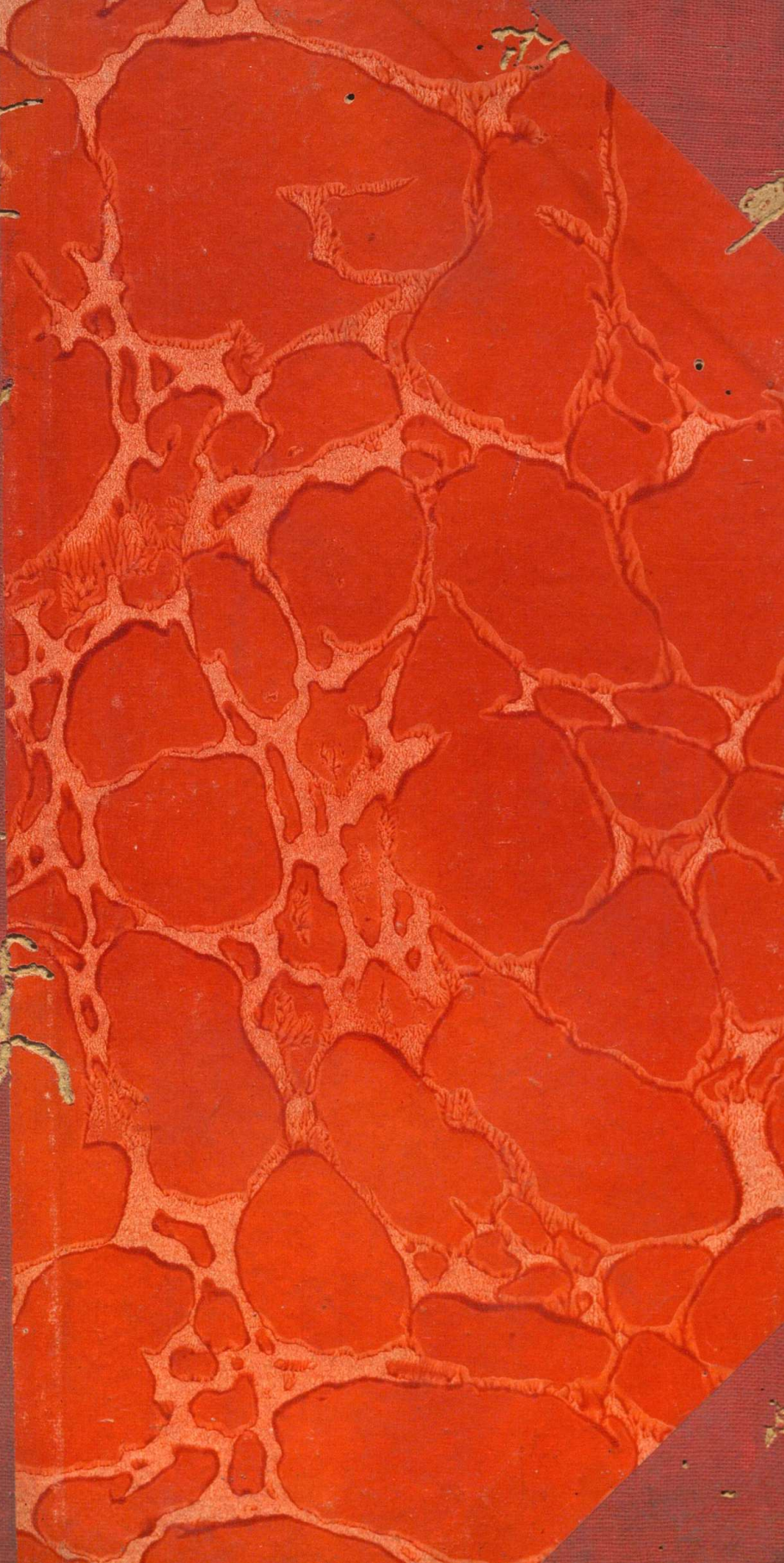


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LIME-SAND BRICKS, SLABS AND TILES
ACKO



GEOLOGICAL DEPARTMENT, TRAVANCORE.

THE MATERIALS

AVAILABLE IN

TRAVANCORE

FOR THE MANUFACTURE OF

lime-sand BRICKS, SLABS
AND TILES

BY

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LIME-SAND BRICKS, SLABS AND TILES.

LIME-SAND BRICKS.

The making of bricks and slabs with sand is a recent industry. The first successful plants were erected in France and Germany in 1895 and the industry has been expanding ever since. On the continent of Europe, France, Germany, Holland and Belgium were, before the commencement of the war, great centres of this industry. It is estimated that, during the last 17 years, the world's out-put of lime-sand bricks has increased from a few millions to 2000 millions per annum. The value of sand-lime bricks produced in the United States increased from \$155,040 in 1903 to \$1,238,325 in 1913, the total out-put in the latter year being 190 million bricks from 68 active factories.

PHYSICAL PROPERTIES.

It is man's nature to prefer a thing to which he is accustomed to one that is new. In the early days of lime-sand bricks, builders looked askance at them and doubted their qualities as a building material. But the lapse of time and laboratory tests have amply proved that lime-sand bricks are equal, if not superior, to clay bricks in strength and durability. Sand bricks have an advantage over clay bricks in that they are more easily and cheaply made and have a colour which can be modified to suit the tastes of builders. The sand and lime of Travancore are the purest and white bricks can be prepared out of them. The white colour can be modified to suit the taste of consumers.

In external appearance lime-sand bricks resemble fine natural sandstones. The surface of these bricks is smooth and of close texture and is said to be highly resistant to rain. Buildings built of lime-sand bricks do not require plastering and periodical white washing. The exposed surfaces are self-cleaning in wet weather and any dirt or moss can be removed by mere washing.

Lime-sand bricks are exceptionally regular in shape and size. The process of hardening these bricks is such that all bricks are uniformly affected and uniform results are produced in consequence. In the case of clay bricks, the heating in

the process of burning may not be uniform and the bricks^s are subjected to different degrees of stress. Hence clay bricks are not quite so uniform in size and shape. Again lime-sand bricks do not shrink as much as clay bricks in the process of hardening and this is another factor which is conducive to the uniformity of size.

The cementing material in the sand bricks is lime which, combining with fine sand, under the action of high pressure steam, apparently produces calcium silicates. It is found that this cementing material gains in strength in course of time by the absorption of carbon-di-oxide. May be molecules of lime, which remain uncombined with silica during the process of steam hardening, combine with the carbon-di-oxide to form calcium carbonate, which gives additional strength to the cementing material. The following table gives a comparison of the crushing strength of lime-sand and clay bricks:—

Kind of bricks	Crushing strength lbs. per sq. inch
Ordinary lime-sand bricks.....	2,200 to 3,000
Best quality lime-sand bricks.....	4,500 to 9,000
Lime-sand bricks for paving.....	8,500 to 95,00

CLAY BRICKS.

Best London stock bricks.....	1,600 to 2,800
Common London stock bricks.....	1,240 to 1,865
Staffordshire blue bricks.....	2,130 to 7,200

(Vide “Bricks and Artificial Stones of Non-plastic materials” by A. B. Searle. p. 108.)

Among clay bricks Staffordshire blue bricks are exceptionally strong. But best quality lime-sand bricks are, on an average, stronger than these, while ordinary clay bricks are quite inferior to ordinary lime-sand bricks in crushing strength. Specimens of ordinary lime-sand bricks have been found, after five years of exposure to air, to show a crushing strength of 8000 lbs. per Sq. inch. Clay bricks are not found to improve in strength by lapse of time.

The porosity of bricks is measured by the quantity of water they absorb when kept soaked in water for a sufficiently long time. A certain amount of porosity is necessary in bricks to keep the internal surfaces of the walls dry. The percentage by weight of water absorbed by some kinds of lime-sand bricks and clay bricks is given in the following table:—

LIME-SAND BRICKS.

	Percentage of weight.
Ordinary lime-sand bricks	... 8 to 12
Best quality lime-sand bricks	... 3 to 9
Lime-sand paving tiles	... 0 to 2

CLAY BRICKS.

