Bonding Materials

Material with adhesive and cohesive properties which make it capable to bond building units into a compact whole. This definition embraces a large variety of cementing materials, among them:

1. Gypsum plaster
2. Lime
3. Cement

Gypsum plaster:

Gypsum plaster comprise all that class of plastering and cementing materials which are obtained by partial or complete dehydration of natural gypsum.

Raw materials - **Gypsum rocks:**

Pure gypsum is a hydrous lime sulfate ($CaSO_4 . 2H_2O$), the composition of which by weight is:

Lime sulfate →	Lime CaO	32.6%
	Sulfur trioxide SO_3	46.5%
Water H_2O		20.9%
Total =		100 %

Natural deposit of gypsum are very seldom pure, the lime sulphate being adulterated with silica, alumina, iron oxide, calcium carbonate and magnesium carbonate. The total of all impurities varies from a very small amount up to a maximum of about 6%.

Manufacture of gypsum plaster:

Process of manufacture:

There operations are involved in the process of manufacturing plaster. **Crushing, grinding and calcinations.** Rock gypsum is crushed to fragments about 25mm in diameter, which are passed through a finishing mill. The grain gypsum is then calcined in rotary kilns.

Theory of calcinations:

If pure gypsum is subjected to any temperature above 100 °C, but not exceeding 190°C, three-fourth of the water of combination originally present is driven off:

$$CaSO_4.2H_2O \xrightarrow{100\text{-}190°C} CaSO_4\,.\,{}^1/_2\ H_2O + 1{}^1/_2 H_2O$$

The resultant product is called plaster of Paris ($CaSO_4.\ {}^1/_2\ H_2O$). Plaster of Paris readily recombines with water to form gypsum, hardening in a very few minutes:

$$CaSO4.\ {}^1/_2\ H2O + 1{}^1/_2\ H2O \longrightarrow CaSO_4.2H_2O$$

If the gypsum is calcined at temperature much above 190 °C it losses all its water of combination, becoming an anhydrous sulfate of lime:

$$CaSO_4.2H_2O \xrightarrow{T > 190°C} CaSO_4 + 2\ H_2O$$

Properties of gypsum plasters:

1) Setting and hardening:

The term "setting" is meant the initial loss of plasticity, whereas "hardening" means the subsequent gain in strength and in ability to resist indentation or abrasion. The setting of plaster of Paris and other gypsum plasters is a process recombination of the partly or totally dehydrated lime sulfate or gypsum.

2) Percentage of water in plaster:

The water-plaster ratio is greatly affecting the strength of plaster. The higher the water plaster ratio, the greater are the plasticity and flow ability of plaster, but when it exceed the optimum value, part of water remain between paste particles and tends to pull the particles apart, reducing the cohesion between them and between the plaster and building units and leading to a reduced strength and durability.

3) Condition of setting:

The strength of plaster drops to a large degree when the plaster remains wet for a long period exceeding 3-days after setting. The reason is due to decomposition of some of plaster crystals in water, leading to reduced chemical adhesion.

Gypsum products:

1- Plaster of Paris:

Produced by calcinations of a pure gypsum, no foreign materials being added either during or after calcinations.

Uses:

1) It is used as a wall plaster in finish coat.
2) It is used as a mortar for masonry construction.
3) It is used for casting ornamental work.

2- Ordinary plaster:

It is a hemi hydrate product (CaSO4. $^{1}/_{2}$ H_2O), produced by the calcinations of a gypsum containing certain natural impurities or by the addition to a calcined pure gypsum of certain materials which serve to retard the set or render the product more plastic.

Uses:

a. It is used as a wall plaster in first coat.

b. It is used as a mortar for masonry construction.

Chemical requirements in accordance with Iraqi standard No.28/1988:

1. The percentage of SO3 not less than 35%.
2. The percentage of CaO not less (2\3 SO_3)
3. The sum of soluble salts expressed as (Na2O+MgO) not more than 0.25% by weight of plaster.
4. The percentage of chemically combined water not more than 9%.
5. The percentage of loss of ignition not more than 9%

Physical requirements in accordance with Iraqi standard No. 28/1988:

1. Fineness: The percentage retained on 1.18mm sieve not more than8%.
2. Setting time should be between (8-25) minutes.
3. Compressive strength: Not less than 3MPa for standard cube 50*50*50mm.

3- Technical plaster:

It is produced by mixing two types of plaster: Hemi hydrate product (CaSO4. $^1/_2H_2O$) and anhydrous product ($CaSO_4$) with 50% for each.

Uses:

1) It is used as a wall plaster in first coat, and all finishing coat.
2) It is used as a mortar for masonry construction.

