YILDIZ TECHNICAL UNIVERSITY – DEPARTMENT OF ARCHITECTURE
2017 -2018 ACADEMIC YEAR – SPRING SEMESTER
BUILDING MATERIALS LECTURE NOTES / Dr. Polat DARÇIN

BASIC MATERIALS – 1

CEMENT

Cement, in general, is an adhesive and cohesive material which is capable of bonding together particles of solid matter into a compact durable mass.

Cement is a hydraulic material that sets and hardens both in water and air and turn into a stable product. When mixed with water, a plastic paste is formed. At the beginning, it is possible to give any desired form to this paste, but with time, it begins to harden and loses its plasticity and gains strength against deformation.

Setting starts when the paste begins to lose its plasticity and it stops when the paste is stiffened. After the setting, hardening starts and this process gives its mechanical strength to cement.

Cement can be manufactured either from natural cement stones or artificially by using calcareous and argillaceous materials. The most common artificial cement in general use around the world is Portland cement.

Portland Cement

This cement is made by heating limestone (calcium carbonate) with other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination, whereby a molecule of carbon dioxide is liberated from calcium carbonate to form calcium oxide, or quicklime, which then chemically combines with silica (SiO_2), aluminum oxide (Al_2O_3) and ferric oxide (Fe_2O_3) of clay to form calcium silicates and other cementitious compounds.

limestone

clay

The resulting hard substance, called “clinker” (grains with sizes 1-3 cm), which does not react with water and have a binding property, is then ground with a small amount of gypsum into a powder to make ordinary Portland cement, the most commonly used type of cement. Gypsum is used to retard hardening of cement. The name Portland comes from its resemblance to a natural stone quarried from Portland in UK.

The grounded and powdered clinker is then cooled and stored in silos. Generally, cement is stored in bags of 50 kg.