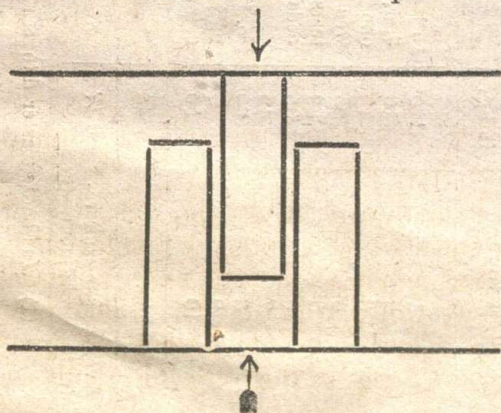
Common bricks	... 10 to 25
Facing bricks	... 5 to 15
Medium engineering bricks	... 1 to 5

The weight of lime-sand bricks is the same as that of clay bricks, volume for volume. The specific gravity of sand bricks is about 2.56, which is not sensibly different from that of clay brick. The specific gravity of bricks will, of course, vary within certain limits depending on the nature of the material used for their manufacture.

The pure varieties of our sand consists mostly of quartz of which the specific gravity is 2.65. The bricks will naturally show a smaller specific gravity owing to closed pores and the admixture of lime.

Well made lime-sand bricks are said to possess a slightly higher elasticity than natural sandstones. This is an important factor. The greater elasticity makes it less brittle and less liable to crack when subjected to impulses like earthquake waves.

Mortar adheres at least as firmly to lime-sand bricks as to clay bricks. The following table is taken from Messrs. Herbert Alexander & Co.'s booklet on sand bricks. In these experiments three bricks were laid together with mortar as in the sketch and after three months exposure to air, pressure was applied in the directions of the arrow heads. The pressures at which the bricks separated are given in the table.



Description of bricks.		Machine-made clay bricks.				Sand-lime bricks.			
Description of mortar.		1 volume thick lime paste and 3 vol. sand.		2 vol. lime, 1 vol. cement, 8 vol. sand.		1 vol. thick lime paste and 3 vol. sand.		2 vol. lime, 1 vol. cement, 8 vol. sand.	
Thickness of mortar.		0·8 cm.		1·1 cm.		0·8 cm.		0·8 cm.	
Average surface.		265 qcm.		288 qcm.		288 qcm.		288 qcm.	
Test No.	Pressure in kg.	Notes.	Pressure in kg.	Notes.	Pressure in kg.	Notes.	Pressure in kg.	Notes.	
1	120	In tests No. 1, 2,	1115	In tests 1, 4 and 7	—	Tests 1 and 5	1710	Tests 1, 3, 5, 6, 7,	
2	10	3, 4, 6, 8 and 9	1490	the mortar had	510	broke when put-	2060	8 and 9 let go	
3	10	one mortar bed	985	let go the brick ;	440	ting into machine.	1575	the brick ; tests	
4	25	was broken ; at	970	in test 2, 4, 5,	170		2040	2 and 4 crack	
5	30	tests 5 and 7 two	550	8 and 9 the crack	—	With the other	1670	went through	
6	85	beds were broken.	235(1)	went through the	605	tests the mortar	1230	mortar.	
7	45		830	mortar.	480	left the brick.	2185		
8	20	No. 10 broke when	500		310		1900		
9		putting into ma-	495		415		1670		
10	50	chine.	...		220		270(1)		
Average.	44		867		394		1782		
Average shearing re-	0·17		3·27		1·37		6·19		
sistance per kg/qcm.									

(1) Was badly plastered together, therefore not taken into consideration.

Lime-sand bricks made of proper materials are found to be refractory and can be used for lining furnaces where they do not come into contact with basic molten materials. Some varieties of sand found abundantly in Travancore consist purely of quartz and it may be predicted, although it has not been actually tried, that the bricks made of these sands will be quite suitable for being used as fire bricks. For this purpose the bricks made out of selected materials are burnt in a special kiln at a temperature of 1500°C after they have been hardened as ordinary bricks. This is an advantage which the manufacturer of lime-sand bricks has over the manufacturer of ordinary clay bricks which can never be used for lining furnaces. If I am correctly informed, the fire bricks needed in India are now imported from Europe. The need for fire bricks will be constantly increasing in India with the development of industries.

The following table giving a comparison of the properties of the various kinds of clays is taken from Mr. A. B. Searle's book on "Bricks and Artificial Stones of Non-Plastic materials":—

Table of comparison of properties of various kinds of bricks.

	Lime-sand Bricks.	Clinker Bricks.	Slag Bricks.	Cement-sand Bricks.	Red Bricks of Plastic clay.
Appearance.	Like natural sand stones	Light grey	Light grey	Like natural sand-stone	Characteristic
Texture.	do.	Like natural sand-stones	Like natural sand-stones.	do.	do.
Shape	Accurate	Accurate	Accurate	Fairly accurate	Liable to twist in drying and burning.
Size	do.	do.	do.	do.	Varies with shrinkage in drying and burning.
Colour	Very uniform	Uniform	Uniform.	Very uniform	Variable. Seldom two bricks exactly alike.
Crushing Strength. Tons per. sq. ft.	140 to 600	257 to 385	340 to 400.	100 to 200	80 to 250
Porosity o/o	5 to 12	3 to 10	3 to 15.	3 to 10	5 to 25
Permeability	As red clay bricks	As red clay bricks	As red clay bricks.	As red clay bricks	...
Rate of drying	do.	do.	do.	do.	...

*Table of comparison of properties of various
kinds of bricks (contd.)*

	Lime-sand Bricks	Clinker Bricks.	Slag Bricks.	Cement-sand Bricks;	Red Bricks of Plastic clay.
Relative weight	do.	do.	do.	do.	...
Density	do.	do.	do.	do.	...
Adhesion of mortar	do.	do.	do.	do.	...
Hardening of mortar	do.	do.	do.	do.	...
Refractoriness in Seger cones	18 to 32	10 to 20	12 to 22	18 to 30	Under 18 fire-bricks 26-32
Fire resistance	Better than red clay bricks	As red clay bricks	Rather better than red clay bricks	Often better than red clay bricks	...
Frost resistance	Rather better than red clay bricks	Rather better than red clay bricks	do.	Rather better than red clay bricks	...
Weather resistance	As red clay bricks	As red clay bricks	As red clay bricks	As red clay bricks	...
Time required for manufacture	1 day	1 day	1 day	1 month	20 to 90 days
Cost of manufacture	16 s	15 s	15 s	1 month	18

THE RAW MATERIALS.

The raw materials required for the manufacture of lime-sand bricks are ordinary sand and lime. In this section it is proposed to deal with the qualities of these materials which are suitable for the manufacture of bricks and to describe the materials available in Travancore.

The sand most suitable for the manufacture of bricks is that which contains the highest percentage of quartz, that is, silica. Varieties of sand consisting almost entirely of silica are abundant in Travancore. In the southern half of the Travancore coast the sand is usually mixed with a high percentage of ilmenite and magnetite, mostly the former. But north of Alleppey the percentage of ilmenite or magnetite is extremely small. The Shertallay and Vaikom taluks furnish the best kind of sand for the purpose of brick manufacture. The sand dunes of Pallipuram and Panapally consist of very pure quartz sand of a spotless white colour. Even this sand contains a small percentage of ilmenite; but the percentage is so small that it is not believed that it will

have any appreciable effect on the quality of bricks made of it. In cases where an exceptionally high quality of bricks or tiles is aimed at, this small quantity of ilmenite may be removed by washing or by a magnetic separator, which is a necessary piece of machinery in all well-appointed lime-sand brick factories.

It was believed at one time that the suitability of sand for brick-making depended upon the amount of "soluble silica", that is, silica soluble in a strong solution of caustic soda. The idea was that only this kind of silica would combine with lime to form the binding material of bricks. But it is found that all kinds of silica will combine with lime at the temperature and pressure of the hardening chamber, provided it be in a sufficiently fine condition. To ensure this combination and to fill up vacant spaces, some dust sand or ground sand is added to the ordinary sand.

It may be supposed that the presence of some clay in the sand is necessary in order that the sand may be moulded into the different shapes required. But the presence of clay is not necessary for this purpose.

