LIME

1. Introduction

Until the invention of Portland cement, lime was used as the chief cementing material in the building construction both for mortar and plasters. Most of the ancient palaces, forts, temples, monuments, etc., have been built with lime. Though Portland cement has almost replaced lime, but still at places, where lime is available locally and during the period of shortage of ordinary Portland cement lime provides a cheap and alternative to cement. Usually, lime in Free State is not found in nature.

The raw material for the manufacture of lime (CaO) is calcium carbonate which is obtained by the calcination of lime stone. The varieties of limestone commonly used in the construction Industry are tufa, limestone boulders and kankars. Lime can also be obtained by the calcination of shell, coral, chalk and other calcareous substances. Coral and shells are sea animals. White chalk is a pure limestone whereas kankar is an impure limestone. Coral lime is claimed to be the purest source of lime.

Lime is obtained by burning limestone at a temperature of about 800°C.

$$CaCo_3 + 42.52 \xrightarrow{Heating+Calcination} Cao + Co_2$$

2. Varieties of Lime

Pure Lime Stone is called calcite and that containing magnesite is called dolomitic limestone. The mineral containing calcium carbonate and magnesium carbonate in equimolecular quantities is called dolomite.

Stone Lime is almost pure lime obtained by calcination of limestone and is used for making lime-sand mortar for superstructures; lime-surkhi mortar for substructures and: lime terracing and flooring. Stone lime has hydraulic properties.

Kankar Lime is an impure lime obtained by calcination of kankars dug out from underground sources. These occur in the form of nodules and compact blocks. It is suitable for making lime sand mortars for substructures. It is commonly used for making hydraulic lime.

Shell Lime is very pure lime obtained by calcination of shells of sea animals and corals. It is used for lime punning, white wash and color wash, soil stabilization and glass production.

Magnesian Lime is manufactured from dolomite and contains magnesia more than 5 per cent. It is used for making mortar and plaster.

Quick Lime (CaO) Pure lime, generally called quick lime, is a white oxide of calcium. Much of commercial quick lime, however, contains more or less magnesium oxide, which gives the product a brownish or grayish tinge. Quick lime is the lime obtained after the calcination of limestone. It is also called caustic lime. It is capable of slaking with water and has no affinity for carbonic acid. The specific gravity of pure lime is about 3.40.

Fat Lime has high calcium oxide component and, sets and hardens by the absorption of CO_2 from atmosphere. These are manufactured by burning marble, white chalk, calcareous tufa, pure lime stone, sea shell and coral. It is used for white washed

Hydraulic Lime contains small quantities of silica, alumina, iron oxide in chemical combination with calcium oxide component. These are produced from carboniferous lime stones and magnesian limestone. It has the property to set and harden under water.

Hydrated Lime When quick lime is finely crushed, slaked with a minimum amount of water, and screened or ground to form a fine homogeneous powder the product is called hydrated lime.

Lump Line is the quick-lime coming out of the kilns.

Milk Lime is a thin pourable solution of slaked lime in water.

3. Characteristics of Lime

1. Lime possesses good plasticity and is easy to work with.
2. It stiffens easily and is resistant to moisture.
3. The excellent cementitious properties make it most suitable for masonry work.
4. The shrinkage on drying is small because of its high water retentivity.

- **Uses:** In construction slaked lime is mainly used to make mortar for laying masonry and plastering. When so used quick lime should be completely hydrated by slaking from 3 to 14 days, depending upon the kind of lime, temperature, and slaking conditions. Hydrated lime, although immediately usable, is usually improved by soaking overnight or longer.
- Hydrated lime is often added to Portland cement mortar in proportions varying from 5 to 85 per cent of the weight of the cement to increase plasticity and workability.
- Most of the historical buildings had been plastered in lime. Lime punning—about 3 mm thick shell lime layer to improve the plastered surfaces and to give a shining appearance—is used very commonly now a days in the new structures.
- Some of the other uses of lime are manufacture of lime bricks, artificial stones, paints, glass; as stabilizer for soils and as a flux in metallurgical processes.

