Picrite
Quartz- dolerite		Serpentinite
Spilite		
Granite Group	Gritstone Group (including fragmental Volcanic rocks)	Hornfels Group
Gneiss	Arkose	Contact -altered rocks
Granite	Greywacks	Of all kinds except marble
Granodiorite	Grit	
Granulite	Sandstone	
Pegnatite	Tuff	
Quartz-diorite		
Syenite		
Limestone Group	Porphyry Group	Quartzite Group
Dolomite	Aplite	Ganister
Limestone	Dacite	Quatzitic sandstone
Marble	Felsite	Re-crystallized Quartzite
	Granophyres	
	Keratophyre	
	Microgarite	
	Porphyry	
	Quarz-prophyrite	
	Rhyolite	
	Trachyte	
Schist Group		
Phyllite		
schist		
Slat		
All severely sheared rocks		

ASTM C 294 – 86 give a description of some of the more common minerals found in aggregates which is summarized below: [3]

1. Silica minerals – (quartz, opal, chalcedony, tridymite, cristobalite).
2. Feldspars.
3. Micaceous minerals.
4. Carbonate minerals.
5. Sulfate minerals.
6. Iron sulfide minerals.
7. Ferromagnesian minerals.
8. Zeolites.
9. Iron oxide minerals.
10. Clay minerals.

2.3.3 Shape and texture classification:

The shape of three dimensional bodies is difficult to describe, and it is convenient to define certain geometrical characteristics of such bodies.

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. The actual roundness is the consequence of the strength and abrasion resistance of the parent rock and of the amount of wear to which the particle has been subjected. In the case of crushed aggregate, the shapes depend on the nature of the parent material and on the type of crusher and its reduction ratio, i.e. the ratio of initial size to that of the crushed product (Table 2.5). [1]

Table 2.5 Particle classification of aggregates, BS 812: Part1:1975 with examples. [3]

Classification	Description	Examples
Rounded	Fully water-worn or completed Shaped by attrition	River or seashore gravel; desert, seashore and wind-blown sand
Irregular	Naturally irregular, or partly shaped by attrition and have rounding edges	Other gravels; land or dug flint
Flaky	Material of which the thickness is small relative to the other two dimensions	Laminated rock
Angular	Possessing well-defined edges formed at intersection of roughly planar faces	Crushed rock of all type talus; crushed slag
Elongated	Material, usually angular, in which the length is considerably larger than the other two dimensions	
Flaky and Elongated	Material having the length considerably Larger than the width, and the width considerably larger than the thickness	

A classification used in United States is as follows [3]:

1. Well rounded – no original faces left
2. Rounded – faces almost gone
3. Subrounded – considerable wear, faces reduced in area
4. Subangular – some wear but faces untouched
5. Angular – little evidence of wear

The classification of the surface texture is based on the degree to which the particle surfaces were polished or dull, smooth or rough. Surface texture depends on the hardness, grain size and pore characteristic of the parent material (hard, dense, and fine-grained rocks generally having smooth fracture surfaces) as well as on the degree to

which forces acting on the particle surface have smoothed or roughened it (Table2.6) . [1]

Table2.6 Surface texture classification of aggregates with example.[2]

Group	Surface texture	Characteristic	Examples
1	Glassy	Conchoidal fracture	Black flint, vitreous Slag
2	Smooth	Water- worn, or smooth due to fracture of laminated or fine-grained rock	Gravels, chert, slat Marble, some rhyolites
3	Granular	Fracture showing more or less uniform rounded grains	Sandstone, oolite
4	Rough	Rough fracture of fine-or medium grained rock containing no easily visible crystalline constituents	Basalt, felsite, porphyry, limestone
5	Crystalline	Containing no easily visible crystalline constituents	Granite, gabbro, gneiss,
6	Honeycombed	With visible pores and cavities	Brick, pumice, foamed slag, clinker, expanded clay

2.3.4 Sampling:

The main sample is made up of a number of portions drawn from different parts of the whole. The minimum number of these portions called increments (Table 2.7). [3]

Table 2.7 Minimum mass of samples for testing (BS 812: Part102: 1989).[2]

Maximum particle size present in substantial proportion mm	Minimum mass of sample dispatched for testing kg
28 or larger	50
Between 5 and 28	25
5 or smaller	13

2.3.5 Mechanical properties:

The following properties give an indication of the quality of the aggregate:

(1) **Bond:**

The determination of the quality of bond is rather difficult and no accepted test exists. Generally, when bond is good, a crushed concrete specimen should contain some aggregate particles broken right through, in addition to the more numerous ones separated from the paste matrix.[1]

(2) **Strength :**

The required information about the aggregate particles has to be obtained from indirect tests (crushing strength of prepared rock samples, crushing value of bulk aggregate, and performance of aggregate in concrete). Good average value of crushing strength of such samples is about 200 MPa. Compressive strength of concrete cannot significantly exceed that of the major part of the aggregate contained. [1]

(3) **Toughness :**

Toughness can be defined as the resistance of aggregate to failure by impact, and it is usual to determine the aggregate impact value of bulk aggregate. Full details of the prescribed tests are given in BS 812 – 112:1990 and BS EN 1097 – 2: 1998. [1]

(4) **Hardness :**

Hardness or resistance to wear is an important property of concrete used in road and in floor surfaces subjected to heavy traffic. [1]

2.3.6 Physical properties:

(1) Specify gravity :

According to ASTM C 127 – 04, specific gravity is defined as the ratio of the density of a material to the density of distilled water at a stated temperature. [1]

(2) Bulk density :

When aggregate is to be batched by volume it is necessary to know the bulk density which is the actual mass that would fill a container of unit volume, and this density is used to convert quantities by mass to quantities by volume.[2]

The bulk density depends on:

- How densely the aggregate is packed.
- The size distribution.
- Shape of the particle.

The degree of compaction has to be specified. BS 812 – 2: 1995 and BS EN 1097 – 3: 1998 recognize two degrees:

- (i) Loose.
- (ii) Compacted.

The voids ratio indicates the volume of mortar required to fill the space between the coarse aggregate particles. The void ratio can be calculated from the expression:

$$\text{Voids ratio} = 1 - \frac{\text{bulk density}}{\rho \times \text{unit mass of water}}$$

(3) Porosity and absorption:

The porosity, permeability and absorption of aggregate influence the bond between it and the cement paste, the resistance of concrete to freezing and thawing, as well as chemical stability, resistance to abrasion, and specific gravity. The range of porosity of common rocks varies from 0 to 50 per cent, and since aggregate represents some three-quarters of the volume of concrete it is clear that the porosity of the aggregate materially contributes to the overall porosity of concrete.[2]

(4) Moisture content of aggregate :

The moisture content is the water in excess of saturated and surface-dry condition. The total water content of a moist aggregate is equal to the sum of absorption and moisture content (Figure2.2). [2]

$$\text{The total moisture content} = \frac{B-C}{C-A} \times 100$$

Where;

A = the mass of an air-tight container.

B = the mass of an air-tight container and sample.

C = the mass of the container and sample after drying to a constant mass.

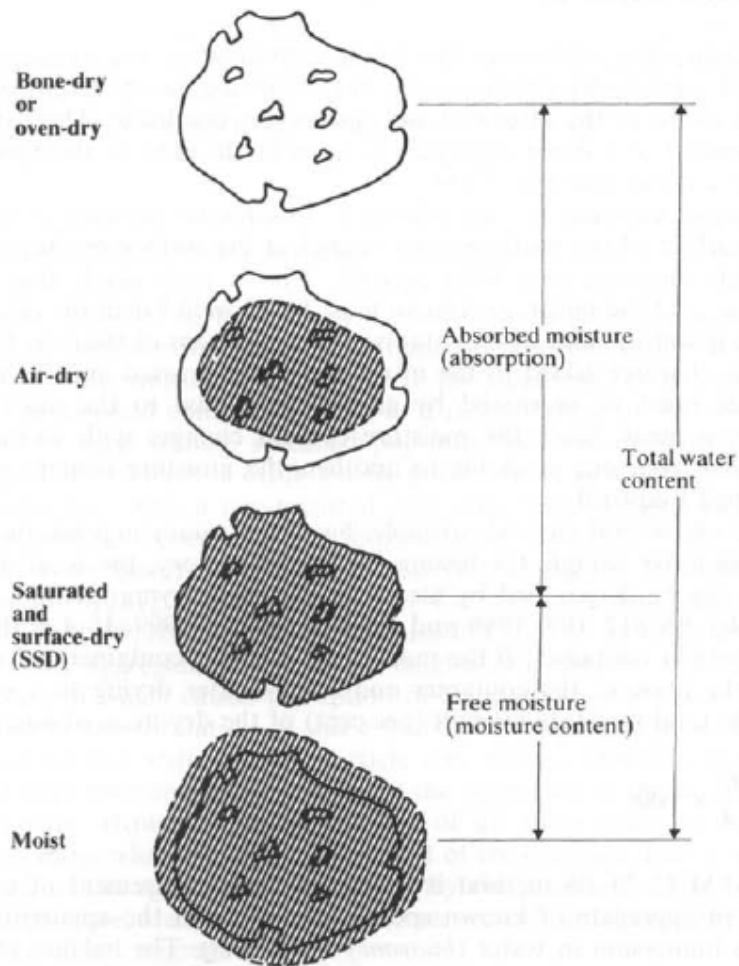


Figure 2.2 Schematic representation of moisture in aggregate.[1]

(5) Bulking of sand :

In the case of volume batching, bulking results in smaller mass of sand occupying the fixed volume of the measured box so the mix becomes deficient in fine aggregate and appears “stony” and the concrete may be prone to segregation and honeycombing, also the yield of concrete is reduced. The extend of bulking depends on the percentage of moisture present in the sand and on its fineness. [2]

(6) Unsoundness due to volume changes :

The physical causes of large or permanent volume changes of aggregate are freezing and thawing, thermal changes at temperature above freezing, and alternating wetting and drying. Unsoundness is

exhibited by porous flints and cherts, especially lightweight ones with a fine-textured pore structure, by some shales, and by other particles containing clay minerals. [1]

2.3.7 Thermal properties:

1. Coefficient of thermal expansion.
2. Specific heat.
3. Conductivity.

2.3.8 Sieve analysis:

The process of dividing a sample of aggregate into fractions of same particle size is known as a sieve analysis, and its purpose is to determine the grading or size distribution of the aggregate. Table 2.3 lists the sieve sizes normally used for grading purposes.[2]

2.4 Mixing water:

The amount of water needed to union with cement is about 25-30 % of the weight of the cement (Figure 2.3), but when getting mixed the ratio increases so the fresh concrete don't be so dry, To facilitate the process of mixing and casting and compaction to be at the lowest possible amount for this purpose and appropriate quantity of water range for operation is between (0.45 – 0.55) from the cement weight for normal mixtures. In the case of using the amount of water less than required operation the mixture will be dry and difficult to operate which leads to be voids within the concrete and thus weaken the hardened concrete and decrease the resistance and durability, and also the increasing of the mixing water from limit required lead to damage in the resistance and durability and for the mechanical properties required for workability required the amount of water required and interoperability must be balanced. [1]

It reacts with the cement and also lubricates the fresh concrete enabling it to be placed into position and compacted.

It is the one of the important and fundamental elements in the concrete depending main functions:

- a- Works on cement hydration of the components of the cement past that work on the cohesion of aggregates granules.
- b- Works on wetness of the aggregate and surrounded by a layer of water to prevent absorption granular aggregates water needed for rehydration.
- c- Increase the workability.

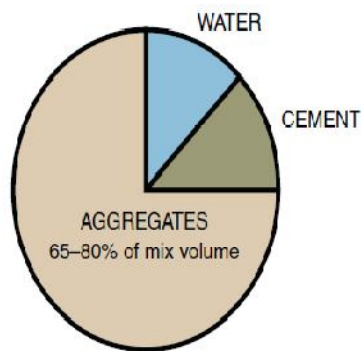


Fig 2.3 Concrete Materials [2]

2.5 Admixtures:

Admixture is a material other than water, aggregates, and hydraulic cements used as an ingredient of concrete or mortar and added to the batch immediately before or during mixing to concrete at the mixing stage to modify some of the properties of the mix. Admixtures should never be regarded as a substitute for good mix design, good workmanship, or use of good materials. [3]

2.5.1 Types of admixtures:

There are two type main type of admixtures as follows:

(1) Chemical Admixtures:

- Type A: Water-reducing (WR)
- Type B: Set retarding (SR)
- Type C: Set accelerating (SA)
- Type D: WR + SR
- Type E: WR + SA
- Type F: High-range water-reducing (HRWR)
- Type G: HRWR + SR

(2) Mineral Admixtures:

Mineral Admixtures are insoluble siliceous materials, used at relatively large amounts (15-20% by weight of cement).

- Class N: Raw or calcined pozzolans.
- Class F: Fly ash produced from burning bituminous coal.
- Class C: Fly ash normally produced from burning lignite. (subbituminous) coal. [2]

Types of admixture depending on concrete properties:

(1) Admixtures for Durability:

- Frost action: Air-entraining agents.
- Sulfate and acidic solutions: Pozzolans, polymer emulsions.
- Alkali-aggregate expansion: Pozzolans.
- Thermal Strains: Pozzolans.

