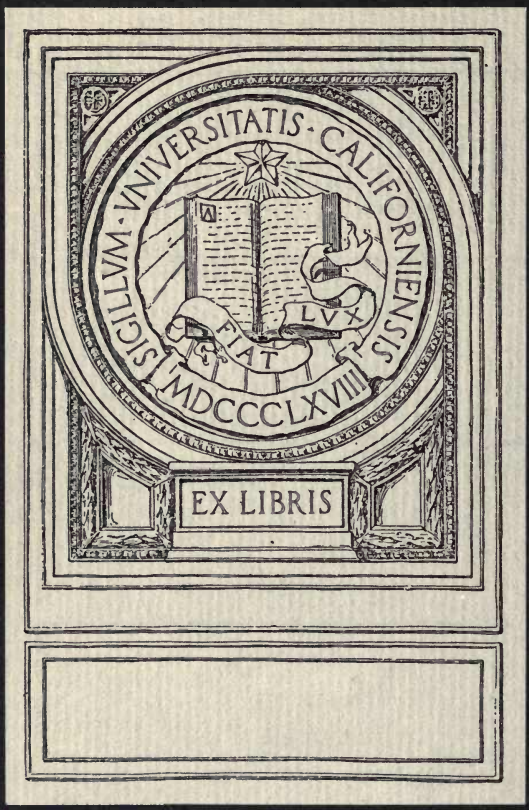
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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

BUILDING RESEARCH BOARD

SPECIAL REPORT NO. 1

SAND-LIME AND OTHER CONCRETE BRICKS

BY

H. O. WELLER, B.Sc., M.Inst.C.E.,
DIRECTOR OF BUILDING RESEARCH

LONDON:
Published for the Department of Scientific and Industrial Research by His Majesty's Stationery Office, and to be purchased at the addresses given overleaf.

1921

Price Threepence Net

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PREFATORY NOTE

The Building Research Board, appointed by the Committee of the Privy Council for Scientific and Industrial Research to consider and direct the conduct of research on building materials and methods of construction, propose to issue a series of Special Reports in connexion with the research work carried on under their direction.

The present report, the first of the series, has been prepared by Mr. H. O. Weller, B.Sc., M.Inst.C.E., Director of Building Research, and has been published for the Department on the recommendation of the Building Research Board.

Department of Scientific and Industrial Research,
16 and 18, Old Queen Street,
London, S.W.1.

March 1921.

SAND-LIME AND OTHER CONCRETE BRICKS

INTRODUCTION

Without denying the special merits of other blocks in special circumstances, it may be safely asserted that for all ordinary uses there is no better building-block than the ordinary brick. It has been evolved by thousands of years' experience in all parts of the civilised world as the ideal block for hand use.

Its size varies within narrow limits; for instance, in Scotland and India it is slightly larger than in England; in the United States and Belgium it is slightly smaller. But this small variation is, in itself, a clear testimony to the suitability of the standard; to depart from it entirely is merely to make a block that is quite unsuitable for ordinary use.

In material there is scope for greater variation; within the universal standard material, burnt clay, there is so wide a range of quality that it would be difficult to go outside it with any other material.

It is at all times legitimate, therefore, and in present circumstances profitable, to consider the preparation and use of bricks made of materials other than burnt clay.

SECTION I

SAND-LIME BRICKS

The history of sand-lime bricks begins with "mortar bricks" made by an Englishman above 80 years ago. These bricks were merely a mixture of sand and lime left to harden in the air; the process took from 6 to 18 months. In this hardening there was developed a very small amount of calcium silicate.

Subsequent attempts at improvements resulted chiefly in an exploration of dead-ends, till Dr. Michaelis, of Berlin, took out his master-patents for the true sand-lime (calcium-silicate) brick rather less than 40 years ago.

It is the Michaelis process, modified with circumstances, all patents having long ago expired, which is now exclusively used.

