

THE POSSIBILITIES OF MANUFACTURING  
PORTLAND CEMENT IN THE UNITED  
PROVINCES

By

E. R. Watson & others.

**BULLETINS OF INDIAN INDUSTRIES & LABOUR**

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**HISTORY OF THE SUBJECT**

The engineers of the Irrigation Branch of the Public Works Department gave a good deal of attention to the possibility of manufacturing Portland cement in the Punjab and the United Provinces about the year 1873. A series of articles was published on the subject in Professional Papers on Indian Engineering (Brownlow, Series 1, VII, 400-412; Thomson, Series 2, I, 491-496; Nielly, Series 2, II, 115-140 (1873); Nielly, Series 2, VI, 378-389; King, Series 2, IV, 333-347; Nielly, Higham and Brownlow, Series 2, VI, 127-168). Brownlow recommended making cement from slaked lime (pure rich lime from the lower Himalayan ranges) and clay by burning the mixture with charcoal. He calculated that this would be a paying proposition even if the cement produced had only a quarter of the strength of Portland cement. Thomson gave the analysis of samples of *kankar* obtained from various places in the United Provinces. Nielly concluded from Thomson's analysis that some of these *kankars* would produce ordinary cements whilst others had almost the composition required for superior cement. He made some experiments with Bathala *kankar* and got as high a tensile strength as 265 lb. per square inch in briquettes which were two years old. (In those days the specification for Portland cement

was 300-350 lb. after 7 days) but the tensile strength of Nielly's briquettes after 7 days was very low. King experimented with various kinds of *kankar* and with mixtures of *kankar* and clay and *kankar* and lime. The highest strength he got was 275 lb. per square inch after one year. He did not measure the strength after 7 days. Nielly, Higham and Brownlow estimated the cost of making cement from *kankar* by various processes at Rs. 5-8, Rs. 6-8 and Rs. 12-8 per ton.

The low tensile strength obtained in these experiments is of no importance. It cannot be accepted as any reason for supposing that Portland cement up to British Standard Specifications cannot be made from *kankar* because none of these experiments were controlled by chemical analysis. In those days the exact composition of a mixture necessary to produce cement of the highest quality was not known with the same certainty as at the present day.

Comparatively recently, large cement works equipped on modern lines have been erected at Porbundar on the Bombay side of India, at Bundi in Rajputana and at Katni in the Central Provinces. A description of these works is given by H. A. F. Musgrave, Superintendent of the Government Test House at Calcutta, in a brochure entitled "Manufacture of Portland Cement in India", published by the Government of India. At Bundi the correct mixture is obtained by the proper admixture of argillaceous limestones from several quarries near which the factory is situated. At Katni local limestone and the overlying clay are used. The cements produced in all these factories comply with British Standard Specifications. According to Musgrave's report, that produced at Porbundar was rather low in tensile strength. In this factory the furnaces were of a vertical type. At Katni there was for a time some difficulty about setting time, but Musgrave reported that that difficulty had been overcome.

Additional cement works are being erected in the Central Provinces and at Japla, Palamanu district, in Chota Nagpur, the latter being erected by Messrs. Martin and Company as Agents of the Associated Portland Cement Manufacturers Limited.

In 1919 an enquiry was addressed from Cawnpore to the Director of Industries, United Provinces, as to the possibility of manufacturing Portland cement near Cawnpore.

About the same time Mr. Hallidy, a State Railway engineer, urged on the Railway Board the desirability of the Government

manufacturing its own cement for railway and canal work and was placed on special duty to study the lime deposits of the Oudh and Rohilkhand Railway with regard to their suitability for cement manufacture. The Railway Board printed his report at the end of 1920, but it was not published for general information. With the permission of the Railway Board this report is given as an appendix to this *Bulletin* as it bears directly on the present enquiry. Hallidy discovered deposits of marl near Lucknow which, in his opinion, were very suitable for cement manufacture. He surveyed deposits at Dilarmau and Madharmau, about 10 miles from Lucknow, and estimated that they would supply sufficient marl to manufacture 100 tons of cement daily for 40 years. Plenty of suitable clay was found adjacent to the marl. He calculated that it would be profitable to manufacture cement at this place. He also considered travertine deposits near Hardwar and in the Tanatpur district and thought that they would probably be suitable if hydro-electric power were developed. He thought that most of the *kankar* available on the Oudh and Rohilkhand Railway was not suitable for cement manufacture.

The present investigation was considered desirable in view of the enquiry from Cawnpore and the present high price of cement in India. In addition to checking and supplementing Hallidy's estimates of the quantity of calcareous material in the Province and his chemical analysis of these materials, it was thought desirable, in view of the large amount of capital required for cement manufacture, to confirm conclusions based on chemical analysis by the actual production on a small scale of cement from materials which analysis indicated as suitable, and tests of the samples of cement produced.

The Irrigation Branch of the Public Works Department of this Province has been considering the advisability of manufacturing cement locally for use in the construction of the Sarda Canal. So far as is known, the present opinion is against Government undertaking the manufacture itself. The writers understand that private interests have also been attracted by the proposition suggested by Hallidy, *viz.*, to manufacture cement from the marl deposits near Lucknow. The Development Board of this Province was asked whether Government would give any guarantee to take a certain amount of cement if a private factory were started, but the reply was not encouraging.

Mr. Bion, Chief Engineer, Public Works Department, Sarda Canal, interviewed by one of the writers at the end of June 1922 on this subject, said that he had recommended Government to manufacture its own cement for the Sarda Canal but had been informed that that would be contrary to Government policy, as the manufacture of cement in India was no longer in the experimental stage and it was not Government policy to compete with private manufacturers. He was asked to invite private firms to manufacture cement in the Province, but on enquiry found that Calcutta and Bombay firms had no capital available for such a project or were not attracted by it. The matter was then referred to the Director of Industries, who reported that a certain person in Lucknow was willing to start the manufacture of cement near Lucknow. This proposal apparently gave rise to the above mentioned enquiry from the Development Board, and no further progress had been made with the negotiations. Mr. Bion said that Government could not afford to use cement at the present high prices for the Sarda Canal, but if they could manufacture or purchase cement at about Rs. 30 per ton they would use large quantities of it. Otherwise they would have to use other materials as far as possible and only a limited quantity of cement. From estimates supplied to him he thought Government could manufacture at about this price. Asked about the electric power installation at the upper Ganges Canal head works at Hardwar, he said it was at present lying idle; they were trying to come to some arrangement for it to be taken over by three adjacent municipalities for the electric lighting of those municipalities, but there were difficulties. So the possibility of utilizing this hydro-electric plant for the manufacture of cement from Hardwar travertine was not yet excluded from consideration.

## RAW MATERIALS AVAILABLE

### A.—CALCAREOUS MATERIALS

The most obvious calcareous material in the Province is *kankar*.

*Kankar* It is used almost everywhere as road-making material and is obtained locally. In most cases the *kankar* is extracted close to the road which has to be repaired. On ravine land the *kankar* comes to the surface, and it is usual to obtain all that is required within a few feet of the surface.

In determining the suitability of any material both quality and quantity have to be considered. Some analysis of *kankar* had been published before this investigation was started (Thomson, *loc. cit.*)

Locality from which obtained	CaO. CO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub>	MgO.	Siliceous residue	Water, loss organic matter, etc.
Ghaziपुर . . . . .	40.0 32.0	11.0	0.4	15.2	1.4
Aligarh . . . . .	15.5 12.8	38.4	2.8	30.5	..
Do. No. 3 . . . . .	37.0 30.3	20.8	5.4	7.1	..
	CaCO <sub>2</sub>				
Saharanpur No. 1 . . . . .	57.18	10.32	trace	32.5	..
Do. No. 2 . . . . .	79.33	6.73	trace	13.94	..
Do. No. 3 . . . . .	78.54	8.42	trace	13.04	..
Allahabad . . . . .	52.80	3.64	none	42.39	0.60
Delhi No. 1 . . . . .	53.49	3.00	1.57	41.41	0.67
Do. No. 2 . . . . .	28.97	4.09	0.94	63.63	2.32

Nielly (Professional Papers on Indian Engineering, Series 2, II, 115-140) gave a few additional rough analyses—

Name of <i>kankar</i>	Carbonate of lime	Clay
Lucknow No. 1 . . . . .	72.3	27.7
„ No. 2 . . . . .	70.2	29.8
„ No. 3 . . . . .	67.7	32.3

and a few more are given in Oldham's *Geology of India*, p. 437—

	1	2	3
Carbonate of lime . . . . .	72.0	56.93	78.5
Carbonate of magnesia . . . . .	1.3	1.72	2.0
Oxide of iron . . . . .	0.7	1.67	2.0
Clay . . . . .	22.0	30.0	10.5
Sand . . . . .	2.0	9.67	7.0
	4	5	6
Carbonate of lime . . . . .	54.0	65.4	66.3
Carbonate of magnesia . . . . .	..	..	..
Oxides of iron and alumina . . . . .	2.7	1.9	10.32
Water and organic matter . . . . .	2.7	2.3	..
Insolubles . . . . .	40.6	30.4	32.50

- 1, 2, 3. Raniganj . . . . . Dejour, *Records*, VII, 123 (1874).  
 4. Barmuri . . . . .  
 5. Ramnagar . . . . .  
 6. Sanctoria . . . . . } All near Raniganj. Twean, *ibid*



The primary requirement of calcareous material for cement making is that the percentage of calcium carbonate should be 75 or over. It will be seen that only Saharanpur Nos. 1 and 2 meet this requirement; the other samples of *kankar* would require admixture with some other material richer in calcium carbonate for cement making. But the Saharanpur *kankars*, e.g., Nos. 1 and 2 mixed together, should produce a mixture suitable for cement making. Taking, for example, the specifications given in the article on cement in Thorpe's *Dictionary of Chemistry* for finished cement—

CaO	. . . . .	from 58.0 to 67 per cent. ; mean 62.5
SiO <sub>2</sub>	. . . . .	from 18.0 to 27 "
Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub>	. . . . .	from 5.0 to 17 "

and calculating a mixture of Saharanpur Nos. 1 and 2, which would give 62.5 per cent. CaO in the finished product, the analysis is found to be—

		Per cent.
CaO	. . . . .	62.5
SiO <sub>2</sub>	. . . . .	26.4
Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub>	. . . . .	11.1

so that all the constituents would lie within the prescribed limits. There would apparently be no trouble as regards MgO, which should not exceed 3 per cent.

This preliminary consideration of old analyses justified the belief that a suitable mixture of *kankars* or a mixture of *kankar* with a small quantity of some material richer in calcium carbonate should yield satisfactory cement.

An enquiry was therefore made as to the amount of *kankar* available. As already mentioned, the general impression gained from residence in the Province is that any amount of *kankar* is available in almost any part of it. An enquiry was addressed to all Executive Engineers as to the amounts available in their divisions, and the following estimates were obtained for the different districts. In the following list the districts are given from north to south and from west to east of the Province, so that it gives at a glance an idea of the distribution of the material in the Province :

Dehra Dun	. . . . .	Nil
Saharanpur	. . . . .	1,744 lakhs c.ft.
Roorkee	. . . . .	no return.
Muzaffarnagar	. . . . .	3,348 lakhs c.ft.
Meerut	. . . . .	5½ lakhs c.ft. annually.

Moradabad . . . . .	{ (1) 3 lakhs c.ft. (2) 13 lakhs c.ft. (3) 3,766 lakhs c.ft annually.
Pilibhit . . . . .	. more than 4 lakhs c.ft.
Bulandshahr . . . . .	. 11 lakhs c.ft. annually.
Bareilly . . . . .	. 4 lakhs c.ft.
Aligarh . . . . .	{ (1) 1.5 lakhs c.ft. (2) 1.7 lakhs c.ft. annually.
Budaon . . . . .	. 1 lakh c.ft.
Shahjahanpur . . . . .	. 1½ lakhs c.ft.
Kheri . . . . .	. ½ lakh c.ft.
Muttra . . . . .	{ (1) 32 lakhs c.ft. (2) plenty
Etah . . . . .	. 96½ lakhs c.ft.
Sitapur . . . . .	. ½ lakh c.ft.
Mainpuri . . . . .	. 25½ lakhs c.ft.
Hardoi . . . . .	. 1½ lakhs c.ft.
Gonda . . . . .	. small quantities all over.
Agra . . . . .	. 8½ lakhs c. ft.
Etawah . . . . .	. no information.
Bara Banki . . . . .	. plenty.
Cawnpore . . . . .	. 0.1 lakh c.ft.
Fyzabad . . . . .	} plenty.
Rai Bareli . . . . .	
Sultanpur . . . . .	
Partabgarh . . . . .	} small quantities.
Jhansi . . . . .	

The returns from Saharanpur, Muzaffarnagar and Moradabad (3), which are, roughly speaking, one hundred times as great as the other returns, were all given by one engineer and in the form of an estimate of the area of the *kankar* beds with the thickness of the strata, whilst the others were in the form of an estimate of the amount available from the quarries. Hence the discrepancy. One officer gave his returns as the amount available annually, and as these are of the same order as other estimates for the same and adjacent districts, it is probable that in all cases the estimates were intended as the amount available annually.

Mr. Vick, Agricultural Engineer to the Government of the United Provinces, has kept records of the strata passed through in sinking tube wells in many parts of the Province, and strata of *kankar* were invariably passed through, generally amounting to many feet altogether.

Mr. Hallidy, speaking in connection with cement manufacture, says that the portions of the United Provinces served by the Oudh and Rohilkhand Railway contain very large deposits of lime *kankar*. He took samples from places which would evidently give a large supply, and these places were Badshahpur, Utrawari, a place between Balamau and Daluagar, mile 9 on the Balamau-Anhadpur Branch, mile 3 on the Sitapur Branch, Belakhera, Lachmanpur A. R. C. Railway, a place between Baghaulti and Balamau, Phapamau, Dauadpur, Partabgarh, a place between Dilarmau and Rai Bareli, Chandnagar. He also remarks that a very large quantity of *kankar* is found on the Cawnpore-Banda Railway at the Jumna River and at the Chandrawal River and that the supply is replenished from year to year.

The general conclusion from these data is that plenty of *kankar* is available almost anywhere in the Province, and that, if this material is suitable for cement manufacture, a large factory might be started at almost any place in the Province and be sure of a sufficient supply of the material. A factory turning out 100 tons of cement *per diem* would consume something like 7 lakhs cubic feet per annum.

From considerations of demand for the finished product and distance from the coalfields some place near Cawnpore or Lucknow seems most suitable for the location of a cement factory. A sample of Cawnpore *kankar* gave the following analysis:

	Per cent.
CaO . . . . .	29.00
SiO <sub>2</sub> . . . . .	31.10
Fe <sub>2</sub> O <sub>3</sub> +Al <sub>2</sub> O <sub>3</sub> . . . . .	11.60
MgO . . . . .	2.30

This would require admixture with a more highly calcareous material for the manufacture of cement. The samples of *kankar* already referred to, viz., Saharanpur Nos. 1 and 2 which had a percentage of calcium carbonate over 75, seem to have been exceptional, and, indeed, the samples Lucknow Nos. 1 and 2, with figures approximating to 75, seem also, exceptional. Hallidy gives the analysis of 15 samples of *kankar* from the places on the Oudh and Rohilkhand Railway already mentioned, and the percentage of CaO lies between 13.42 and 26.16, whilst 75 per cent. calcium carbonate is equivalent to 42 per cent. CaO. The nearest approach

to this figure in the samples analysed by Hallidy was the *kankar* from Chandrawal, which had 38·84 per cent. CaO.

A very important consideration was raised by Hallidy when he remarked that the percentage of magnesia in *kankars* from the Oudh and Rohilkhand Railway was frequently too high for cement manufacture. According to British Standard Specifications the percentage of MgO in finished cement should not exceed 3; the American Standard Specifications permit 4. In twelve samples of *kankar* from the Oudh and Rohilkhand Railway Hallidy found a minimum of 2·44 per cent. MgO and a maximum of 8·34 per cent. MgO. Even the minimum is coming unpleasantly near the British Standard Specification maximum limit, when it is remembered that, owing to loss of carbonic acid on burning, the percentage of magnesia in finished cement is higher than that in the raw materials. The lowest percentage of magnesia was found by Hallidy in the *kankar* from Chandrawal, Cawnpore-Banda Railway (1·73 per cent.). These results are strikingly different from those of Thomson (*loc. cit.*) who records MgO *nil* in Allahabad *kankar*, a trace only in three samples from Saharanpur, 0·4 only in Ghazipur *kankar* and MgO only exceeding 2 per cent. in material from Aligarh. But the method of analysis described by Thomson is faulty and would not detect or estimate any magnesia present as silicates insoluble in dilute acid. This question of magnesia is very important. It is believed that reliable cements can be made containing considerably more than 4 per cent. MgO, but one or two serious accidents which were due to faults developing after several years in cement containing a high MgO content have caused engineers to be very suspicious of excess of magnesia, and no engineer with British training would care to use on important work any cement containing more than 3 per cent. Consequently, any proposition to use for cement manufacture material with a high magnesia content would certainly be rejected if material were available more suitable in this respect. Mr. Musgrave informs the writers that in India many otherwise suitable sites for factories have had to be passed over owing to the presence of excessive magnesia.

The writers have analysed some additional samples of *kankar* from Shikohabad, Agra, Meerut and Delhi and have obtained 4·99 per cent., 1·88 per cent., 5·04 per cent. and 7·42 per cent. magnesia, respectively. From the observations available it is not easy to find any certain relation between geographical position and magnesia.

content; but, at any rate, no sample of *kankar* with too high a percentage of magnesia has so far been recorded from the south-west of the Province, and it may be that calcareous deposits in the alluvium in the north-east of the Province, deriving from the Himalayas, contain rather too much magnesia, whilst those in the south-west, which may be derived from the rocks of the Central Provinces, are more satisfactory in this respect. Mr. Musgrave is of the opinion that in the Dehri-on-Sone district, where there are large deposits of limestone, much is suitable for Portland cement manufacture but large quantities are unsuitable owing to high magnesia content. Sufficient work has not yet been done on the *kankars* of this Province to say definitely that beds with a sufficiently low percentage of magnesia do not occur in all parts of the Province.

It has already been remarked that the percentage of calcium carbonate in most of the *kankars* is lower than that required in a mixture for cement manufacture. The commonest form of *kankar* is nodular, and clayey matter is retained in the cavities and crevices of the nodules. Washing the nodules raises the percentage of calcium carbonate to some extent, but not generally sufficient to make the *kankar* suitable for cement manufacture without the addition of other calcareous matter.

As already mentioned, Hallidy discovered deposits of marl near Lucknow and has published a detailed survey of the beds at Dilarmau and Madharmau, from which he calculated that they would feed a factory turning out 100 tons of cement daily for 40 years. He gave numerous analyses of the marl from these beds in which the CaO percentage was generally above 42 and the MgO percentage, in the few samples in which it was estimated, was about 1.6. Analysis of samples sent to the Government Test House at Alipore confirmed these figures.

On reading Hallidy's report it struck the authors that one very necessary piece of information was wanting, *viz.*, whether the high percentage of CaO persisted from top to bottom of the beds surveyed by Hallidy or whether the samples analysed were above the average in this respect. A visit to Madharmau and Dilarmau produced temporary misgiving on this point, as the material excavated frequently differs in colour from top to bottom of the beds. But analysis of a good many samples taken from top to bottom of the

beds showed a consistently high percentage of CaO. The analytical figures obtained were :—

*Percentage of CaCO<sub>3</sub> in the samples of marl of the Lucknow district (calculated on the percentage of CO<sub>2</sub> evolved from dry material)*

	Per cent.
Contractor's sample from Dilarman . . . . .	71.2
Dilarman No. 1 . . . . .	89.5
Dilarman No. 2 . . . . .	89.6
Madharmau, from a heap near the main road . . . . .	71.7
Madharmau, 18 feet under the surface . . . . .	89.3
Madharmau, white . . . . .	76.2
Birwa . . . . .	81.1
Madharmau, 18 ft. . . . .	84.4
Madharmau, 12 ft. main road . . . . .	78.8
Madharmau, 12 ft. . . . .	87.0

A typical, large sample used for experiments on cement manufacture analysed :—

	Per cent.
CaO . . . . .	46.50
SiO <sub>2</sub> . . . . .	9.50
Fe <sub>2</sub> O <sub>3</sub> and Al <sub>2</sub> O <sub>3</sub> . . . . .	3.80
MgO . . . . .	2.1

One interesting feature of these marl beds not mentioned by Hallidy is the occurrence in them of innumerable very small mollusc shells.

The travertine deposits near Hardwar and the calcareous deposits near Kathgodam and Tanatpur have not been examined by the writers. They understand that Mr. A. D. Banerjee, who has experience as a cement chemist and was assistant to Hallidy, was placed on special duty by the Irrigation Branch of the Public Works Department to investigate the Tanatpur deposits and decided that they were not so suitable as the Lucknow marl.

The Geological Survey Department, when asked for information about the calcareous deposits of the Province, singled out the limestone of Almora. A sample was analysed by the Industrial Chemist to the Government of the United Provinces, who reported—

	Per cent.
Calcium carbonate . . . . .	96.00
Magnesium carbonate . . . . .	3.00
Iron and alumina . . . . .	1.5
Insolubles . . . . .	0.35

But the inaccessibility of Almora makes this of very little practical interest.

The attention of the writers was directed by Mr. M. Sinha, who was a Deputy Director of Industries in this Province in 1920, to the limestone deposits in the south of the Mirzapur district. According to the District Gazetteer there are large quantities of limestone in that locality, and also coal, but at present the area is almost inaccessible. A survey for a branch railway across this area has been notified in the Gazette, and when this has been constructed the mineral wealth of the Mirzapur district may be exploited. Without this the only possibility of getting out the limestone from this area would be by boat on the Sone, when it would be carried to Dehri-on-Sone and would come into direct competition with the large quantities of limestone already available in the neighbourhood.

The limestone in the neighbourhood of Sutna and Katni is probably the nearest and best. The Sutna Stone and Lime Co., Ltd., publish the following analysis of lime prepared from their limestone :—

Calcareous material  
which might be im-  
ported

	Per cent.
Lime . . . . .	94.20
Magnesia . . . . .	1.00
Oxides of iron and alumina . . . . .	1.70
Sulphuric acid . . . . .	0.10
Carbonic acid . . . . .	trace
Siliceous matter . . . . .	2.80
Alkalies and loss . . . . .	0.20
	<hr/>
TOTAL . . . . .	100.00

A sample of limestone supplied by them for the authors' experimental work analysed :—

	Per cent.
CaO . . . . .	53.40
SiO <sup>2</sup> . . . . .	3.20
Fe <sub>2</sub> O <sub>3</sub> and Al <sub>2</sub> O <sub>3</sub> . . . . .	1.50
MgO . . . . .	1.20

It was stated, however, by the General Manager of the Katni Cement Works that limestone purchased by them from Sutna did not average such a high percentage of CaO, and, in fact, in some cases approximated to 42 per cent.

## B.—ARGILLACEOUS MATERIALS

*Kankar* may be regarded as a mixture of calcareous and argillaceous materials, with the latter generally present in larger quantity than is required for a cement mixture. The alumina, iron and silica seem generally present in suitable relative proportions.

To make cement from the Lucknow marls would require clay adjacent to the marl. There is clay both above and below the marl which appears to be of suitable quality. Hallidy gives several analyses. If the clay is taken too near the surface it may contain sand, which does not reach well in the furnace during the manufacture of the cement, but there appears to be plenty of clay free from this defect. The percentage of MgO, according to Hallidy, runs from 1.66 to 3.7. Samples obtained for the authors' experiments on cement manufacture analysed :

	Madharman clay	Dilarmau clay
	Per cent.	Per cent.
CaO . . . . .	33.26	2.24
SiO <sub>2</sub> . . . . .	24.09	53.91
Fe <sub>2</sub> O <sub>3</sub> and Al <sub>2</sub> O <sub>3</sub> . . . . .	10.83	26.03
MgO . . . . .	2.52	2.84

The worst feature about these clays is the percentage of MgO. Taken with the typical marl from this area in a suitable proportion for cement manufacture, calculation shows that the cement would contain from 3.3 to 3.4 per cent. of MgO. Analysis of cement actually produced from these materials gave 2.9 to 3.2 per cent. of MgO.

Clay from the brickfields at Alambagh, Lucknow, was also analysed to see whether it was any better as regards the percentage of MgO. It was not appreciably better.

Some experiments in washing the ground mixture of marl and clay showed that this would bring down the MgO percentage in the finished cement within the 3 per cent. limit of the British Standard Specifications.

## C.—FUEL AND OTHER SOURCES OF POWER

Irrigation engineers have considered the project of manufacturing cement with wood, charcoal or *upla* (cow-dung cakes) as fuel,



but now-a-days it is doubtful whether anything but powdered coal, which is the fuel required for rotary furnaces, is worth considering. It is doubtful whether cement of sufficient strength to meet modern requirements could be manufactured by the use of other fuels. By the use of coal or coke in vertical furnaces the Porbundar factory was not able to get the same strength as that obtained by the Bundi and Katni factories by means of rotary furnaces. Even inferior grades of coal are not suitable for cement manufacture. At Katni coal from the Bengal coalfields is used. Coal is obtainable much nearer to Katni in the Central Provinces, but it has not been found satisfactory for the rotary furnace as its calorific power is not sufficiently great. It is stated that a cement factory is to be started in the Central Provinces with a new type of furnace recently invented in Germany for the use of low-grade fuel and that it is intended to use Central Provinces coal in this factory.

But even if it is now possible to use low-grade fuels in the manufacture of satisfactory cement, it is doubtful whether any other fuel can compete with Bengal coal in the United Provinces. The senior author of this *Bulletin* published a Note on "The Calorific and Manurial values of Indian Cow-dung commercially considered" as a supplement to the *Indian Trade Journal* of the 27th August 1908, and he there summarized the relative calorific powers and prices of various fuels in the United Provinces as follows:—

Fuel	Calorific power (calories per gram)	Cost in annas per maund
Cow-dung cake . . . . .	2,400	4.5
Firewood . . . . .	4,000	8.0
Kerosene oil . . . . .	10,900	71.5
Bengal coal . . . . .	6,600	8.8

From these figures it will be seen that Bengal coal was then the cheapest fuel. The prices were retail, but the wholesale price would have been still more in favour of coal. Prices of all commodities have changed greatly since 1908, but there seems to be no particular reason for thinking that the relative prices of the different fuels have changed to any considerable extent.

## ECONOMIC CONSIDERATIONS

The high price to which imported Portland cement rose during the war and the equally high price of cement manufactured in the country made the manufacture of this material appear a very attractive proposition in 1920. At the present time (1922) owing to general financial depression there is not the same eagerness to undertake any new enterprise. Wages have risen and labour has become more expensive, and at the present time the cost of buildings and machinery is very high. The large capital required to start cement works under present conditions can be judged from the paid up ordinary capital of the Central Provinces Portland Cement Co., Ltd., which is Rs. 60 lakhs.

The price of cement at Indian ports in 1921 was about Rs. 125 per ton. Although it has dropped, it is still about Rs. 105 per ton, and with calcareous material at about Rs. 2-8 per ton there still seems ample room for profit in the manufacture. Taking, for instance, the project of manufacturing cement at Cawnpore from local *kankar* and Sutna limestone, for 1 ton of cement about 0·8 ton of Cawnpore *kankar*, 0·8 ton of Sutna limestone and 0·75 ton of coal would be required. The cost of raw materials and fuel would be approximately :—

	Rs. A.
0·8 ton Cawnpore <i>kankar</i> at Rs 2·8 per ton . . . . .	2 0
0·8 ton Sutna limestone (f. o. r. Sutna) at Rs. 2·8 per ton . . . . .	2 0
0·75 ton Bengal coal at Rs. 15 per ton . . . . .	11 4
Freight on 0·8 ton limestone from Sutna (about 250 miles) at 0·23 pie per maund per mile, and on 0·75 ton coal from coalfields (about 250 miles) at 0·15 pie per maund per mile . . . . .	10 4
TOTAL . . . . .	25 8

But it would, no doubt, be unsafe to rely on the present high price of cement. In fact, the proper expansion of the demand for this building material is, no doubt, dependent on a drop in price. The present high price of imported cement is due largely to high shipping freights. The present quotation for Portland cement, Best English, delivered London, is 70s. 6d. to 76s. per ton. The pre-war figure was about Rs. 23 per ton f.o.b. at English ports.

In forming an opinion as to the soundness of any project for manufacturing Portland cement in the United Provinces it would be safer not to rely on the present high price of this article but to compare the cost of production in the Province with the cost of production in other parts of India. For the local market the local factory would have the advantage over other factories in the matter of freight on the finished article. It seems scarcely necessary to consider the question whether Indian Portland cements as a whole will be able successfully to stand the competition of imported cements. With suitable calcareous material alongside the coal, as at Japla near Dehri-on-Sone, about 350 miles from Calcutta, the largest consuming centre, there seems no reason to doubt the ability of the Indian industry to face foreign competition.

Cawnpore and Lucknow are well situated as supply centres for the United Provinces. Any imported cement is bound to pass through either Cawnpore or Lucknow, so that for the provincial market we can compare the cost of manufacturing at Cawnpore or Lucknow with the cost of manufacturing at other Indian factories *plus* the freight on the cement to Cawnpore or Lucknow. A prosperous cement works is in existence at Katni, but a factory which should have a greater advantage from position is that which is being erected at Japla near Dehri-on-Sone which will be very close both to limestone and coal. For the purpose of calculation the freight on coal may be taken as 0.15 pie per maund per mile and that on cement and limestone as about 0.23 pie per maund. The East Indian Railway have quoted the writers a rate of 4 annas 3 pies per maund for limestone from Sutna to Cawnpore (Schedule C, O.R., C.C., L) and this works out at about 0.23 pie per maund.

For each ton of cement manufactured at Cawnpore from local *kankar* and Sutna limestone freight would have to be paid on 0.8 ton limestone from Sutna (about 250 miles) at 0.23 pie per maund per mile, and on 0.75 ton of coal from the coalfields (about 250 miles) at 0.15 pie per maund = Rs. 10.4 per ton.

For each ton of cement manufactured at Katni and carried to Cawnpore freight would have to be paid on 0.75 ton of coal from the coalfields to Katni (about 250 miles), and on 1 ton of cement from Katni to Cawnpore = Rs. 12.2 per ton.

For each ton of cement manufactured at Japla near Dehri-on-Sone and carried to Cawnpore (about 250 miles) freight of Rs. 8.1 would have to be paid = Rs. 8.3 per ton.

According to this calculation the cement manufactured at Cawnpore would have an advantage over Katni cement for United Provinces markets but would be at some disadvantage compared with the works being constructed at Japla.

The manufacture of cement near Lucknow from local marl and clay would have an advantage over the Cawnpore project because a Lucknow factory would not have to pay freight on any raw material except coal.

For each ton of cement manufactured at Lucknow freight of Rs. 4-11 per ton would have to be paid on 0.75 ton of coal from the coalfields to Lucknow—Rs. 4-11 per ton.

So that for the United Provinces market it would have a freight advantage even over the Japla works.

A point remaining for consideration is the demand for Portland cement in India in general and in the United Provinces in particular, and whether there is any danger of the cement factories in India producing more than is required or of a factory in the United Provinces producing more than is required for the local market.

The following figures give the imports into British India :—

	Total imports (cwt.)						
	1914-15	1915-16	1916-17	1917-18	1918-19	1919-20	1920-21
Private merchandise	2,899,451	2,632,505	1,787,764	1,675,105	548,540	77,230	127,420
Government stores (cwt.)	415,028	216,876	163,096	36,782	...	982	7,375

No figures for Portland cement are given in the annual reports on the Inland Trade of the United Provinces nor are such figures obtainable elsewhere.

Hallidy remarks that the total weekly output of the three modern cement factories in India in 1916 was approximately 1,500 tons. Several other factories of much greater dimensions are being started. It may be expected, therefore, that sufficient quantity will be produced in India in the near future to satisfy the present needs of the country. But the necessity for a greatly extended use of cement on railways is apparent to any railway engineer, and Hallidy understands that irrigation engineers would use enormous quantities of cement on the canals if they could get it sufficiently cheap. The extension of the use of reinforced concrete in India is most desirable for many reasons and this, again, would consume large quantities of cement.

### EXPERIMENTAL INVESTIGATIONS

From the preceding chapters it will have been gathered that two projects for manufacturing Portland cement in the United Provinces appear promising, *viz.*: (1) from marl found near Lucknow and adjacent clay, (2) from Cawnpore *kankar* and Sutna limestone. Chemical analysis of these materials indicates that they would be suitable for the purpose. But the capital necessary for starting a modern cement factory made it appear desirable to confirm the results of analysis by making cement on a small scale, if possible, from the suggested materials and testing the properties of the product produced.

Very little information could be obtained about a small furnace suitable for making cement on a laboratory scale. Hallidy says that he had not the time to get the necessary grinding apparatus from England and that burning was difficult as the necessary fine grinding and the small size of the furnace forced the use of very small specimens which lost a certain amount of lime in burning through contact with the fuel ash. Most text-books or treatises on Portland cement say nothing about production on a laboratory scale. Towards the end of the writers' investigations they found some description of furnaces for small-scale work in Meade's "Portland Cement," but the author there observes that in a small furnace which he had he could never quite get the temperature up to the point necessary for a thorough burning of the Lehigh cement-rock limestone mixtures without adding some soda to the mixture. In another part of his book he remarks that alkali makes cements quick-setting, and that the way in which this trouble may be surmounted to some extent is to raise the temperature of burning. It therefore seemed very doubtful whether Meade had been able to manufacture really satisfactory cement in his small furnace, and the present writers did not think it worth while further to delay their report in order to experiment with a furnace according to his design. Meade also refers to the experimental rotary furnace used by E. D. Campbell of the University of Michigan, but in this investigation (Original papers, *Jour. Amer. Chem. Soc.*, XXIV, 248 and 969) he does not mention how his products stood the ordinary tests for tensile strength and soundness.

The writers' first experimental burnings were made in a simple wind furnace constructed first of ordinary bricks and afterwards of

fire-clay bricks. The dry, powdered mixture was placed in fire-clay crucibles covered with fire-clay lids and the crucible were completely surrounded by fuel. The mixture reacted with the walls of the crucible, producing a kind of glass at the surface of contact, and the clinker had to be carefully separated from this glass. This reduced the yield of clinker considerably, and there was always uncertainty as to whether the whole of the clinker had not been influenced to a certain extent by the fire-clay crucible.

The first modification was to make the mixture into a paste with water, mould it into balls generally about the size of a cricket-ball, and then, after air-drying, to place it in the furnace in direct contact with the fuel. Charcoal was tried as fuel but did not seem to give such good results as good coke, perhaps because the charcoal was lighter and burnt away too quickly. After burning it was seen that the cement material had reacted with the coke-ash at a few points to produce a more fusible clinker, but the outer layer was removed before grinding and testing the clinker. In the earlier burnings this was very easy, as the balls were found to have a concentric structure and, on cooling, generally broke up, the outer layer separating from the inner portion. Analysis of the finished cement showed that the coke-ash had not appreciably affected it.

Before any burnings could be made, the proportions in which the two ingredients were to be mixed had to be calculated. In the first experiments the writers took the limits for Portland cement mentioned in the article on "Cement" in Thorpe's *Dictionary of Applied Chemistry*, viz., CaO must lie between 58 per cent. and 67 per cent., SiO<sub>2</sub> between 18 and 27 and Al<sub>2</sub>O<sub>3</sub> plus Fe<sub>2</sub>O<sub>3</sub> between 5 and 17. The writers calculated a mixture of marl and clay which, after burning, would contain CaO, SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> plus Fe<sub>2</sub>O<sub>3</sub> within these limits and, as the limits are rather wide, a mixture was selected which would approach as nearly as possible to the mean of these limits. A similar procedure was followed in experimenting with Cawnpore *kankar* and Sutna limestone.

The materials taken for the experiments had the following composition :—

Madharmau marl			Madharmau clay		
		Per cent.			Per cent.
	SiO <sub>2</sub>	. . . 9.50		SiO <sub>2</sub>	. . . 24.09
	Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub>	. . . 3.80		Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub>	. . . 10.83
	CaO	. . . 46.80		CaO	. . . 33.20
	MgO	. . . 2.1		MgO	. . . 2.52

Cawnpore <i>kankar</i>		Sutna limestone	
		Per cent.	Per cent.
	SiO <sub>2</sub> . . .	31.10	SiO <sub>2</sub> . . . 3.20
Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub> . . .		11.60	Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub> . . . 1.50
	CaO . . .	29.00	CaO . . . 53.40
	MgO . . .	2.30	MgO . . . 1.20

and the first burnings were made with the following mixtures:—

57.7 parts marl  
42.3 parts clay

Calculated composition of burnt mixture	Mean of limits mentioned in <i>Thorpe's Dictionary</i>
SiO <sub>2</sub> . . . 23.8	SiO <sub>2</sub> . . . 22.5
Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub> . . . 10.3	Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub> . . . 11.0
CaO . . . 62.4	CaO . . . 62.5
MgO . . . 3.5	MgO . . . ...

53.4 parts Sutna limestone  
46.6 parts Cawnpore *kankar*

SiO <sub>2</sub> . . . . .	24.5
Al <sub>2</sub> O <sub>3</sub> and Fe <sub>2</sub> O <sub>3</sub> . . . . .	9.4
CaO . . . . .	63.5
MgO . . . . .	2.6

For these first experiments only a 100-mesh sieve was available. The materials were mixed in the desired proportion, ground and passed through the sieve, the residue being further ground until all had passed through the sieve. This procedure was adopted with the idea of getting an intimate mixture at the same time as the material was reduced to the requisite degree of fineness.

The material, either in a crucible or in the form of balls, was placed in the furnace surrounded by coke, the furnace was filled up with coke and the fire started. It took about two hours to attain the maximum temperature, which was maintained for about two hours. When the fire had burnt out the material was removed, the good clinker separated from the glass or outer layer, mixed with 1 per cent. calcium sulphate, powdered, passed through the 100-mesh sieve, allowed to stand in the air for a few days and subjected to the standard tests for (1) tensile strength, (2) soundness, (3) setting time.

The first experiments gave the following results:—

MARL AND CLAY

Experiment No.	TENSILE STRENGTH (LB. PER SQUARE INCH)		Expansion (mm.)	Setting time
	7 days	28 days		
4 . . . . .	..	210	1.5	..
7 . . . . .	190	300	..	..
8 . . . . .	190	300	..	..
9 (inner clinker)	410	425	..	..
(outer clinker)	180	..	..	..
11 . . . . .	350	400	1.0	Quick
13 . . . . .	435	495	..	Quick

CAWNPORE *kankar* AND SUTNA LIMESTONE

6 . . . . .	{ 300	480	..	..
	{ 260			
12 . . . . .	{ 240	..	..	..
	{ 220	..	..	..
	{ 285	..	..	..

British Standard Specifications require a tensile strength of at least 450 lb. per square inch after 7 days and a tensile strength after 28 days equal to tensile strength at 7 days  $\frac{40,000}{\text{tensile strength at 7 days}}$

Soundness is measured by expansion in Le Chatelier's gauge, which must not exceed 12 mm.

From these tests it will be seen that the writers had almost attained success with the marl and clay mixture but were very far from it with the *kankar* and limestone.

The fact that success had almost been attained in one case appeared to indicate that it was not so much the burning which was at fault as the method of calculating the mixture. In the case of the marl and clay a fairly correct mixture had been obtained, but this was not so in the case of *kankar* and limestone.

Mr. A. D. Banerjee, who was for some time assistant to Mr. Hallidy and had also been employed by the Bundi Cement Works, informed the writers that the correct mixture should not be calculated as they had done but by the application of Newberry's formula.



A re-calculation in the way suggested by him gave a mixture of 61.4 parts Sutna limestone and 38.6 parts *kankar* lime. But this mixture, on burning in the authors' furnace, gave a clinker which fell to pieces and had no setting properties at all.

The writers then considered various possible ways of calculating the mixture. In the *Journal of the Society of Chemical Industry*, 1907, p. 1280, R. K. Meade gives the following limits of chemical composition met with in freshly made American Portland cements which pass the standard specifications for soundness, setting-time and tensile strength:— $\text{SiO}_2$ , 20-24 per cent.;  $\text{Al}_2\text{O}_3$ , 5-9 per cent.;  $\text{Fe}_2\text{O}_3$ , 2.4 per cent.;  $\text{CaO}$ , 60-63.5 per cent.;  $\text{MgO}$ , 1.2 per cent.; and  $\text{SO}_3$ , 1.5 per cent. These are narrower limits than those given in Thorpe's *Dictionary*.

The *Chemists' Year Book* shows 12 analyses of typical Portland cements, and gives another set of limits of chemical composition which agree fairly well with Meade's limits.

Careful consideration convinced the present writers that these figures needed some correction before they could be used as a guide in calculating a mixture. The mean of the 12 analyses shown in the *Chemists' Year Book* is given in column 1 of the calculation below:—

	Mean of 12 analyses	Same minus $\text{CaSO}_4$	Same re- calculated to 100
$\text{CaO}$ . . . . .	62.79	61.79	65.06
$\text{Al}_2\text{O}_3$ . . . . .	7.05	7.05	7.42
$\text{Fe}_2\text{O}_3$ . . . . .	3.02	3.02	3.18
$\text{MgO}$ . . . . .	1.58	1.58	1.66
$\text{SiO}_2$ . . . . .	21.52	21.52	22.65
$\text{SO}_3$ . . . . .	1.41	...	...
TOTAL . . . . .	...	94.96	99.97

Now the first five of these constituents add up to 100 in the calculated composition of a burnt mixture of calcareous and argillaceous



materials, but in actual cement analysis these constituents do not add up to 100 because there is always some  $\text{SO}_3$ , loss on ignition, alkali, etc. Deducting an amount of  $\text{CaO}$  equivalent to the  $\text{SO}_3$ , because this represents  $\text{CaSO}_4$  added after burning, the figures shown in column 2 are obtained, which add up to 94.96. Re-calculating these on a basis of 100 to make allowance for loss on ignition a corrected mean is obtained (column 3) which can be used in calculating a mixture.

It was next calculated that a mixture of Cawnpore *kankar* and Sutna limestone could be made which, on burning, would give exactly these percentages of  $\text{CaO}$  and  $\text{SiO}_2$  but would be a little low as regards  $\text{Al}_2\text{O}_3$  plus  $\text{Fe}_2\text{O}_3$ . This calculation is shown in the accompanying diagram, where the continuous line represents the composition of burnt Cawnpore *kankar* and the line of dashes the composition of burnt Sutna limestone. They cross twice. Any line which passes through these points of intersection represents the composition of a mixture which may be obtained from those materials. The dotted line which passes through these points of intersection is seen to give exactly the corrected mean percentages of  $\text{CaO}$  and  $\text{SiO}_2$  of the 12 typical analyses. The proportion of the burnt *kankar* and limestone required to give a mixture of this composition is easily calculated from the diagram. Thus

$$\frac{\text{percentage of CaO in burnt limestone } 65.0}{65.06 \text{ percentage of CaO in burnt kankar}} = \frac{\text{amount of burnt kankar to be taken}}{\text{" " " limestone " " "}}$$

This would require a mixture of 56.4 parts Sutna limestone and 43.6 parts Cawnpore *kankar*.

According to British Standard Specifications the ratio  $\frac{\text{CaO}}{\text{SiO}_2 + \text{Al}_2\text{O}_3}$  (in chemical equivalents), known as the Hydraulic Modulus, should lie between 2.0 and 2.85. These are very wide limits and almost any mixture will meet these requirements. For the 12 analyses given in the *Chemists' Year Book* the limiting values for the Hydraulic Modulus are 2.46 and 2.78 with a mean of 2.64. A mixture of 57.8 parts Sutna limestone and 42.2 parts Cawnpore *kankar* would give this Hydraulic Modulus.

According to Newberry's ideas that good Portland cement should be a mixture of tricalcium silicate and dicalcium aluminaté,  $\frac{\text{CaO} (3a+2b)}{a \text{ SiO}_2 + b \text{ Al}_2\text{O}_3} = 1$  (where  $\text{CaO}$ ,  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  are in chemical equivalents). A modification of this formula which makes allowance for  $\text{Fe}_2\text{O}_3$  and  $\text{MgO}$  is  $\frac{2.8 \text{ SiO}_2 + 1.1 \text{ Al}_2\text{O}_3 + 0.7 \text{ Fe}_2\text{O}_3}{\text{CaO} + 1.4 \text{ MgO}} = 1$ . This would give a mixture of 59.8 parts Sutna limestone and 40.2 parts *kankar*.

These various calculations are put together in the following small table :—

	Already taken	Calculated to give H.M.=2.64	Calculated according to Newberry's formula	Calculated to give corrected mean of 12 typical analyses
Cawnpore <i>kankar</i> . . . .	46.6	42.2	40.2	43.6
Sutna limestone . . . .	53.4	57.8	59.8	56.4

Before starting on a fresh series of burning experiments it was found necessary to prepare and analyse a fresh lot of ground *kankar*. This gave the following analysis :—

SiO <sub>2</sub> . . . . .	31.34
Al <sub>2</sub> O <sub>3</sub> . . . . .	8.86
Fe <sub>2</sub> O <sub>3</sub> . . . . .	3.09
CaO . . . . .	30.34
MgO . . . . .	2.42

Calculating (1) a mixture to give a Hydraulic Modulus of 2.64 and (2) a mixture to give CaO and SiO<sub>2</sub> the same as the corrected means from the 12 typical analyses, and taking the mean, a mixture was obtained of—

	Parts
Sutna limestone . . . . .	56.4
Cawnpore <i>kankar</i> . . . . .	43.6

which was used in the further experiments.

Calculation in the same way gave a mixture of :—

	Parts
Madharman marl . . . . .	65.9
„ clay . . . . .	34.1

By this time one of Morgan's small prospectors' furnaces had been obtained, in which a temperature of 1,250°—1,300°C could be attained (as determined by Segers' Cones), and sieves of 150 and

180 mesh. The following burnings were performed in Morgan's small prospectors' furnace with good coke :—

Experiment No.	Mesh of sieve through which mixture was passed	Conditions of heating	TENSILE STRENGTH		Expansion in mm.	Setting time
			After 7 days	After 28 days		
		<b>CAWNPORE <i>kankar</i> AND SUTNA LIMESTONE</b>				
16	150	Kept for 4 hours at full heat of furnace.	435	..	70	
17	150	Some of balls from previous experiment were again heated for 4 hours at full heat of furnace.	675	..	41 (after 1 day) 27 (after 14 days)	
18	150	Allowed the coke in the furnace to burn completely out.	540	705	4	
20	180	Allowed the coke in the furnace to burn completely out.	360	..	1	Medium
		<b>LUCKNOW MARL AND CLAY</b>				
21	180	Allowed the coke in the furnace to burn completely out, and again heated under same conditions.	648	..	19	Medium
22	180	Burnt only once, allowing the coke to burn completely out.	655	..	1.5	Quick

It will be seen from the foregoing table that complete success was attained with Lucknow marl and clay and also with Cawnpore *kankar* and Sutna limestone, *e.g.*, in Experiments 18 and 22. But the results were not so consistent as had been hoped. The writers were especially troubled as regards soundness. A great deal of work was done before the question of soundness was settled. For a long time they thought that they were getting unsoundness because the temperature of the furnace was not high enough, and a large hand-worked forge-bellows was attached to the prospectors' furnace, thereby raising the attainable temperature to 1,460°C to 1,500°C as measured by Segers' Cones. Laborious experiments were also tried in the direction of raising the temperature very gradually, to imitate as closely as possible the thermal treatment which material receives in a large, modern rotary furnace. It is well known to cement manufacturers that a high lime mixture requires a higher burning temperature than one with a lower lime content, and endeavours were accordingly made to reduce the lime

content of the mixtures, but this could not be carried out without a prejudicial effect on the tensile strength. Eventually it was found that the experiments had been producing quite satisfactory cement for a long time without the fact being recognized, the reason being that the product had not been given a long enough time in which to season. Almost all soundness trouble disappears if the cement is allowed to season. The writers were put on the right track by Meade, who says (p. 471) "if cement that is unsound is stored for any length of time it will gradually become sound." This is illustrated by the behaviour of five samples of cement none of which were perfectly sound when freshly ground, one becoming sound after one day, another after seven days and the others taking 14, 28 and 90 days, respectively, but eventually becoming perfectly sound. Meade says "Cement which has seasoned sound is just as good as one which was sound when freshly made, and the writer does not think the engineer need concern himself whether the manufacturer prefers to make cement which is sound when fresh or whether he prefers to age it sound in his stock-house. So long as it is sound he is secure."

All the later cements produced showed satisfactory soundness after 17 days' seasoning. The following examples may serve to show that the writers were able consistently to produce satisfactory cement:—

Experiment No.	Mesh of sieve through which mixture was passed	Conditions of heating	TENSILE STRENGTH		Expansion in mm.	Setting time
			After 7 days	After 28 days		
24	180 mesh	CAWNPOR <i>bankar</i> AND SUTNA LIMESTONE Heated in prospectors' furnace with bellows for 2½ hours.	525	585	0.5	
26	180 mesh	Mixture made up in smaller balls. Heated in prospectors' furnace, slow burning at beginning, bellows for 1 hour at end, and fire allowed to burn out.	530	..	NU	
27	180 mesh	Heated for 7½ hours in old furnace without chimney, 7½ hours in new furnace without chimney, 3 hours in old furnace with chimney and 5½ hours in new furnace with chimney and bellows.	555	..	7.0 (after 5 days).	

## APPENDIX

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### REPORT ON THE POSSIBILITIES OF CEMENT MANUFACTURE IN THE TERRITORY SERVED BY THE OUDH AND ROHILKHAND RAILWAY

BY R. J. HALLIDY, B.E., M.I.C.E.

The writer addressed the President of the Railway Board, unofficially, in November 1917, and again in December 1918, on the desirability of an investigation into the possibilities of cement manufacture from the lime deposits on the Oudh and Rohilkhand Railway territory, with the view to a factory operated departmentally being started. He based his arguments on the high and increasing prices of both imported and Indian cements, and of the small output of the latter. He also addressed the Agents of the Eastern Bengal Railway and the Oudh and Rohilkhand Railway, and asked these officers to place their views before the Board. As the result of this correspondence, the Railway Board, in their letter No. 12-E.-19 of the 10th February 1919 to the Agent of the Eastern Bengal Railway, sanctioned the employment of the writer, for six months in the first instance, on special duty to study the lime deposits on the Oudh and Rohilkhand Railway. They made it clear, however, that this sanction did not imply that Government would undertake such an enterprise, even if the prospects were found to be favourable. The services of the writer could not be spared immediately by the Eastern Bengal Railway Administration, and work was not started until the 8th August 1919 when a small laboratory and office were opened at Roorkee.

2. Although the writer has been informed recently by the Railway Board, in their letter No. 12-E.-19 of the 13th January 1920, that they do not intend to set up a cement factory for the State Railways and that his investigations must therefore be largely academic, he considers it desirable, and, at any rate, useful to repeat and enlarge in this report his arguments for such extension of function on the part of the State Railways. He trusts this will not be considered as undue persistence in his own ideas, but the personnel of the Board has largely changed since the date of the correspondence leading to this enquiry. Moreover, this correspondence was entirely unofficial, and it should, therefore, be found useful to have every argument and fact connected with the matter in one report.

3. At present, in India, there are three factories turning out cement by modern methods. The total weekly output from these was, in 1916, approximately 1,500 tons. Several other factories of much greater dimensions are projected and may be expected to come shortly into being. There are also a few natural cement works which may in the near future change the character of their product to Portland cement. It may be expected, therefore, that sufficient quantity will be produced in India, in the near future, to satisfy the present needs of the country. The writer does not consider it likely that prices will fall to any great extent, unless a stimulus thereto is supplied by Government, or unless imported cement causes such fall

by competition, and this is a relief that cannot reasonably be expected for a long time. Under modern business conditions, it is no longer safe to rely on competition between manufacturers in the same country to keep prices to a reasonable level in that country. The tendency is to keep home prices at a high level by agreement and to compete only for foreign business. The type of business man who built up the cement industry in England does not exist in India; we have here only the financial agent of short domicile who wants large profits quickly and is not much interested in the longevity of the business. Pre-war prices of cement were too high to encourage its use in public works. These prices were less than half of what the Indian manufacturers now charge, or anticipate to charge in the future, if one judges from their prospectuses. The necessity for greatly extended use of cement on railways is apparent to any railway engineer, and it is understood by the writer that irrigation engineers would use enormous quantities of cement in the canals if they could get it sufficiently cheap. The extension of the use of re-inforced concrete in India is most desirable for many reasons, but such extension is unlikely to take place with high cement prices. The writer is aware that in certain places in India limes can be found which, used properly, are good enough for most building work. With one or two exceptions such limes are not standardized, and there is much ignorance shown in their use. Even in the few cases in which lime can be purchased in bulk from well-known firms, it will be found that tests are not made continuously, and the sellers are merely shopkeepers, and not expert lime makers. The belief of many engineers in mixtures of fat limes and *soorkee*, and in *kankar* limes, can only be classed as superstition. A considerable amount of study in each case is required before such materials should be used on important works; this study is not often given nor, indeed, in general can it be easily given. It is too often taken for granted that a lime is, as cement is, a substance of definite measurable qualities. If it were clearly recognized that it is a substance on which no reliance can be placed, without extensive experiments, lasting continuously over a long period, and which are not then conclusive except for the portions actually used in the experiments, it would cease to be used on important works. A great decrease in yearly repair costs would be an immediate result to railways. It is too obvious to argue about that a cheap reliable cement is necessary to the engineer, and it is difficult to see a reason why great building departments, such as railways and canals, cannot get it, and are forced for the sake of economy in first cost to use untrustworthy materials in great public works. These departments are already used to acting departmentally in most of the important parts of their works, and manufacture bricks and lime with only a nominal aid from the contracting class. There is not, therefore, any departure in principle from present methods in undertaking the manufacture of the cement they require. It is clearly a question of expediency only. Thus, if an engineer requires 2,000 tons of cement only, he will find it expedient to buy it where he can most cheaply; but if he requires 20,000 tons per year, and if he has the necessary materials at hand, he should prefer to manufacture—until manufacturers' profits are a function of skill rather than the possession of a monopoly.

4. The manufacture of cement is not a difficult operation, given the proper materials and a modern plant. The prevalent idea of the economic size of a factory equipped with modern plant is, in the writer's opinion, an erroneous one in existing circumstances in India. It is true that European writers consider a factory of



output of 700 tons per week the minimum size to be worked economically. This economic limit is with regard to European pre-war prices and not with reference to present Indian prices. The use of large-size rotary kilns undoubtedly reduces the fuel cost, but the reduction is small in comparison with the difference in cost price and selling price in use and likely to continue to be in use with the Indian firms. When the large-size rotary kiln becomes the machine determining profit and loss, as it may do in a highly competitive market, it will be unnecessary for Government departments to undertake cement manufacture, but the dawn of that day in India is still far distant. Meanwhile, it will, in many cases, be worth while to erect plants of much less size. It should also be remembered that, although the rotary kiln is the greatest modern contribution to cement plant, much good Portland cement was manufactured before its introduction and the vertical kiln is still used by many good makers. The rotary kiln was chiefly developed in America, where labour is scarce and expensive. The vertical kiln is quite suitable for small cement works in India. Also, the development of the rotary kiln has been so rapid that a plant can get out of date in a few years. In 1905 the usual size in England was 60 to 70 feet long and 6 feet diameter with a daily output of 20 to 25 tons. A few years later the length of kiln was increased to 150 ft. with the effect of doubling the output and greatly reducing the fuel costs, and kilns are now in use 200 ft. to 230 ft. long and 9 ft. diameter. A fair pre-war cost price in England was 23 to 25 per ton and in the United States about the same. Mr. W. A. Brown in his "Portland Cement Industry" gives an estimate of 11s. 4½d. per ton labour and supply costs, excluding interest and depreciation costs. A figure of Rs. 20 to Rs. 22 should cover all cost prices for an Indian factory.

5. Although the manufacture of Portland cement is very thoroughly understood in that demands of certain strength, speed of setting, and constancy of volume, within fairly wide limits, can be met, yet chemists are far from agreed as to the processes that take place in the kiln and in the setting. Le Chatelier and Newberry concluded that definite chemical compounds were formed in the kiln which broke up in the presence of water when setting into other definite chemical substances. Richardson recognized clinker as being formed of certain solid solutions of calcic aluminates and silicates, and that, of the substances so formed, "alite" and "celite" were the most important. He considered the setting chiefly due to the crystallization of calcium hydrate derived chiefly from the break up of "alite." The colloidal theory of setting first advanced by Michaelis is more satisfactory to the engineer in explaining the phenomena he is acquainted with. A jelly-like substance is formed by the action of the water on the "alite" round each grain of cement. The desiccation of this jelly constitutes setting. This covering of the cement grains makes access of the water to it more and more difficult, though this is never stopped. A piece of hardened cement will thus consist mainly of this desiccated and hardened jelly substance, grains of unchanged cement, and, perhaps, crystals of calcium hydrate. This seems to the writer to explain more clearly than any other theory the continual hardening and increasing strength with time of cement mortars, the observed necessity for very fine grinding of the clinker, and the fact, which he has known for a long time, that cement set perfectly hard will, if re-ground, set again, and give a very strong mortar. In his own practice he has always burned the set cement to a red heat before grinding. This makes grinding easier, but

may produce bad effects through dehydration of lime hydrate crystals. Various rough formulæ have been derived from these theories to guide the cement maker in the choice and grading of his materials. Mr. Eckel considers fat limes, hydraulic limes, Portland cement, natural cement and puzzulona material on a grade depending on the amount of argillaceous material present. He suggests a cementation index derived from Newberry's formula—

$$\frac{2.8 \text{ Si O} + 1.1 \text{ Al}_2 \text{ O}_3 + .7 \text{ Fe}_2 \text{ O}_3}{\text{Ca O} + 1.4 \text{ Mg O}}$$

percentages by weight being used. A value less than unity suggests hydraulic limes, 1 to 1.15 a Portland cement, 1.15 to 1.60 a natural cement that demands high firing, 1.60 to 2 a low-valued natural cement and below 2 merely puzzulona.

6. Other rough indices used are :—

$$\text{Hydraulic Index} = \frac{\% \text{Si O}_2 + \% (\text{Al}_2 \text{ O}_3 + \text{Fe}_2 \text{ O}_3)}{\% \text{CaO}}$$

and the value should be between .40 and .60 for Portland cement mixtures and between .60 and 1.50 for natural cements. The German cement manufacturers use the rule that the minimum percentage of lime by weight must be 1.7 parts by weight of silica and alumina. The setting of hydraulic limes, natural cements and puzzulona mortars, though assumed to be similar to that of Portland cement, are even less understood.

7. The portion of the United Provinces served by the Oudh and Rohilkhand Railway contains very large deposits of lime *kankars*. The writer had not, previous to this enquiry, any practical experience with these *kankars*, but had used largely the *kankars* on the right bank of the Ganges met with during the construction of the Cawnpore-Banda Railway. From his experience with these *kankars*, some details of which are given further on in this report, he had hoped by a small addition of fat lime, which it might be necessary to purchase, to get from some of the large *kankar* fields on the Oudh and Rohilkhand Railway a suitable material for cement. Every large deposit of *kankar* on the railway has been examined with very disappointing results. The material is altogether too poor in lime content, and frequently carries too much magnesia, to permit of its being considered of any value as a source of cement. Another source of lime supply in the United Provinces is from boulders in the torrents at the foot of the hills. A considerable amount of lime is manufactured from these in the torrents below Mussoorie. The boulders, however, vary so much in composition, frequently carrying large amounts of magnesia, and are so mixed up in complete confusion with boulders from every other type of rock, that cement manufactured from them does not seem a practical proposition. At several places on the scarp of the hills a chemical deposit of lime, travertine, is found. This is a very promising material as it consists of almost pure carbonate of lime, is soft and easy to crush, and there is water and clay in abundance beside the deposit. Two deposits have been examined in some detail, i.e., at Doiwalla on the Hardwar-Dehra Line, and at Ohunam about half-way between Ramnagar and Kathgodam. These deposits do not seem very large, and it was not found possible in this enquiry to determine the amount available in any exact manner. Lime has been burned in Lucknow for many years from a material locally called "chur," found a few miles from Lucknow in the valley of the Goomtee. This is a

fresh water marl, and the writer has given considerable time to its detailed investigation. It is almost a pure carbonate of lime in a very fine state of division, and is eminently suitable for cement manufacture. It is found in many places along the valleys of the Sabai and Goomtee; and, from a recent report, is also found along the Gogra. The writer has had time only to examine one locality in detail but has visited several others. The marls examined lie under 6 feet to 12 feet of clay, and so have been deposited and covered up many years ago. The writer is convinced that it is possible to find this substance now in process of precipitation, though he has not been successful in doing so. As this marl is the most important of the lime substances examined, and has been treated in greater detail than the others, an account will be given of it in the first place, and the other substances then treated in their order of importance.

8. A marl is a precipitate deposit of carbonate of lime from water carrying bicarbonate in solution. The hills of Kumaon and Garhwal contain large amounts of limestone, and it is to be expected that the streams percolating through this material, and which finally deliver themselves to the Goomtee and Gogra, carry a large amount of bicarbonate of lime in solution. The smaller capacity of warm water than cold to hold this material in solution, the loss of  $\text{CO}_2$  directly and through the action of plants and the consequent precipitation of the carbonate, will account for the formation of this marl in spills and marshes in the warm plains. Although the marl, being a chemical deposit, should be a pure carbonate of lime, yet, in the course of deposition and after, it gets mixed with fine sand and clayey matter, but these substances, in the marls under examination, are in such a fine state of division that they will enter readily into combination in the kiln. Moreover, the proportions of these substances are small. In some of the analyses given the proportion of  $\text{SiO}_2$  seems large, but this is due mostly to the methods of excavation, but sometimes to deliberate adulteration, and, indeed, most of the samples carrying a large proportion of  $\text{SiO}_2$  were purchased. The material is found in pockets up to 50 chains long and from 200 feet to 1,500 feet wide and from 3 to 14 feet thick. It lies under a bed of clay from 4 feet to 12 feet thick. Excavation, as it is practised, consists of sinking circular shafts about 2 feet in diameter, to the surface of the marl, and excavating as much as the inflow of water will allow, and then sinking similar shafts alongside, until, over the whole area, about 6 feet thick, where such thickness or over exists, has been excavated, when the holes are filled in and the ground made over to cultivation again. About 1,000 cart loads, or 1,200 tons, are sent yearly from Dilarman to Lucknow, where it is used, after being burned, for fine plaster work, and to a certain extent in building operations.

9. It was evident to the writer in December 1919 that the marl deposits about Dilarman, 10 miles from Lucknow on the Sultanpur road, and on the alignment of the proposed Lucknow-Sultanpur Railway, were well worth working out in full detail. There is nothing on the surface which will indicate the position of the marl underneath. It must have been formed in a depression originally, but the marshes now existing do not give any indication of these old marshes, and in some cases have been formed by the excavation of all the marl that had lain underneath. Certain information was available from the villagers, but such as to be useful only as a guide to a detailed enquiry. Such marl beds may wind about considerably and vary in breadth, depth and character, as well as in direction. The whole valley is highly cultivated. Permission was accordingly asked from the Railway

Board to gazette the land and examine it in detail by boreholes at a moderate distance apart. The Railway Board in their letter, already cited, of the 13th January did not consider this necessary, and suggested that a survey with trial pits at such places as by permission from the owners could be obtained, would be sufficient. A survey on these lines has been carried out during the past three months.

10. The result of the analysis of the marls taken from places as noted are given in the table attached to this report. Analyses of clays found in the vicinity are also given.

A combination of 7 parts by weight of L 23 and one part of L 100 will give a mix of constitution

SiO <sub>2</sub>	22.1
Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub>	7.6
CaO	67.6
MgO	2.6

and 3 parts of L 56 and one of L 100 will give the mix—

SiO <sub>2</sub>	21.7
Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub>	7.8
CaO	68.2
MgO	2.3

and 4 parts of L 56 and one of L 65 will give the mix—

SiO <sub>2</sub>	20.00
Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub>	11.9
CaO	65.2
MgO	2.8

Two samples of marl were sent to Alipore for complete analysis. The results are :—

	L 37	L 38
SiO <sub>2</sub> free	13.3	17.9
SiO <sub>2</sub> combined	2.7	2.1
Al <sub>2</sub> O <sub>3</sub>	2.2	2.2
FeO	1.6	1.7
Ca	43.6	40.9
MgO	1.7	1.6
SO <sub>2</sub>	Nil	Nil
Alkali	.1	.4

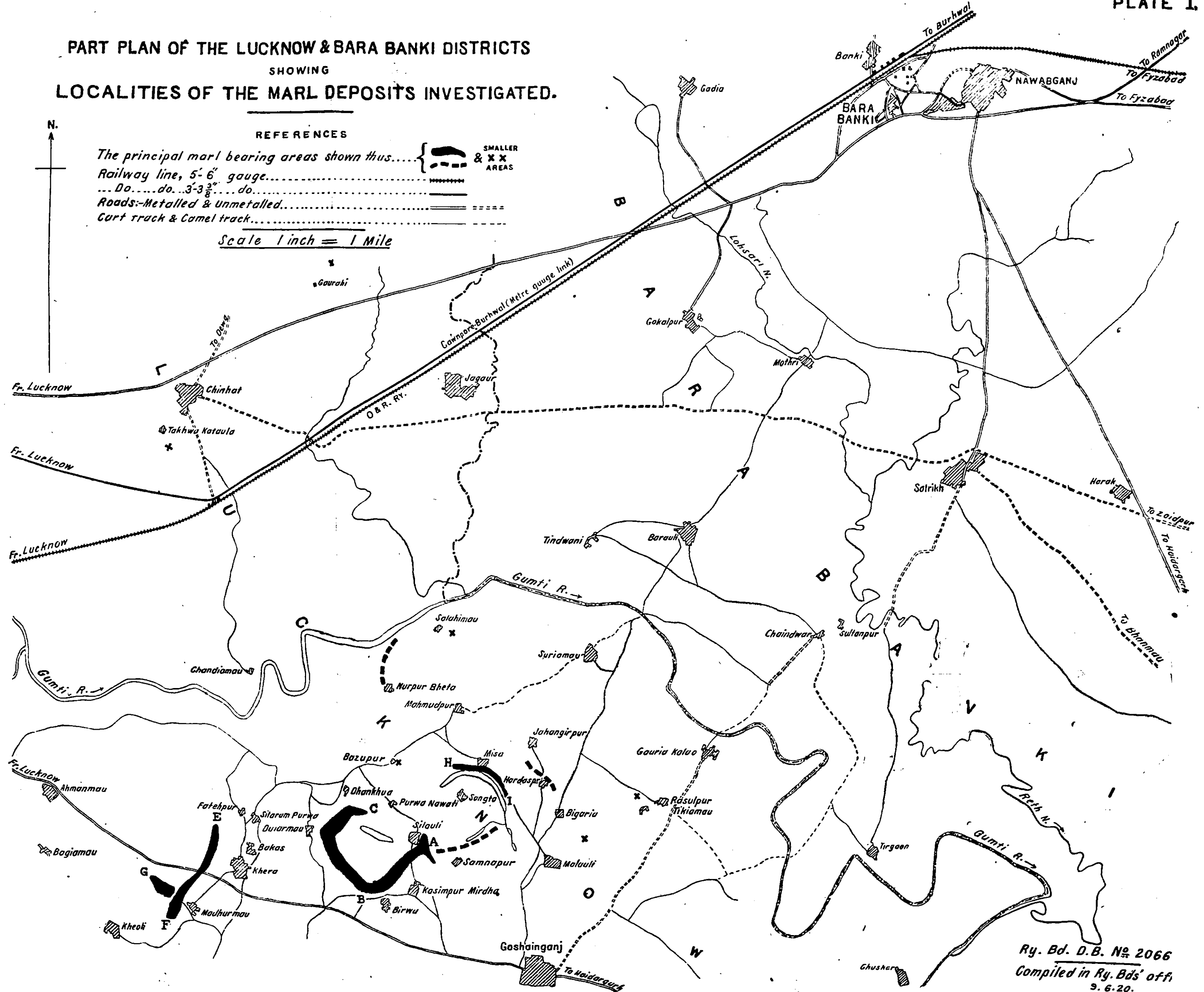
These samples were purchased, and the large amount of free SiO<sub>2</sub> is certainly due to adulteration, as samples collected personally by the writer did not carry nearly as much. The proportion of MgO was determined only in a few cases and is about 1.5 per cent. to 1.7 per cent. in general. Some small samples of clinker were made which gave good results. With the apparatus the writer had it was extremely difficult to make clinker. There are a number of designs of laboratory grinding apparatus on the market, but the short period of the enquiry made it useless to

PART PLAN OF THE LUCKNOW & BARA BANKI DISTRICTS  
SHOWING  
LOCALITIES OF THE MARL DEPOSITS INVESTIGATED.

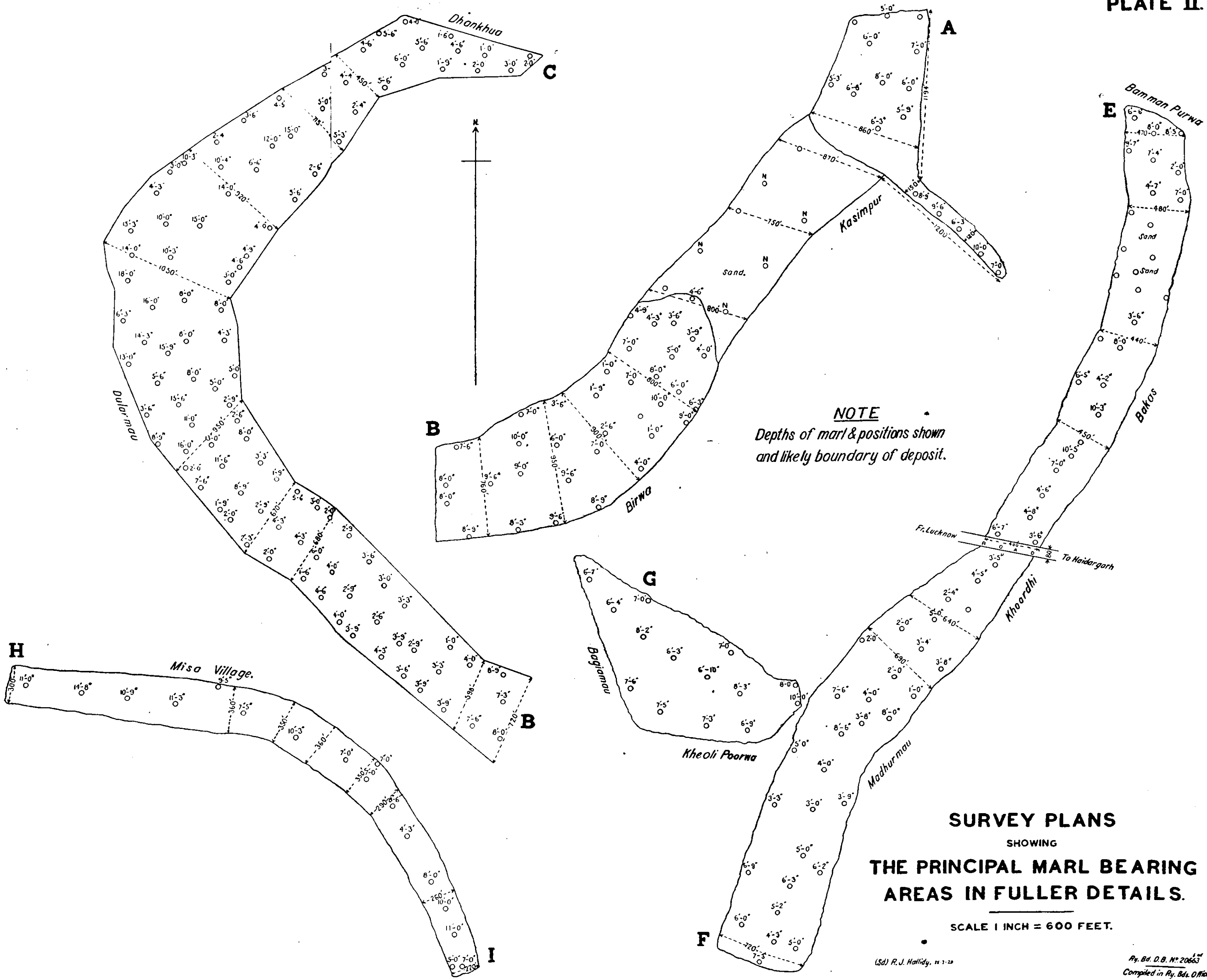
REFERENCES

The principal marl bearing areas shown thus...  
Railway line, 5'-6" gauge...  
Do do 3'-3 3/8" do...  
Roads:-Metalled & unmetalled...  
Cart track & Camel track...

Scale 1 inch = 1 Mile



Ry. Bd. D.B. No. 2066  
Compiled in Ry. Bds' offi  
9.6.20.



**NOTE**  
 Depths of marl & positions shown  
 and likely boundary of deposit.

**SURVEY PLANS**  
 SHOWING  
**THE PRINCIPAL MARL BEARING**  
**AREAS IN FULLER DETAILS.**

SCALE 1 INCH = 600 FEET.

(Sd) R. J. Halliday, 11.1.22

Ry. Bd. D.B. No. 20663  
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attempt to get them from England, and they could not be obtained in India. Burning was also difficult, as the necessary fine grinding and the small size of the furnace forced the use of very small specimens, which lost a certain amount of lime in burning through contact with the fuel ash.

11. In the accompanying map (Plate I) of the Lucknow and Bara Banki Districts are marked the localities in Dilarman and its vicinity in which the marl deposit has been investigated. A survey plan (Plate II) attached to the report shows in fuller details areas

- (a) A to B
- (b) B to C
- (c) E to F—G
- (d) H to I

These are the principal marl bearing areas. The approximate amount of marl available in each is:—

A to B . . . . .	18,400,000	cubic feet.
B to C . . . . .	32,300,000	„
E to F—G . . . . .	16,300,000	„
H to I . . . . .	7,000,000	„
	a total of	74,000,000 cubic feet in the principal areas.

In the outlying areas:—

Samnapur and Silauli . . . . .	4,000,000
Hardaspur . . . . .	2,000,000
Behra . . . . .	700,000

and smaller amounts in the other places marked on the map. Assuming that 100 cubic feet is, with the necessary clay, sufficient for 1.75 tons of cement, and this is a conservative estimate, since the marl, though water-logged, is consolidated under a considerable load of clay, and considering only the amount exhibited in the principal areas—

74,000,000 cubic feet marl is equivalent to  
1,295,000 tons of cement, or equivalent

to a supply of 100 tons per day for 40 years of 330 working days each. For estimating purposes a supply of 100 tons per day for 30 years only will be assumed. In assessing the value of land required, it is assumed that land covering marl up to 6 feet thick will not be greatly damaged by the operations, and that a return sale value of 60 per cent. may be expected, that the portions carrying deep marl will take many years to work out, and that in the meantime a fair rental can be obtained for the rest of the land purchased. If work is started in the heavy deposits between B and C, the total amount of land covering this deposit, and hence the utmost that need be at once acquired, is 50 acres, since these deposits will last about 14 years. For the remaining portion land can be relinquished almost as quickly as fresh land need be acquired. Allowing the high figures of Rs. 1,500 per acre, the total cost of the land used up in the full operations should not exceed Rs. 1,50,000; and Rs. 80,000 only should be required for a number of years after operations had

begun. It is very difficult, under present circumstances, to estimate correctly the cost of the machinery, kilns, etc. Heavy machinery for raw grinding is not required for this soft marl. Allowing for an increase of 70 per cent. on pre-war prices, the cost of plant, excluding cost of track, rolling stock and buildings, should not exceed Rs. 6,00,000 for an output of 100 tons per day. An estimate for the capital cost, therefore, should lie well inside the figures

	Rs.
Land . . . . .	1,50,000
Track and rolling stock, etc. . . . .	1,80,000
Buildings . . . . .	1,00,000
Cement plant . . . . .	6,00,000
	<hr/>
TOTAL . . . . .	10,30,000
Add . . . . .	51,000 contingencies.
	<hr/>
TOTAL . . . . .	10,81,000 say, Rs. 11,00,000

and will probably exceed figures as

Land . . . . .	80,000
Track and rolling stock . . . . .	30,000
Buildings . . . . .	40,000
Cement plant . . . . .	4,00,000
	<hr/>
TOTAL . . . . .	5,50,000 say, Rs. 6,00,000

An estimate of the cost of the manufacture of the cement should be covered by figures as, taking the higher limit of capital cost,

(a) Standing charges—

	Rs.
Interest on Rs. 11,00,000 at 5 per cent. . . . .	55,000
Sinking fund to clear capital in 30 years . . . . .	22,000
Repairs and renewals at 5 per cent. on capital cost of machinery and buildings . . . . .	47,500
	<hr/>
TOTAL . . . . .	1,24,500

for an output of 33,000 tons or at the rate of Rs. 4 per ton—

	Per ton		
	Rs.	A.	P.
Standing charges . . . . .	4	0	0
Excavation . . . . .	1	12	0
Coal and supplies . . . . .	11	0	0
Labour . . . . .	2	0	0
Supervision, office, etc. . . . .	1	0	0
	<hr/>		
TOTAL . . . . .	19	12	0



and so a rate of Rs. 21 per ton should be a maximum, inclusive of all charges f.o.r.

12. Marl has also been discovered at—

- (a) Three miles from Harauni on the Cawnpore Branch in the valley of the Sahai River. Site was visited by writer.
- (b) Kathanta Tal and Imbibon near Chinhat on the Bara Banki road. Sites were visited by the writer.
- (c) Three miles south from Nigohan station on main line.
- (d) Habiskhera, about  $1\frac{1}{2}$  miles north of Mohanlalganj station.

13. Three miles north of Doiwalla, on the Hardwar-Dehra Dun Railway, and touching the Railway boundary, a deposit of travertine, an almost pure carbonate of lime, is found. It is a chemical deposit, and so the accident of its formation is nearly as uncertain as that of a marl. It is worked for lime to a small extent now. As far as the writer could determine, from pits sunk by the lime contractor and old pits made by the builders of the railway, the deposit is about 2,000 feet by 1,600 feet and from 8 feet to 11 feet thick. The analyses as below were made:—

	SiO	Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO
L 31—purchased . . . . .	6.47	1.99	48.22	n d
L 30—obtained new surface . . . . .	1.3	.4	52.8	1.5
L 91— " " " " . . . . .	1.2	.8	52.8	n d
L 92—8 feet below surface . . . . .	.66	.34	55.4	1.5
L 93—11 feet below surface . . . . .	.66	.76	53.1	n d
L 94—clayey matter underneath bed of travertine . . . . .	2.0	1.0	52.2	n d

MgO was determined in a few cases only, but by calculation it does not exceed 1.5 in any of the samples. The clay overlying was not analysed, as it is likely that the boulder clay underneath will be found most useful for the mix. A boulder clay obtained from Ramnagar underlying a similar deposit gave an analysis—

SiO <sub>2</sub> (insol) . . . . .	63.68
Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub> . . . . .	24.53
Ca O . . . . .	.6
Mg O . . . . .	2.16

An analysis of sand from Rispana, a few miles away, is—

Si O <sub>2</sub> . . . . .	60.59
Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub> . . . . .	18.79
Ca O . . . . .	5.75
Mg <sub>2</sub> O . . . . .	5.88

This is chiefly derived from shale ; the MgO content is rather high. A mix between this sand and L 91 will give a mean of analysis—

Si O <sub>2</sub>	24.6
Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub>	8.1
Ca O	63.1
Mg O	4

which is by English practice too high in MgO. A small sample of cement made from this mixture seemed satisfactory.

A sample of clay obtained near Rispana has an analysis—

Si O <sub>2</sub> combined.	29.14
SiO <sub>2</sub> free .	30.00
Al <sub>2</sub> O <sub>3</sub>	21.69
Fe <sub>2</sub> O <sub>3</sub>	4.32
Ca O	3.00
Mg O	3.36

and a mix between L 91 and this will have—

SiO <sub>2</sub>	22
Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub>	10.1
Ca O	64.8
MgO	3

and the MgO is still a little too high.

Allowing 8 feet thick of this material over an area of 1,800 feet by 1,500 feet, and estimating that 100 cubic ft. of it, with the necessary clay, will give 3 tons of cement, and, as the material is solid, this is a safe estimate, there is sufficient in the deposit for 640,000 tons of cement. Water power is available alongside the deposit. The writer could not, in the time available, make sufficient surveys to estimate the amount of power available, but the stream is large with abundance of water in March, and there is certainly a much greater quantity available than is necessary for a small cement factory and re-inforced concrete works. The travertine is somewhat harder than chalk, but much softer than ordinary limestone. Exclusive of the cost of land, which is forest land, the cost of an up-to-date factory to turn out 50 tons per day should not exceed Rs. 8,00,000. If vertical kilns be used it will likely be possible to keep the first cost of machinery, kilns, and buildings below Rs. 3,00,000, though the running charges will in this case be higher. The use of hydro-electric power will greatly offset the high price of coal due to long lead. The writer cannot give nearer estimates without considerable further survey and study of the proposition. The site is particularly attractive for the erection of re-inforced concrete works in connection with the cement factory. There is an inexhaustible supply of good aggregate, and there is hydro-electric power available, as already noted. A combined cement factory and re-inforced concrete works can probably be erected for Rs. 4,00,000, if vertical kilns are used instead of rotary kilns with elevators and conveyors.

14. The writer visited another travertine deposit at Chunam, about 12 miles from Ramnagar on the Ramnagar-Kathgodam road. It is exhibited on the scarp of the hill and is in places seen to be 60 ft. thick. The writer followed the deposit back along stream beds. It is seen for a considerable distance back from the scarp and forms the steps for waterfalls along the streams. Much hard boring would be necessary to determine the amount available, and the position of the deposit, 15 miles from a railway, does not increase its attractiveness as a cement proposition. A railway could be cheaply made along the watershed to some point on the Lalkua-Kashipur Railway and through a seemingly paying country.

An analysis of this material—

L 6 is a fair sample of the exhibit—

SiO <sub>2</sub>	. . . . .	7.91
Al <sub>2</sub> O <sub>3</sub>	} . . . . .	1.59
Fe <sub>2</sub> O <sub>3</sub>		
CaO	. . . . .	48.98
MgO	. . . . .	1.7

L 53 near junction with underlying boulder clay—

SiO <sub>2</sub>	. . . . .	23.98
Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub>	. . . . .	5.81
CaO	. . . . .	37.32

15. *Kankar* is an impure carbonate of lime chemically deposited. It occurs in large sheets several feet thick, or in nodules varying from several cubic inches in size to that of a small pea. The first type is known as block *kankar*, the second, nodular, and, when very small, pea *kankar*. The carbonate of lime content varies from 85 per cent. to less than 20 per cent. A *kankar* obtained from Oharki Dadri, Bombay, Baroda and Central India Railway, has the composition SiO<sub>2</sub>—5.47, Al<sub>2</sub>O<sub>3</sub> Fe<sub>2</sub>O<sub>3</sub>—1.58, CaO—48.21. Nine deposits of block *kankar* and five of nodular *kankar* from the Oudh and Rohilkhand Railway territory were examined; a pea *kankar* from the Cawnpore-Banda Railway was also examined. It was not considered useful to examine any deposit that would not evidently give a large supply. The table attached to this report gives description, source of supply and analysis of these *kankars*. Some experiments were made with L 3, L 8, L 9 and L 5. If completely burnt, *i.e.*, till all CO<sub>2</sub> is driven off and very finely ground, they will harden under water, if allowed to get an initial set in damp air for from 12 to 24 hours. Even after 3 months, however, the strength arrived at was very small. These samples were tested neat. When mixed with sand in proportions of 1 to 1 the set was exceedingly poor. These *kankars*, with the exception, possibly, of L 48, are altogether useless as materials for cement manufacture, and are almost as useless as limes. The Oudh and Rohilkhand Railway use L 3 on the Moradabad district, but the writer did not get a satisfactory "set" with any experiments made with it. Mixed with  $\frac{1}{2}$  vol. of slaked Sutna lime it attained considerable hardness under water after 12 hours in damp air. The writer would not use limes made from any of these *kankars*, with the exception of L 48, for any engineering works, though they might be used in small buildings. A large quantity of small

pea *kankar* is found on the Cawnpore-Banda Railway at the Jumna River and at the Chandrawal river. The writer used this *kankar* largely in building the Jumna Bridge and much of the rest of the railway. It is found in very large quantities and the supply is replenished from year to year. The lime manufactured from it set hard under water in a month and took a dose of sand in proportions of 1 to 1 well. The analysis is not constant. The analyses of four specimens are :—

	L 47	L 48	L 50	III
Insol. (chiefly SiO <sub>2</sub> ) . . . . .	33·07	16·39	21·19	30·9
Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> . . . . .	5·19	9·21	4·07	5·12
CaO . . . . .	31·11	38·84	38·43	32·62
MgO . . . . .	n d	1·73	1·81	1·88
Cementation index . . . . .	2·9	1·36	1·55	2·6

L 48 and L 50 should give good natural cements and L 47 and III should not be very satisfactory. In practice, the lime made in bulk was quite satisfactory. In these analyses the Insol. matter is not altogether SiO<sub>2</sub>, so the C. I. shown is really higher than actual. A mean analysis would be SiO<sub>2</sub>—25·37, Al<sub>2</sub>O<sub>3</sub>+Fe<sub>2</sub>O<sub>3</sub>—6·14, CaO—35·25, MgO—1·75, and a mix between this and L 59, the marl from Harauni on the Cawnpore branch, in equal parts by weight would have the analysis

SiO<sub>2</sub>—26·7, Al<sub>2</sub>O<sub>3</sub>+Fe<sub>2</sub>O<sub>3</sub>—6·0, CaO—64·8, MgO—2·5, a very good cement mixture. This would involve bringing the marl to the Chandrawal on the Cawnpore-Banda Railway, and the writer does not know of any nearer source of fat lime, so that the raw material would cost between Rs. 5 and Rs. 6 per ton of cement, which is quite a possible figure with present cement prices. Sample L 59 was taken close to the surface, and it is likely that the marl lower down is much purer, which would reduce the amount of it necessary per ton of cement.

16. A fine outcrop of limestone is exhibited at Mallah, 8 miles from Chandigarh on the Delhi-Umballa-Kalka Railway. The material is available in large quantities and is very suitable for cement manufacture on a large scale. Water is plentiful. The approach from the railway is extremely difficult. The writer learned on the spot that the Patiala Government had surveyed these deposits, with the view of starting cement factories, and that they intended to construct a railway to them. He addressed the Chief Engineer, Patiala State, on the subject, who informed him that it was intended to build a fair weather line to these quarries, but that he did not then know the further intentions of the State as regards their development. Some analyses of the materials are here given :—

	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO
L 32 limestone . . . . .	3·99	1·73	—	52·49	·49
L 33 " . . . . .	2·39	·99	—	53·10	·50
L 34 sand (shale) . . . . .	67·39	17·31	6·08	3·23	n d
L 35 boulder clay (selected fine stuff). . . . .	21·97	4·59	—	39·68	·93
L 36 boulder clay . . . . .	25·53	5·39	—	66·32	1·29

The small proportion of MgO in these samples is noticeable. At Narnaul on the Bombay, Baroda and Central India Railway, and two miles from the station, excellent limestone is found.

An analysis gives—

Insol ( $\text{SiO}_2$ )—1.39,  $\text{Al}_2\text{O}_3 = \text{Fe}_2\text{O}_3$ —.39,  $\text{CaO}$ —54.06,  $\text{MgO}$ —1.16.

These quarries are also situated in Patiala State, so no further enquiry was made regarding them

17. As already mentioned in this paper, lime is manufactured in considerable quantity from the boulders in the torrents below Mussoorie. A few analyses from boulders picked up at random were made thus :—

L 2,  $\text{SiO}_2$ —6.51,  $\text{Al}_2\text{O}_3$ —2.39,  $\text{Fe}_2\text{O}_3$ —.40,  $\text{CaO}$ —49.6,  $\text{MgO}$ —1.75.

L 20,  $\text{SiO}_2$ —6.68,  $\text{Al}_2\text{O}_3$ ..  $\text{Fe}_2\text{O}_3$ —1.66,  $\text{CaO}$ —35.8,  $\text{MgO}$ —12.99.

It is therefore seen that considerable difficulty would be experienced in keeping the mix uniform, as a small amount of L 20 would be fatal. Moreover, the manner in which the lime boulders are mixed up in confusion with boulders from other types of rock makes a cement proposition, in the writer's opinion, practically impossible.

18. The writer, from his work on the Nagda-Muttra Railway, was well acquainted with the limestone formations in Kotah and Bundi States. He had some samples of limestone sent for examination, but as this part of the country was outside his commission he did not pursue the matter further. The Amta quarries situated on the Baran-Kotah Railway offer an excellent position for a large cement plant. Stone, clay and water are plentiful. An analysis received from Mr. Devon, Engineer, Kotah State, is—

Insol ( $\text{SiO}_2$ )—10.4,  $\text{Al}_2\text{O}_3$   $\text{Fe}_2\text{O}_3$ —9.12,  $\text{CaO}$ —45,  $\text{MgO}$ —Nil.

and an analysis made in the writer's laboratory—

$\text{SiO}_2$ —15.8,  $\text{Al}_2\text{O}_3$   $\text{Fe}_2\text{O}_3$ —3.3,  $\text{CaO}$ —40,  $\text{MgO}$ —1.44.

The difference is considerable, but the limestone in Rajputana varies considerably from layer to layer, and to such an extent that the Bundi works use no clay but only different layers of stone.

The writer is much indebted to Mr. Wood, C.S.I., Principal of the Thomason College, Roorkee, for his direct kindness on many occasions and for the use of instruments from his chemical laboratory. He has also to acknowledge gratefully the considerable help he received from the Agent and Officers of the Oudh and Rohilkhand Railway, and from Rai Bahadur Chotey Lal, O.B.E., Contractor, Moradabad.

LUCKNOW ;

The 4th April 1920.

B. J. HALLIDY, M.I.C.E.,

Executive Engineer

## ANALYSIS OF MARLS

Laboratory reference No.	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> plus Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	REMARKS
L 23	7.99	3.97	45.04	1.62	From Dilarmau—Purchased.
L 37	10.68	6.74	42.48	1.60	" " "
L 38	15.47	7.70	39.65	1.58	" Madharmau "
L 39	19.59	3.05	37.21	n d	" " "
L 60	19.32	3.45	40.20	n d	" " " picked up from contractor's stack.
L 61	17.20	3.56	41.00	n d	From Madharmau picked up from contractor's stack.
L 62	11.12	2.80	43.00	n d	From Dilarmau—Excavated.
L 63	10.44	2.72	44.02	n d	" " "
L 64	1.68	.72	49.52	n d	" Missa "
L 66	31.52	4.20	33.60	n g	From Bazepur—very wet and mixed with clay.
L 68	9.00	3.12	45.50	n d	From between Dilarmau and Kasimpur—Excavated.
L 69	7.68	2.80	47.00	n d	From between Dilarmau and Kasimpur—Excavated.
L 70	6.82	6.20	47.60	n d	From between Dilarmau and Kasimpur—Excavated.
L 72	4.14	1.24	48.30	n d	From Missa—Excavated.
L 73	5.00	2.92	48.00	n d	From Hardaspur—Excavated.
L 74	3.00	1.10	53.40	n d	From Bazepur—Excavated.
L 75	1.09	1.40	50.00	n d	From Missa—Excavated.
L 76	1.56	3.40	46.00	n d	" " "
L 77	1.40	.52	49.20	n d	" " "
L 79	2.3	2.40	43.00	n d	From Sumnapur—Excavated.
L 80	8.90	3.30	46.80	n d	From Madharmau—Excavated.
L 81	4.00	3.60	49.20	n d	" " "
L 82	15.10	3.90	43.50	n d	" " "
L 84	27.90	6.30	33.00	n d	From Dilarmau—clay from underneath marl.
L 59	8.20	1.56	46.20	n g	From Rajmaganar near Harauni on Cawnpore Branch.
L 101	5.56	2.6	47.80	n d	From Mazampur—Excavated.
L 102	4.24	2.24	50.00	n d	From Takima—Excavated.

## ANALYSIS OF KANKARS

Laboratory reference No.	Insoluble chiefly SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> plus Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	REMARKS
L 5	36.57	12.29	19.39	7.41	Block kankar from Badshahpur.
L 11	57.99	6.67	14.91	3.74	" " " Utrawari.
L 13	43.03	5.39	18.76	n d	" " " between Balamau and Dehnagar.
L 14	54.15	5.22	13.42	n d	Block kankar from mile 9 Balamau-Auhadpur Branch.
L 15	45.78	16.82	13.78	5.25	Block kankar from mile 3 Sitapur Branch.
L 16	45.03	3.59	19.97	6.83	Block kankar from Belakhers.
L 17	38.42	14.20	24.11	3.46	Block kankar from near Lachmanpur, A. R. C. Railway.
L 18	41.99	4.99	21.61	6.25	Block kankar from between Baghauil and Balamau.
L 26	30.07	4.27	24.79	8.34	Block kankar from Lachmanpur, A. R. C. Railway.
L 7	42.02	13.37	24.86	n d	Nodular kankar from Phapamau.
L 8	22.46	13.60	24.00	n d	" " " Danadpur.
L 9	45.19	4.87	24.95	2.44	" " " Partabgarh.
L 10	33.78	11.48	26.16	2.99	Nodular kankar from between Delamau and Rae Bareilly.
L 27	46.59	15.04	16.74	3.10	Nodular kankar from Chandnagar.
L 3	46.79	17.98	22.08	2.87	Burnt lime prepared for Railway use at Moradabad.
L 48	16.39	9.21	38.84	1.73	Pea kankar from Chandrawal, C. B. Railway.

## ANALYSIS OF CLAYS NEAR DILARMAU

Laboratory reference No.	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> plus Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	REMARKS
L 83	58.9	15.5	11.0	2.0	Surface clay—Dilarmau.
L 71	57.4	30.72	1.4	2.9	" " —Mirzapur.
L 67	40.00	20.00	16.8	3.7	" " —Dhaurata.
L 65	59.52	24.00	1.8	2.48	" " —Musa.
L 100	51.60	9.84	12.1	1.66	Clay, underneath marl—Takiman.

N.B.—These clays are all in a very finely divided state.

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