SETTING

Setting refers to a change from a fluid to a rigid stage

Cement + water → cement paste → lose its plasticity gradually → when it lose its plasticity completely → setting occurs.

The stages of setting include:
- **Initial setting**
- **Final setting:** It is important to distinguish setting from hardening—which refers to the gain of strength of a set cement paste.

The two first to react are $C_3A$ and $C_3S$. The setting time of cement decreases with a rise in temperature.

The importance of setting in **concrete works** comes from the importance to keep the fresh concrete in the plastic stage for enough time necessary to complete its mixing and placing under practical conditions (*this is the purpose from initial setting time*). But, from the **economical side**, it is important that the concrete hardens at convenient period after casting (*this the purpose of final setting time*).

**Vicat apparatus** - use to measure the setting time for cement paste.

- **Initial setting time** - refers to the beginning of the cement paste setting.
- **Final setting time** - refers to the beginning of hardening and gain of strength.

**Iraqi Standard Specification** No. 5 limits:
- Initial setting time not less than 45 minutes.
- Final setting time not more than 10 hours.
Factors affecting the setting

1- Water/cement (w/c) ratio - The setting time of cement increase with the increase of w/c ratio.
2- Temperature and relative humidity - The setting time of cement decreases with a rise in temperature and decrease of relative humidity.
3- Fineness of cement - The setting time of cement decreases with a rise in fineness of cement.
4- Chemical composition

Flash setting

It is abnormal premature stiffening of cement within a few minutes of mixing with water. - It differs from flash set in that:
- No appreciable heat is evolved.
- Remixing the cement paste without addition of water restores plasticity of the paste until it sets in the normal manner and without a loss of strength.

Occurs when there is no gypsum added or exhausting the gypsum (added with little amount). so $C_3A$ reacts with water causing liberation high amount of heat causing rapid setting of cement, and leading to form porous microstructure that the product of hydration of the other compounds precipitate through unlike the normal (ordinary) setting that have much lower porosity microstructure.

Causes of false setting

1- Dehydration of gypsum - when interground with too hot a clinker formed: hemihydrates ($CaSO_4 \cdot 0.5H_2O$) - when temperature between 100- 190° C - or anhydrite ($CaSO_4$) - when temperature > 190° C -.

And when the cement is mixed with water these hydrate to form gypsum, with a result stiffening of the paste.
2- Reaction of alkalis of the cement

During bad storage - alkalis in the cement react with CO₂ (in the atmosphere) to form alkali carbonates, which they react with Ca(OH)₂ liberated by the hydrolysis of C₃S to form CaCO₃. This precipitates and induces a rigidity of the paste.

\[
\text{K}_2\text{O} + \text{Na}_2\text{O} + \text{CO}_2 \rightarrow \text{K}_2\text{O}_3 \text{ or Na}_2\text{CO}_3
\]
\[
\text{K}_2\text{CO}_3 \text{ or Na}_2\text{CO}_3 + \text{Ca(OH)}_2 \rightarrow \text{CaCO}_3
\]

3- Activation of C₃S subjected to wet atmosphere

During bad storage - water is adsorbed on the grains of cement (the water stick on their surfaces) and activates them. and these activated surfaces can combine very rapidly with more water during mixing: this rapid hydration would produce false set.

FINENESS OF CEMENT

The last steps in the manufacture of cement is → the grinding of clinker mixed with gypsum.

Hydration → starts at the surface of the cement particle (it is the total surface area of cement) → Represent the material available for hydration → The rate of hydration depends on the fineness of the cement particles.

Higher fineness is necessary → For a rapid development of the strength as shown in Figure below.

It reduce the water layer separate one the mixture surface due to bleeding.
On the other hand the fineness of cement has disadvantages:

1- Increasing the cost of grinding with increase fineness

2- Storage difficulties, due to the finer the cement the more rapidly deteriorates on exposure to the atmosphere. Because the increasing of surface area that exposed to atmosphere.

3- Increasing the cement fineness means increasing in drying shrinkage.
Finess of cement is tested in two ways:

1- sieve Method

It is the classical method to measure the cement fineness, in which the residue percent of cement on sieve No.170 (90 µm) according to BS (British Standard) shall not exceed 10% for ordinary Portland cement.