The making of the bricks is a process for the manufacturer, not for the builder; but once the plant is installed it provides by far the quickest method of getting bricks. When "fat" lime and a sharp clean pit sand are used it is quite ordinary practice to mix the materials one day, carry on the manufacturing process during the night, and deliver the finished bricks for sale next morning.

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MATERIALS

Any clean silicious sand, from quarry, pit, or river, may be used; many other refractory and waste materials or by-products, such as slag, clinker, shale, quarry-waste, shards, &c., are suitable.

The only other necessary material is lime. Either hydraulic or "fat" lime may be used, but it is found to be economical to go to considerable expense to use a "fat" lime if it is available.

There are in the country experts who will set up a plant to tackle any problem of difficult materials, and they will only hand it over when its out-turn is satisfactory.

COST

At present prices a capital of about £12,000 is needed for an output of 3,000,000 sand-lime bricks per annum; a capital of about £15,000 is needed for an out-turn of 5,000,000 per annum—this is a unit plant, working at full power.

It is not easy at present to say what is the cost of manufacture; before the war, sand-lime bricks cost 11 to 12 francs per 1,000 in France, 15 to 17 marks in Germany, perhaps 15*s*. to 20*s*. in England. Their present price in England is from 75*s*. at the field to £5 per 1,000 f.o.r., their gross manufacturing cost being probably about 45*s*. to 50*s*. per 1,000; but this depends on the rate charged to the process for the sand.

QUALITY

In appearance sand-lime bricks are white, cream, or grey in colour, perfectly regular in shape and size, and of a texture varying from that of sand-stone to that of the Staffordshire blue brick. Ordinary white bricks can be coloured with harmless pigments to any reasonable tint.

A good sand-lime brick is a calcium-silicate brick; a bad one is merely calcium carbonate mixed with sand. Unfortunately it is not easy to tell good sand-lime bricks from bad by mere inspection or easily applied tests. The process lends itself to dishonesty, and can also be easily wrecked by benevolent incompetence. It is essential that the bricks shall remain in the hardening chamber for from 8 to 12 hours, varying with the materials and with the steam pressure used; but the purchaser cannot assure himself that the bricks he is buying have been treated for this period. Until a standard is set up, such as that for Portland Cement, the purchaser's only guarantee is the reputation of the brickmaker. At present that guarantee would be sufficient possibly in all cases, but if the industry expands, as seems likely, it will be to the advantage of all concerned that a Standard shall be set up. In Germany such a Standard was set up years ago by an association of the industry, and in America "The history of sand-lime brick

manufacture has been largely influenced by the activities of the Sand-Lime Brick Association. This body comprises about 40 members in the United States and Canada. It has been in existence for 12 years, and has worked consistently to cheapen the cost and improve the quality of the brick."*

The crushing-strength of sand-lime bricks may reach over 200 tons per square foot.

USES

They can be used as a general substitute for ordinary burnt-clay bricks, and they have those additional advantages which their regular shape, light colour, sharp angles, and composition give them. For instance, they are used as a fair substitute for white-glazed bricks for the interior finish in school rooms and corridors, dark passages, and ill-lighted public rooms. They do not disintegrate in frost; they resist acid fumes, and are, therefore, suitable for chemical works and chimney stacks.

It is claimed for them that they are fire-bricks, but this claim can only be accepted with reserve; they will stand in many positions where fire-bricks are ordinarily used, but they will not stand a combination of great heat and pressure; under these conditions they do not warp or fuse, they collapse. They can be made wherever there is a suitable sand, or a suitable slag or other waste. Two successful installations in this country are in potteries where sand occurs over the clay, and would be worse than a waste material if not used in brick making. The process of manufacture shortly described is :—

MANUFACTURE

Preparation of Lime.—The lime is thoroughly slaked and finely powdered. An ordinary " fat " stone or chalk lime, slaked to a flour and screened, gives the best results. It is essential that the lime be completely slaked before the brick is made up; this makes the process more complicated when a hydraulic lime such as Blue Lias is used. Lime made from magnesian limestone is sometimes used in America, but calcium limestone is preferred.

