Searle A B (1935) *Limestone and its Products, Their Nature, Production and Uses.* London. Ernest Benn Ltd.

Hydraulic limes are prepared by calcining an argillaceous limestone, the clay present entering into combination with a portion of the lime and forming what may be regarded as a mixture of Portland cement and quicklime.

The chief raw material in this country for hydraulic limes is the blue Liassic limestone of Warwickshire, South Wales, etc., but other argillaceous limestones may be used. As will be understood from the previous section on the raw materials used for Portland cement, a much superior cement is obtained when the composition of the material is adjusted so as to give a product of approximately the same composition as Portland cement.
The composition of the limestones used for making hydraulic limes must lie between (1) pure limes with 3 per cent, of clay, and (2) marls or mixtures of clay and chalk which contain no excess of lime. It has been found that argillaceous limestones with 70-80 per cent, of calcium carbonate, 10-17 per cent, of silica, and not more than 3 per cent, of iron and alumina are best, as, in the hydraulic limes made from these, most of the clay is combined with lime, yet there is sufficient free lime present to cause the material to slake satisfactorily. Hydraulic limes may also be produced by under-burning a rock which would, at a higher temperature, produce an excellent natural cement, but these are very inferior and unsatisfactory.

Hand Slaked Lime. Until a few years ago, all slaked lime was prepared by hand. The essential feature of the slaking is the addition of water to the lime in such proportions and at such a rate as to produce either a dry powder or a plastic paste, according to what is required, if a dry powder is desired the process is often known as *dry slaking,* but if a paste or putty is to be produced the term *wet slaking* is used. If a large excess of water is added rapidly the slaking tends to be incomplete or so seriously retarded that the lime is said to be " drowned "; what really occurs is that the wet surface of the lime becomes impervious to water so that the latter does not reach the interior of the lumps. If " drowned lime " is used for plastering, the pieces of quicklime, which have been protected in the " slaking " and are, therefore, unaltered, gradually absorb moisture from the air, swell, and cause objectionable " blebs " or " blisters " on the surface of the plaster.

In slaking a fat lime by hand, the water should be sprinkled over the surface of the lime, the weight of water required being about half that of the lime, or about five gallons to each 1 cwt. of lime. If the lime were perfectly pure, the quantity of water which would combine with it would be exactly 32.1%, but so much heat is generated during the slaking that a considerable quantity of water is driven off as steam, so that more than the theoretical quantity of water must be added.

When slaking a fat lime it is preferable to add the water slowly, but all at once, as when it is added in two or more successive portions, water is lost by evaporation and too little may remain in combination with the lime. The workman should place a convenient quantity (say 100 lb.) of lime on a concrete or stone surface and sprinkle water on it—preferably through the rose of a watering can—and then turn the material over repeatedly with a spade until the slaking is sufficiently advanced for it to be completed without further attention.

If insufficient water is used some parts of the lime will remain unslaked and this may cause serious trouble when the slaked lime is used. Incompletely slaked lime is said to be "burned." Precisely what causes "burning" during hydration is not known, but it appears to be due to the addition of too much water at first and too little at a later stage of the hydration, or to the use of too little water through the slaking. The excessive heat developed appears to cause the colloidal hydroxide to become hard and, therefore, non-plastic so that the "workability" of the lime under a trowel is diminished or even destroyed.

If too much water is used, however, the lime is said to be "drowned" and the resultant produced is a thin watery paste of little or no value.

When the slaking is properly conducted the product is either a light, dry and fine powder or a moderately soft paste according to whether hydrated lime or lime putty is required.

The men engaged in slaking lime by hand should have their mouths and noses carefully protected by means of respirators.

Unless the source of lime is changed too frequently, a man will usually be able to judge fairly accurately the amount of water required and the best rate at which to add it. Unless exceptional care is used, however, lime slaked by hand tends to be too moist and, therefore, "sticky," hence, the custom of making it into a putty or paste.

The slaked lime should be carefully examined and any unslakable materials such as unburned limestone, pebbles, or flints, removed. If, later, they are mixed and ground with the slaked material they will detract from its quality.

