Table 4-2-7 Chemical Analysis of Moei River Silica Sand

(wt.% on dry basis)

Sample No.	L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Total	P_2O_5	Cl
S01 & S02	0.8	86.3	7.3	0.2	0.3	0.1	0.0	0.79	3.50	99.3	0.04	0.000
S03	1.1	86.6	7.6	0.9	0.6	0.2	0.0					
Average	1.0	86.4	7.4	0.6	0.4	0.2	0.0	0.79	3.50	99.3	0.04	0.000

Table 4-2-8 Chemical Analysis of Non Poh Iron Ore

(wt.% on dry basis)

Sample No.	L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Total	P_2O_5	Cl
F-1	6.3	45.6	9.1	37.1	1.2	0.6	0.0	0.06	0.04	100.00	0.04	0.02
F-2	6.0	41.6	9.0	42.3	1.0	0.1				100.00		
Average	6.2	43.6	9.0	39.7	1.1	0.4	0.0	0.06	0.04	100.00	0.04	0.02

Table 4-2-9 Chemical Analysis of Phichit Gypsum

(wt.% on dry basis)

Sample	Combined Water	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	Total
Phichit	19.8	1.3	0.1	0.0	32.2	46.5	99.9

Table 4-2-10 Chemical Analysis of Ash of Mae Ramat Coal

(wt.% on dry basis)

Sample	L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total
Mae Ramat coal ash	1.7	49.1	40.4	3.4	2.1	1.2	97.9

(2) Physical test

(i) Apparent specific gravity

Testing method:
Several lumps of sample having a diameter of 10 mm - 40 mm were dried and weighed. Then the lumps were covered by thin paraffine coating and weighed both in air and water. The apparent specific gravity was calculated using those data.

The results are shown in Table 4-2-11.

Silica sand was tested by similar testing method as above.

Table 4-2-11 Apparent Specific Gravity

Sample	Apparent Specific gravity
Doi Din Chi limestone L-07	2.68
Ban Huai Kalok oil shale OSH, DDH4-6	2.06
Ban Huai Kalok marl M04	2.20
Ban Huai Kalok marl M03	1.92
Moei river silica sand (S01+S02)	2.31

(3) X-ray diffraction analysis

(i) Testing method

The samples were pulverized finely and tested by the following apparatus.

Apparatus:

Automatic recording X-ray diffractometer attached with Cu target X-ray tube and graphite monochrometer.

(Geigerflex, Rigaku Denki Co., Ltd.)

(ii) X-ray diffraction patterns

X-ray diffraction patterns are shown in Fig. 4-2-1 - 4-2-8.

(iii) Results of analysis

Table 4-2-12 summarizes the minerals determined by the analysis on the X-ray diffraction patterns shown in Fig. 4-2-1 - 4-2-8.

Table 4-2-12 Results of X-ray Diffraction Analysis

Sample	Mineral detected by X-ray diffraction analysis
Doi Din Chi limestone L-07	Calcite (Quartz)
Doi Din Chi limestone L-13	Calcite (Quartz)
Ban Huai Kalok oil shale OSHLK2'	Dolomite, Zeolite, Calcite, Quartz
Ban Huai Kalok oil shale OSHDDH4-6	Dolomite, Zeolite, Calcite, Quartz
Moei river silica sand S1 + S2	Quartz Mica (Feldspar)
Phichit gypsum G - 2	Gypsum
Non Poh iron ore F - 1	Hematite
Non Poh iron ore F - 2	Hematite

Note: Underlined minerals are delected as minerals with strong intensity in the diffraction patterns, minerals in ( ) are with weak intensity.

List of X-ray Diffraction Diagram

Fig 4-2-1	Doi Din Chi limestone sample	L-07
Fig 4-2-2	Doi Din Chi limestone sample	L-13
Fig 4-2-3	Ban Huai Kalok oil shale sample	OSHLK 2'
Fig 4-2-4	Ban Huai Kalok oil shale sample	OSHDDH 4-6
Fig 4-2-5	Moei river silica sand sample	S1 + S2
Fig 4-2-6	Phichit Gypsum sample	G - 2
Fig 4-2-7	Non Poh iron ore sample	F - 1
Fig 4-2-8	Non Poh iron ore sample	F - 2

