UNIT 5 WORKABILITY AND FRESH CONCRETE - I

Structure

5.1 INTRODUCTION

You have already studied about the concrete materials, i.e. Cement, Aggregates, Water and Admixtures in the Ist block. Now in this starting unit of 2nd block you will study about workability of Concrete. This is a prime property of Fresh Concrete which affects the strength of Hardened Concrete.

Fresh concrete is like a plastic material which can be moulded into desirable shapes. The properties of fresh concrete decide the choice of equipment needed for transportation, placing and compaction of concrete, which ultimately affects the properties of hardened concrete. Therefore, while making concrete we have to cater for short-term requirements of plastic state which are collectively called as **Workability** and the long-term requirements of hardened concrete such as strength, durability and volume stability. It is seen that these two sets of requirements are not complementary and actually a compromise has to be struck to satisfy both. In this unit, we will concentrate on the short-term requirements of fresh concrete which has been termed as workability. We will discuss about workability, tests to measure it and about segregation and bleeding.

Objectives

At the end of this unit, you should be able to :

* describe various factors which affect workability,
* describe and discuss the tests for measurements of workability, and
* distinguish between segregation and bleeding.

5.2 WHAT IS WORKABILITY ?

The workability signifies very wide properties and quality of fresh concrete and any one definition may not be sufficient to describe it. The Road Research Laboratory, UK, have defined workability as *the property of concrete which determines the amount of useful internal work necessary to produce full compaction.* Elsewhere it has been defined as *the ease with which concrete can be fully compacted having regard to mode of compaction and place of deposition.*

However, we can, based on site experience can state that for a particular work, the fresh concrete must satisfy the following requirements :

a) The fresh concrete must be easily mixable and transportable.

b) It must be of uniform quality.

c) It should possess flow properties such that it completely fills the form work and adheres to the reinforcement.

d) It must have the ability to be fully compacted without application of excessive energy.

e) It should not segregate during placing and compaction.

f) It must be capable of being finished properly.

All these properties and requirements are contained in the word **Workability**. Let us now examine in detail the various factors which affect workability of concrete.

5.3 FACTORS AFFECTING WORKABILITY OF CONCRETE

The workability of concrete is affected by a number of factors, which are :

a) Water content of the Mix

b) Mix Properties

c) Aggregate Size

d) Aggregate Shape

e) Aggregate Texture

f) Grading of Aggregate

g) Admixtures

h) Time and Temperature

5.3.1 Water Content of the Mix

The single most important factor which governs the workability is the water content. Any increase in amount of water leads to increasing of ease with which the concrete flows and can be compacted. Many ignorant site supervisors arbitrarily resort to adding more water for increasing workability, which results in reduction of strength and may also lead to segregation and bleeding. In general, any collection of particles requires a certain amount of water to achieve plasticity so that it is workable. The amount of water depends on the specific area of the particles. Thus the water contents of the mix cannot be considered in isolation from the aggregate grading. It may be noted that addition of more water to achieve workability should be the last recourse. Also a corresponding higher quantity of cement is added to keep the water/cement ratio constant so that the strength remains the same.

5.3.2 Mix Proportions

The aggregate/cement ratio plays an important role in influencing workability. Higher the aggregate/cement ratio, leaner the mix, hence lesser mobility because of less quantity of paste which provides lubrication. On the other hand in richer mix with lower aggregate/cement ratio, more paste is available to produce cohesive and fatty mix and hence it possesses more workability. The relative proportions of coarse and fine aggregate is also important. A deficiency in fine aggregate results in harsh mix which is difficult to finish, while an excess of fine aggregate will lead to a rather more permeable and less economical concrete which may be easily workable. It should be noted that rich mix does not necessarily means better workability.

5.3.3 Aggregate Size

The aggregate size determines its surface area and hence the amount of water required for wetting it. The bigger the size of the aggregate, the less is the surface area and hence less amount of water is required for wetting the surface and less matrix of paste is required for lubricating the surface. Within certain limits, for a given quantity of water and paste a bigger size of aggregate will give higher workability.