For some purposes the slaked lime is passed through a sieve with 24 holes per running inch, and, occasionally, a much finer sieve is used. Hand slaked lime, is, however, regarded as a crude product, and, consequently, few attempts are made to convert it into an attractive one. This is the more unfortunate as hydrated lime of first-class quality can be obtained by careful hand slaking followed by suitable screening or air separation.

Some men, when slaking lime by hand, add most of the required water to the lump lime and after a suitable time, place the product on a sieve with ½ - ¾ in. holes; the finer material which falls through the sieve is used as slaked lime, whilst the coarser pieces are treated separately with more water to see whether they then fall to powder. This method separates the larger pieces of impurity and "core," but unless the fully slaked lime is passed through a fine sieve most of the other impurities will become mixed with the hydrated product.

If the process is carried out properly and suitable lime is used, the lumps will evolve much steam and will gradually fall to a moderately fine powder free from lumps. If an impure lime is used, or the process has been badly controlled, an unsatisfactory mixture of lumps and powder will be produced.

Notwithstanding the apparent crudity of the method of slaking by hand, some of the best commercial hydrated lime on the market is obtained by this method.

In *dry slaking* by hand the lime is spread on the ground in a layer, 4-6 in. thick, and is sprinkled with water by means of a rose on a watercan. It is mixed with the aid of a shovel, and is then heaped up and left to itself for a day, so that it may be fully slaked. It is advisable to cover the heap with sacks so as to retain the heat in it. It is also wise to watch the heap during the first few hours, as the temperature reached in slaking lime is often sufficient to set cloth or wood on fire.

In an alternative method, the lumps of lime, in a basket, are immersed in water for a short time and are then withdrawn and placed in heaps or silos to prevent the escape of water. The lime slakes and falls to powder but is very liable to contain some unslaked lime.The dry, slaked lime is sifted, usually through sieves with 4-8 holes per running inch. Such coarse sieves are unsatisfactory, as they allow many particles, which have not been sufficiently burned, and also small clots of paste to pass through them. It is much better to employ sieves with 36 or more meshes per linear inch, so that all coarse particles are separated and a really fine, soft powder is obtained. Indeed, the present tendency is to require all dry-slaked lime to leave less than 6 per cent, of residue on a 200-mesh sieve.

If the lime is properly slaked it will quickly fall to an apparently dry powder, but if a slight excess of water is added the product may be adhesive and plastic. Unless the excess of water added is large, the apparently pasty lime may evolve so much water that by the time it is cold it may be a dry powder.

During the slaking of lime a considerable amount of expansion takes place. One bushel of lump lime (made from stone) which contains little or no non-volatile impurities will produce 3-3 ½ bushels of dry powder. This is the case with the best limes made from blue or grey limestone. The colour of these stones before burning is due to combustible bituminous matter; this burns away, leaving a pure white lime.

The amount of swelling depends partly on the purity and porosity of the lime and partly on the manner in which the water is added, the swelling being less if the water is added very slowly. This is particularly noticeable with magnesian limestone.

Dry slaking is *not* suitable for hydraulic limes.

In-wet slaking by hand the lime is mixed with three or four times its weight of water *{i.e.* 33-45 gallons for each 1 cwt. of lime) in a shallow tub or trough, the mixture being well stirred with a wooden rake so as to produce a *milk* or *slurry;* this is run off into another vessel or into a pit, as desired. This process ensures the complete hydration of the lime, which is uncertain with dry slaking, and produces a stronger mortar when such lime is mixed with sand or trass.

Care should be taken not to "drown" the lime in an excess of water, and it is desirable not to add too much water at a time. When the slaking is skillfully done the mixture remains at a boiling heat for some time. Wet slaked lime should not be run through a grate or sieve, as this creates too great a temptation to use a large excess of water. Any pieces which cannot be slaked soon settle and remain behind when the slurry is run off. If a paste or putty is required it is sometimes better to dry slake the lime first and obtain a dry powder to which can afterwards be added the water necessary to produce a paste. If all the water needed is added at once, some parts of the lime may be "drowned."