Fig. 4-2-1 Doi Din Chi Limestone Sample L-07

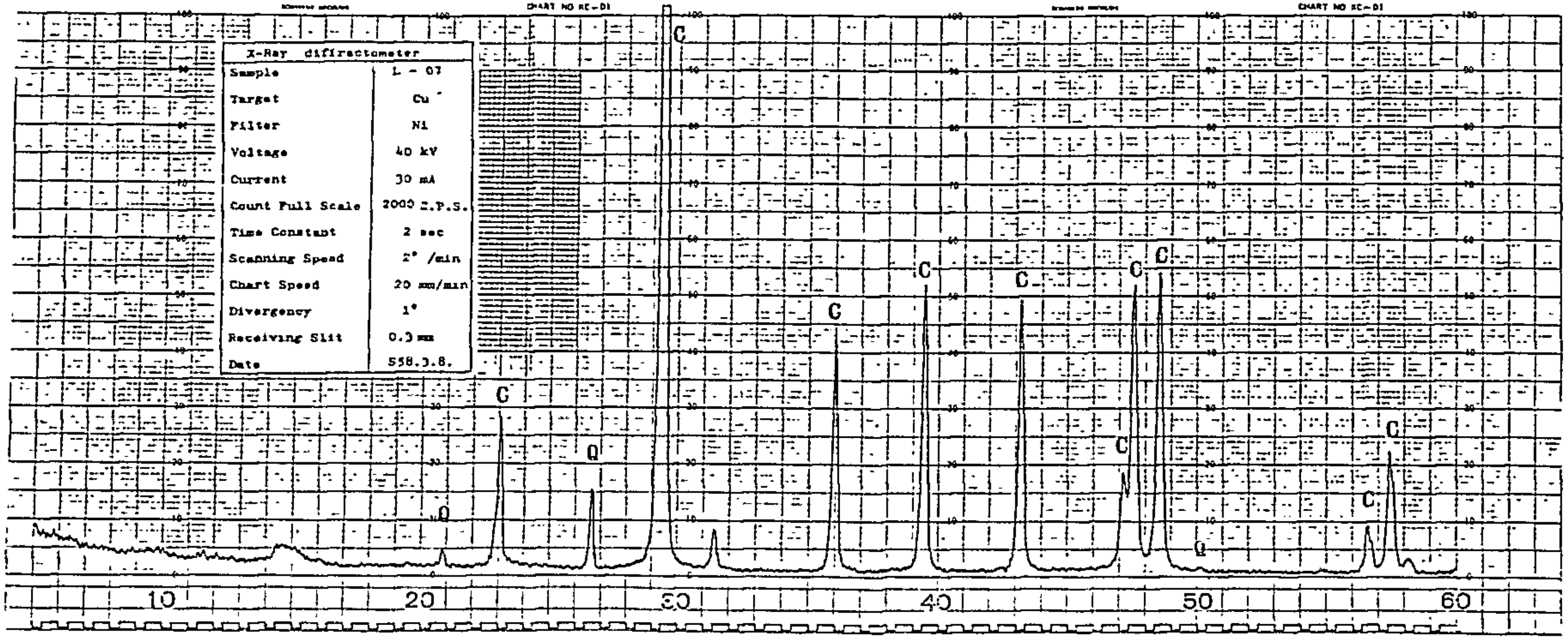


Fig. 4-2-2 Doi Din Chi Limestone Sample L-13

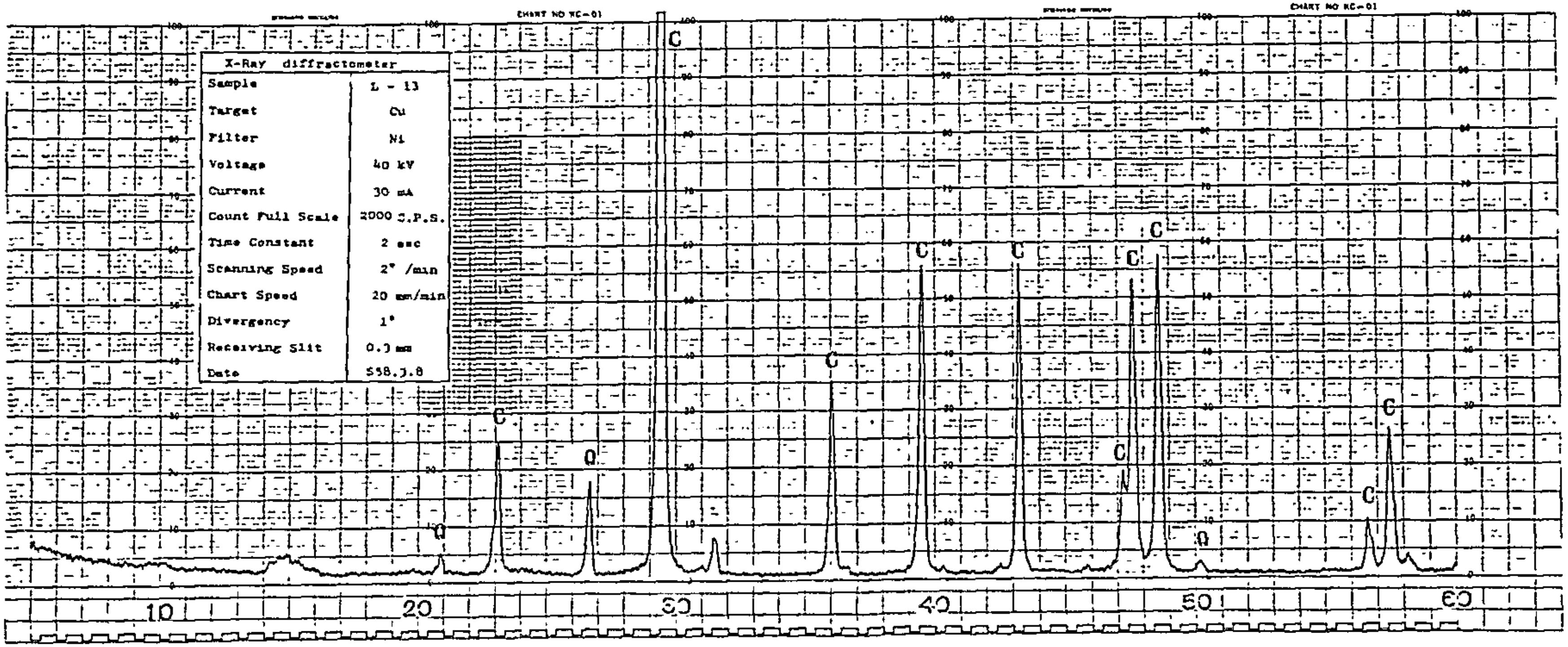


Fig. 4-2-3 Ban Huai Kalok Oil Shale Sample OSHLK-24

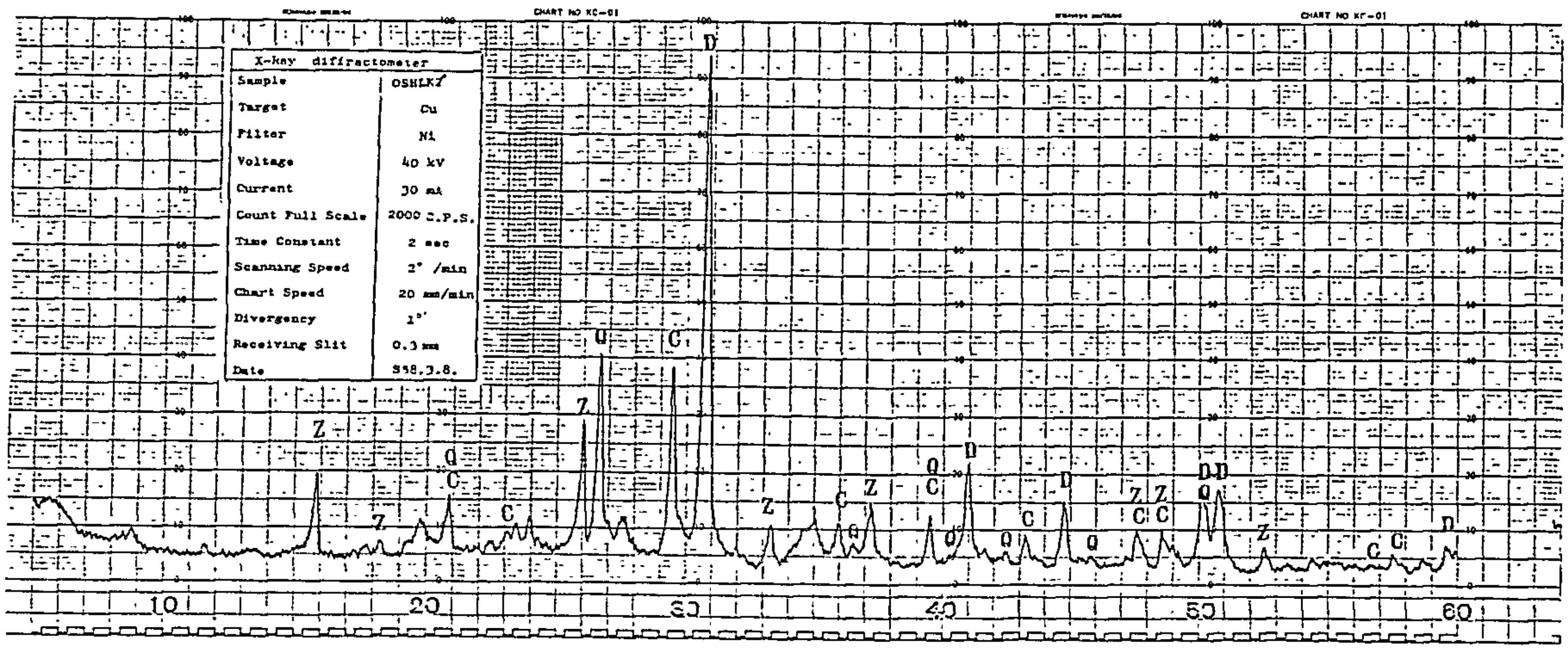


Fig. 4-2-4 Ban Huai Kalok Oil Shale Sample OSHDDH4-6

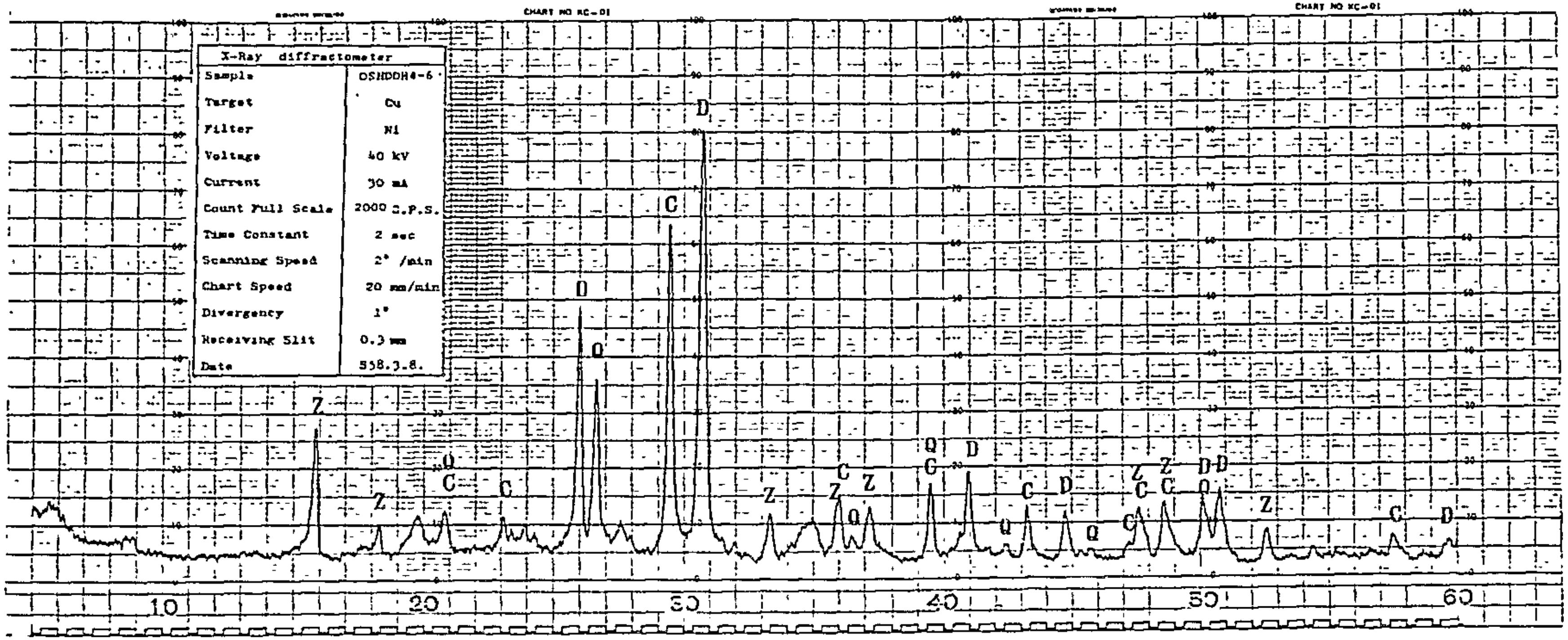


Fig. 4-2-5 Moei River Silica Sand Sample SO1 + SO2

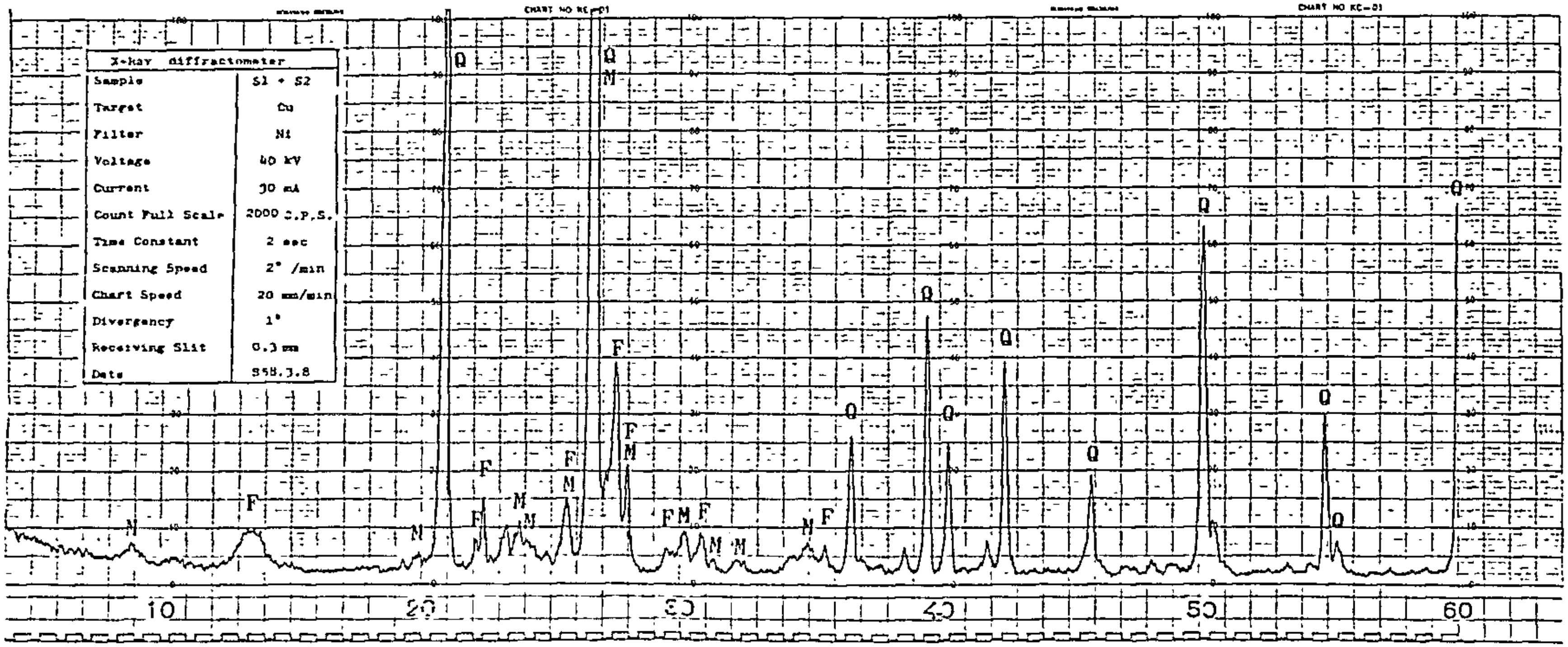


Fig. 4-2-6 Phichit Gypsum Sample G - 2

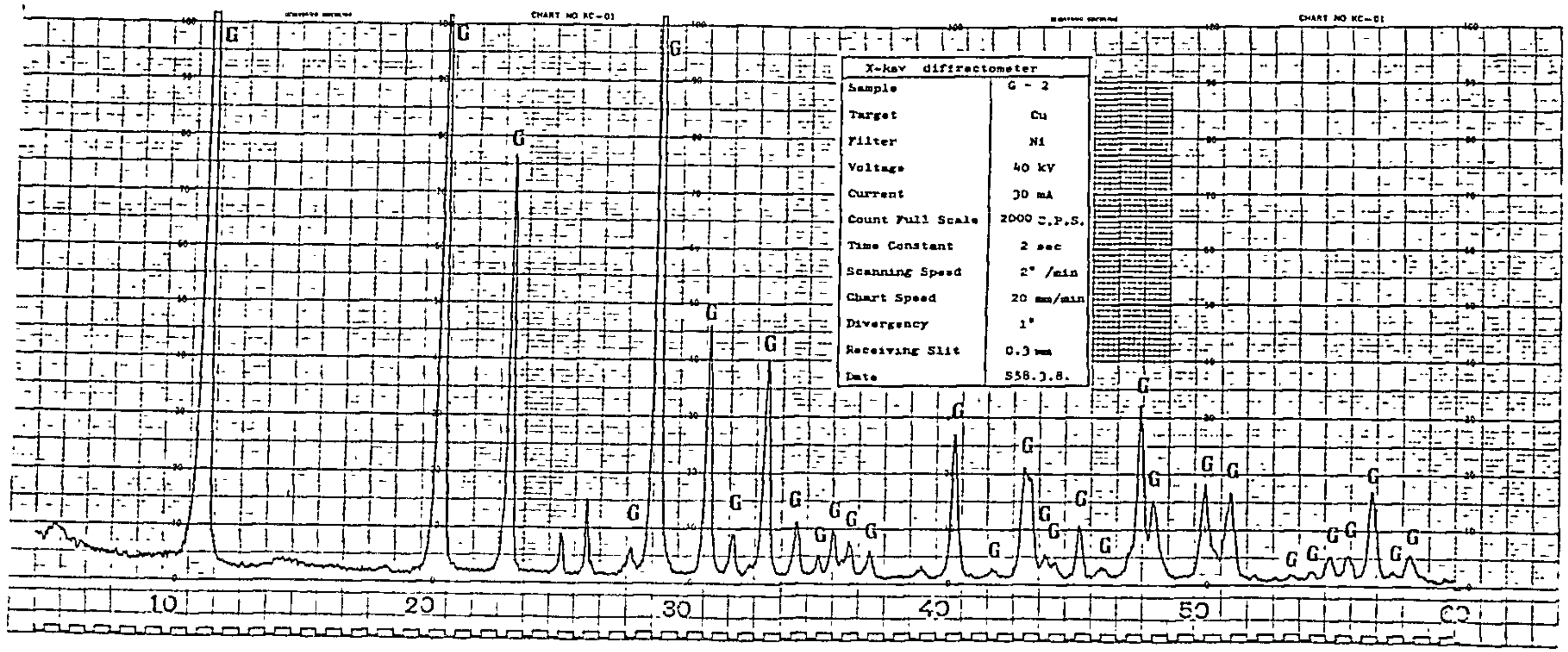


Fig. 4-2-7 Non Poh Iron Ore Sample F - 1

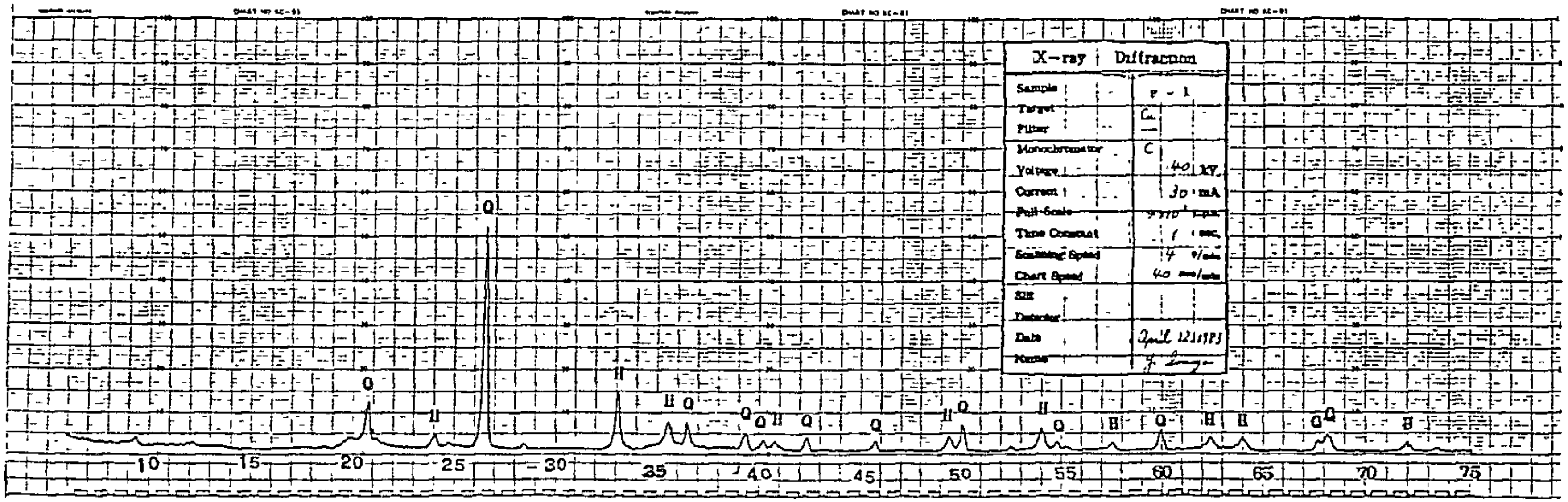
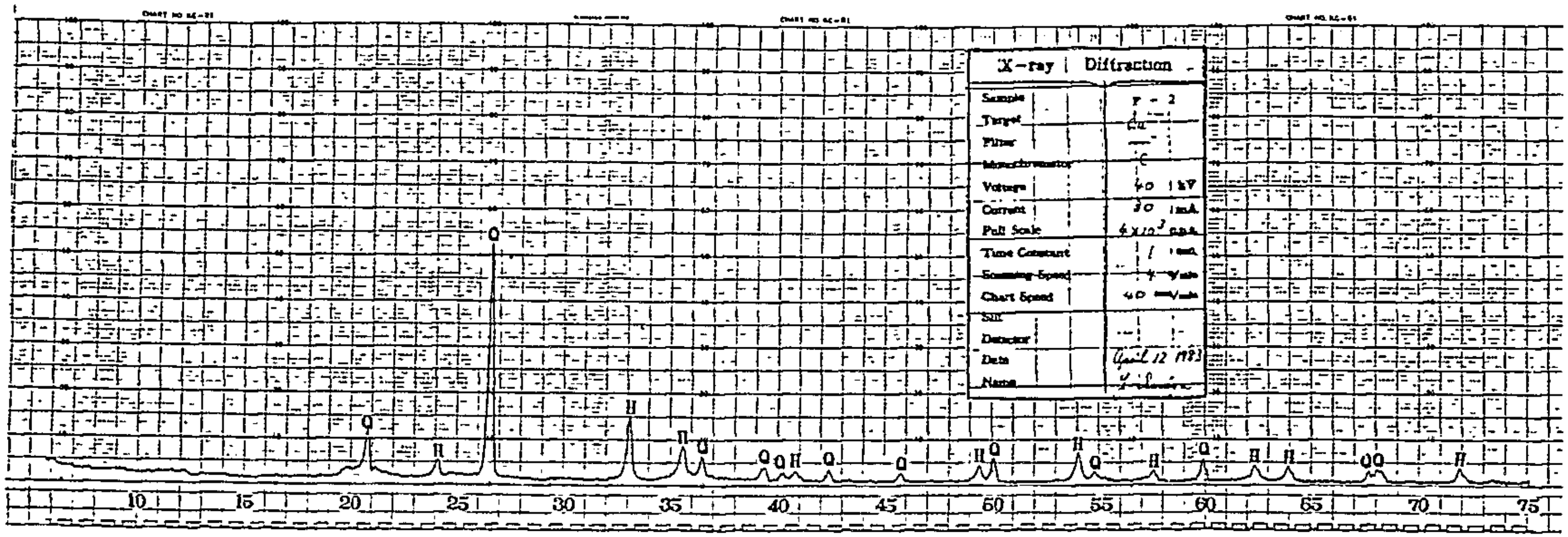


Fig. 4-2-8 Non Poh Iron Ore Sample F - 2



(Sign of Minerals Used in Fig. 4-2-1 - Fig. 4-2-8)

Sign	Mineral	Molecular formula
C	Calcite	$CaCO_3$
D	Dolomite	$CaCO_3 \cdot MgCO_3$
F	Feldspar	-
G	Gypsum	$CaSO_4 \cdot 2H_2O$
He	Hematite	Fe_2O_3
M	Mica	-
Q	Quartz	SiO_2
Z	Zeolite	-

(4) Microscopic observation of sliced sample

(i) Testing method

The samples were sliced to about 30 micron thick and then observed by a polarizing microscope and the microscopic photographs were taken.

(ii) Results of microscopic observation

The microscopic photographs are shown in Photo 4-2-1 - 4-2-2, and the detailed explanation is described in pages of the photographs respectively. The minerals observed by the polarizing microscope are summarized in Table 4-2-13.