Some manufacturers condemn the presence of clay as detrimental whilst others maintain that the addition of 2 or 3 per cent. of clay to clean sand to be an advantage. Some sands contain naturally a small percentage of clay. The dune sands available in Travancore are perfectly free from clay. It is said by experts that those who express themselves in favour of the presence of a little clay in the sand probably mistake fine sand for clay and that their opinion is based upon this mistake. Anyhow it is certain that, if a sufficient quantity of fine sand is present in the aggregate, clay is not a necessary ingredient. If clay be present, its quantity must not be so great as to leave a surplus after combination with the lime. If any uncombined clay remains in the bricks after the hardening process, they will be weak.

The presence of salt in the sand is said to be injurious, as bricks made from such sand are liable to become scummed and to remain moist. For this reason sand dug directly from the sea shore should be avoided. The dune sands such as those at Pallipuram have for so long been subjected to the action of rain that they are not likely to contain an injurious amount of salt.

The strength of the bricks depends to a great extent on the shape of the grains of sand. Flat or flaky grains are

not suitable as they have a tendency to slip or shear under pressure. The most suitable grains are round and angular. The grains of sands available in Travancore are of this description. Flat or flaky grains are likely to be numerous in sands containing much felspar or mica. The dune sands of Travancore are free from these minerals, consisting entirely of quartz grains. The grains of these sands are more or less rounded. Mr. A. B. Searle says that repeated tests made by him have shown that a sand with rounded grains often gives better results than a sharp sand, both being well graded, because the rounded grains have fewer voids and make denser bricks. Also the rounded grains roll more easily into the voids, thus ensuring compactness of the bricks. If the grains are too much rounded, the sand tends to make weak bricks.

A sand, the grains of which are much polished also is not suitable for bricks. In this case the grains cannot interlock so as to give strength to the bricks. Our dune sands are not polished. The grains of these sands are nearly rounded and quite rough. Anyhow the grading of our sands is to be rectified by the addition of ground sand and it is known that even polished sand becomes suitable for bricks by the addition of ground sand.

The sizes of grains of sand are of great importance. If all the grains of a sand are nearly of the same size, the sand is not suitable as it is. If all the grains are of the same size, the vacant spaces between grains cannot be filled up. To fill up the spaces between grains of one size, grains of a smaller size are necessary. The spaces between these little grains and the former grains can be filled up only by still smaller grains and so on.

As regards the sizes of sand grains, the opinion of experts is that the whole of the sand must pass through a sieve having 20 holes per linear inch and about 10 percent of the whole sand must pass through a sieve having 150 holes per linear inch. But it is observable that there should be a small percentage of flour sand which will pass through a sieve having 200 holes per linear inch. I have not yet been able to test our sands in sieves having less than 30 holes per linear inch or more than 90 holes per linear inch. Finer sieves than those having 90 holes per linear inch cannot be had in India at present and it is difficult, owing to the war conditions, to get them down from Europe. Although

our sands have not been tested in sieves having less than 30 holes per linear inch, it may be asserted with a fair certainty that the whole of our ordinary dune sands will pass through a sieve having 20 holes per linear inch. The residue they leave in a 30 mesh sieve is usually very small, more than 90 percent usually passing through this sieve. The residue left in the 30 mesh sieve is not much coarser than the grains that pass through it and may be expected to pass through 20 mesh sieve. Anyhow the quantity that may be left in a 20 mesh sieve will be very small and cannot affect the quality of the average brick.

The proportion of sand that pass through 90 mesh seive also is small. In many samples examined, the quantity that passes through such a sieve is not more than 5 per cent. The scarcity of very fine grains is a guarantee that the sand is pure and free from any undesirable quantity of clay. At the same time it makes it necessary that a fairly large quantity, at least 10 per cent., of sand must be ground to flour, so that the bricks may be strong.

Samples of Sand from Pallipuram.

	A	B	C	D	E	F	Average.
Percentage remaining in 30 mesh sieve.	6.444	9.683	8.434	11.623	7.240	5.362	8.131
" " in 60 mesh sieve but passing through 30 mesh.	67.854	62.059	77.532	81.213	73.824	39.726	67.034
" " in 90 mesh sieve but passing through 60 mesh.	23.654	26.408	12.523	4.614	17.640	51.780	22.769
" " passing through 90-mesh sieve.	2.048	1.848	1.510	2.538	1.314	3.131	2.064
Total.	100.000	99.998	99.999	99.993	100.018	99.999	99.998

Flour sand consists of grains that will pass through a 200 mesh seive. The proportion of flour sand needed in the sand used for brick making is determined by the sizes of the other grains and can be arrived at only by actual experiment in brick making. Flour sand is most satisfactorily produced

by grinding coarser sand in a ball mill. This mill will be described in a subsequent part of this paper.

For the making of strong sand bricks it is essential that the sand used should be properly graded. Whether a sand is properly graded or not is best examined by determining the total vacant space or voids in the sand. The less the voids in a sample of sand, the greater is the surface of contact among the sand grains and the stronger will be the bricks made of it. The sum of voids in a sample of sand is determined by measuring its volume and the volume of the water displaced by it. The difference between these two volumes gives the sum of the voids in the sample of sand. The sum of voids is best expressed as so much per cent. of the total volume of the sand.

The coarser the sand, the greater is the sum of voids or vacancy. In a sand used for brick making the vacancy should not be more than 20 or less than 8 per cent. The vacancy observed in natural sands taken from different parts of Travancore is much in excess of this maximum. In the dune sands the vacancy is never less than 39 per cent, and it is often between 40 and 45 per cent. This fact shows that the ordinary natural deposits of sand in Travancore are not suitable for brick manufacture in the state in which they occur. Ground sand must always be added to the natural sand. We arrived at the same conclusion when we were considering the sizes of the grains of our dune sands.

BINDING MATERIALS.

In the early days of sand bricks several kinds of binding materials were tried. The chief among these were water-glass—a soluble sodium silicate—and calcium chloride prepared by treating lime with hydrochloric acid. These processes have gone out of use chiefly owing to the cost of these binding materials. Lime and Portland cement are now the binding materials that are in extensive use. As has already been observed, lime (Portland cement contains lime) combines with fine particles of silica at the temperature of the hardening chamber and under the action of steam forming a strong bond. It was the ignorance of this fact that led early investigators to use such costly stuff as water-glass and calcium chloride.

Although we have not got any large supply of limestone in Travancore, we have a practically inexhaustible

supply of shells in our back waters, which can be obtained at a small cost. Shell lime is always purer than lime prepared from lime-stone which often contains impurities like silica, iron oxide, alumina, etc. As long as we can get a cheap supply of shells, we are not any the worse for want of extensive deposits of lime stone. In the absence of a supply of shells at moderate cost, we may employ Portland cement which is manufactured in Madras. But the depletion of the back-water shells is not likely to occur in the near future. The supply from the back-waters has been meeting the demands of Travancore and Cochin for ages and there is a constant addition to the supply.

In the selection of lime for the manufacture of sand brick, good care is to be employed. We need not fear any chemical impurities in the shell-lime. Usually shell gatherers wash the shell well. But careless washing is likely to leave some sand in the hollows of the shells. So special care is to be taken to sample the shells properly. But what is to be specially guarded against is the inequality of burning. Even this defect will not be so great in shells as in lime-stone. Lime stone being burnt in large lumps, equalization of temperature through the whole mass is not effected with so much ease as in the case of shells which are thin and of small sizes. In the samples of lime we usually get, under-burnt shells are sometimes met with. But such shells form only a small percentage of the lime. Moreover it is said that under-burnt lime is not as injurious as over-burnt lime in the manufacture of bricks.

It is said that the strength of bricks depends more on the quality of lime than on the quality of the sand. The percentage of calcium oxide in the lime employed for the manufacture of sand bricks should not be less than 94. The manufacturer should try to keep the percentage well above this limit. The proportion of lime used in the mixture for lime-sand bricks is so small that a less pure lime may not contain enough of calcium oxide to form a strong bond.

The proportion of lime required for the manufacture of sand bricks will, of course, depend on its purity.