The use of mechanically hydrated lime is increasing so rapidly that the production of hand slaked lime is quickly diminishing. This is unfortunate, because a skilled lime slaker can adjust the quantity of water added to suit each batch of lime, whereas a machine must be adjusted in order to produce slaked lime of " average " quality.

Hand slaking is very slow and, therefore, costly, but hand slaked lime is, for some special purposes, superior to mechanically slaked lime.

Greystone lime is slaked in a similar manner to fat lime, but a longer time is required, as the silica present is combined with some of the lime similarly to that in hydraulic limes.

Hydraulic lime is slaked in a different manner because such lime is really a mixture of two materials: *[a)* quicklime, and *[b)* a hydraulic cement. The slaking relates only to the first constituent, the resulting product being a powder containing unslakeable lumps *{grappiers)* which must be separated by screening unless the original lime has been ground to powder, prior to slaking. Unless a hydraulic lime is to be used at once it is important not to add any more water than is needed to slake the quicklime present. Any excess of water will cause some of the " cement " to harden and will render it useless.

Unlike quicklime, hydraulic limes do not swell appreciably when slaking, and they develop far less heat. A hydraulic lime may, therefore, be mixed with a limited amount of water with little or no risk of spoiling it. According to Le Chatelier, the vapour tension of calcium hydrate, when cold, is practically nil, but that of calcium silicate is several millimetres of mercury. At 100° C it is not more than 1 mm for the first, but several centimetres for the second. Consequently, in a mixture of lime and silicate the lime will hydrate progressively without the silicate being hydrated and the silicate will, if necessary, part with its combined water until all the lime is fully hydrated. If only sufficient water is added to a lump of hydraulic lime, only the calcium oxide and magnesia will be hydrated, but the expansion due to this slaking should cause the whole lump to crumble to a fine powder, consisting essentially of calcium hydroxide, tricalcium silicate, tricalcium aluminate, and a complex mixture of more or less inert matter, the whole forming a cementitious material resembling a weak Portland cement.

About 10-15 per cent, of water is usually required for slaking a hydraulic lime, but the optimum proportion should always be found by trial as imperfectly slaked lime can cause serious trouble when in use. The water should be supplied in the form of a very fine spray so that no part of the lime receives an excessive quantity of water. If the water is added through coarse jets, part of the lime becomes too wet and then loses its cementitious properties unless it is used immediately.

The best qualities of hydraulic lime are not used for some time after being slaked, so as to ensure complete slaking.

A good hydraulic lime should fall to powder when immersed in water for 24 hours, or when sprinkled with a suitable quantity of water, and at the end of this time should not leave more than 5 per cent of residue on a No. 24 sieve. A properly hydrated hydraulic lime will usually require only 7-8 per cent, of its weight of water, but 10-11 per cent, is usually added to allow for loss by evaporation.

A dry slaked hydraulic lime usually contains a considerable proportion of lumps (grappiers) of harder material; these should be removed by passing the product over a 50-mesh screen or sieve. As these grappiers can be ground and made into cement, it is an advantage if hydraulic cements are slaked by the manufacturer who can make use of the grappiers.

It may seem strange that hydraulic lime requires so long to slake completely because all movement ceases within 48 hours of adding the water and no vapour appears to be set free! The true test is that mortars made with hydraulic lime which has only been slaked for 48 hours, crack and show other signs of incomplete slaking, whilst mortar made of the same lime which has been slaked for a fortnight will be excellent. A hydraulic lime purchased in a ground state should pass completely through a 24-mesh sieve and not leave more than 10 per cent of residue when washed through a 200-mesh.

Ample time must be allowed for slaking hydraulic cements, both when neat and when mixed with sand, but care must be taken to avoid re-working a material which has been slaked with too much water and has begun to set. If the lime is slaked whilst warm, as it comes out of the kiln, or if *hot* water is used, the time of slaking may sometimes be reduced to three hours.