5.3.4 Aggregate Shape

It is seen that angular, elongated or flaky aggregate makes the concrete very harsh when compared to rounded or cubical shaped aggregates. This is because for a given volume or weight, rounded aggregate has less area and less voids than angular or flaky aggregates. This explains the reason why river sand and gravel provide greater workability to concrete than crushed sand and aggregate. The rounded shape also acts as **ball bearing** and reduces internal friction.

5.3.5 Aggregate Texture

The influence of texture on workability is again related to the total surface area which is more in case of rough textured aggregate than rounded and smooth aggregate of same volume. Hence, smooth rounded aggregate gives better workability.

5.3.6 Grading of Aggregates

The grading of aggregate, as we have seen earlier in the Unit on Aggregate, exerts great influence on concrete properties including workability also. A well graded aggregate has least voids in a given volume. Other factors remaining the same, when total voids are less, excess paste is available to give better lubricating effect. It also results in cohesive mix, with no segregation and so better compaction with less effort. Therefore a well graded aggregate enhances workability.

5.3.7 Admixtures

Air entraining agent and pozzolanic material greatly increases the workability when other factors are constant. The air-entraining agent being surface active, reduces the internal friction between the particles. The air bubbles can be viewed to act as ball bearings, enabling the particles to slide past each other, thus increasing mobility. The pozzolanic material also offer better lubricating effects. However, it should be noted that chemical admixtures react differently with different cements and aggregates, and can in some circumstances aggravate the loss of workability.

5.3.8 Time and Temperature

It is seen that as ambient temperature increases, the workability decreases, since higher temperature will increase both the evaporation and the hydration rate. Therefore, you will appreciate that to maintain the same workability you will have to adopt other measures. These measures are :

a) Use of admixtures

b) Pre Cooling of materials

c) Use of Chilled water

On the other hand, some laboratory evidence indicates that at least for short times, workability is not affected by temperature. Therefore, in situations where temperatures may be important factor, field tests should be carried out with specific materials in order to determine the temperature effects for a given job.

SAQ 1

Fill in the blanks and check your answers with preceding text :

a) Workability has been defined as the ease with which concrete can be .... having regard to mode of compaction and .... of deposition.

b) The fresh concrete must be easily .... and ....

c) The single most important factor which governs the workability is the ....

d) Within certain limits, for a given quantity of water and paste a .... size of aggregate will give higher workability.

e) The .... shape also acts as ball bearing and reduces internal friction.

f) A well graded aggregate has .... voids in a given volume

g) The air bubbles can be viewed to act as .... enabling the particles to .... paste each other, thus .... mobility.

5.4 TESTS FOR MEASUREMENT OF WORKABILITY

By now, you have seen that the workability of concrete is a complex phenomena and is difficult to be defined precisely. The measurement of workability is equally difficult. A large number of workability tests have been researched but they are all empirical. None of the available tests measures workability in terms of fundamental properties of fresh concrete. The available tests cannot even easily be compared to each other as they tend to measure somewhat different properties of concrete. However, the existing tests do provide information on variations in workability for a given mix and are therefore useful as quality control measures.

We will now discuss the following tests which are commonly employed to measure workability :

a) Slump Test
b) K – Slump Test
c) Compacting Factor Test
d) Flow Test
e) Kelly Ball Test
f) Vee Bee Consistometer Test

The tests mentioned above a), c), d) are also prescribed in I.S. code, and other tests are optional.

5.4.1 Slump Test

The slump test is the oldest and most widely used field test of workability. The apparatus for conducting the slump test mainly consists of a metallic mould in the form of frustum of a cone having the internal dimensions as under :

Top Diameter	: 20 cm
Bottom Diameter	: 30 cm
Height	: 10 cm
Thickness of Metallic Sheet	: Not thinner than 1.6 mm

The internal surface of the mould is lightly moistened and placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers, each being approximately one fourth the height of the mould. Each layer is tamped 25 times by the 16 mm diameter tamping rod uniformly. After the top most layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is now lifted vertically so as to leave the concrete behind. This allows the concrete to subside. The difference in level between height of the mould and highest point of subsided concrete is measured and is taken as slump of concrete (see Figure 5.1).