Preparation of Sand or other Aggregate.—The only essential in the sand is that it shall be silicious, clean and sharp. If a suitable slag is used it should be water-granulated and graded. Shells, quarry wastes, and such materials must be crushed, screened and graded. (It is advisable that one of the firms who specialise in the process should be asked to advise on proposed aggregates and, if necessary, to set up an experimental plant.)

Mixing.—The proportion of lime used varies from 5 to 10 per cent. of the sand, the more silicious sand taking up the more lime. Mixing may be done dry, in an ordinary pan mortar

* Technologic Paper of the Bureau of Standards, U.S.A., No. 85 of March 1917.

mill, just sufficient water being added to make the mixture cling together when clutched in the hand—the " semi-dry " state. This mixture, when a " fat " lime is used, may be fed straight away into the press through a hopper. When a hydraulic lime is used the lime must remain in contact with the damp sand for two or three days, or other means must be taken to slake the lime completely. The press turns out bricks sufficiently firm to handle; they are lifted without pallets and stacked on trolleys; each trolley contains about 2,000 bricks, and they do not leave these trolleys till they are ready for the market. There is very little handling with a properly designed plant.

Hardening.—The loaded trollies are wheeled into a long, steel hardening cylinder, made like a boiler-shell, with a special door; steam is admitted and a pressure of 100 lbs. per square inch, or over, is maintained for 8 to 10 hours. Usually the chamber is loaded in the evening and unloaded next morning, or the process may be continuous with two cylinders, one exhausting into the other, to save fuel. Under a recent patent the long steel cylinders are replaced by ferro-concrete chambers. The steam is used at a pressure of a few pounds, superheated to a temperature corresponding to a pressure of about 120 pounds per square inch. This reduces the cost of the plant very considerably.

Unloading.—At the end of the steam-hardening period the pressure is released and the chamber opened; when cool enough to handle the trolleys are wheeled out, and the bricks are stacked ready for transport. Their manufacture is finished; they need no time to harden in the air.

Artificial Stone.—When once the mixing and hardening plant has been installed the out-turn is not limited to bricks. The use of a press is not essential: " tamping " will do almost as well, and any shape of artificial stone, useful or ornamental, may be made up and hardened in sand-lime material. In appearance the resulting stone can be equal to any natural sandstone.

Further information on the sand-lime process of manufacture can be obtained in the May (1920) number of " La Nature " (p. 215, an illustrated article, " Fabrication de la Brique Silico-Calcaire "), and in Bulletin No. 85, " Manufacture and Properties of the Sand-Lime Brick," issued by the U.S.A. Bureau of Standards.

A Report of the Munitions Inventions Department issued during the war may also be quoted :—

" The most objectionable impurity is felspar, as it is apt to cause efflorescence in the brick, but clay can safely be present up to 5 per cent. . . . Blast furnace slag, clinker, destructor refuse, burnt shale tips, all make excellent bricks when ground with the proper proportion of lime and pressed and steamed. Of these bricks, those made from blast-furnace slag are the cheapest to manufacture. The hot slag is run into water to granulate it, the

granulated slag is ground and mixed with the proper proportion of lime and, after pressing into bricks, merely requires to be steamed in chambers with live steam without pressure or exposed for some time to the air to finish the brick." This last is not a true sand-lime brick; ground slag is often an excellent cement in itself.

Another quotation from the same report is :—

"The Committee is of the opinion that, if a good sand-lime brick is used, a sound and durable hollow wall for cottage construction can be built with these bricks placed on edge, and connected by the usual iron binder."

The report also gives the consumption of fuel as 2½ cwts. of coal per 1,000 bricks.

Durability.—Although the manufacture of sand-lime brick is not widespread in England, there are, nevertheless, excellent examples of English houses built from 12 to 16 years ago of sand-lime bricks which have stood, if anything, better than burnt clay bricks in the same locality. Their use at Reading, in particular, has been extensive and most successful.