Hydraulic limes should always be sifted after slaking, in order to remove any imperfectly slaked lumps (grappiers) and it is preferable to grind the lime to powder before slaking so as to avoid inconvenience caused by the formation of these lumps.

When large quantities of hydraulic lime are to be slaked, as in France where the slaking is done at the lime works, the lime is spread out in layers on large floors, sprinkled with just sufficient water to slake the free lime, and then shoveled into heaps or placed in bins where it is kept for about ten days, during which the slaking is completed. The product—which should chiefly consist of a fine powder—is then sieved or screened—usually through 50-mesh gauze—or passed through an air separator to remove the lumps (grappiers) and is then ready for sale or use. A portion of the grappiers is usually ground to powder and added to the sieved product so as to increase the hydraulicity of the latter. The process used is described under " Ground Lime." In slaking prior to sale, an excess of water should be avoided, or some of the cementitious part of the lime will be spoiled.

GRAPPIERS

The coarse material separated when hydraulic lime is slaked is known as *grappiers*. It is a highly cementitious and hydraulic material, though inferior to Portland cement. It is obtained as a by-product when hydraulic cement is hydrated at the works, as is usual on the Continent, and requires to be ground so as to leave not more than 10 per cent residue on a 180-mesh sieve in order to be of the same fineness as Portland cement, for which it is used as a substitute. To be useful, the grappiers must be free from more than about 15 per cent of unburned limestone and the more nearly their composition resembles that of Portland cement, the more valuable will be the grappiers.

Crude grappiers is an irregular mixture of white, grey, and black particles. It is first exposed to the air for a month or more, so as to hydrate the free lime completely. Sometimes steam is admitted to the aerating rooms in order to hasten the hydration. The product is screened and the fine "heavy lime" added to ordinary hydraulic lime. The residue is ground and forms the *white cement* largely used for mosaic work. The harder portions, which occur as tailings from the " white cement " screens, form a grey sand which, when finely ground, produces *grey grappier* cement….

In France, where the grappiers industry is more extensive, there is an increasing tendency to simplify the procedure by grinding the lumps of grappiers as finely as possible and adding them to the hydrated lime, thereby increasing the hydraulicity and cementing power of the latter….

3. THE USE OF LIME IN BUILDING CONSTRUCTION

For most building purposes, a somewhat impure lime is often preferable, because the argillaceous material present, or the siliceous material introduced by burning the stone in contact with the fuel, produces feeble hydraulic properties which make a stronger joint or surfacing material.

A rough distinction exists in the building trade between " fat " or " rich," and " poor " or " lean" limes. The former slake rapidly with high rise in temperature; the latter slake slowly and without much rise in temperature. Fat limes set only by absorption of carbon dioxide, but lean limes are hydraulic and set like diluted cements.

LIME FOR USE IN MORTAR

Mortar is a mixture of sand and water with some binding material, such as lime or cement or both. A fibrous material, such as hair, is often added to increase the strength. In lime mortar the lime forms a colloidal gel with some of the water and this gel coats the sand grains. As the mortar dries, the colloidal gel dries and shrinks and so holds the particles together. A small proportion of crystalline calcium carbonate is also formed and the interlacing of the crystals increases the strength of the mass. The mixing of the various ingredients must be thorough; all fat lime mortars are improved by prolonged mixing, but in those containing hydraulic lime cement the mixing must not be continued after the cementitious portion has begun to set. The mixing may be by hand or machinery; the use of the latter is generally known as *grinding,* but no actual grinding should occur with properly prepared materials. Mortar made with fat lime should not be used for 24 hours or more as storage greatly improves its workability.

For the production of ordinary mortar for general use by builders, either a fat lime, a lean lime, or a hydraulic lime (Lias lime) may be used. Fat limes are preferred, but lean limes can be employed if they do not slake too slowly; they are regarded less favourably by some builders, because they have a much smaller sand carrying capacity, and-the resulting mortar does not "work" very smoothly. Hydraulic limes are stronger in cementing power, and behave like a mixture of fat lime and Portland cement.