(2) Admixtures for Increasing Strength

- Water reducing agents
- Pozzolans to reduce the water content while maintaining a given consistency.[2]

- **Types of admixture according to their effect:**

1. Plasticizers (water-reducing agents).
2. Superplasticizers (high range water reducers).
3. Air entrainers.
4. Accelerators.
5. Retarders.
6. Others.[4]

1- Plasticizers:

When added to a concrete mix, plasticizers (water-reducing agents) are absorbed on the surface of the binder particles, causing them to repel each other and deflocculate. This results in improved workability and provides a more even distribution of the binder particles through the mix. The main types of plasticizers are lignosulphonic acids and their salts, hydroxylated carboxylic acids and their salts, and modifications of both.[4]

Dosage :

The typical dosage of a plasticizer varies from 200 ml to 450 ml per 100 kg of cementitious material.

Uses :

Plasticizers usually increase the slump of concrete with given water content. Plasticizers can reduce the water requirement of a concrete mix for a given workability, as a rule-of-thumb, by about 10%. The addition of a plasticizer makes it possible to achieve a given strength with lower cement content. Plasticizers may improve pumpability.[4]

Practical considerations :

A number of plasticizers contain a retarder and can cause problems if overdosed. While some plasticizers entrain varying amounts of air, others are reasonably consistent in the amount of air they entrain. Where

plasticizers are used to increase workability, the shrinkage and creep will invariably be increased.[4]

2- Superplasticizers:

These admixtures are chemically distinct from normal plasticizers and although their action is basically the same, it is more marked. When they are used to produce flowing concrete a rapid loss of workability can be expected and therefore they should be added just prior to placing. Superplasticizers are usually chemical compounds such as sulphonated melamine formaldehyde, sulphonated naphthalene formaldehyde, modified lignosulphonates and Polycarboxylate based materials.[4]

Dosage :

The normal dosage of a superplasticizer is between 750 ml and 2500 ml per 100 kg of cementitious material.[4]

Uses :

1. In areas of congested reinforcement.
2. Where a self-leveling consistence facilitates placing.
3. For high-strength concretes by decreasing the water: cement ratio as a result of reducing the water content by 15–25%.

Practical considerations :

1. Special mixes must be designed for superplasticizers and their use must be carefully controlled.
2. The effect of a superplasticizer will last between 30 minutes to 6 hours depending on the admixture used.
3. They have a relatively high unit cost.

3- Air entrainers:

An air-entraining agent introduces air in the form of minute bubbles distributed uniformly throughout the cement paste. The main types include salts of wood resins, animal or vegetable fats and oils and sulphonated hydrocarbons.[4]

Dosage :

Typical dosage for air-entraining agents is between 50 ml and 150 ml per 100 kg of cementitious material.[4]

Uses :

1. Where improved resistance of hardened concrete to damage from freezing and thawing is required.
2. For improved workability, especially in harsh or lean mixes.
3. To reduce bleeding and segregation, especially when a mix lacks fines.

Practical considerations :

1. Air entrainment may reduce the strength of concrete and overdosing can cause major loss of strength. As a rule of thumb, 1% air may cause a strength loss of 5%. It is therefore important that mixes be specially designed for air entrainment and that the percentage of air entrained during construction be monitored.
2. Because the doses are so small, special dispensers and accurate monitoring are required.
3. Different types and sources of cement/cement extenders may result in the entrainment of different amounts of air for the same dose and mix proportions.
4. A change in cementitious content, in the grading or proportions of the fine fractions of sand will normally alter the volume of air entrained.
5. The amount of air entrained may depend on the source and grading of sand in concrete.
6. Forced-action mixers entrain larger volumes of air than other types.
7. Increasing ambient temperature tends to reduce the volume of air entrained.

8. The use of ground granulated blast furnace slag (GGBS) and fly ash (FA) tends to reduce the amount of air entrained.
9. Duration of mixing can also affect air content.[4]

4- Accelerators:

These admixtures speed up the chemical reaction of the cement and water and so accelerate the rate of setting and/or early gain in strength of concrete. Among the main types of accelerators are chloride based, non chloride bases and concrete accelerators.[4]

Dosage :

Chloride based: 500 ml to 2 000 ml per 100 kg cementitious Non-chloride based: 500 ml to 2 000 ml per 100 kg of cementitious material. Concrete accelerators react almost instantaneously, causing stiffening, rapid set and rapid hardening of the concrete.[4]

Uses :

1. Where rapid setting and high early strengths are required (e.g. in shaft sinking).
2. Where rapid turnover of moulds or formwork is required.
3. Where concreting takes place under very cold conditions.[4]

Practical considerations :

All chloride-based accelerators promote corrosion of reinforcing steel and should not be used in:

1. Reinforced concrete.
2. Water-retaining structures.
3. Prestressed concrete.
4. Steam-cured concrete.

Overdosing with these materials can cause instant setting of the concrete resulting in equipment damage. Accelerators work more effectively at lower ambient temperatures.[4]

5- Retarders:

These admixtures slow the chemical reaction of the cement and water leading to longer setting times and slower initial strength gain. The most common retarders are hydroxylated carboxylic acids, lignins, sugar and some phosphates.[4]

Dosage :

Typical dosages for retarders are between 150 ml and 500 ml per 100 kg cementitious material.

Uses :

1. When placing concrete in hot weather, particularly when the concrete is pumped.
2. To prevent cold joints due to duration of placing.
3. In concrete which has to be transported for a long time.

Practical considerations :

1. If a mix is overdosed beyond the limit recommended by the supplier, retardation can last for days.
2. Retarders often increase plastic shrinkage and plastic settlement cracking.
3. Delayed addition of retarders can result in extended retardation.