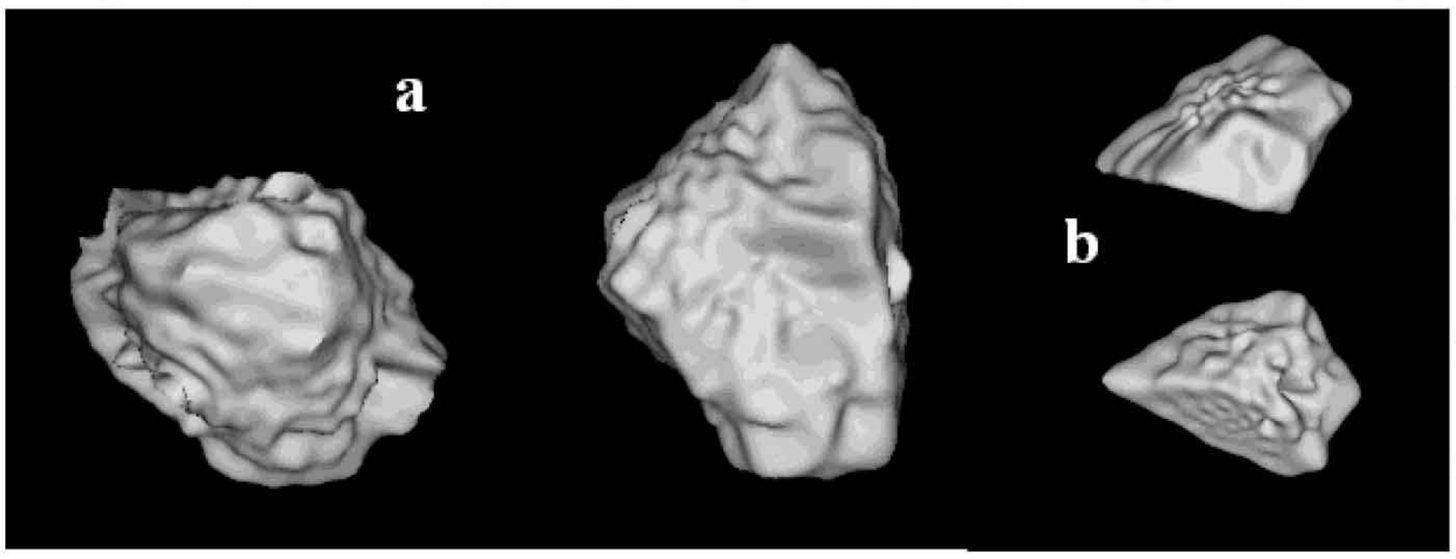
clinker

substance		function	composition (%)
CaO calcium oxide (quicklime)		Controls strength and soundness. Its deficiency reduces strength and setting time.	60 – 65
SiO_2 silicon dioxide (silica)		Gives strength. Excess of it causes slow setting.	17 – 25
Al_2O_3 aluminum oxide		Responsible for quick setting, if in excess, it lowers the strength.	3 – 8
Fe_2O_3 iron three oxide (ferric oxide)		Gives colour and helps in fusion of different ingredients.	0,5 – 6
MgO magnesium oxide		Imparts colour and hardness. If in excess, it causes cracks in building components and unsoundness.	0,5 – 4
$Na_2O + K_2O$		These are residues, and excess of them causes efflorescence and cracking. Makes cement sound.	0,5 – 1,3
TiO_2			0,1 – 0,4
P_2O_5			0,1 – 0,2
SO_3			1 – 2

(Table is taken and adapted from Duggal, 2008)

Grain Size of Cement

The degree of fineness of cement is the measure of the mean size of the grains in it. Resulting individual cement particles have a variety of angular shapes and a wide range of sizes.

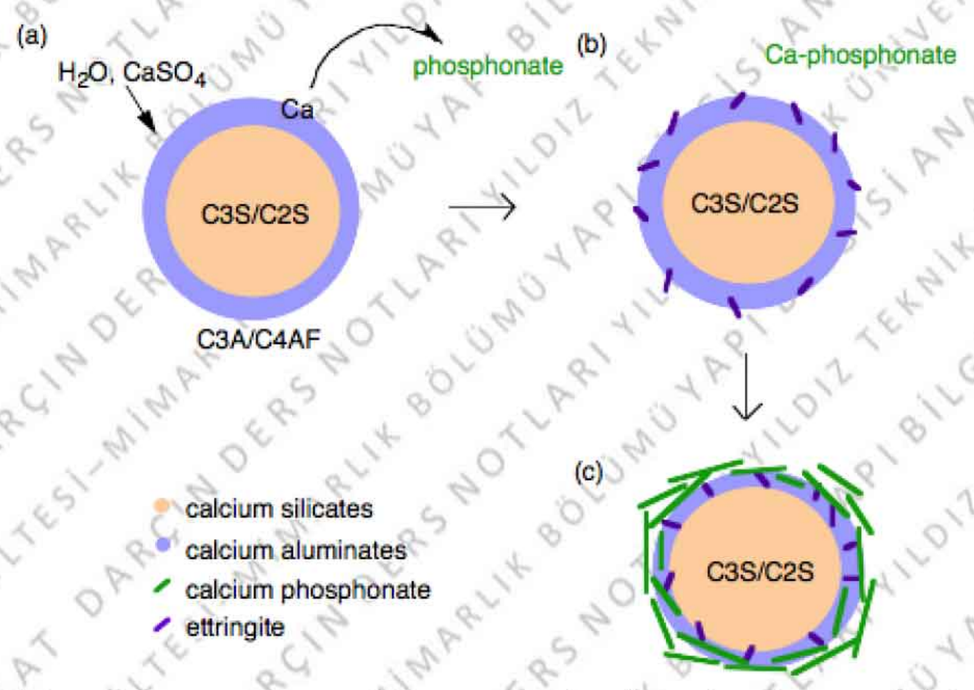


The size of a cement particle has an important effect on the rate at which it will hydrate when exposed to water. As it reacts, a layer of hydration product forms around the outside of the particle, separating the unreacted core of the particle from the surrounding water. As this layer grows thicker,

the rate of the hydration slows down. Therefore, a small particle will react much more quickly than a large particle. Clearly the particle size distribution is critical for controlling the rate at which a cement sets and gains strength. There must be a certain amount of small particles to ensure that the cement sets in a reasonable amount of time, but if there are too many small particles, the cement will set too quickly, leaving no time for mixing and placing. In a typical Portland cement, about 10 % by weight of the cement is made of particles larger than 50 µm and only a few per cent is particles larger than 90 µm. On the fine end, less than 10 % of the cement is particles smaller than 2 µm.

Hydration of Cement

The chemical reaction between cement and water is known as hydration of cement, which can be thought as a two-step process. In the first step, called dissolution, the cement dissolves, releasing ions into the mix water. The mix water is thus no longer pure H_2O, but a solution containing a variety of ionic species called the pore solution. Eventually the concentrations increase to the point that the pore solution is supersaturated, meaning that it is energetically favorable for some of the ions to combine into new solid phases rather than remain dissolved. This second step of the hydration process is called precipitation. A key point is that these new precipitated solid phases, called hydration products, are different from the starting cement minerals. Precipitation relieves the supersaturation of the pore solution and allows dissolution of the cement minerals to continue, thus cement hydration is a continuous process by which the cement minerals are replaced by new hydration products.