When the lime is sufficiently pure, about 6 per cent. of it will be quite enough. The usual proportion is 7 to 8 per cent., though as little as 3 per cent. may sometimes be used. For an out put of 20,000 bricks a day, each weighing about 7 lbs. the daily demand of lime will be between four and five

tons. It was found by De la Roche that the proportion of lime required depended on the pressure with which the bricks were pressed during the process of manufacture, the quantity of lime being less when the pressure was greater. Thus to produce bricks of a minimum crushing strength of 2000 lbs. per square inch, which is the minimum permissible in Germany by law, a certain sample of sand required 15 per cent of lime when the pressure in the press was 3600 lbs. per square inch, while the percentage of the same lime required for the same sand to produce bricks of the same crushing strength was only 8 when the pressure in the press was doubled. But Mr. A. B. Searle thinks that, if the sand is properly graded, the quantity of lime required is independent of the pressure employed. He further thinks that correct grading is both better and cheaper than the employment of excessive pressures. If the sand is quite correctly graded the proportion of lime may be reduced to 3 per cent. and no difficulty should be experienced in using 5 to 6 per cent.

PRELIMINARY PREPARATION OF THE MATERIALS.

The mixture employed for the manufacture of lime-sand bricks consists of the following ingredients :—

Aggregate (sand)	85 per cent.
Lime	8 „
Water	7 „

In order that the bricks may be strong, the following conditions must be satisfied :—

(1) The aggregate must be of properly graded particles as we have already seen.

(2) Each grain of the aggregate should be coated with lime; this is effected by thorough mixing.

(3) The lime should be completely hydrated (slaked) before the mixture is sent to the brick press.

The proportion of water in the aggregate is an essential factor. The percentage of water should not exceed 8. If the sand already contains this proportion of water no more water need be added. But, if the aggregate contains more than this amount of water, it is necessary to dry it. It is seldom necessary to effect this by artificial drying. If the sand is too wet, it may be dried by laying it on a sloping, impervious bed of concrete or wood and exposing it to air for a few days. Ordinarily the Travancore dune sand will not

require this treatment. Ordinarily the sand is dry. But, in the rainy season, the sand will be wet. This wetness will be confined to a thin surface layer of sand on the dunes. Below this layer tolerably dry sand may be found even in the wet season. The place whence the sand is obtained for the works may be roofed over in the wet season. It is not thought that drying will ever be an expensive operation in a sand brick factory in Travancore.

In brick works where coarse material is used as aggregate, the aggregate is ground down to grains of suitable size. It will not be necessary to grind the sand available in Travancore as the grains are already of small sizes. Still a certain percentage of the aggregate will have to be ground always in mills. Quick lime may be ground alone or with twice or three times its weight of aggregate. In the former case the lime is ground to such a fineness that the grains pass completely through a sieve of thirty to fifty holes per linear inch. In the latter case, the mixture should be ground to such a fineness that not more than 20 per cent. of the mixture should remain in a sieve with 200 holes per linear inch. It is thought that, with sand as aggregate, this latter method is more advantageous.

The reduction of lime and aggregate to a fine flour is effected in tube mills. A tube mill consists of a steel tube 10 ft. to 25 ft. in length and 4 ft. to 6 ft. in diameter. It is lined with silica-stone $2\frac{1}{2}$ in. to 4 in. thick and revolves on ties and rollers. The tube mill is filled to rather more than half its total capacity with flint pebbles. The mixture of lime and sand is charged into the tube-mill at one end and, after being ground fine during its passage through the tube, is discharged at the other end. The grinding is effected by the rolling and tumbling of the flint pebbles or of steel balls which may be used instead of flint pebbles.

A 20 ft. tube, 4 ft. 6 in. in diameter, will require about 55 horse power to drive it and will produce four to seven tons of ground lime and sand of the required fineness, per hour.

Usually the mixture of lime and sand is ground in the dry state. But it is thought that wet grinding produces the best results. By the wet grinding of siliceous rocks a thin film of colloidal silica is formed on the surfaces of the siliceous

grains and this silica combines more readily with lime, forming a strong bond. The following table shows the improvement of the cementing power due to wet grinding:—

Sand.	Cementing power.		Ratio of improvement.
	Dry ground.	Wet-ground.	
A	25	78	3.1
B	61	174	2.8
C	12	34	2.9

From this table we see that wet grinding of the sand and lime increases the strength of the bricks about three fold. This improvement is taken advantage of by mixing the fine ground dry lime and sand, that is, the product of the tube mill, with the required quantity of aggregate and water and treating the whole batch in an edge-runner mill for a few minutes. In this process no grinding is aimed at. It is in fact only a mixing, during which colloidal silica is formed. The rollers of the edge-runner need not, therefore, be very heavy.

It is necessary that the ingredients of the batch should be carefully measured before mixing. For this purpose several kinds of automatic measuring machines are supplied by the makers of machinery for lime sand brick works. At this stage of our investigations it is not necessary to enter into any discussion of the comparative merits of machinery used for this and other purposes in the manufacture of lime-sand bricks.

MIXING OF THE MATERIALS.

Lime sand brick works have been and are employing several methods of mixing the materials. The following are the chief methods.

1. Mixing the sand with the lime which has been previously slaked with water.
2. Mixing the aggregate, ground lime and water in the required proportions and then conveying them to a silo where the hydration (slaking) of the lime is completed.

3. Mixing the ground lime with twice or three times its volume of aggregate and putting this mixture in a silo. The remainder of the sand is added during a further mixing and does not enter the silo.

4. Grinding the lime with twice or thrice its volume of aggregate, mixing this with the remainder of the aggregate and then storing the whole in a silo until the hydration is complete.

5. Treating the materials in a hydrator or hydrating drum with steam.

Advantages are claimed for each of these methods by its champions and, in fact, each method may be better than the others under certain conditions. Experts are in favour of the fourth method and I believe it is suitable for the conditions in Travancore. This method is a little more expensive than other methods, but it ensures a high quality of bricks and avoids possible troubles. This method alone will be described in this paper.

In this method, as has already been indicated, the quick lime together with a quarter of the aggregate, is placed in a tube mill and ground to fine flour. This fine flour is then treated with water and stored for some hours in a silo, where the hydration of the lime is completed. It is then mixed with the remainder of the aggregate in an edge-runner mill. Or again the flour and remainder of the aggregate may be mixed in a trough mixer and thence passed into the silo. Of these two variations of methods, the former is regarded as better, *viz*, the storing of the ground flour in the silo in a moistened condition and the subsequent mixing of the flour and the remainder of the aggregate in an edge runner.

Before proceeding further it is necessary to give a brief description of the silo. It is merely a basin or chamber in which the mixture is stored for the completion of the hydration of the lime. Although it is a simple matter, its construction requires much care, as otherwise much trouble and unnecessary current expenditure will ensue. Originally silos used to be built of bricks. Some of the old brick silos are still in use. But in all modern installations, silos made of steel are employed in which there are arrangements for discharging the material automatically into the conveyor which carries it to the place of further treatment of the material.

It is not necessary at this stage to enter into a more detailed description of the shape and construction of the silos.

This method may be further described with reference to the accompanying diagrammatic sketch of a factory. The lime is fed into a ball mill, A, and ground so as to pass through a sieve of 25×25 holes to the square inch. It is then raised by means of an elevator into the lime hopper, C. This hopper feeds one barrel of the measuring machine, D, and the other barrel is fed with sand from the sand bin. The machine, D, measures the sand and lime in the required proportion for the preliminary mixture and delivers them to an elevator, which elevates it to the hopper, F. This hopper feeds the tube mill which reduces the mixture to flour. The elevator, M, raises this flour and feeds it into a differential mixer, N, along with the rest of the sand which is fed by an automatic feeder. In this mixer the flour and the bulk of the sand are thoroughly mixed with the required quantity of water. The batch is then deposited in the silo, O, where it remains for some time for the hydration to be complete. An elevator, R, carries the material from the silo and delivers it into the waggons, S, for charging the auto-feeders, V. From this feeder the material is passed through a mixer, V, where it is finally mixed. From this mixture it passes to the press, W, where it is pressed into bricks.

As the bricks are delivered from the presses they are stacked into waggons, which are run into the hardening chambers, X, and after eight hours steaming in these hardening chambers are ready for use.