Depending on the mix, three distinct types of slump may occur, as shown above.

a) **True Slump** consists of a general subsidence of the mass without any breaking up. This occurs in a plastic mix.

b) **Shear Slump** often indicates lack of cohesion. It tends to indicate harsh mixes or mixes prone to segregation. It may indicate that the concrete is not suitable for placement.

c) **Collapse Slump** generally indicates a lean, harsh or more likely a very wet mix.

However, slump test has its *limitations*. In case of dry mix no variation can be detected between mixes of different workability. Also it is not suitable for very wet mixes. It does not measure all factors which contribute to workability, nor is it always indicative of placeability of conerete.

Despite these limitations, the slump test is very *useful* at site for keeping a check on hour to hour and day to day variation in quality of mix. For example, a sudden increase in slump may be a pointer to the site engineer that the moisture content of the aggregate has suddenly increased or there has been a sudden change in the gravity of the aggregates or in the amount of water or admixture being used. Thus it gives warning to take corrective action, if

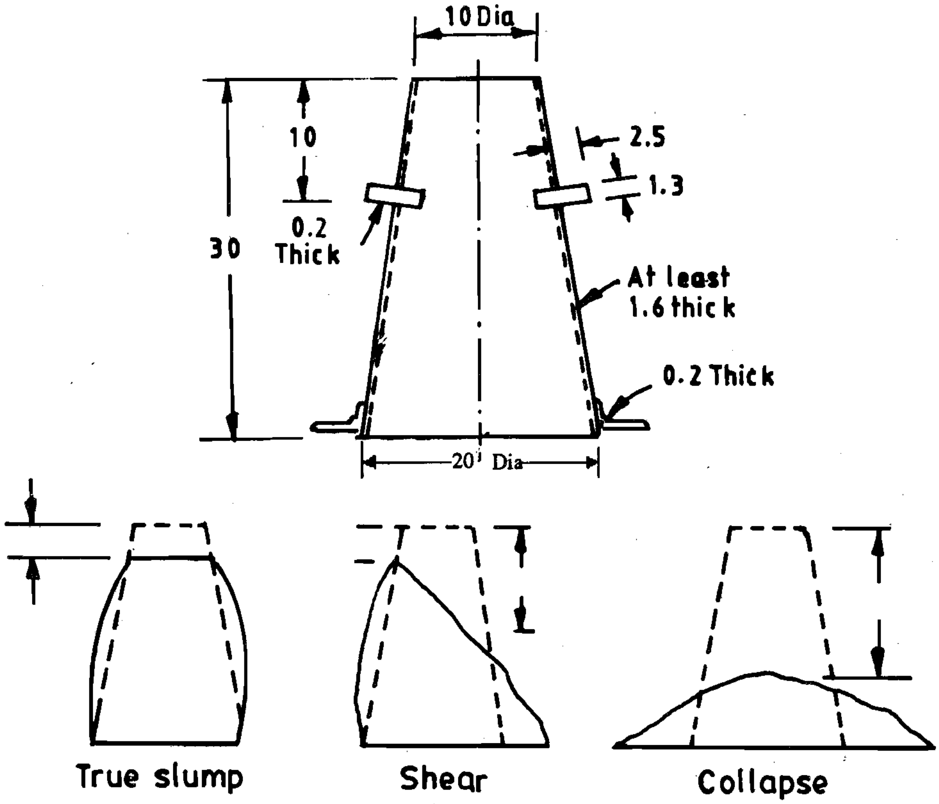

Figure 5.1 : Slump Test

necessary. The test is still popular because of its simplicity. The table which follows relates the slump value with different degrees of workability and the use for which the concrete is suitable is given in Table 5.1.