Chemical requirements in accordance with Iraqi standard No. 28/1988:

1. The percentage of SO3 not less than 40%.
2. The percentage of CaO not less than (2\3 SO_3)
3. The sum of soluble salts expressed as (Na_2O+MgO) not more than 0.25% by weight of plaster.
4. The percentage of chemically combined water not more than 9%.
5. The percentage of loss of ignition not more than 9%

Physical requirements in accordance with Iraqi standard No. 28/1988:

1. Fineness: The percentage retained on 1.18mm sieve not more than 5%.
2. Setting time should be between (12-20) minutes.
3. Compressive strength: Not less than 6MPa for standard cube 50*50*50mm.

4- <u>Anhydrous plaster:</u>

It is produced by the complete dehydration of gypsum, the calcinations being carried on at temperature exceeding 180 °C. It has low solubility in water compared with ordinary plaster, thus certain material can be added during the grinding process to increase its ability to react with water.

Uses:

1) As wall plaster in all coats.
2) It is used as a mortar for masonry construction.

5- <u>Keen cement:</u>

It is anhydrous plaster produced by the calcinations, at a red heat or over, of gypsum to which certain substances, usually $(Al_2(SO_4)_2.18H_2O)$ had been added.

Properties:

1) Its set is extremely slow, usually between 1-4 hours.
2) It gains in strength very gradually, but ultimately attains a great degree of hardness and a strength exceeding that of any ordinary gypsum plaster.
3) Its plasticity is high.
4) Its resistance to water is higher than ordinary plaster.

Uses:

1) It is used as a wall plaster in finishing coat and corners.
2) It is used as a wall plaster in areas exposed to moisture instead of cement and lime.

Lime

Definition and classification

Quick lime:

Is the name applied to the commercial form of calcium oxide CaO, obtained by the calcinations of a stone in which the predominating constituent is calcium carbonate $CaCO3$, this product being one that will slake on the addition of water?

Hydrated lime:

Is quick lime has been chemically satisfied with water during manufacture.

Raw materials - **Lime stone rocks**:

Pure lime stone rocks consist entirely of $CaCO_3$. Pure calcium carbonate consists of 56 parts by weight of CaO to 44 parts of $CO2$.

Lime stones encountered in practice depart more or less from this theoretical composition. Part of the lime is almost always replaced by a certain percentage of magnesia MgO. In addition to magnesia, silica, iron, oxide and alumina are usually present and too slight extent, sulfur, and alkalies.

The physical character of the lime stone has an effect upon the burning temperature. A naturally, coarse, porous stone is acted upon by heat much more rapidly than a dense, finely crystalline stone, and may be burned more rapidly and at a lower temperature.

Manufacture of lime - Theory of **calcinations**:

The burning or calcinations of lime accomplishes three objects:

1) The water in the stone is evaporated.

2) The lime stone is heated to the request temperature for chemical dissociation.

3) The CO_2 is driven off as a gas, leaving the oxides of calcium and magnesium.

Uses of Quick Lime:

1) Building materials.

2) Finishing Material.

Properties of Quick Lime

Plasticity:

The term "plasticity" is commonly used to describe the spreading quality of the material of the material in plastering. If it spreads easily and smoothly, it is plastic, if it sticks under the trowel, or cracks, and drops behind the trowel, it is non plastic.

Setting time:

The setting of lime and lime mortar is a chemical process involving the evaporation of the large excess of water used in forming the lime paste, followed by the gradual replacement of the water of hydroxide by CO_2 in the atmosphere, causing the lime hydrate to revert to the original calcium carbonate.

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

Sand- carrying capacity:

Practically all lime used structurally is made up in the form of mortar by the addition of sand to lime paste for the following reasons:

1) Sand is cheaper than lime.

2) To diminish the great shrinkage which accompanies the setting and hardening of lime, and to prevent the consequent cracking.

3) To counteract the extreme stickiness' of some high- calcium limes.

It is important that the "sand- carrying capacity" of the lime be properly established. If too little sand is used, excessive shrinkage will cause a weakening of bond between the plaster or mortar and the masonry materials or plastered surface. On the other hand, too much sand produces a non-plastic and weak mortar.

Tensile and compressive strength of lime mortars:

The physical properties of lime mortar vary with the:

1) Chemical composition of the lime: Magnesia lime makes it stronger than calcium limes.

2) Character of the sand: Fine sand makes stronger mortar than coarse sand.

3) The amount of water: Suitable amount of water produces stronger lime mortar.

4) The conditions under which the mortar sets: The humidity and amount of CO_2 in the atmosphere influence the rate of setting of lime drying the air and charging it with carbon dioxide, greatly accelerating the setting process.