Sand-lime bricks which are known to be not of the highest class must not be used in damp situations, or below the damp course in any situation; they rapidly deteriorate to the condition of bad old lime mortar. On the other hand, the life of good sand-lime bricks—*i.e.*, those in which the sand has combined with the highest possible proportion of lime, to form Calcium Silicate—may be put as equal to the life of good sandstone; and especially it has been found that they improve with age in damp situations.

SECTION II

CEMENT-CONCRETE BRICKS

These are plain concrete bricks made of a "semi-dry" mixture of Portland Cement with sand or other aggregate. The making of these bricks is the essence of simplicity; it is a process for the builder rather than for the manufacturer.

For an out-turn of 1,000 bricks a day the special plant required costs only £8, and can be carried on a wheelbarrow. For an out-turn of 5,000 bricks a day the special plant costs from £250 to £800, and can be carried on an ordinary builder's cart. Bricks made on the smaller apparatus will be rather of the rough-and-ready type, and a good deal of flat ground is required, as they are not stacked on pallets.

When a suitable aggregate is on the spot—a condition essential to economy—brickmaking by this process places a builder almost independent of transport difficulties; the only outside material he has to arrange for being Portland Cement. His

equipment for making cement concrete bricks, moreover, supplemented by a few wooden moulds and a little bar iron will enable him to make lintels, door sills, and any other feature usually of stone. On one typical Housing Scheme a six to one mixture of destructor clinker and cement is used for everything, including roofing tiles.

MATERIALS

The best aggregate is a sharp, clean, pit or river sand; but any aggregate that is used for ordinary cement concrete may be used, so long as it is not too coarse. Excellent bricks can be made of quarry waste, broken brick, furnace clinker, ashes, broken chalk, with those proportions of cement which are found suitable after experiment. The aggregate must be well graded; except when it is so soft that it breaks down partially when tamped, and all voids are, incidentally, filled. So-called "coke breeze" and "clinker" should be tested for unburned coal. Destructor ash may contain salts which will cause efflorescence.

Portland Cement to the British Engineering Standard Specification should be used where procurable, but for work exposed to sea-water a slag-cement may be preferable. True "Iron Portland Cement" may be used with confidence as a substitute for Portland Cement.

When no cements are available, in emergency, Blue Lias Lime, to which 5 per cent. of coarse Plaster of Paris has been added for a quick handling set, may be used.

The cement proportion should not ordinarily fall below 6 of the aggregate to 1 of Portland Cement where the bricks are hand-made, or 9 to 1 where they are power-tamped. But a 12 to 1 mixture has given good results with chalk as aggregate, and it may be stated as a general principle that the better graded the aggregate the smaller is the proportion of cement necessary.

COST

The £8 plant is suitable only for a small job, such as the erection of farm buildings or a single cottage. The larger plant is suitable for Housing Schemes. One machine can turn out the bricks for a group of 20 houses. A typical estimate for such a plant is :—

	£
One brick machine, making 6 bricks at a time, complete	50
2,000 combined pallets and drying racks, approximately	500
1–3 cubic foot mixer - - - - - - - -	94
Total - - -	£644

to which may be added £165 for a power tamper, if power is available. Another estimate is :—

One brick-making machine for 6 bricks at a time, with set of pallets (steel) - - - - - - - -	£250

Drying racks for this outfit would be made locally of wood by the builder. Work could be carried on in the open, but it is better to build a shed to protect the machine, so that work can go on during bad weather. A shed 40 ft. by 15 ft. is a convenient size for one machine; it gives sufficient space for an output of 2,500 bricks a day, and stacking room for two days' manufacture. Mixing may be done by hand, but machine-mixed mortar is undoubtedly more uniform, also if the size of the plant justifies the purchase of a mixer the bricks are cheaper in the end.