Magnesian limes are generally suitable for mortar and sometimes exceed calcium limes in smoothness, working, sand carrying power, and resistance to weather. There is also evidence that magnesian limes give mortars that eventually give greater strength than those made of high calcium limes. They slake more slowly than calcium limes, and, unless care is taken, the mortar may prove to be unsound by a steam pat test. The slow slaking is often due to partial over-burning of the lime.

Greystone limes are highly appreciated for the strength of the mortar which they produce as a result of being feebly hydraulic, though this reason is seldom realized. Ground greystone lime requires about one month after being mixed with water before it develops appreciable hydraulic strength. It loses this property if the lime is stored in the form of putty or if it is soaked and kept for a long time before use.

Mortar made with *fat lime* or a *lean lime* with a low silica-content does not "set" in the same manner as hydraulic lime or concrete. Such lime merely dries, and by gradual absorption of carbon dioxide on its surface it becomes moderately hard externally, but the interior of the mass may remain soft for several hundred years *(really?)*. The purer the lime and sand used in the preparation of the mortar, the softer will be the mortar, no matter how long it has been in use. The carbon dioxide absorbed from the air combines with the lime at the surface of the joints, and, by closing the pores, prevents a further penetration, so that most joints in old masonry are only hard for a very short distance below the surface *(this is prejudice, certainly not observation)*.

Hydraulic lime, on the contrary, undergoes a complex chemical change when in contact with water and " sets " to a hard mass. It does this equally well in air or under water, **provided the mortar is supplied with sufficient water to ensure its adequate setting and subsequent hardening. If the supply of water is insufficient, the hardening will be incomplete.**

Fat limes can be caused to harden like hydraulic lime and cement, by adding a suitable proportion of a material which will combine with the lime, forming a compound somewhat resembling those in hardened cement concrete. Such material is known as *pozzuolana;* the commonest variety is *trass,* which is extensively used on the Continent, but an equally good substitute is made by grinding underburned bricks or tiles to a fine powder, provided they are sufficiently rich in clay.

Pure limes to which no pozzuolana has been added should not be used for work in contact with water, but only for structures above ground level.

High calcium limes are generally regarded as preferable, because they slake readily and completely in a short time whereas magnesian limes slake more slowly and uncertainly and may, therefore, cause trouble …

In limes used for building construction, the physical characteristics, such as plasticity, time of set, colour, hardness, and strength, are of great importance, whereas chemical composition is immaterial except indirectly, inasmuch that limes made from limestone of different purity and composition usually have different physical characteristics. Thus, magnesian limes in general are more plastic than high calcium limes and are preferred for " finishing " purposes …The lime which can carry the largest quantity of sand should be the best for mortar.

A useful indication of the quality of a lime is to measure its volume before and after slaking. All good limes will increase in volume, but a fat one should increase to three times its original size. Limes which produce less than twice their volume of slaked lime are described as *lean* or *poor*.

Before mixing it with sand or any other solid material, a quicklime should be slaked and made into *lime putty*;- the hydrated lime merely requires to be mixed with water, and the hydraulic lime should be slaked by sprinkling it with water, avoiding an excess, and finally passing it through a No. 5 or finer sieve.

The chief disadvantages of lump lime for use in mortar are:

- (i) It requires slaking, which is troublesome and tedious.
- (ii) It frequently contains much *core* and useless material.
- (iii) The quality varies greatly and cannot easily be checked by the builder; consequently, the quality of the mortar also varies.
- (iv) It soon spoils if kept before being used.
- (v) It is inconvenient to keep on account of its caustic properties.

In short, it has all the disadvantages of a crude material. In the United States, it has been replaced almost completely by hydrated lime, which is free from all these objections.

In some localities, the quality of lime, as compared with that made fifty years ago, has deteriorated seriously. This is due to the skilled burners having left or died and other men with less care and skill having taken their places. To a smaller extent, the change is also due to the use of inferior coal, which does not burn the stone so effectively, and introduces a larger percentage of ash into the lime. It is, therefore, more than ever necessary that builders should ascertain the quality of the lime they are buying…..