Table 5.1 : Use of Concrete with Degree of Workability

Degree of Workability	Slump (mm)	Compacting Factor		Use for which concrete is suitable
		Small Apparatus	Large Apparatus	
Very Low	0 – 25	0.78	0.80	Roads vibrated by power-operated machines. At the more workable end of this group, concrete may be compacted in certain cases with hand-operated machines.
Low	25 – 50	0.85	0.87	Roads vibrated by hand-operated machines. At the more workable end of 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	50 – 100	0.92	0.935	At the less workable end of this group, manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibration.
High	100 – 175	0.95	0.96	For sections with congested reinforcement. Not normally suitable for vibration.

5.4.2 K – Slump Test

The main apparatus used in the test is very handy and can be used to measure the slump directly in one minute after it is inserted in the fresh concrete up to the level of the floater disc. This apparatus is called as **K-Slump Tester** and it has four major parts :

a) A chrome plated steel tube with external and internal diameters of 1.9 cm and 1.6 cm respectively. The tube is 25 cm long and its lower part is inserted in the concrete to conduct the test. The length of this part is 15.5 cm which includes the solid cone. Two types of openings are provided in this part : 4 rectangular slots and 22 round holes in it.

b) A disc floater which divides the tubes into two parts, upper part serving as handle and lower one is used for testing.

c) A hollow plastic rod (measuring rod) which contains a graduated scale in centimeters. This rod can move freely inside the tube and can be used to measure the height of mortar that flows into the tube and stays there.

The total weight of the apparatus is 226 grams (see Figure 5.2).

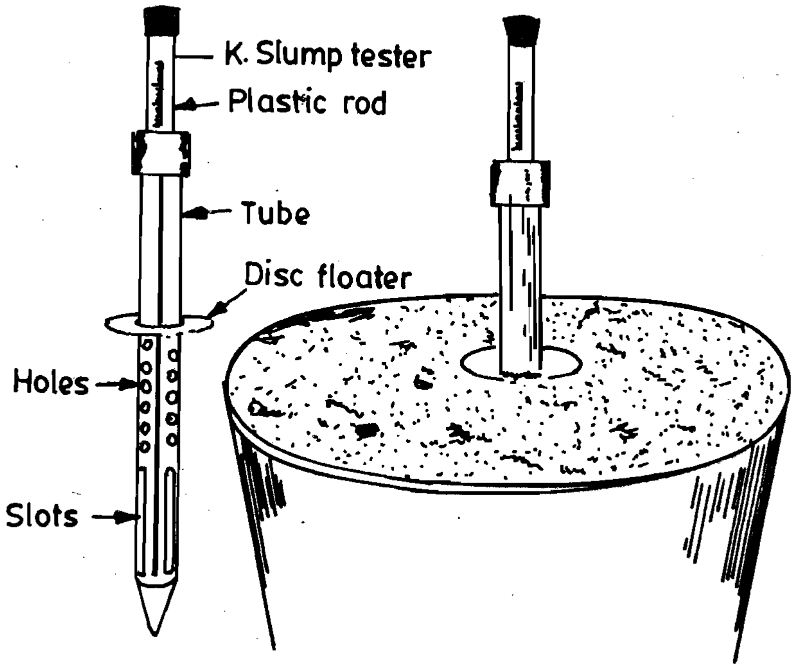

Figure 5.2 : K - Slump Test Appratus

Let us now go through the procedure of the usage of the K–Slump Tester :

i) Wet the tester, raise the measuring rod and insert vertically till the disc floater rests on the levelled surface of concrete.

ii) After one minute, lower the measuring rod slowly till it rests on the surface of the concrete which has entered the tube. Read K–Slump directly on the scale of the measuring rod.

iii) Remove the tester completely from the concrete vertically upwards. Now lower the measuring rod slowly till it touches the surface of the concrete retained in the tube and read workability (W) directly on the scale of the measuring rod.

Therefore you can see that K–Slump tester is simple to use and can be used directly on to buckets, wheelbarrows, slabs or any location where the fresh cement is placed. However it is not very effective in discriminating among stiff mixes.