6- Other admixtures:

Other admixtures with different chemical compositions and effects are available (e.g. pumping aids, pigments, expansion aids and grouting admixtures). These are beyond the scope of this leaflet, and information should be obtained from the admixture suppliers.[4]

2.5.2 Uses of admixtures:

The most common reason for use admixtures in concrete are:

1. Improve or modify some or several properties of Portland cement concrete.
2. Compensate for some deficiencies.
3. Increase workability without changing water content.
4. Reduce water content without changing workability.
5. Effect a combination of the above.
6. Adjust setting time.
7. Reduce segregation and/or bleeding.
8. Improve pumpability.
9. Accelerate the rate of strength development at early ages.
10. Increase strength.
11. Improve potential durability and reduce permeability.
12. Reduce the total cost of the materials used in the concrete.
13. Compensate for poor aggregate properties.[1]

2.6 Concrete properties:

Fresh concrete is a transient material with continuously changing properties. It is, however, essential that these are such that the concrete can be handled, transported, placed, compacted and finished to form a homogenous, usually void-free, solid mass that realizes the full potential hardened properties. A wide range of techniques and systems are available for these processes, and the concrete technologist, producer and user must ensure that the concrete is suitable for those proposed or favored. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, proportion of the mix, the method of compaction and other controls during placing, compaction and curing. [2]

2.6.1 Fresh concrete properties:

Fresh concrete technology has advanced at a pace similar to many other aspects of concrete technology over the past three decades, and indeed many of these advances have been inter-dependent. For example, the availability of superplasticizers has enabled workable concrete to be produced at lower water/binder ratios thus increasing the in-situ strength.[2]

The fresh concrete properties are:

(a) Workability:

The workability of a concrete mix gives a measure of the ease with which fresh concrete can be placed and compacted. The concrete should flow readily into the form and go around and cover the reinforcement, the mix should retain its consistency and the aggregates should not segregate. A mix with high workability is needed where sections are thin and/or reinforcement is complicated and congested.

The main factor affecting workability is the water content of the mix. Admixtures will increase workability but may reduce strength. The size of aggregate, its grading and shape, the ratio of coarse to fine aggregate and the aggregate-to-cement ratio also affect workability to some degree.[2]

-Loss of workability :

Fresh concrete loses workability due to the following:

1. Mix water being absorbed by the aggregate if this is not in a saturated state before mixing.
2. Evaporation of the mix water.
3. Early hydration reactions (but this should not be confused with cement setting).
4. Interactions between admixtures (particularly plasticizers and superplasticizers) and the cementitious constituents of the mix.[3]

Most available data relates to loss of slump, which increases with:

1. Higher temperatures.
2. Higher initial slump.
3. Higher cement content.
4. High alkali and low sulfate content of the cement.

(b) Placing and compaction:

The methods chosen for placing and compacting the concrete will depend on the type of construction, the total volume to be placed, the required rate of placing and the preferences and expertise of the construction companies involved. There are, however, several basic rules which should be followed to ensure that the concrete is properly placed and compacted into a uniform, void free mass once it has been delivered to the formwork in a satisfactory state:

1. The concrete should be discharged as close as possible to its final position, preferably straight into the formwork.
2. A substantial free-fall distance will encourage segregation and should therefore be avoided.
3. With deep pours, the rate of placing should be such that the layer of concrete below that being placed should not have set; this will ensure full continuity between layers, and avoid cold joints and planes of weakness in the hardened concrete.
4. Once the concrete is in place, vibration, either internal or external, should be used to mould the concrete around embedment's e.g. reinforcement, and to eliminate pockets of entrapped air, but the vibration should not be used to move the concrete into place.
5. High-workability mixes should not be over vibrated – this may cause segregation.[3]

The behavior of concrete during vibration has two stages:

1. Initial settlement in which the coarse aggregate particles are moved into a more stable position.
2. Entrapped air bubbles rising to the surface.

The stages can be quite distinct with low-workability concrete, but stage one is less apparent in high-workability concrete.[3]

(c) Segregation and bleed after placing:

Fresh concrete is a mixture of solid particles with specific gravities ranging from about 2.6 (most aggregates) to 3.15 (Portland cement). After the concrete has been placed, the particles tend to settle and the water to rise (Figure 2.4). This can lead to segregation, in which the larger aggregate particles fall to the lower parts of the pour, and/or bleeding, in which water or water-rich grout rises to the surface of the concrete to produce laitance, a weak surface layer, or becomes trapped under the aggregate particles thus enhancing interface transition zone effects. These processes are hindered by the interlocking of the particles and for the smaller particles, the surface forces of attraction. It follows that the major causes of segregation and bleeding are poorly graded aggregates and excessive water contents. Bleeding also decreases with increasing fineness of the cement, cement content of the concrete, and the incorporation of cement replacement materials. It is not possible to generalize about the effect of admixtures.[3]

Bleed can be measured in two ways:

1. The reduction in height (i.e. settlement) of a sample of undisturbed concrete.
2. The amount of bleed water rising to the surface of an undisturbed sample, which is measured after drawing off with a pipette (as in ASTM C 232–92).

In both types of test, the rate as well as the total bleeding can be measured. Excessive bleeding and segregation can lead to problems of plastic shrinkage and plastic settlement cracking on the top surface of pours.

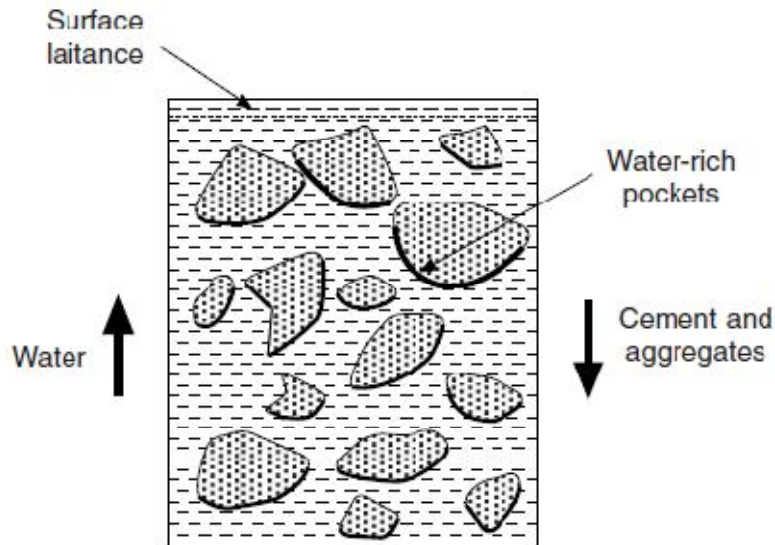


Figure 2.4 Segregation and bleed in freshly placed concrete.[4]

(d) Curing:

Typical definition of curing (BS 8110, 1997) is the process of preventing the loss of moisture from the concrete whilst maintaining a satisfactory temperature regime. This particular definition adds that the curing regime should prevent the development of high temperature gradients within the concrete. [3]

Many other definitions exist which include references to hydration, durability and cost but there are three basic elements to consider:

1. Moisture.
2. Heat.
3. Time.

2.6.2 Hardened concrete properties:

The hardened concrete properties are:

(a) Strength of concrete:

Strength of concrete is commonly considered to be its most valuable property. It usually gives an overall picture of the quality of concrete because it is directly related to the structure of cement paste. The strength of concrete is almost invariably a vital element of structural design and is specified for compliance purposes. [1]

In engineering practice, the strength of concrete at a given age and cured in water at prescribed temperature is assumed to depend primarily on two factors only (Figure 2.5):

