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MADRAS RECORD OFFICE.

Government of Madras.

Public Works **DEPARTMENT.**

G.O. No. 2896 Press / ~~Misc.~~
116-164

Dated 7-12- 1872.

Not to be folded or roughly handled

Proceedings of the Madras Government, Public Works Department, 7th December 1872.

No. 166. Read the following Proceedings of the Government of India in the Public Works Department :—

Cement Manufacture.—(Here enter No. 52, dated 9th October 1872.)

No. 167. ORDER THEREON, 7th December 1872, No. 2,896.

IRRIGATION, No. 10.

COMMUNICATED to the District Engineers for information.

(True Extract.)

(Signed) G. W. WALKER, Colonel, R.E.,
Secretary to Government.

To District Engineers.
,, Major R. B. Kennedy.
To the Chief Engineer for Irrigation.
To Dr. Nicholson.
To the Consulting Engineer for Railways.

Engd. S. T. Austin.

CIRCULAR No. 52 PUBLIC WORKS.

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

IRRIGATION.

To The Secretary to the Government of Madras P.W. Department

SIMLA, OCTOBER 9, 1872.

The following papers are forwarded to Local Governments and Administrations in all Branches of the Public Works Department for information.

1. Report by Mr. Dejoux, No. 72, dated 5th April 1872, and Appendices.
2. Do. do. do. „ 89, „ 1st June „
3. Do. do. do. „ 104, „ 16th July „
4. Do. do. do. „ 109, „ 23rd „ „
5. Note by Colonel Haig, dated 29th August 1872.

(By Order)

Captain R. E.,
Secy. to the Govt. of India.

No. 72, dated the 5th April 1872.

From—P. DEJOUX, ESQ., Executive Engineer, Cement Experiments Division.

To—The Officiating Superintending Engineer, South-Western Circle.

I HAVE the honor to submit a report of my operations on cement experiments as follows:

2. I occupied the house rented for my office on the 1st of December last, and immediately entrusted Messrs. Burn and Company with a contract for the construction of the works noted in the margin, which were completed satisfactorily on the 15th February 1872.

2 Kilns for Cements.
2 „ Lime,
1 Kiln Pozzolanna.
1 „ Samples.
1 Shed for workmen.
1 Reservoir.

3. As it was found necessary, however, to allow some time to elapse for the kilns to get dry, I could only, on the 13th March, safely commence to burn samples in the small kiln.

4. On the 16th of January I commenced to receive specimens of clay and lime-stones from different parts of Bengal, and the following statement affords details of such receipts up to the 31st March:

Dates of receipt.	Whence received.	No. of Specimens of	
		Limestones.	Clay.
16th January 1872 ...	Selye Division	...	4
30th ditto ...	Soane Circle	3	5
1st February ...	Aera Division	...	1
1st ditto ...	Andaman Islands	1	...
20th ditto ...	Orissa Circle	10	19
23rd ditto ...	Barrackpore Division	...	2
1st March ...	Cossye Division	5	7
5th ditto ...	Dinapore Division	3	2
19th ditto ...	Pakour Sub-Division	2	1
22nd ditto ...	Canal Division	...	1

5. Upon my laboratory being furnished with chemicals and chemical apparatus, I began on the 23rd February a rough analysis of some of the specimens, and arrived at the following conclusions:

SELYE DIVISION.

6. The clays received were found very nearly pure, containing little or no sand, with some traces of oxyde of iron; but as no fat lime-stone is to be found in this part of the country, the manufacture of cement there will be impossible.

SOANE CIRCLE.

7. It is evident at present that the Soane Circle contains such of the best materials as will enable the manufacture of good cement. Of the specimens received, two have been found very suitable for the purpose. These are called in French *Marnes Argileuses* (marly clay); one of these, B 6, is very nearly like the *Marne of Boulogne Sur Mer* which produces a cement which is considered by many Engineers better than the English Portland cement; the other marked B 7, sent to me as white clay, is also a *Marne*, and by its combination with B6 will enable the manufacture of a cement of the kind which is commonly called *Roman cement*.

The clays B6 and B 7 are very friable, and consequently very easily pulverized; on this account it is certain (by reducing them to that state and eventually forming bricks with them) to secure a good homogeneity.

You will find in my Abstract B. of the results of the experiments on cement a rough analysis of these two descriptions of marly clay.

The samples A1, A2, and A3 may be also considered as cement stones, but the layers of these stones are of different qualities; some are cement stones, and others similar to those called by Vicat *Chana Limites*, which are always dangerous to use.

Should these stones be, however, burnt to a high temperature and attempts made to slake them with boiling water, the result will be that while the portion containing the *Chana Limites* gets slaked, the other remains unaffected. I opine, therefore, that they must be rejected on account of their want of homogeniety, and principally on account of the presence of the *Chana Limites*; nevertheless I intend making further experiments with them.

The clay from Dehree, B9, contains 8 per cent. of sand, but after washing it may be used with marly clay, and besides it may answer, if necessary, to increase for slow-setting cements the proportion of clay.

ACRA DIVISION.

8. The clay received contains only 2 per cent. of sand and some organic matters, which can easily be got rid of by washing. It will answer well for cement.

ORISSA CIRCLE.

9. The ghooting stone, A 8, from Mootree, 14 miles from Cuttack, contains 28 of clay, but on account of a proportion of 10 per cent. of oxide of iron I do not think it will ever make a good cement.

I have not as yet had time to analyse the small samples of limestone sent from the hills near Cuttack.

The clay marked B6 from the bed of the Mahanuddy contains only 2·66 per cent. of sand. This will be good for artificial cement manufacture.

The red ochre earth, B22, called in French *Terres Ocreuses*, contains—

52	clay
48	sand and pyrite of iron
100	

This burnt on a slow fire makes a kind of pouzolanna, which, added to fat lime or hydraulic lime, increases a great deal the hardness of the mortar and sets quickly in water.

The result of this has been shown in the abstract of experiments annexed, marked B.

I am expecting now to receive a certain quantity of this red ochre, which will enable me to make experiments on a larger scale, and to calculate at what cost it would be possible to manufacture this pouzolanna. If the carriage charges are not too heavy, the manufacture will certainly be of great utility to the hydraulic works in Orissa.

COSSYE DIVISION.

10. The ghooting A11 from the second reach of the canal is one mixed with clay.

The ghooting of which an analysis will be seen from Statement A., appended, will answer to make a good cement; as it is not too hard, it can be pulverized and formed into bricks and burnt Should further experience show that little more of clay is wanted, a certain quantity of the clay in which it is found could be added.

This clay contains in itself 15 per cent. of carbonate of lime.

DINAPORE DIVISION.

11. The samples of ghooting A15, containing 35·33 per cent. of clay, may perhaps be turned into a good cement by very careful burning, but I should prefer to use the ghooting A17, which contains 32 per cent. of clay.

As this ghooting looks rather homogeneous, it can be burnt in its natural state.

PAKOUR SUB-DIVISION.

12. The stone lime A19 contains—

22	per cent.	of sand.
59·20	„	„ clay.
19	„	„ carbonate of lime and traces of oxide of iron.

This stone is only a simple agglomeration of sand, clay, and pure carbonate of lime.

There is no combination whatever, and, therefore, it will be of no use at all.

13. I have now to make my—

General remarks on ghooting lime-stones.

The nodular lime-stone called ghooting or kunkur in India generally is by its chemical properties the combination of a hydraulic stone and a cement stone, rather a little too rich in clay, so that when the stones are not too hard to break, pulverizing and mixing them with sufficient water to form a rather hard paste, and then making small bricks or balls and burning them sufficiently, will enable the manufacture in some cases of Portland or slow-setting cement, and in other cases a kind of Roman cement or quick-setting cement. When the ghooting is burnt, as is generally done in Bengal, the part which is slaked when taken out from the kiln is the part containing the quantity of clay necessary to make good hydraulic lime; large portions of the parts which are not slaked are those containing more clay and are cement stones; but as generally they contain too large proportions of clay, it will not do to burn those portions again, but, on the contrary, it will be better to burn the whole until they cannot be slaked.

As the ghooting-stones are found generally all over Bengal, I consider it highly important to make a series of experiments on the whole of them. This I intend doing soon.

In treating about ghooting lime-stone, I may as well state that the great defect in hydraulic lime extracted from it and used throughout in Bengal lies from its not being sifted fine enough. Failures in buildings, are, I believe, ascribable in a great measure to the mortar prepared with this defective lime; for straining ghooting lime properly, however, I am of opinion that no sieves less fine than one of 20 meshes to an inch should be used.

14. In order, therefore, to give my conjecture a trial and my opinion stability as to the defect above noticed, I made a rough analysis of the ghooting lime used in the Drainage Department of the Calcutta Municipality, and found, as anticipated, the following result:

Lime	47·
Clay	6·
Sand	17·5
Ashes	4·
Carbonate of line, half burnt }	25·5
	100·

15. In conclusion, I beg to state that I purpose leaving by the end of this week for the Soane Circle, where I desire to explore the quarries of Margohi, in order to choose certain quantities and qualities of materials, which upon arrival here and after due preparation are to be burnt in the large kilns. I will at the same time proceed with a complete analysis of of the specimens which may be found important enough to require it.

A.

Rough analysis of the specimens which have been burnt for the purpose of making cement.

Numbers.	Materials from whence obtained.	Composition.	
B6	Marly clay from Margohi in the Soane Circle...	Carbonate of Lime ...	60 65
		„ of Magnesia ...	14 35
		Oxide of Iron ...	0·67
		Clay ... Silica ... / Alumina ...	23 33
		Sand	1·00
			100·00
B7	Marly clay from Margohi in the Soane Circle	Carbonate of Lime ...	80 00
		„ of Magnesia ...	Traces, but not appreciable.
		Oxide of Iron ...	Ditto.
		Clay ... Silica ... / Alumina ...	20·00
		Sand	00 00
			100 00
A1	Blue stone from Margohi in the Soane Circle	Carbonate of Lime ...	54·07
		„ of Magnesia ...	11·00
		Oxide of Iron ...	1·33
		Clay ... Silica ... / Alumina ...	32·00
		Sand	1·60
			100·00
A3	White lime-stone from Margohi in the Soane Circle	Carbonate of Lime ...	75·73
		„ of Magnesia ...	0·44
		Oxide of Iron ...	0·50
		Clay ... Silica ... / Alumina ...	23 33
		Sand	0 00
			100·00
A8	Ghooting-stone from Mootree, 14 miles from Cuttack (Orissa)	Carbonate of Lime ...	60·67
		„ of Magnesia ...	
		Oxide of Iron ...	10·00
		Clay ... Silica ... / Alumina ...	28·00
		Sand	1·33
			100 00

Numbers.	Materials from whence obtained.	Composition.	
A11	Ghooting from Canal, 2nd Reach (Midnapore)	Carbonate of Lime ...	67·00
		„ of Magnesia ...	4·34
		Oxide of Iron ...	0·66
		Clay ... Silica ... / Alumina ...	26·67
		Sand	1·33
			100·00
A17	Ghooting-stone from Dinapore ..	Carbonate of Lime ...	77·00
		„ of Magnesia ...	
		Oxide of Iron ...	1·00
		Clay ... Silica ... / Alumina ...	32·00
		Sand	Not appreciable.
			100·00
B22	Red ochre from Bydessur Hills, 13 miles from Cuttack	Clay ... Silica ... / Alumina ...	52·00
		Sand	
		Pyrite of Iron ...	48 00
			100·00

Remarks about the preparation of the samples for cement.