5.4.3 Compacting Factor Test

The compacting factor test was developed in Great Britain in 1947. It is claimed to be the most efficient tests for measuring the workability of concrete. This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. This test is primarily designed for use in the laboratory but it can also be used in the field.

Apparatus

The diagram of the apparatus is shown in Figure 5.3 followed by details of essential dimensions. Please examine it in detail so as to understand the procedure of its usage.

Procedure

a) Place sample of concrete to be tested in the hopper A so as to fill it to the brim.

b) Open trap door of hopper A so that concrete falls into hopper B.

c) Now open trap door of hopper B so that concrete falls into the cylinder C.

d) Remove excess concrete above the top of the cylinder and clean it externally. Weigh it now upto nearest 10 grams. This is called **Weight of partially compacted concrete.** Let it be denoted by D .

e) Now empty the cylinder and refill with concrete from original sample in layers of 5 cm deep approximately. Ram the layer or vibrate them so as to obtain full compaction. Weigh it to nearest 10 grams. This is known as **Weight of fully compacted concrete.** Let us call this as E .

Then the compaction factor $= \frac{D}{E}$

You must have observed from above that this test is more precise and sensitive than slump test. It is particularly useful for mixes of very low workability which are normally used in situations where compaction is done by vibration. This test thus relates closely to the workability requirements of concrete.

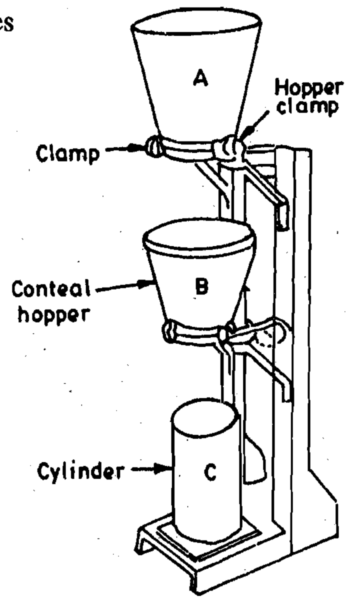

Figure 5.3 : Compacting Factor Test Apparatus

Table 5.2 : Dimensions of Compacting factor Apparatus

Sl. No.	Essential Dimensions of the Compacting factor Apparatus for use with Aggregate not exceeding 40 mm Normal Max Size	Dimension (cm.)
1.	Upper Hopper, A	
	Top internal diameter	25.4
	Bottom internal diameter	12.7
	Internal height	27.9
2.	Lower Hopper, B	22.9
	Top internal diameter	12.7
	Bottom internal diameter	22.9
	Internal height	
3.	Cylinder, C	15.2
	Internal diameter	30.5
	Internal height	
4.	Distance between bottom of upper hopper and top of lower hopper	20.3
5.	Distance between bottom of lower hopper and top of cylinder	20.3

5.4.4 Flow Test

Flow tests measure the ability of a concrete to flow under jolting or continuous vibration and provide information as to the quality of concrete with respect to consistency, cohesiveness and the proneness to segregation.

Apparatus

The apparatus consists of a flow table of about 76 cms diameter with concentric circles marked on it. The details are shown in the Figure 5.4.

Procedure

a) Clean the flow table top and wet it. Now place the mould with 25 cm base diameter at centre of the table and fill it with sample of concrete in two layers.

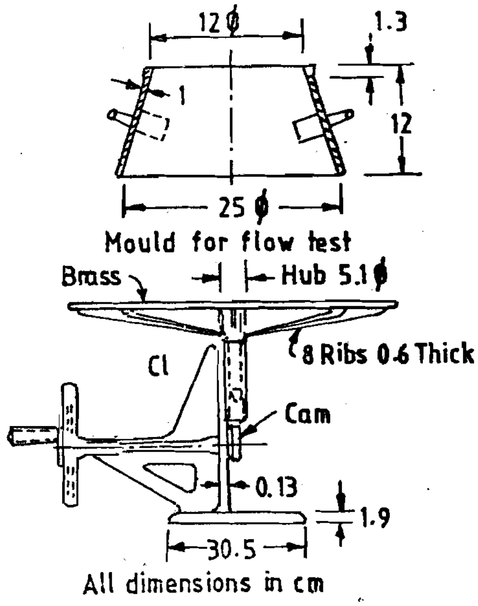

Figure 5.4 : Flow Test Apparatus

Rod each layer 25 times with a tamping rod of 1.6 cm diameter, 61 cm length. Remove excess of concrete from top.