1. Water / cement ratio.
2. The degree of compaction.

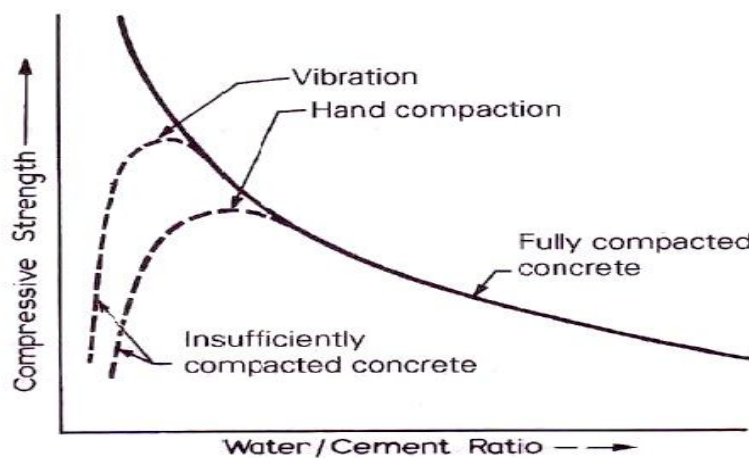


Figure 2.5 The relation between strength and water / cement ratio of concrete. [2]

For a given cement and acceptable aggregates, the strength that may be developed by a workable, properly placed mixture of cement, aggregate, and water (under the same mixing, curing, and testing conditions) is influenced by the following:

1. Ratio of cement to mixing water.
2. Ratio of cement to aggregate.
3. Grading, surface texture, shape, strength, and stiffness of aggregate particles.
4. Maximum size of the aggregate.

Figure 2.6 shows that the graph of strength versus water / cement ratio is approximately in the shape of hyperbola. This applies to concrete made with any given type of aggregate and at any given age. [3]

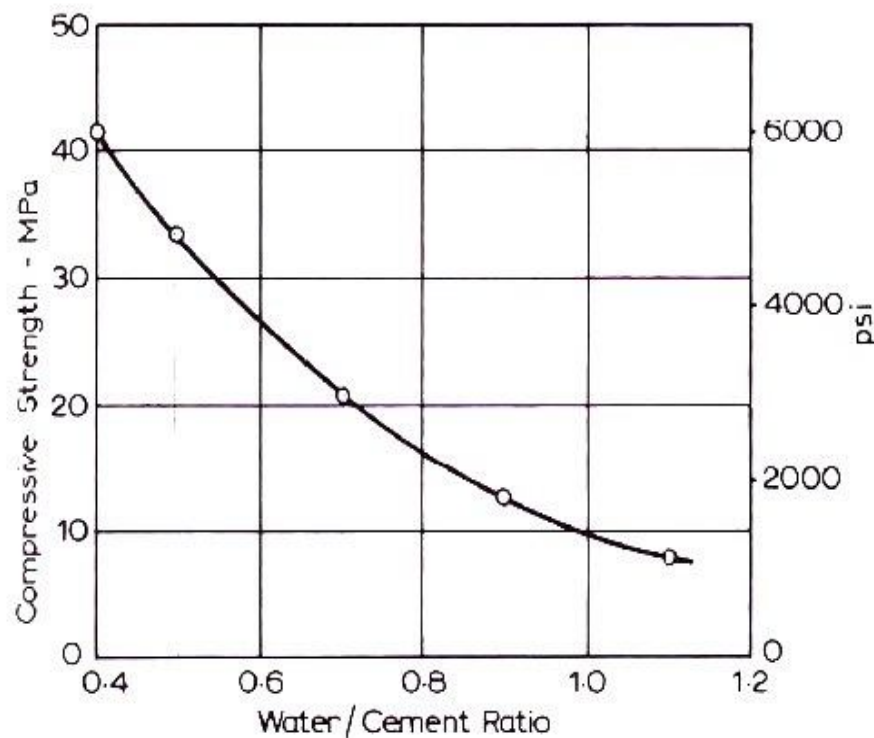


Figure 2.6 Relation between 7-day strength and water / cement ratio for concrete made with rapid hardening Portland cement. [2]

(b) Durability of concrete:

Most concretes are excellent at 28 days. If not, a simple repair or replacement may be done. However, concrete is meant to last for decades or centuries. After the first 28 days concrete will continue to mature and age, depending on the original material composition and properties and the environmental actions during service. [1]

In that ageing a number of transport processes are involved. Most of the changes and deterioration that occur in concrete over time follow from transport of various substances. [3]

2.7 Concrete tests:

Interest of testing of fresh concrete and hardened concrete has increased considerably, and significance advances have been made in techniques, equipment, and methods of application.

Changes in cement manufacture, increased use of cement replacements and admixtures, and a decline in standards of workmanship and construction supervision have all been blamed. Particular attention has thus been paid to development of test methods which are related to durability performance and integrity. There is also an increasing awareness of the shortcomings of control or compliance tests which require a 28-day wait before results are available. The tests should be performed and interpreted by experienced specialists, many difficulties arise both at the planning and interpretation stages because of a lack of common understanding. A great deal of time, effort and money can be wasted on unsuitable or badly planned testing, leading to inconclusive results which then become the subject of heated debate.[7]

2.7.1 Fresh concrete:

The fresh concrete test are:

(a) Slump test:

This test is carried out by filling the slump cone with freshly mixed concrete which is tamped with a steel rod in three layers; the concrete is leveled off with the top of the slump cone. The slump test (Figure 2.7), which is simple, quick and cheap, is almost universally used for nearly all types of medium and high workability concrete. There are also some differences in practice with its use in different countries. The mould for the slump test is frustum of a cone, 305mm (12in) high. The base of 203mm (8in) diameter is placed on smooth surface with the smaller opening of 102mm (4in) diameter at the top, and the container is filled with concrete in three layers. Each layer is tamped 25 times with standard 16mm ($\frac{5}{8}$ in) diameter steel rod, rounded at the end, and the top surface is struck off by means of screeding 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 centre of the slumped concrete is called slump and is measured to the nearest 5mm ($\frac{1}{4}$ in). [7]

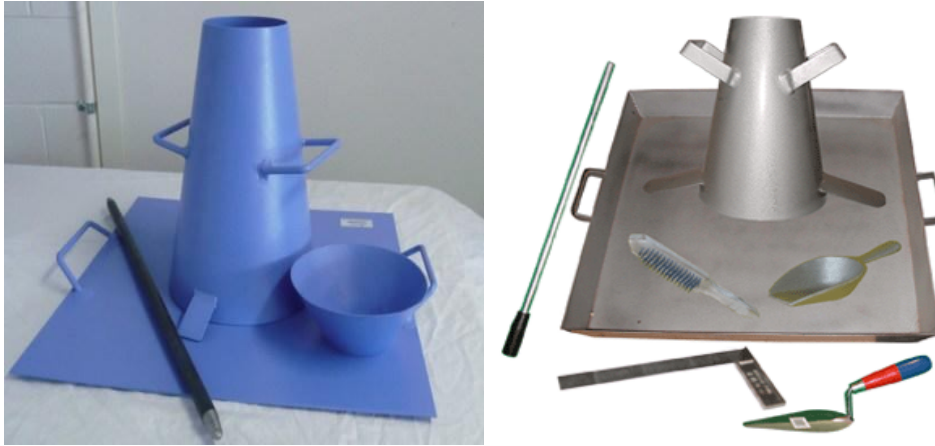


Figure 2.7 slump set

Mixes of stiff consistence have a zero slump, so that in the rather dry range no variation can be detected between mixes of different workability. There is no problem with rich mixes, their slump being sensitive to variations in workability.