1*st*.—The samples marked Nos. 1, 2, 3, 4, 5, 6, 7, 8, 13, 14, and 15 have been pulverized and passed through a sieve of 60 meshes to one inch. The proportions of each have been carefully measured in volume, after being mixed in water; the water was then removed by decantation, and the mixture left until formed into the consistence of a rather hard paste. Of this paste, balls were made of about 2½ inches in diameter; these balls were exposed to the sun for seven days and burnt in the small kiln with *coke*. When taken out from the kiln, they were pulverized and strained through a sieve of 60 meshes to one inch.

The powder thus obtained was mixed with a little water and made into a rather stiff paste, of which while a portion was put into a tumbler and immersed in water, of the other a cake was made and left exposed to the air.

The cement in water eventually was tested with the Aiguille of Vicat.

2*nd*.—The samples marked Nos. 9, 11, and 12 were not pulverized, but I put only the stones (well washed previously) in the kiln, and after burning sifted them through the same sieve of 60 meshes.

P. DEJOUX.

Executive Engineer, Cement Experiments Division.

B.

Result of experiments on cements up to the 1st April 1872.

Nos.	Composition. Quantities.	Composition. From whence materials were obtained.	Hours taken in burning.	In what sort of fire.	Color of stone burnt.	When mixed and put in water. Date.	When mixed and put in water. Hour.	Time taken for the setting in water.	Quality of the cement under water.	Quality of the cake when exposed to the air.	Remarks.
1	1 part of Marly clay, B6. 1 ditto ditto, B7..	Margohi, Soane.	58	Slow fire.	Reddish grey.	Mar. 20	2-30 P. M.	4 days	Rather soft	Pretty hard	Requires evidently more burning (it retains after burning carbonic acid).
1'	Ditto ditto ...	Ditto ditto...	90	Ditto ...	Grey ...	Do. 26	8 A. M.	H. M. 1 15	Very hard...	Very hard ...	The hardness has been increasing very sensibly to the present date (it retains carbonic acid).
1''	Ditto ditto ...	Ditto ditto...	100	Ditto ...	White reddish.	Do. 28	3-45 P. M.	40 Ms.	Pretty hard	Hard ...	This will become perhaps after a certain time as good as No. 1' (it retains carbonic acid).
2	2 parts of Marly clay, B6. 1 part of ditto, B7.	Ditto ditto...	58	Ditto ...	Grey ...	Do. 18	3 P. M.	5 hours	Hard ...	Very hard ...	Hardness always increasing (it retains carbonic acid).
2'	Ditto ditto ...	Ditto ditto...	90	Ditto ...	Reddish grey.	Do. 23	1-45 P. M.	H. M. 4 30	Ditto ...	Hard ...	Will become as hard as No. 2, if not more (retains carbonic acid).
2''	2 parts of Marly clay, B6. 1 part of Marly clay, B7.	Margohi, Soane.	100	Slow fire	Grey, greenish.	Mar. 20	2-25 P. M.	4 hours	Pretty hard	Pretty hard	I tried two of the balls burnt at the same time, and found the cement of one after 5 days of immersion in water with slight cracks (it retains carbonic acid).
3	1 party of Marly clay, B6.	Ditto ditto...	58	Ditto...	Red ...	Do. 16	12 P. M.	6 days	Rather hard	Rather hard	Requires evidently more burning (it retains a great deal of carbonic acid).
3'	Ditto ditto ...	Ditto ditto...	58	Ditto ...	Grey, reddish	Do. 18	12 P. M.	14 hours	Hard ...	Very hard...	This is not quite so hard as No. 2 (retains some carbonic acid).
3''	Ditto ditto ...	Ditto ditto...	90	Ditto ...	Reddish	Do. 26	7-45 A. M.	H. M. 2 15	Rather hard	Rather hard	Contains carbonic acid.
3''' 1st ball.	Ditto ditto ...	Ditto ditto..	100	Ditto ...	Grey, greenish.	Do. 26	1-40 P. M.	Not set	Very bad ...	Bad ...	In water this remains in the state of a very soft paste (retains no carbonic acid).
3''' 2nd ball	Ditto ditto ...	Ditto ditto..	100	Ditto ...	Grey ...	Do. 28	2-30 P.M.	H. M. 18 30	Rather hard	Pretty hard	These two balls were inserted in one kiln and were found burnt exactly at the same time; the color was, however, a little different, and slight traces of carbonic acid remained.
4	1 part of Marly clay, B7.	Ditto ditto...	58	Ditto ...	Reddish blue.	Do. 20	1-30 P. M.	H. M. 1 30	Very hard ...	Very hard ...	Retains carbonic acid.
4'	Ditto ditto ...	Ditto ditto...	90	Ditto ...	White ...	Do. 23	12-37 P.M.	H. M. 4 30	Hard ...	Hard ...	The cake does not break well (retains little carbonic acid).

[6]

[7]

Nos.	Composition. Quantities.	Composition. From whence materials were obtained.	Hours taken in burning.	In what sort of fire.	Color of stone burnt.	When mixed and put in water. Date.	When mixed and put in water. Hour.	Time taken for the setting in water.	Quality of the cement under water.	Quality of the cake when exposed to the air.	Remarks.
5	1 part of lime-stone, A3. 1 part of Marly clay, B6.	Ditto ditto...	58	Ditto ...	Grey ...	Do. 18	3-25 P. M.	24 hours	Very hard ...	Very hard ...	The cake is harder sensibly than No. 1' and No. 4 (it retains carbonic acid).
5'	Ditto ditto ...	Ditto ditto ..	90	Ditto ...	Grey ...	Do. 25	1-35 P. M.	H. M. 4 30	Hard ...	Bad ...	The cake was getting pretty hard up to the 8th day, after which cracks appeared, and on the 9th day it turned very soft and began to fall in powder (it retains little carbonic acid.)
5"	Ditto ditto ...	Ditto ditto...	100	Ditto ...	Grey ...	Do. 28	3-35 P. M.	19 hours	Rather hard	Bad ...	After 5 days cracks appeared in the cake, after which it fell in powder (retains no carbonic acid).
6	1 part of Marly clay, B6 2 parts of ditto, B7	Ditto ditto...	58	Ditto ...	Grey ...	Do. 20	1 P. M.	H. M. 1 30	Rather hard	Very hard ...	The cake gets harder by degrees, and at length obtains a very good hardness (retains carbonic acid).
6'	Ditto ditto ...	Ditto ditto...	90	Ditto ...	White ...	Do. 26	7-55 A. M.	H. M. 1 40	Very hard ...	Hard ...	After 6 days more this one will be, I think, better than No. 6 (retains little carbonic acid).

[8]

7	1 part of red ochre, B22. 1 part of Sylhet lime, slaked.	Orissa ...	12	Slow fire	Red ...	Mar. 22	12 P. M.	9 hours	Hard ...	Hard ...	In this sample, which is the combination of a kind of pouzolanna and fat lime, the ochre was burnt alone and mixed afterwards with slaked Sylhet lime; this was obtained from the bazar and appears to have been rather old. If fresh lime, however, was used, the result would have been better.
7	Ditto ditto ...	Ditto ...	36	Ditto ...	Red ...	Do. 22	12-30	11 hours	Very hard ...	Very hard ...	This has taken more time than No. 7 to set in water; but after 10 days 7' is very sensibly harder than No. 7.
8	2 parts of red ochre, B22. 3 ditto of Sylhet lime, slaked.	Ditto ...	12	Ditto ...	Red ...	Do. 22	1 P. M.	29 hours	Pretty hard	Pretty hard	*Nil.*
8'	D. ...	Ditto ...	36	Ditto ...	Red ...	Do. 22	1-30 P. M.	24 hours	Hard ...	Hard ...	This sample is sensibly better than No. 8, but not exactly quite so hard as No. 7.
9	1 part of lime-stone, A3.	Margohi, Soane.	58	Ditto ...	White ...	Do. 20	2-30 P. M.	4 days...	Indifferent...	Indifferent...	Retains carbonic acid.
9'	Ditto ditto ...	Ditto ditto...	100	Ditto ...	White ...	Do. 28	3-55 A. M.	16 hours	Rather soft	Hard ...	Retains little carbonic acid.
11	1 part lime-stone, A1	Ditto ditto...	58	Ditto ...	White yellowish.	Do. 20	2 A. M.	24 hours	Pretty hard	Pretty hard	Retains carbonic acid.
11'	Ditto ditto ...	Ditto ditto...	90	Ditto ...	Ditto ...	Do. 20	3 A. M.	4 days	Rather soft...	Soft ...	A small portion of this sample has been slaked in hot water (retains little carbonic acid).

[9]

Nos.	Composition.		Hours taken in burning.	In what sort of fire.	Colour of stone burnt	When mixed and put in water.		Time taken for the setting in water.	Quality of the cement under water.	Quality of the cake when exposed to the air.	Remarks.
	Quantities.	From whence materials were obtained.				Date.	Hour.				
11"	1 part lime-stone, A1.	Margohi, Soane.	100	Slow fire	White ...	Mar. 28	8-45 A. M.	Not set	Bad ...	Very bad ...	After three days cracks appeared in the cake, and the day after it fell in powder. A small portion also could be slaked in hot water.
12	1 part of ghooting stone, A7.	Dinapore ...	100	Ditto ...	Greenish grey.	Do. 26	1-25 P. M.	35 Ms.	Very hard ...	Pretty hard ..	The cake has been getting harder very slowly, nevertheless its hardness kept on increasing sensibly.
13	1 part of ghooting stone, A8.	Orissa ...	58	Ditto ...	Red ...	Do. 17	3-30 P. M	Not set	Very bad ...	Very bad ...	*Nil.*
13'	Ditto ditto ...	Ditto ditto ..	100	Ditto ...	Grey brown	Do. 26	3 P. M.	48 hours	Rather hard	Rather hard	Is setting slowly, but I fear it contains too much of oxyde of iron to become a good cement.
14	1 part of ghooting, A11.	Midnapore Division.	58	Ditto ...	Grey reddish.	Do. 17	3 P. M.	10 days	Rather soft	Hard ...	It retains a great portion of carbonic acid.
14'	Ditto ditto ...	Ditto ...	90	Ditto ...	Reddish ...	Do. 23	2 P. M	Not set	Bad ...	Bad ...	*Nil.*
14"	1 part of ghooting, A11.	Midnapore Division.	90	Slow fire	Grey ...	Mar. 23	2-10 P. M.	31 hours	Hard ...	Hard ...	This will make a good cement, but more experiments are necessary as regards the burning (retains carbonic acid).
14'''	Ditto ditto ...	Ditto ditto ...	100	Ditto ...	Reddish ...	Do. 26	...	Rather soft.	Rather soft	Hard ...	This is a little better than No. 14, and it is getting sensibly harder (retains little carbonic acid).
15	3 parts of ghooting, A11. 1 part of clay with which the ghooting is mixed in its natural state.	Ditto ditto ...	100	Ditto ...	Ditto ...	Do. 29	9-25 A. M.	23 hours	Ditto ...	Rather soft ...	This mixture requiries more burning, and will make, I believe, a slow setting cement of good quality, but I purpose putting 4 parts of ghooting-stone and 1 part of clay, instead of 3 and 1. It must be considered then that clay in itself contains about 15 per cent. of carbonate of lime.