An excellent plant for the making of cement-bricks has recently been introduced from Denmark. The cost of the items are (approximately) £260, c.i.f. for the brick machine itself, with power-tamping, and £155, c.i.f., for a suitable concrete-mixer. About 2,000 wooden pallets would also be required, at a cost of 1*s*. each. The power required for the plant is 4 h.p. electric, or 5 h.p. oil-engine, and the output would average 5,000 bricks a day. A sand-cement proportion of 10 to 1 can be used. This machine makes 10 bricks at once, without frogs.

Estimated on the following prices :—

	£	*s*.	*d*.	
Portland Cement - - - - -	3	5	0	per ton
Aggregate - - - - - -	0	5	0	„ „
Labour - - - - - - -	0	2	0	an hour

the cost of bricks will work out to be from £2 4*s*. a thousand using one of the larger plants to £2 10*s*. a thousand using the smaller plant.

MANUFACTURE

The process is simple. In the £8 machine the mixture is filled into the moulds with a shovel, tamped and swept off by the same shovel. In the larger plant the tamping instrument is either a special form of wooden beetle, or a power tamper. In the larger plant the bricks are made on pallets; they are carried off by hand from the machine on the pallets, placed on racks and left to harden for two days; 12 hours after being made they are sprinkled with water. The third day they are taken off the pallet and stacked closely to retain the moisture. They are watered twice a day for a fortnight, protected from hot sun or frost. At the end of the fortnight they are finished ready for use. They do not attain their mature strength for months; they go on hardening, indeed, for years.

A quick maturity may be obtained by adding 10 per cent. to 15 per cent. of thoroughly hydrated fat lime to the cement; bricks so made are fit for use in a week. But the method is not recommended; the result of such mixtures has not been fully investigated, and there is the danger of unslaked lumps of lime " blowing " pieces out of the brick.

Real maturity is hastened legitimately by steam-curing; exposure for 48 hours in a closed vessel to steam at atmospheric

pressure will give a maturity normally attained in three months; exposure for 24 hours will make the bricks fit for immediate use. The crudest apparatus gives good results.

Burnt-earth Bricks.—A new method of making bricks is by a patented process in which almost any earth is incinerated at 1,500° Centigrade, and used as an aggregate with cement. The process is: the earth is burnt in an oil-fired furnace, moulded semi-dry, with a small proportion of cement, immersed in still water for 24 hours, cooled (not below 32° F.) and dried in a current of air. It is claimed that the cooling "lengthens the crystal."

The water used should be soft, or softened water. The brick can be made either by tamping in ordinary brick moulds with a high proportion of cement, or in a brickmaking press, such as a sand-lime press, with an 8 to 1 mixture of aggregate and cement. Pressure is said to be cheaper than cement in this process. The furnace is lined with Zirconia and fired with petroleum residue; the working cost of firing is said to be about 1*s.* for 1,000 bricks. Sample bricks have been recently tested at the National Physical Laboratory; the results were:—

Weight	6 lbs.
Porosity	40 per cent.

(these two quantities vary, of course, with the original earth)

Cracking load	from 28·3 tons to 38 tons.
Crushing load	„ 39·3 „ 46·3 tons.

This gives an average crushing strength of about 150 tons per square foot. The burnt-earth brick is scarcely on the market, and it is difficult to say exactly what the manufacturing cost will be. The patentee claims, however, that his brick will be the cheapest of all. He claims to be able to use any earth; it is obvious that there must be serious difficulties involved in the incineration of some earths.

QUALITY

It is sometimes said that semi-dry concrete has only half the strength of powdered concrete; this is not correct. Each material being at its best, wet-mixed concrete well rammed is certainly better than concrete made "semi-dry"; but taking each material as it is normally made on building work, there is not much difference. Semi-dry concrete blocks made 12 years ago in Surrey of six parts sand to one of cement, are harder than the local sandstone. Selected cement concrete bricks made "semi-dry" have stood, when matured, a crushing load of 220 tons per sqnare foot.

To produce a good brick the essential is regular and thorough sprinkling with water. It may be true that the centre of a large concrete block is scarcely reached by this sprinkled water, but a brick is not a large block.