4. Impurities in Lime

Magnesium Carbonate Lime stones contain magnesium carbonate in varying proportions. Presence of this constituent allows the lime to slake and set slowly, but imparts high strength. Further, the production of heat and expansion are low. The magnesium lime stones are hard, heavy and compact in texture. In burning limestone, the magnesium carbonate is converted to magnesium oxide at a much lower temperature whereas calcium carbonate is oxidized at a little higher temperature. By the time calcium carbonate is oxidized most of the magnesium oxide formed is over burnt. Magnesium lime stones display irregular properties of calcination, slaking and hardening. Up to 5 per cent of magnesium oxide imparts excellent hydraulic properties to the lime.

Clay It is mainly responsible for the hydraulic properties of lime. It also makes lime insoluble in water. The percentage of clay to produce hydraulicity in lime stones usually varies from 10 to 30. If, it is in excess, it arrests slaking whereas; if in small quantities the slaking is retarted. Thus, limes containing 3-5 per cent of clay do not display any hydraulic property and do not set and harden under water. Whereas, when clay is present as 20-30 per cent of lime, the latter exhibits excellent hydraulic properties and is most suitable for aqueous foundations.

Silica In its free form (sand) has a detrimental effect on the properties of lime. Limes containing high percentage of free silica exhibit poor cementing and hydraulic properties. Limes containing 15-20 per cent of free silica are known as poor limes.

Iron Compound Iron occurs in small proportions as oxides, carbonates and sulphide. They are converted into Fe2O3 at lower temperatures of calcination. At higher temperatures iron combines with lime and silicates and forms complex silicate compounds. Pyrite or iron sulphide is regarded to be highly undesirable. For hydraulic limes 2-5 per cent of iron oxide is necessary.

Carbonaceous Matters Carbonaceous matters in lime are seldom present. Its presence is an indication of the poor quality of lime.

Sulphates if present, slow down the slaking action and increase the setting rate of limes.

Alkalies When pure lime is required the alkalis are undesirable. However, up to 5 per cent of alkalis in hydraulic limes do not have any ill effect but improve hydraulicity.

5. Classification

According to the percentage of calcium oxide and clayey impurities in it, lime can be classified as lean, hydraulic and pure lime. Since magnesium oxide slakes slowly, an increase in its percentage decreases rate of hydration and so is with clayey impurities as well.

Lean or Poor Lime It consists of CaO + MgO 80 to 85% with MgO less than 5% and clayey impurities of about more than 7 per cent in the form of silica, alumina and iron oxide. It sets on absorbing CO_2 from atmosphere.

Characteristics

- Slaking requires more time and so it hydrates slowly. Its expansion is less than that of fat lime.
- It makes thin paste with water.
- Setting and hardening is very slow.
- The colour varies from yellow to grey.

Uses It gives poor and inferior mortar and is recommended for less important structure.

Hydraulic Lime It is a product obtained by moderate burning (900°-1100°C) of raw limestone which contains small proportions of clay (silica and alumina) 5-30 per cent and iron oxide in chemical combination with the calcium oxide content (CaO + MgO 70-80% with MgO less than 5%). In slaking considerable care is required to provide just sufficient water and no excess, since an excess would cause the lime to harden. Depending on the percentage of clay present these are classified further as, feebly, moderately and eminently hydraulic lime. It sets under water.

Feebly Hydraulic Lime has less than 5-10 per cent of silica and alumina and slakes slowly, after few minutes (5 to 15). The setting time is twenty one days. It is used in damp places and for less important structures.

Moderately Hydraulic Lime has 10-20 per cent of impurities, slakes sluggishly after 1-2 hours. The setting time is seven days. It is used in damp places.

Eminently Hydraulic Lime has clayey impurities 20-30 per cent and slakes with difficulty. Its initial setting time is 2 hours and final setting time is 48 hours. It is used in damp places and for all structural purposes.