Table 4-2-13 Results of Microscopic Observation

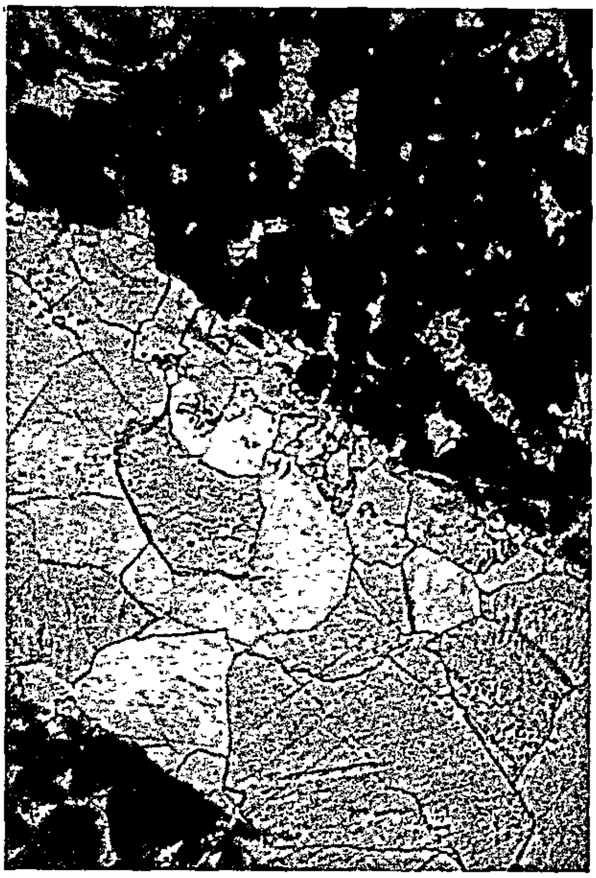
Sample	Minerals observed	Size of crystals
Doi Din Chi limestone L-07	Calcite	Calcite: Average 100-200μ
Ban Huai Kalok oil shale OSHLK 2'	Dolomite Calcite Quartz	Dolomite: 10-20μ Quartz: 10-20 μ (Max 40 μ)

List of Microscopic Photographs

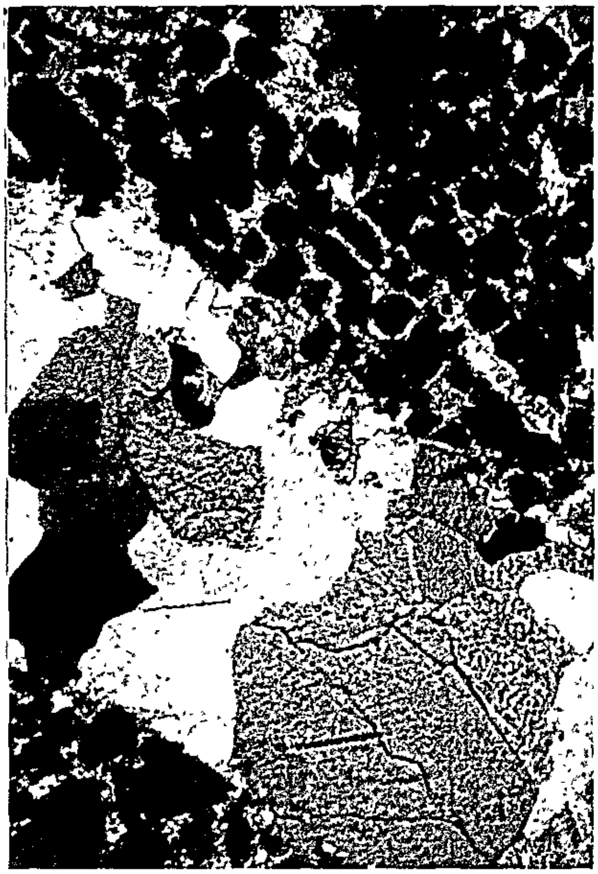
Photo 4-2-1	Doi Din Chi limestone sample	L-07
Photo 4-2-2	Ban Huai Kalok oil shale sample	OSHLK-2'

Photo 4-2-1

Limestone Sample Collected at Doi Din Chi Area



Open Nicol



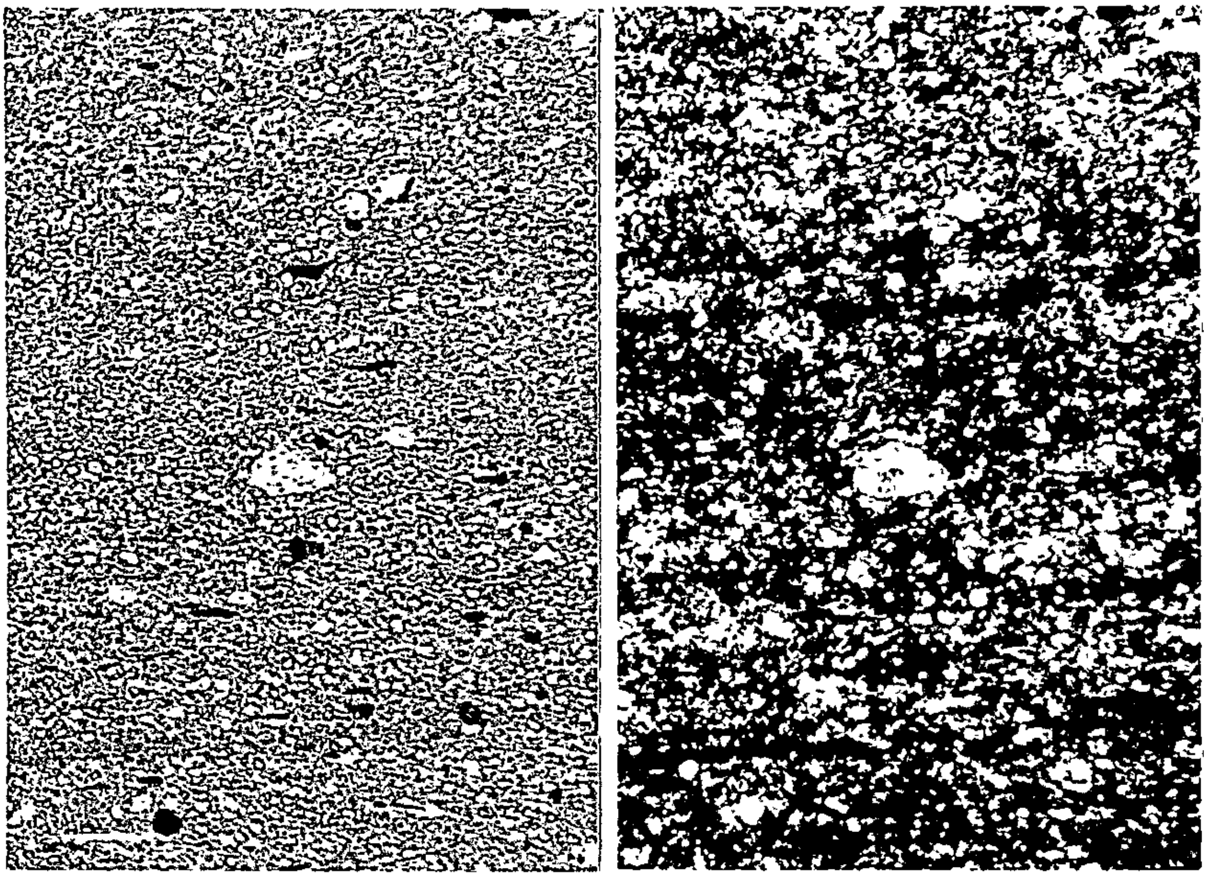
Cross Nicol

500 micron

This limestone is composed of fine crystal of calcite, and calcite pellets. Many pellets of 100 - 200 micron in size are found in the fine calcite matrix.
This matrix is cut by a calcite veinlet with 0.5 to 1.0 mm width.

Photo 4-2-2

Oil Shale Sample Collected at Ban Huai Kalok Area



Open Nicol　　　　　　　　Cross Nicol

100 micron

This oil shale sample is composed of crystals of dolomite, calcite, quartz, and zeolite in the organic matrix. The sizes of dolomite and calcite crystals are 10 micron - 20 micron, and that of quartz is generally 10 micron - 20 micron but 40 micron at maximum. Other unknown opaque mineral and very fine clay mineral are recognized. The matrix has the parallel lamina structure.

(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 burnability of the raw meal prepared from raw materials used in cement plant in Japan.

(i) Raw materials

The chemical composition of Thai raw materials and Japanese raw materials used for the test are shown in Table 4-2-14 and 4-2-15 respectively.

Table 4-2-14 Chemical Composition of Raw Material Samples Used for Burnability Test

(Thai Raw Material Samples)

Sample	Chemical composition (wt.% on dry basis)								
	L.O.I.	SiO_2	Al_2O_2	Fe_2O_3	CaO	MgO	Total	Na_2O	K_2O
Doi Din Chi limestone LS-1	42.5	2.7	0.1	0.1	53.9	0.4	99.7		
Ban Huai Kalok oilshale OSHLK 2'	32.0	28.8	10.8	2.5	16.6	5.1	95.8	(1.28)	(2.43)
Moei River silica sand S1 + S2	0.8	86.3	7.3	0.2	0.3	0.1	95.0	(0.79)	(3.50)
Non Poh iron ore F - 2	6.0	41.6	9.0	42.3	1.0	0.1	100.0		
Ash of Mae Ramat coal	1.7	49.1	40.4	3.4	2.1	1.2	97.9	(0.00)	(2.25)

Table 4-2-15 Chemical Composition of Raw Material Samples Used for Burnability Test

(Japanese Raw Material Samples)

Sample	Chemical composition (wt.% on dry basis)								
	L.O.I.	SiO_2	Al_2O_2	Fe_2O_3	CaO	MgO	Total	Na_2O	K_2O
Limestone	43.6	0.2	0.2	0.2	55.2	0.4	99.8	-	-
Clay	7.8	59.3	19.7	6.7	0.9	1.7	96.1	(1.39)	(2.11)
Silica stone	1.2	90.5	3.0	1.5	1.2	1.2	98.6	(0.29)	(0.60)
Copper slag	(-3.4)	36.6	7.6	48.6	5.6	1.5	96.5	-	-

(ii) Raw meal preparation

Three kinds of raw material combinations were adopted as follows. (Refer to Table 4-2-16)

T-1 and T-2 combinations were prepared by using Thai materials (to be used for the Project), and the modulus of each combination was adjusted to be equivalent to typical actual figures in Japan, and the moduli used in Dotternhausen plant in West Germany where oil shale cement is currently produced, respectively.

J-1 was prepared by using typical Japanese raw materials and the typical modulus for reference purpose.

The methods 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 4-2-17 and 4-2-18, the mixed material was ground finely by a vibration mill. The fineness and grinding time are shown in Table 4-2-19.

Amount of coal ash mixed in raw meal was ajusted to make ash content in clinker to be 1.4 wt.%.

Table 4-2-16 Moduli of Clinker Samples

Combination	Moduli of clinker samples		
	HM	SM	IM
T - 1	2.08	2.5	1.7
T - 2	2.08	2.2	
J - 1	2.08	2.5	1.7

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

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

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

T-1, T-2 : Thai raw materials

J-1 : Japanese raw materials

Table 4-2-17 Mixing Proportion of Thai Raw Material

Combina-tion	Proportion of raw materials (wt.% on dry basis)				
	Doi Din Chi limestone LS-1	Ban Huai Kalok oil shale OSHLK 2'	Moei river silica sand S1 + S2	Non Poh iron ore F - 2	Ash of Mae Ramat coal
T-1	69.50	22.15	4.23	3.28	0.84
T-2	63.99	33.65	0.00	1.49	0.87

Table 4-2-18 Mixing Proportion of Japanese Raw Materials

Combi-nation	Proportion of raw materials (wt.% on dry basis)				
	Japanese limestone	Japanese clay	Japanese silicastone	Japanese copper slag	Coal ash
J-1	77.26	16.37	3.86	1.62	0.89

Table 4-2-19 Fineness and Grinding Time of Raw Meal

Combination	Fineness wt.% (Residue on 88μ sieve)	Grinding time (Sec)
T-1	9.8	80
T-2	10.2	85
J-1	9.7	75

(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 in an electric furnace maintained at 800°C for 1 hr, and subsequently burnt in an electric furnace maintained at 1450°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 burnt clinker, and free lime of the clinkers are shown in Table 4-2-20 and 4-2-21, respectively.

Table 4-2-20 Chemical Composition and Moduli of Clinkers

Combi-nation	Chemical composition (wt.% on dry basis)					Moduli		
	SiO_2	Al_2O_3	Fe_2O_3	CaO	Total	HM	SM	IM
T-1	22.6	5.6	3.4	66.1	97.7	2.09	2.5	1.7
T-2	21.0	6.4	3.3	64.1	94.8	2.09	2.2	2.0
J-1	22.8	6.0	3.3	66.3	98.4	2.07	2.5	1.8

Table 4-2-21 Free CaO Content of Clinker

(%)

Combination	Burning temperature		
	1,450°C	1,450°C	1,450°C
	Burning time		
	10 min.	20 min.	30 min.
T-1	4.50	1.73	0.84
T-2	3.56	1.37	0.72
J-1	1.78	0.62	0.30

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) Consideration

(a) The burnability of the raw meal to be used for the Project is a little inferior to typical Japanese raw meal but is suitable for manufacturing portland cement.

(b) In this test the effect of silica modulus on burnability was examined by changing the mixing ratio of silica sand. The more silica sand is, the more inferior the burnability is, so it is advisable to minimize the amount of silica sand in raw meal preparation.

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

- Change of moduli especially of HM and SM
- Increase of fineness
- Increase of homogeneity
- Improvement of operation control etc.

It is necessary to reexamine the items mentioned above to meet the required quality of cement produced in the actual operation.

(6) Grindability test of raw material

Since the grinding with closed circuit system will be adopted at the 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 same raw materials used for the burnability test were used for the grindability test. In the Project, oil shale and other raw materials will be ground separately, so the grindability test were carried out for these two kinds of raw materials.
The raw materials used for the test and the mixing proportion are shown in Table 4-2-22.

Table 4-2-22 Mixing Proportion of Raw Materials

(wt.% on dry basis)

Combi-nation	Sample of raw materials	Mixing proportion of raw materials
1	Ban Huai Kalok oil shale LK-2	100 %
2	Doi Din Chi limestone LS-1 Non Poh iron ore F-2	97.7 % 2.3 %

(ii) Testing method

The grinding work index can be measured by a test ball mill specified in the test method.

Specification of the test mill and grinding media;

Steel 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 micron and determine under size (%) of P_1(micron) and 80% particle size F(micron).

Note. 1. In this test P_1(micron) is 88 micron.

2. 80% particle size: In case that the under size of a particle size is 80% of pulverulent 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(micron) sieve and measure over size A (g).

(d) Calculate Gbp from under size of P_1(micron), 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(micron) produced by one revolution of test mill (g)

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

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

(g) Repeat the procedure of step (d) - (f), until the circulating rate reaches steady rate 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(micron) sieve obtained in item (g) and calculate 80% particle size of P(micron).

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 for oilshale	Wi = 20.7 kWh/t
Work index for limestone and iron ore	Wi = 15.8 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(micron) sieve to repeat the grinding and therefore the results are close to the actual operation figures.

The test results of Thai raw material and those of raw materials used in the cement plant in Japan are shown in Table 4-2-23.

Table 4-2-23 Work Index (Wi) of Thai Raw Materials and Japanese Raw Materials

Raw material	Wi (kWh/t)
Thai raw material (oil shale)	20.7
Thai raw material (limestone + Iron ore)	15.8
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 4-2-23, the grindability of Thai raw material is somewhat low as compared with those of Japanese raw materials.

Although this result seems to be caused by the hardness of limestone, no problem is foreseen in the grinding process of raw material in the actual operation.

The Work Index (Wi) of oil shale is relatively high value, which is assumed to be due to slip of sample in the test mill.

(7) Fuel tests

(i) Coal

The test results of sample of Mae Ramat coal are shown in Table 4-2-24.

Table 4-2-24 Test Results of Mae Ramt Coal

(Constant Moistened Basis, JIS)

Test Items	Test results
Moisture	12.6 %
Ash	12.4 %
Volatile matter	33.6 %
Fixed carbon	41.4 %
Gross calorific value	5,440 cal/g

(ii) Oil shale

The calorific values of oil shale in Ban Huai Kalok area are shown in Table 4-2-25.