The advantages of hydrated lime in making mortar are:

(i) It can be stored indefinitely and easily.
(ii) It requires no slaking.
(iii) It is more uniform in quality.
(iv) It contains less "core" or useless material and so can be used without waste.
(v) It avoids the production of bad putty through carelessness or ignorance of the man in charge of the mortar.
(vi) It avoids the loss otherwise caused through having to make more putty than is needed to allow for useless material in the lime.
(vii) It is particularly easy to measure and use.
(viii) E. W. Lazell has shown that mortar made with hydrated lime is stronger than that made with hand slaked lime and used immediately. The reason is that mechanical slaking under proper control ensures complete hydration, whereas, with hand slaking, the paste must be left for some weeks before the hydration is complete. Moreover, in hydrated lime, the coarser, unaltered particles are separated, so that the risk of caustic lime in hydrated lime from a good firm is negligible. Much of the hydrated lime on the market is not as good as a hand slaked lime putty about a year old, because the plasticity of lime can only be developed in the presence of more water than is permissible in hydrated lime. For most building purposes, however, hydrated lime is as good as need be desired.

…. The *advantages* of fat lime—either lump or hydrated—are:

(i) It enables bricks to be laid more rapidly and more easily than when cement is used, as lime is more plastic than cement. A greater strength can be used by replacing some or all of the lime by Portland cement, but where such additional strength is wholly unnecessary there is no object in securing it, and lime mortar has ample strength for all ordinary buildings.

(ii) Fat lime produces the only mortar that can be prepared in large quantities in advance, *i.e.* that made from either quicklime or hydrated lime. All the lime mortar needed for a structure can be mixed before the walls are started. It may be stored, either in a stack or pit, until required, and, in fact, is actually better and more easily worked because of the ageing. This feature of lime mortar affords a good chance for economy, as machine mixing is particularly suitable and satisfactory. As the mortar is required, it may be re-tempered to the desired consistency and used with full confidence.

(iii) Fat lime makes the most economical mortar. The cost of the materials is low, because of the high sand carrying capacity of the lime. The strength of the mortar is ample, thus permitting jt to be used under practically all conditions. The natural plasticity of the lime decreases the cost of mixing the mortar, of spreading the mortar bed, and of placing the bricks. No mortar is wasted. If the mortar is mixed as needed, any left over at the end of a day, or not used, because of a sudden shut down on the job, can be stacked and used when work begins again. If cement mortar works short, the droppings are excessive, 10 per cent, being sometimes wasted. This is not the case with lime mortar, for the only droppings are due to trimming the joints, and these are negligible.

(iv) Fat lime mortar avoids delaying the bricklayers, who, when cement mortar is used, have to wait for mortar to be mixed. Lime mortar is always ready for use and so increases the efficiency of the entire force and makes maintenance of construction schedules easy.

Some builders add a small proportion (15 per cent.) of Portland cement to lime mortar in order that it may set quickly enough for the bricklayers to work rapidly, as in many modern steel skeleton structures with brickwork panels.

In order to secure the best results, the lime must be properly treated. The best method is to prepare a lime putty by slaking the lump lime or by mixing the hydrated lime with water. The modern desire for speed makes most builders unable to keep the putty for a long time, and, consequently, the full plasticity of the lime is seldom developed in modern mortar. This is wasteful of lime as old lime putty will carry more sand, than newly made putty…

Hydraulic limes can be purchased-in the lump or ground form, the latter being far more convenient. They are characterized by their power of setting and hardening in water and behave in many respects like a mixture of Portland cement and lime. **They differ greatly in composition and properties,** and are conveniently divided into three classes: (i) feebly hydraulic; (ii) moderately- hydraulic; and (iii) eminently hydraulic….

Hydraulic limes are chiefly used where a mortar is required to have a greater strength than can be produced with a fat lime. At one time they were widely used, but since the use of Portland cement has become so popular the latter is usually preferred, as it is stronger and more regular in composition and properties.

Hydraulic limes are also used in foundations and in locations where the brickwork or masonry may be in occasional or constant contact with water.