Pure, Rich or Fat Lime It is soft lime (CaO + MgO more than 85% with MgO less than 4%) obtained by the calcination of nearly pure limestone, marble, white chalk, olitic limestone and calcareous tufa. Also known as white washing lime should not have impurities of clay and stones, more than 5 per cent. Fat lime is nearly pure calcium oxide and when it is hydrated with the required amount of water the solid lumps fall to a soft fine powder of $Ca(OH)_2$ and the high heat of hydration produces a cloud of steam. It sets on absorbing CO_2, from atmosphere.

Characteristics

- Slaking is vigorous and the volume becomes 2-3 times.
- It sets slowly in contact with air, and hence is not suitable for thick walls or in wet climate.
- If kept under water a fat lime paste does not lose its high plasticity and consequently does not set and hard.
- Sp. gr. of pure lime is about 3.4.

Uses Fat lime finds extensive use in making mortar, matrix for concrete, base for distemper and in white wash, manufacturing of cement, and metallurgical industry.

6. Manufacturing

Fat lime is obtained by burning limestone and hydraulic lime is obtained by burning kankar. Limestone is usually burned in some form of vertical kiln which may be a tunnel or flare shaped working on continuous (Fig. 01) or intermittent (Fig. 02) systems. The kilns may also be classified as mixed-feed and separate-feed on the basis of the arrangement of fuel and limestone. In the mixed-feed type, bituminous coal and limestone are fed into top of the kiln and in alternate layers. In the separate-feed type, the limestone is not brought into contact with the fuel during the burning process: the fuel is burned in a grate which is attached to the sides of the kiln and is so arranged that the heat produced will ascend into the stack. The mixed-feed kiln uses less fuel, but does not produce as high grade product as the separate-feed kiln. Modern furnace fired lime kilns yield about 25-35 cu m of good hydraulic lime per day.

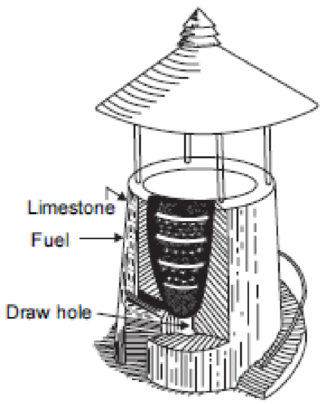

Fig 01. Continuous Kiln

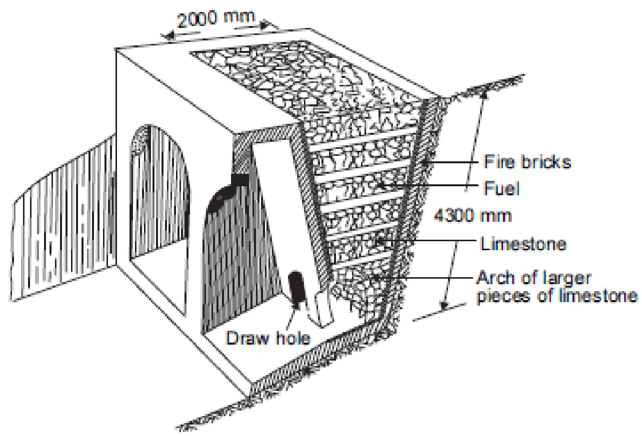

Fig 02. Intermediate Kiln

Essentially, the process of making lime consists in heating calcite ($CaCO_3$) or magnesia limestone ($xCaCO_3 + yMgCO_3$), containing 6 to 20 per cent of argillaceous impurities, to a temperature sufficiently high to drive off the carbon dioxide. As burning, seriously injures the setting properties, high-magnesia limes should not be subjected to temperatures above 1000°C and high-calcium limes should be burned at temperatures lower than 1300°C. A part of CaO resulting from the decomposition of calcium carbonate combines in solid state with oxides SiO_2, Al_2O_3 and Fe_2O_3 contained in the clay minerals, to form silicates ($nCaO\ SiO_2$), aluminates ($nCaO\ Al_2O_3$) and calcium ferrites ($nCaO\ Fe_2O_3$) that are capable of hardening not only in the air, but in water as well. High calcium lime expand more in setting and shrink more in drying than magnesium limes. They are also more liable to injury through burning in slaking. Lump lime has porous structure on burning. Limestone releases carbon dioxide which constitutes up to 49 per cent of its weight, but the volume of the product decreases only by 10 per cent which means that lump lime has a porous structure. A flow diagram for the manufacture of lime is shown in (Fig. 03).

