Plain & Reinforced Concrete-1

CE-313

Workability of Concrete

WORKABILITY OF CONCRETE

- ***Segregation*** of concrete means separation of concrete constituents accompanied by settling of bigger particles.
- A coherent and almost homogeneous mass of concrete is actually required in place of segregation.
- ***Bleeding*** of concrete means separation of cement slurry from the concrete mass.
- Usually, either this paste comes on top of the concrete surface or leaks through the pores in the formwork.

- Workability of the fresh concrete is a property related with its ease of transportation, placing, compaction and finishing without any detrimental effects such as segregation or bleeding.
- Following are the three important properties of the workability of concrete:
  - Degree of compaction is related with the workability of the concrete.
  - Workability of concrete is not an absolute quantity but is a physical property of concrete.
  - Workability of fresh concrete is judged based on **compactibility**, **mobility** and **stability**.

Relation With Degree of Compaction

- The long-term properties of hardened concrete, such as strength, stability, imperviousness and durability depend upon its degree of compaction.
- This compaction, in turn, is related with the workability of the concrete.

Workability of concrete is not an absolute quantity but is a relative term

- For example, the workability requirements for a mass concrete work are significantly different from that of concreting in thin or heavily reinforced sections.
- Similarly, concreting with hand compaction and another by using vibrations need totally different degrees of workability.

Workability of fresh concrete required for a particular project is based on its compactibility, mobility and stability.

- ***Compactibility*** refers to the ease with which the concrete is compacted and the air voids are removed.
- ***Mobility*** is a measure of the ability of concrete to flow into the molds and around the reinforcement.
- ***Stability*** is a property of fresh concrete to remain as a coherent homogeneous mass during handling and vibration without segregation or bleeding.

Mechanism of Workability

- When the ingredients of concrete are mixed in dry state, air voids are entrapped within the particles.
- After the addition of water and wet mixing, the air bubbles may automatically move up due to their lesser density as compared with all other constituents of concrete.
- The only obstruction to this movement of the air bubbles is caused by the surrounding thick paste and the aggregate particles due to mechanical interlocking and chemical adhesion.

- If particles move relative to each other, the air bubbles may find their way up and may escape.
- Hence, movement of particles is required for compaction.
- This may be achieved in two ways.
  - In the first method it is tried to reduce the friction between the particles by adding more water or plasticizers.
  - The second method is to provide external energy to overcome the friction between the particles by rodding or by vibration of the concrete.

- Quantitatively, a good measure of workability is the useful internal work or energy required to overcome the internal friction between the particles of the concrete so that they may settle down with elimination of voids to produce full compaction.
- In practice, however, additional work or wasted energy is also associated with the useful energy for two different reasons.
    - Firstly, this is required to overcome the surface friction between concrete and the formwork or the reinforcement.
    - Secondly, this is also required to vibrate the molds and the already compacted concrete.

- The strength of hardened concrete is significantly reduced if voids are left in the compacted concrete mass.
- The term ***honeycombing*** is used to describe the presence of large and usually interconnected voids in the concrete showing extremely poor quality concrete produced by escape of fine particles along with slurry of cement and water.
- The average reduction in concrete strength by the presence of voids is shown in Table 22.1.

Table 22.1. Average Reduction of Concrete Strength due to Presence of Voids.

Voids Percentage	Strength Reduction
2%	10%
5%	30%
10%	55%
20%	85%

- The water required for hydration of cement is approximately 25 percent of the weight of cement.
- However, if concrete is made using this W/C ratio, it will be very dry and almost impossible to compact.
- A considerably larger amount of work is required to liberate the air, which is originally entrapped between the aggregate particles.
- Some extra water is added to concrete mixes to lubricate the particles.

- The extra water, after evaporation, further produces voids in concrete and hence its amount should be kept to a minimum.
- The voids in hardened concrete may either be bubbles of entrapped air or spaces left by evaporation of excess water.