[10]

[11]

CALCUTTA;
The 5th April 1872.

P. DEJOUX,
Executive Engineer, Cement Experiments Division.

Abstract of disbursements made in the Office of the Executive Engineer, Cement Experiments Division, under the authority of Government of India's letter No. 621, dated 15th January 1872, and Bengal Government Estimate No. 112 of 1871-72.

Description of Work, &c.	Amount sanctioned.		Amount disbursed from 1st December 1871 to 31st March 1872.	Balance on 1st April 1872.	Remarks.
	Rs. A. P.		Rs. A. P.	Rs. A. P.	
Kilns	2,305	1,040 0 0	2,024 0 0	281 0 0	* Paid to Messrs. [illegible] Engineering Firm, Calcutta, for Contract Work.
Reservoir		184 0 0			
Shed for coolies ...		722 0 0			
Shed for engine and soorkey mill ...		359 0 0			
Tools		300 0 0	169 6 0	130 10 0	
Chemical balance ...	720	320 0 0			
Chemicals, &c. ...		200 0 0	119 12 0	600 4 0	
Chemical apparatus ...		200 0 0			
Coals for kiln and engine	1,632	450 0 0	22 12 0	427 4 0	
Coke for ditto ...		1,050 0 0	25 0 0	1,025 0 0	
Firewood for ditto ...		132 0 0	2 0 0	130 0 0	
Coolies for 1 year ...		840 0 0	65 4 0	774 12 0	
Office rent for 1 year ...		1,200 0 0	300 0 0	900 0 0	
Office and work contingencies for 1 year ...		600 0 0	358 13 3	241 2 9	
Carriage of materials for 1 year		600 0 0	5 14 0	594 2 0	
TOTAL ...		8,197 0 0	3,092 13 3	5,104 2 9	

The 5th April 1872.

P. DEJOUX,
Executive Engineer,
Cement Experiments Division.

No. 89, dated the 1st June 1872.

From—P. DEJOUX, ESQ., Executive Engineer, Cement Experiments Division.

To—The Superintending Engineer, South-Western Circle.

I HAVE the honor to submit herewith a paper treating on the manufacture of lime, mortar, and concrete.

No. 1.

Paper treating on the manufacture of lime, mortar, and concrete.

Manufacture of ghooting lime.—Lime as a rule ought to be sifted fine enough to be free of all unburnt or overburnt particles which do not slake immediately but which may slake after a certain time and consequently may injure the quality of the mortar.

As ghooting lime, from want of homogeneity, can never be well burnt, a fine sifting of the lime after slaking will largely increase the cost of the lime.

In grinding the lime and the unburnt portion, which ought to pass through a sieve of 8 meshes to one inch, some of the parts not slaked may act as cement, while others will remain inert.

It may happen that in the case of the presence of *chaux limites** (argillaceous intermediate limes), some other parts slaked a long time after and falling in powder may disintegrate some portions of the mortar.

It is, however, very difficult to ascertain the presence of the *chaux limites*, but as far as I can judge, I do not think there is much probability of finding them amongst the generality of ghooting.

My opinion, however, is that the best and cheapest way to deal with the manufacture of ghooting lime-stone consists in the following plan:

1*st*.—To burn the ghooting lime-stone in a kiln as per sketch marked A. Before burning, the kiln must be, if necessary, carefully plastered, both outside and inside, with a mortar composed of four parts of clay and one of lime. First a layer of 6 inches of coal is to be put, then 9 inches of ghooting, then 3 inches of coal, and then 9 inches of ghooting, &c., &c.; the last layer must be of ghooting proceeding from the last burning, and which not being perfectly burnt is generally called "refuse ghooting."

With some lime-stones 2 inches of coal will suffice. I have noticed that, owing to kilns being built generally in a careless manner, the loss of caloric must be enormous in them. The firing of the kilns may be begun when three layers of stone have been put in it. A portion of the opening (*a* and *b*) may be shut, leaving sufficient room for ventilation according to the state of the weather. It will be advisable, as a preventive against the effect of the stormy winds when the fire is likely to reach the uppermost layer, to have screens of corrugated iron put on the top of the kiln in the direction of the prevailing wind. Lime is frequently very badly burnt solely from want of this precaution. When the discharging of the kiln is commenced, the iron bars are to be taken out, and then ⅓rd of the total height of the stone inside may be drawn and the kiln re-charged. It will be advisable, when the kiln is in full blaze, to re-fit the bars every eight days, and by such means to remove the ash from the ash holes and quicken the fire.

2*nd*.—As soon as the lime is burnt, it is to be taken out of the kiln *immediately*, and the stone separated from the ashes. The lime-stone is then set against a wall in layers of about 4 inches. On each layer water is to be thrown by means of garden watering pots. A heap of about 5 or 6 feet high may be made, and the ghooting may be left in this state for about four days; the top of the heap should be watered a little on the second day. After the expiration of four days, it must be sifted through a sieve of 8 meshes to one inch.

It will be judicious always to put the burnt stone in large and high heaps, because by this being done the heat will be concentrated and the slaking facilitated. As regards the sifting, I think for large works it will be better to use a revolving sifting machine as used in France. I am making a drawing of one, and will submit it, when completed, for approval.

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* An explanation of this term will be found in Vicat on limes and cements. *Chaux limites* are limes obtained from stones containing too large a proportion of clay to be hydraulic lime-stones and too small a proportion to be cement stones.

3rd.—The lime may then be pulverized in a soorkey-mill separately, or mixed with the requisite quantity of sand for mortar.

Sand mortar.—I would advise the use always of sand, instead of soorkey, when sharp clean sand of middling size is obtainable.

Soorkey ought to be used only when sand cannot be obtained, and for this reason:

If the lime is very hydraulic, the soorkey, which is very often made from bricks imperfectly burnt, acts only as an inert body; in such a case sand, which is harder, has evidently the advantage over soorkey; sand has also the great advantage that it is generally much cheaper.

If the lime is not hydraulic enough, and if no other kind of pozzolana can be obtained soorkey made with first rate burnt bricks and reduced to impalpable powder will increase the hydraulicity of the lime; but as it has been said before, the soorkey generally used is prepared with bricks imperfectly burnt on account of such bricks being more brittle, and the powder is always too coarse to act efficiently as a pozzolana.

Mortar made with soorkey seems after a short time harder than sand mortar, but after a longer time sand mortar, if well made, will be found superior. One of the greatest precautions to be taken with sand mortar is to have the bricks or stones thoroughly soaked in water; the default of using this precaution is the great cause of the apparent inferiority of the sand mortar as compared with the soorkey mortar, because the soorkey retains much more moisture than the sand.

Comparatively *less* water ought to be used in the manufacture of sand mortar than that of soorkey mortar, as it (the mortar) must be made to the consistency of a plastic paste.

Care must be taken in the sand mortar, especially to prevent too rapid drying, because hydraulic lime being an anhydrous silicate of lime (with an excess of lime) which gets hard by the hydratation of the lime, it is evident that a certain degree of moisture is necessary. Water must, however, not be thrown on the mortar before it has commenced to set sensibly, for the water might wash out the lime.

During the time necessary for the setting, the masonry ought to be covered either with wet mats, wet straw, or wet sand.

In the case of ghooting lime, it is only after the fourth day on which the mortar has been used that watering can be commenced.

In the case of fat lime, the hardness of the lime is caused by the crystallization of the calcareous carbonate recomposed; if the setting is allowed to take place too soon, an incomplete crystallization will be attained, together with some carbonate in a pulverulent state.

In a hot climate like that in India, in the case of hydraulic mortars which take a long time to arrive at the maximum of hardness, it is absolutely necessary to proceed with the watering until the mortar is pretty hard, both outside and inside.

Pozzolana.—There is a kind of Puzzolana which is, I think, very commonly found in India in places where laterite exists; it is made of red ochre earth. The ochre I received from Orissa has, as I have already stated in my report No. 72, dated 5th April last, yielded a good result, and I have since found ochre of about the same description at Midnapore, which promises the same results.

By using this pozzolana with mortar in the following proportions—

3 Sand,
2 Lime,
1 Pozzolana,

or

1 Sand,
1 Lime,
1 Pozzolana,

the quickness of setting of the mortar will be augmented to a great extent; the cost of such a pozzolana on the spot, as far as I can judge now, will be from 4 annas to 6 annas per cubic foot.

Concrete.—In the concrete I would advise also the use of sand, instead of soorkey.

To ascertain the quantity of mortar necessary for the making of a good concrete, it is necessary to take a water-tight box measuring 1 cubic foot and fill it first with khoa or broken brick-stone, or pebbles (which are to be used in the concrete) and then with water. The quantity of water is then to be measured, and this will be found equal to the quantity of mortar necessary to fill interstices.

As regards broken bricks or stone in small pieces, the quantity of mortar required for 100 cubic feet of broken bricks varies from 46 to 50 cubic feet of mortar.

In the case of pebbles and small round stones, 100 cubic feet of stones will require from 37 to 40 cubic feet of mortar.

For mixing khoa or stones with mortar, I strongly advise the use of a "Betonniere", of the kind I have seen used in France, of which I annex a drawing (marked B). I gave last year to the Executive Engineer, Cossye Division, a sketch of such a "Betonniere." Some were made accordingly by him, and have been used with great success in his works.

The mode of using such an apparatus consists only in throwing the materials inside by the opening (*a*) and in taking care to throw alternately two baskets of khoa and one of mortar if the proportions of the concrete are 2 to 1, and thus the whole comes out from the machine by the opening (*b*) perfectly mixed.

With a "Betonniere" 1,000 cubic feet of concrete can be manufactured easily per day.