Table 4-2-25 Calorific Value of Oil Shale (cal/g)

Sample No.		Calorific value (cal/g)
OSHLK	402-1	207.6
	-2	945.1
	403-1	359.6
	-2	633.9
	404-1	293.8
	-2	266.7
	405-1	378.8
	-2	266.3
	406-2	300.8
	407	272.2
OSHLK	1301-2	963.1
	1302-1	708.2
	-2	233.1
	1305-1	543.9
	-2	470.0
	1306-2	938.2
	1307-1	384.0
	-2	780.3
	1308-1	284.6
	-2	351.6
OSHLK	1600-1	608.5
	1601-1	543.8
	-2	830.9
	1602-1	578.2
	1603-2	654.4
	1605-1	268.9
	-2	890.5
OSHLT	1801-2	609.9
	1802-2	558.0
	1803-1	579.2
	1804-1	912.8
	1805-2	676.6

Sample No.		Calorific value (cal/g)
OSHLK	2001-2	369.8
	2002-1	649.0
	2004-2	441.3
Average		534 cal/g
OSHLK	2′	940 cal/g

Note:

<u>Correction of oil shale calorific value depending on decomposition of calcium carbonate and magnesium carbonate.</u>

When calorific value of oil shale is tested, carbonate of calcium and magnesium contained in oil shale decompose on heating which is endothermic reaction. So measured value is apparently lower than real value and needs correcting.
For example, in the case that the amount of CaO and MgO is 17.0 and 3.7 % respectively which are average value for oil shale. Correction value is calculated as follows:

Heat of decomposition for $CaCO_3$ (at 900°C); - 706 cal/g-CaO
Heat of decomposition for $MgCO_3$ (at 550 - 600°C); - 585 cal/g-MgO

Therefore corrected calorific value is calculated as follows:

$$706 \times 0.170 + 585 \times 0.037 = 142 \text{ cal/g}$$

(8) Test results of cement

In the project, oil shale is used not only as a raw material but also as a fuel in cement clinker production. Furthermore oil shale cement to be produced in the Project is produced by mixing ordinary portland cement clinker with oil shale combustion residue from the fluidized bed boiler for generation of electric power.
In the Kingdom of Thailand, so-called mix cement is produced by mixing the ordinary portland cement with inert materials such as limestone or silica sand.
In the Project, oil shale combustion residue is used as substitutes for inert materials in the production of mix cement.

Results of necessary tests to confirm the feasibility of the above mentioned scheme are shown below.

(i) Properties of cement clinker made from oil shale

The method of preparation of clinker sample are as follows.
At first raw meal is prepared from raw materials which will be used in the Project. The raw meal is burnt to clinker in an electric furnace maintained at 1450°C for 20 minutes. Cement is then prepared by grinding the burnt clinker with gypsum. The physical tests have been carried out for this cement sample.

(a) Raw materials

The chemical composition of Thai raw materials used for the test are shown in Table 4-2-26.

Table 4-2-26 Chemical Composition of Thai Raw Material Samples Used for Clinker Sample

Sample	Chemical composition (wt.% on dry basis)								
	L.O.I	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total	Na_2O	K_2O
Doi Din Chi limestone LS-1	42.5	2.7	0.1	0.1	53.9	0.4	99.7		
Ban Huai Kalok oilshale OSHLK 2'	32.0	28.8	10.8	2.5	16.6	5.1	95.8	(1.28)	(2.43)
Non Poh iron ore F - 2	6.0	41.6	9.0	42.3	1.0	0.1	100.0		
Ash of Mae Ramat Coal	1.7	49.1	40.4	3.4	2.1	1.2	97.9	(0.00)	(2.25)

(b) Raw meal preparation and burning

The moduli of clinker sample as shown Table 4-2-27 are adopted.

Table 4-2-27 Moduli of Clinker Sample

Moduli of clinker sample	
HM	SM
2.08	2.2

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

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

The methods of preparation of raw meal powder are as follows.
At first, each raw material is crushed by a laboratory jaw crusher and then ground to the fineness of less than 1.2 mm by a roll crusher.
After mixing each raw material according to the mixing proportion described in Table 4-2-28, the mixture is further ground by a vibrating mill.

Table 4-2-28 Mixing Proportion of Raw Material

(%)

Limestone	Oil shale	Iron ore	Coal ash
63.99	33.65	1.49	0.87

The proportion of coal ash mixed is adjusted to make ash content in clinker to be 1.4%.

The chemical composition of test clinker is shown in Table 4-2-29.

Table 4-2-29 Chemical Composition of Test Clinker

(%)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Total	f.CaO
Test clinker	20.8	7.0	3.3	64.6	3.2	0.0	98.9	1.3

(c) Test cement properties

Test cement is prepared by grinding the above mentioned clinker with a proper amount of gypsum. Strength test has been carried out according to ASTM C 109-80 similar to the cement specification of Thailand.
The test results are shown in Table 4-2-30.

Table 4-2-30 Strength of Test Cements

(kg/cm^2)

	3 days	7 days	28 days
Test cement	250	322	369
Thai specification TIS-15	85	150	245

This table shows that test cement in which oil shale is used as one of raw materials, satisfies the cement specification of Thailand, TIS-15 I type.

(ii) Test results of test oil shale cement

In order to study the technical viability of the production scheme of oil shale cement which is produced by mixing the oil shale combustion residue generated from the power station with the normal portland cement, the oil shale combustion residue was prepared experimentally and test oil shale cement was made by mixing commercial portland

cement clinker and the oil shale combustion residue in the ratio of 70:30.
The test was carried out for this oil shale cement.

(a) Chemical composition of used oil shale

The chemical composition of oil shale which was used in this test is shown in Table 4-2-31.

Table 4-2-31 Chemical Composition of Oil Shale

(wt.%)

	L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	S
Oil shale	31.6	30.4	9.7	4.1	12.8	7.2	2.59	1.37	0.08	0.15

(b) Preparation of oil shale combustion residue

Oil shale samples were ground to fineness shown in Table 4-2-32 and burning tests were carried out at 750°C, 800°C and 850°C in an electric furnace for about 30 minutes.

Table 4-2-32 Particle Size Distribution of Oil Shale Sample

(%)

Particle size (mm)	0-0.25	0.25-0.5	0.5-1	1-2	2-4	4-8
Oil shale distribution	5.1	4.8	8.3	10.6	24.9	46.3

The weight-loss of oil shale sample and characteristics of burnt oil shale ash (combustion residue) at different temperature are shown in Table 4-2-33 and Table 4-2-34 respectively.

Table 4-2-33 The Weight-loss of Oil Shale by Heating

Temperature	Weight loss (%)
750°C	29.1
800°C	30.8
850°C	32.1

Table 4-2-34 Characteristics of Oil Shale Combustion Residue

(wt.%)

Sample No.	Burning temperature	Loss at 1000°C	CO_2	Residual C	SO_3	S	Free CaO
BS-1	750°C	3.67	2.47	0.86	0.61	0.08	0.14
BS-2	800°C	1.95	0.93	0.80	0.43	0.06	0.20
BS-3	850°C	1.00	0.42	0.39	0.51	0.07	0.77

(c) Properties of oil shale cement

The preparation of the samples was carried out as follows:
At first, a clinker which was used for all the tests was ground by a laboratory mill to cement fineness.
The ground clinker, burnt oil shale ash and gypsum (under 30 micron) were proportioned as shown below and the mixture was ground by the laboratory mill to produce oil shale cement.

Clinker	68.9%
Oil shale combustion resiude	30.0%
Gypsum	1.1%

The properties of these cement are shown in Table 4-2-35.

Table 4-2-35 Properties of Oil Shale Cement

Sample No.			BS-1	BS-2	BS-3-1	BS-3-2	Cement Clinker
Burning temperature (°C)			750	800	850	850	
Grinding time (min)			8	8	8	6	6
Blain specific surface area (cm^2/g)			5240	5200	5340	5120	4490
Setting time	Water (%)		32.4	32.2	31.8	32.4	31.0
	Initial setting (hr-min)		3-30	3-21	2-57	2-47	2-08
	Final setting (")		3-55	3-50	3-52	3-45	2-26
Compressive strength (kg/cm^2)		3 days	178	171	166	180	229
		7 days	276	260	241	250	314
		28 days	322	302	275	284	356

The tests were carried out according to ASTM.

This result shows the tendency that the cement mixed with the combustion residue produced at lower temperature has higher strength.
All cement samples have sufficient properties to satisfy the cement specification of Thailand, TIS-15 type I.

Furthermore the oil shale cement was prepared by mixing cement clinker produced in (i) of this chapter with oil shale combustion residue BS-1 in the ratio of 70:30.
The strength test results of this oil shale cement are shown in Table 4-2-36.

Table 4-2-36 Strength of Experimental Oil Shale Cement

(kg/cm^2)

	3 days	7 days	28 days
Oil shale cement sample	89	240	293
Thai specification TIS-15	85	150	245

Oil shale cement satisfies the cement specification of Thailand.

(iii) Test results of mortar binder

(a) Preparation of mortar binder

Normal cement clinker, burnt oil shale ash and gypsum used in (ii) of this chapter were proportioned in the ratio shown below.

This mixture was ground to produce mortar binder.

Clinker	29.1%
Oil shale combustion residue	70.0%
Gypsum	0.9%

The properties of the mortar binder are shown in Table 4-2-37.

Note: Mortar binder is the mixture which consists of more oil shale ash and fewer cement clinker as mentioned above and is mainly used for road foundation.

Table 4-2-37 Properties of Mortar Binder

<table>
<tr><th colspan="2">Sample No.</th><th>MB-1</th><th>MB-2</th><th>MB-3</th></tr>
<tr><td colspan="2">Burning temperature (°C)</td><td>750</td><td>800</td><td>850</td></tr>
<tr><td colspan="2">Grinding time (min)</td><td>8</td><td>8</td><td>8</td></tr>
<tr><td colspan="2">Surface area (cm²/g)</td><td>7783</td><td>7508</td><td>7377</td></tr>
<tr><td rowspan="3">Setting time</td><td>Water (%)</td><td>43.2</td><td>42.8</td><td>42.0</td></tr>
<tr><td>Initial setting (hr-min)</td><td>1-27</td><td>3-59</td><td>5-06</td></tr>
<tr><td>Final setting (")</td><td>3-15</td><td>5-25</td><td>6-37</td></tr>
<tr><td rowspan="3">Compressive strength (kg/cm²)</td><td>3 days</td><td>46</td><td>48</td><td>42</td></tr>
<tr><td>7 days</td><td>102</td><td>82</td><td>59</td></tr>
<tr><td>28 days</td><td>195</td><td>151</td><td>111</td></tr>
</table>

Oil shale ash burnt at lower temperature provides better strength cement and generally all mixture has strength suitable to its purpose.

(iv) Mixed cement

In the Project, it is intended to produce not only the oil shale cement but also the mix cement which consists of oil shale cement and oil shale combusiton residue as inert material in the ratio of 75:25.
The proportion of cement clinker and oil shale combustion residue in this cement is set as follow.

Oil shale cement clinker	70 x 0.75 = 52.5%
Oil shale combustion residue	30 + 70 x 0.25 = 47.5%

The strength of this cement is estimated from the strength of oil shale cement and mortar binder as shown in Table 4-2-38.

Table 4-2-38 Estimated Strength of Mixed Cement

Burning temperature (°C)		750	800	850	TIS80-2517
Compressive strength (kg/cm^2)	3 days	121	119	111	65
	7 days	200	175	161	115
	28 days	263	236	203	–

This results shows that all mixed cement satisfies the mix cement specification of Thailand sufficiently and are possible to be produced and sold.
In three samples of mixed cement, the lower of burning temperature, the higher the strength of mixed cement.
Especially, mixed cement in which oil shale ash burnt at 750°C was used, also satisfies Thai cement specification TIS-15 type I. (ordinary portland cement)

IV-3 Plan for Raw Materials Supply

IV-3-1 Raw Material Demand

The kinds of raw materials to be used for the Project and their respective annual requirements are as shown in the following table.

Table 4-3-1 Respective Raw Material Requirements

Kind of Raw Material	Annual requirement (t/yr)	Uses	Moisture (%)
Limestone	577,703	Cement Raw Material and Additive	2
Oil Shale	642,654	Power Generating and Cement Raw Material	4
Ferrous material	9,032	Cement Raw Material	3
Gypsum	27,612	Cement Raw Material	2

Note: The above quantitites are on wet basis to meet the clinker production of 462,000 t/y.

The plans to meet the above raw material requirements are explained below.

IV-3-2 Supply Plan for Limestone

(1) Output capacity of limestone quarry.

The output capacity of the limestone quarry must be determined on the basis of the above annual requirement in relation to the expected number of working days.

As the Doi Din Chi limestone deposit is favoured with thin top soil, gentle topography and relatively small influence of rainfall, the number of annual working days can be assumed to reach 300 d/yr (25 d/mo).

Accordingly, the required output capacity will be as follows:

- monthly capacity	48,142 t/mo
- daily capacity	1,926 t/d

(2) Topography and geomorphology of Doi Din Chi limestone deposit

The deposit is located approx. 5 km to the southwest of the proposed plant site, and can be divided into the north deposit and the south deposit. Both deposits are considered possible to be developed. However, the south deposit seems to have better conditions as follows:

(a) Easy quarrying from a topographical viewpoint.

(b) Better condition for construction of road to quarry face.

(c) Degree of rain water influence on water collecting surface.

Obstructions affecting quarry development do not exist around the deposits.

(3) Plan for supply

(i) Basic policy and standard development policy

The following conditions must be considered when developing a limestone quarry.

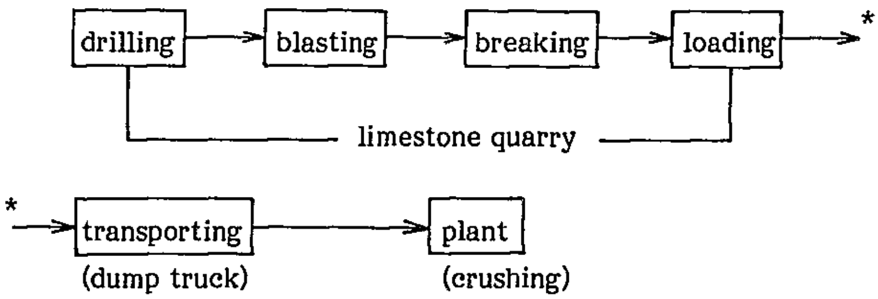
(a) Stable production of required quantity

(b) No problems in environment and safety of workers and equipment

(c) Economy of the development and operation cost

(d) Economical layout of facilities taking account of the plant facilities

When these conditions are considered, the outline of operation flow for the Doi Din Chi limestone deposit would be as follows:



It is more advantageous from a power supply viewpoint to locate the crushing equipment at the plant. Therefore the blasted rocks are directly transported to the plant. The preparatory constructions necessary prior to the operation are clearing quarry area, constructing quarry face and road construction between the quarry and the plant. A large scale development construction is not necessary.