<u>Hydrated lime:</u>

<u>Process of manufacture:</u>

Hydrated lime is a dry powder resulting from the hydration, at the place of manufacture, of ordinary quick lime. Three stages of manufacture characterize the preparation of hydrated lime:

1) The quick lime is crushed or pulverized to a fairly small size.
2) The crushed materials are thoroughly mixed with a sufficient quantity of water.
3) The slaked lime is, by air separation, screening, or otherwise separated from lumps of anhydrate lime and impurities, or the entire mass must be finely pulverized.

<u>Uses of Hydrated Lime:</u>

Hydrated lime may be used as:

1) Building materials.
2) Finishing materials.

<u>Properties:</u>

1) Mortar prepared from hydrated lime is generally inferior to those prepared from quick lime from the stand point of plasticity and sand - carrying capacity.
2) The strength of hydrated lime mortars, both in tension and in compression, is somewhat higher than that of the corresponding quick lime mortars.
3) Hydrated lime mortars are more quickly setting than from ordinary quick lime mortars.

PORTLAND CEMENT

Definition of Cement

Portland cement is the name given to a cement obtained by intimately mixing together calcareous and argillaceous, or other silica-, alumina-, and iron oxide-bearing materials, burning them at a clinkering temperature, and grinding the resulting clinker. And it is a material with adhesive and cohesive properties which make it capable of bonding minerals fragments into a compact whole.

Sample of Cement

For constructional purposes, the meaning of the term "cement" is restricted to the bonding materials used with stones, sand, bricks, building stones, etc. The cements of interest in the making of concrete have the property of setting and hardening under water by virtue of a chemical reaction with it and are, therefore, called hydraulic cement. The name "Portland cement" given originally due to the resemblance of the color and quality of the hardened cement to Portland stone – Portland Island in England.

<u>Manufacture of Portland cement</u>

Raw materials

• Calcareous material – such as limestone or chalk, as a source of lime (CaO).

• Clayey material – such as clay or shale (soft clayey stones), as a source of silica and alumina.

Methods of cement manufacturing

1 - <u>Wet process</u>: grinding and mixing of the raw materials in the existence of water. Thus, the percentage of the moisture in the raw materials is high.

2 - <u>Dry process</u>: grinding and mixing of the raw materials in their dry state. Thus, the percentage of the moisture in the raw materials is low.

Dry process used in different cases, such as,

- Raw materials are so hard (solid) that they do not disintegrate.
- Cold countries, because the water might freeze in the mixture by water.
- Shortage of the water needed for mixing process.

They two methods can be described as follows:

<u>Wet process</u>

When limestone is used, it has to be blasted, and then crushed, usually in two progressively smaller crushers (initial and secondary crushers), and then fed into a ball mill with the clay dispersed in water. The resultant slurry is pumped into storage tanks. The slurry is a liquid of creamy consistency, with water content of between 35 and 50%, and only a small fraction of material – about 2% - larger than a 90 µm.

The slurry mix mechanically in the storage tanks, and the sedimentation of the suspended solids being prevented by bubbling by compressed air pumped from bottom of the tanks. The slurry analyze chemically to check the achievement of the required chemical composition, and if necessary changing the mix constituents to attain the required chemical composition. Finally, the slurry with the desired lime content passes into the rotary kiln. This is a large, refractory-lined steel cylinder, up to (3-8m) in diameter, and its length may vary anything from 30m to 200m, which lined with refractory materials, and slightly inclined to the horizontal. The slurry is fed in at the upper end while pulverized coal (oil or natural gas also might be used as a fuel) is blown in by an air blast

at the lower end of the kiln, where the temperature reaches about 1450°C. The slurry, in its movement down the kiln, encounters a progressively higher temperature. At first, the water is driven off and CO_2 is liberated; further on, the dry material undergoes a series of chemical reactions until. Finally, in the hottest part of the kiln, some 20 to 30% of the material becomes liquid, and lime, silica and alumina recombine. The mass then fuses into balls, 3 to 25 mm in diameter, known as clinker. The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum to produce Portland cement.