(b) Compacting factor test:

The test was developed in the UK and is describing in BS1881: part 103:1993 and in ACI Standard 211.3-75. The apparatus consist essentially of two hoppers, each in the shape of a frustum of a cone, and one cylinder, the three being above one other. The hoppers have hinged doors at the bottom, as shown in figure (2.8). All inside surface are polished to reduce friction. The upper hopper 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 fall into the lower hopper. This hopper is smaller than the upper one and is, therefore, filled to overflowing 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 released and the concrete falls into the cylinder. Excess concrete is cut by two floats sliding across the

top of the mould ,and the net mass of concrete in the known volume of the cylinder is determined (see Table 2.8). [7]



Figure2.8 compacting factor apparatus.[14]

Table 2.8 Workability, slump, and compacting factor of concretes with 19 or 38mm ($\frac{3}{4}$ or $1\frac{1}{2}$ in) maximum size of aggregate. [1]

Degree of workability	Slump		Compacting factor	Use of which concrete is suitable
	mm	in		
Very low	25 - 0	0 - 1	0.78	Road vibrated by Power- operated machine. At the more workable end of this group, concrete may be compacted in certain cases with hand-operated machines.
low	25 - 50	1 - 2	0.85	Road vibrated by hand-operated machines. At the more workable of end this group, concrete may be manually compacted in roads using aggregate of rounded or irregular shape. Mass concrete foundations without vibration or lightly reinforced sections with vibration.
medium	25 - 100	2 - 4	0.92	At the less workable end of this group, manually compacted flat slabs using crush aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibration.
High	100 - 175	4 - 7	0.95	For sections with congested reinforcement. Not normally suitable for vibration.

(c) Flow table:

This test recently become more widespread in its use, particularly for flowing concrete made with super plasticizing additive. The apparatus, shown in figure (2.9), consists essentially of a wooden board covered by a steel plate with a total mass of 16kg. This board is hinged a long one side to a base board, each board being a 700 mm (27.6 in) square. The upper board can be lifted up to a stop so that the free edge rises 40mm (1.6 in). Appropriate markings indicate the location of the concrete to be deposited on the table. [7]

The table top is moistened and a frustum of a cone of concrete, lightly tamped by a wooden tamper in a prescribed manner, is placed using a mould 200mm (8 in) high with a bottom diameter of 200mm (8 in) and a top diameter of 130 mm (5 in). Before lifting the mould, excess concrete is removed, the surrounding table top is cleaned, and after an interval of 30 sec the mould is slowly removed. The table top is lifted and allowed to drop, avoiding a significant force against the top, 15 times, each cycle taking approximately 4sec. In consequence, the concrete spreads and the maximum spread parallel to the two edges of the table is measured. The average of these two values given to the nearest millimeter, represented the flow. A value of 400 indicates a medium workability and 500 a high workability. Concrete should at this stage appear uniform and cohesive or else the test is considered inappropriate for the given mix. Thus the test offers an indication of the cohesiveness of the mix. [7]



Figure 2.9 flow table set.[15]

2.7.2 Hardened Concrete:

Tests can be made for different purposes but the main two objectives of testing are quality control and compliance with specifications.

Where member strength cannot be adequately determined from the results of insitu materials tests, load testing may be necessary. The expense and disruption of this operation may be offset by the psychological benefits of a positive demonstration of structural capacity which may be more convincing to clients than detailed calculations. In most cases where load tests are used, the main purpose will be proof of structural adequacy, and so tests will be concentrated on suspect or critical locations. Static tests are most common but where variable loading dominates, dynamic testing may be necessary. [7]

Load testing may be divided into two main categories:

- (i) Destructive: Tests on members removed from a structure.
- (ii) Non-destructive: In-situ testing.

(i) Destructive tests:

The destructive tests are:

(a) Compressive strength test:

The most common of all tests on hardened concrete is the compressive strength test, partly because it is an easy test to perform, and partly because many, though not all, of the desirable characteristics of concrete are qualitatively related to its strength; but mainly because of the intrinsic

importance of the compressive strength of concrete in structural design.[2]

The strength test results may be affected by variation in:

1. type of test specimen
2. Specimen size.
3. Type of mould.
4. Curing.
5. Preparation of the end surface.
6. Rigidity of the testing machine.
7. Rate of application of stress.

The age at which service specimens are tested is governed by the information required. On the other hand, standard specimens are tested at prescribed ages, generally 28 days, with additional tests often made at 3 and 7 days. [4]

Two types of compression test specimens are used:

1. Cubes: used in Great Britain, Germany, and many other countries in Europe.
2. Cylinders: are the standard specimens in the United States, France, Canada, Australia, and New Zealand.

Universal ball seated upper platen .10*10*10 cm, 15*15*15 cm, 20*20*20 cm cube, 75*150*cm, 15*30 cm and 6" *12" standard cylinder samples can be tested. Distant pieces are supplied according to sample sizes (Figure2.10). Upper and lower platens are hardened. After samples tested, the results are compressive strength.