- Using a lesser amount of water in the mix may leave bubbles of entrapped air and using more water may lead to more spaces left by the excess water.
- The best amount of water to be added is that which keeps the sum of volumes of both types of voids to a minimum for a given method of compaction.
- This optimum water content may vary for different concreting projects according to the site requirements.
- Concrete with the minimum volume of total voids is the most desirable because it produces dense and strong concrete.

Factors Affecting Workability Available For A Mix

- Water content (and not necessarily the W/C ratio).
- Aggregate type.
- Aggregate grading.
- Aggregate/cement ratio.
- Presence of admixtures.
- Fineness of cement.
- Time required for mixing, transportation, placing and compaction of concrete.
- Prevailing temperature and humidity.
- Air entrainment.

Water content

- This is the most important factor that influences workability.
- In general, more water content increases lubrication of particles and hence gives more workable mixes.
- However, excessive water may also produce segregation and bleeding and thus may disturb the workability.
- A well-designed mix with such a water content that gives a coherent mass but allows easy placing and compaction for the given means of compaction, type of construction and type of formwork is usually desirable.

Aggregate type

- The porosity, surface texture, size and shape of particles influence the workability of a concrete mix.
- If aggregates absorb more water, workability may be reduced.
- Rough textured particles need more lubrication and hence more water to move one above the other.
- Finer particles require more water to wet their larger outer surface.
- A rounded natural aggregate develops less friction than an irregular aggregate reducing the water demand.
- Lightweight aggregate lowers the workability due to its high porosity.

Aggregate grading

- A well-graded aggregate with spaces between the larger particles filled by the smaller particles avoids segregation and a more homogeneous mass may be obtained improving the workability.
- A high ratio of coarse aggregate to fine aggregate produces a harsh and less workable mix.
- Mixes with too many fines give more workability but the durability of the concrete reduces.

Aggregate-over-cement ratio

- When aggregate over cement ratio is low, more particles will be finer resulting in a higher total surface area of solids.
- This reduces workability up to certain extent.
- The grading of aggregate may be made coarser in such cases to regain the same workability.

Presence of admixtures

- Plasticizers and super-plasticizers are used in concrete to improve the workability up to a large extent at given water / cement ratio without adversely affecting the strength.
- The extreme case possible with the help of super-plasticizers is to get flowing and self-compacting concrete with lesser water / cement ratio and no segregation.
- Accelerators may reduce workability depending on the time consumed after mixing of water in the concrete.

Fineness of cement

- Finer cement may require more water for a workable mix but the effect is relatively less pronounced.

Time required for mixing, transportation, placing and compaction of concrete

- After the initial mixing, workability reduces due to evaporation of water, absorption by aggregate and stiffening of the cement gel.

Prevailing temperature and humidity

- A higher temperature and low humidity condition reduces the workability due to more loss of water and quicker stiffening of cement gel.
- Over longer periods, loss of workability with temperature may be considerable.
- Above 50° C with relative humidity lower than 20%, the workability reduces considerably.
- However, for normal durations and temperature and humidity conditions, the effect of these factors is insignificant.

Air entrainment

- Entrained air consists of very fine bubbles of air intentionally added to the concrete to improve some desirable properties of concrete such as resistance against frost action.
- In general, entrapped air improves workability but is associated with some loss of strength.