There can hardly be a Standard made for cement bricks, as they are not likely to be an article of sale in the market. It cannot even be laid down that the proportion of cement shall not fall below any stated figure. The whole process, in any event, is under the close supervision of the builder, and it lies with him entirely whether good or bad bricks are made.

Where an attractive surface is desired, pigments (harmless oxides) may be added to the mixture; but more pleasing results can be obtained by using a selected sand for the facing bricks; certain natural sands in Surrey and the Midlands imitate red sandstone surfaces very well, and crushed sandstone waste is excellent.

Durability and Uses.—Cement bricks are merely small blocks of cement concrete. It is not too much to say that there is nothing more generally durable than good cement concrete. Its many good and few bad points are too well known to need description; they should not be forgotten, however, as advantage may be taken, where the extra expense is justified, to modify the concrete to suit special circumstances. For instance, where a hard-wearing surface is required, the bricks may be built up in the moulds with a face of granite chips, or other vitreous aggregate. If the bricks are to be exposed to sea-water, a percentage of " Puzzolanic " material may be added, or Slag Cement may be used instead of Portland. For integral water-proofing an 8 per cent. solution of potash soap (" soft soap ") may be used as the mixing water; this develops an alum soap in the body of the concrete, and is better than using a proprietary article of indefinite composition. A solution of silicate of soda (" water-glass ") may be used for the same purpose.

The use of any oil or organic material in concrete should be avoided.

There are many proprietary articles advertised to increase the strength of concrete; they might be worth using if their cost were less than that of the small additional quantity of cement needed to get the same increase.

In general it may be said that although some proprietary articles are not without virtue, they should be avoided unless their composition is known, not forgetting that it is usually possible to make up similar material at a lower cost. The extensive advertisement of a substance under a striking name does not, in any way, reinforce its properties.

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Report of the Fuel Research Board for the years 1918 and 1919. Price 1*s.* 6*d.* (by post, 1*s.* 8*d.*).

Fuel for Motor Transport. An interim Memorandum by the Board. 1920. Price 3*d.* (by post, 4*d.*).

The Winning, Preparation and use of Peat in Ireland.—*Reports and other documents.*

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No. 1. Report on Pulverised Coal Systems in America, by Leonard C. Harvey (*with plates and diagrams*). 1919. Price 2*s.* 6*d.* (by post, 2*s.* 8½*d.*).

No. 2. The Peat Resources of Ireland. A lecture given before the Royal Dublin Society, on 5th March, 1919, by Professor Pierce F. Purcell, Assoc. M.Inst.C.E. Price 9*d.* (by post, 10½*d.*).

No. 3. "The Coal Fire." (*An investigation into the efficiency of open fires*), by Margaret White Fishenden, D.Sc. 1920. Price 4*s.* (by post, 4*s.* 2½*d.*).

TECHNICAL PAPERS :

No. 1. The Assay of Coal for Carbonisation Purposes: A New Laboratory Method. 1921. Price 6*d.* (by post, 7*d.*).

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MISCELLANEOUS REPORTS, ETC.

Science and Industry—Industrial Research in the United States of America, by Mr. A. P. M. Fleming, M.I.E.E. 1916 (*with numerous illustrations*). Price 1*s.* (by post, 1*s.* 2½*d.*).

Notes on the Conditions under which Grants are made to Individual Research Workers and Students-in-Training. (*Revised April*, 1920.) Price 2*d.* (by post, 3*d.*).

First Report on Colloid Chemistry and its General Industrial Applications. 1917. Price 2*s.* 6*d.* (by post, 2*s.* 7½*d.*).

Second Report on Colloid Chemistry and its General and Industrial Applications. 1919. Price 1*s.* 6*d.* (by post, 1*s.* 8½*d.*).

Third Report on Colloid Chemistry and its General and Industrial Applications. 1920. Price 2*s.* 6*d.* (by post, 2*s.* 8*d.*).

Report of Joint Conference on Colloid Chemistry (*General Discussion between the Faraday and Physical Societies at a meeting held on 25th October, 1920*) (*in the press*).