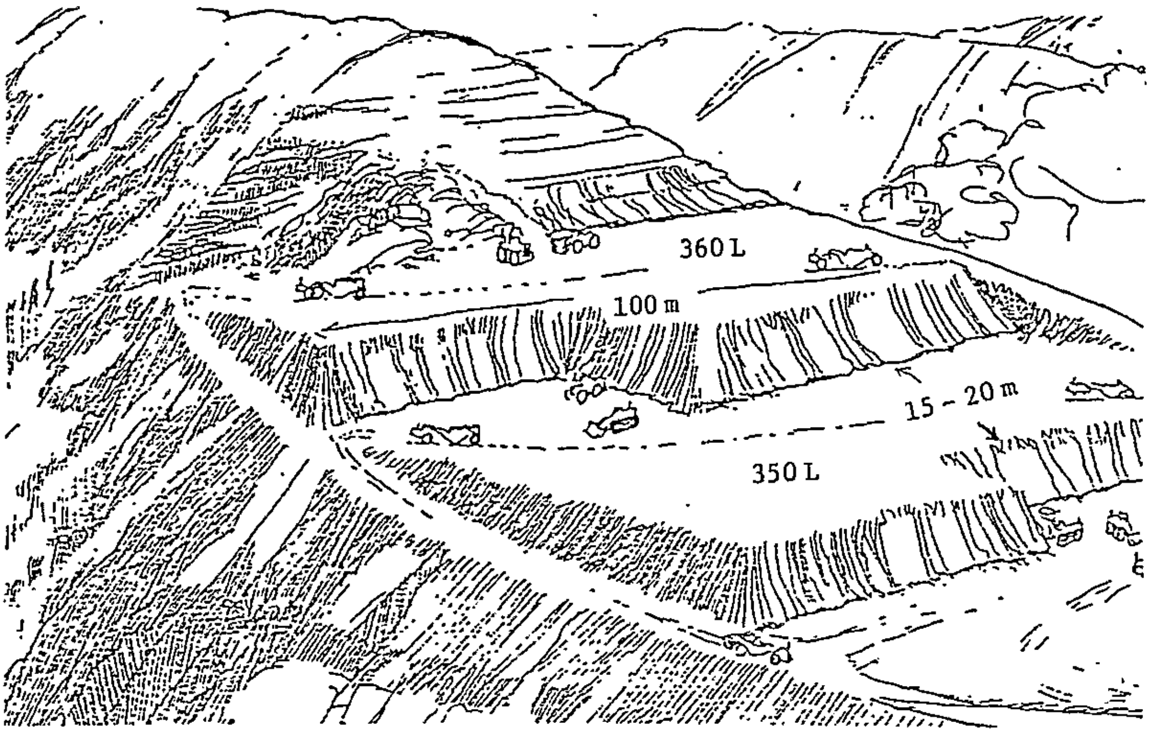
Furthermore, since the development area can easily be approached from the existing quarry on the southern side of the development area, the preparatory construction for the development can be implemented simultaneously with the road construction.

(ii) Development of quarry face

The limestone will be quarried downward from the top of the quarry. Before commencing the mining, it is necessary to clear the area and to construct the quarry face. This quarry face is desirable to be limited to an area as small as feasible to preserve greenery, to limit the amount of dirty water flow and rock fall.

An initial clearing area of approximately 30,000 m^2 is sufficient to exploit the limestone deposit existing above the 320 m level of the south deposit. At the initial stage, it is not necessary to conduct any special clearance since the overburden is thin. It is only necessary to prepare the quarry face of 15 m - 20 m width and 100 m length as shown in Fig. 4-3-1.

Fig. 4-3-1 Perspective of Quarry Face Preparation



The amount of limestone quarried for preparing the quarry face is estimated to be approximately 100,000 m^3. This limestone will be piled on the flat surface along the bottom of the quarry and will be used as raw material for cement production after the plant comes into operation.

(iii) Transportation road

The road is very important for this quarry since limestone will be transported by dump trucks, also workers and materials transportation will rely on this road. The specification of the road will basically be the same as that for the plant access road described in VI-3.

The description of the road is given hereunder separated into the transportation road from the plant to the quarry foot and the quarry road from the quarry foot to the quarry face.

(a) Transportation road: from plant to quarry face, approximately 5.5 km.

The road from the plant to the 240 m level quarry foot can be selected along a route with smooth low slope and no special obstructions.

About 2 km along this route will be existing road which can be used with only partial repair, and an example of a route is shown in the attached DWG. No. M-03. This road excluding the portion running through the mountain should have simple pavement to prevent dust owing to traffic.

(b) Quarry road: from quarry foot to quarry face, approximately 1.0 km

The route above the quarry foot at 200 m has steep areas which require a substantial amount of rock removal for road construction. The average slope of the road has been set at 1/8 for the level above 300 m and 1/10 for the 240 m - 300 m level in order to improve dump-truck transportation efficiency and economize construction cost.

Since this road would influence the construction cost, limestone transportation cost and safety, the route should be determined after conducting a detailed topographical survey.

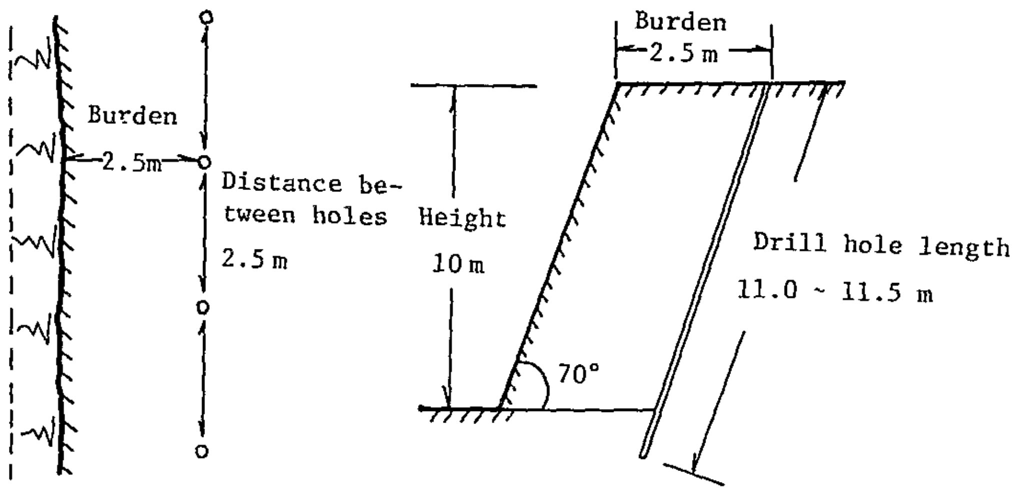
(iv) The method of quarry

The bench-cut method will be applied. This method is to construct bench floors at 10 m interval from the top and to slice down the 10 m height face. It has the advantages of safe operation, effective recovery of limestone, and efficient and rational operation. An outline of this method is shown in Fig. 4-3-1.

(a) Drilling and blasting

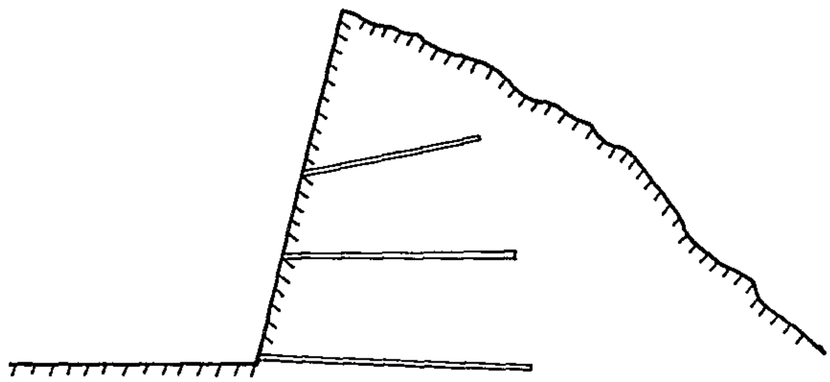
From the viewpoint of safe operation, the drilling and blasting will be performed on a one shift a day operation. The drilling will be performed with a crawler drill, and the standard drilling pattern for a 65 m - 75 mm bit gage is shown in Fig. 4-3-2.

Fig. 4-3-2 Standard Drilling Pattern



When a flat surface to operate the drilling equipment cannot be obtained around the quarry floor, horizontal or upward drill holes as shown in Fig. 4-3-3 may be partially used.

Fig. 4-3-3 Supplementary Drilling Pattern



(b) Breaking

Blasted rocks which cannot be transported directly to the plant are collected and broken into smaller pieces. Breaking can be performed by secondary blasting, but usually is performed by pneumatic or hydraulic breakers.

(c) Designing quarry face

The main factor for continuous stable production in bench-cut method is to constantly provide an effective quarry face. The necessary quarry face is usually calculated from the following formula.

Quarry face $L(m) = k \cdot \frac{Q}{D \cdot H \cdot R}$

where Q:	daily production	1,926 tons
D:	minimum burden	2.5 m
H:	height of bench	10 m
r:	specific gravity of limestone	2.68
k:	constant (safety factor)	

The length for this quarry from the above figures would be 86.2 m. Therefore a bench design which constantly provides a height of 10 m and an effective length of 100 m will be sufficient, and usually such length can be provided by one bench.

(v) Loading and transportation

The blasted limestone is broken into a suitable size, loaded by crawler tractor shovel onto dump trucks and transported to the plant.

The loading and transporting operation is performed on a two shift operation to be adaptable with the crushing operation and to decrease investment by decreasing the number of loading equipment and transporting equipment. Since this operation is a simple operation, no safety or equipment problems would arise by performing a two shift operation.

It is very important to arrange a suitable combination of tractor shovels and dump trucks. If large size equipment is used, the number of equipment can be decreased and efficiency can be increased, but on the other hand, losses from breakdown will increase and elasticity in quarrying operation will decrease, therefore there is a limit in increasing the size of equipment.

In this quarry, two crawler type tractor shovels (bucket capacity 2.2 m^3, 200 PS class) operating 10 hours daily are considered to be suitable.

The transporting distance by dump truck from the quarry face to the plant is approximately 6.5 km, and for this quarry, 10 - 15 ton trucks are considered to be suitable when considering adaptability with loader, road condition and receiving facility. One cycle of truck operation is estimated to be about 30 minutes.

(4) Limestone quarry facilities

(i) Quarry equipment

The quarry equipment is shown in the following table.

Table 4-3-2 List of Quarry Equipment

Equipment	Number	Specification
Crawler drill	3	65 - 75 m/m
Portable compressor	3	17 m^3/min class
Breaker	1	
Tractor shovel	2	2.2 m^3 200 PS
Dump truck	8	15 tons (incl. 1 spare)
Bulldozer	1	25 - 30 ton class
Hand hammer	2 - 3	supplement to drill. 25 - 30 kg

(ii) Other facilities

The following auxiliary facilities are also necessary for limestone quarry operation.

(a) Diesel engine

Office lighting, water pump and as small power source

(b) Explosive storage

(c) Office

(d) Room for workers (2 rooms, 1 at the top of quarry and 1 at the foot)

(e) Water supply (incl. well)

(f) Settling pond (temporary storage for dirty water flowing out from the quarry, dugout pit)

(g) Transportation vehicle (explosives, materials, personnels)

(h) Storehouse

(i) Others

(5) Environmental measures

Since no residential area exists and farmlands are few around the limestone quarry, environmental problems can be solved by suitable measures.

(i) Dust

Dust emission from quarry operation would occur when drilling holes and when blasting. The dust from drilling is very small while that from blasting is momentary, therefore their effect to the area would be negligibie.

Dust occurring from transportation can be suppressed by spraying water on the road, also it is advisable to pave part of the road to the plant to prevent dust.

(ii) Noise

Noise arising in quarrying comes from the operation of quarry equipment, but the location of the quarry is such that no problems should arise.

(iii) Dirty water from the quarry

In open pit mining, rain water flowing down the quarry becomes muddy water. It is difficult to suppress the flow of such muddy water, so a settling pond is provided at the foot of the quarry to prevent dirty water from flowing directly out of the quarry area. The pond can be only a dugout pit, but it is necessary to dredge out the sediment before rainy season and when sediment accumulates.

IV-3-3 Supply Plan for Oil Shale

This chapter contains a description of oil shale recovery operation from the stripping of overburden to the refilling the mined area.

(1) Operation of the oil shale mine

Oil shale mining operation includes stripping of overburden, assorting low grade ore and refilling of mined area. The oil shale ash generated at the power plant shall be used as raw material and mixing material for cement production and it does not need to be refilled.

The annual production, when based on a 240 day operation (20 days/month) taking wet season into consideration, are as shown in the following table.

Table 4-3-3 Production at Oil Shale Mine

	Oil shale ore (t)	Low grade ore (t)	Overburden (m^3)
Annual production	642,654	192,796	623,374
Monthly production	53,555	16,066	51,948
Daily production	2,678	803	2,597
Remarks:			
Apparent specific gravity	1.3		1.3
Moisture	4 %		4 %

Low grade oil shale and overburden quantities are estimates based on boring core.

(2) Topography and geology of the planned development area

The area 1 km - 2 km northeast of the proposed plant site is suitable for open pit mining.

(3) Supply plan

The mining of oil shale will be downward mining from the ground surface due to the nature and shape of deposit, and aside from the conditions described in "Chapter IV-3-2, (3)-(i) limestone quarry", the following important conditions must be considered.

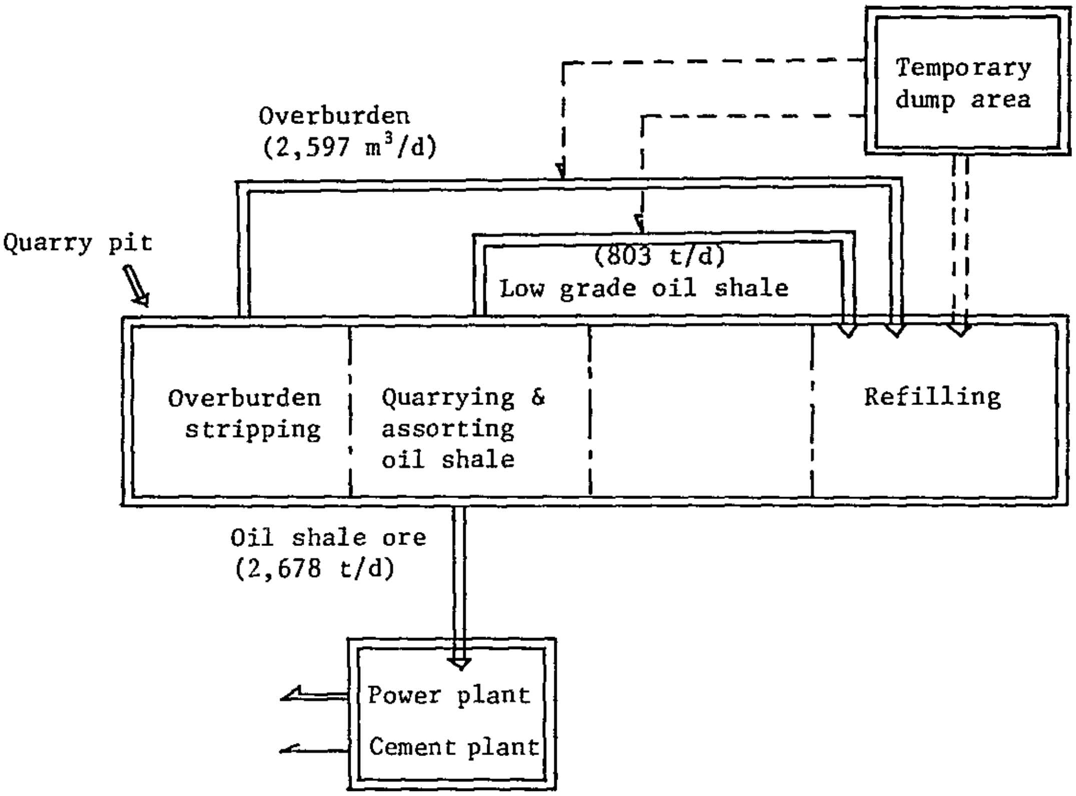
(a) Easy quality control at quarry face (assortment and disposal of low quality ore)

(b) Suitable combination with refilling operation

(c) Effect from stored rainwater is low

The operation flow for oil shale mining is outlined in Fig. 4-3-4.