This is a brief epitome of the process of brick making which is suited to the materials available in Travancore. In the sequel I shall give a little more detailed description of the presses and hardening chambers employed in the process.

THE PRESSING OF BRICKS.

The pressure with which the bricks are pressed must be at least two tons per square inch. A brick is usually 9 inches long and $4\frac{3}{4}$ inches broad. Thus the pressure required is about 80 tons per brick. But in the best presses a pressure of 100 to 150 tons per brick is usually employed.

We have two classes of high class English presses to choose from. Of these, the "Hercules" press invented by Herbert Alexander of Messrs. Herbert Alexander & Co., Leeds, England, is to be considered first. It is the pioneer

among British presses and forms the basis of all high class modern presses. It is made in six sizes with an out-put ranging from 500 to 4800 bricks per hour. The moulds are placed on a revolving table which revolves with an intermittent motion. At each movement a brick is automatically moulded, pressed and delivered ready to be removed by the attendant. The bricks are delivered to the surface of the table. They are not pushed off and thus damaged in its unhardened condition as in the case of some other presses. The attendant removes each brick as it comes from the mould, perfect in shape and with clean, sharp edges, thus producing a first class facing brick.

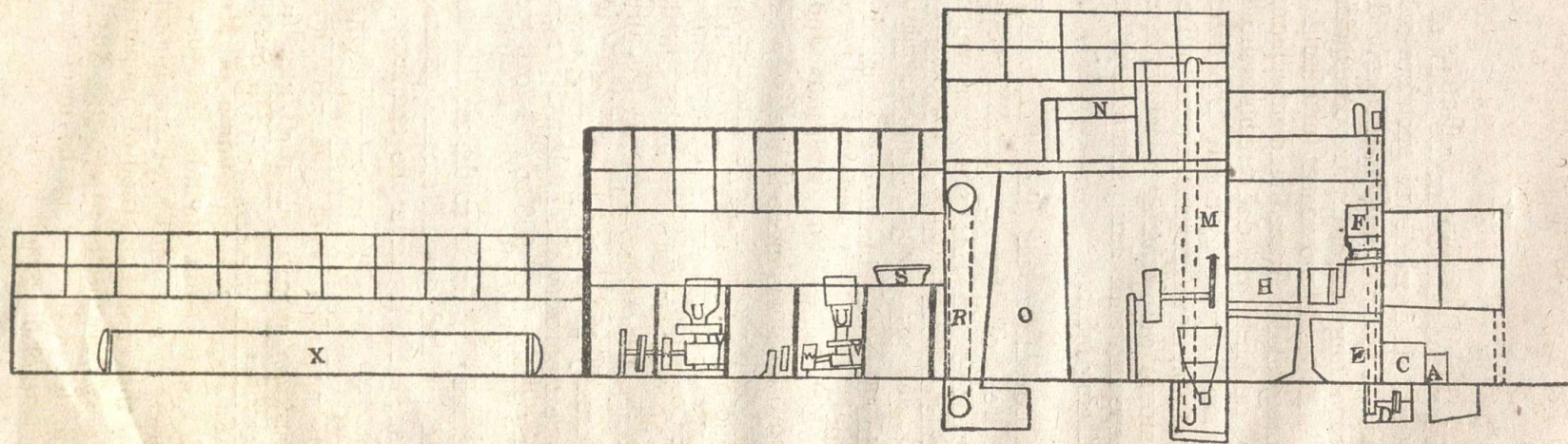
An improvement on the "Hercules" press is the "Emperor" press of Messrs. Sutcliffe, Speakman & Co., Leigh, Lancashire. In this press the working parts are above the table and can be kept under observation. Further the working parts, being above the table, are protected from material falling into the bearings and causing unnecessary wear and tear.

Blocks and slabs are made in precisely the same manner as bricks, but owing to their large size a modification in the press is necessary. For these purposes Messrs. Sutcliffe, Speakman & Co., supply a special kind of press.

Paving slabs and bricks can be made by the use of sufficient lime (usually 15 to 20 per cent.) and are so dense that they have a porosity of less than 2 per cent. and an ultimate crushing strength of 500 to 600 tons per square foot.

Linings may be fitted to the moulds so as to produce imitations of cut and dressed stone. If sand is used for the aggregate, such blocks have the characteristics of a hard natural sandstone, but they can be made much more cheaply than by carving or dressing natural quarried stone.

Fancy moulded bricks and flooring tiles also can be manufactured in these presses.



THE HARDENING OF BRICKS.

As soon as the bricks have been pressed, they ought to be hardened. It is important that the bricks should not stand about too long before they are hardened. If the green bricks remain exposed to air for a long time, the lime absorbs carbon dioxide from the atmosphere and becomes converted into calcium carbonate. This compound does not combine with silica to form a bond. For this reason lime also should not remain exposed to air for a long time after it has been burnt and before it is mixed with the aggregate. The whole process of mixing, pressing and hardening must be completed the same day.

Hardening consists of heating the bricks in a steam chamber for about eight hours. The steam chamber consists of boiler-shaped cylinders placed in a depression on the ground, with its axis horizontal. It is connected with steam pipes to a boiler. One end of the hardening chamber is open and the waggons containing the green bricks are pushed into it on rails. Then the open end is hermetically closed with a lid which is held fast with nuts and bolts. Then steam is let into the chamber. 2/

The most suitable diameter for a hardening chamber is said to be 6ft. The length varies according to the capacity required. The steam employed should remain at a pressure of about 120 lbs. per square inch. As has already been said, the steaming of the bricks, should continue for eight hours. With steam at a higher pressure, the hardening will be complete in less time. The time depends also on the quality of the material. If the grains of the aggregate are large, a longer time is required. With fine grains of aggregate, the time required will be less.

MACHINERY REQUIRED.

Two important British firms supplying machinery required for the manufacture of lime-sand bricks are Messrs. Sutcliffe, Speakman & Co., Leigh, Lancashire, and Messrs. Herbert Alexander & Co., Leeds. The quotations of these firms are given below. The quotation of Messrs. Sutcliffe, Speakman & Co., does not include the cost of steam engine and accessories, while neither of the quotations take into consideration the special method of preparing and mixing the materials we have discussed above. Anyhow the quotations give an idea of the cost of the machinery required for the manufacture of lime-sand bricks.

MESSRS. SUTCLIFFE, SPEAKMAN & Co.

QUOTATION

for

LIME-SAND BRICK MAKING PLANT.

Capacity.....18,000 Bricks per day of 24 hours.

Size of Bricks.... $9'' \times 4\frac{3}{8}'' \times 2\frac{5}{8}''$

Tracing Number.....4601.

HP.		Weight. Tons.	£	s.	d.
	One 9 ft. Overdriven Grinding and Mixing Mill with solid bottom and to be of the self delivery type, substantially as regards frames and design as per page 1 of the enclosed circular dealing with Grinding Mills, but with solid bottom which would revolve: the rim being stationary with a hinged door for the discharge. Mill to have narrow concentrated load rollers, fitted with Manganese steel rims, in sections as shown on photograph enclosed. Rollers to be 4 tons in weight each. Discharge door to be operated with screw and hand wheel. One Automatic Feeder to consist of a circular pan 36 1/d, arranged for support by upper flangs to your hopper. Base of Feeder consists of a rotating disc of cast iron, driven by worm and worm wheel on self contained bed-plate, with a suitable verticle spindle in upright bearing.				
30		20	525	0	0

HP.		Weight. Tons.	£.	s.	d.
1	An adjustable discharge door is provided in pan of Feeder with the requisite door to regulate the discharge.	$\frac{3}{4}$	48	0	0 .
1	One inclined elevator for feeding the Press. To be complete with guide rods, and buckets on rollers.	2	76	0	0
	One Patent Single "Emperor" Press substantially as per the enclosed illustration, and to be of our standard construction.				
	The moulds to be your standard size.				
	The table to be of cast iron with rolled steel hoop shrunk on, and afterwards turned up true ; the moulds to be all accurately slotted out to templet, and fitted with renewable steel liners on our patent "Economic" principle.				
	Our improved trip gear to be fitted for retaining the plungers level with the table top on discharge of the bricks.				
	The table plungers to be of cast iron with renewable high carbon steel top plates.				
	The top and bottom crossheads to be of cast steel forged to fit the main columns, the latter to be of mild steel screwed with a buttress thread at each end for the steel nuts securing the columns in place.				
	The ejecting levers to be cast steel, securely keyed to main rocking shaft of mild steel turned to fit the supporting bearings.				