The cost of one will be about Rs. 150.

P. DEJOUX,
Exe. Engr., Cement Experiments Division

The 1st June 1872.

No. 104, dated the 16th July 1872.

From—P. DEJOUX, ESQ., Executive Engineer, Cement Experiments Division.

To—The Superintending Engineer, South-Western Circle.

I HAVE the honor to submit a further report of my experiments on cement, limes, and mortars from the 1st April to the 30th June 1872.

2. During the month of April I left Calcutta to proceed to the Soane Circle to inspect the lime-stone quarries of Margohi, and, in order to choose certain qualities and quantities of materials, to carry on experiments on a more extensive.

On arriving at Dehree I determined, on the suggestion of Mr. Levinge, the Superintending Engineer of the Soane Circle, to explore not only the quarries of Margohi, but also those of Bucknour, near Rohtas.

Margohi Quarries.

3. These quarries are only 10 miles distant from the head works at Dehree, and about 5 from the tramway at Dhodand, which communicates with the head works.

The quarries are at the foot of the hills, and can be worked very easily.

On the surface there is to be found a sandy clay to a depth of 12 to 15 feet, after which a kind of shelly useless clay.

This shelly clay is found in great abundance with the yellow clay B77, the latter containing 88 per cent. of clay or sand and 12 per cent. of carbonate of lime, and under it the yellow marly clay B6, which is also plentiful, but which can very easily be distinguished from the shelly clay.

The fourth strata consisted of blue stones A and A2, mixed with the white marly clay B7, and the fifth of white stone A3.

The clay B7 is not to be found in very large quantities, but for the manufacture of cement we could use equally well the white stone A3, which possesses very nearly the same chemical composition, and may be pulverized almost as easily as the white clay.

The rates are as follow:

Extracting raw materials	...	1 rupee per 100 cubic feet.
Breaking ditto	...	4 annas ditto ditto.
Carriage from Margohi to Dehree ...	...	5 rupees ditto ditto.
Coolie labor, per coolie ...	...	from 2 annas to 2 annas 6 pie.
Fire-wood per 100 maunds ...	...	12 rupees 8 annas.
Coal per maund	...	9 annas.

Bucknour Quarries.

4. These quarries are 5 miles distant from Rohtas, 24 from Dehree, and 1 from the River Soane. They are also at the foot of the hills, and the extraction is very easy. I found here a larger variety of stones and clays than at Margohi.

The more hydraulic stones are those which are found on the surface of the earth. In excavating from 6 inches to 1 foot, you arrive to some beds of nearly pure fat lime, but in going in deeper many varieties of marly clay are found, similar to those got at Margohi.

I was enabled within a very small space of ground to collect as many as eight different kinds of stones and four of marly clay, varying from the fat lime to stone or clay containing even too much clay for being cement stones, which, however, could be used as pozzolana.

Analysis subsequently proved to me that the specimen marked A48 will produce a slow-setting cement, and its homogeneity will afford the advantage of burning it in its natural state.

These quarries have heretofore been worked only by natives who manufactured fat lime and sent it to Patna. Some years ago they manufactured as much as 1,25,000 maunds in one year for the railway; but now the annual manufacture varies from 20 to 25,000 maunds only.

When the Soane Canal is opened, there will be every facility for the transport of cement manufactured at these quarries, owing to their vicinity to the river.

The rates at Bucknour are as follow:

Extracting raw materials	...	1 rupee per 100 cubic feet.
Breaking ditto	...	4 annas ditto ditto.
Carriage from Bucknour to Dehree	...	7 to 8 rupees per 100 maunds.
Ditto ditto to Patna	...	18 rupees ditto ditto.
Coolie labor, per coolie	...	from 1 anna 6 pie to 2 annas.
Fire-wood (rather scarce) per 100 maunds	...	7 rupees.
Coal per maund	...	8 annas 6 pie.

5. I think a patient and deliberate exploration of the range of hills from Margohi to Rohtas will lead to the discovery of several varieties of useful stones. I intend to carry out a careful research personally if the Government sanctions the construction of a small cement factory at Dehree.

6. As I had, before proceeding to Dehree, tested the materials from Margohi, I got a certain quantity of them collected on the spot, which were to be sent to me by the Executive Engineer of the Dehree Division.

I could not do the same, however, with the materials from Rohtas, as I had to return to Calcutta to make a complete analysis and some preliminary experiments with some specimens I brought away.

7. During the month of May I proceeded, according to your orders, to inspect the limes and mortars of the Cossye Division. The result of my tour has already been reported to you in my letter No. 88, dated the 1st June 1872.

8. I have since the 1st April received now specimens of lime-stones and clays, and the following statement affords details of such receipts up to 20th June 1872:

Dates of Receipt.	Whence received.	Numbers of Specimens of	
		Limestones.	Clays.
3rd April 1872 ...	Darjeeling Division	2	1
10th " " ...	Midnapore "	8	17
16th " " ...	Burrakur "	3	1
16th " " ...	Grand Trunk Road, 1st Division ...	3	...
19th " " ...	Nuddea Local Rivers "	1	1
19th " " ...	Nuddea Division	...	4
29th " " ...	Ramgurh "	2	2
30th " " ...	Hidgellee "	5	...
6th May " ...	Dacca "	...	3
14th " " ...	1st Presidency "	4	7
16th " " ...	Dehree "	8	2
13th June " ...	Sylhet "	2	2
26th " " ...	Lower Assam "	2	2

9. Having analyzed and tried experiments on most of the important specimens received, the result of which will be seen from Statement A. annexed, I have arrived at the following conclusions:

Darjeeling Division.

10. The lime-stone from Satti, 38 miles north of Darjeeling, marked A20, has been found from analysis to be a very nearly pure carbonate of lime, and to yield a good fat lime.

The limestone A21 from Chooni, 36 miles north of Darjeeling, produces also a fat lime, which is very nearly as good as A20.

The clay from Darjeeling is too sandy for use in the manufacture of cement.

Should, however, hydraulic lime be manufactured at Darjeeling, this clay may be used, but after being washed carefully so as to render it entirely free of sand and particles of gneiss which are found in rather large proportions in it.

Midnapore Division.

11. Relative to this Division I beg to refer you to my report No. 89 of the 1st June 1872 on limes, mortar, and concrete.

I tried the ghooting stones of this Division, in order to see if any would be useful for making cement, but the only specimen which seemed to succeed is the ghooting A11 sent by the Executive Engineer of the Cossye Division. The 10th paragraph of my report No. 72, dated the 5th April last, however, contains the details of my experiment with this specimen, but I now submit a statement (B) showing how that cement stands after three months and ten days.

Burrakur Division.

12. The ghooting stone A30 from Kapasarah, on the west bank of the Burrakur River, produces a petty fair hydraulic lime, although there is rather a large proportion of sand mixed with it. I tried to make cement with it, but without success, owing to the sand being excessive.

The ghooting A31 from Bhikundee is only feebly hydraulic.

Grand Trunk Road, 1st Division.

13. I analyzed only the ghooting A35 from Cutwa, and the analysis shows that it must possess good hydraulic properties.

Nuddea Division.

14. I received from this Division only samples of common clay, but no lime-stones.

Ramghur Division.

15. The lime-stone A37 of Chunic Bugrail, five miles south-west of Hazareebaugh, is a kind of magnesian lime-stone, containing only feeble traces of clay and sand, and producing a *meagre* lime of inferior quality. I believe that if the clay B65, which is found in these quarries, was pulverized, made into balls and burnt as an artificial hydraulic lime, it would produce a lime possessing hydraulic properties.

The kunker A38 from Pubrah is a very hydraulic lime-stone.

I tried also the red ochre from Pubrah, but it contains too much sand to make a good kind of pozzolana.

Hidgellee Division.

16. All the specimens of ghooting received from this Division are very fair hydraulic lime-stones, but they do not contain sufficient proportions of clay for the manufacture of cements, as they ought to be burnt in their natural state, being much too hard to be easily pulverized.

The most hydraulic of these specimens is A42 from Gowakhally; the lime sets in water, enough to support the weight of the Aguille of Vicat after 60 hours. Besides it is good for mortar; one part of it and two of sand turns into a very fine hardness in a short time.

Dacca Division.

17. As the Executive Engineer reports that no lime-stones are obtainable within the limits of the Dacca Division, I did not analyse any of the specimen of clay sent to me, of which none by appearance can be used even as pozzolana.

1st Presidency Division.

18. The ghooting A44, sent from the Girhidee Road Division, contains the proportion of clays (which is necessary in all descriptions of ghooting lime-stones generally) for

making a good hydraulic lime; but the proportion of sand in it being 15 per cent., the lime obtained from such a material must make a mortar of inferior quality. When used, it will always be necessary to increase the proportion of lime in the mortar; that is to say, if generally two parts of sand and one of lime are used with ordinary ghooting lime with the lime A44, at least three parts of sand and two of lime must be used, and it will be even safer to use in that case equal parts of sand and lime.

The ghooting A45, procured also from the Girhidee Road Division, contains a less proportion of clay than A44, and will yield an ordinary hydraulic lime.

The kunkur A46, from the Girhidee Road Division, also ought to be always rejected, the analysis showing a proportion of 33 per cent. of sand in it.

I have had no time to analyse the specimen A47.

All the samples of ghooting-stones from the Girhidee Road Division were sent to me without any number of particular description of the places in which they were found.

Dehree Division.

19. My inspection of the quarries of Margohi and Bucknour, and the series of experiments I have already made on the specimens from those quarries, confirm me in the opinion that this is, for the present, the best place for manufacturing both slow and quick-setting cements.

Sylhet Division.

20. The two kinds of lime-stones received from this Division may be considered as nearly pure carbonate of lime, but by analysis the one marked A. by the Executive Engineer, Sylhet Division, and A56 of my analysis number, is a little superior to the other B. or A57, the proportion of sand being smaller in A56 than in A57.

These limes might evidently be used for the manufacture of artificial cement made of slaked lime and clay.

The two specimens of clay B79 and B80 received from Sylhet could be used, but I should prefer the clay B80 taken from a brick-field on the Sylhet and Cachar Road close to the River Gograh, marked D. in the Executive Engineer's forwarding letter.

I received all the specimens from Sylhet so late that I had no time to make sufficient experiments with them. I, however, made a mixture of five parts of lime slaked A56 and A57 and three of blue clay B79 and B80, and it is now burning.

The lime I used was burnt in my small experimental kiln, and when passed through a sieve of 20 meshes to one inch, the refuse was not more than 2 or 3 per cent. on the total quantity of lime slaked.

Lower Assam Division.

21. The specimens having been received only on the 26th of June, I could not do anything with them.

General Remarks on Ghooting Lime, Sand, Mortar, &c., &c.