According to American Standards ASTM the residue percentage on sieve No.200 (74µm) shall not exceed 22%.

2- By determination of specific surface (total surface area of all the particles in one gram of cement by air-permeability apparatus).cm²/gm or m²/kg.

a- Wagner Turbidimeter Method, ASTM C115-10

b- air-permeability Method, BS 12:1971


This method used by Iraqi Standards No.5.

According British Standard BS 12:1971, the minimum specific surface measured by air-permeability Method is 2250 cm²/gm for ordinary Portland cement.
CONSISTENCY OF STANDARD PASTE (NORMAL CONSISTENCY)

It's defined as the percentage by mass of water to cement required to produce cement paste of desired consistency. It is used in the determination of the initial and final setting times and soundness of cement.

The consistency is measured by the Vicat apparatus, and it is defined as that consistency which will permit a Vicat plunger having 10 mm diameter to penetrate the paste to a point (5±1 mm) from the bottom of the mould.

SOUNDNESS TEST

The testing of soundness of cement to ensure that the cement does not show any appreciable subsequent expansion is of prime importance which could result in a disruption of the hardened cement paste (namely the cement paste, once it has set, does not undergo a large change in volume).

The unsoundness in cement is due to

1- The delayed or slow hydration.
2- The presence of excess of lime than that could be combined in kiln.
3- Excessive proportion of magnesium.
4- Excessive proportion of sulphates.

Because unsoundness of cement is not apparent until after a period of months of years, therefore accelerated tests are required to detect the unsoundness of cement. The cement soundness could be tested by two methods:

1- Autoclave Test, ASTM C 151-09
2- Le Chatelier Test, BS EN 196-3:2005
1- Autoclave Test, ASTM C 151-09

The autoclave test is sensitive to both free magnesia and free lime. In this test, prescribed by ASTM C151-09, a neat cement bar, 25 mm (or 1 in.) square in cross-section and with 250 mm (or 10 in.) gauge length, is cured in humid air for 24 hours. The bar then placed in an autoclave (a high-pressure steam boiler), which is raised to temperature of 216 °C in 60 min, and maintained at this temperature for 3 hours. The high steam pressure accelerates the hydration of both magnesia and lime. The autoclave is cooled and the length measured again. The expansion of the bar due to autoclaving must not exceed 0.8 per cent.

2- Le Chatelier Test, BS EN 196-3:2005

Le Chatelier apparatus consists of a small brass cylinder split along its generatrix. Two indicators with pointed ends are attached to the cylinder on either side of the split; in this manner, the widening of the split, caused by the expansion of cement, is greatly magnified and can easily be measured. The cylinder is placed on a glass plate, filled with cement paste of standard consistency, and covered with another glass plate. The whole assembly is then placed in a cabinet at 20 ± 1 °C and a relative humidity of not less than 98 percent. At the end of that period, the distance between the indicators is measured and the mould is immersed in water and gradually brought to the boil in 30 minutes. After boiling for 3 hours, the assembly is taken out and, after cooling, the distance between the indicators is again measured. The increase in this distance represents the expansion of the cement, and for Portland cements is limited to 10 mm by BS EN 197-1 : 2000.
CEMENT STRENGTH

The compressive strength of hardened cement is the most important of all the properties for structural use. The strength of mortar or concrete depends on the cohesion of the cement paste, and its adhesion to the aggregate particles and to a certain extend on the strength of the aggregate itself. The last factor is not considered at this stage, and is eliminated in tests on the quality of cement by the use of standard aggregates.

Strength tests are not made on a neat cement paste because of difficulties of moulding and testing with a consequent large variability of test results. Cement-sand mortar and, some cases, concrete of prescribed proportions and made with specific materials under strictly controlled conditions, are used for the purpose of determining the strength of cement.

There are several forms of strength tests:

a- Direct compression
b- Direct tension
c- Flexure

Direct tension strength and flexure strength of concrete are generally of lesser interest than compressive strength. Nowadays the compressive strength of cement that considered to be crucial.