HP.		Weight. Tons.	£.	s.	d.
	Main crankshaft to be of mild steel of double web type the crankpin being cut from the solid. Crankshaft bearings and pulley shaft bearings to be fitted with renewable brasses in halves. Press to be complete with fast and loose pulleys and belt gear. One improved hardening chamber, 40 ft. long and 6 ft. in diameter. Chamber to be of Siemens steel plates $\frac{5}{8}$" in thickness. Hinged door to be provided at one end only, to be held in place by 44 special fall-back bolts. All holes to be drilled and not punched. The whole constructed in strict accordance with the requirements of the Manchester Steam Users Association, and a certificate to that effect will be given. Brick Waggon of steel for the bricks, to be capable of carrying about 700 bricks each. Wheels and axles to be of steel mounted on roller bearings. Two special Turntables to be mounted on ball bearings and ball supports, to be a high class turntable, and to be moved by foot. One transfer car of steel with steel wheels and axles, and to be mounted on roller bearings.				
10		13 $\frac{1}{2}$	850	0	0
25		13	472	0	0
		7 $\frac{1}{2}$	262	0	0
		$\frac{3}{4}$	24	0	0
42		58 $\frac{1}{4}$	2278	0	0

MESSRS. HERBERT ALEXANDER & CO., LTD.
ENGINEERS, LEEDS ENGLAND.

ESTIMATE FOR A LIME SAND BRICK MAKING PLANT: CAPABLE
OF PRODUCING BRICKS FROM A MIXTURE OF SAND AND
LIME: AT THE RATE OF 18,000 TO 20,000
BRICKS IN 20 WORKING HOURS.

LIME SECTION.

One lime hydrating machine: complete.
One screener: mounted in a suitable frame.
One dust proof steel cased elevator: complete.
One conveyor: complete to lime silo.

MIXING : TEMPERING : MOULDING & PRESSING
SECTION.

One 7 ft. dia: overdriven mixing and tempering mill:
of our self-delivery type: complete. In this machine a measured quantity of lime and hydrated lime is mixed and tempered to the desired consistency.

One extra strong steel bucket elevator: Complete.
One double shafted differential mixer: Complete.
One No: 01 "Hercules" brick moulding and pressing machine: complete, to be fitted with moulds to your sizes. The machine to embody all our latest improvements including our safety devices to prevent breakage owing to over-pressure.

POWER AND TRANSMISSION.

One steam boiler: complete. To Board of Trade requirements of ample capacity and power to generate the necessary steam for driving all the machinery and use in the hardening cylinder.

One steam engine: complete. Of ample power for driving the whole of the above specified machinery.

One pump: complete.
One feed water heater: complete.
Complete arrangement of shafting, bearings, brackets, wall boxes, pulleys and belting for transmitting power to all the machinery arranged as per our drawing No. 927.

Complete arrangement of steam and water piping with all necessary connections and valves.

HARDENING CYLINDERS AND TRANSPORT SECTION.

Two steel cylinders: of our special design to receive the loaded brick waggons. The two cylinders to have a capacity of 18/20,000 bricks per day of 24 hours. Each cylinder to be provided with a loose door with suitable fastening arrangement and automatic steam tight joint, inlet and exhaust valves and also safety valve.

Two adjustable blocks: for carrying the loose doors.

Seven special turntables complete:

The lengths of portable railway track: as per our drawing No. 927.

Twenty six (26) special transport waggons: on which the bricks are placed to be hardened in the cylinders. These waggons require to be very strong, well balanced and free from vibration when loaded.

Price: We will supply the whole of the above specified machinery and plant for the sum of £6,105-0-0 (Six thousand one hundred and five pounds) f. o. b. Hull or Liverpool.

THE COST OF MANUFACTURE.

The cost of production will, of course, depend upon very many local circumstances, such as the price of raw materials and wages of labour. It will not be possible to give a correct estimate of the cost before actual experience is gained under local conditions. I may, however, make certain observations which will give a rough idea of the cost of production. Readers having experience in industrial matters may be able to make corrections in the figures and arrive at a more accurate estimate.

The cost of making lime-sand bricks may be divided into four parts:—

- (a) The cost of raw materials.
- (b) The cost of actual production
- (c) Overhead expense.
- (d) Selling expense.

The cost of raw Materials:—Mr. A. B. Searle says that, under certain favourable conditions, the industry will be paying even if the cost of sand be as high as 10 s per 1000 bricks. This will amount to about 3 s per ton. But if we locate a factory at a place like Pallipuram, we are sure to get sand at about a sixth of this price. Practically all that has to be paid for sand is the cost of transport for a distance of about a furlong.

The price of unslaked lime is about 18 chs. or 10 as per parah in Trivandrum. The parah used for measuring lime is a box measuring 20" × 20" × 10" internally. This is equivalent to a capacity of about 2·3 cubic feet. The weight of this volume of unslaked lime is found to be 117 lbs. From this it is seen that the price of a ton of unslaked lime is only about Rs. 12 in Trivandrum. The average price of lime given by Mr. Searle in his estimates is 19 s-2 d or Rs. 14-6 as. per ton. Thus even in Trivandrum the price of lime is less than what is given in Mr. Searle's estimate. But lime will be cheaper in the region round the Vembanad lake, where the raw materials, shells and firewood, are cheaper than in Trivandrum. The price arrived at above is calculated from the retail rate and includes the lime-burner's profits. If a lime-sand brick works burns its own lime, its cost will be lower. I have already indicated that Pallipuram (Vaikom) is an ideal place for the location of lime-sand brick works. Under any circumstances, the price of lime there cannot exceed Rs. 10 per ton and may be less.

The cost of Production:—By cost of production is here meant all wages of labour, carriage and cartage, fuel, water, repairs, supplies (oil, etc.) and wastage, but not management and selling expenses, depreciation, bad debts or interest on capital.

The cost of making lime-sand bricks is regulated chiefly by the cost of raw materials, the manual labour involved being very small. The machinery works almost automatically.

Since there are no lime-sand factories in India, we have to make comparisons with foreign factories. The following table gives some facts regarding fourteen foreign lime-sand brick works. The first column gives the year in which the works came into existence. The other figures are the averages since then up to 1914.

Table showing the approximate cost of production and profits obtained by
Fourteen Lime—Sand Brick Works.

In operation since.	Net profit realized per cent.	Yearly Production in Millions.	Cost of Production (Shillings).	Selling price per 1000 (Shillings.)
1903	15	2	17/-	22/6-
1902	10-12	2	17/-	23/-
1904	10	2	16/6	23/-
1900	8-9	1½	16/- to 16/6	19/- to 20/-
1904	8	2	17/-	21/-
1903	15	3	15/- to 16/-	22/- to 24/-
1899	12	2½	15/6	22/6
1903	12½	3	14/6 to 15/-	21/6
1902	8	2	15/-	19/-
1901	4	2	15/-	18/-
1899	10	3	13/6	19/6
1900	9	1½	14/-	22/-
1904	10	2	13/-	18/-
1900	4½	2	13/-	15/- to 16/-

Instead of coal we shall have to use wood as fuel in Travancore. It is then desirable to see how the heating power of wood will compare with that of coal and the relative prices of the two. It is a pity that no data are available about the composition or heating power of the various kinds of wood employed for power production in Travancore. But the composition of wood is more or less the same and to form a rough idea of the heating power of wood we may take an example at random.