Factors Affecting Workability Of A Mix Required For A Particular Project

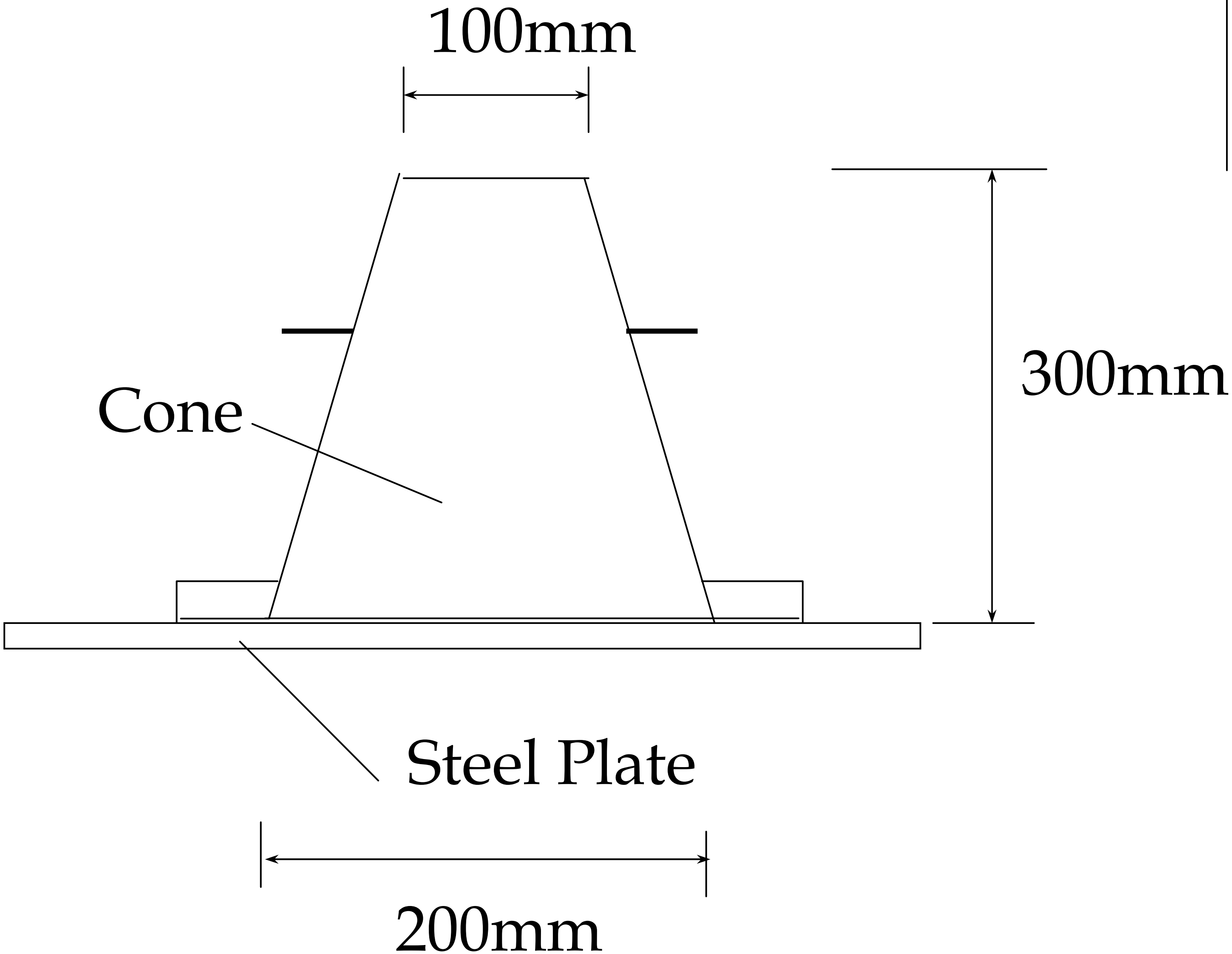
- Means of compaction, manual rodding or by vibration.
- Concrete dimensions, especially the least dimension of structural members.
- Open concreting or concreting in molds.
- Type of formwork.
- Amount and placement of reinforcement.
- Time required for mixing, transportation and placing.
- Required concrete finish.
- Temperature and humidity.
- Drop height for columns and walls.

Tests For Workability

- Slump test
- Compacting factor test
- Vebe test
- Flow table test
- Ball penetration test
- ASTM flow test
- Remolding test
- Nasser’s K-tester
- Two-point test

Slump test

- The slump test is the most common field method for the determination of the workability.
- The apparatus is portable and the test may be carried out in a lesser space and consuming lesser time.
- The procedure of the test is given in ASTM C143. The apparatus consists of a steel mold and a steel plate.
- The mold is a frustum of a cone having top diameter of 100mm and bottom diameter of 200mm, with a height of 300mm, as shown in Fig. 22.1.
- The mold is placed on the steel plate with the operator standing on the footrests provided on the two sides of the mold.
- The inner surface of the mold and the base plate are moistened before start of the test.