b) Lift mould vertically upward and concrete stands on its own now.

c) Using the mechanism fitted in the table, raise and drop the table through a height 12.5 mm at the rate of 15 times in about 15 seconds.

d) Now measure the diameter of the spread concrete in six directions to the nearest 5 mm and work out their average.

Then,

$$\text{Flow (\%)} = \frac{\text{Spread Diameter in cm} - 25}{25} \times 100$$

This value could range between 0 to 150 per cent.

5.4.5 Kelly Ball Test

This is one of the penetration tests which measures the depth of penetration of a indenter into concrete. In Kelly Ball test this indenter is 15 cms in diameter and is a metal hemisphere weighing 13.6 Kgs. The apparatus is shown in the Figure 5.5.

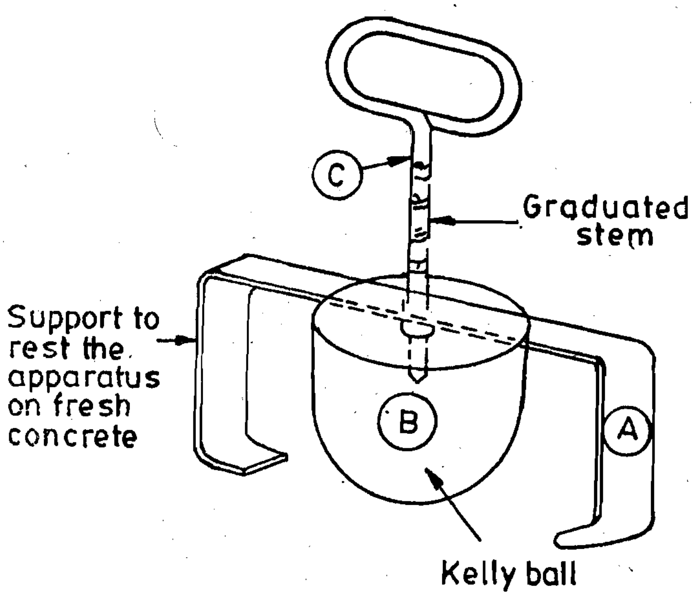

Figure 5.5 : Kelly Ball Test Apparatus

Procedure

a) Level the concrete surface to be tested.

b) Place the Kelly Ball tester on concrete and lower the ball gradually on the surface of concrete.

c) Read the penetration directly on the stem to the nearest 6 mm.

This test can be performed in about 15 seconds and the results are more consistent than Slump test. However the disadvantage is that it requires a large sample of concrete and it cannot be used when concrete is used in thin members. The minimum depth of concrete must be a minimum of 20 cms and minimum distance from the centre of the ball to nearest edge of concrete has to be minimum 23 cms.

5.4.6 Vee Bee Consistometer Test

This is probably one of the most suitable tests for determining differences between consistency of very dry mixes. This test is widely used in Europe. It is however only applicable to concretes with a maximum size of aggregate of less than 40 mm..

Apparatus

The equipment consists of vibrating table, a metal pot, a sheet metal cone and a standard iron rod (see Figure 5.6).