In Sexton's Text Book of Metallurgy, the following is given as the average composition of an air dried sample of wood:

Carbon	40.0 per cent.
Hydrogen	4.8 "
Oxygen	32.8 "
Nitrogen	0.8 "
Ash	1.6 "
Water	20.0 "
Total	100.0

The Theoretical evaporative power of this sample of wood will be

$$\frac{.4 \times 8080 + (.048 - \frac{.328}{8}) \times 34000 - (.20 + .048 \times 9) 637}{537} = 5.7 \text{ (approx.)}$$

In other words one pound of the wood can evaporate 5.7 lbs of water at 100° C. to steam at 100° C

An average sample of Aix-la-chapelle steam coal is of the following composition:

Carbon	=	91.45 per cent.
Hydrogen	=	4.18 "
Oxygen	=	2.12 "
Ash	=	2.25 "
Total		100.00

The evaporative power of this sample of coal will be theoretically

$$\frac{.9145 \times 8080 + (.0418 - \frac{.0218}{8}) \times 3400 - 9 \times .0418 \times 637}{537} = 13.5 \text{ (approx.)}$$

Comparing the wood with the coal, we see that, to produce the heating power of one ton of coal, we must have about 2.4 tons of wood.

Now, in his estimates, Mr. Searle puts down the price of coal at 16/- or Rs. 12 per ton. Fire wood will cost at the factory about Rs. 5 per ton. At this price 2.4 tons of wood which is the equivalent of one ton of coal will cost Rs. 12. I think fire wood may be obtained at Pallipuram at a few annas less than Rs. 5 per ton. It will be seen from these figures that, on theoretical considerations of the heating power of wood and coal, we shall not be under any disadvantage by having to use wood as fuel instead of coal.

The disadvantage of wood lies in its greater bulk which entails a greater space for storage and larger fireplaces for its combustion. But where land is cheap the former defect is not a great disadvantage. On the other hand wood has three advantages:—

1. It kindles very readily.
2. It burns with a long flame.
3. Its ash is small in quantity, and comparatively free from deleterious substances.

Mr. Searle's estimate for 18,000 bricks which is the daily out put for the machinery, the cost of which is quoted in another part of this paper is given below. This estimate is based upon a comparison of the cost of production of a number of English lime-sand brick works.

	£.	s.	d.
Sand for 18,000 bricks	1	18	0
Lime, 7 per cent, say, 4 tons	3	16	8

	£	s.	d.
Coal 2½ tons	2	0	0
Wear & tear at 1s. 3d. per 1000 l	1	2	6
1 man feeding sand	0	5	0
1 man grinding lime	0	5	0
1 man mixing (good man)	0	5	6
3 men at press	0	15	0
4 men wheeling and stacking	1	0	0
2 boiler men 1 day & 1 night-	0	11	0
1 Engineer or Mechanic	0	7	0
1 labourer	0	3	6
	£ 12	9	2

Cost per 1000, say, 13s-10d. or Rs. 10-6as.

Now we will see what reduction we can possibly make in the cost of production under the conditions obtaining in Travancore. The above estimate is for a factory working only in the day time the hardening alone being effected during night. But it is cheaper to have the factory working continuously both day and night. Giving a shift of eight hours, we shall require three labourers for every one labourer in the above estimate. But the wages of labour being much lower in Travancore than in England, there will still be a reduction of cost in the matter of labour. It is further to be remembered that the initial cost of a plant working day and night will be much less for the same output than that of a plant working only during day. Herein lies the chief advantage of a plant working both day and night.

Our estimate for 18,000 bricks will be as follows:—

	Rs.	as.	p.
Sand (54 tons)	20	0	0
Lime (4 tons)	40	0	0
Fire-wood (6 tons)	27	0	0
Wear and tear	16	14	0
3 men feeding sand	1	8	0
3 men grinding lime	1	8	0
3 men mixing	1	8	0
* 9 men at press (at 6 as)	3	6	0
* 12 men wheeling and stacking	4	8	0
3 boiler men (at 12 as)	2	4	0
1 Engineer	3	8	0
3 labourers	1	2	0
	Rs. 123	2	0

Cost per 1000=Rs. 6—13 as.

*Since the rate of output of a plant working day and night will not be so fast as that of one working only during day, so many men may not be required. These numbers may be reduced to 6 and 9, making corresponding changes in the wages.

This cost does not include the charges for management and depreciation. For management or overhead expenses and selling expenses, such as advertisements, etc., we may put down Re. 1 per 1000 bricks or about Rs. 5400 per year. We have charged 15 as. per 1000 bricks or about Rs. 16 per day for renewals and repairs and this is included in the cost of Rs. 6-13 as. per 1000. In addition to this we may make a charge for depreciation. The price of the machinery required for the works will be about a lakh of Rupees and let us say that the machinery will have to be renewed entirely once in ten years. Then on an average we have to add about Rs. 2 to the cost per 1000. Thus the total cost per 1000 bricks will be Rs. 9-13 as. or say Rs. 10 at the most.

Now let us compare this with the prices current for clay bricks in Travancore. Harrisons & Crosfield's price is Rs. 28 per 1000 for facing bricks and Rs. 14 per 1000 for wire cut bricks. It must be remembered that every lime-sand brick prepared with the materials in Travancore and with ordinary care will be a facing brick. But let us not expect a high price and fix our selling price at Rs. 14 per 1000.

If we can create a demand for the whole out-put of 18,000 bricks per day and if the factory be working for 300 days in the year, there will be a total profit of Rs. 21,600 per year. Deduct from this Rs. 6750, the interest of Rs. 1,50,000, the probable capital outlay required for the enterprise. This will leave us a net profit of more than 9 per cent per annum. In this estimate we have made a very liberal allowance for management, depreciation and repairs, while the selling price we have assumed is that of the worst kind of clay brick.

Further every one of the lime-sand bricks is after further treatment a silica brick which can be used for the lining of furnaces, etc. This treatment consists of burning the hardened bricks in kilns as the ordinary clay bricks. Most of the fire bricks required in India are now imported from abroad and they cost about Rs. 12 per 100 or Rs. 120 per 1000. The cost of burning the hardened lime-sand bricks will be quite insignificant compared with the increase of price. A local lime-sand brick works will always be able to undersell imported fire bricks and, if, by this means, a demand is created for the locally made silica bricks in the Indian markets, the profits from the works will be enormous.

FLOOR-TILES ETC.

Now we shall consider the cost of making flooring tiles for which the demand is greater than for bricks. Volume for volume flooring tiles will cost somewhat more than bricks. First of all the percentage of lime required for flooring tiles is greater. Again a greater proportion of the aggregate must be ground to flour so that the tiles may be sufficiently strong and impervious. Let us say that flooring tiles will cost 50% more than bricks bulk for bulk on account of the extra expense. The size of the bricks for which we have given the above estimate is 9 in. $\times$ 4 $\frac{3}{8}$ in. $\times$ 2 $\frac{1}{16}$ in. Flooring tiles are usually 9 in. square. Ordinarily the thickness need be only 1 in. But in view of the consideration that the tiles will have to withstand frequent impulses of falling goods, etc., on the floors of godowns and factories, let us give them a thickness of 1 $\frac{1}{2}$ in. Then the bulk of a thousand of the bricks will be equal to that of about 880 flooring tiles and this number of tiles will cost about Rs. 15 or a thousand tiles will cost about Rs. 17. Harrisons and Crosfields' selling price of flooring tiles of this size is Rs. 39-8 as. per 1000 for the first class and Rs. 29-8 as. per 1000 for the second class. Even if we assume this lower price, there will be a net profit of about Rs. 12 per 1000,

Roofing tiles can also be manufactured with sand and lime. In fact every article that can be made of clay by pressing can be made of lime-sand mixture also; and none of the articles will be inferior in quality to those made of clay. The manufacture of these articles besides bricks will yield a net dividend greatly in excess of 9 per. cent., which is the figure we arrive at on the supposition that the factory produces only building bricks.

CONCLUSION.

I may conclude these notes with a quotation from Molinari, Professor of Industrial Chemistry in the Commercial University of Luigi Bocconi at Milan. He describes lime-sand bricks under the name arenolite.