Clinker of Cement

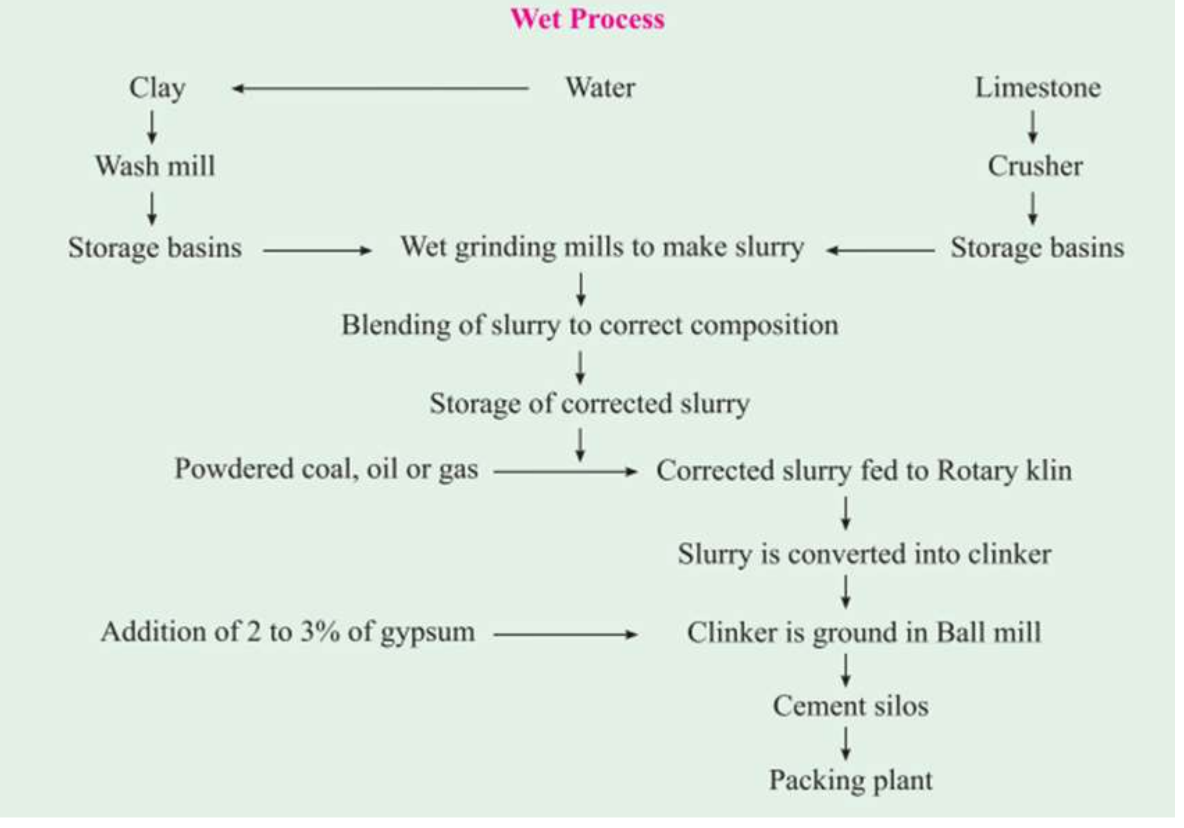

Diagram to Show Manufacture of Cement with Wet Process

Dry process

The raw materials are crushed and fed in the correct proportions into a grinding mill, where they are dried and reduced in size to a fine powder. The dry powder, called raw meal, is then pumped to a blending silo, and final adjustment is now made in t he proportions of the materials required for the manufacture of cement. To obtain a uniform mixture, the raw meal is blended in the silo, usually by means of compressed air.

The blended meal is sieved and fed into a rotating dish called a granulator, water weighing about 12% of the meal being added at the same time. In this manner, hard pellets about 15 mm in diameter are formed.

The pellets are baked hard in a pre- heating grate by means of hot gases from the kiln. The pellets then enter the kiln, and subsequence operations are the same as in the wet process of manufacture.

Grinding of the clinker

The cool clinker (produced by wet or dry process), which is characteristically black and hard, is inter ground with gypsum $CaSO_4.2H_2O$ in order to prevent flash setting of the cement, and to facilitate the grinding process. The grinding is done in a ball mill. The cement discharged by the mill is passed through a separator, fine particles being removed to the storage silo by an air current, while the coarser particles are passed through the mill once again.

Rotary Kiln for Manufacturing Cement Clinker

Comparison between wet and dry process

Wet process	Dry process
1- Moisture content of the slurry is 35-50%	1- Moisture content of the pellets is 12%
2- Size of the kiln needed to manufacture the cement is bigger	2- Size of the kiln needed to manufacture the cement is smaller
3- The amount of heat required is higher, so the required fuel amount is higher	3- The amount of heat required is lower, so the required fuel amount is lower
4- Less economically	4- More economically
5- The raw materials can be mix easily, so a better homogeneous material can be obtained	5- Difficult to control the mixing of raw materials process, so it is difficult to obtain homogeneous material
6- The machinery and equipments do not need much maintenance	6- The machinery and equipments need more maintenance