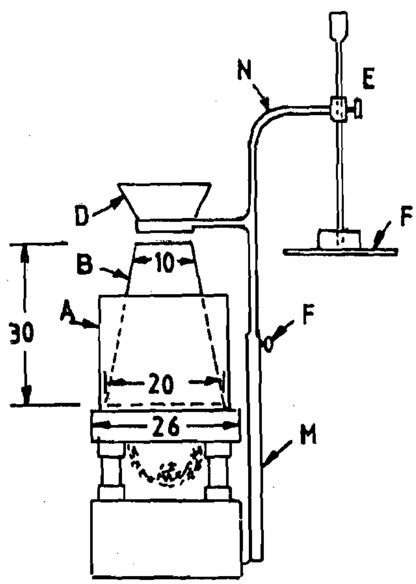

Figure 5.6 : Vee-Bee Consistometer

Procedure

a) As discussed earlier in 5.4.1, the slump test is conducted by placing the slump cone B inside the sheet metal cylinder pot A of the consistometer which in turn rests on the vibrating table.

b) The glass disc C attached to the swivel arm is turned so that it is above the concrete.

c) The electrical vibrator is now switched on and the stop watch is started. The vibration is continued till such time the conical shape of the concrete assumes the cylindrical shape of cylinder A. (This is judged by viewing through C.) The stop watch is switched off as soon as this occurs.

d) The time required for this change of shape from conical to cylindrical is called Vee Bee Degree.

Let us now study two more phenomenon which can occur in fresh concrete, namely Segregation and Bleeding, which will follow after SAQ 2.

SAQ 2

a) What is compacting factor ?

b) What is the principle of compacting factor test ?

c) What is a true slump ?

d) What does shear slump indicate ?

e) What does the flow test measure ?

f) What are the common tests for measuring workability ?

5.5 SEGREGATION

Segregation refers to a separation of the components of fresh concrete resulting in a non-uniform mix. In general, it means that coarse aggregates are separating from the mortar. Such concrete obviously can not be used. The lack of homogeneity will also induce undesirable properties in hardened concrete.

As you are aware there are considerable differences in sizes and specific gravities of different constituents of concrete like cement, coarse aggregates, fine aggregate, water etc. Naturally, therefore, there will be a tendency for them to separate or segregate. This segregation could be of three types :

a) The coarse aggregate separating out or settling down from the paste,

b) The paste or the matrix separating away from coarse aggregate, and

c) The water being of lowest specific gravity, separating out from the rest of the materials.

The conditions which could encourage segregation are :

a) Badly proportioned mix where sufficient matrix is not available to bind and contain the aggregate.

b) Insufficient mixed concrete with excess water content.

c) Dropping of concrete from height as in case of column.

d) Discharging concrete from a mixer with worn out blades.

e) Long distance haulage of concrete, without proper care.

f) Vibrating too wet a mix excessively for a long time.

You might have observed at site that a mason may have tendency to work too much with the trowel, float or tamper immediately on placement of fresh concrete. This action leads to processing of coarse aggregate downwards which results in upward movement of excess paste to the surface. This causes segregation which affects homogeneity and serviceability of concrete.

It is therefore obvious that tendency for segregation can be overcome by correct mix design, transporting, placing and finishing. Infact a cohesive mix would have the least tendency to segregate. Use of certain workability agents and pozzolonic materials help in reducing segregation. Air-entraining agents are also very useful.

Although there are no quantitative tests for segregation but the pattern of subsidence in a slump test or the pattern of spread in a flow test, gives a good idea about the quality of concrete with respect to segregation.

5.6 BLEEDING

Bleeding may be defined as the appearance of water on the surface of concrete after it has been consolidated but before it has set. It is also sometimes referred as water gain. Water being the lightest component, segregates from the rest of the mix and therefore bleeding could be termed as a special form of segregation. Bleeding is generally observed in highly wet mixes, badly proportioned and insufficiently mixed concrete. Excessive bleeding is also observed in thin concrete members like roof slab and road slabs when concreting is in progress in sunny weather. Bleeding rate increases with time up to about one hour or so and thereafter the rate decreases, but the process continues till the final setting of cement.