Fig. 4-3-4 Operation Flow for Oil Shale Mining



The deposit to be mined is at present planned for a depth of 30 m considering the economics of open pit mining. The boring core section diagram indicates that a thick oil shale stratum exists below the 50 m level, but this deposit will be reconsidered if a substantial deposit is verified as a result of further detailed survey. All oil shale operation will be conducted on a two shift operation.

(i) Stripping of overburden

There seems to be a fair amount of variation in the overburden thickness, but stripping is planned on a 19.4 m thickness. Stripping must be conducted prior to ore mining, and it is better to expedite stripping during the dry season since stripping will be more difficult during wet season because the overburden contains moisture. This will also be effective to suppress the influence of dirty water during the wet season. The average expedited operation period will be about 2 - 3 months.

(a) Stripping and loading

The overburden such as shale and marl etc. can be stripped and loaded with a tractor shovel. Therefore a tractor shovel is sufficient for normal stripping purpose, but it is advisable to provide a bulldozer to remove tree roots, hard spots and pushing out material.

(b) Transporting and piling

The stripped overburden will be loaded on trucks and transported out of the pit to a suitable location where it will be temporarily piled. After ore mining, the stripped overburden will be refilled into the pit.

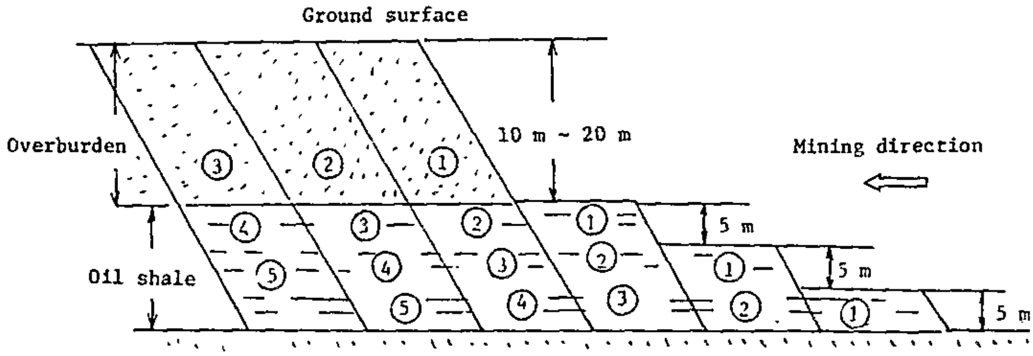
The dump truck should be selected after considering factors such as running condition, combination of the loader and properties of the materials to be transported. The location of the temporary storage should be selected near the mining pit and should be easy to unload and load, since the stored overburden will be refilled into the pit. The amount of stripped overburden prior to mining operation is estimated to be approximately 200,000 m^3.

(ii) Mining of oil shale

Oil shale will be mined by bench-cut method from the area where overburden stripping is completed.

A large variation in the quality of the deposit is expected, therefore homogenizing at the plant is required, but assortment of low grade ore must be performed at the mining site too. The bench-cut operation must keep quality control under consideration, therefore the height of bench must be kept low and very large equipment must not be used. A pattern of the mining is shown in Fig. 4-3-5.

Fig. 4-3-5 Cross Section of Oil Shale Mining

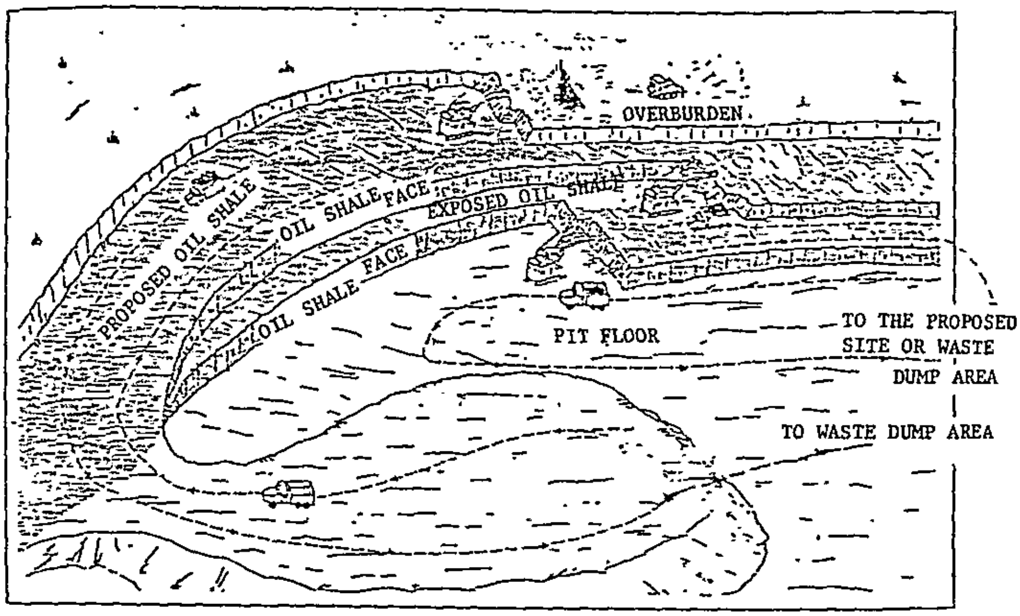


①-⑤ shows a standard mining sequence

(a) Design of mining pit

It is desirable to limit the mining pit as small as possible to decrease the influence of mining operation on surrounding area, to perform concentrated mining, to increase efficiency and to limit the effect of rainfall. Therefore the design of the pit shall be carefully executed by investigating and studying the condition and quality of ore, topography, thickness of overburden, etc. A perspective view of the mining pit is shown in Fig. 4-3-6.

Fig. 4-3-6 Oil Shale Mining Pit



(b) Mining method

It is expected that most of the oil shale stratum can be mined directly with a tractor shovel. The oil shale will be mined systematically by bench-cut method, and low grade ore will be thoroughly sorted at the mining site paying careful attention to the variation of ore quality. The bench height will be changed depending on the thickness of the oil shale stratum, but control will be easier if the height is kept below 5 m.

The oil shale stratum thickness within 30 m depth at this area is expected to be 10 m - 15 m, therefore ,the oil shale stratum will be cut by 2 - 3 benches.

The sorting of low grade will be performed by visual observation, but efforts should be made to lower the error in sorting by collecting data through the actual operation.

The amount of low grade oil shale given in Table 4-3-3 was calculated under the assumption that low grade oil shale ratio to ore will be 30%. Any low grade ore which cannot be used at the plant will be piled together with the overburden and refilled into the mined pit.

The necessary bench length for oil shale mining is about 300 m, so if the effective width of the pit is 150 m, two benches of 5 m height would be sufficient. However, the decrease of mining efficiency during the wet season must be taken into account because of water collection on the bottom bench. The hard portion must be drilled by a crawler drill and blasted.

(c) Water drainage measure

Since oil shale will be mined downward from the ground surface, the mining will be affected by rainfall and necessary drainage must be provided within the pit. The monthly rainfall during the 5 year period from 1978 to 1982 recorded at the Mae Sot meteorological station is given in the following table.

Table 4-3-4 Monthly Rainfall During 1978 - 1982

(mm/mo.)

Month	Average	Maximum	Minimum	Remarks
Jan.	0.3	1.4	0	
Feb.	6.5	32.6	0	
Mar.	1.9	6.4	0	
Apr.	41.7	54.1	19.7	
May	174.4	283.0	107.8	
Jun.	238.3	331.5	136.8	rainy season average 249.4
Jul.	258.9	426.5	138.6	
Aug.	373.4	507.7	151.3	
Sept.	202.2	251.0	159.1	
Oct.	72.1	108.0	26.7	
Nov.	17.5	79.8	0	
Dec.	0.3	0.6	0	
Total	1387.5	-	-	

The maximum rainfall during this period was 507.7 mm in August 1982. The rainfall tendency indicates that drainage measures are only necessary for the 5 month period from May to September. Furthermore, it is concluded from these data that the rainfall is such that large scale drainage facility would not be required. The capacity of the drainage pump will be decided after determining the intensity of rainfall from historic data and calculating the amount of water collecting on the pit floor. Since the size of the pit is not large for this mine, the water collection was calculated as follows, assuming a rainfall of 100 mm/day.

Pit floor:

{area (m^2)} x {rainfall (m/d)} x {flow factor}
340 m x 240 m x 0.1 x 0.8 = 6,500 m^3/d

If this amount is discharged in a day, the hourly capacity would be as follows.

6,500 m^3/d   24 h/d x 1.2   320 m^3/h

Therefore a pump capacity of 40 m head to pump 320 m^3/h of water would be sufficient.

From the rainfall tendency, it is considered that a permanent facility is not necessary, and if rainfall collection pit is dug on the bottom bench floor with necessary drainage route in May each year and is provided with drainage pump, it would be sufficient.

It is also desirable to set up a bank and a drainage ditch around the pit to prevent rainfall from flowing into the pit through the access road and from around the pit.

(iii) Loading and transporting

The loading will be performed by a crawler tractor shovel which is also used for mining. Since the shovel will be used for stripping of overburden, and sorting of low grade ore, the shovel must be distributed with flexibility and efficiency considering the variation of work volume.

It is considered that the standard distribution of the shovel would be 6 for overburden stripping, 1 for low grade ore sorting and loading, and 3 for ore loading.

The transportation will be performed by dump trucks of which distribution would also change with the variation of respective work volume. It is considered that the standard distribution would be 3 for overburden stripping, 1 for sorting and 3 for ore transporting.

The road between the plant and the mine greatly influences the transportation efficiency, therefore it is desirable to provide simple pavement for permanent roads. Since the topography is flat, the road construction along any route would be quite easy.

(4) Refilling

Normally, mined oil shale pits are refilled for the restoration of the land and the inexpensive disposal of waste materials. The average amount of materials generated for refill of this mine is shown in Table 4-3-5.

Table 4-3-5 Types and Estimated Amount of Refill Materials

Type	Amount		Percent (%)	Remarks
	t/mo.	t/d		
Over-burden	103,896	5,195	86.6	Bulk density 1.3 t/m^3
Low grade ore	16,066	803	13.4	Bulk density 1.3 t/m^3
Total	119,962	5,998	100.0	-

The oil shale ash (combustion residue) will be used for cement raw material and mixing material, and is not planned to be refilled. With the exception of the beginning of development, the above total amount can be refilled.

Refilling will be performed by a bulldozer which will push in the material and compact them. However, since the discharged overburden frequently contains water and becomes muddy, it is advisable to provide a bulldozer for wet land use. Also the discharged materials should be piled at a low angle under 15^{o} during the wet season in view of the materials properties.

The refilling will not commence seriously until after 5 months, therefore the overburden stripped during this period must be temporarily piled outside the pit. The amount of temporary stored material is expected to amount to approximately 360,000 m^3 (loose piled) if mining is commenced from around LK-17. An area of approximately 720,000 m^2 is estimated to be necessary if piled to a height of 5 m.

(5) Distribution of mining equipment at oil shale mine

An example of mining equipment at the oil shale mine is shown in table 4-3-6.

Table 4-3-6 Mining Equipment at Oil Shale Mine

Equipment	Number	Specification
Tractor shovel	10	3 m^2 250 PS class
Dump truck	17	15 t load
Dulldozer	2	30t ~ 40 t class
Dulldozer	2	25t ~ 30 t class, 1 unit for wet land use
Crawler drill	1	Spare for hard rock
Portable compressor	1	"

(6) Environmental measures

Farmlands are scattered around the oil shale mine, therefore when purchasing land for mining, storage, road, etc., it is necessary to purchase sufficient extra land. If suitable measures are taken, it is believed that environmental problems will not arise in view of the topography of deposit, amount mined and properties of the ore.

(i) Dust

Dust generated during mining operation would not cause any problem, but dust from dump truck traffic is expected during the dry season. Therefore it is necessary to constantly spray the road and also pave the main roads to prevent environmental problems from arising.

(ii) Noise

Noise generated from operation of mining equipment would not be a problem in view of the surrounding condition.

(iii) Dirty water

It is necessary to prevent muddy water flowing out from the pit and temporary storage to flow into the surrounding farmlands and river during the rainy season.

Since it is impossible to eliminate this water flow, the following measures must be taken.

(a) Limit the barren land due to mining as small as possible and refill the piled overburden into the pit as quickly as possible to reduce the amount of muddy water.

(b) Provide drainage ditch and settling pond to prevent muddy water from flowing directly out of the mine.

(iv) Refill

The mined pit shall be restored to the original land by refilling simultaneously with the mining. The refilled land will be suitable for rice fields, so the influence of the mining to surrounding area can be limited to a minimum.

From the viewpoint of usage, it is advisable to refill the pit with low grade ore at the bottom and overburden at the top.

IV-3-4 Supply Plan for Ferrous Material

The iron deposit located in the Non Poh area, Nakorn Sawan province is considered as a source for ferrous material. Assuming that the iron ore at this deposit has an Fe_2O_3 content of 40 %, the necessary amount of ferrous material for the Project would be only about 9,000 t/yr, therefore it is advantageous to purchase the ore. The distance from Non Poh to the proposed plant site at Mae Sot is about 290 km, furtheremore the road is so good that truck transportation would be of no problem.

IV-3-5 Supply Plan for Gypsum

Gypsum can be purchased from the Thai Gypsum Co., Ltd. in Doi Kui area, Phichit province. The gypsum consumption for the Project is about 28,000 t/yr. The distance from the Doi Kui to the proposed plant site at Mae Sot is about 270 km and since the road is good, truck transportation would be of no problem.

IV-3-6 Supply Plan for Other Materials

In the original plan, clayey and siliceous materials are not required. However, as described in IV-1, deposits for these raw materials were surveyed and the reserves of deposit, mining condition and transportation condition were investigated.

From this investigation, it was concluded that if clayey or siliceous material become necessary due to changes in raw mix design, the materials can be obtained in Mae Sot area by repairing existing roads and constructing a few access roads. Furthermore, silica sand to be used as siliceous material is presently quarried for construction material, and it is preferable to purchase them from dealers.

SECTION V ASSESSMENT OF FUEL

In the Project, domestic coal (lignite) and oil shale are planned to be used as principal fuel sources for the production of cement and electricity, and use of imported coal as a supplementary fuel source is also investigated.
Therefore, use of other possible fuel source such as heavy fuel oil and natural gas is not examined in this study. No detailed evaluation on motor fuel is made in this report, as gasoline and diesel are to be used for mining equipment and other vehicles.

V-1 Domestic Coal

In the Kingdom of Thailand, total of fourty-nine coal (lignite) deposits occur (confirmed) in North, North East, Central and South part of the country, of which five mines (two in Lampang province, two in Lamphur province and one in Tak province) are currently being mined. Total coal output from these mines in the recent 5 years is summarized in Table 5-1-1.