100mm
300mm
Cone
Steel Plate
200mm

- The concrete is placed in three different layers and each layer is tamped with 25 blows of a standard 16mm diameter rod with rounded end.
- Rolling and moving the tamping rod from one to the other end level the top surface of concrete in the mold.
- All extra concrete around the mold is removed and the place is thoroughly cleaned.
- After filling and tamping, the cone is gently lifted and placed closer to the concrete specimen in upside down position.
- The concrete settles down due to workability and the decrease of the height with respect to the cone is noted to the nearest 5mm. This value is called slump of the concrete.

- Depending on the type of settling of the concrete during a slump test, three types of slumps may be defined. A ***true slump*** occurs if the concrete after the removal of the cone only bulges out. If the concrete excessively settles as well as flows outwards at the base, the resulting slump is called ***collapse slump***. A ***shear slump*** is obtained if some part of the concrete slides down at inclined plane and is separated from rest of the mass.

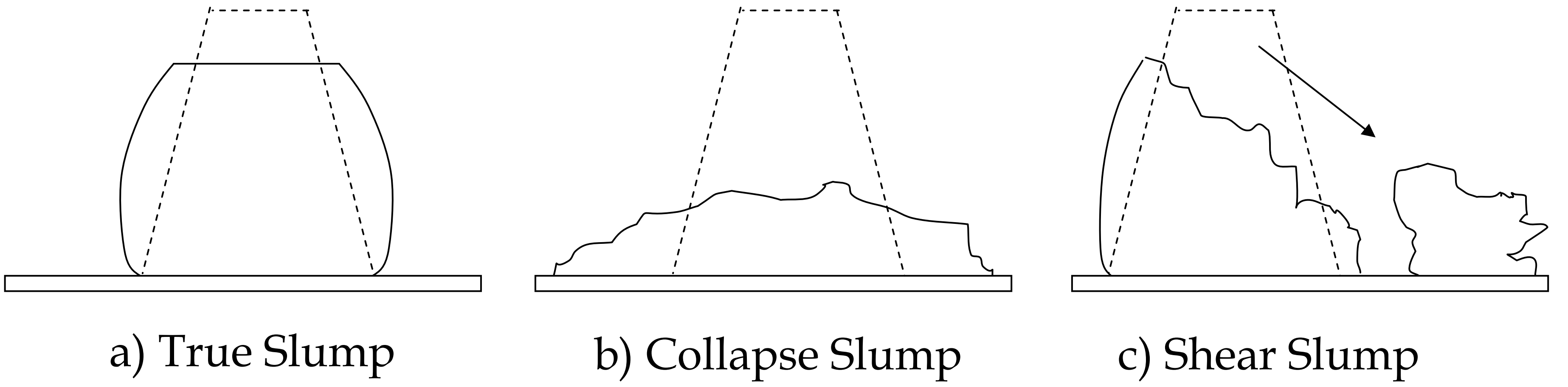


Fig. 22.2. Types of Slump Failures.