"The advantages of these artificial stones consist in the great regularity of shape, without deformation, and of resistance to pressures of 400 kilos and more per square centimetre; they may also be employed for work under water; they are bad conductors of heat, very resistant to fire, as hard as cement, are able to be painted or varnished directly, and can be used immediately after manufacture; they absorb less

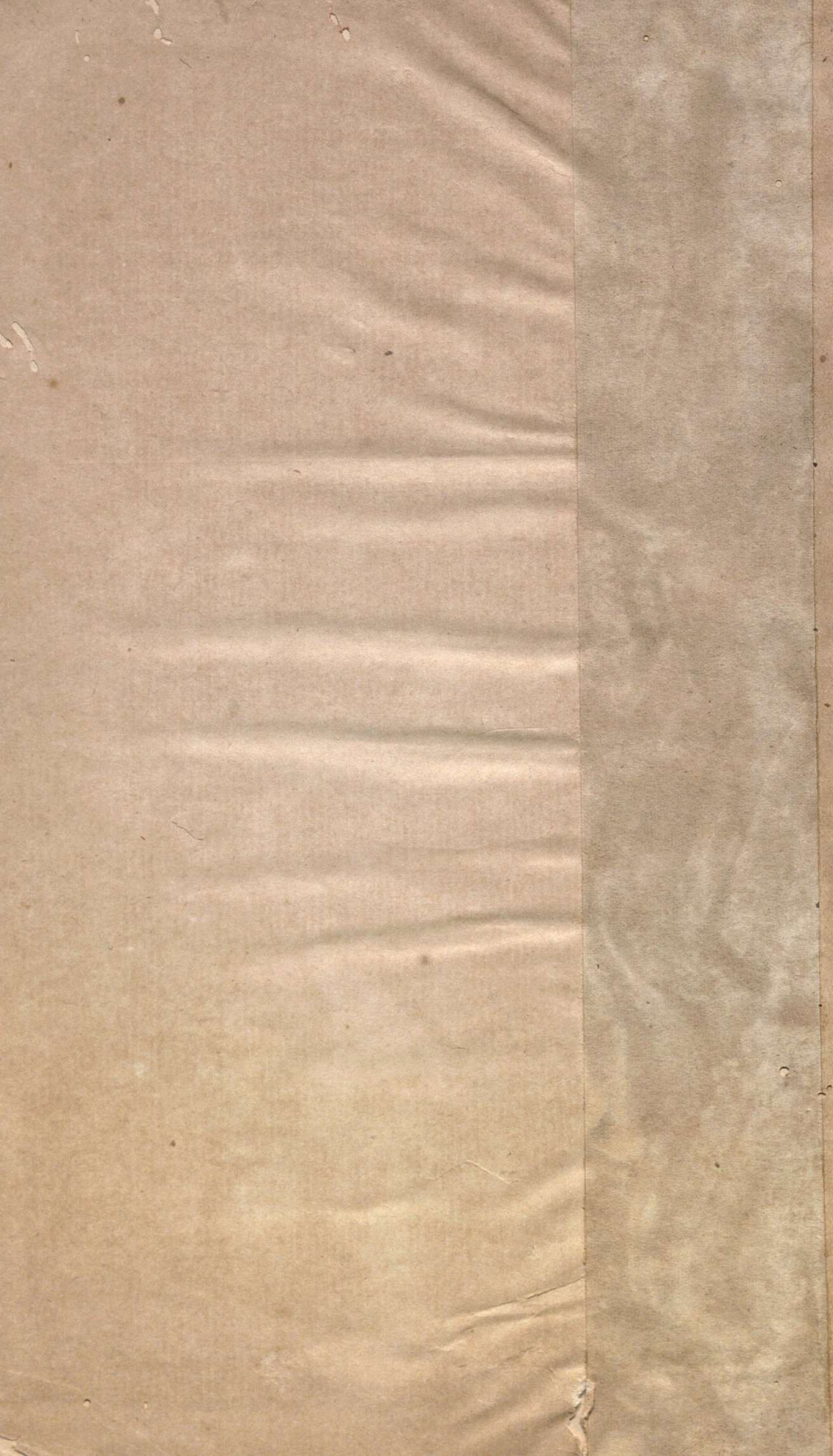
water than ordinary bricks and dry rather more rapidly. Light artificial bricks, either compact or perforated, are now produced with infusorial earth (kieselguhr.)

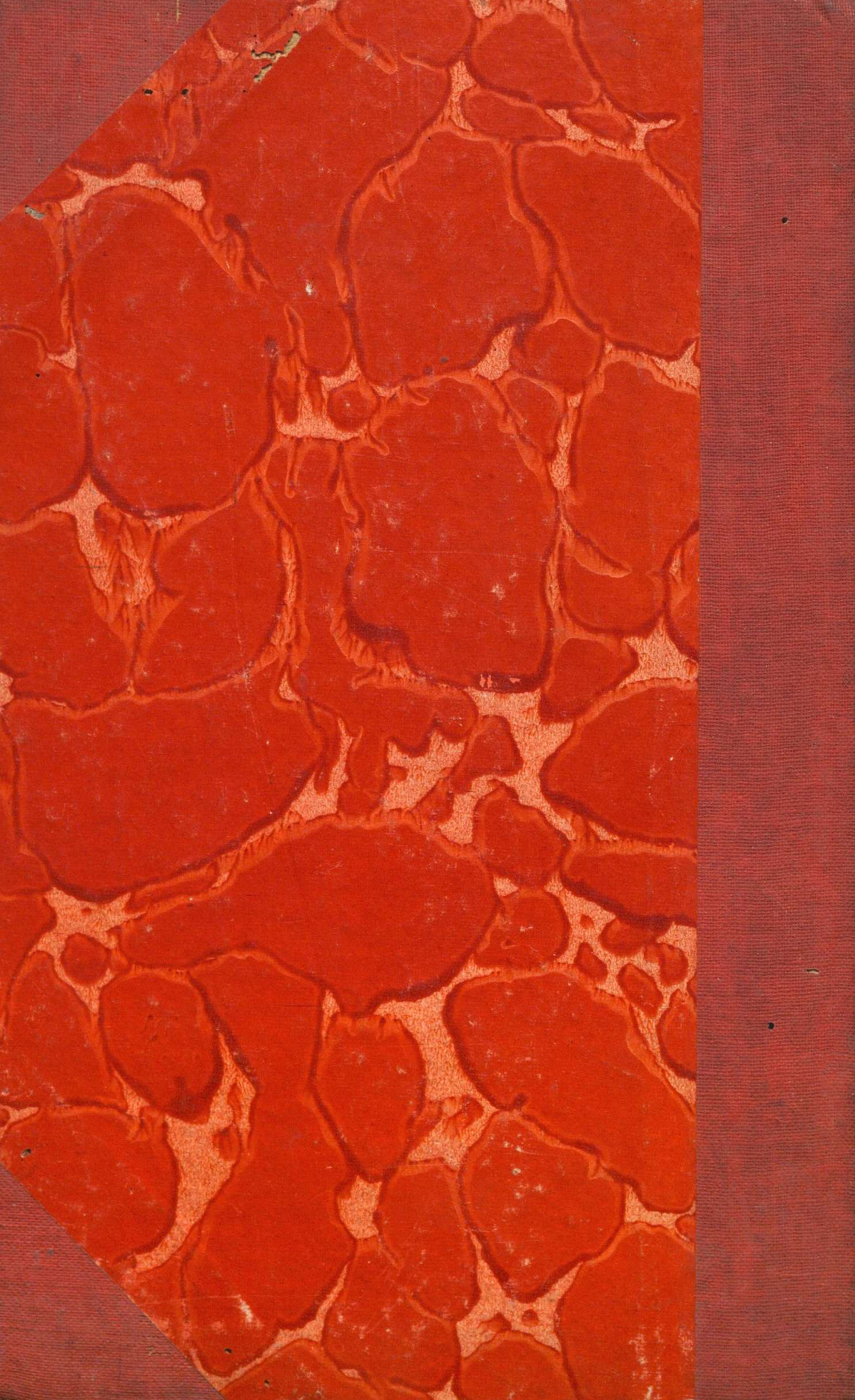
The installation of a works for manufacturing such stone costs less than that of a brick-kiln and requires less space and less manual labour. The price of 100* bricks of the ordinary size ($6 \times 13 \times 26$ c. cm.) varies from 9s. 7d. to 12s. 10d. The works in Berlin and neighbourhood annually produce 400,000,000 arenolite bricks."

Trivandrum, }
12th Nov. 1917. }

I. C. CHACKO,
State Geologist.

* This is evidently a printer's mistake for 1000.





MD132 E8 LIME-SAND BRICKS, SLABS AND TILE JACKO