Table 5-1-1 Coal (Lignite) Output in Recent 5 Years

(t/yr)

Province	1977	1978	1979	1980	1981
Lampang	140,570	280,942	952,357	947,308	1,242,052
Lamphur	48,000	83,000	100,110	94,190	103,400
Tak	-	-	-	68	2,592
Krabi	250,000	275,000	304,000	385,000	338,000

Table 5-1-2 Outline of Coal Mine

Location	Reserve (m.t)		ASTM Classification	Owner	Uses
	Probable	Proved			
Lampang province Mae Moh county Mae Moh	1,000,000,000	650,000,000	Lignite B - Subbituminous C	EGAT	Power
Lampang province Ngao county Mae Tip	10,000,000	1,000,000	Subbituminous A - High Volatile C Bituminous	Phrae Lignite Co., Ltd.	Tabacco industry Cement industry
Lamphur province Li county Li	10,000,000	6,000,000	Subbituminous A - High Volatile C Bituminous	National Energy Administration (NEA)	Tabacco industry
Lamphur province Li county Li	5,000,000	2,000,000	High Volatile C Bituminous	NEA World Fuel Co., Ltd.	Tabacco industry
Tak province Mae Ramat county Mae Tun	(2,000,000)	1,230,000	High Volatile C - High Volatile A Bituminous	Thai Lignite Co., Ltd.	Tabacco industry
Krabi province Khlong Thom county Khlong Khanan	20,000,000	6,000,000	Lignite B - Lignite A	EGAT	Power

Table 5-1-2 shows the outline of coal mines in Thailand. As classified in Table 5-1-2, various quality of coals, from lignite to bituminous coal are produced in the country. Among five coal mines, two mines, Mae Moe (Lampang province) and Mae Ramat (Tak province), have distinct advantage in transportation distance over other mines as a coal supply source for the Project, and Mae Ramat has been selected as a coal mine from which coal is supplied to the proposed cement plant considering the disadvantages of Mae Mo mine described below.

V-1-1 Disadvantage of Mae Mo Mine

(a) Mae Mo mine has been developed by World Bank's fund, and exclusive sale of coal to large scale enterprises is restricted by the conditions imposed by the World Bank.

(b) Mae Mo mine, despite of its large reserve, produces low grade lignite as shown in Table 5-1-3.

Table 5-1-3 Average Quality of Lignite, Mae Mo Mine

Ash	20 wt%
Calorific Value	2,600 kcal/kg
Sulfur	1-5 wt%
Water	30 wt%

Calorific value of 2,600 kcal/kg is too low for the direct use for clinker burning (kiln fuel).

(c) Longer distance from Mae Sot

Mae-Sot —— Mae Mo approx. 295 km

Mae-Sot —— Mae Ramat approx. 180 km (via Tak)*

* When direct load between Mae Sot and Mae Ramat is completed, this distance will be shortened to 30 km.

(d) High coal price (500 Baht/t) for low quality coal

V-1-2 Outline of Mae Ramat Mine

Mae Ramat mine is located in Ko Lo Mae, Mae Tun, Mae Ramat county, Tak province which is 30 km north from Mae Sot. Mae Ramat coal mine, having its probable reserve of 2,000,000 tons in three-beded coal layers, is currently being mined by open-pit-mining method, supplies its all annual output of 120,000 tons to a private cement company on a contract basis. All coal output mined at Mae Ramat is stored in coal storage yard which is located in Ban Tak. This storage yard is provided in order to secure continuous supply of coal in the rainy season when access to the mine becomes difficult due to road conditions. The capacity of storage is approximately 50,000 tons.

Mae Ramat coal is classified as a bituminous coal, and its average quality of coal is shown in Table 5-1-4. Anlaysis of Mae Ramat coal sample which was collected at the Ban Tak storage yard by the study team is also shown in Table 4-2-24.

Table 5-1-4 Average Quality of Bituninous Coal, Mae Ramat Mine

Fixed carbon	42.51	wt%
Volatile matter	31.85	wt%
Moisture	8.32	wt%
Ash	17.30	wt%
Sulfur	1.31	wt%
Calorific value	4,800-5,500	kcal/kg*

Note: * Contract basis

Mae Ramat mine is operated by Thai Lignite Co., Ltd. and the company's supply record in May 1982 to the cement company is shown in Table 5-1-5.

Table 5-1-5 Coal Supply Record (Thai Lignite Co., Ltd.)

Period	Supply Volume (t)	Calorific Value (kcal/kg)		
		Max.	Min.	Average
Beginning May 1982	9,036	5,390	4,871	5,089
Middle May 1982	5,309	5,724	5,042	5,342
End May 1982	7,090	5,293	4,477	4,814
Total /Average	22,035	5,469	4,797	5,082

Current price of Mae Ramat Coal is 600 Baht/t at the Ban Tak storage yard, and the freight to Mae Sot is estimated to be 100 Baht/t.

It has been confirmed that the annual coal requirement of approx. 35,000 t for the Project can be supplied from Mae Ramat mine when the Project becomes operational phase. Besides the existing Mae Ramat mine, it is reported that undeveloped coal deposits exist in the area for future possible development.

As discussed thus far, Mae Ramat bituminous coal having relatively high calorific value (4,800-5,500 kcal/kg) can be directly used as a fuel for the cement kiln. However, in order to secure the stable supply of coal to the Project, possibility of use of imported high quality coal as a supplementary fuel source has been also investigated in this study.

V-2 Oil Shale

In Thailand, several oil shale deposits, all of which remains undeveloped, have been found only in the northern part of country. In the Project, the largest oil shale deposit in the country, which occurs in Mae Sot area, is planned to be developed to supply oil shale as a fuel source both for the electricity generation and for the cement production. In the proposed integrated power and cement plant, oil shale is used as a combustion fuel both for the cement kiln preheater and for the power generation boiler (fluidized bed boiler). Furthermore, oil shale combustion residue from the power generation boiler is also effectively utilized both as a cement mixing material and as a raw material (clay-substitute) for the cement production. Evidently, ash content of the oil shale used as the combustion fuel for the cement kiln preheater is also utilized as a raw material (clay-substitute) for the cement production. As described above, a complete utilization of oil shale, not only as the fuel source but also as the raw material and mixing material for the cement producton, can be achieved in the Project. Further detailed discussion on the evaluation of oil shale is made in SECTION IV of this report.

V-3 Conclusion

In the Project, all fuel including cement kiln fuel, preheater fuel and power boiler fuel is domestically available and moreover in the very close vicinity of the proposed plant site, making the fuel evaluation result of the Project very favourable.

It should be noted that the information on Mae Ramat mine contained in this report is all based on hearing results and published information, and it is recommended that a field survey of the coal mines be made in the future.

SECTION VI UTILITIES AND INFRASTRUCTURE

VI-1 Electric Power

(1) Power requirement in the Project

Necessary electric power for the Project is approximately calculated as follows taking account of the installed capacity, load factor, utilization factor or demand factor.

(i) Installed capacity

(a)	Oil shale quarry	100 kW
(b)	Power plant (including, fuel receiving, storing, grinding facilities and auxiliary equipment in plant)	3,800 kW
(c)	Cement plant	
	Raw material Dept. (including raw material receiving, drying, grinding and storing facilities)	3,900 kW
	Kiln Dept. (including kiln fuel grinding facilities)	2,500 kW
	Cement Dept. (including additives receiving and grinding facilities)	4,500 kW
	Shopping Dept.	300 kW
	Indirect Dept. (including utilities, lighting, etc.)	400 kW
	Sub-total	11,600 kW
(d)	Grand total	15,500 kW

(ii) Necessary electric power

The necessary electric power requirement in the Project is calculated to be 12,500 kW maximum or 10,700 kW average based on the load factor and demand factor estimated from actual records of existing plants and taking account of the scale of the Project as follows.

	Unit	Quarry	Power plant	Cement plant
Unit power consumption	kWh/t-cement	0.2	30	76 *1
Average power	kW	20	3,000	7,700
Load factor	%	40	100	82
Max. power	kW	50	3,000	9,500
Demand factor	%	50	79	82

Note: 1) As oil shale combustion residue is planned to be utilized as mixing materials to cement in the Project, the unit power consumption per one ton of cement is assumed to be lower than that of ordinary cement plant with a unit power consumption of approx. 110 kWh.

2) Average power is calculated by multiplying the unit power consumption by the hourly cement production capacity in ton.

3) Load factor is calculated from the formula, (average power) ÷ (maximum power). As the material flow is somewhat simple in the Project because types of cement to be produced in the Project is a few, the load factor can be assumed to be higher by about 10 % than that in typical cement plants.

4) The maximum power is calculated by dividing the average power by the load factor.

5) Demand factor is calculated by dividing maximum power by the installed capacity.

(2) Electric power supply

As described in the above clause (1), the amount of necessary electric power supply is 12,500 kW maximum (10,700 kW average) which is planned to be generated from the private power generating plant installed in the Project. As for power supply to the oil shale quarry, small-sized diesel engine generators exclusively used for the purpose will be provided in the quarry, taking account of the economic comparison between the cost of installing a power distribution line from the cement plant and the cost of installing generators.

In addition, an emergency diesel power generating equipment will be provided in the power plant for temporary power supply required at start-up of the power plant.

The differential amount of 1,800 kW between the maximum and the average output of the power plant is planned to be utilized for power supply to general consumers in Mae Sot area.

(3) Electric supply system

The electric supply system to be applied to the Project is planned as follows:

(i) Extra high voltage (for power supply to Mae Sot area)
AC 22kV 50 Hz 3 Phases 3 wires 1 circuit

(ii) High voltage (for the power generator, distribution lines and motors with large capacity)
AC 3.3kV 50Hz 3 phases 3 wires

(iii) Low voltage (for general-use motors and heaters with large capacity)
AC 415V 50Hz 3 phases 4 wires

(iv) For control and lighting
AC 230V 50Hz single phase 3 wires

Note: 1) Same as the existing distribution voltage.

2) Direct current of 100 V is planned for instrumentation and special usage.

(4) Electric energy cost

The estimate of the electric energy cost, in the case that the total amount of necessary electric power for production of cement in the Project is received from the EGAT is calculated to be about 104.9 Bahts/t-cement based on the abovementioned condition.
The figure is about the same as the electric energy cost, for the case of power generation (106.7 Bahts/t-cement).

Item	Unit	Case of power receiving	Case of power generation
Unit power consumption	kWh/t-cement	*1 76.2	106.2
Maximum power	kW	9,500	12,500
Cement production capacity	t/yr	808,500	808,500
Total power consumption	10^3kWh/yr	61,608	*4 99,000
Demand charge	10^3Baht/yr	8,436	-
Energy charge	10^3Baht/yr	76,394	-
Total charge	10^3Baht/yr	84,830	86,245 *5
Unit energy cost	Baht/t/cement	104.9	106.7
Unit price of energy	Baht/kWh	1.38	0.87

Note: 1) The unit power consumption in the case of power receiving does not include the energy consumption to be used for auxiliary equipment in the power plant.

2) The PEA-Special rate 74 Baht/kw-month in the tariffs on electricity is applied for the demand charge (See table 2-2-9).

3) The energy charge is calculated based on the unit price of energy charge of 1.24 Baht/kWh (See table 2-2-9).

4) This figure indicates the total generating power in a year (12.5MW x 24 hr/d x 330 d/y).

5) This figure indicates the depreciation of construction cost plus operation cost minus power sales income.

VI-2 Water

(1) Water supply plan for the Project

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

Feed water for boiler	:	37 t/hr
Cooling water for power plant	:	3,000 t/hr
Industry water for cement plant	:	200 t/hr
Drinking water for both plants	:	150 t/d

On the other hand, since it is assumed that total amount of necessary water cannot be supplied from the Moei river close to the proposed plant site, a water circulating system consisting of a storing pond and cooling equipment with a capacity of 2,000 t is planned in the Project.

As water losses caused by evaporation, waste-blow of the boiler and others in the plant are assumed to be equal to about 3 % of the total amount of water, it is necessary to replenish water at a rate of about 200 t/hr.

Therefore, this total amount of water to be replenished is planned to be intaken from the Moei river. (For the amount of flow of the Moei river, refer to VI-1-3(2))
For the drinking purpose in the plant, fresh drinking water will be supplied to the plant site by the Mae Sot Water Supply Office (with supply capacity of 250 t/hr, while actual demand is 125 t/hr at present).

(2) Measurement of the Moei river flow

Since no information on the Moei river flow rate was available, the following measurement was carried out in the site survey by the study team.

(i) Date of measurement: December 14, 1982

(ii) Location of measurement: Moei river bank in Mae Sot

(iii) General description on the river flow

It was during the dry season of the area when the measurement was carried out, therefore, the water level of the Moei river was less than half the level of that observed during the rainy season. The followings are records of the water level of the Moei river measured by the Mae Sot Irrigation Office.

Table 6-2-1 Water Level of The Moei River

(m)

	Max.	Min.	Ave.
1982. 7	4.15	1.63	2.19
1982. 8	5.80	2.91	4.07
1982. 9	3.99	2.13	2.64
1982. 10	2.67	1.65	1.93
1982. 11	1.63	1.39	1.49
1982. 12*1	1.39	1.30	1.34

Note: *1 Records up to Dec. 15, 1982

(iv) Method of measurement

After selecting a zone where the width and the depth of the river are nearly uniform over a length of more than 10 m, the time required for a wooden float to flow a distance of 10 m in the same zone was measured. Three measurements were made repeatedly.

(v) Obtained data

The cross sectional area and the flow velocity at the location where the measurement was carried out are shown in the following table.

Table 6-2-2 Flow Measurement Results

Width (m)	Depth (m)	Cross sectional area (m^2)	Velocity (m/s)	Flow rate (m^3/hr)
60	1.0	60	0.45	97,200

However, some correction on the flow quantity should be made because (1) the measured velocity is made at one point of flowing surface and not an average one, and (2) the flow velocities are not uniform over the entire width, especially slow along the edges of the streams.

Taking a correction coefficient of 0.7 to the measurement above, the flow rate is computed to be approximately 68,000 t/hr, so it is sufficient even in the dry season to intake the water quantity required for the Project from the Moei river.

(3) Water supply cost

(i) As mentioned above, since necessary water quantity for the Project can be taken from the Moei river close to the proposed site, no water supply cost except for initial construction cost which is planned to be made within the budget of the Project is necessary. Furthermore, any cost concerning water rights can be neglected.

(ii) Drinking water

Drinking water is planned to be supplied by the Mae Sot Water Supply Office as aforesaid, and the unit price of 5 Baht/m^3 shall be applied based on the estimated consumption of approximate 4,000 m^3/mo.

(Minimum fare is assumed to be 10,695 Baht/mo.).
On the other hand, the construction cost of piping for drinking water to the proposed plant site is not included in the Project construction cost, because Mae Sot Water Supply Office will bear the piping cost.

Since drinking water necessary for the quarry is designed to be obtained from the well in the quarry, there is no need to calculate any additional water cost to the Project.

VI-3 Road Condition

The share of transport volume by roads in the total transport volume in Thailand can be summarized as below, based on the data from the World Bank and the Ministry of Transportation and Communication.

(1) Passenger transport

Air: Railway: Roads = 0 : 14 : 86

Yearly passenger transport volume by roads is estimated to be 37 billion passenger-kilometers.

(2) Cargo transport

Railway: Roads: Coastwise = 18 : 74 : 8

Yearly cargo transport by roads is estimated to be 4.52 million net ton in weight, with the total net-ton-kilometers of 11.8 billion.

As indicated in the above figures, road transport predominates in the total transport volume of the country. The road conditions in the northern region of the country, where the Project is planned, is favourable to the road-transportation of products and construction materials.

VI-3-1 Road Network

(1) Present road network

The total length of road network in the country, excluding roads under planning and/or construction, reaches 28,079km in 1980, resulting from the past successive construction efforts stimulated by foreign aids like the Colonbo Plan.