When slaking hydraulic lime, the use of too much water must be avoided; too little will do no harm. It is usually better to buy the hydraulic lime ready- slaked.

LIME FOR WINTER MORTAR

When brick laying must be carried out in very cold weather, the most satisfactory mixture consists of one measure of Portland cement, two of fat lime, and nine of sand. This is much cheaper than a cement-sand mortar, is less sensitive to frost, and is easier to work. Mortar must not be used during actual frost, and bricks laid just prior to a frost must be covered, or otherwise protected until the mortar has hardened.

LIME IN CEMENT MORTAR

The addition of a little lime putty or hydrated lime to cement mortar makes the latter spread more easily and work more smoothly. It also increases the adhesive properties of the mortar.

The lime putty, or a paste made by mixing hydrated lime with water, should be added to the dry mixture of cement and sand, any additional water required being then added and the whole mixed thoroughly.

On work frequently exposed to water, the addition of lime is undesirable as it tends to be washed out and leaves a porous mortar.

The best lime is a fat, high calcium lime, such as is used for *fine stuff* in plastering. Hydrated lime is more convenient than lump lime.

LIME CEMENT

Lime cement is a term applied to lime when mixed with sand so as to form a mortar or plaster which is used as a cementing agent. Before the invention of Portland cement, lime was extensively used as a cement, and today when speed of hardening is not important, it is still useful for many purposes. **Unfortunately, the tendency to require rapid hardening materials for all purposes, even under conditions where time is of minor importance, has led to an increasing failure to recognize the advantages of lime as a cement.**

For this purpose, two kinds of lime are available : (a) a fat lime, and (b) a hydraulic lime.

The fat lime should be high in calcium oxide and very low in magnesia. In course of time, magnesian limes form products which are as hard and strong as those in which pure calcium oxide is used, but magnesian limes slake very slowly and somewhat uncertainly, so that they are generally less suitable than calcium limes.

The lime should contain at least 95 per cent, of lime and magnesia (on the ignited sample) and not more than 5 per cent, of carbon dioxide. It should, when slaked and washed through a sieve with water, pass completely through a No. 20 sieve and not leave more than 20 per cent on a No. 100 sieve.

Hydrated lime, equal in quality to the lump lime just mentioned, may be used, instead of lump lime and is usually more convenient as it does not require to be slaked.

Lime cement of the kind described is merely a good quality of lime, but lime cements composed of lime and casein or similar materials are quite different; they are described later.

Lime cements composed solely of hydraulic limes resemble a mixture of fat lime and Portland cement, **but are somewhat uncertain in their behaviour**. For structures requiring a material stronger than ordinary mortar, but not so strong as a cement sand mortar they are excellent and cheap.

LIME CONCRETE

Long before the invention of Portland cement, lime concrete was extensively used, especially in the East. The lime is mixed with twice its volume of coarse aggregate. If half the sand is replaced by trass, or, still better, by an artificial pozzuolana made by lightly calcining clay and grinding the mass to powder, a better concrete will be produced. The concrete is excellent in quality, but requires longer to harden sufficiently than do cement mortars.

The lime used should be a fat lime, such as is employed for mortar, but hydraulic lime is also used for the same purpose.

When rapid hardening is not essential, lime concrete will serve many purposes for which cement concrete is generally used, and will be much cheaper. It is not, however, suitable for reinforced concrete.

… Fat lime is particularly suitable for interior plaster, because:

(i) It is more plastic than any other, can be spread with less effort, and covers a large surface.

(ii) It is cheaper than cement or plaster of Paris, both in first cost and in sand carrying power.

(iii) It does not spoil (like cement) if used slowly.

(iv) The plaster can be prepared some time before and used when required.

(v) There is less waste than with other materials.

(vi) It is an ideal base for colours and decoration.

Lime for use in plastering must not crack when in use. The shrinkage of fat lime is overcome by the use of a suitable proportion of sand. It is a common mistake for plasterers to use too little sand; the result is that the plaster shrinks, cracks, and may fall away. For ceilings, the addition of a little plaster of Paris is an advantage which is well worth the extra cost.