Harmful Effects

1) **Laitance** : When bleeding occurs, water moves to the surface and brings certain amount of cement also along with it. When the surface of concrete is worked up with trowel and floats, the aggregates go down and cement and water moves up. This forms a layer of paste at the surface which is called *Laitance.* This produces dust in summer and mud in rainy season. Also the shrinkage cracks are more since the surface contains more water and less aggregate matter. Another drawback is that laitance forms a plane of weakness which reduces bond with next layer of cement. You could avoid this by brushing away the laitance completely before the next lift of concrete is poured.
2) **Permeability** : When bleeding occurs and water traverses through the concrete from bottom to top, it makes continuous channels. It is seen that when water/cement ratio is more than 0.7, the bleeding channels remain continuous and unsegmented even by the developing gel. These continuous channels are one of the causes of increased permeability of concrete structures.
3) **Reduction in Bond** : During bleeding the water's upward movement may be intercepted by aggregates. This is likely to result in accumulation of water below the aggregate creating voids and hence reducing bond between aggregate and paste. Similarly the bleeding water which accumulates below the reinforcing bars, particularly the cranked bars, reduces the bond between reinforcement and the concrete thus affecting the stress transfer.

Remedial Measures

1) The harmful effects of bleeding can be remedied by controlled revibration of concrete. The formation of laitance can be reduced by delayed finishing operations.
2) Bleeding can also be reduced by use of finely divided pozzolonic material, finer cement, cement with low alkali contents and air-entraining agents.

However it may be noted that bleeding is not completely harmful if the rate of evaporation of water from the surface is equal to the rate of bleeding. Also, removal of excess water will do good to concrete. You must keep in mind that it is the delayed bleeding which is harmful, which occurs when concrete has lost its plasticity.

SAQ 3

a) What are the conditions which encourage segregation ?

b) What is Laitance ?

c) How does bleeding causes reduction in bond in concrete ?

5.7 SUMMARY

In this Unit we have discussed a part of the Workability and Fresh Concrete chapter. We concentrated on firstly defining what is workability and found that no one definition can fully describe it. One of the popular definition is *Workability is the ease with which concrete can be fully compacted having regard to mode of compaction and place of deposition effectively.* Next we examined the various factors which affect workability. We observed that water content is one of the most important factors which governs workability of concrete. Further mix proportions play an important role in deciding whether the resulting concrete would be cohesive or harsh. Aggregates being the largest constituent, their size, shape, texture and grading influence workability considerably. Admixtures can help us in improving workability by inducing mobility.

You also saw that the measurement of workability is as difficult as it is to understand the phenomena of workability. However the various available tests do provide information on variations in workability for a given mix. These tests which measure slump, compacting factor, penetration or consistency of concrete, do help us in understanding the different aspects of workability of concrete. Slump test still remains as one of the most popular test inspite of its limitations. However its quicker versions like K–Slump Tester can be used directly on buckets and wheel barrows.

Both segregation and bleeding are harmful to concrete. While segregation refers to separation of components of fresh concrete, bleeding refers to appearance of water on the surface of concrete after it has been consolidated but before it has set. We will study the Manufacturing Process of Concrete in Unit 6 – Workability and Fresh Concrete - II.

5.8 KEY WORDS

Batching	:	Measurement of materials.
Bleeding	:	Upward movement of water to the surface of concrete.
Segregation	:	Tendency of concrete constituents to separate.
Slump	:	Subsidence.
Workability	:	Ease of placing and full compaction.

5.9 ANSWERS TO SAQs

SAQ 1

Check your answer with the preceding text.

SAQ 2

a) The compacting factor is defined as the ratio of density actually achieved in the compacting factor test to the density of same concrete when fully compacted.

b) The compacting factor test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height.

c) If in a slump test the concrete slumps evenly then it is called True Slump.

d) The shear slump indicates that the concrete is non-cohesive and shows the characteristic of segregation.

e) Flow Test measures the ability of concrete to flow under jolting or continuous vibration and provides information as to the quality of concrete with respect to proneness to segregation.

f) The common tests for measuring workability are

   i) Slump Test
   ii) K – Slump Test
   ii) Compacting Factor Test
   iv) Flow Test
   v) Kelly Ball Test
   vi) Vee Bee Consistometer Test

SAQ 3

Check your answer with the preceding text.