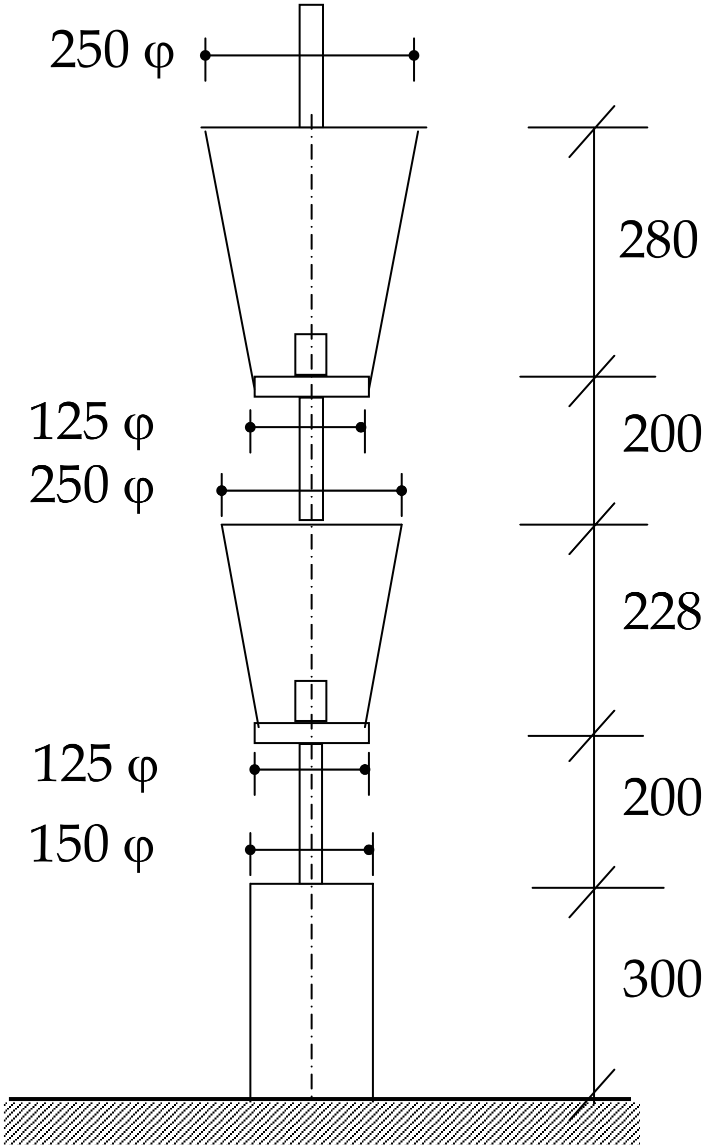
- In case of a shear slump, the test is to be repeated once and the type of failure is to be confirmed.
- A shear slump indicates lack of cohesion of the mix and such types of mixes are to be avoided in practical situations.

Table 22.2. Recording Readings for the Slump Test.									
Mix No.	**Mix Propor-tions**	**W/C Ratio**	**Type of Fine Agg.**	**Type of Coarse Agg.**	**Admix-ture**	**Tempe-rature**	**Humi-dity**	**Slump (mm)**	**Type of Slump**

Slump required for various projects

Table 22.3. Average Values of Slump for Various Jobs.		
Use of Concrete	**With Vibrations** (mm)	**Without Vibrations** (mm)
1. Mass concrete, roads	10 to 25	50 to 75
2. Large open sections, foundations, etc.	25 to 50	40 to 115
3. Thin sections (beams, walls and columns) and slabs with moderate steel	30 to 60	100 to 150
4. Thin section with congested reinforcement	50 to 80	125 to 175

Compacting factor test



- The apparatus consists of a larger conical hopper at the top, a smaller conical hopper in the middle and a cylinder at the bottom.
- Both of the hoppers have hinged doors at their bottom.
- The upper hopper is gently filled with concrete without any compaction and is leveled at the top.
- When the bottom door of this hopper is opened, the concrete falls into the smaller hopper and the extra concrete spills down.
- The purpose of this step is to get a fixed amount of concrete in a particular state, minimizing the effect of way of filling the top hopper.

- When the door of lower hopper is opened, the concrete falls in to the cylinder with the extra concrete spilling down.
- A certain amount of energy is supplied to the mix by dropping it from a standard height.
- This concrete is also partially compacted due to fall from a fixed height.
- The top surface of concrete in the cylinder is then leveled and the extra concrete sticking to the mold is removed.
- Weight of this partially compacted concrete is noted.
- The same concrete is then fully compacted in the cylinder and again weight of fully compacted concrete is noted.

- Compacting factor is calculated as the ratio of weight of partially compacted concrete during the test to the weight of fully compacted concrete.
- Its value of 0.78 to 0.85 indicates low workability, while a value in the range 0.86 to 0.95 indicates medium to high workability.

Concluded