22. I beg to refer you to my report No. 89 of the 1st June 1872, bearing on the subject.

General Remarks about Cements.

23. I was obliged to continue experiments in my small experimental kiln with different mixtures, owing to the materials I expected from the Soane Circle not having arrived before the 19th of June, and hence I was unable to make experiments on the Margohi cement on a larger scale.

The statement C., appended, shows the result of the new experiments made by me, while statement B. shows how the samples mentioned in statement B. of my report No. 89 of the 1st June 1872 have been standing since.

On the 19th of June, upon receipt from the Dehree Division of 160 cubic feet of the following materials, *viz.*, yellow marly clay B6, white marly clay B7, white stone A3, and yellow clay B77, I commenced immediately the manufacture of cements, but instead of hiring monthly, or bying a soorkey mill and an engine for pulverizing the materials, I found it more convenient, and comparatively less expensive, to hire one of Messrs. Burn and Company's soorkey mills at Bow Bazaar at Rs. 18* per day whenever I require it. Accordingly my materials were sent, and they were very easily reduced into fine powder, and afterwards I had the following mixtures of raw materials made:

* Including cost of coal, tindal, &c.

1st ... { 2 parts of B6 / 1 part of B7 } In which the average of clay was 22 per cent.

2nd ... { 3 parts of B6 / 1 part of B7 } Average of clay 23 per cent.

3rd ... { 2 parts of B6 / 1 part of B7 / ½ „ of B77 } Average of clay 32¾ per cent.

These I put into vats of the reservoir, which I filled with water, and agitated the whole until the appearance of a perfect homogeneity. The water was afterwards allowed to flow off gently, and the deposit is now drying, and I hope, weather permitting, to see it arrive in a few days to a consistence sufficient to enable me to form cakes, &c.

24. From all the experiments on a small scale I have hitherto made on the ghooting stones or kunkur, I feel convinced that it will be possible to make good cement with some of them.

I had intended to send for a certain quantity of ghooting stones, A11 and A15, from Midnapore and Dinapore, respectively, to carry on experiments on a more extensive scale, but considered it better to wait a certain time to see if no injurious action would take place in the samples already manufactured. This doubt has since been overcome by the steady increase of the hardness of some of the materials, and I am, therefore, about to apply to the Executive Engineers of the above two Divisions to send me certain quantities of the materials as early as possible.

25. The most convenient places for manufacturing cement with ghooting stones, on account of the proximity of Calcutta and of the Railway, and also for the cheapness of the raw materials and coal, would be Burrakur and Raneegunge; but the samples from Burrakur proved to me that the ghooting stone is unsuitable for cement purposes, and I expect now some specimens from different places between Assensole and Raneegunge which may be useful.

26. Doubtless artificial cement of the kind of Portland cement could be manufactured with the limes and clays from Sylhet; but we have to consider if it would not be better, instead of manufacturing the cement in Sylhet, to have the lime (carefully burnt and slaked) exported from Sylhet to Calcutta, and to mix it with some of the blue clays so common in Calcutta and so cheaply obtained.

As I have just received 30 cubic feet of fresh burnt lime from Sylhet, I am about compounding a mixture of five portions of that lime and three of blue clay from Calcutta to burn in my cement kiln.

Margohi Cement.

27. The composition which seems to me at present the best and the most easy to burn for the making of a slow-setting cement is—

2 parts of B6.
1 part of B7.
½ „ of B77.

It can be burnt near vitrification, and sets in ten hours.

For another quick-setting cement, I consider the following composition the best:

3 parts of B6.
1 part of B7.

The cement produced from this sets in 35 minutes, and is very easy to use, as it does not set too quickly. It requires a slow heat, and consequently, not much fuel; it must be burnt only near to complete calcination and consequently ought always to retain a small quantity of carbonic acid. When too much burnt, if immediately used, it produces a very bad result as shown in sample A. of statement C.; but if instead of using it immediately it is left exposed for about one month to the air, some carbonic acid returns, and it turns out as good as if not too much burnt; it takes only a little more time in setting. This result is shown by sample 17B.

On account of this peculiarity it will only be necessary, after having taken out of the kiln the cement, which may often contain some portions too much burnt (which are very easily detected with a little practice), to grind them and to leave them exposed in open sheds for a certain time before using them.

The same peculiarity exists also in all the cements obtained from the different mixtures of the marly clays B6 and B7.

Another example of it is shown in statement C. by the experiments of 2ivA. and 2ivB.

28. As regards the quality of cement No. 17, I tried the tractile strength of a certain quantity burnt for 100 hours comparatively with the strength of English Portland cement; the *procès verbal* annexed (D.) shows the result of the experiments.

I made also balls of mortars composed of—

No. 1 ... { 2 parts of sand, / 1 part of cement No. 17; and

No. 2 ... { 2 parts of sand, / 1 part of Portland cement.

No. 1 put under water, two hours after being made, was not affected by the water, and since its hardness has been increasing very sensibly.

No. 2 put under water similarly fell into pieces.

29. I will have in a few days a machine for testing cement (Grant's system); and as Colonel Hyde has kindly consented to my using a small testing hydraulic press at the Mint, I will be able to ascertain exactly, by traction and crushing power, the strength of the cements I am about to burn in my large kilns.

30. I think it would be advisable, as soon as the rains are over, to commence the building of a factory, on a small scale, at Dehree, and to have the raw materials brought from Margohi and Bucknour.

31. As far as I can judge at present, the probable cost (including burning by coal) of manufacturing a cement equal to No. 17 at Dehree would be as follows:

		Rs.	A.	P.	
Extracting materials	... ...	1	0	0	per 100 c. ft.
Breaking ditto	... ...	0	4	0	" "
Carriage of ditto from Margohi to Dehree	...	5	0	0	" "
Grinding raw materials	... ...	10	0	0	" "
Mixing and washing materials, as also making cakes or balls	... ...	3	0	0	
Loading and unloading kiln	... ...	2	8	0	
Grinding burnt cement	... ...	15	0	0	
Wear and tear of bags per trip at 6 pie per bag		3	2	0	
		39	14	0	
20 maunds of coal at 9 annas per maund	...	11	4	0	
		51	2	0	
Contingencies about 20 per cent.	...	10	0	0	
Total	...	61	2	0	

32. I think that in using a flame-kiln of the kind described by Vicat for the burning of artificial hydraulic lime, we could burn the cement with fire-wood.

In such a case the cost will be as follows:

	Rs.	A.	P.
Extracting, carriage, grinding, &c., as above shown ...	39	14	0
33 maunds of fire-wood, at Rs. 12-8 per 100 maunds ...	4	2	0
Contingencies, say	10	0	0
	54	0	0

33. As I have, in calculating the probable cost, used the higher rates which may hereafter be considerably reduced when the works will have assumed a certain importance, I may say that in case of coal being burnt, the cost of the cement will not exceed Rs. 61-2 per 100 cubic feet, or 9 annas 10 pie per cubic foot, or in round numbers 10 annas; but if fire-wood be used, the cost will not exceed Rs. 54 per 100 cubic feet, or 8 annas 6 pie per cubic foot.

A.

Statement shewing the result of the analysis of the most important specimens received by the Executive Engineer, Cement Experiments Division.

Number.	Materials from whence obtained.	Composition.		Remarks.
A2	Blue stone ? from Margohi (Soane Circle) ...	Carbonate of Lime ...	81·34	Hydraulic lime-stone containing lime limites in notable proportion.
		Clay { Silica ... / Alumina ...	16·00	
		Sand ..	0·66	
		Oxide of Iron ...	2·00	
		Total ...	100·00	
A15	Ghooting stone from the banks of the Rivers Ganges and Gograh from Chuprah westward of Ranegunge (Dinapore Division) ...	Carbonate of Lime ...	64·67	Very hydraulic.
		„ Magnesia		
		Clay { Silica ... / Alumina ...	33·33	
		Sand ...	2·00	
		Total ...	100·00	
A19	Stone found from the Mohawagaree Hills, Sonthal District (Pakour Sub-Division) ...	Carbonate of Lime ...	44·50	Very bad.
		„ Magnesia	Traces.	
		Oxide of Iron ...	1·50	
		Clay { Silica ... / Alumina ...	33·00	
		Sand ..	21·00	
		Total ...	100·00	
A20	Lime-stone from Latte, 38 miles north of Darjeeling	Carbonate of Lime ...	98·00	Fat lime-stone.
		„ Magnesia	Traces.	
		Oxide of Iron ...	Very feeble traces.	
		Clay { Silica ... / Alumina ...	2·00	
		Sand ...	None.	
		Total ...	100·00	
A21	Lime-stone from Chooni, 36 miles north of Darjeeling..	Carbonate of Lime ...	92·60	Ditto ditto.
		„ Magnesia	5·60	
		Oxide of Iron ...	1·10	
		Clay { Silica ... / Alumina ...	0·70	
		Sand ...	None	
		Total ...	100·00	

Number.	Materials from whence obtained.	Composition.		Remarks.
A22	Yellow ghooting-stone found at Debrah near Midnapore (Cossye Division) ...	Carbonate of Lime..	74·67	Feebly hydraulic lime-stone.
		Clay { Silica ... / Alumina ...	16·66	
		Sand and Quartz ...	8·67	
		Total ...	100·00	
A22i	Grey ghooting-stone found at Debrah near Midnapore (Cossye Division) ...	Carbonate of Lime..	70·00	Ordinary hydraulic lime-stone.
		Clay { Silica ... / Alumina ...	26·00	
		Sand ...	4·00	
		Total ...	100·00	
A22ii	Ghooting-stone found at Booramoollah near Midnapore (Cossye Division) ...	Carbonate of Lime..	75·00	Ditto ditto.
		Clay { Silica ... / Alumina ...	19·50	
		Sand ...	5·50	
		Total ...	100·00	
A22iii	Ghooting-stone found at the Midnapore Anicut (Cossye Division) ...	Carbonate of Lime..	77·00	Ditto ditto.
		Clay { Silica ... / Alumina ...	20·00	
		Sand ...	3·00	
		Total ...	100·00	
A30	Ghooting lime-stone from Kapasarah, west bank of the Burrakur River, at a distance of 2 or 3 miles from the nearest Railway Station ...	Carbonate of Lime.. / „ Magnesia	70·50	Ditto ditto.
		Oxide of Iron ...	22··0	
		Clay ...	7·50	
		Sand ...		
		Total ...	100·00	
A31	Ghooting lime-stone from Bhikundee (Burrakur Division), 40 miles from the nearest Railway Station ...	Carbonate of Lime.. / „ Magnesia	80·50	Feebly hydraulic lime-stone.
		Oxide of Iron ...	2·00	
		Clay ...	10·50	
		Sand ...	7·00	
		Total ...	100·00	
A37	Lime-stone found at Choonia Bugril, 5 miles south-west of Hazareebaugh (Ramghur Division) ...	Carbonate of Lime.. / „ Magnesia	72·00 / 28·00	Magnesian lime-stone producing a *meagre* lime of inferior quality.
		Oxide of Iron ...	Feeble traces	
		Clay { Silica ... / Alumina ...	Ditto	
		Sand ...	None	
		Total ...	100·00	