Figure 2.10 Compressive machine test.[15]

(b) Cores testing:

The examination and compression testing of cores cut from hardened concrete is a well-established method, enabling visual inspection of the interior regions of a member to be coupled with strength estimation. Other physical properties which can be measured include density, water absorption, indirect tensile strength and movement characteristics including expansion due to alkali-aggregate reactions. Cores are also frequently used as samples for chemical analysis following strength testing. In most countries standards are available which recommend procedures for cutting, testing and interpretation of results; BS 1881: Part 120 in the UK, whilst ASTM C42 and ACI 318 are used in the USA (figure2.11). [7]



(1)



(2)

Figure 2.11 Core represented: (1) Core cutting drill (2) Typical core.[7]

-Compression testing:

Compression testing will be carried out at a rate within the range 12–24 N/ (mm² ·min) in a suitable testing machine and the mode of failure noted. If there is cracking of the caps, or separation of cap and core, the result should be considered as being of doubtful accuracy. Ideally cracking should be similar all round the circumference of the core, but a diagonal shear crack is considered satisfactory, except in short cores or where reinforcement or honeycombing is present. [7]

(ii) Nondestructive tests:

The non destructive tests are:

(a) Rebound test:

The hammer measures the rebound of a spring loaded mass impacting against the surface of the sample. The test hammer will hit the concrete at a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by the test equipment. By reference to the conversion

chart, the rebound value can be used to determine the compressive strength. [7]

The Swiss engineer Ernst Schmidt first developed a practicable rebound test hammer in the late 1940s, and modern versions are based on this. Figure (2.12) shows the basic features of a typical type N hammer, which weights less than 2 kg, and has impact energy of approximately 2.2 Nm.

The equipment is very simple to use figure (2.13) and may be operated either horizontally or vertically either upwards or downwards.

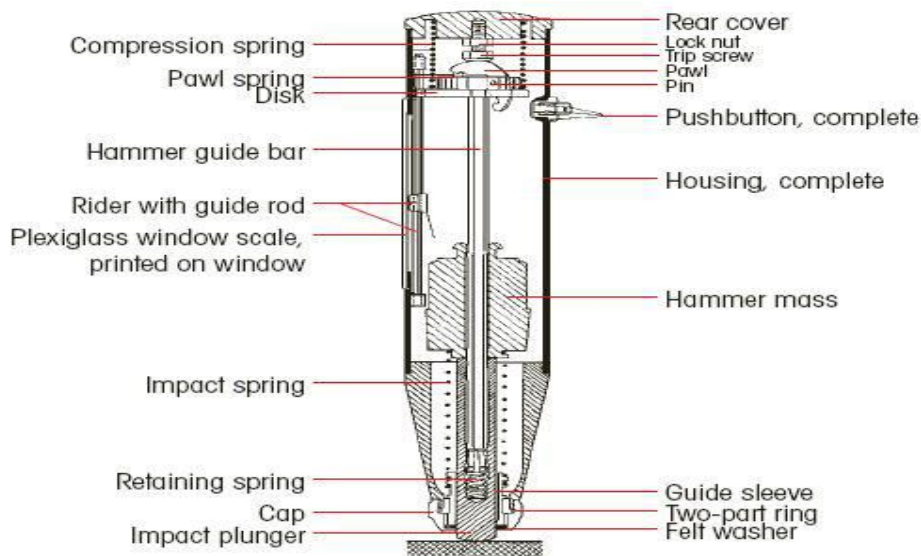


Figure 2.12 Typical rebound hammer.[7]



Figure 2.13 Schmidt hammer in use.[7]

(b) Ultrasonic pulse velocity test equipment:

The test equipment must provide a means of generating a pulse, transmitting this to the concrete, receiving and amplifying the pulse and measuring and displaying the time taken. The basic circuitry requirements are shown in figure 2.14.

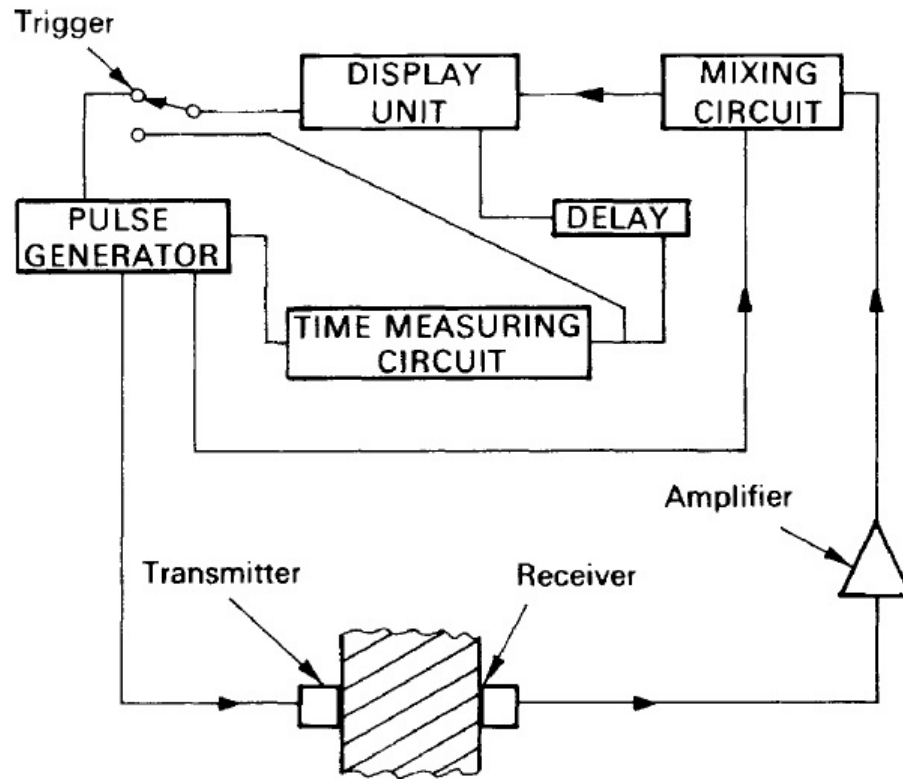


Figure 2.14 Typical UPV testing equipment.[14]

Figure 2.15 shows the PUNDIT set up in the laboratory with 54 kHz transducers and a calibration reference bar. This steel bar has known characteristics and is used to set the zero of the instrument by means of a variable delay control unit each time it is used. The display is a four digit liquid crystal and gives a direct transit time reading in microseconds.



Figure 2.15 PUNDIT in laboratory.[14]

2.8 Mix design:

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative quantities with the purpose of producing an economical concrete which has certain minimum properties, notably workability, strength and durability. [1]

2.8.1 Methods of concrete mix design:

The mix design methods being followed in different countries are mostly based on empirical relationships, charts and graphs developed from extensive experimental investigations. [6]

Following methods are in practice:

1. ACI Mix design method.
2. USBR Mix design method.
3. British Mix design method.
4. Mix design method according to Indian standard.

2.8.2 Factors to be considered in mix design:

Factors to be taken into account in the process of mix design applied to designed mix are [6]:

1. Grade of concrete: This gives the characteristic strength requirements of concrete. Depending upon the level of quality control available at the site, the concrete mix has to be designed for a target mean strength which is higher than the characteristic strength.
2. Cement content: The type of cement is important mainly through its influence on the rate of development of compressive strength of concrete as well as durability under aggressive environments ordinary Portland cement (OPC) and Portland Pozzolana cement (PPC) are permitted to use in reinforced concrete construction.
3. Aggregate content: It is found that larger the size of aggregate, smaller is the cement requirement for a particular water cement ratio. Aggregates having a maximum nominal size of 20mm or smaller are generally considered satisfactory.
4. Water / cement ratio: The minimum w/c ratio for a specified strength depends on the type of cement.
5. Workability: The workability of concrete for satisfactory placing and compaction is related to the size and shape of the section to be concreted.
6. Type of cement.
7. Water content.