For *Exterior Plaster,* including *rough-cast* and *stucco,* lime is the most suitable binding agent. It has a greater covering power than Portland cement. It is a mistake to use too little sand with the lime, as both "rough cast" and "stucco" should be as lean as possible.

The most suitable lime is a fat lime, such as that specified for interior plaster ("fine stuff") and, whilst an inferior lime may be used, it is not recommended.

The advantages of lime for exterior work are:

(i) It is cheaper and "goes further" than Portland cement.

(ii) It is equally durable.
(iii) It has a greater sand carrying power.
(iv) It is more plastic and so is easier to use.
(v) The slow hardening enables the material to adjust itself to the background better than cement plaster can do.
(vi) The waste is much less.

… LIME PUTTY

Lime putty or *Plasterer's putty* is made by slaking a fat lime with as much water as will produce a soft plastic paste. All lump lime must be converted into this form before it can be used satisfactorily for plastering. The putty must be kept for at least a week and preferably for several months before it is used, so as to ensure every particle of lime being fully slaked. Any unslaked pieces of lime will slake whilst the plaster is in place on walls or elsewhere, and will cause pimples, popping, or other unsightly defects. Lime putty does not spoil appreciably on storage.

Lime putty is made by placing the lime in a tub of water in which it is stirred and slaked. The slaked lime is then carefully sifted through a fine sieve into a wooden bin; the residium which does not pass is rejected for plasterer's work.

A considerable excess of water is added and the surplus is allowed to drain away from the bottom or through the sides of the vessel in which the putty is stored.

The finely sifted calcium hydrate with excess of water may be left with safety for a year or so to mellow, the water which rises to the top drains away through the joints of the wood-bin, or it evaporates, leaving the pure slaked lime putty as a creamy mass; only the thin outer crust exposed to the air will set. For the setting coat of plaster work, putty should not be used until it has mellowed for at least three months…. The long time required for ageing the best lime putty has caused hydrated lime to be used wherever possible, but even hydrated lime should be mixed with water to form a putty and kept for at least 24 hours before it is used.

LIME IN WALL COATINGS

Under the term *limewash, whitewash, distemper, etc.* is included a milky suspension of slaked quicklime or hydraulic lime or hydrated lime in water. No definite proportions of lime and water are used, the user judging by the appearance of the wash when applied to a surface. **Equal weights of lime and water** usually produce an excellent lime wash, but much depends on the nature of the lime.

The addition of 30 lb. of common salt or 10 lb. of dry calcium chloride to 100 lb. of the slaked lime or hydrated lime produces a superior lime wash. The addition of a little glue is also advantageous and prevents earlier work from being rubbed oft. A mixture of 6 lb. of glue, 4 gallons of water, and a cream containing 100 lb. of slaked or hydrated lime is generally quite satisfactory. Instead of common salt, a mixture of 4 lb.

of zinc sulphate and 2 lb. of common salt per bushel of lime is preferred by some architects. The zinc sulphate combines with the lime, forming a substance similar to plaster of Paris and rendering the whitewash more durable.

Some users find that the addition of linseed oil or melted tallow lessens the tendency of the material to be "rubbed off," and one well-known builder uses milk instead of water for the same reason.

A more elaborate whitewash is made as follows:

Add enough water to 12 lb. of hydrated lime to make a thick cream. Dissolve 1 lb. of washing soda in 1 gallon of boiling water, and add this to the lime. Dissolve 1 lb. of glue and 1 lb. rice flour in 3 quarts of water. Add this to the above mixture and apply. The above quantities will make enough whitewash to cover about 600 square feet.

Hydraulic lime must be carefully selected or the wall or other surface will not be sufficiently white. It will, however, be more durable than when quick-lime or hydrated lime is used.

The mixture of lime and water (with or without other ingredients) should be made fairly thick, passed through a No. 50 or finer sieve, and then diluted with water as required. If the screening is omitted, the wash may not have a sufficiently smooth surface.

Whitewash is the cheapest of protective paints, but it requires frequent renewal. Its slight disinfectant power adds greatly to its value.