Number.	Materials from whence obtained.	Composition.		Remarks.
A38	Kunkur from Pulrah, 4 miles north of Hazareebaugh (Ramghur Division)	Carbonate of Lime...	69·20	Good hydraulic lime-stone.
		„ Magnesia	Feeble traces	
		Oxide of Iron ...	1·40	
		Clay { Silica ... / Alumina ...	26·00	
		Sand	3·40	
		Total ...	100·00	
A39	Ghooting-stone from Ghattal (Hidgellee Division)..	Carbonate of Lime... / „ Magnesia	73·94	Ditto.
		Oxide of Iron ...		
		Clay { Silica ... / Alumina ...	24·66	
		Sand	1·40	
		Total ...	100·00	
A40	Ghooting-stone from Ghattal (Hidgellee Division)..	Carbonate of Lime... / „ Magnesia	71·94	Ditto.
		Oxide of Iron ...		
		Clay { Silica ... / Alumina ...	26·66	
		Sand	1·40	
		Total ...	100·00	
A41	Ghooting-stone from Ballyghie (Hidgellee Division)	Carbonate of Lime.. / „ Magnesia	72·00	Ditto.
		Oxide of Iron ...		
		Clay { Silica ... / Alumina ...	27·00	
		Sand	1·00	
		Total ...	100·00	
A42	Ghooting-stone from Gowakhally (Hidgellee Division)	Carbonate of Lime .. / „ Magnesia	67·04	Ditto.
		Oxide of Iron ...		
		Clay { Silica ... / Alumina ...	30·66	
		Sand	1·40	
		Total ...	100·00	
A43	Ghooting-stone from Austee, Patna (Hidgellee Division)	Carbonate of Lime... / „ Magnesia	69·33	Ditto.
		Oxide of Iron ...		
		Clay { Silica ... / Alumina ...	30·00	
		Sand	0·67	
		Total ...	100·00	

Number.	Materials from whence obtained.	Composition.		Remarks.
A44	Ghooting-stone from Girhidee Road Division (1st Presidency Division) ...	Carbonate of Lime..	58·60	Hydraulic lime-stone, contains too much sand.
		„ Magnesia	Feeble traces	
		Oxide of Iron ...	None	
		Clay {Silica ...	26·40	
		{Alumina..		
		Sand	15·00	
		Total ...	100·00	
A45	Ghooting stone from Girhidee Road Division (1st Presidency Division) ...	Carbonate of Lime..	74·20	Ordinary hydraulic lime.
		„ Magnesia	Traces	
		Oxide of Iron ...	2·00	
		Clay {Silica ...	17·10	
		{Alumina		
		Sand	6·70	
		Total ...	100·00	
A46	Kunkur from Girhidee Road Division (1st Presidency Division)	Carbonate of Lime..	41·60	Bad.
		„ Magnesia	Traces	
		Oxide of Iron ...	2·90	
		Clay {Silica ...	22·50	
		{Alumina..		
		Sand	33·00	
		Total ...	100·00	
A48	Grey lime-stone from Rohtas Hill, 24 miles from Dehree (Soane Circle) ...	Carbonate of Lime..	72·34	Cement stone.
		Clay and Sand ...	27·66	
		Feeble traces of Oxide of Iron and Carbonate of Magnesia ...	.....	
		Total ...	100·00	
A49	Yellow lime-stone from Rohtas Hill, 24 miles from Dehree (Soane Circle) ...	Carbonate of Lime..	76·00	Ditto.
		Clay and Sand ...	24·00	
		Feeble traces of Oxide of Iron and Carbonate of Magnesia ...	.....	
		Total ...	100·00	
A50	Lime-stone from Rohtas Hill, 24 miles from Dehree (Soane Circle) ...	Carbonate of Lime..	85·50	Feebly hydraulic lime-stone.
		„ Magnesia	Feeble traces	
		Oxide of Iron ...	1·00	
		Clay {Silica ...	11·80	
		{Alumina..		
		Sand	1·70	
		Total ...	100·00	

Number.	Materials from whence obtained.	Composition.		Remarks.
A36	Grey lime-stone from Sylhet	Carbonate of Lime	92·50	Good fat lime-stone.
		„ Magnesia	1·20	
		Oxide of Iron ...	None	
		Clay {Silica ...	2·80	
		{Alumina ...		
		Sand	3·50	
		Total ...	100·00	
A37	Blue lime-stone from Sylhet	Carbonate of Lime	92·97	Ditto.
		„ Magnesia	3·23	
		Oxide of Iron ...	0·70	
		Clay {Silica ...	1·80	
		{Alumina ..		
		Sand	1·20	
		Total ...	100·00	
B23	White clay found at Narajee, 13 miles from Cuttack (Orissa Circle) ...	Clay	58·00	Good for fire-bricks.
		Sand, Quartz, &c....	42·00	
		Total ...	100·00	
A35	Ghooting-stone from Cutwa, Grand Trunk Road, 1st Division) ...	Carbonate of Lime	75·30	Good hydraulic lime-stone.
		„ Magnesia		
		Oxide of Iron ...	0·70	
		Clay {Silica ...	22·00	
		{Alumina ...		
		Sand	2·00	
		Total ...	100·00	
B45	Red earth from laterite beds at Gope in Midnapore (Midnapore Division) ...	Clay {Silica ...	55·00	Good for a kind of pozzolana.
		{Alumina ...		
		Oxide of Iron ...		
		Sand	45·00	
		Pyrate of Iron ..		
		Total ...	100·00	
B65	Marly clay found in the quarries of lime-stone A37 at Choonia Bugrul, 5 miles from Hazareebaugh (Ramghur Division) ...	Carbonate of Lime	86·80	May be used for an artificial hydraulic lime.
		„ Magnesia	1·20	
		Oxide of Iron ...	Feeble traces	
		Clay {Silica ...	8·60	
		{Alumina ...		
		Sand	3·40	
		Total ...	100·00	

Number.	Materials from whence obtained.	Composition.		Remarks.
B77	Yellow clay found at Margohi (Soane Circle) ...	Carbonate of Lime...	11·50	Good for manufacture of slow-setting cement.
		" Magnesia	0·70	
		Oxide of Iron ...	None	
		Clay { Silica ...	82·00	
		{ Alumina ...		
		Sand ...	5·80	
		Total ...	100·00	
B78	White marly clay found at Rohtas, 24 miles from Dehree (Soane Circle) ...	Carbonate of Lime	81·00	Hydraulic lime.
		" Magnesia	2·00	
		Oxide of Iron ...	None	
		Clay { Silica ...	17·00	
		{ Alumina ...		
		Sand ...	None	
		Total ...	100·00	
B78i	White and reddish marly clay found at Rohtas, 24 miles from Dehree (Soane Circle) ...	Carbonate of Lime ..	57·00	Contains too much clay to be used alone for cement.
		" Magnesia	None	
		Oxide of Iron ...	None	
		Clay { Silica ...	42·50	
		{ Alumina ..		
		Sand	0·50	
		Total ...	100·00	
B79	Grey clay from Sylhet ...	Carbornate of Lime	0·37	Pretty good for artificial cement.
		" Magnesia	Feeble traces	
		Oxide of Iron ...	2·00	
		Clay { Silica ...	93·13	
		{ Alumina ...		
		Sand	4·50	
		Total ...	100·00	
B80	Blue clay from Sylhet ...	Carbonate of Lime ..	Feeble traces	Good for artificial cement.
		" Magnesia	Ditto	
		Oxide of Iron ...	9·00	
		Clay { Silica ...	89·70	
		{ Alumina ...		
		Sand	1·30	
		Total ...	100·00	

J. DIJOUX,
Executive Engineer,
Cement Experiments Division.

B.

Statement shewing the ultimate state of Cements after the experiments made on them on the 1st April 1872, as shewn in Statement B. annexed to the Report, No. 72, dated 5th April 1872, of the Executive Engineer, Cement Experiments Division.

Numbers of Experiments as shewn in Statement B above-mentioned.	From whence the materials were obtained.	Remarks.
1 ...	Margohi (Soane Circle)	It has been getting harder sensibly in cake and in water.
1' ...	Ditto ditto ...	Ditto ditto ditto, but less than 1.
1" ...	Ditto ditto ...	As hard as 1' in water, but rather soft in cake.
2 ...	Ditto ditto ...	It has been getting harder sensibly, and it is even better than 1.
2' ...	Ditto ditto ..	It is about or like 1.
2" ...	Ditto ditto ...	Less hard in cake than in water as the preceding 2'.
3"' 2nd ball...	Ditto ditto ..	The mixture is the only one which seems pretty good in the series 3.
4' ...	Ditto ditto ...	About the same as 1'.
4" ...	Ditto ditto ...	About the same as 1' in water, but the cake is not so hard.
5 ...	Ditto ditto ...	The same as 1. All the other samples of the series No. 5 are good in water, but bad in cakes.
6 ...	Ditto ditto ...	The same as 1.
6" ...	Ditto ditto ...	Indifferent.
7 and 8 ...	Orissa	Getting harder sensibly, but slowly.
9 and 9" ...	Margohi (Soane Circle)	Very hard in water, but bad in cakes.
11 and 11' ...	Ditto ditto ...	Hard in water, but indifferent in cakes.
11" ...	... ...	Bad.
12 ...	Dinapore	Pretty hard in cake, but very hard in water.

Numbers of Experiments as shewn in Statement B above-mentioned.	From whence the materials were obtained.	REMARKS.
13' ...	Orissa ...	Indifferent.
14' and 14''...	Minapore Division ...	These samples obtained a very fair hardness in cake and in water.
15 ...	Ditto ditto ...	The hardness increased very slowly, but is now very fair.

NOTE.—It will be observed from this statement that the best sample is No. 2.

It consists of a mixture of { 2 parts of marly clay, B6 / 1 part of ditto, B7 } from Margohi (Soane Circle) which was burnt with a slow fire.

F. DEJOUX,
Executive Engineer.

C.

Result of experiments on Cements from 1st April to 30th June 1872.