2.8.3 Mix design procedure:

The mix is designed as follows:

- (a) Arrive at the target mean strength from the characteristic strength required.
- (b) Choose the water cement ratio for target mean strength.
- (c) Arrive at the water content for the workability required.
- (d) Calculate the cement content.
- (e) Choose the relative proportion of the fine and coarse aggregate.
- (f) Arrive at the concrete mix proportions.

2.8.4 Trial mix:

The calculated mix proportions should be checked by making trial mixes. Only a sufficient amount of water to be producing the required workability should be used.

2.9 Previous studies :

The following studies were shown previous study in improvement of concrete.

(a) Effect of PFA on fresh and hardened concrete:

Ahmed Abdalla Dafalla present a thesis on effect of PFA on fresh and hardened concrete .Mass concrete structures, such as dams, always require special measures to be taken to produce a qualified concrete . The use of PFA in concrete has become an accepted practice partly due to have a consistent concrete and the eliminate heat of hydration as well as to improve the quality of concrete.

This research was formulated to evaluate the performance of concrete when PFA was used at Merowe. [8]

Dam project, as are placement of cement in the range 0 % to 35% and changing the water-cement ratio from 0.45 to 0.65 adding 0.05. In trial mix stage , samples of 180 cubes and 180 cylinders were taken for

maximum size 38 mm of coarse aggregate and the same numbers for 76mm and tested for 3,7 and 28 days. After full curing a compressive strength tests were performed. The results showed low strength recorded in the early age with increment of PFA dosage and qualified strength at 28 days.

Based on that results it was recommended to use 15% of PFA replacing of the cement, but at early of the construction period increased to 25 % to mitigate alkali –silica reaction. [8]

(b) High strength concrete by using local materials in Sudan:

Afaf Mahgoub Osman presented a thesis on high strength concrete by using local material in Sudan. The objective of this thesis to obtain high grade concrete in Sudan by using local available material and small amount of cement as possible by using cement replacement materials (fly ash), With high workability that is normally required when using pumps to construct structures, high workability is achieved by adding admixture to the concrete mix to make it workable with low water – cement ratio to achieve that purpose , the constituent materials of concrete mixes were brought from different sources around Khartoum state and were tested in the laboratory to make sure that material chosen to be according to standards. And also used mineral admixture (Fly ash) as a replacement of cement to decrease the amount of cement as possible to avoid shrinkage (crakes) due high heat of hydration and as the same time gives high grade concrete. [9]

The experimental program was divided in two phases:

First: Preliminary studies on basic materials and the effect of recommended doses of admixture on the properties of fresh and hardened concrete.

Second: Phase is concrete testing program which contains eight mixes:-

- Ordinary reference mix with water – cement ratio (0.4)M

- Same mix with admixtures (Superplasticiser dosage one litter/100Kg cement), to increase the workability (M1).
- Mix with admixtures (Superplasticiser dosage 1.25litter/100Kg cement), with water / cement ratio (0.38) to increase the workability and strength (M2).
- Mix with admixtures (Superplasticiser dosage 1.5litter/100Kg cement), with water-cement ratio (0.35) to increase the workability and strength (M3).
- Mix with admixtures (superplasticiser dosage 1.5litter/100Kg cement), with water- cement ratio (0.30) to increase the workability and strength (M4).
- Mix with admixtures (Superplasticiser dosage 1.5litter/100Kg cement and 20% fly ash) with water –cement ratio, to increase the workability, strength and reduce of the amount cement content (M5).
- Mix (Superplasticiser dosage 1.5litter/100Kg cement and 25% fly ash) with water-cement ratio (0.30), to increase the workability, strength and reduce of the amount cement content (M6).

The results of preliminary tests were carried out to ensure that the main constituents of concrete (cement, aggregate, water and additive) are adequate and conforming to the requirement can be used to:

1. Increase the workability of concrete (slump for 10 to 240 mm)
2. Increase the strength by 40.5% at 28 days.

The percentages used in this study were not gave the same strength in early age of the same mix without fly ash may be at later age. 20% Fly ash gave more strength in both compressive strength and indirect tensile strength (Flexural strength and splitting strength).[9]

(c) Use Graygrebs natural Pozzalana in concrete mixes:

Mohja Mohammed Osman Presented a thesis on the use of Graygrebs natural Pozzalana in concrete Mixes. This research presents an experimental investigation on the use of the natural Pozzalana in concrete mixes. The local natural Pozzolana used in thesis was obtained from location in (AL- Grayegreeb) at central Sudan. The natural pozzolanas were used to partially replace Portland cement with 10, 20 and 30% by mass of binder. Other mixes of burnt Pozzalana with lime was used at 30% by mass. Comparison of the setting time, compressive strength and workability were performed with control mix up to 20% Pozzalana can increase the initial setting lime. [10]

Compressive strength depends on pozzolana percentage and curing time with burnt pozzolana and lime high compressive strength and increase in workability and sitting time were noticed. There for natural pozzolana in Sudan can be used in concrete to replace the cement content.[10]

(d) To obtain high-strength concrete and the resistance through the improvement of natural additions:

Research presented investigated the effect of Gum Arabic liquid in concrete mixes to obtain high compressive strength concrete and good workability. This was achieved by preparing concrete mixes using Gum Arabic liquid at ratios between 0.2% to 0.8 % of cement content. Evaluate the effect of softening the addition of Gum Arabic had been done by a device measuring the viscosity (sotard), which allows at the same time checks for the presence of characteristic self –measurement of the level when the dough by means of sclerosing anatomy of the pulp . Gum Arabic influence on the cohesion of cement paste and refused to use the rotor of measuring viscosity and difficult to interpret the information

that obtained in this way to feature an integrated technology- the ability of the brushes. [11]

The research concluded that Gum Arabic liquid ratios of 0.6% and 0.8% resulted in high compressive strength and good workability. Gum Arabic influence on the strength of the cement cube (resistance) feature allows gum reduced the percentage of water/ cement ratio, and this of course doubles the strength of the cement cube. On the other hand, the Gum Arabic, like many organic materials soluble in water can adversely affect the cement hydration and formation of cement per cubic structure.[11]

The following chapter briefly discuss concrete additions of both types of chemical and organic material, includes basic research topic.