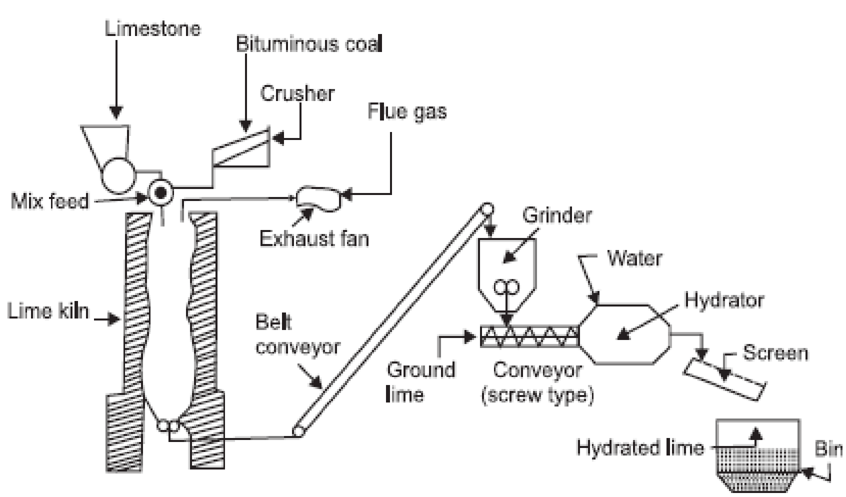

Fig 03. Flow Diagram for Lime Manufacturing

7. **Slaking/ Hydration of lime**

Quick lime, obtained by burning limestone, when sprinkled with water slakes within 10 minutes and becomes powder. It is then used for various engineering purposes such as white washing, plastering, making mortars and lime putty. The process is also known as hydration of lime.

$$CaO + H_2O \xrightarrow{Hydration} Ca(OH)_2 + 15.6kcal$$

In the above reaction high heat of hydration is generated at a temperature of about 350°C. The energy liberated during this reaction causes the lumps of quick lime to split and fall to powder. In hydration of lime the heat of hydration generated is not sufficient to break the lime to powder and therefore, the lime is broken mechanically to a suitable size and sometimes pulverized before hydration. Limes from coarse-grained stone, lump limes, and pulverized usually slake rapidly; limes from fine-grained stones, and dense lumpy limes usually slake slowly. Over burning or under burning of the limestone causes the lime to slake more slowly and injures the mortar strength. Theoretically, the requirement of water for slaking of lime is 32 per cent of the weight of CaO. The amount of water used is 2 or even 3 times greater, depending upon composition, degree of burning and slaking methods, because a part of the water used is vaporized by the released heat. However, to avoid burning and to promote workable pastes, masons usually slake limes with 1.5 to 2 times as much water as lime.

Fat lime slakes in 2-3 hours, whereas hydraulic lime slakes in 12-48 hours. Great care should be exercised to slake the lime completely. The burned lime should be slaked soon after it is drawn from the kiln. The burned lime may also be slaked in the form of paste in slaking tanks (Fig. 04) and is termed as putty. Lime, if not slaked immediately, reacts with the carbonic acid from atmosphere in presence of the moisture and becomes air slaked, forming carbonates of lime.

Consequently, the lime loses its properties and becomes unsuitable for sound construction. The slaked lime should not be kept in damp places.

$$Ca(OH)_2 + Co_2 \longrightarrow CaCo_3 + H_2O$$

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The hydration of lime is accompanied by an increase in volume which is about 2.5-3 times except for hydraulic lime where it is only 50 per cent.

The process of slaking until recent years was done at the site. But since each type of lime needs different treatment, great skill and knowledge of the type of lime being used is required.

Moreover, site slaking requires a fair amount of space, which is not always readily available. Partly for this reason site slaking is being rapidly superseded by factory slaking or hydrating.