About an average 23 per cent of water by weight of cement is required for complete hydration of Portland cement. This water combines chemically with cement compound and is known as bound water. Some quantity of water, about 15 per cent by weight of cement, is required to fill the cement gel pores and is known as gel water. Therefore, a total of 38 per cent of water by weight of cement is required to complete the chemical reaction.

This hydration reaction is mostly exothermic, which means during the reaction heat is generated.

Setting

When water is added to cement, the resulting paste starts to stiffen and gain strength and lose the consistency simultaneously. The term setting implies solidification of the plastic cement paste. Initial and final setting times may be regarded as the two stiffening states of the cement. The beginning of solidification called the initial set, marks the point in time when the paste has become unworkable. The time taken to solidify completely marks the final set, which should not be too long in order to resume construction activity within a reasonable time after the placement of paste. It is important to know the initial setting time, because of loss of useful properties of cement if the paste is placed in moulds after this time. The importance of final setting time lies in the fact that the moulds can be removed after this time. The former defines the limit of handling and the latter defines the beginning of development of mechanical strength.

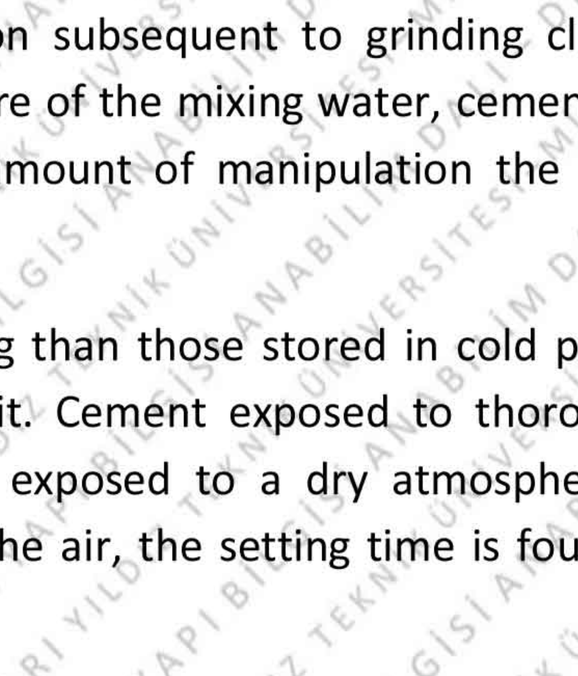
The factors influencing the setting properties of cement are its composition, the percentage of retardant, degree of calcinations, fineness of grinding, aeration subsequent to grinding clinker, percentage of water used to make cement paste, the temperature of the mixing water, cement and the atmosphere where the cement paste is placed and the amount of manipulation the paste receives.

Cements stored in warm rooms will, in general, be quick setting than those stored in cold places. Cold mixing water retards set while warm water accelerates it. Cement exposed to thoroughly saturated atmosphere will set much more slowly than those exposed to a dry atmosphere. If however, a considerable proportion of moist CO_2 is present in the air, the setting time is found to reduce greatly.

Types of Cement

Portland cement blends: In order to change the properties of the cement, some substances can be added to the cement mixture.

blast furnace cement (yüksek fırın cüruf çimentosu)	contains up to 95 % ground granulated blast furnace slag, with the rest Portland clinker and a little gypsum. As slag content is increased, sulfate resistance increases (e.g. sea water) and early strength is reduced.
Portland pozzolan cement (traslı çimento)	includes natural or artificial pozzolans[1]. In countries where volcanic ashes are available (Italy, Chile, Mexico, Philippines) these cements are often the most common form in use. This type of cement is mostly preferred for structures in water due to low permeability and hydration heat.
white blend cements	made by using white clinker (containing little or no iron) and white supplementary materials such as high purity metakaolin.



fly ash (class C), metakaolin, silica fume, fly ash (class F), slag, calcined shale

Storage of Cement

Portland cement is kept in sacks of 50 kg capacity for local use. These are stored for short period of time in air tight room avoiding moisture and dampness, at some distance from walls and at some height from floors. The stack should be covered with suitable coverings to avoid circulation of air through the stack and not more than ten bags should be stacked one over another.

---

[1] Pozzolans are a broad class of siliceous or siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties.