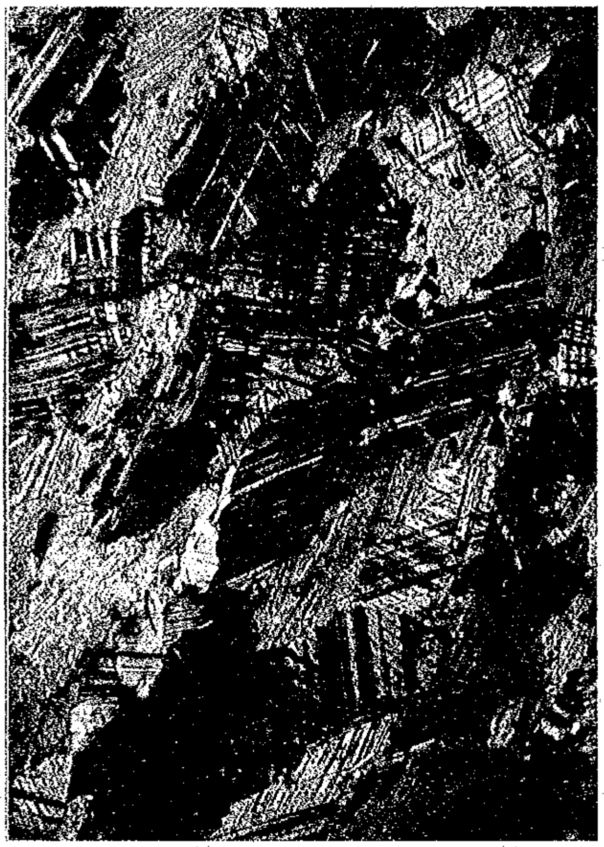
Photo 5-3-1

Sample Sindali limestone S-053



Open Nicol Cross Nicol 500 μ

Only calcite crystals are observed in this sample.
Although the size varies widely from several 10 μ to several 1,000 μ, as clearly shown in the photograph most of them are around 1,000 μ.
Many lines of cleavage are observed.

Photo 5-3-2

Sample Sindali limestone S-065

Open Nicol

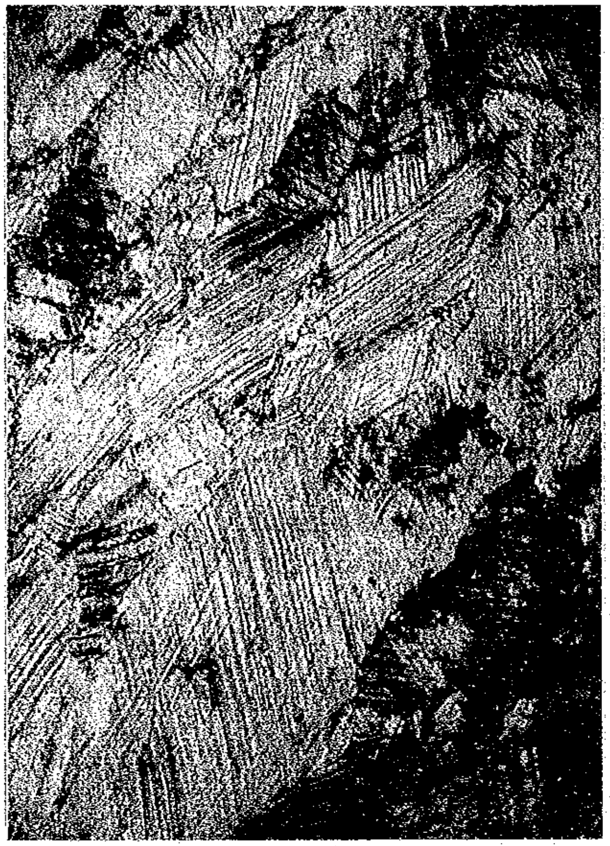
Cross Nicol

500 μ

This sample is composed of a large quantity of calcite crystals and a very small quantity of dolomite crystals.
Although the size of calcite crystals widely varies from several 10 μ to several 1,000 μ, most of them are around 1,000 μ. In the photograph small crystals (about 10 μ long) are found.
The lines of cleavage are observed.

Photo 5-3-3

Sample Sindali limestone S-211



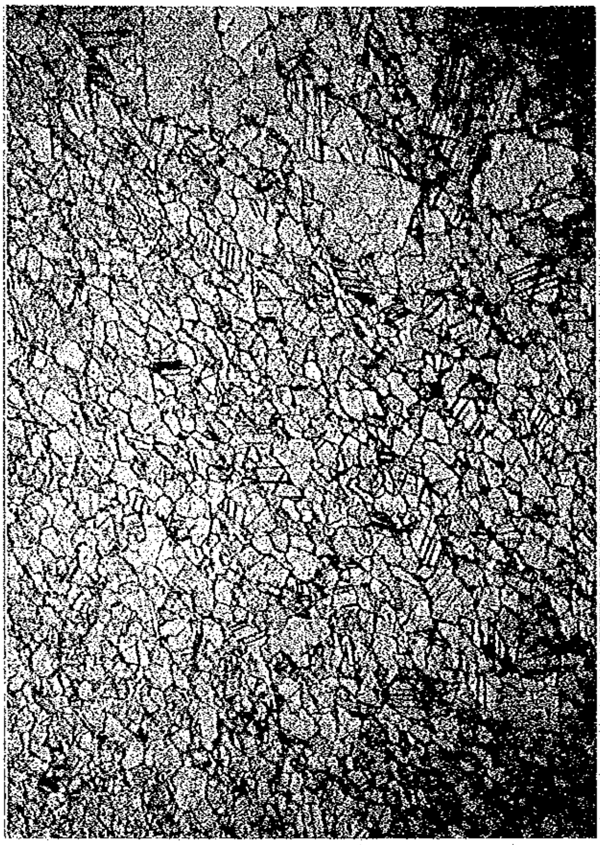
Open Nicol

Cross Nicol 500 μ

This sample is composed of a large quantity of calcite crystals and a very small quantity of dolomite crystals.
Although the size of calcite crystals widely varies from several 10 μ to several 1,000 μ, most of them are around 1,000 μ. In the photograph large crystals (more than 1,000 μ long) are found.
The lines of cleavage are observed.

Photo 5-3-4

Sample Sindali dolomite S-029



Open Nicol

Cross Nicol

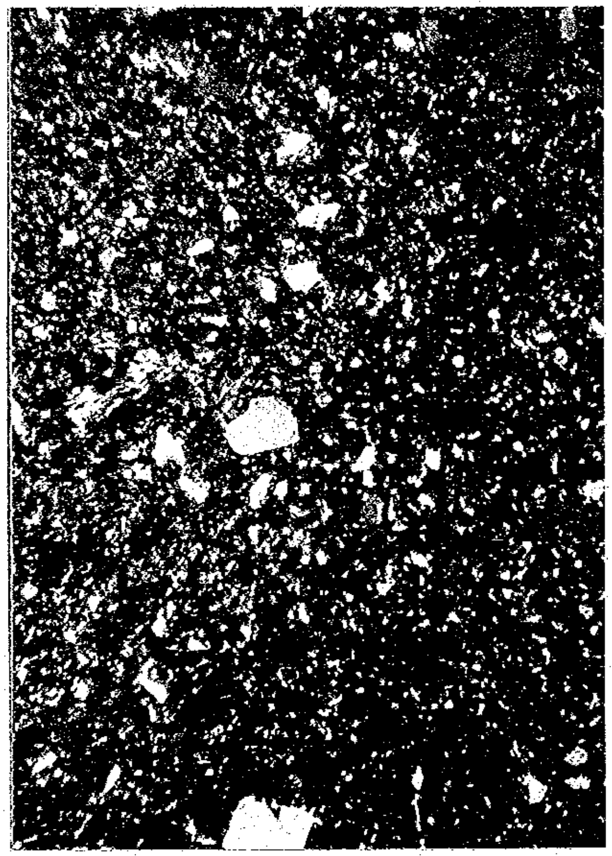
500 μ

This sample is composed of a large quantity of dolomite crystals and a small quantity of calcite crystals.
The size of dolomite crystals are uniform within a range of 100 μ ~ 200 μ.
The lines of cleavage are observed.

Photo 5-3-5

Sample Beltar clay B-28

Open Nicol



Cross Nicol

500 μ

In this sample, the crystals such as quartz, sericite and kaolinite are observed.

The size of quartz crystals varies from 10 μ to 200 μ and 100 μ on the average.

The yellowish threadlike crystals are sericite.

The clay sample is generally composed of fine crystals and is well weathered.

(5) Burnability test of raw material

In order to investigate the burnability of the raw meal of ordinary portland cement prepared from the proposed raw materials, the burnability test was carried out in comparison with the raw meal prepared from raw materials used in cement plant in Japan.

(i) Raw materials

The chemical composition of Nepalese raw materials and Japanese raw materials used for the test are shown in Table 5-3-18 and 5-3-19 respectively.

Table 5-3-18 Chemical Composition of Raw Material Samples Used for Burnability Test
(Nepalese Raw Material Samples)

Sample	Chemical composition (wt. % in dry basis)								
	L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total	Na_2O	K_2O
Sindali limestone BH-10	43.4	0.8	0.4	0.2	53.1	1.7	99.6	0.02	0.13
Beltar clay B-1230	6.4	61.2	19.2	6.9	0.2	1.1	95.0	0.21	4.04
Beltar clay 2.1.4	3.5	77.6	11.9	2.8	0.4	0.5	96.7	-	-
Trijuga river silica sand No. 1	1.4	86.1	6.1	1.5	0.4	0.3	95.8	0.72	2.06
Phulchoki iron ore No. 1	1.1	8.0	7.8	80.0	1.2	0.4	98.5	0.04	0.46
Ash of Assam coal	1.6	59.9	20.6	11.5	1.1	1.1	95.8	1.09	1.52

Table 5-3-19 Chemical Composition of Raw Material Samples Used for Burnability Test
(Japanese Raw Material Samples)

Sample	Chemical composition (wt. % in dry basis)								
	L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total	Na_2O	K_2O
Japanese limestone	43.6	0.9	0.3	0.1	54.5	0.6	100.0	-	-
Japanese clay	6.1	60.3	21.8	6.8	0.6	1.3	96.9	0.17	2.85
Japanese silicastone	1.2	89.3	4.8	1.0	0.7	0.8	97.8	-	-
Japanese copper slag	-	36.6	7.6	48.6	5.6	1.5	99.9	-	-

(ii) Raw meal preparation

Two kinds of raw material combinations were adopted as follows. (Refer to Table 5-3-21.)

(a) Sindali limestone, Beltar clay (northern deposit), Trijuga silica sand and Phulchoki iron ore

(b) Sindali limestone, Beltar clay (northern deposit), Beltar clay (Eastern deposit) and Phulchoki iron ore

In the latter, Beltar clay having high SiO_2 was used as siliceous material in place of Trijuga silica sand.

The moduli of clinker were determined as shown in Table 5-3-20.

The method of preparation of raw meal powder are as follows.

At first each raw material was crushed by a laboratory jaw crusher and then ground to the fineness of less than 1.2 mm by a roll crusher. After mixed according to the mixing proportion described in Table 5-3-21 and 5-3-22, the mixed material was ground finely by a vibration mill. The fineness and grinding time are shown in Table 5-3-23.

Table 5-3-20 Moduli of Clinker Samples

Combination	Moduli of clinker samples		
	HM	SM	IM
N-1	2.10	2.6	1.8
N-2	2.10	2.6	1.8
N-3	2.10	2.2	1.8
J-1	2.10	2.6	1.8

Note :

$$\text{HM (Hydraulic modulus)} = \frac{CaO}{SiO_2 + A\ell_2O_3 + Fe_2O_3}$$

$$\text{SM (Silica modulus)} = \frac{SiO_2}{A\ell_2O_3 + Fe_2O_3}$$

$$\text{IM (Iron modulus)} = \frac{A\ell_2O_3}{Fe_2O_3}$$

Table 5-3-21 Mixing Proportion of Nepalese Raw Material

Combination	Proportion of raw materials (wt. % in dry basis)						
	Sindali limestone BH-10	Beltar clay B-1230	Beltar clay 2.1.4	Trijuga silica sand No. 1	Phulchoki iron ore No. 1	Ash of Assam coal	Total
N-1	79.50	14.15	0	4.29	0.76	1.30	100
N-2	79.45	12.38	6.07	0	0.80	1.30	100
N-3	79.30	17.64	0	1.00	0.76	1.30	100

Table 5-3-22 Mixing Proportion of Japanese Raw Materials

Combination	Proportion of raw materials (wt. % in dry basis)				
	Japanese limestone	Japanese clay	Japanese silicastone	Japanese copper slag	Total
J-1	78.61	14.75	4.83	1.81	100

Table 5-3-23 Fineness and Grinding Time of Raw Meal

Combination	Fineness, wt. % (Residue on 88 μ sieve)	Grinding time (sec)
N-1	7.7	18
N-2	8.0	21
N-3	8.0	20
J-1	8.2	20

(iii) Burning of raw meal

After added a proper quantity (about 18 %) of water the raw meal was pelletized to pellets of 10 mm in diameter (weight : about 3 g) and dried at 110°C in an electric drying oven until all the moisture was evaporated.

The pellets, 3 pieces for each raw meal, were put in platinium crucibles and burnt simultaneously in an electric furnace maintained at 1,500°C. The burning time was three levels of 10, 20 and 30 minutes.

(iv) Free lime of clinker

The chemical composition and moduli of the clinkers burnt and free lime of the clinkers is shown in Table 5-3-24 and 5-3-25 respectively.

Table 5-3-24 Chemical Composition and Moduli of Clinkers

Combination	Chemical composition (wt. % in dry basis)						Moduli		
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total	HM	SM	IM
N-1	22.42	5.62	3.08	65.45	2.11	98.68	2.10	2.58	1.82
N-2	22.48	5.62	3.12	65.58	2.01	98.81	2.10	2.57	1.80
N-3	21.28	6.24	3.42	65.03	2.31	98.28	2.10	2.20	1.82
J-1	22.82	5.66	3.10	66.29	1.01	98.88	2.10	2.60	1.83

Table 5-3-25 Free CaO Content of Clinker

Combination \ Burning temp. / Burning time	1,500°C 10 min.	1,500°C 20 min.	1,500°C 30 min.
N-1	2.99	1.15	0.56
N-2	2.34	0.77	0.26
N-3	2.84	1.23	0.75
J-1	2.59	0.90	0.31

Note : The free lime content of clinker corresponds to the quantity of uncombined CaO. If the free lime content of clinker prepared and burnt under the same condition is higher than the others, the burnability of the clinker is judged to be inferior as compared with the others.

(v) Microscopic observation of sliced clinker

The clinker of combination N-1 and burnt for 30 minutes at 1,500°C was sliced and observed by a polarizing microscope.

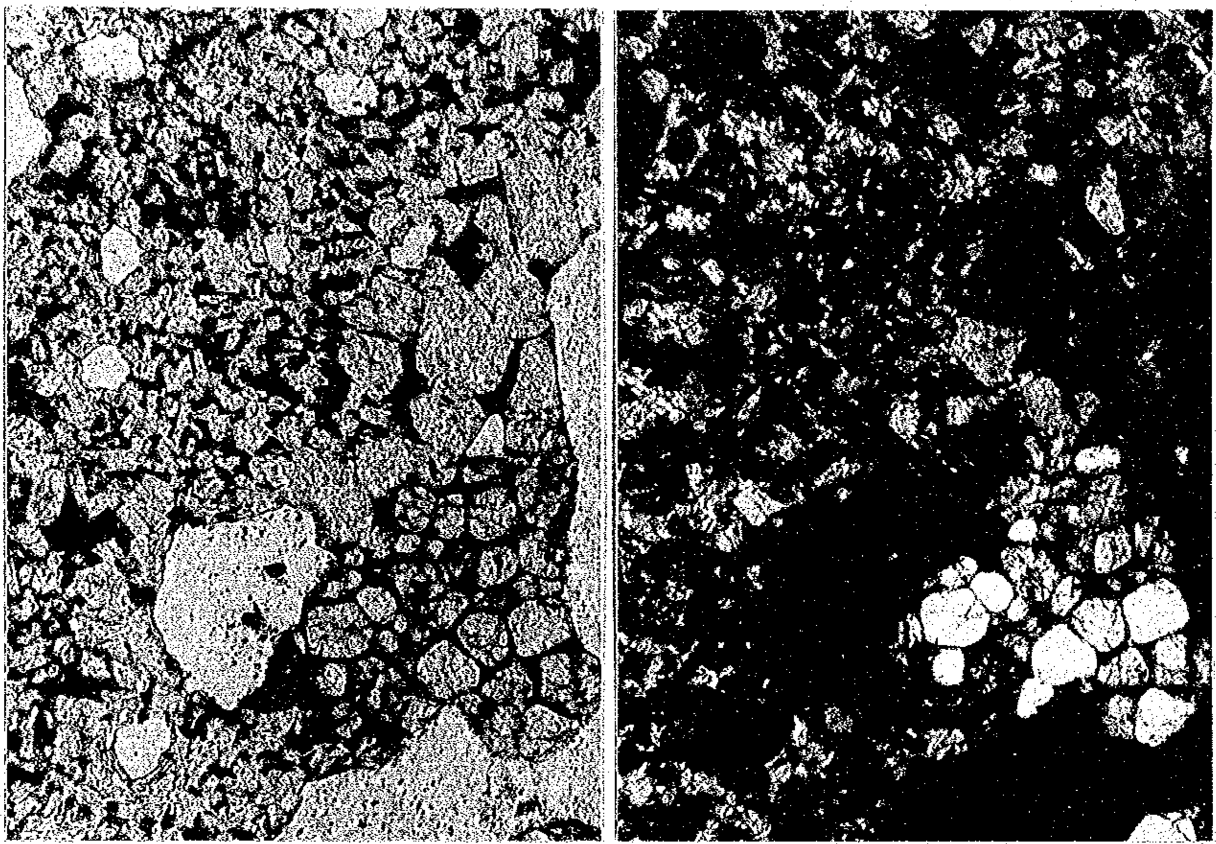
The microscopic photograph and clinker minerals observed by a microscope is shown in Photo 5-3-6 and Table 5-3-26 respectively.

Table 5-3-26 Clinker Minerals Observed by Microscope

Clinker mineral	Size of crystal
Alit	10 ~ 60 μ
Belit	20 ~ 40 μ
Interstitial material	–

Photo 5-3-6

Sample Clinker N-1



Open Nicol　　　　Cross Nicol　　　　100 μ

As clinker mineral, alite, blite and interstitial material are clearely observed, which shows that the clinkering reaction has sufficiently been taken place.
The crystals of alite with a size of 10 to 60 μ have dark rectangular or hexagonal shapes and are distributed all over the photograph.
While the crystals of belite with a size of 20 to 40 μ have light round shapes and gather at the right below corner of the photograph.

(vi) Consideration

(a) The burnability of the raw meal to be used for the Project is the same as or a little better than that of Japanese raw meal.

(b) In this test the effect of silica modulus on burnability was examined by changing the mixing ratio of silica sand.
However in the range of this test the effect was not remarkable and the burnability of raw meal of both high and low silica modulus are almost the same with each other.

(c) When the high siliceous clay was used as siliceous material in place of silica sand, the burnability of the raw meal became better.

Note : In general to improve the burnability of raw meal the following measures are recommended.

- Change of moduli especially of HM and IM
- Increase of fineness
- Increase of homogeneity
- Improve of operation control etc.

It is necessary to examine the items mentioned above referring the quality of cement produced in actual operation.

(6) Grindability test of raw material

Since the grinding with closed circuit system will be adopted at actual operation, the grindability test was performed according to "Testing method of grinding work index" which consists of closed circuit system. The test result was examined by comparing with those of raw materials used in Japanese cement plant.

(i) Mixing proportion of raw materials

The raw materials used for the burnability test were used for the grindability test and the mixing proportion was almost the same as that of combination N-1 of burnability test. Therefore this mixing proportion corresponds to the following moduli.

HM : 2.10
SM : 2.6
IM : 1.8

The raw materials used for the test and the mixing proportion are shown in Table 5-3-27.

Table 5-3-27 Mixing Proportion of Raw Materials

(wt. % in dry basis)

Sample of raw materials	Mixing proportion of raw materials
Sindali limestone BH-10	80.54
Beltar clay B-1230	14.34
Trijuga river silica sand No. 1	4.35
Phulchoki iron ore No. 1	0.77
Total	100

(ii) Testing method

The grinding work index can be measured by a test ball mill according to this method.

Specification of the test mill and grinding media

Still pot mill

inside diameter		305 mm
inside length		305 mm
revolution		70 revolution per min.
grinding media	:	bearing ball of steel
diameter		quantity
36.5 mm		43 pcs.
30.2 mm		67 pcs.
25.4 mm		10 pcs.
19.1 mm		71 pcs.
15.9 mm		94 pcs.

Procedure

(a) Measure the particle size distribution of the raw mix sample crushed to as fine as less than 3.360 μ and determine under size (%) of P_1(μ) and 80 % particle size F (μ).

Note. 1. In this test P_1(μ) is 88 μ.

2. 80 % particle size : In case that the under size of a particle size is 80 % of pulvenulent body which has particle size distribution, this particle size is called 80 % particle size.

(b) Put the prepared sample into a measuring cylinder measure the weight of sample of 700 mℓ volume and charge this quantity into the test mill with the grinding media and then operate the mill for 100 revolutions.

(c) After 100 revolutions screen all the ground material carefully by $P_1(\mu)$ sieve and measure over size A (g).

(d) Calculate Gbp from under size of $P_1(\mu)$, i.e. (W-A)(g) and estimate the revolutions of next trial by which the circulating rate of next trial reaches 250 %.

Note. Gbp : Under size of $P_1(\mu)$ produced by one revolution of test mill (g)

(e) Add the new prepared sample, which is the same weight as the under size of $P_1(\mu)$, i.e. (W-A)(g), to the over size A (g) and charge into the test mill.

(f) Operate the mill by the revolutions estimated in item (d).

(g) Repeat the procedure of item (d) ~ (f), until the circulating rate reaches steady state at about 250 %.

Calculate the average value of Gbp (Gbp) from the last three trials.

(h) Measure the particle size distribution of under size product of P_1 (μ) sieve obtained in item (g) and calculate 80 % particle size of P (μ).

Calculation formula of Wi

$$Wi = \frac{44.5}{(P_1)^{0.23} \times (Gbp)^{0.82} \times \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right)} \times 1.102 \text{ (kWh/t)}$$

(iii) Result of test

Work index Wi = 19.0 kWh/t

(iv) Consideration

The grinding work index (Wi) is the index based on Bond's "The third theory of comminution" and principally represents the grinding resistance of material.

Since this experimental work index (Wi) shows good correlation with the work index (Wio) obtained by actual plant operation, the grindability can be examined based on the index.

The characteristics of this method lies in the adoption of closed circuit system by adding a new feed to the over size of $P_1(\mu)$ sieve to repeat the grinding and therefore the results are close to the actual operation figures.

The test result of Nepalese raw material and those of raw materials used in the cement plant in Japan are shown in Table 5-3-28.

Table 5-3-28 Work Index (Wi) of Nepalese Raw Materials and Japanese Raw Materials

Raw material	Wi (kWh/t)
Nepalese raw material	19.0
Japanese raw material A	9.3 ~ 9.8
Japanese raw material B	10.2
Japanese raw material C	12.2
Japanese raw material D	8.5
Japanese raw material E	12.9
Japanese raw material F	9.2
Japanese raw material G	9.4 ~ 11.2

Judging from the tests results shown in Table 5-3-28, the grindability of Nepalese raw material is somewhat low as compared with those of Japanese raw materials.

Although this results seems to be caused by the hardness of limestone which amounts about 80 % of raw material, no problem is foreseen in the grinding process of raw material.

(7) Quality of industrial water

The results of test of Trijuga river water taken in the vicinity of Gaighat and the well water taken in Motigarha village are shown in Table 5-3-29.

Those water can be used as industrial water.

Table 5-3-29 Test Results of Water Samples

Name of sample	pH	Alkalinity		Total hardness (as $CaCO_3$)	SO_4^{--}	$C\ell^-$	Fe
		M (as $CaCO_3$)	P (as $CaCO_3$)				
Trijuga river water	8.55	146	< 2	150	3.3	0.48	0.076
Motigarha well water	7.50	107	< 2	150	9.5	21	0.055

Note : Test results are expressed by the unit of mg/ℓ (p.p.m.) except for pH.

(8) Quality of coal

The test results of the sample of Assam coal obtained from India through DMG (Department of Mines and Geology) are shown in Table 5-3-30.

Table 5-3-30 Test Results of Assam Coal

Test items	Test results
Moisture	1.73 %
Ash	10.28 %
Volatile matter	40.84 %
Fixed carbon	48.88 %
Gross calorific value	7,210 kcal/kg
Sulfur	3.24 %
Hydrogen	5.38 %

Note : Test results are expressed by wt. % in dry basis except calorific value.

V-3-3 Other Use of Limestone of Sindali Deposit

Since the limestone of Sindali deposit is of good quality other various uses than the raw material of ordinary portland cement are considered. A couple of examples are stated as follows.

(1) The raw material of white cement

The quality of the limestone used for the raw material of white cement is generally the same as that of ordinary portland cement, but it is necessary to maintain Fe_2O_3 content less than the allowable limit (0.08 %).

As shown in Table 5-3-3, the limestone sample with a Fe_2O_3 content of 0.07 % (for example, sample No. S-109, S-216 and S-217 etc.) are found. If it is ascertained that the limestone of such quality can be exploited selectively and is sufficient in quantity, the use for raw material of white cement is expected.

In such a case, the white clay is necessary in the following proportion besides the limestone.

Limestone	about	1,200 kg/t·cℓ
White clay	about	300 kg/t·cℓ

Sometimes a very small quantity of fluorspar is added as a melting agent.

(2) Lime product

The followings materials are produced as lime products, namely, quick lime, hydrated lime, heavy calcium carbonate, light calcium carbonate and crushed stone etc.

These products could be produced from the limestone of Sindali deposit.

Since the quality of the products depends on the quality of the raw limestone, it is necessary to examine the possibility wherever the product of high quality is required.
For the production of quick lime the calcination method should carefully be examined depending on the characteristics of limestone.

Remark : It is necessary to carry out a detailed feasibility study before an execution for both cases of (1) and (2) mentioned above.

- The raw material for calcium carbide and iron industries.

The limestone used for the purposes mentioned above is required to be of very high quality.
Especially the allowable values of MgO and P_2O_5 are small as shown in Table 5-3-30.

Table 5-3-30 Allowable Value of MgO and P_2O_5 in Limestone (%)

	CaC_2	Cast iron plant	Steel plant
MgO	≤ 0.5 ~ ≤ 1.75	≤ 0.5	≤ 0.5
P_2O_5	≤ 0.01 ~ ≤ 0.06	≤ 0.02	≤ 0.05

Data on chemical analysis of Sindali limestone which show the content of MgO and P_2O_5 in the same sample are shown in Table 5-3-3 and Table 5-3-4.
For MgO content many data are available in this report.
According to those data the samples which meet the allowable value of Table 5-3-30 are very rare.
Therefore to use Sindali limestone for calcium carbide and iron industries, further detailed investigation will be necessary.

V-3-4 Results of Chemical Analysis Carried out by DMG (Reference)

(1) Chemical analysis of Sindali limestone (Drilling hole samples)

Legend No. : Sample No, Core : Length of core(m), Ins : Insoluble residue
Fe : Fe_2O_3, Aℓ : $A\ell_2O_3$, Av. : Average

(%)

Drilling hole No. BH-1

No.	Core	Ins	Fe	Aℓ	CaO	MgO
1/1	1.40	1.38	0.13	1.15	34.21	17.53
2	0.45	2.42	0.11	1.35	51.59	2.41
3	0.15	0.90	0.16	1.04	52.71	0.20
4	1.65	2.22	0.08	1.14	54.39	0.80
5	0.13	3.86	0.30	1.18	40.37	11.28
6	3.37	2.54	0.11	1.53	51.59	2.01
7	2.60	1.36	0.14	1.06	54.95	0.40
8	0.45	0.58	0.48	0.92	41.49	12.09
9	0.45	0.40	0.24	1.06	52.15	3.02
10	0.15	0.48	0.14	0.66	36.45	17.33
11	3.70	1.64	0.19	1.11	53.27	1.41
12	1.35	1.42	0.21	1.37	54.67	0.20
13	3.75	1.20	0.45	1.61	40.37	11.69
14	4.50	1.88	0.42	1.30	53.27	1.20
15	4.50	2.32	0.31	1.33	52.15	0.60
16	3.15	2.82	0.32	1.46	50.19	2.01
17	2.75	3.02	0.41	1.59	49.91	2.20
18	1.00	2.92	0.29	1.51	51.31	1.61
1/1	1.40	1.38	0.13	1.15	34.21	17.53
Av. 2~18	34.10	2.04	0.28	1.35	50.84	2.71

Drilling hole No. BH-2

No.	Core	Ins	Fe	Aℓ	CaO	MgO
2/1	3.15	1.26	0.34	0.28	31.68	19.75
2	4.80	2.38	0.32	0.54	31.96	19.35
3	2.65	1.82	0.15	0.45	38.37	13.91
4	5.15	0.86	0.37	0.13	30.56	21.37
5	3.25	1.46	0.25	0.59	32.96	18.74
6	2.15	2.96	0.25	0.77	45.14	7.66
7	0.50	0.48	0.34	0.50	37.01	15.72
8	1.00	0.98	0.18	0.84	48.22	5.44
9	0.35	0.50	0.24	0.48	33.64	19.75
10	3.05	1.92	0.21	1.01	52.71	1.61
11	2.65	2.12	0.27	1.01	51.59	0.80
12	4.10	1.12	0.45	0.67	52,99	0.60
13	3.20	3.34	0.21	0.69	51.87	0.20
14	3.95	1.40	0.21	0.71	29.72	20.76
15	3.90	2.20	0.19	0.77	51.31	1.81
16	2.50	3.94	0.65	0.41	52.31	0.40
17	1.15	8.38	0.85	1.37	46.54	1.41
18	0.18	2.32	1.71	0.59	34.72	15.12
Av. 1~9	23.00	1.61	0.29	0.44	34.56	17.37
Av.* 10~17	20.55	2.66	0.35	0.79	51.83	0.96

* Excluding Sample 2/14

Drilling hole No. BH-3

No.	Core	Ins	Fe	Aℓ	CaO	MgO
3/1	1.70	1.74	0.29	1.45	50.75	2.82
2	2.00	4.08	0.57	1.97	49.63	2.21
3	2.50	1.60	0.34	1.70	50.75	2.82
4	1.50	1.94	0.28	1.46	51.87	1.61
5	2.80	0.70	0.18	1.26	52.43	2.02
6	3.05	0.66	0.29	1.39	52.43	2.62
7	3.00	0.62	0.11	0.95	53.55	0.80
8	3.00	2.58	0.22	0.94	52.99	0.60
9	2.95	0.52	0.11	0.95	51.03	1.81
10	2.20	0.66	0.08	0.62	53.27	2.00
11	3.70	1.08	0.12	0.90	53.83	0.20
12	4.60	1.24	0.14	0.92	53.83	0.60
13	3.00	1.04	0.06	0.96	54.39	0.60
14	3.10	1.12	0.17	0.79	54.39	0.60
15	1.45	1.30	0.12	1.00	52.99	1.00
16	2.25	3.42	0.06	1.00	51.03	1.81
17	2.45	9.48	0.33	0.55	47.66	1.61
18	3.15	4.04	0.19	1.21	49.91	1.81
19	1.75	2.50	0.54	0.52	49.63	2.41
20	1.75	3.16	0.57	0.69	50.19	1.61
Av. 1~20	51.90	2.04	0.21	1.04	52.08	1.45

Drilling hole No. BH-4

No.	Core	Ins	Fe	Aℓ	CaO	MgO
4/1	3.25	2.14	0.30	0.82	31.28	19.75
2	3.05	1.62	0.31	0.75	31.12	20.16
3	2.85	3.76	0.30	1.00	51.31	1.20
4	0.45	1.30	0.10	1.36	52.43	1.61
5	0.15	0.80	0.37	0.45	32.80	18.34
6	3.75	2.14	0.21	0.77	49.91	2.62
7	4.15	0.82	0.08	0.94	52.15	1.81
8	4.15	1.56	0.21	0.79	52.43	0.40
9	4.40	1.56	0.32	1.12	30.28	22.39
10	2.90	0.86	0.28	0.78	49.35	4.23
11	3.65	1.50	0.24	1.46	52.43	1.41
12	2.90	1.76	0.30	1.50	52.71	0.80

(%)

No.	Core	Ins	Fe	Aℓ	CaO	MgO
4/13	2.80	4.72	0.34	2.18	49.35	0.80
14	2.30	1.36	0.22	1.12	52.15	1.41
15	3.70	2.90	0.36	1.32	51.87	0.60
16	2.35	1.86	0.29	0.79	52.71	1.20
17	3.90	4.00	0.38	2.08	50.75	0.20
18	3.55	2.72	0.26	1.44	51.59	0.60
19	2.90	3.74	0.38	1.32	51.87	0.60
20	0.50					
Av. 1~5	6.90	1.82	0.29	0.81	32.62	18.71
Av. 6~20	43.00	2.29	0.26	1.26	51.48	1.25

Drilling hole No. BH-5

No.	Core	Ins	Fe	Aℓ	CaO	MgO
5/1	1.25	2.98	0.36	0.46	30.28	20.56
2	3.55	1.41	0.14	0.52	33.08	19.15
3	0.90	1.46	0.17	0.53	34.76	16.33
4	0.30	7.08	0.08	0.76	41.21	8.26
5	0.60	2.34	0.55	0.59	41.22	11.09
6	1.75	1.74	0.25	0.57	51.31	2.62
7	1.65	0.80	0.25	0.27	47.94	6.25
8	1.00	0.48	0.18	0.84	33.92	18.54
9	0.80	0.84	0.22	0.28	49.63	4.84
10	3.05	1.32	0.24	0.40	52.15	2.01
11	2.75	1.38	0.24	0.24	52.99	1.81
12	3.45	1.82	0.30	0.36	51.03	1.81
13	3.90	0.62	0.15	0.27	52.99	1.41
14	3.10	1.70	0.25	0.17	51.03	2.62
15	3.55	1.46	0.21	0.33	52.71	1.41
16	3.45	2.98	0.37	0.47	49.91	3.02
17	3.15	2.64	0.35	0.49	52.15	1.41
18	3.15	2.72	0.25	0.47	51.03	2.62
19	1.45	1.98	0.22	0.37	51.03	2.62
20	0.20	30.72	0.33	3.77	34.76	1.00
21	0.30	5.14	0.37	0.75	49.35	2.62
22	0.40	0.90	1.04	0.60	38.13	14.50
Av. 1~5	6.60	2.05	0.21	0.52	33.88	17.80
Av. 6~22	36.70	1.91	0.25	0.39	50.90	2.75

Drilling hole No. BH-6

No.	Core	Ins	Fe	Aℓ	CaO	MgO
6/1	1.40	1.24	0.64	0.37	52.00	1.61
2	2.00	1.00	0.64	0.82	54.71	-
3	1.20	3.64	0.32	0.97	53.47	0.16
4	3.40	1.38	0.40	2.38	51.00	1.12
5	2.97	1.34	0.64	0.48	54.81	-
6	2.80	1.00	0.80	0.50	53.70	1.12
7	2.65	1.58	0.32	0.90	52.00	0.82
8	1.65	1.12	0.48	0.82	53.20	0.60

No.	Core	Ins	Fe	Aℓ	CaO	MgO
6/9	1.85	1.44		1.50	52.71	0.80
10	0.90	1.50		1.10	52.93	0.96
11	3.75	1.16		1.00	52.71	1.33
12	1.05	1.24	0.64	0.37	52.00	1.61
13	3.80	1.19		1.00	52.84	1.60
14	0.15	2.08		1.00	52.71	0.80
15	4.95	1.32		1.50	52.71	1.20
16	4.65	1.72		1.10	52.80	0.88
17	2.55	2.10		1.50	52.71	0.72
Av. 1~17	41.72	1.44	0.54	1.11	52.86	1.08

Drilling hole No. BH-7

No.	Core	Ins	Fe	Aℓ	CaO	MgO
7/1	1.80	1.24	0.18	3.08	50.47	1.41
2	2.35	0.48	0.20	3.10	50.19	2.82
3	3.90	0.56	0.13	2.69	51.03	2.01
4	4.00	0.74	0.16	3.04	50.17	2.61
5	3.75	2.62			49.63	2.21
6	3.95	2.60	0.33	3.87	48.50	2.01
7	2.35	0.94	0.30	2.80	49.91	2.01
8	3.00	1.14	0.22	4.74	49.35	1.21
9	2.40	1.12	0.19	2.95	51.59	0.20
10	2.50	2.02	0.24	2.22	52.15	0.20
11	3.00	6.06	0.40	1.98	47.94	2.01
12	1.70	4.94	0.37	2.66	48.78	1.00
13	0.80	2.74	0.58	3.44	47.10	2.41
Av. 1~13	35.50	2.02	0.25	3.07	49.85	1.77

Drilling hole No. BH-8

No.	Core	Ins	Fe	Aℓ	CaO	MgO
8/1	3.40	1.72	0.35	0.17	31.95	20.20
2	4.00	2.36	0.34	1.56	31.12	19.35
3	1.90	2.96	0.34	0.42	52.17	0.40
4	2.70	0.96	0.18	0.28	52.99	1.41
5	3.40	1.60	0.22	0.16	53.55	1.00
6	3.60	1.18	0.18	0.32	54.11	1.41
7	3.10	0.60	0.15	0.21	52.99	2.21
8	5.40	0.74	0.18	0.58	52.43	2.82
9	3.75	1.62	0.28	0.40	53.27	1.61
10	3.65	1.22	0.15	0.21	54.67	0.60
11	2.75	1.20	0.24	0.32	52.71	2.41
12	2.65	1.36	0.21	0.71	53.55	1.00
13	2.65	2.12	0.24	0.08	52.15	1.81
14	1.90	1.74	0.17	0.23	53.55	0.80
Av. 1~2	7.40	2.07	0.34	0.92	31.50	19.74
Av. 3~14	37.45	1.34	0.21	0.34	53.21	1.57

(%)

Drilling hole No. BH-9

No.	Core	Ins	Fe	Aℓ	CaO	MgO
9/1	3.65	0.09		1.20	53.70	0.37
2	1.60	1.88		1.57	52.25	0.94
3	2.50	1.85		1.26	61.98	0.86
4	3.25	0.69		1.41	52.68	1.12
5	3.65	1.82		1.01	52.70	1.11
6	3.10	1.38		1.06	52.31	1.03
7	2.70	1.05		1.18	53.83	0.10
8	1.55	0.97		1.44	52.81	0.77
9	2.70	2.49		1.20	54.00	0.60
10	3.65	1.98		1.43	52.91	0.27
11	3.65	1.94		1.98	53.42	0.04
12	2.55	1.83		1.15	53.66	0.09
13	2.10	1.84		0.87	53.66	0.15
14	3.35	2.62		2.82	52.30	0.31
15	2.80	0.22		0.83	54.83	0.13
16	3.25	1.98		1.88	52.63	0.12
Av. 1~16	46.05	1.61		1.42	53.11	0.49

Drilling hole No. BH-10

No.	Core	Ins	Fe	Aℓ	CaO	MgO
10/1	2.25	4.16	0.54	0.54	49.35	3.02
2	2.60	0.90	0.16	0.58	52.15	2.41
3	4.25	1.14	0.14	0.90	51.87	2.22
4	3.45	1.08	0.25	0.45	52.43	2.01
5	4.35	1.32	0.20	0.60	51.59	2.62
6	2.90	0.80	0.11	0.65	51.90	2.22
7	3.95	1.30	0.09	0.61	51.59	3.02
8	3.80	0.98	0.05	0.73	51.03	3.02
9	2.95	0.92	0.11	1.29	52.43	1.61
10	4.25	2.84	0.28	0.66	50.47	2.41
11	1.25	1.34	0.25	0.21	51.59	2.62
12	1.20	0.36	0.71	0.31	51.87	3.22
13	2.65	0.42	0.11	0.35	53.27	1.41
14	2.00	0.32	0.06	1.14	52.99	1.81
15	4.10	0.40	0.10	0.38	52.43	2.22
16	4.65	1.06	0.19	0.97	51.03	3.02
17	4.10	1.02	0.19	0.93	52.15	1.61
18	4.80	0.90	0.17	0.97	51.59	2.42
19	1.70	1.62	0.22	0.82	52.15	1.61
20	1.05	64.82	4.62	3.56	11.77	1.61
Av. 1~19	61.2	1.23	0.18	0.72	51.71	2.36

Drilling hole No. BH-11

No.	Core	Ins	Fe	Aℓ	CaO	MgO
11/1	2.25	0.36	0.09	0.49	53.84	1.01
2	2.60	0.70	0.06	0.56	52.99	1.20
3	3.55	1.04	0.19	0.35	51.59	2.62
4	3.75	1.96	0.19	0.27	50.47	2.82
11/5	4.35	3.74	0.81	0.76	34.77	15.52
6	2.90	1.80	0.38	0.38	33.92	17.13
7	3.60	1.16	0.70	0.60	30.84	19.55
8	2.00	1.64	0.37	0.82	33.65	17.34
9	4.50	1.62	0.17	0.43	44.30	7.86
10	1.05	0.58	0.46	0.64	37.01	14.71
11	3.40	1.38	0.21	0.38	51.59	2.62
12	1.55	0.82	0.28	0.44	41.23	11.69
13	3.00	1.06	0.14	0.36	51.31	2.82
14	4.00	1.64	0.41	0.33	52.71	1.00
15	3.55	0.82	0.19	0.49	52.72	2.02
16	5.25	1.28	0.24	0.88	52.43	2.02
17	4.55	1.26	0.25	0.25	51.03	3.23
18	4.40	0.70	0.19	0.27	52.43	2.42
19	3.65	1.02	0.22	0.92	51.31	3.43
20	3.45	0.84	0.16	0.32	51.59	3.02
21	2.40	1.04	0.14	0.36	52.43	2.22
22	3.15	2.38	0.30	0.46	52.72	1.01
23	3.30	3.70	0.31	0.45	51.59	1.01
24	6.15	4.14	0.41	1.39	51.03	1.41
25	2.95	1.78	0.19	0.33	52.99	1.21
Av.* 1~25	66.90	1.60	0.23	0.53	51.69	2.31

* Excluding Sample 11/5 ~ 11/9

Drilling hole No. BH-12

No.	Core	Ins	Fe	Aℓ	CaO	MgO
12/1	1.10	1.36	0.16	0.40	53.27	0.60
2	2.40	1.12	0.20	0.50	52.71	1.00
3	3.90	1.64	0.18	0.52	52.27	1.00
4	3.95	2.40	0.22	0.44	52.15	1.00
5	1.95	1.26	0.28	0.36	53.27	0.60
6	4.10	1.84	0.20	0.48	53.27	0.20
7	2.55	2.28	0.33	0.81	52.71	0.20
8	5.00	2.40	0.24	0.40	49.91	3.42
9	2.65	1.26	0.17	0.61	53.55	0.20
10	2.95	1.52	0.23	0.31	52.71	0.60
11	3.00	3.24	0.64	0.52	49.63	2.01
12	2.90	0.76	0.28	0.32	52.71	1.00
13	5.60	2.90	0.32	0.78	50.75	1.61
14	4.85	0.74	0.64	0.94	52.43	1.41
15	2.05	0.56	0.44	0.70	44.86	9.07
16	4.65	0.48	0.34	0.54	50.47	4.83
17	1.05	1.10	20.24	0.72	39.82	1.81
18	3.10	0.82	0.30	0.76	53.83	1.41
19	3.05	1.32	0.16	0.40	51.59	1.81
20	4.55	1.14	0.13	0.17	52.71	1.00
21	3.15	2.44	0.18	0.50	51.59	1.00
22	1.45	3.20	0.46	0.26	51.59	1.61
Av.* 1~22	68.90	1.67	0.28	0.53	51.82	1.72

* Excluding Sample 12/17

(%)

No.	Core	Ins	Fe	Aℓ	CaO	MgO
Drilling hole No. BH-13						
13/1	2.15	1.26	0.14	0.16	53.27	0.20
2	3.35	2.36	0.21	0.27	52.15	2.01
3	1.65	1.56	0.21	0.31	52.99	1.61
4	2.55	0.72	0.14	0.36	53.55	1.41
5	3.00	1.50	0.18	0.30	52.71	1.41
6	2.40	3.08	0.31	0.49	51.31	1.61
7	3.05	3.86	0.39	0.53	51.87	1.00
8	3.35	3.24	0.30	0.52	50.19	2.01
9	4.30	3.26	0.21	0.53	52.43	0.20
10	0.65	1.40	0.16	0.48	53.55	0.80
11	4.55	2.04	0.19	0.25	52.99	1.20
12	2.30	0.62	0.11	0.43	51.87	2.82
13	2.05	0.98	0.27	0.31	54.95	0.20
14	3.70	1.50	0.19	0.21	53.28	1.01
15	3.55	2.40	0.28	0.26	52.15	1.41
16	4.40	0.80	0.14	0.22	52.43	2.02
17	3.50	1.94	0.40	0.29	51.87	1.81
18	3.85	1.04	0.20	0.26	52.99	1.41
19	2.40	2.50	0.27	0.45	52.43	1.21
20	0.30	2.41	0.41	0.53	52.43	1.01
21	4.50	0.88	0.19	0.14	52.72	1.81
22	3.90	1.08	0.15	0.37	52.99	1.61
23	3.65	2.16	0.23	0.32	52.15	1.21
24	4.65	1.64	0.31	0.63	52.43	1.41
25	2.90	0.55	0.23	0.31	54.39	0.40
26	4.75	1.40	0.21	0.23	53.28	1.01
27	3.25	1.92	0.29	0.17	52.99	1.01
28	1.90	1.10	0.23	0.41	53.56	0.81
29	3.10	0.98	0.24	0.51	53.56	1.01
30	3.50	1.18	0.25	0.33	52.72	1.81
31	3.75	2.00	0.28	0.76	51.59	1.81
Av. 1~31	96.90	1.72	0.23	0.35	52.64	1.34
Drilling hole No. BH-14						
14/1	1.00	1.08	0.18	0.30	52.72	1.61
2	0.75	0.90	0.89	0.95	39.82	12.49
3	0.40	7.22	1.33	0.57	29.72	17.74
4	1.35	0.99	0.17	0.30	53.28	1.41
5	3.20	0.94	0.15	0.15	53.84	1.21
6	3.30	1.43	0.17	0.29	52.99	1.61
7	3.90	1.18	0.15	0.19	52.15	2.42
8	2.00	1.60	0.19	0.27	53.28	1.41
9	3.35	1.34	0.14	0.32	53.83	0.60
10	4.05	0.62	0.14	0.46	52.71	2.41
11	3.80	1.46	0.13	0.31	53.70	1.20
12	3.60	6.40	0.58	0.52	46.82	3.62
13	2.55	5.16	0.79	0.37	45.98	5.24
14	3.30	2.28	0.08	0.28	51.03	2.62
15	0.25	2.14	0.89	0.53	45.42	4.63
16	3.50	3.66	0.26	0.38	48.79	3.43
14/17	3.00	1.22	0.53	0.27	50.47	3.02
18	4.50	1.06	0.20	0.20	51.87	2.42
19	4.90	1.36	0.22	0.20	51.87	2.02
20	4.50	1.32	0.21	0.25	51.59	2.22
21	3.80	1.60	0.25	0.23	51.35	2.42
22	4.75	0.66	0.31	0.57	52.15	2.82
23	4.00	0.38	0.15	0.37	52.71	3.02
24	3.05	1.50	0.26	0.44	52.15	2.62
25	4.00	0.64	0.15	0.39	52.71	2.62
26	4.95	1.14	0.19	0.37	52.43	2.41
27	4.40	0.64	0.15	0.41	53.27	2.01
28	4.75	2.40	0.28	0.64	52.15	1.61
29	4.30	5.82	0.52	0.90	48.22	2.41
30	2.00	3.60	0.32	0.80	51.59	1.41
31	4.35	5.50	0.45	0.97	50.59	2.01
Av.* 1~31	99.40	2.12	0.26	0.41	51.89	2.32
* Excluding Sample 14/1 ~ 14/3						
Drilling hole No. BH-15						
15/1	1.55	6.52	0.67	1.65	50.47	1.20
2	1.50	0.86	0.18	0.40	52.71	2.82
3	2.30	1.90	0.37	0.67	53.27	1.61
4	2.60	1.60	0.32	0.48	53.27	2.01
5	4.55	0.56	0.18	0.36	54.39	1.61
6	4.35	1.64	0.32	0.60	53.83	1.20
7	2.20	2.42	0.36	0.58	52.71	1.20
8	3.95	1.26	0.42	0.48	54.11	1.20
9	2.40	1.38	0.23	0.41	54.39	1.00
10	2.85	0.72	0.23	0.11	53.83	1.41
11	2.60	2.06	0.28	0.36	53.55	1.41
Av. 1~11	30.85	1.64	0.31	0.50	53.58	1.46
Drilling hole No. BH-16						
16/1	2.35	1.60	0.22	0.56	52.43	1.00
2	3.30	0.60	0.19	0.13	52.43	2.21
3	1.80	2.04	0.31	0.95	50.75	2.01
4	2.90	2.46	0.31	0.65	51.87	1.00
5	2.65	2.00	0.28	0.18	53.27	trace
6	3.00	1.98	0.07	0.23	53.27	trace
7	2.20	1.74	0.28	0.04	53.27	trace
8	4.35	2.00	0.22	1.12	52.99	0.60
9	4.00	1.58	0.17	0.25	52.43	2.21
10	4.10	0.54	0.09	0.17	52.71	2.21
11	4.35	3.72	0.28	0.78	50.49	1.81
12	5.15	2.64	0.49	0.55	51.87	0.80

(%)

No.	Core	Ins	Fe	Aℓ	CaO	MgO
16/13	2.20	1.82	0.27	0.43	51.03	2.82
14	5.30	2.02	0.24	0.66	53.27	0.40
15	4.40	2.36	0.14	0.01	53.83	trace
16	3.00	1.50	0.19	0.19	51.87	2.21
17	3.05	2.40	0.14	0.02	53.55	trace
Av. 1~17	58.10	1.99	0.23	0.42	52.49	1.12

Drilling hole No. BH-17

No.	Core	Ins	Fe	Aℓ	CaO	MgO
17/1	3.00	2.00	0.85	0.06	52.99	1.00
2	2.40	3.00	0.28	1.07	30.84	18.14
3	3.80	1.60	0.14	0.38	54.67	0.40
4	3.10	1.60	0.09	0.23	51.59	2.21
5	4.30	3.1	0.21	0.44	54.51	trace
6	3.70	2.60	0.25	0.27	50.75	2.42
7	3.65	0.66	0.35	0.29	44.58	8.46
8	4.05	2.14	0.14	0.60	53.27	0.80
9	4.40	1.38	0.14	0.38	51.03	3.22
10	1.40	1.02	0.07	0.98	53.27	2.00
11	4.40	1.32	0.15	0.55	50.19	3.42
12	4.90	1.02	0.09	0.23	51.59	2.82
13	4.45	1.22	0.34	0.68	53.27	1.21
14	3.30	2.64	0.38	0.36	52.43	0.80
15	4.70	0.90	0.14	0.68	53.83	0.40
16	4.85	0.54	0.12	0.28	52.71	2.21
17	4.30	1.06	0.15	0.25	53.27	1.21
18	4.40	2.02	0.15	1.39	51.31	1.20
19	4.20	1.30	0.44	0.16	52.71	1.20
20	2.60	0.58	0.14	0.30	53.55	1.21
21	4.70	0.92	0.20	0.42	53.83	1.01
22	4.05	2.26	0.28	0.16	52.99	trace
23	3.80	1.74	0.22	0.34	53.27	1.21
24	3.45	2.44	1.13	0.01	53.27	trace
25	3.55	3.50	0.56	0.12	52.36	1.81
26	3.00	4.02	0.42	0.04	52.43	trace
27	4.10	3.50	0.28	0.02	52.71	trace
28	3.15	1.18	0.17	0.43	53.55	1.01
Av.* 1~28	100.30	1.75	0.25	0.38	52.41	1.55

* Excluding Sample 17/1 ~ 17/2

Drilling hole No. BH-18

No.	Core	Ins	Fe	Aℓ	CaO	MgO
18/1	1.55	2.24	5.39	0.35	51.03	-
2	3.40	1.64	0.79	0.61	53.27	0.81
3	0.35	0.2	0.35	0.05	54.39	trace
4	2.70	1.06	0.35	0.33	51.87	2.21
5	2.95	0.7	0.42	0.18	53.83	1.00
6	4.10	0.50	0.15	0.17	51.87	2.41
7	5.05	-	0.41	0.09	54.11	1.40
18/8	1.50	1.30	0.21	0.87	52.43	2.41
9	3.95	1.66	0.21	0.85	53.27	1.40
10	3.10	2.06	0.20	0.42	51.03	2.21
Av.* 1~10	27.10	1.01	0.35	0.39	52.85	1.65

* Excluding Sample 18/1

Drilling hole No. BH-19

No.	Core	Ins	Fe	Aℓ	CaO	MgO
19/1	0.70	1.54	0.46	0.60	52.16	0.81
2	0.45	1.09	0.19	0.26	52.58	1.41
3	1.35	0.88	0.21	0.34	52.99	1.01
4	0.35	1.01	0.26	0.28	52.44	1.41
5	0.65	2.30	0.43	0.29	52.15	1.20
6	2.80	1.04	0.22	0.10	51.59	2.01
7	1.85	1.90	0.95	0.49	51.03	1.81
8	1.00	0.82	0.09	0.77	52.15	2.21
9	1.85	0.76	0.22	0.20	51.31	2.62
10	3.15	1.18	0.07	0.87	53.27	1.09
11	3.50	1.14	0.14	0.30	51.59	2.42
12	4.10	1.12	0.28	0.74	52.71	1.20
13	4.45	1.96	0.14	0.34	53.27	1.20
14	4.70	1.56	0.14	0.44	54.39	trace
15	4.60	1.96	0.07	0.75	51.24	1.00
16	4.75	2.24	0.14	0.60	52.76	0.40
17	4.20	1.76	0.14	0.52	49.91	4.03
18	3.45	2.00	0.14	0.64	50.47	2.22
19	4.30	0.66	0.14	0.28	53.76	1.20
20	5.00	2.68	0.14	0.16	52.99	trace
21	3.80	1.26	0.28	0.02	53.56	1.41
22	4.20	2.72	0.28	0.60	52.64	0.84
23	3.00	1.94	0.14	0.69	53.20	trace
24	3.55	4.88	2.69	0.07	50.92	trace
25	4.10	1.56	0.14	0.74	52.71	trace
26	3.45	5.00	0.28	0.02	52.64	trace
Av.* 1~26	75.75	1.85	0.19	0.45	52.48	1.15

* Excluding sample 19/24

Drilling hole No. BH-20

No.	Core	Ins	Fe	Aℓ	CaO	MgO
20/1	0.70	1.08	0.07	0.13	52.71	1.21
2	2.85	2.88	0.49	0.63	41.16	11.28
3	4.30	3.42	0.28	0.68	33.08	16.53
4	3.65	1.50	0.56	0.22	33.04	18.54
5	4.20	0.94	0.26	0.10	40.37	12.29
6	5.00	3.16	0.14	0.16	32.48	18.14
7	2.00	2.80	0.42	0.04	50.19	3.22
8	2.20	4.22	0.71	1.29	43.18	8.06
9	3.85	2.54	0.56	0.06	36.68	15.72

(%)

No.	Core	Ins	Fe	Aℓ	CaO	MgO
20/10	4.65	0.86	0.42	0.10	43.18	9.47
11	3.25	2.00	0.14	0.22	32.48	18.95
12	3.20	1.32	0.42	0.44	33.10	17.70
13	1.85	2.44	0.14	0.28	52.36	1.41
14	3.80	1.40	0.42	1.00	41.72	9.87
15	1.75	2.42	0.64	0.76	32.53	17.54
16	1.90	1.62	0.30	0.44	51.59	1.82
17	4.35	1.64	0.26	0.18	53.56	0.81
18	4.55	0.92	0.24	0.16	52.16	1.82
19	4.05	0.40	0.26	0.22	52.72	1.61
20	4.00	0.46	0.26	0.20	52.72	1.61
21	3.90	1.30	0.33	0.32	52.72	1.21
22	3.55	0.84	0.22	0.18	53.56	1.01
23	2.90	1.16	0.26	0.22	53.28	1.01
24	4.90	0.74	0.16	0.18	53.84	0.81
Av. 1~15	47.25	2.17	0.38	0.39	37.04	13.37
Av. 16~24	34.10	0.96	0.25	0.22	52.98	1.27

Drilling hole No. BH-21

No.	Core	Ins	Fe	Aℓ	CaO	MgO
21/1	0.70	0.96	0.14	0.25	54.78	trace
2	2.55	0.78	0.14	0.22	54.78	trace
3	1.10	0.65	0.28	0.11	54.22	0.60
4	2.40	4.81	0.14	0.34	52.15	0.40
5	2.60	0.86	0.14	0.18	51.14	3.02
6	3.45	1.06	0.14	0.15	52.80	1.21
7	3.85	1.51	0.28	0.03	54.60	0.60
8	3.95	0.83	0.14	0.09	53.83	0.80
9	3.65	0.88	0.14	0.14	54.22	0.60
10	4.05	1.18	0.14	0.07	53.87	0.40
11	3.60	0.91	0.14	0.30	53.83	0.88
12	4.25	1.47	0.14	0.07	52.15	2.03
13	3.40	0.31	0.14	0.12	53.87	1.09
14	4.70	0.59	0.07	0.26	53.87	0.81
15	3.55	0.49	0.14	0.34	51.63	2.82
16	4.50	1.23	0.28	0.11	51.59	3.21
17	5.05	0.71	0.14	0.21	53.27	3.21
18	4.45	0.81	0.14	0.34	53.83	0.88
19	4.50	0.98	0.14	0.68	54.22	trace
20	4.10	0.71	0.14	0.57	53.87	1.80
21	4.45	1.07	0.14	0.75	53.87	0.80
22	3.45	0.86	0.14	0.45	53.87	1.80
23	1.45	2.10	0.14	0.16	54.75	trace
Av. 1~23	79.75	1.05	0.15	0.31	53.45	1.18

Drilling hole No. BH-22

No.	Core	Ins	Fe	Aℓ	CaO	MgO
22/1a	2.70	1.00	0.24	0.28	52.43	2.21
22/1	3.20	3.00	0.36	0.38	52.15	1.00
2	3.50	3.46	0.36	0.52	52.71	1.00
22/3	3.90	4.40	0.43	0.53	51.87	0.80
4	4.20	1.98	0.41	0.43	52.43	1.81
5	3.85	1.86	0.31	0.29	52.43	1.81
6	4.05	1.88	0.25	0.37	52.99	1.00
7	3.50	2.10	0.68	0.68	23.56	17.94
8	1.90	1.14	0.63	0.45	31.12	20.36
9	3.60	0.70	0.63	0.37	30.28	20.96
10	3.80	2.46	0.15	0.51	43.18	9.67
11	4.45	1.20	0.28	0.34	52.43	1.81
12	3.55	1.32	0.18	0.30	52.71	1.21
13	3.40	1.72	0.21	0.39	52.99	1.81
14	2.75	0.82	0.35	0.37	52.15	2.21
15	4.15	0.26	0.26	0.26	52.43	9.42
16	4.25	0.34	0.21	0.17	53.55	1.81
17	4.45	1.72	0.37	0.53	51.59	1.81
18	3.00	0.84	0.22	0.30	52.99	1.81
19	3.70	1.06	0.16	0.38	52.15	1.61
Av.* 1a~19	59.10	1.68	0.29	0.37	52.50	1.63

* Excluding Sample 22/7 ~ 22/10

Drilling hole No. BH-23

No.	Core	Ins	Fe	Aℓ	CaO	MgO
23/1	3.50	1.68	0.20	0.32	51.59	2.52
2	4.25	1.10	0.14	0.24	53.27	1.61
3	3.60	0.96	0.34	0.34	52.01	2.62
4	2.80	0.84	0.34	0.32	51.73	2.72
5	3.35	1.30	0.17	0.17	52.01	2.02
6	2.82	5.08	2.43	0.27	36.87	12.10
7	3.10	2.12	2.14	0.14	34.48	16.12
8	3.15	3.16	0.52	0.56	31.97	18.14
9	2.90	1.76	0.34	0.26	50.05	3.63
10	4.10	2.52	0.34	0.18	49.63	3.93
11	4.90	1.06	0.26	0.14	52.58	2.02
12	4.05	1.36	0.28	0.21	53.14	1.41
13	5.30	1.36	0.31	0.19	52.58	1.81
14	4.40	0.68	0.34	0.16	50.89	3.83
15	4.55	0.72	0.31	0.21	50.89	3.83
16	4.65	1.16	0.26	0.30	53.83	1.31
17	3.30	0.90	0.22	0.28	52.57	2.11
18	4.60	1.42	0.25	0.37	53.13	1.71
19	4.45	0.86	0.28	-	52.43	2.31
20	3.75	2.20	0.31	0.41	52.29	1.71
21	4.05	8.10	0.85	0.41	49.07	0.80
22	2.05	0.96	0.97	0.37	52.86	1.81
Av.* 1~22	74.55	1.64	0.33	0.26	51.96	2.28

* Excluding Samples 23/6 ~ 23/8

(2) Chemical analysis of Beltar clay (Pit samples)

Legend No. : Sample No., T : Thickness (m), Si : SiO_2(%), Fe : Fe_2O_3(%)
Aℓ : $A\ell_2O_3$(%), Ca : CaO (%), Mg : MgO (%), Av. : Average,
Sav : Section average

(%)

No.	T	Si	Fe	Aℓ	Ca	Mg
Section -						
1/1	1.30	70.70	6.06	14.89	2.10	0.50
Section 1-1'						
2/1	0.50	63.93	7.66	18.24	0.70	0.50
2	1.60	62.58	8.45	19.70	0.70	1.08
Av.	2.10	62.90	8.26	19.35	0.70	0.94
3/1	0.50	68.73	6.46	16.29	0.70	0.50
2	1.00	67.62	6.94	14.86	2.80	0.50
3	1.00	64.68	7.02	20.38	0.70	0.50
4	1.00	62.85	7.98	19.82	0.70	0.50
5	1.00	63.47	7.82	18.88	0.70	-
6	1.00	63.47	7.66	18.84	0.70	-
7	0.95	64.10	7.34	18.81	0.70	-
Av.	6.45	64.71	7.38	18.42	1.03	0.27
4/1	0.50	67.63	5.64	15.96	0.70	1.51
2	1.00	65.78	6.27	18.08	1.50	1.00
3	0.55	74.99	6.11	11.64	1.40	1.51
4	1.00	66.07	6.74	17.21	1.40	1.51
5	1.00	68.52	6.27	16.93	1.40	1.51
6	1.00	63.23	7.68	20.22	-	1.00
7	1.00	62.80	7.84	18.61	2.10	-
8	1.70	63.99	7.68	20.17	-	1.00
Av.	7.75	65.84	6.97	17.91	0.96	1.07
5/1	0.50	64.57	5.74	19.36	0.70	0.50
2	1.00	68.37	6.38	14.87	0.70	1.00
Av.	1.50	67.11	6.17	16.37	0.70	0.83
Sav	17.8	65.52	7.20	18.13	0.93	0.75
Section 2-2'						
6/1	0.50	69.14	6.38	13.32	0.70	0.50
2	1.00	66.01	5.58	18.02	0.70	0.50
3	1.00	64.41	9.57	14.93	0.70	0.50
4	1.00	64.20	8.29	17.21	0.70	0.50
5	1.10	65.03	6.86	17.99	0.70	0.50
Av.	4.60	65.37	7.43	16.65	0.70	0.50

No.	T	Si	Fe	Aℓ	Ca	Mg
7/1	0.50	67.11	17.29	13.26	0.70	0.50
2	1.00	65.27	8.29	14.61	1.40	0.50
3	1.00	63.19	8.58	15.67	0.70	0.50
4	1.00	62.21	8.58	17.57	1.05	0.25
5	1.35	62.82	8.29	17.26	0.70	0.50
Av.	4.85	63.72	8.31	16.03	0.92	0.45
8/1	0.50	70.57	7.29	12.21	0.70	0.50
2	0.95	69.41	7.72	11.78	1.40	0.50
Av.	1.45	69.80	7.56	11.92	1.16	0.50
Sav	10.90	65.23	7.84	15.75	0.86	0.48
Section 3-3'						
10/1	0.50	66.19	7.86	13.74	3.50	1.00
2	1.00	63.23	8.86	15.49	2.10	0.50
3	1.00	61.79	8.72	17.63	2.80	1.00
4	1.00	62.15	8.72	17.03	2.10	0.50
5	0.75	63.05	8.58	15.27	1.40	2.01
Av.	4.25	62.96	8.62	16.11	2.31	0.94
11/1	0.50	69.18	7.15	12.90	1.40	1.01
2	0.95	66.78	7.06	15.79	0.70	1.00
3	0.50	71.43	6.50	13.32	0.35	1.26
4	1.00	64.44	7.37	18.28	-	-
5	1.00	62.83	8.72	16.40	1.40	-
6	1.40	62.16	8.72	16.98	1.40	0.50
Av.	5.35	65.05	7.82	16.18	0.92	0.52
12/1	1.30	70.59	7.15	11.85	1.40	1.01
Sav	10.90	64.90	8.05	15.64	1.52	0.74
Section -						
13/1	0.50	72.12	7.01	10.99	0.70	1.01
2	0.70	71.57	7.01	10.99	1.40	0.50
Av.	1.2	71.79	7.00	10.98	1.10	0.71

(%)

No.	T	Si	Fe	Aℓ	Ca	Mg
Section 4-4'						
14/1	0.50	65.88	6.87	17.83	0.70	0.50
2	1.00	64.95	7.25	17.45	1.40	0.50
3	1.50	65.35	7.56	17.29	0.70	0.50
Av.	3.00	65.32	7.34	17.43	0.93	0.50
15/1	0.50	67.14	6.50	17.75	0.70	0.50
2	1.00	64.90	7.43	17.52	0.70	0.50
3	1.00	65.31	7.99	16.81	0.70	0.50
4	0.80	62.78	7.62	19.38	0.70	0.50
Av.	3.30	64.85	7.50	17.79	0.70	0.50
16/1	0.50	64.19	7.43	17.92	0.70	0.50
2	1.00	67.10	7.86	14.59	0.70	1.41
3	1.00	Not yet received				
4	1.00	63.98	8.86	17.69	0.28	0.90
5	1.00	63.48	8.29	17.46	0.14	0.80
Av.	3.50	64.76	8.21	16.77	0.42	0.96
17/1	0.50	70.35	6.51	14.49	0.70	1.51
2	1.20	73.11	5.83	11.97	0.70	1.00
Av.	1.70	72.29	6.02	12.70	0.70	1.15
Sav	11.50	66.04	7.46	16.63	0.68	0.74
Section 5-5'						
18/1	0.50	65.97	6.87	16.58	0.70	1.00
2	1.00	63.32	7.30	19.65	1.40	-
3	1.00	62.27	7.71	19.64	0.70	0.50
4	1.50	64.84	7.30	18.25	0.70	0.60
Av.	4.00	63.96	7.35	18.73	0.88	0.44
19/1	0.50	66.44	6.04	17.26	0.70	0.50
2	1.00	64.50	6.87	19.53	1.40	0.50
3	1.00	62.06	7.50	19.75	0.70	0.50
4	1.25	62.72	7.71	20.09	0.70	1.00
Av.	3.75	63.51	7.21	19.45	0.89	0.67
20/1	0.50	67.71	6.69	13.71	1.05	0.25
2	1.00	64.21	7.43	15.52	1.05	0.25
3	1.60	62.29	7.80	17.25	0.70	0.50
Av.	3.10	63.78	7.50	16.12	0.87	0.38
21/1	0.50	66.60	6.13	14.26	1.42	0.25
2	1.00	64.02	6.87	16.68	1.05	0.25
3	1.00	61.52	7.43	18.02	0.70	0.75
4	1.00	62.00	7.62	17.68	0.70	0.50
5	0.85	62.51	7.95	17.25	0.70	0.50
Av.	4.35	62.98	7.29	17.05	0.86	0.47
22/1	1.20	70.58	8.00	13.50	0.70	1.51
2	1.30	71.10	6.87	11.83	1.40	1.00
Av.	2.50	70.85	7.41	12.63	1.06	1.24
Sav	17.70	64.57	7.34	17.15	0.90	0.60
Section 6-6'						
23/1	0.50	58.57	9.28	20.47	0.70	-
2	1.10	58.89	7.95	20.95	2.10	0.50
Av.	1.60	58.78	8.36	20.79	1.66	0.34
24/1	0.50	67.42	5.85	14.60	0.70	1.00
2	1.00	63.14	7.21	17.54	1.40	0.50
3	1.50	63.01	7.42	17.28	1.40	-
Av.	3.00	63.79	7.11	16.92	1.98	0.33
25/1	0.50	67.17	6.69	15.41	1.05	0.25
2	1.00	63.19	7.44	17.67	1.40	-
3	1.25	62.91	7.99	17.66	1.40	-
Av.	2.75	63.78	7.55	17.25	1.37	0.05
26/1	0.50	69.55	5.94	13.31	1.05	0.50
2	1.30	69.84	6.32	16.13	0.70	0.50
Av.	1.80	69.76	6.21	15.34	0.80	0.50
Sav	9.15	64.08	7.28	17.39	1.28	0.28
Section 7-7'						
27/1	0.50	68.32	6.27	16.28	0.70	0.76
2	1.00	66.46	6.16	17.49	1.40	0.50
3	0.90	65.63	6.27	17.98	1.40	0.76
Av.	2.40	66.53	6.23	17.42	1.25	0.65
28/1	0.50	67.67	7.52	14.98	1.40	-
2	1.00	64.36	8.00	17.00	1.40	-
3	1.00	62.90	8.00	20.35	0.70	1.00
4	0.85	63.85	8.16	18.44	0.70	1.00
Av.	3.35	64.29	7.97	18.06	1.01	0.55
29/1	0.50	66.82	6.50	14.65	-	1.00
2	1.00	63.16	7.85	18.70	0.70	0.25
3	1.25	62.73	7.62	19.38	-	0.50
Av.	2.75	63.63	7.50	18.27	0.25	0.50
30/1	0.50	67.17	6.24	17.41	0.70	0.50
2	0.60	66.87	7.56	15.29	1.40	0.05
3	0.55	69.09	7.56	14.29	0.70	1.00

(%)

No.	T	Si	Fe	Aℓ	Ca	Mg
30/4	1.00	63.83	8.00	17.60	0.70	1.00
5	1.30	64.16	8.00	18.05	-	1.51
Av.	3.95	65.55	7.65	16.91	0.57	0.96
31/1	1.50	69.61	6.87	14.48	0.70	1.00
Sav	13.95	65.47	7.37	17.28	0.75	0.72

Section 8-8'

No.	T	Si	Fe	Aℓ	Ca	Mg
33/1	0.50	68.46	6.05	14.70	1.05	1.01
2	1.00	67.96	6.49	16.86	1.75	0.25
3	1.30	65.32	6.72	18.88	1.05	0.76
Av.	2.80	66.82	6.52	17.41	1.29	0.62
34/1	0.50	71.72	6.97	11.03	0.70	0.12
2	1.00	67.35	8.33	14.94	0.70	0.25
3	1.70	65.76	9.01	13.29	0.70	0.37
Av.	3.20	67.18	8.48	14.51	0.70	0.46
35/1	0.50	68.10	8.33	13.29	0.52	0.50
2	1.10	64.71	8.84	15.58	0.70	0.37
3		65.12	8.67	15.65	0.70	0.37
Av.	2.70	65.67	8.67	15.18	0.67	0.39
Sav	8.70	66.59	7.91	15.65	0.88	0.49

Section -

No.	T	Si	Fe	Aℓ	Ca	Mg
36/1	0.50	65.47	8.50	15.97	0.52	0.25
2	1.00	66.09	8.10	14.97	0.70	0.37
3	1.25	68.94	8.16	12.04	0.70	0.37
Av.	2.75	67.27	8.20	13.82	0.67	0.35
37/1	0.90					

Section 9-9'

No.	T	Si	Fe	Aℓ	Ca	Mg
38/1	0.50	70.16	7.67	12.83	1.40	-
2	1.00	70.26	7.52	12.58	1.40	-
3	1.20	66.21	8.16	15.44	0.70	0.50
Av.	2.70	68.71	7.83	13.89	1.09	0.22
39/1	0.50	73.27	6.40	12.05	1.40	-
2	1.00	69.87	7.52	13.23	1.40	-
3	1.00					
4	1.25	67.10	8.32	14.18	0.70	0.50
Av.	2.75	69.22	7.68	13.44	1.08	0.23
40/1	0.50	72.20	6.42	12.18	0.35	-
2	1.40	69.10	7.02	14.58	-	-
Av.	1.90	69.92	6.86	13.95	0.09	-
Sav	7.35	69.21	7.52	13.74	0.83	0.17

Section 10-10'

No.	T	Si	Fe	Aℓ	Ca	Mg
42/1	0.80	71.98	6.66	13.49	-	-
43/1	0.50	77.46	5.35	8.80	0.71	0.38
2	1.00	74.97	5.95	11.05	0.70	0.37
3	1.00	71.46	6.42	12.58	0.52	0.50
4	1.00	71.43	6.66	12.36	0.70	0.37
5	1.10	74.26	6.30	11.60	0.70	0.12
Av.	4.60	73.54	6.23	11.55	0.66	0.34
44/1	0.50	74.08	5.71	11.39	-	-
2	1.70	71.22	6.30	14.10	-	-
Av.	2.20	71.86	6.16	13.48	-	-
Sav	7.60	72.89	6.25	12.32	0.40	0.21

Section 12-12'

No.	T	Si	Fe	Aℓ	Ca	Mg
46/1	0.50	74.30	5.80	10.70	0.70	0.50
2	1.00	67.10	6.36	16.89	0.70	0.50
3	1.00	71.80	6.36	12.69	0.70	0.50
4	1.00	69.01	6.69	15.81	0.70	1.00
Av.	3.50	70.01	6.37	14.50	0.7	0.64

Section 13-13'

No.	T	Si	Fe	Aℓ	Ca	Mg
47/1	0.50	72.70	6.24	11.41	0.91	0.50
2	1.00	73.61	5.69	12.22	0.35	-
3	0.90	69.21	7.02	13.93	-	0.75
Av.	2.40	71.77	6.30	12.69	0.33	0.28

SECTION VI BASIC STUDY OF THE CEMENT PLANT PROJECT

VI-1 Outline of the Process

VI-1-1 Choice of the Process

(1) Conclusion

In order to choose the most suitable process, various cement manufacturing process have been examined and compared with each other, taking into consideration all the economic and technical conditions of the Project.

As a result, a dry process with suspension type preheater kiln (hereafter in this report called dry process with SP kiln) is recommended for the Project. Details of the study are described hereinafter.

(2) Types of cement manufacturing processes

The cement manufacturing processes are mainly divided into two processes, i.e. dry process and wet process, both of which are subdivided into several processes as follows, mainly by the types of kiln to be used.

(i) Dry process

(a) Suspension type preheater kiln

(b) Long kiln

(c) Short kiln with waste heat boiler

(d) Shaft kiln

(e) Lepol kiln

(ii) Wet process

(a) Short kiln with waste heat boiler

(b) Long kiln

(c) Lepol kiln

(3) Conditions in the choice of the process

In order to choose the most suitable process out of processes mentioned above, following conditions should be examined.

(i) Economic factors

(a) Investment cost

(b) Consumption of fuel, electric power and water

(c) Personnel requirement

(d) Area to be required for the plant

(ii) Technical factors

(a) Properties of raw material

- Homogeneity in chemical composition

- Content of undesirable impurities such as alkali and chlorine
- Physical properties such as moisture content and stickiness

(b) Kind of fuel to be used

(c) Quality of cement to be produced

(d) Easiness to operation

(e) Repair expenses

(f) Capacity of kiln

(4) Reasons of recommendation of dry process with SP kiln

(i) This process is economically advantageous because of remarkably low heat consumption.

Fuel cost occupies a great part in direct cost of cement manufacture.

Heat consumption of SP kiln in case of the Project will account for 850×10^3 kcal/t·clinker, which corresponds to 65 Rs/t·clinker. (Refer to VI-4 Utilities)

The figures mentioned above are considerably small compared with $1,300 \times 10^3$ kcal/t·clinker or 99 Rs/t·clinker in the case of a dry process with long kiln, which also could be adopted for the Project from technical viewpoint.

(ii) Alkali content is comparatively low and chlorine content is considerably low, as for the raw materials to be used for the Project. (Refer to V-3 Quality of Raw Material)

Therefore, it is expected that there seldom occurs clogging trouble by burnt raw material adhered to the inside of suspension preheater.

(iii) Dry process with SP kiln has such advantages as follows : -

(a) Suspension preheater to be installed at the back of kiln has no movable parts.

Therefore, the operation and maintenance of SP are much easier than those of such machinery and equipment as boiler, lepol grate, pan-pelletizer, etc., all of which may be provided in other processes.

(b) Dry process with SP kiln has a big production capacity per kiln inside volume. The kiln size for the Project is estimated to be 4.4 mϕ x 82 mL (in case of 1,500 t/d basis), which is smaller than the size of dry long kiln with the same production capacity, 5.0 mϕ x 170 mL.

(c) Exhaust heat gas from suspension preheater can be utilized for drying of limestone and clay.

(iv) Dry process with SP kiln is easy of operation and maintenance, next to dry process with long kiln.

Note :

Wet process is suitable for the case that main raw materials fluctuate widely in quality or they contain extremely high moisture content.

However, recently wet process has hardly been adopted by reason of its extremely high heat consumption.
Recently, dry process with SP kiln has been adopted for a lot of new cement plants, as far as any particular problems such as above-mentioned factors in raw materials are not foreseen.

Consequently, dry process with SP kiln is the most suitable process for the Project.

VI-1-2 Choice of Main Machinery and Equipment

Main machinery and equipment to be used in this plant has been selected taking into consideration qualities and procurement conditions of raw materials and fuel, the process of the plant and social and natural conditions at the plant site.

Details of the study are described hereinafter.
(Refer to VI-3 Specification of Main Machinery and Equipment)

(1) Raw material storage

(i) Limestone and clay

(a) Storage capacity

Judging from the amount of rainfall and number of rainy days during the rainy season in Udaipur district, clay mining at Beltar deposit seems to be impossible for a long period owing to the increase in moisture content of clay.

Considering the period mentioned above, clay storage should have a capacity sufficient for two (2) months operation.

Clay storage is to be provided with an adequate roof in order to minimize the increase in moisture content during the rainy season.
As to limestone deposit, it is expected that limestone mining will be possible even during the rainy season, except in extremely heavy rain.
Considering the above, limestone storage with a capacity for twenty (20) days operation will be enough.
The moisture content of limestone will increase little even during the rainy season, therefore, limestone storage yard will not need a roof.
It will effect an advantage in the construction cost for the plant.

(b) Storing and discharge

Each of limestone and clay is to be stacked in its own storage yard and is to be discharged by a reclaiming scraper in order to improve homogeneity of its quality.

(ii) Other raw materials

(a) Silica sand

Silica sand can be procured from the dry river beds of several tributaries of the Trijuga river within short distances from the proposed plant site.

This silica sand is to be stored in an open storage yard which should have a capacity sufficient for twenty (20) days operation.

In order to transport silica sand to the silica sand mixing tanks by truck, upper part of silica sand stockpile with low moisture content is to be extracted by shovel loader during fine days.

(b) Iron ore

Iron ore is to be stored in an iron ore mixing tank which should have a capacity sufficient for one (1) month operation.

(c) Gypsum

Imported gypsum is to be stored in an open storage yard which should have a capacity sufficient for two (2) months operation.

Gypsum is to be extracted and transported to a gypsum tank, by the same method as that of silica sand.

(2) Coal storage yard

(i) Storage capacity

Whole quantity of coal will be imported from India.
Therefore, the more the storage capacity is, the more it is desirable taking into consideration unstableness of its supply and fluctuation of its quality.

On the other hand, it is undesirable to have a huge stockpile, because of the risk of its natural outbreak of fire.

In case of this plant, coal storage should have a capacity sufficient for two (2) months consumption considering the conditions mentioned above.

(ii) Storing

It seems that the quality (calorific value particularly) of coal produced in India has wide fluctuation.
(Refer to VI-4 Utility)

Therefore, coal, every time when supplied, is to be piled with a layer of 0.4 - 0.6 m in order to improve homogeneity of its quality.

In order to prevent natural outbreak of fire, each layer of coal is to be trodden down by a sheep foot roller or equivalent, and stockpile height should not exceed 4 m.
To prevent the coal from increase in its moisture content during the rainy season, coal storage should be provided with an adequate roof, because it is expected that Indian coal contains a lot of small sized

particles which cause increasing in moisture content during the rainy season.

(iii) Discharging

Coal is to be discharged by shovel loader and transported by truck to a hopper in the coal grinding house.

(3) Limestone and clay drying

Before mixing of raw materials, both of limestone and clay are to be dried by adequate dryers separately.
The reasons are as follows : -

(i) Limestone and clay contain high moisture content, which will certainly increase further during the rainy season.

(ii) By reason mentioned above, it is expected that moisture content of limestone and clay will fluctuate, and hence the quality of such raw mixture will fluctuate as a result.
Rotary type dryer is recommendable for limestone and clay drying because of its reliable operation.
Exhaust gas from suspension preheater can be utilized as a heat source for limestone and clay drying, however, hot gas generators using heavy oil or diesel oil should be provided for emergency such as the cases of extremely high moisture content limestone and clay.

Note : -
Recently, drying-cum-grinding mill has been adopted for drying and grinding of raw material, because it need not have independent drying process.

However, it is not recommendable for the Project by reason of high moisture content with wide fluctuation of limestone and clay as mentioned above.

(4) Raw material grinding

After raw material mixing, raw mixture is to be ground by tube mill.

Grinding system is to be of closed circuit type with air separator.

(5) Raw meal homogenizing and storage

In general, chemical composition and fineness of raw meal after grinding process inevitably fluctuate by the reasons of fluctuation in quality of each raw material, deviation in mixing process and mill operating condi-

tion, etc.
In order to steadily operate the kiln and to produce clinker of stable quality, it is necessary to homogenize raw meal in homogenizing silos provided before raw meal storage silos.

Two (2) sets of storage silos are recommended.

Total capacity of one (1) set of homogenizing silo and two (2) sets of storage silos is to be sufficient for seven (7) days raw material requirement.

(6) Kiln and cooler

Type of kiln is to be of suspension preheater type kiln as mentioned in clause "VI-1-1 Choice of the Process".

In regard to the type of cooler the horizontal grate cooler is recommendable, because it is quite reliable by reasons as follows ;
(i) Air for kiln burning obtained from this type of cooler has high temperature, and (ii) temperature of cooled clinker is relatively low and steady.

(7) Clinker storage

In general, silos and stock yards are adopted for clinker storage.
For this plant, clinker silo is recommendable, taking into considerarion prevention of dust scattering during clinker storing, simplification of machinery and equipment and easiness of its operation and control.

Clinker storage of two (2) sets of silos in all should have a capacity sufficient for ten (10) days clinker production.

(8) Cement grinding

Clinker is to be ground by a closed circuit grinding system with tube mill and air separator.

(9) Cement storage

Two (2) sets of cement silos are to be provided with a total capacity sufficient for ten (10) days cement production.

(10) Cement packing

Rotary packer is recommended for cement packing and the belt loader is recommendable for loading of bagged cement onto truck.

On the occasion of plant design, the following are to be taken into consideration.

(i) In order to cope with the increase in cement demand and the vicissitude of form of cement consumption, the shipment of bulk cement will be needed in future.

Therefore, it is recommended to keep space for installing bulk loading equipment in shipping house.

(ii) Although, jute bags are planned to be used for cement packing at present, it is recommended to change jute bags for paper bags at the earliest possible time, in order to prevent the deterioration of cement quality and loss in weight during transportation of bagged cement.

(11) Coal grinding

The vertical roller mill is recommendable for coal grinding, because the grinding system with vertical roller mill is simple and is able to carry out grinding and drying at the same time.

A part of hot air from clinker cooler is to be utilized for coal drying.

(12) Process control system

(i) Control system and technological level

In designing a control system applicable to a cement manufacturing process, such factors as economic and labour situations, both at present and in future, and the technological level of the operators to be employed must be taken into consideration. It may be more appropriate to adopt a labour-intensive control system for the Project rather than a highly computerized operating system. Multifunctioning of a sophisticated control system could have a serious effect on the processes involved, and it would require skilled technicians to repair it.

In this project, neither high-level technology such as computer control for raw grinding, kiln and cement departments nor fluorescence X-ray analysing system for raw material mixing and grinding processes are proposed. However, technological development some ten years after construction of the plant is to be considered. Consequently, it is recommended that a centralized control system for the important processes in the plant be adopted.

(ii) Centralized control system

In the Kiln Control Room, consecutive processes such as raw materials storage, drying and grinding, raw meal homogenizing and storage, clinker burning and storage, coal grinding, cement grinding and storage processes are controlled collectively.

As a matter of course, in order to operate the kiln properly and to control the quality of the final product, i.e. cement, it is indispensable to understand the quality of raw materials and fuel to be used.

In addition to the relevant processes being operated automatically, the quantity and quality of raw materials, both in storage and in the consumption supply stage, must be monitored constantly and the quantity and quality of the fuel must likewise be constantly monitored. The monitored data are applied to the ensuring processes from raw grinding, homogenizing and storing to clinker burning.

Quality of clinker is applied to the cement grinding process. Thus all the important processes are controlled in the central control room.

(iii) Local control system

For the purpose of operation of each individual machine locally and for the convenience of inspecting and repairing work, local control switches are provided near all the important machines.

As for such departments as raw materials receiving, cement shipping and utilities departments other than the main departments included in the centralized control system, independent control switchboards are installed respectively.

Refer to VII-3-2 (2) & (5).

(iv) Instruments

Instruments and testing apparatus needed for the process control mentioned above are generally provided locally and monitored and operated remotely if necessary.

However, it is necessary, at this stage, to prepare in advance the standardized instrumentation, e.g. a standard signal 4-20 mA DC for analog circuits, in order to be able to install a higher level control system in the future.

VI-2 Production Capacity of the Plant

Taking account of various factors such as the reserves of raw materials, the relation between supply and demand, the infrastructure, the labour condition, the production cost and the plant site etc., the plant capacity of the Project is set in the range from 750 t/d to 1,500 t/d (clinker base).

In case the Project is commenced immediately aiming the supply of the product mainly to the domestic market, the plant capacity is either 750 t/d or 1,000 t/d, out of which the capacity of 1,000 t/d is recommended because of its better profitability.

In case the Project is started comparatively late (after several years) the plant capacity of 1,500 t/d is recommended.

If the considerable amount of export is expected, the commencement of the Project can be advanced even for the case of 1,500 t/d.

In every case, the future expansion of the same capacity should be taken into account in the plant layout.

VI-2-1 Annual Production of Clinker and Cement

Annual Production (t/y)

Production \ Plant capacity	750 t/d	1,000 t/d	1,500 t/d
Clinker	247,500	330,000	495,000
Cement	259,875	346,500	519,750

Note. Working day of kiln : 330 d/y

VI-2-2 Annual Requirement of Raw Materials and Fuel

Annual Requirement of Raw Materials and Fuel (t/y)

Materials \ Plant capacity	750 t/d	1,000 t/d	1,500 t/d
Limestone	309,870	413,160	619,740
Clay	54,945	73,260	109,890
Silica sand	19,305	25,740	38,610
Iron ore	3,218	4,290	6,435
Gypsum	12,375	16,500	24,750
Coal	31,433	41,910	62,865

Note. Working day of kiln : 330 d/y

VI-3 Location of the Plant

VI-3-1 Factors for Selection

In general, the factors to be considered conscientiously in the location of a cement plant site are the followings :

(1) Availability of the calcareous and argillaceous materials within reasonable haulage distance from each other.

(2) Possible sources of minor raw materials such as silica sand, iron ore and gypsum.

(3) Distance from market and distributing centers

(4) Transportation facilities to and from the site

(5) Utilities such as electricity and water supply

(6) Natural conditions such as rain fall, wind direction flood, etc.

(7) Labour available in the vicinity (quality and quantity)

(8) Subsurface condition (geology)

(9) Area and easiness of land preparation

(10) Environment

VI-3-2 Proposed Plant Sites

Since the following five proposed plant sites have been selected in the vicinity of limestone and clay deposit by DMG, the investigation was carried out in and around these sites.

	Place	Remark
(1)	In the vicinity of Gaighat	This site is close to Gaighat.
(2)	In the vicinity of Rupani	This site is situated along the East-West highway.
(3)	In the vicinity of Lahan	This site is situated along the East-West highway.
(4)	In the vicinity of Beltar	This site is close to the clay deposit.
(5)	In the vicinity of Murkuchi	This site is close to the limestone deposit.

As for the location of the sites refer to Fig. 10-1-1.

VI-3-3 Selection of Site

Considering all the factors described in VI-3-1 on each site, it is recommended to select the site at the location shown in Dwg. No. C-02 (N.L. 26°46'50" and Long. 86°41'00"E) in the vicinity of Gaighat.

Reason :

(1) The site is located in economical haulage distance, and the distances both to the limestone deposit and the clay deposit are well balanced with each other. (Refer to V-2.)

(2) The site is located close to East-west highway which runs through the south of Nepal.
After the completion of the road which connect Gaighat with East-west highway by other project (refer to X-1), the transportation of such materials as fuel, raw materials, various materials and product will be carried out satisfactorily.

(3) Electric power can be supplied to the plant site from the East-West power transmission trunk line along East-West highway through a power transmission line, both of which are, to be constructed by other project.
Industrial water can be adopted easily from Trijuga river or nearby wells.

(4) The site is a comparatively well developed place in the Udaipur district and therefore employment of workers and maintenance of machinery and equipment will be performed advantageously.

(5) There exists the land of sufficient area which is well drained and easy to be prepared.

(6) Since the site is situated on the southern plateau of the Trijuga river there is no possibility of flood.

Note. Although the sites of Rupani or Lahan, both being situated along East-west highway, will be advantageous for shipment of product, overall transportation cost of these sites will be higher than that of Gaighat site because of long haulage distance of limestone and clay.

VI-4 Utilities

VI-4-1 Fuel

(1) Choice of fuel

Usually, heavy oil and coal are used as fuel for clinker burning.

Upon choosing kinds of fuel for a project, cost, quality, easiness in their use and procurement conditions are to be taken into consideration.

In either case, heavy oil and coal have to be imported to the Kingdom of Nepal.

For the Project, Indian coal is recommended as fuel for clinker burning.

The reasons are described as follows :-

Fuel cost by using Indian coal will account for approx. 65 Rs/t·clinker, which is equivalent to only 40 % of the cost approx. 150 Rs/t·clinker in case of using heavy oil.
Heavy oil is superior to coal in quality, especially its fluctuation, and in easiness of operation, as well as a little advantageous in initial investment. (Refer to (3) Quality of Assam coal.)
However, it is more advantageous to import coal from the neighbouring country, India, than to import heavy oil from other countries via India. As a whole, Indian coal is recommendable, taking into consideration the great advantage in fuel cost as mentioned above.

(2) Unit consumption and cost

(i) Unit consumption

Heat consumption of dry process with SP kiln

850×10^3 kcal/t·clinker

Net calorific value of coal

Average 6,700 kcal/kg·coal

(The figure has been calculated according to Assam coal specifications given by Coal India Ltd.)

Unit consumption

$$\frac{850 \times 10^3}{6,700} \fallingdotseq 127 \text{ kg·coal/t·clinker}$$

(ii) Fuel cost

Coal price

510 Rs/t·coal

Fuel cost

0.127 x 510 ≒ 65 Rs/t·clinker

(iii) Reference

The following is the calculation of fuel cost in case of using heavy oil.

Net calorific value of heavy oil

9,750 kcal/kg·heavy oil

Unit consumption

$$\frac{850 \times 10^3}{6,700} \fallingdotseq 87 \text{ kg·heavy oil/t·clinker}$$

Heavy oil price

1,765 Rs/t·heavy oil (1,200 IC/kℓ·heavy oil)

(1,200 IC/kℓ·heavy oil has been given by Nepal Oil Corporation.)

Fuel cost

0.087 x 1,765 ≒ 153 Rs/t·clinker

(3) Quality of Assam coal

The following are the specifications of Assam coal, which is one of the typical Indian coal.

(The source : Coal India Ltd.)

(i) Gross calorific value

Average : 6,500 ~ 7,500 kcal/kg·coal (Min. 6,065, Max. 7,755)

(ii) Chemical composition (%)

Particulars	Average	Min.	Max.
Ash	: 15	4	18
Volatile matter	: 40 ~ 42	34	43
Fixed carbon	: 45 ~ 50	40	53
Carbon	: 66 ~ 74	60	77
Hydrogen	: 4.8~5.6	4.2	5.8
Sulphur	: 3 ~ 4	1.5	4.1
Nitrogen	: 1 ~ 1.2	0.9	1.3

(iii) Chemical composition of ash (%)

SiO_2	: 48 ~ 52
Al_2O_3	: 24 ~ 30
Fe_2O_3	: 18 ~ 26
CaO	: 0.8 ~ 1.8
MgO	: 0.6 ~ 1.6
Alkali & others	: 2.5 ~ 3.5

(iv) Size distribution (%)

more than 76 mm	:	11
76 ~ 25 mm	:	19
25 ~ 13 mm	:	16
13 ~ 6 mm	:	11
6 ~ 3 mm	:	16
less than 3 mm	:	27
Total		100

(v) Moisture content (%)

Average : 2 ~ 3
(Min. 1.7, Max. 3.0)

VI-4-2 Electric Power

(1) Electric power situation in the East of Nepal

In Eastern Nepal at present there is no large-scale power transmission network apart from local transmission lines such as : (1) a 33 kV line in Biratnagar area, which is within the jurisdiction of Eastern Electricity Corporation (EEC), employing two sets of diesel generators (total 2,500 kW) combined with power transmission lines from India, (2) a 33 kV line in Bhadrapur area, near the Eastern border, which distributes power from India, (3) a 11 kV line in Sirha area which also distributes power from India and (4) a 11 kV line in Dhankuta area which uses a hydro-generator (240 kW).

According to the schedule prepared by the Electricity Department, Ministry of Water and Power, all the lines except (4) are planned to be connected with the East-West power transmission line when Kankai hydro-power plant (proposed output 37 MW) has been constructed.

Power demand in Eastern Nepal was approximately 6,000 kW in fiscal 1976/77, being of course limited within the areas mentioned above. The annual increase rate of power demand in these areas is forecast at 15 % by the Electricity Department until 1989/90, and at about 10 % after that. This means that the assumed power demand in 1989/90 is 48,000 kW. Kankai hydro-power plant will only be able to meet the demand for a limited number of years. In order to cover the shortage after this time, in addition to the construction of the East-west power transmission line, the construction of several hydroelectric power plants has been proposed in the following order :

- Bagmati hydro-power plant, the Bagmati river, Narayami zone, with a capacity of 70 MW,
- Kamala plant, the Kamala river, Janakpur, 30 MW.
  (Refer to Fig. 2-2-3 and Fig. 2-2-4.)

Incidentally some micro hydro-power plants with a capacity of several hundred kW each are proposed in Eastern Nepal.

(2) Power supply for the Project

As described hereafter, necessary power demand for the Project is calculated as follows ;

Case I (750 t·cℓ/d) 6,000 kW
Case II(1,000 t·cℓ/d) 7,500 kW
Case III(1,500 t·cℓ/d) 11,000 kW

In any case, the plan to use power from the 132 kV East-West power transmission line is more advantageous than providing a private hydro-electric power plant or a diesel power plant.

(a) Power supply from the 132 kV line

It is necessary to install a transmission line from the East-West transmission line to the plant, the length of which is approx. 25 km. Construction work on the line is to be undertaken by the Government. (Refer to X-1-4.)

In Nepal, the tariff system on electric energy varies depending on the locality and the use. Table 6-4-1 shows the present tariff system in Central and Eastern regions.

Table 6-4-1 Tariff System on Electric Energy

Jurisdiction	EEC *[1]			NEC *[2] [3]		
	Small	Medium	Big	Small ≦100kW	Medium >100kW	Big
Voltage (V, kV)	240/400	2.3	11			
Industry						
Demand charge (Rs/kVA·mon)	5.0	9.0	(9.0*[3])	6.5	23.0	(*[3])
Energy charge (Paisa/kWh)	40	30	(30*[3])	25	20	(*[3])
Commercial				>50 kW		
Demand charge (Rs/kVA·mon)	–			18		
Energy charge (Paisa/kWh)				20		
Export to India						
Energy charge (I.C. NP/kWh)	–			14		
Irrigation						
Energy charge (Paisa/kWh)	30~35	–	–	25		
Temporary						
Energy charge (Paisa/kWh)	70	–	–	75		

Note : *[1] – Eastern Electricity Corporation

*[2] - Nepal Electricity Corporation

*[3] - In case of power supply by 11 kV or higher, the rate for such consumers should be sanctioned through the Government. In this report, it is assumed that the rate for the medium size comsumers be applied to the Project.

For reference, a comparative table showing the cost of extra-high voltage power supply in Nepal and in Japan is shown below.

		EEC	NEC	in Japan (round numbers)
Demand charge	Rs/kW·m	9	23	50
	($/kW·m)	(0.75)	(1.92)	(4.20)
Energy charge	Paisa/kWh	30	20	50
	(Cent/kWh)	(2.5)	(1.7)	(4.2)

(b) A new hydro-power plant

(i) Water sources

As shown in Fig. 5-1-3, the flow quantity of the Sun Kosi river, which runs north of the Trijuga river and drains to the Sapta Kosi river, amounts to 200 m^3/sec even in the dry season. Taking into account that the Sun Kosi river has cut deep V-shaped gorges around Udaipur district, which are suited for the construction of dams, it is possible to install a hydro-power plant with a capacity of some ten thousand kW not far from the proposed plant site. It is reported, on the other hand, that a preliminary study of hydro-power generation-cum-irrigation projects in Sagarmatha zone has been carried out starting the 1960's, and that a study of constructing small scale-or micro-hydro-power plants near local administration major quarters has been scheduled.

(ii) Irrigation

Dams and reservoirs are also utilized for irrigation downstream. However, in the case of Sagarmatha zone, the Sun Kosi river is not involved in irrigation schemes at present. The eastern part of Saptari district already has irrigation facilities with water channels from water source at Fatehpur, and the outskirts of the Kamala river in the west are going to be irrigated according to a plan on schedule.

In addition, ground water here in this area is plentiful enough to be pumped up for irrigation. For the Terai regions other than the areas mentioned above, irrigation plans utilizing ground water are under consideration.

(iii) Expected electric load at Gaighat

At present there is no public power supply system at Gaighat. Once electric power is provided via Main Power Substation in the plant under the Project, several hundred kW of electric load are expected for indoor and outdoor lighting, private irrigation pumps for agriculture, for rice mills, etc.

(iv) Availability of a private hydro-power plant

It may be concluded that in Udaipur district a middle-scale hydroelectric power plant with a capacity of several ten thousand kW is not expected in the near future because ; there is no large electric load except the Project, and a hydroelectric power plant needs a great amount of initial investment.

Incidentally, as shown in Fig. 2-2-4, the expected electric load in the East in 1982/83, when Kankai hydroelectric power plant is going to be constructed, is 20 MW which is considerably smaller than the capacity of the power plant, 37 MW.

(c) Diesel-engine generators

Electric load in a cement plant is mainly divided in three departments - raw material, kiln and cement departments -, and load fluctuation in each department is not so big.

As for the case of the Project, it would be quite satisfactory to provide diesel-engine generators to supply stable power as follows :

	Unit output (kW)	No. of sets
Case I (750 t·cℓ/d)	2,500	4
Case II (1,000 t·cℓ/d)	3,500	4
Case III (1,500 t·cℓ/d)	4,500	4

Note. In any case, one set of stand-by diesel generator is included.

Roughly estimated cost for these engine generators will be Rs. 50 ~ 80 million (US$ 4 ~ 7 million).

In Nepal, all fuel has to be imported. The fuel cost of diesel engines is calculated as about 40 Paisa/kWh (3.3 Cents/kWh) applying the market price of diesel oil, 2.2 Rs/ℓ (0.18 $/ℓ). This means that a private power plant with diesel engines is not economically competitive with public power supply because the fuel cost alone exceeds the unit price of public power supply, 32 Paisa/kWh (2.6 Cents/kWh).

However, as a stand-by power supply unit against emergencies, such as public power stoppage, it is necessary to install one set of diesel engine generator with a capacity of 200 ~ 400 kW in the Plant.

(3) Power demand and energy charge in this Project

Necessary electric power for cement plant and limestone quarry is calculated taking into account the installed capacity, utilization factor or demand factor and load factor as follows.

(i) Installed capacity (kW)

	Case I (750 t·cℓ/d)	Case II (1,000 t·cℓ/d)	Case III (1,500 t·cℓ/d)
a. Limestone quarry (including ropeway)	1,400	1,600	2,100
b. Raw materials (including receiving, drying, grinding and raw meal storing)	3,700	4,600	6,200
c. Kiln (including coal grinding)	2,000	2,400	3,300
d. Cement (including gypsum crushing)	2,200	2,700	4,000
e. Shipping	200	250	300
f. Indirect departments (utilities, lighting, etc.)	400	450	600
Total (kW)	9,900	12,000	16,500

(ii) Average power

	Case I	Case II	Case III
a. Unit power consumption*1 (kWh/t·cement)	130	128	125
b. Cement production (t·cement/hour)	32.8	43.7	65.6
c. Average power (kW) {(a) x (b)}	4,300	5,600	8,200

(iii) Maximum demand power

	Case I	Case II	Case III
a. Utilization factor*[2] (%) $\left(\frac{\text{Max. demand power}}{\text{Installed capacity}}\right)$	61	63	67
b. Max. demand power (kW) ((a) x Installed capacity)	6,000	7,500	11,000

For reference, load factor is calculated as follows :

	Case I	Case II	Case III
c. Load factor (%) $\left(\frac{\text{Average power}}{\text{Max. demand power}}\right)$	72	74	75

Note. *[1] Unit power consumption is assumed from the actual results. The smaller the plant capacity is, the greater unit consumption becomes.

*[2] Utilization factor or demand factor varies depending on the situation.
As for the Project, the factor is rather small because (1) there are such processes as ropeway and raw material receiving, the load of which is heavy instantaneously but quite light when averaged out and (2) the capacity of limestone and clay storage is fairly large and clinker and cement silos are provided with provision for reserve storage space as needed and smaller multiple units have been chosen.

*[3] Load factor in this plant is rather small because the rated capacity of raw grinding and cement departments are designed on a larger scale than kiln department due to shorter operating time.

*[4] Regarding power supply for construction works, refer to X-1-4.

(iv) Electric energy cost

According to the above conditions, the electric energy cost is calculated as follows :

Item	Unit	Case I (750 t.cℓ/d)	Case II (1,000 t·cℓ/d)	Case III (1,500 t·cℓ/d)
1. Unit power consumption	kWh/t·ce	130	128	125
2. Max. demand power	kW	6,000	7,500	11,000

Item	Unit	Case I (750 t·cℓ/d)	Case II (1,000 t·cℓ/d)	Case III (1,500 t·cℓ/d)
3. Annual cement production	10^3t/y	260	350	520
4. Annual energy consumption	10^6kWh/y	34	44	65
5. Demand charge (2)xRs 9 x 12 m	10^3Rs/y	700	800	1,200
6. Energy charge (4)xRs 0.30	10^3Rs/y	10,000	13,200	19,500
7. Total charge (5) + (6)	10^3Rs/y	10,700	14,000	20,700
8. Unit energy cost	Rs/t·ce	41	40	40
	($/t·ce)	(3.3)	(3.2)	(3.2)
9. Unit price of electric energy	Rs/kWh	0.32	0.32	0.32
	(Cent/kWh)	(2.6)	(2.6)	(2.6)

(4) Electric system

Electric system for power distribution and control applicable to the Project (including limestone quarry) is recommended as follows :

Extra-high voltage (power supply transmission)

- AC 132 kV 50 Hz 3-phase 3-wire single line *1

High-voltage (power transmission and large motors)

- AC 6.6 kV*2 50 Hz 3-phase 3-wire

Low-voltage power line (motors and large heaters and trunk line for lighting)

- AC 400 V 50 Hz 3-phase 4-wire

Low-voltage control line (control and lighting)

- AC 230 V 50 Hz single-phase 2-wire
- DC 100 V

Note. *1 In the case of the East-West power transmission line being installed as a "double-circuits" power line, it is recommendable to apply double-circuits to this transmission line.

*2 The specifications of the power transmission line to the limestone quarry must be checked when the Project comes into effect. An alternative specification as shown below may be considered taking into account the necessary power for the colony and the villages around the quarry.

- Extra-high voltage, AC 11 kV 50 Hz 3-phase 3-wire

VI-4-3 Water

(1) Water supply plan

The following are the amount of water required for the plant and its personnel residence.

Industrial water	:	400 t/hour (Case I 1,500 t·cℓ/d)
Drinking water for the plant	:	35 t/day (350 persons)
Drinking water for personnel residence	:	150 t/day (300 families, 1,500 persons)

On the other hand, water flow rate of the Trijuga river close to the proposed plant site is estimated to be 2,000 t/hour even in the dry season, according to the result of measurement mentioned in clause (2) Report on the measurement of the Trijuga river flow.

Water quantity mentioned above is sufficient to utilize for the plant and the personnel residence.
And in quality, water taken from the Trijuga river and from the wells around the proposed plant site can be used as industrial water, according to the result of the water analysis carried out by us.
Upon design of the water supply system, the following matters are to be taken into consideration.

(i) Water from the Trijuga river is to be stored in the pond with a capacity of 1,500 t - 2,000 t after filtering, and distributed for the industrial use in the plant.
In case that it is difficult to obtain sufficient water for the industrial use in the cement plant, industrial water is circulated through such appropriate recovery systems as water cooler and filter.
However, in case of the Project, all the industrial water will be allowed to be dumped after using, because sufficient fresh water can be obtained.

In dry process with SP kiln, almost all the industrial water is used for cooling purpose, and water used contains only little impurities such as dust and oil.
Therefore, there is no water pollution, even if such water is returned to the Trijuga river, provided that such impurities is to be removed by adequate method before returning the river.

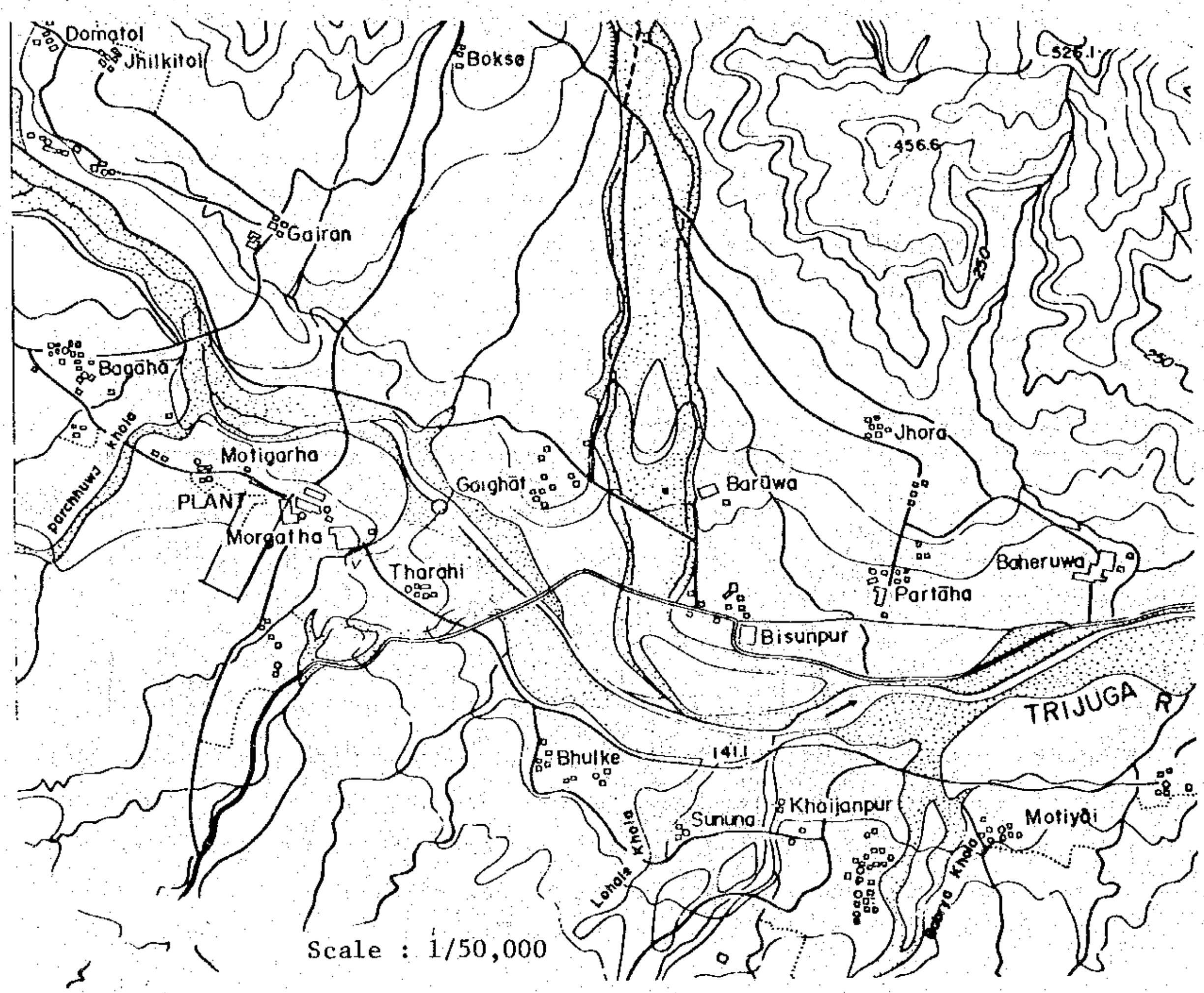
(ii) For the drinking purpose in the plant and the personnel residence, water from the Trijuga river should be filtered and sterilized by adequate apparatuses before distribution.

(iii) The degree of water muddiness of the Trijuga river in the rainy season is unknown, because our field survey for the Project was carried out in the dry season only.
On the other hand, there seems to be considerable quantity of river bed water in the Trijuga river, judging from the said water flow rate of this river.
Therefore, it is expected that the said river bed water can be obtained for the Project by means of providing the wells on the river bed, instead of water to be directly obtained from the river.
In either case, upon design of the plant, the method of water supply should be determined with further survey and examination on the matters mentioned above.

(2) Report on the measurement of the Trijuga river flow

(i) Date of measurement : February 7, 1978

(ii) Location of measurement : Gaighat (the o-marked point in the map below.)



Scale : 1/50,000

(iii) General description on the river flow

It was amidst the dry season of the area when this measurement was carried out, and, therefore, the river bed was mostly exposed. The water was flowing in three narrow streams with widths ranging from 6 to 9 m and depths of nearly 20 cm.

The latest raining day prior to the measurement was January 21. The precipitation of that rainfall is unknown, though. 17 days had elapsed since then.

At the time of the measurement, it was cloudy with calm wind.

(iv) Method of measurement

The flows of the aforesaid three streams were measured by means of the following method.

(For the purpose of convenience, the three streams are referred to hereinafter as Southern Stream, Middle Stream and Northern Stream,)

(a) Measurement of flow sections

Three zones, one for each stream, in the direction of the flows were selected, where the widths and the depths of the respective flows are nearly uniform over a length of more than 10 m. Then, the cross sectional area of the flows were measured at the middle points of the respective zones.

(b) Measurement of flow velocity

Measured was the time required for a wooden float to flow a distance of 10 m in the aforesaid zones, from 5 m upstream to 5 m downstream of the cross sections measured as aforesaid.

Three measurements for each stream were made repeatedly.

(v) Obtained data

The following are the cross sectional areas and the flow velocities of the respective three streams.

	(1) Width (m)	(2) Cross sectional area (m^2)	(3) Velocity (m/s)	(4) (2) x (3) (m^3/s)
Southern Stream	5.7	0.82	0.58	0.48
Middle Stream	7.8	0.99	0.26	0.26
Northern Stream	9.0	1.22	0.07*	0.08*

* Note : Northern Stream flows very slowly compared with the others, and because of the great difference among the data obtained from the three repetition of the measurement the asterisked figures are only for reference and to be neglected.

(vi) Discharge

Neglecting Northern Stream as aforesaid, the distance of the Trijuga river at the time of this measurement is calculated as follows :

The sum of the respective products of the cross sectional areas and the velocities is, if Northern Stream is neglected, 0.48 + 0.26 = 0.74 (m^3/s).

Some correction to this should be made because (1) the measured velocities are those of the flow surfaces and not the average ones, and (2) the flows are not uniform over their entire widths, especially slow along the edges of the streams.

Taking the correction coefficient of 0.7, the discharge is, 0.74 x 0.7 = 0.52 (m^3/s), or 1.9 x 10^3 (m^3/h).

Taking the Northern Stream into consideration again, which is not taken into this calculation, it is concluded that the discharge of the Trijuga river at the time of this measurement was nearly 2,000 m^3/h.

VI-5 Transportation of the Product

The price of portland cement per weight is cheep as compared with other industrial products, and therefore, it is very difficult for this product to bear high transportation cost. A rational transportation is so important that various methods has been planned.

In order to decrease the transport cost, it goes without saying that the mass transportation is advantageous.

The method of mass transportation depends on transportation facilities to be used and is related to container of cement.

The methods available for the Project are described as follows.

VI-5-1 Transportation Facilities

There exists no railway except the narrow guage linking Janakpur with Jaynagar (Indian city).

Accordingly the main transport facilities are trucks.

(In case the export of portland cement to India, the railway in India may be used.)

The loading capacity of trucks is 7.5 ton at present, it is, however, desirable to use a large scale truck in future as far as the road condition permits.

VI-5-2 Container

Jute bags are mainly used as a container of cement both in Nepal and

India at present.

In case of a jute bag cement packed in a bag is apt to be scattered and lost through the bag, while moisture in the air is absorbed by the cement which causes the deterioration of the quality.

Therefore, it is, desirable to use a paper bag in place of the jute bag. Besides, the transportation in bulk should be adopted as much as possible because of the following reasons.

(1) The cost of container can be saved.
(2) Unpacking work can be omitted.
(3) Handling cost can be saved as compared with bagged cement.
(4) Loading and unloading works can be performed in all weather
(5) The quality can easily be maintained.

It is necessary to make a receiving silo at delivery place of cement.

Note. For the Project is is recommended to prepare the space for bulk loading equipment.

A couple of examples of bulk transportation are described hereinafter.

(1) Bulk container

This is a bag made of synthetic rubber etc. with a capacity of 2.5 ~ 3.0 ton and can be used repeatedly for around 100 times.

The price of 2.5 ton bag is about 3,600 Rs/bag.

This corresponds to unit price about 15 Rs/t·cement which is cheaper than that of a jute bag 60 Rs/t·cement.

Loading and unloading of cement can be made easily. The mechanical power is required for the handling due to its weight.

It is satisfactorily used for the middle scale demand or more.

(2) Bulk truck

A bulk truck is recommendable for bigger demand.

As the truck is equipped with a container loading, transportation and unloading can be performed only by its driver.

The bulk truck method is suitable for a large scale public construction works such as construction of dam.

VI-5-3 Relay Base

In case portland cement, many final users are spread extending over wide area.

Besides, quantity and time of delivery are not fixed.

It is sometimes advantageous to establish a relay base of shipping to facilitate a rational transportation instead of direct delivery to the user.

As an expansion of demand in future, the relay base will have to be examined.

VI-5-4 Transportation Road for Cement Shipment

Refer to II-2-2, IV-2 and X-1.

(1) Domestic market

Cement is transported to East-west highway through Gaighat - Kathauna road, and then distributed East-west highway and feeder roads.

(2) Exports

(i) India

Route 2 and/or Route 4 are used. (X-1)

In case the road linking Lahan with Thari is improved, this road could also be used.

(ii) Bangladesh

Route 1 (X-1) is used.

SECTION VII BASIC DESIGN OF THE PLANT

VII-1 Standards, Laws and Regulations

The standards, laws and regulations related to the Project are described hereinafter.

Since some of standards have not been established yet in Nepal, the standards of other countries will be applied wherever necessary.

VII-1-1 Standards

(1) Building and structure :

National Building Code of India, By the Indian Standards Institution

(2) Mechanical division :

The standards accepted internationally such as, ISO, JIS, DIN, BS, ASTM etc.

(3) Electrical division :

The standards accepted internationally such as, JIS, JEC, JEM(Japan) ; DIN, VDE(German) ; BS, IEE(UK) ; NF, UTE(France) ; ANSI, NEMA(USA) etc. and Standards recommended by IEC.

(4) Quality of cement :

Refer to VII-2.

VII-1-2 Laws

(1) Labour and enterprise

(i) On wages

(a) On wages :

N.G.), Vol. 12, No. 44 C April 12, 1963

(b) Minimum wages for industrial workers :

N.G., Vol. 25, No. 38 (January 5, 1976)

(c) Bonus act :

N.G., Vol. 27, No. 32 (September 22, 1977)

(ii) Factory legislation

(a) Nepal factories and factory workers act, 1959 :

N.G., Vol. 23, No. 74(March 24, 1974)

(b) Nepal factories and factory workers rules, 1963 :

N.G., Vol. 13, No. 6 (May 20, 1963)

(iii) Industrial legislation

(a) Industrial enterprises act, 1974 :

N.G., Vol. 23, No. 74(March 24, 1974)

(b) Mills act, 1965 :

N.G., Vol. 15, No. 14(August 30, 1965)

(iv) Development boards and corporations

(a) Development board act, 1956 :

N.G., Vol. 13, No. 29(February 28, 1964)

(b) Corporation act, 1964 :

N.G., Vol. 23, No. 32A(August 31, 1973)

(v) Essential services and installations

(a) Essential services (Operation) act, 1957 :

N.G., Vol. 7, No. 11(December 6, 1957)

(b) Notification of the home secretariat, 1957 :

N.G., Vol. 7, No. 34(December 9, 1957)

(c) Essential installations (Protection) act, 1955 :

N.G., Vol. 17, No. 29 A (October 23, 1967)

(2) Taxes

(i) Income-tax legislation

(a) Income-tax act, 1974 :

(b) Income-tax assessment rates :

N.G., Vol. 26, No. 14 A (August 27, 1976)

(ii) Import tax

(a) Import-tariff, 1976/77

(iii) Road

Road tax rates for vehicles, July, 1976

(3) Road

(i) Nepal road standards, 1970

(4) Mine

(i) Nepal mines act, 1966 :

N.G., Vol. 16, No. 27 A (September 25, 1966)

(5) Others

(i) Land reclamation and resettlement

(a) Law on land reclamation, 1963 :

Legal codes

(b) Land reclamation rules, 1967 :

N.G., Vol. 18, No. 5(May 13, 1968)

(c) Ban on allotment of waste lands, 1969 :

N.G., Vol. 18, No. 39(January 13, 1969)

(d) The department of resettlement :

N.G., Vol. 19, No. 33(September 15, 1969)

(e) Formation of central resettlement board, 1969 :

N.G., Vol. 19, No. 31(November 17, 1969)

(f) Formation of zonal resettlement board, 1969 :
N.G., Vol. 19, No. 27(October 13, 1969)

(g) Rapti valley development area land (Sale and distribution) act, 1967:
N.G., Vol.18, No. 39(April 10, 1969)

(h) Rapti valley development area land (Sale and distribution) rule, 1967:
N.G., Vol. 17, No. 43(February 12, 1968)

(ii) Town planning and regional development

(a) Town development committee act, 1963
N.G., Vol. 16, No. 27A(September 25, 1966)

(b) Town development plans (Execution) act, 1973
N.G., Vol. 22, No. 54(March 6, 1973)

(c) Regional development projects (Execution) act, 1956
N.G., Vol. 13, No. 29(February 28, 1964)

VII-1-3 Environmental Regulation

Although there has been no environmental regulation established yet, it is necessary to pay special attention for the preservation of environment.

VII-2 Quality of Cement

VII-2-1 The Quality of Cement to be Produced

It is assumed that the type of cement to be produced in the Project is ordinary portland cement.

Since the raw materials of Udaipur district are of suitable quality for manufacturing ordinary portland cement as described in V-3, it is possible to produce ordinary portland cement of good quality.

The representative standards of ordinary portland cement are shown below. The ordinary portland cement which complies with any one of those standards can be produced from the raw materials of this district.

Country	No. of standards	Name of cement
UK	BS 12 (1971)	Ordinary portland cement
USA	ASTM C-150 (1976)	Type I
India	IS : 269 (1968)	Ordinary portland cement
Germany	DIN 1164 (1970)	PZ 350 L
Japan	JIS R 5210 (1977)	Ordinary portland cement

The quality of the ordinary portland cement produced in the cement plant in Nepal is shown in Table 7-2-1 for reference.

Table 7-2-1 Quality of Ordinary Portland Cement Made in Nepal

Fineness specific surface area	Bending strength (kg/cm^2)			Compressive strength(kg/cm^2)		
	3 days	7 days	28 days	3 days	7 days	28 days
3,130 cm^2/g	26.3	34.2	52.3	102	150	236

Note. 1. The test was made according to the testing method stipulated in JIS R5210.

2. The test was carried out in Japan.

VII-2-2 Preparing Proportion of Raw Materials

(1) Moduli of cement

The moduli of cement are determined taking account of the quality of cement to be produced, the characteristics of raw materials to be used and the production cost etc.

The moduli of ordinary portland cement to be produced in the Project are assumed as follows.

$$HM \text{ (Hydraulic modulus)} = \frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3} = 2.10$$

$$SM \text{ (Silica modulus)} = \frac{SiO_2}{Al_2O_3 + Fe_2O_3} = 2.6$$

$$IM \text{ (Iron modulus)} = \frac{Al_2O_3}{Fe_2O_3} = 1.8$$

In the calculation of raw meal preparation the moduli mentioned above were used as standard values of clinker and besides the calculation was carried out in cases SM = 2.4 and 2.2, and HM = 2.05 respectively.

(2) Chemical composition of raw material

For this calculation the average values of the following raw materials were used.

(i) Limestone

Drilling core sample of Sindali deposit

BH-10 (15 samples) and BH-16 (17 samples) Total 32 samples

(ii) Clay (1)

Beltar deposit

Northern deposit {B-28, B-30, B-54, B-55, B-80, B-1030, B-1340, B-1390, B-1430}

Southern deposit {B-1230, B-1270, B-1290, B-1510, B-1540, B-1560, B-1580, B-1590A, B-1600, B-1630, B-1810, B-1830}

Total 21 samples

(iii) Clay (2)

Beltar deposit {2.1.1, 2.1.3, 2.1.4, 2.1.5} Total 4 samples

(iv) Silica sand

Trijuga river silica sand

No. 1 1 sample

(v) Iron ore

Phulchoki iron ore

No. 1 1 sample

(vi) Coal ash

Average values of chemical composition described in the test report of Assam coal were used.

(Refer IV-4.)

The chemical composition of each raw material are shown in Table 7-2-2.

Table 7-2-2 Chemical Composition of Raw Materials

		Limestone	Clay (1)	Clay (2)	Silica sand	Iron ore	Coal ash
Chemical composition (wt. % in dry basis)	L.O.I.	43.5	5.8	4.8	1.4	1.1	0
	SiO_2	0.8	64.0	71.2	86.1	8.0	47.9
	Al_2O_3	0.4	18.4	15.0	6.1	7.8	25.8
	Fe_2O_3	0.2	6.1	4.2	1.5	80.0	21.1
	CaO	53.1	0.2	0.2	0.4	1.2	1.2
	MgO	1.7	1.1	0.8	0.3	0.4	1.1
	SO_3	0.01	0.02	–	–	0.01	2.9 (total of SO_3, Na_2O, K_2O)
	Na_2O	0.02	0.17	0.17	0.72	0.04	
	K_2O	0.10	3.17	2.63	2.06	0.46	
	Total	99.83	98.96	99.00	98.59	99.01	100.0
	P_2O_5	0.108	0.042	–	–	0.017	–
	Cl	0.000	0.003	–	–	0.000	–

(3) Combination of raw materials

Among the clay samples, the sample of eastern deposit is a little higher in SiO_2 than those of northern and southern deposit.

Accordingly as the main combination, the combination of the clays of northern and southern deposit with the silica sand was made and besides the combination in which the clay of eastern deposit was used instead of silica sand was made too.

The standard combination (No. 1) and other 4 combinations are shown in Table 7-2-3 together with the moduli of clinker.

Table 7-2-3 Combination of Raw Materials

Combination		No. 1	No. 2	No. 3	No. 4	No. 5
Limestone		o	o	o	o	o
Clay (1)		o	o	o	o	o
Clay (2)						o
Silica sand		o	o	o	o	
Iron ore		o	o	o	o	o
Moduli of clinker (planned)	HM	2.10	2.10	2.10	2.05	2.10
	SM	2.6	2.4	2.2	2.6	2.6
	IM	1.8	1.8	1.8	1.8	1.8

(4) Preparing proportion of raw materials

The preparing proportion of raw materials (dry base), the chemical composition of raw meal, chemical composition of clinker and mineral composition of clinker is shown in Table 7-2-4 ~ 7-2-7 respectively.

Table 7-2-4 Preparing Proportion of Raw Materials

Combination	No. 1	No. 2	No. 3	No. 4	No. 5
Limestone	80.081	80.009	79.928	79.650	80.161
Clay (1)	14.158	15.822	17.690	14.506	1.826
Clay (2)	0	0	0	0	17.073
Silica sand	4.957	3.316	1.473	5.020	0
Iron ore	0.804	0.853	0.909	0.824	0.940
Total	100.000	100.000	100.000	100.000	100.000

(wt. % in dry basis)

Table 7-2-5 Chemical Composition of Raw Meal

Combination		No. 1	NO. 2	No. 3	No. 4	No. 5
Chemical composition (wt. % in dry basis)	L.O.I.	35.7	35.8	35.8	35.6	35.8
	SiO_2	14.0	13.7	13.3	14.3	14.0
	Al_2O_3	3.3	3.5	3.7	3.4	3.3
	Fe_2O_3	1.7	1.9	2.0	1.8	1.7
	CaO	42.6	42.5	42.5	42.4	42.6
	MgO	1.5	1.5	1.6	1.5	1.5
	SO_3	0.01	0.01	0.01	0.01	-
	Na_2O	0.08	0.07	0.06	0.08	0.05
	K_2O	0.63	0.65	0.68	0.65	0.59
	Total	99.52	99.63	99.65	99.74	99.54
	P_2O_5	0.093	0.093	0.094	0.092	-
	Cl	0.000	0.000	0.001	0.000	-
Moduli of raw meal (calculated)	HM	2.23	2.23	2.23	2.18	2.23
	SM	2.8	2.5	2.3	2.8	2.8
	IM	1.9	1.9	1.9	1.9	1.9

Table 7-2-6 Chemical Composition of Clinker

Combination		No. 1	No. 2	No. 3	No. 4	No. 5
Chemical composition (wt. % in dry basis)	SiO_2	22.3	21.8	21.3	22.7	22.4
	Al_2O_3	5.5	5.8	6.2	5.6	5.5
	Fe_2O_3	3.1	3.2	3.5	3.1	3.1
	CaO	65.0	65.0	64.9	64.5	65.1
	MgO	2.4	2.4	2.4	2.4	2.3
	Total	98.3	98.2	98.3	98.3	98.4
Moduli of clinker (calculated)	HM	2.10	2.10	2.10	2.05	2.10
	SM	2.6	2.4	2.2	2.6	2.6
	IM	1.8	1.8	1.8	1.8	1.8

Table 7-2-7 Mineral Component of Clinker

Combination		No. 1	No. 2	No. 3	No. 4	No. 5
Mineral component *1 (wt. % in dry basis)	C_3S	53	54	56	48	53
	C_2S	24	22	19	29	24
	C_3A	9	10	11	10	9
	C_4AF	9	10	10	9	9
L.S.F. *2		0.91	0.92	0.94	0.89	0.91

Note. *1 : Mineral component are calculated according to Bogue's equations. Symbol of each minerals stands for as follows :

C_3S .... Tricalcium silicate $3CaO \cdot SiO_2$

C_2S .... Dicalcium silicate $2CaO \cdot SiO_2$

C_3A .... Tricalcium aluminate $3CaO \cdot Al_2O_3$

C_4AF .... Tetracalcium aluminoferrite $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$

*2 : L.S.F. (Lime saturation factor) are calculated according to the equation stipulated in BS 12.

In the above calculation the quantity of ash to be mixed in clinker was calculated as follows.

Calorific value (net) of coal	6,500 kcal/kg
Ash content of coal (dry base)	15 %
Heat consumption of clinker	850,000 kcal/t·cl
Quantity of ash to be mixed in clinker	20 kg/t·cl

The loss of raw meal due to scattering of dust was neglected.
The preparing proportion of raw materials will have to be changed in the actual operation depending on the fluctuation of moisture and chemical composition of each raw material.
The combination No. 1 was used for the design as the standard combination in this report.

(5) Unit consumption of raw materials (Theoretical value)

Unit consumption of raw materials (Theoretical value) were calculated using the results of the calculation on raw meal as shown in Table 7-2-8.

Table 7-2-8 Unit Consumption of Raw Materials (Theoretical Value)

Combination	No. 1	No. 2	No. 3	No. 4	No. 5
Limestone	1.2216	1.2214	1.2210	1.2120	1.2243
Clay (1)	0.2160	0.2415	0.2702	0.2207	0.0279
Clay (2)	0	0	0	0	0.2607
Silica sand	0.0756	0.0506	0.0225	0.0764	0
Iron ore	0.0123	0.0130	0.0139	0.0125	0.0144
Total	1.5255	1.5265	1.5276	1.5216	1.5273

(t·raw materials in dry basis / t·clinker including coal ash)

(6) Unit consumption of raw materials (Actual value)

Assuming the loss of raw materials in manufacturing process as 2.5 % the unit consumption of raw materials (Actual value) were calculated as shown in Table 7-2-9.

Table 7-2-9 Unit Consumption of Raw Materials (Actual Value)

Combination	No. 1	No. 2	No. 3	No. 4	No. 5
Limestone	1.252	1.252	1.252	1.242	1.255
Clay (1)	0.222	0.248	0.277	0.226	0.029
Clay (2)	0	0	0	0	0.267
Silica sand	0.078	0.052	0.023	0.078	0
Iron ore	0.013	0.013	0.014	0.013	0.015
Total	1.565	1.565	1.566	1.559	1.566

(t·raw materials in dry basis / t·clinker including coal ash)

VII-2-3 Preparing Proportion of Raw Materials
(In case Bihar Coal is used as fuel.)

(1) Moduli of cement

Refer to VII-2-2.

(2) Chemical composition of raw material

Limestone, Clay (1), Silica sand and Iron ore

Refer to Table 7-2-2 of VII-2-2.

Coal ash

The chemical composition of ash of Bihar coal is shown in Table 7-2-10.

Table 7-2-10 Chemical Composition of Coal Ash

L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Total
0.6	58.0	29.0	5.9	2.6	0.8	0.28	0.11	1.7	98.99

Note : TiO is included in Al_2O_3.

(3) Combination of raw materials

Table 7-2-11 Combination of Raw Materials

Combination		No. 1	No. 2	No. 3	No. 4
Limestone		o	o	o	o
Clay (1)		o	o	o	o
Silica sand		o	o	o	o
Iron ore		o	o	o	o
Moduli of clinker (planned)	HM	2.10	2.10	2.10	2.05
	SM	2.6	2.4	2.2	2.6
	IM	1.8	1.8	1.8	1.8

(4) Preparing proportion of raw materials

The preparing proportion of raw materials (dry base), the chemical composition of raw meal, chemical composition of clinker is shown in Table 7-2-12 ~ 7-2-14 respectively.

Table 7-2-12 Preparing Proportion of Raw Materials

Combination	No. 1	No. 2	No. 3	No. 4
Limestone	80.650	80.576	80.495	80.217
Clay (1)	12.686	14.364	16.247	13.032
Silica sand	5.546	3.892	2.034	5.612
Iron ore	1.118	1.168	1.224	1.139
Total	100.000	100.000	100.000	100.000

(wt. % in dry basis)

Table 7-2-13 Chemical Composition of Raw Meal

Combination		No. 1	No. 2	No. 3	No. 4
Chemical composition (wt. % in dry basis)	L.O.I.	35.9	36.0	36.0	35.7
	SiO_2	13.6	13.3	12.9	13.9
	Al_2O_3	3.1	3.3	3.5	3.2
	Fe_2O_3	1.9	2.0	2.2	2.0
	CaO	42.9	42.8	42.8	42.7
	MgO	1.5	1.5	1.6	1.5
	SO_3	0.01	0.01	0.01	0.01
	Na_2O	0.08	0.07	0.06	0.08
	K_2O	0.60	0.62	0.64	0.61
	Total	99.59	99.60	99.71	99.70
	P_2O_5	0.092	0.093	0.094	0.092
	Cl	0.000	0.000	0.000	0.000
Moduli of raw meal (calculated)	HM	2.30	2.30	2.30	2.24
	SM	2.6	2.5	2.3	2.7
	IM	1.8	1.6	1.6	1.6

Table 7-2-14 Chemical Composition of Clinker

Combination		No. 1	No. 2	No. 3	No. 4
Chemical composition (wt. % in dry basis)	SiO_2	22.4	21.8	21.3	22.7
	Al_2O_3	5.5	5.9	6.2	5.6
	Fe_2O_3	3.1	3.3	3.5	3.1
	CaO	65.0	65.0	65.0	64.5
	MgO	2.4	2.4	2.4	2.3
	Total	98.4	98.4	98.4	98.2
Moduli of clinker (calculated)	HM	2.10	2.10	2.10	2.05
	SM	2.6	2.4	2.2	2.6
	IM	1.8	1.8	1.8	1.8

In the above calculation the quantity of ash to be mixed in clinker was calculated as follows.

Calorific value (net) of Bihar coal	5,455 Kcal/kg
Ash content of Bihar coal	19.6 %
Heat consumption of clinker	850,000 Kcal/t·cℓ
Quantity of ash to be mixed in clinker	30.6 Kg/t·cℓ

(5) Unit consumption of raw materials (Theoretical value)

Table 7-2-15 Unit Consumption of Raw Materials (Theoretical value)

Combination	No. 1	No. 2	No. 3	No. 4
Limestone	1.2210	1.2207	1.2204	1.2113
Clay (1)	0.1921	0.2176	0.2463	0.1968
Silica sand	0.0840	0.0590	0.0308	0.0847
Iron ore	0.0179	0.0177	0.0186	0.0172
Total	1.5150	1.5150	1.5161	1.5100

(t.raw materials in dry basis/t·clinker including coal ash)