No.	COMPOSITION. Quantities.	From whence materials were obtained.	Hours taken in burning.	In what sort of fire.	Color of stone burnt.	When mixed and put in water.	Time taken for the setting in water.	Quality of the cement under water.	Quality of the cake when exposed to the air.	REMARKS.
1iii	1 part of marly clay, B6 / 1 ditto ditto, B7	Margohi (Soane Circle)	50	Strong fire	White ...	April 1st	15 M. ...	Very bad ...	Very bad ...	In water and in cake it crumbled to powder after four days.
1iv	Ditto ditto ...	Ditto ...	48	Very slow fire.	Reddish white.	April 30th	H. M. 1 20	Hard ...	Pretty hard...	Retained too much carbonic acid.
2iii	2 parts of marly clay, B6 / 1 part of ditto, B7	Ditto ...	50	Strong fire	Greyish white.	April 1st	10 M. ...	Very bad ...	Very bad ...	In water and in cake it crumbled to powder after two days. Contained no carbonic acid.
2ivA	Ditto ditto ...	Ditto ...	48	Very slow fire.	Reddish...	April 23rd	H. M. 1 15	Very hard ...	Ditto ...	Was getting sensibly harder in cake, but crumbled to powder five days after being made. Contained no carbonic acid.
2ivB	Ditto ditto ...	Ditto ...	48	Ditto ...	Ditto ...	June 20th	1 30	Hard ...	Hard ...	Its hardness increased sensibly.

No.	Composition. Quantities.	Composition. From whence materials were obtained.	Hours taken in burning.	In what sort of fire.	Color of stone burnt.	When mixed and put in water.	Time taken for the setting in water.	Quality of the cement under water.	Quality of the cake when exposed to the air.	Remarks.
2v	2 parts of marly clay, B6 } 1 part of marly clay, B7 }	Margohi (Soane Circle).	70	Very slow fire.	White ...	May 5th	30 M. ...	Hard ...	Very hard ...	Retained little carbonic acid.
3iv	Ditto ditto ...	Ditto ...	50	Strong fire	Grey ...	April 1st	Not set ...	Very bad ...	Soft ...	After four days crumbled to powder under water.
14iv	1 part of ghooting-stone, A11	Midnapore Division.	50	Very strong fire.	Greyish brown.	April 1st	5 hours ...	Very hard ...	Hard ...	The burning was only a little too strong. Retained no carbonic acid.
16	2 parts of marly clay, B6 } 1 part of lime-stone, A3 }	Margohi (Soane Circle).	50	Ditto ...	Reddish brown.	April 1st	1 M. ...	Very bad ...	Very bad ...	After three days crumbled to powder in water and cake. Retained no carbonic acid.
16i	Ditto ditto ...	Ditto ...	16	Very slow fire.	Reddish ...	„ 23rd	15 M. ...	Hard	Very soft ...	Required more burning. Was found very hard for nearly three weeks, but after that time the cake cracked in different places and began to turn soft.
16ii	Ditto ditto ...	Ditto ...	60	Ditto ...	Ditto ...	April 26th	50 M. ...	Pretty hard	Pretty hard	Required a little more burning. Contained much carbonic acid.
17 (A)	3 parts of marly clay, B6 } 1 part of ditto, B7 }	Ditto ...	50	Very strong fire.	Greyish white.	April 1st	5 M. ...	Very bad ...	Very bad ...	Crumbled to powder in water and cake after five days. Contained no carbonic acid.
17 (B)	Ditto ditto ...	Ditto ...	50	Ditto ...	Ditto ...	May 1st	40 M. ...	Very hard ...	Very hard ...	Was left exposed to the air for one month, and the absorption thus of carbonic acid was the cause of its turning good.
17i	Ditto ditto ..	Ditto ...	60	Very slow fire.	Reddish ..	April 26th	25 M. ..	Very hard ...	Hard ...	Retained carbonic acid, but required more burning.
17ii	Ditto ditto ...	Ditto ...	110	Ditto ...	Reddish grey.	June 10th	35 M. ...	Ditto ...	Very hard ...	Has had just the burning it required; contains a feeble proportion of carbonic acid. The hardness in this sample increased much more rapidly than in others.
17iii	Ditto ditto ...	Ditto ...	48	Very strong fire.	Yellowish grey.	June 15th	10 M. ...	Very bad ...	Very bad ...	Crumbled to powder in water and in cake two days after.
18	4 parts of marly clay, B6 } 1 part of ditto, B7 }	Ditto ...	50	Ditto ...	Grey ...	April 1st	Not set ...	Ditto ...	Pretty hard .	Ditto to powder in water after 24 hours.
18i	Ditto ditto ...	Ditto ...	70	Very slow fire.	Red ...	April 30th	30 M. ...	Hard ...	Rather soft .	Required evidently more burning.

D.

PROCES VERBAL

On experiments on the comparative tractile strength of Cement No. 17 and English Portland Cement (just imported and in very good condition).

Cement No. 17. Composition... { Three parts of yellow marly clay / One part of white marly clay } From Magohi (Soane Circle).

Three bricks were joined together by means of a mortar made with this cement, pure, and were left exposed to the air for 24 hours.

These were then put under water for 10 days, and, on being taken out, were left exposed for two days and 17 hours, and then tried, making a total of 13 days and 17 hours after the manufacture.

Fig. 1.

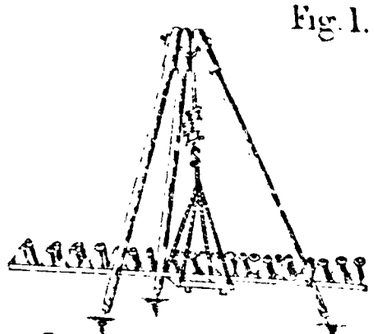
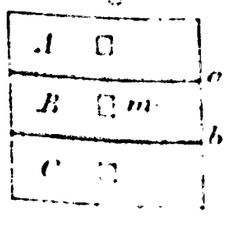
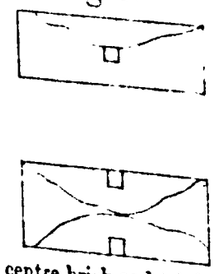


Fig. 2.



I put the block held by the clamps as shown in Figure 1., and loaded it with 1,063lbs. The block stood without any apparent injury for about three minutes, and then the brick C. gave way partially as shown by the following :

Fig. 3.



I made a new hole (*m*) in the centre brick and tried it again.

When loaded with 1,316 lbs., the joint (*a*) gave way, the first brick, A., remaining intact, and the brick B. having a portion K. broken; *vide*—

Fig. 4.

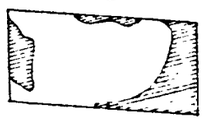
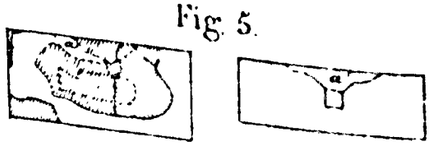


Fig. 5.



Figures 4 and 5 show in red the parts of the cement which remained attached to bricks A and B. The portion marked blue shows the cement joints separated in pieces upon the two bricks.

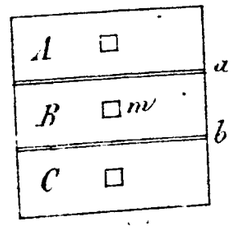
The cement inside the joints was found very hard; the bricks were first rate burnt bricks, but the bricks A. and B. (principally A) were found sensibly better and harder than C.

In putting the cement mortar between the two bricks A. and B., the precaution of putting an hollow part against a flat one not having been taken, two hollow parts being put together, air got within and left the hollow portion marked in red line in Figure 5; the surface of that portion in which the mortar did not touch the brick was 8 square inches.

The total area of the brick was $4\frac{1}{4} \times 9\frac{1}{2}$ square inches $= 42\frac{3}{4}$ square inches; deducting from this the 8 square inches above mentioned, a balance of $34\frac{3}{4}$ square inches for the total surface was left, which may fairly be calculated to oppose resistance to the tractile strength, and it may consequently be said that a weight of 37·87 per square inch was necessary for the breaking of the joint.

Portland Cement. The same process as the last answered for this experiment.

Fig. 6.



I put the block held by the clamps as shown by Figure 1, and loaded it with 1,148 lbs.; the brick C. broke, but at the same time a crack appeared in the joint *b*, and I could separate the bricks B. and C. easily.

The state of the breakage of the brick is shown in Figure 7.

Fig. 7.

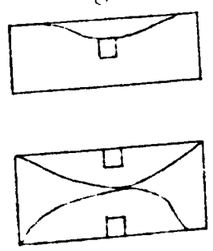


Fig. 8.

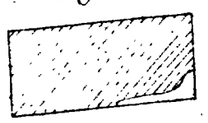
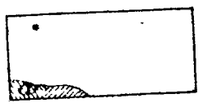


Fig. 9.



I made a new hole (*m*) (Figure 6) on the brick B. and tried it again. When loaded with 1,036 lbs., the brick A broke in the same way as the first one, but the joint remained intact.

Figures 8 and 9 show how the mortar remained attached to the bricks.

A small piece of the brick (*a*) broke and remained fixed on the other brick.

In joining these two bricks, some air got in also, and left in the mortar a hollow portion, the surface of which was $1\frac{3}{4}$ square inches; this being subtracted from the total surface of $42\frac{3}{4}$ square inches, the balance was 41 square inches. It may, therefore, be said that a weight of 28 lbs. per square inch was necessary for the breaking of the joint.

NOTE.—I stopped the experiments having the intention of trying the remaining joints intact when they become two months old.

P. DEJOUX,

Exe. Engr., Cement Experiments Division.

The 4th July 1872.

No. 109, dated the 23rd July 1872.

From—P. Dejoux, Esq., Executive Engineer, Cement Experiments Division.

To—Colonel J. F. Stoddard, M. S. C., Supdg. Engr., South-Western Circle.

With reference to your memorandum No. 1946, dated the 10th instant, forwarding, for information and report, copy of letter No. 431 I of the 4th ultimo from the Assistant Secretary to the Government of India, I have the honor to observe that as the particular portion "of my general remarks on ghooting lime-stones, which was not clearly understood," has not been definitely communicated, I can only infer that the following portion was perhaps referred to: "Where the ghooting is burnt, as it is generally done in Bengal, the part which is slaked when taken out from the kiln is the part containing the quantity of clay necessary to make good hydraulic lime; large portions of the parts which are not slaked are those containing more clay and are cement stones; but as generally they contain too large a proportion of clay, it will not do to burn those stones again, but, on the contrary, it will be better to burn the whole until they cannot be slaked."

2. If so, I must acknowledge that I ought to have supplied more details on the point, but I will now try to explain how I arrived at the opinion communicated in the paragraph under notice:

I.—When I have to conduct the analysis of a stone of the same kind as a ghooting-stone, I select from a cubic foot of stone a dozen pieces of different shapes, sizes, and appearances; I pulverize them roughly, and mix as much as possible the powder so obtained.

I take afterwards a small quantity of it, and reduce it by means of an agate mortar into an impalpable powder, of which, when dried, I take a quantity weighing 150 grains, and it is on this last quantity that the analysis is conducted.

II.—Proceeding in this way, I found that in the Bengal ghooting-stone the proportion of clay varies from 10·50 to 33·33 per cent., the average, however, being 25 per cent.

Now, if we look to the analysis of the lime believed to be the most hydraulic of all the limes known, *viz.*, the lime of Theil (France), we find that the lime-stone from which that lime is obtained contains only 14·90 per cent. of clay, and we may further say that few hydraulic lime-stones at home contain more than 15 per cent., and none more than 20 per cent. of clay.

III.—The analysis of the ghooting-stones giving an average proportion of 25 per cent., they could naturally be taken for cement stones, but experience proves them to be only argillaceous lime-stones.

Therefore we can only say that, if the ghooting-stones were more homogeneous, they could have been classified in the category of natural cement stones.

To prove this opinion, I may say that, if we separate some nodules from a piece of ghooting taken in its natural state, it will be found that they generally differ in texture and appearance, and that analysis shows that while some contain as much as 50 and 55 per cent. of clay, others are very nearly pure carbonate of lime.

From the experiments I have made I feel authorized to say that as regards the generality of ghooting-stones, those which contain from 20 to 25 per cent. of clay are very hydraulic lime-stones, while those containing only from 10 to 14 per cent. are feebly hydraulic.

As regards those in which the proportions of clay exceed 25 per cent., they produce only a small quantity of lime, and the percentage of portions which cannot be slaked increases proportionately with the quantity of clay.

I have been able to verify the truth of these last remarks in many places in Lower Bengal, where large quantities of ghooting lime are manufactured.

I may, however, state that some ghooting-stones or kunkur may be found sufficiently homogeneous to follow the ordinary rules of hydraulic lime-stones, but such may very seldom be the case.

IV.—When such a stone as ghooting has been well burnt, all the proportions containing less than 20 per cent. of clay slake when immersed in water, but the portions containing an excess of clay, called generally "refuse ghooting" in Bengal, remain inert.

V.—Now, supposing that, after having burnt ghooting-stone containing an average of 20 per cent clay, the half only of the total quantity (which we will suppose to be 100 cubic feet) slakes and yields an ordinary hydraulic lime, it must be taken as a datum that this lime proceeded from a lime-stone containing about 10 per cent. of clay.

Consequently the 50 cubic feet of refuse ghooting, which did not slake, must be considered as an argillaceous lime-stone, containing about 30 per cent. of clay, bearing in mind that the proportion of clay in the total quantity of 100 cubic feet of ghooting was 20 per cent.

Therefore I draw the conclusion that this ghooting must be considered as the agglomeration of two different stones, *i. e.*, while one yields 10 per cent. of clay, and produces an ordinary hydraulic lime, the other contains 30 per cent, and may be transformable into cement.

VI.—Again, supposing that the 100 cubic feet of ghooting contains 30 per cent. of clay, and that we obtain after slaking a lime very hydraulic, and 50 cubic feet of refuse ghooting, this lime, according to its degree of hydraulicity, must be considered as proceeding from a lime-stone yielding about 15 per cent. of clay.

It follows also that the refuse ghooting must be considered as an argillaceous stone, yielding about 45 per cent. of clay, and consequently quite useless for the manufacture of either lime or cement.

VII.—Under such circumstances, therefore, we have to consider the two following alternatives, if it be intended to use ghooting for making cements.

In the first case, if the proportion of clay in the refuse ghooting be the proportion generally found in cement stones, we have only to begin by burning the ghooting in the usual way, then to let it slake, separate from the refuse ghooting the lime obtained, and to re-burn the refuse more or less according to requirement for either slow or quick-setting cement.

In the second case, which is the most general, and where the proportion of clay exceeds the limit of the quantity usually found in cement stones, we may follow the theories of Messrs. Minard and Lacordaire (Ingenieurs des Ponts et Chaussies), who are of opinion that some argillaceous lime-stones, of which portions containing clay in excess may, by a long process of calcination with a moderate fire, be transformed into cement.

VIII.—The soundness of this fact was nevertheless tested by the experiment I made on the specimen of ghooting-stone A7 from Dinapore, as described in Statement B. annexed to my letter No. 72 of the 5th April 1872.

This ghooting yielded a quick-setting cement when calcined with a moderate fire until it would not slake.

We could in such a case as the last use a flame-kiln for calcinating the ghooting to the required degree.

IX.—I must, however, reiterate that it will be more certain and more easy, principlly on account of the burning, to choose, for the manufacture of cement, ghooting-stones which, containing the proper proportion of clay, may easily be pulverized, and that in such a case they may be treated similarly as *non-homogeneous marly clay*.

Note by Lieutenant-Colonel F. T. Haig, R. E., *Officiating Chief Engineer, Bengal, Irrigation Branch, on the Cement Experiments, dated 29th August* 1872.

Mr. Dejoux's experiments up to the present time seem to have pretty well established two points—

(1) that a cement quite equal to Portland cement, as received in this country, can be made from a combination of a marly clay and a lime-stone found close together at the base of the hills skirting the Soane from the Dehree Stone Quarries at Dhodand to Rohtas, a distance of 20 miles;

(2) that an equally good cement may be manufactured from the Sylhet lime and Calcutta blue clay.

With regard to the first cement, Mr. Dejoux states that any quantity of the materials is available. The strata lie generally near the foot of the hills, which have a rather steep slope; but there will be no need to cut deeply into the face of the hill at any point, which would be expensive, as by going a little further along the hill more of the material can be obtained.

Calculating on the data as to cost of extraction, carriage, &c., afforded by the works at Dehree, for which lime is now brought from Margohi (a point in the hills referred to, about 5 miles from the stone quarries), Mr. Dejoux thinks that the cost of the cement at Dehree would be about Rs. 61 per 100 cubic feet, if coal were used, or Rs. 54, if wood.

The cost of carriage to Arrah by canal would be Rs. 8 per 100 cubic feet.

From Arrah to Calcutta by rail the cost would be Rs. 40 per 100, and from Arrah to Cawnpore by rail Rs. 40.

Thus the cost of the cement in Calcutta would be for—

	Rs.
Carriage—	
Dehree to Arrah	8
Arrah to Calcutta	40
Terminal charges, shifts, &c. ...	10
	58
Cost of cement at Dehree ...	60
	118 per 100 c. ft.

The cost at Cawnpore would be—

Carriage—

Dehree to Arrah	...	...	...	Rs. 8
Arrah to Cawnpore	...	..	...	... 40
Terminal charges, &c.	...	...	...	... 10
				58
		Prime cost		... 60
				118 per 100 c. ft.

If the cement were sent by water all the way to Calcutta, the cost there would be about Rs. 100.

The cost of Portland cement in Calcutta is Rs. 9 per cask, containing 5 cubic feet, but there is always a wastage of half a cubic foot, so that the actual cost is Rs. 2 per cubic foot, or Rs. 200 per 100 cubic feet.

Adding railway charges, the cost of the same cement in Cawnpore would be Rs. 290 at least.

Thus the relative costs at each place would be—

Calcutta—

Portland Cement	...	...	...	...	Rs. 200
Margohi „	...	...	...	...	100 to 118
Cawnpore—					
Portland Cement	...	...	...	...	290
Margohi „	...	...	...	...	118

These calculations seem sufficient to show that, if the cement can be made for anything like Rs. 60 per 100 cubic feet there would be a very extensive demand for it.

Mr. Dejoux's experiments with the cement manufactured from Sylhet lime have not yet gone far enough to enable him to judge what its cost would probably be, but he thinks it would be about Rs. 100 per 100 cubic feet.

Mr. Dejoux also reports that some specimens of kunkur lime sent him by Captain Heywood, which came from a bed somewhere in the Shahabad District, not far from the line of the Arrah Canal, appear to form a natural cement. I am inclined, however, rather to distrust any natural cement produced from this source on account of the want of homogeneity in the material, and think that for the present operations had better be confined to the Margohi stone.

I think there is now quite enough to warrant the commencement of the manufacture of cement at Dehree, or in that neighbourhood, on a small scale. The Soane works alone will require a certain quantity; and if the manufacture is limited, in the first instance, to their requirements, we shall probably, in the course of a year or two, by gradual improvements in the processes, arrive at a really first-rate cement.

On this account I think Mr. Dejoux's proposal to build a small manufactory at Dehree a good one. The Margohi stone is constantly brought in there for use on the works; and if a few kilns are built, the manufacture of the cement can be carried on as required.

It is uncertain whether Dehree would be the best site eventually for a manufactory for the supply of the districts along the Ganges generally. At Rohtas lime-stone has been quarried for years and sent down to Patna and other places by the Soane. At the present time Mr. Dejoux states that 20,000 to 25,000 maunds are annually exported in this way. As the same materials are found there as at Margohi, it might be found better to establish a factory at that place instead of at Dehree, as the hills are only half a mile distant from the river, which appears to be navigable after a fashion for about eight months of the year.

This point might be settled afterwards.

At present I think the factory should be at Dehree.

Mr. Dejoux is now preparing the designs for the kilns, sheds, &c., which he considers would be necessary for this purpose. He will shortly submit a detailed report and estimates; but meantime he states that he would propose to erect three kilns large enough to contain about 400 cubic feet each, two of them flame-kilns, one for wood fuel and the other for coal, and the third to burn the lime in alternate layers with either coal or charcoal.

After trial of these, he would eventually select, for future use, the one that gave the best result in point of economy and excellence of cement.

He estimates the probable cost of the works and apparatus as follows:

					Rs.
3 kilns	...	...	...	...	3,000
1 drying-shed	...	...	...	...	1,000
1 set of reservoirs	...	...	...	...	1,000
2 pug-mills ...	...	...	...	...	700
1 sifting machine	...	...	...	...	650
Soorkey-mill and engine already available.					
			Total	...	6,350

or say Rs. 7,000.

One of these kilns, if constantly worked, would turn out about 2,400 cubic feet of per month.

This is probably more than enough for the works, and the size of the kiln might be reduced; but, on the other hand, the size of the kiln has something to do with the of the cement, and it might be better, therefore, to carry on the experiment on this the smaller scale, as the results would be more reliable.

P. W. 1872 Department.

No 5398.

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

IRRIGATION.

To

CIRCULAR No. 52 PUBLIC WORKS.

Dated SIMLA, 9th *October* 1872.

Received 5th November 1872.

Communicated to the Supdg. Engineer for information

No 2896 -

Reply sent

Cement Manufacture.

No 2896-7 Excerpt -

Reply dated 9/12/73 with a copy of Circular No 52 sent to each Govt & Admn. Public Works Department

Regd. in Dy. Secy's Office

Dy. Secy's Office

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Sub-Divl. Officer

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C/25395

Govt. of Madras.

PUBLIC WORKS.

Dutch Engineers

P.V

Nos. 166 & 167

Cement. Circulars from the Early Dutch Engineers relative to the Manufacture of, & the Experiments conducted with, Cement, Cont.d & the Papers connected.