The present status of road network and road construction in the country is shown in Table 6-3-1.

Table 6-3-1 Present Status of Road Network and Road Construction

	No.of Provinces	Area (1000km 2)	Population (Million)	Opened to traffic (km)			Under Planning/ Construction (km)			Total (km)
				Paved	Unpaved	Sub-total	Paved	Unpaved	Sub-total	
North	17	170	9	5,608	1,025	6,633	442	5,187	5,629	12,262
North-east	16	170	16	6,221	2,389	8,610	163	3,565	3,728	12,338
Central	25	104	15	5,628	1,486	7,114	340	2,485	2,325	9,939
South	14	70	6	4,875	847	5,722	35	2,842	2,877	8,599
Total	72	514	46	22,332	5,747	28,079	980	14,079	15,059	43,138

(2) Principal highways

National highways starting from Bangkok, connect Bangkok with all region of the country, namely, North, North-east, Central and South part of country, as shown in Table 6-3-2.

Table 6-3-2 Principal National Highways

Region	Highway No.	Route	Distance (km)
North	Route No.1	Bangkok-Sara Buri-Chiang Rai	823
North-east	Route No.2	Sara Buri-Korat-Nong Khai	508
Central	Route No.3	Bangkok-Chon Buri-Trat	387
South	Route No.4	Bangkok-Hat Yai-Malaysia	1,304

Source: Highway Dept.

Part of national highways (primary and secondary) of Thailand is integrated in the Asia Highway network, forming six of its sub-routes within the country as illustrated in Fig. 6-3-1 (Asia Highway Map).

(3) Transport route for construction materials

Based on the site survey results by the study team, the following route has been selected for the transport of construction materials.

Route	Highway	Distance (km)	Cumulative (km)
Bangkok Port → Bangkok		10	10
Bangkok → Nakhon Sawan	Highway no. 32	241	251
Nakhon Sawan → Tak	Highway no. 1	182	433
Tak → Mae Sot	Highway no. 105	80	513
Mae Sot → Mae Pa Tai	Provincial Highway no. 1085	4	517
Mae Pa Tai → The First Bridge	Local Road	4	521
The First Bridge → Proposed Plant Site	Construction Road (New)	1	522

Road conditions of the route selected above may be summarized as follows. The route from Bangkok to Mae Sot, forming A-1 route and A-2 route of the Asia Highway network as illustrated in Fig. 6-3-1, is flat along the Chao Phraya river and the Ping river between Bangkok and Tak. The route then crosses over a pass in the mountainous area lying between Tak and Mae Sot.

In the pass area, a frequent traffic of heavy-lumber-trailers to Bangkok is observed, indicating little transportation problem of heavy construction materials for the Project.

However, it is recommended that a detailed study on road conditions and transport schedule be made when the Project becomes implementation stage, as several steep acclivities and sharp curbes are observed in the route.

Observation data on traffic on the route is shown below.

- Observation Place	Highway no. 32, at Nakhon Sawan
- Observation Date	Dec. 13, 1983
- Observer	Study team
- Method	Number of automobiles passed by in one hour was recorded, while observer also moving by jeep towards opposite direction.
- Results	360 (Smaller vehicles except automobiles were not counted).

From the observation results, the traffic per hour in one direction is estimated to be about 180 by halving the observed number (360 x 1/2 = 180), since the observation was made from moving jeep in the opposite direction.

(4) Route for product transportation

The site survey result by the study team indicates the following route for the product transportation from the proposed cement plant to the north part of Thailand, which is considered as a potential market for the Project.

Route	Highway	Distance (km)	Cumulative (km)
Proposed Plant Site			
↓	Construction Road (New)	1	
↓	Local Road/Provincial Highway no. 1085	4/4	9
Mae Sot			
↓	Highway no. 105	80	89
Tak			
↓	Highway no. 1	181	270
Lamp Pang			
↓	Highway no. 11	100	370
Chaing Mai			

This route, overlaping A-2 route of the Asia Highway, shows excellent road conditions throught the way.

Road conditions to the direction toward Bangkok is also excellent as described in VI-3-1.

VI-3-2 Highway Standards

Outline of highway standards of the country is described below, based on the information from the Department of Highway, Ministry of Communication.

(1) Highway classification

i) Special highways: Highway no. 32, Highway no. 35, Highway no. 304 are in this category. Highway no. 35 and Highway no. 304 forms Bangkok loop highways. These highways are not completed.

ii) Primary highways: Highway no. 1 - Highway no. 41

iii) Secondary highways: Highway no. 101 - Highway no. 410

iv) Provincial highways: Designated by four-digits number

v) Rural roads

vi) Municipal roads

(2) Highway standards

The highway standards of Thailand is basically equivalent to the AASHO (the American Association of State Highway Officials) standards with some minor modifications.

The design standards for provincial highway are shown in Table 6-3-3, Fig. 6-3-3 and Table 6-3-4.

(3) Design standards for highway bridges

The AASHO standards, mentioned in VI-3-2-(2), also applies to the design of highway bridges.

1) Design Standards

i) Live load on the highway bridges
H loading system: H10, H15, H20
HS loading system: HS15, HS20
Two systems of loading are privided. The Department of Highways adopts the maximum loading in HS system which are HS20 for the design of highway (national highway, provincial highway) bridges.

ii) Live load on sidewalk

Sidewalk floors, stringers and their immediate supports should be designed to carry a live load of $415kg/m^2$ - sidewalk area.

iii) Width of highway bridge

8m

IV-3-4 Construction and Administration of Highways

Four categories of highways, special highways, primary highways, secondary highways and provincial highways, are under the administration of the Department of highways, Ministry of Communication. Rural roads and municipal roads are governed either by municipal authorities or by the Ministry of Interior.

Construction of highways is under the control of the same authorities.

Fig. 6-3-1 Asian Highway Map

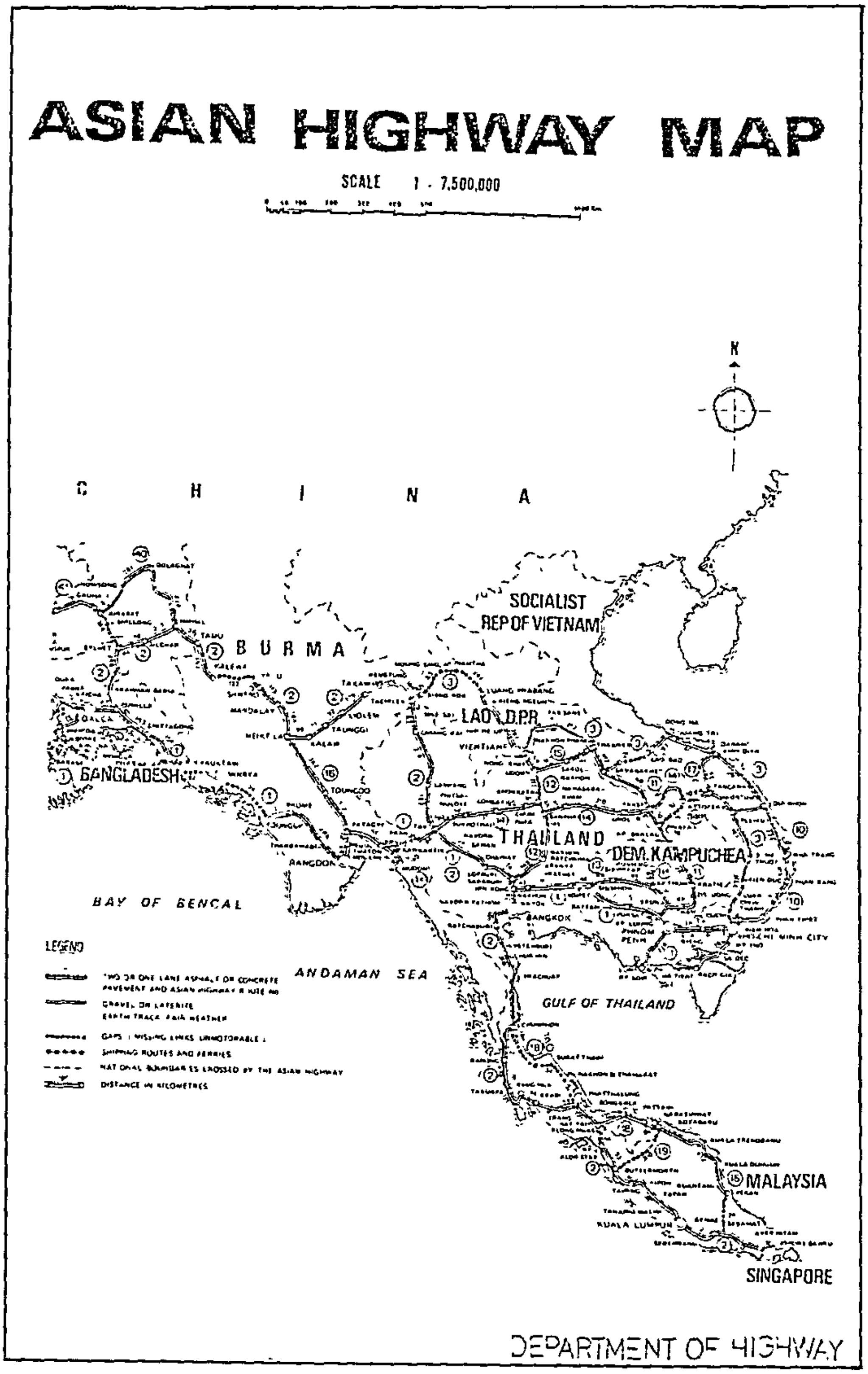


Fig. 6-3-2 Highway Map Central and Northern Region

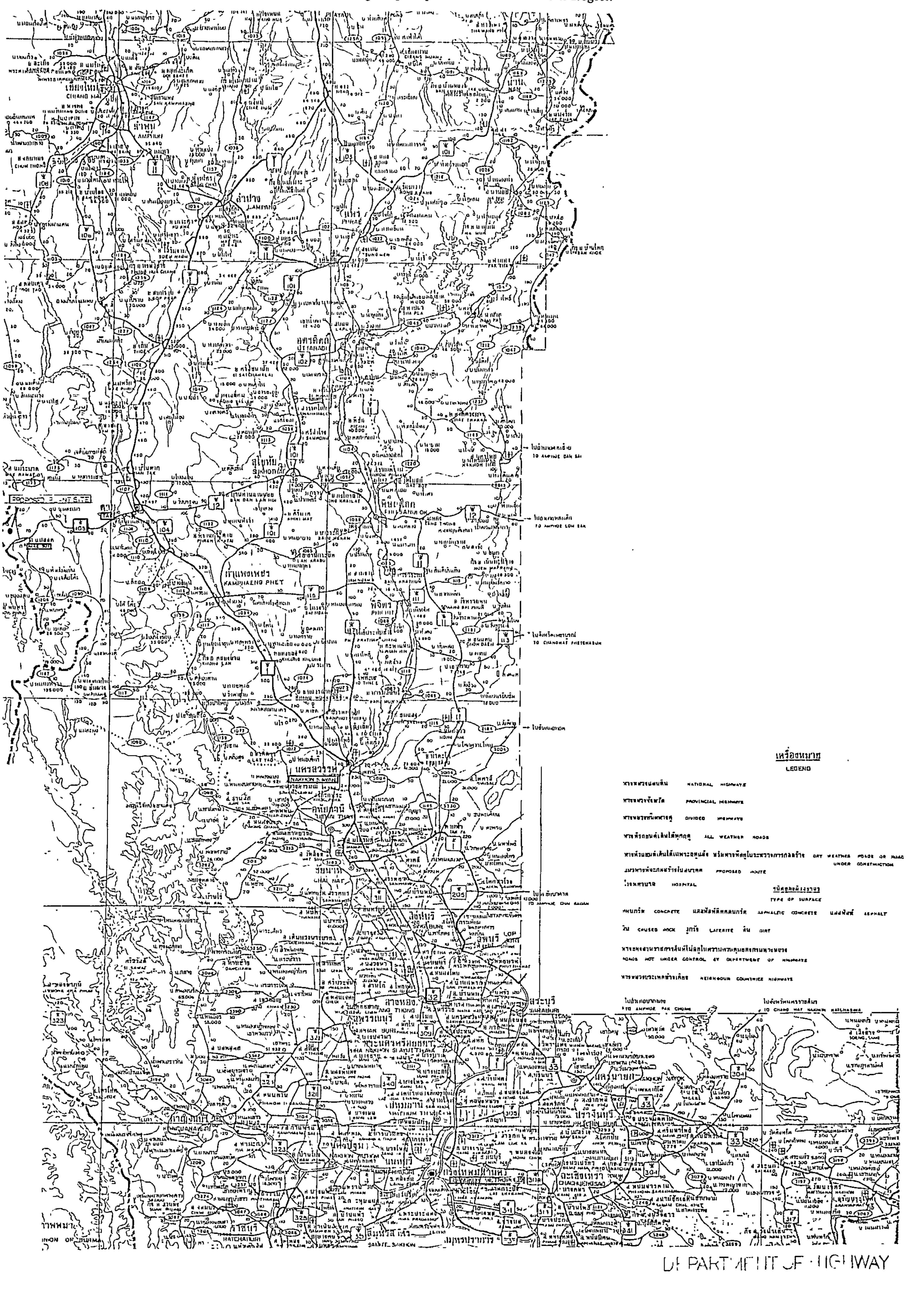


Table 6-3-3 Minimum Design Standards for Provincial Roads (Rural)

MINIMUM DESIGN STANDARDS FOR PROVINCIAL ROADS (Rural)

Controlling Factor

1. Access control : When designated under the Highway Law.
2. Highway Crossing : Grade Separation only after proven viable by economic feasibility calculations.
3. Railroad Crossing : Grade Separation only after proven viable by economic feasibility calculations.
4. Bridge width (1) : 8 m for F_1 & F_2, 7 m for F_3 to F_6
5. Vertical clearance = 4.50 m.
6. Design bridge loading = HS 20
7. Pavement design shall be based on the accumulated number of equivalent axle load predicted during the first 7-year after construction.
8. Follow AASHO recommendation for any design details not separately specified.

Class (5)	F_D	F_1	F_2	F_3	F_4	F_5	F_6
Average Daily Traffic (5)	Above 8,000	4,000-8,000	2,000-4,000	1,000-2,000	300-1,000	Below 300	
Design Speed k.p.h. (2)							
Flat and moderately rolling	70-90				60-80	60	
Rolling and hilly		55-70			45-60	45	
Mountainous		40-55			30-45		
Maximum Gradient % (3)							
Flat and moderately rolling	6				8	12	
Rolling and hilly	8				10	12	
Mountainous	10				10	12	
Suggested Surface Type	High		Intermediate		Low	Soil Aggregate	
Width of Carriageway m.	Divided2@7.00	7.00	6.50	6.00	5.50	9.00	6.00
Width of Shoulder m.	2.50	2.50	2.25	2.00	1.75	Travelled x	Travelled
Right of Way m. (4)	40-60					20-40	

Explanatory Notes

(1) Any F_D, F_1 or F_2 road that planned to be raised to National Highway system in the future, bridges less than 15 m. long shall be to the full roadbed width.

(2) Design speed may be relaxed in exceptional circumstances on account of right of way difficulties or mountainous terrain.

(3) Refer to the AASHO policy on Geometric Design of Rural Highways to relate desirable grade lengths, climbing lanes, etc.

(4) May be reduced in urban or semi-urban conditions at the discretion of the Department provided that a suitable cross section including service roads, where necessary, is obtainable.

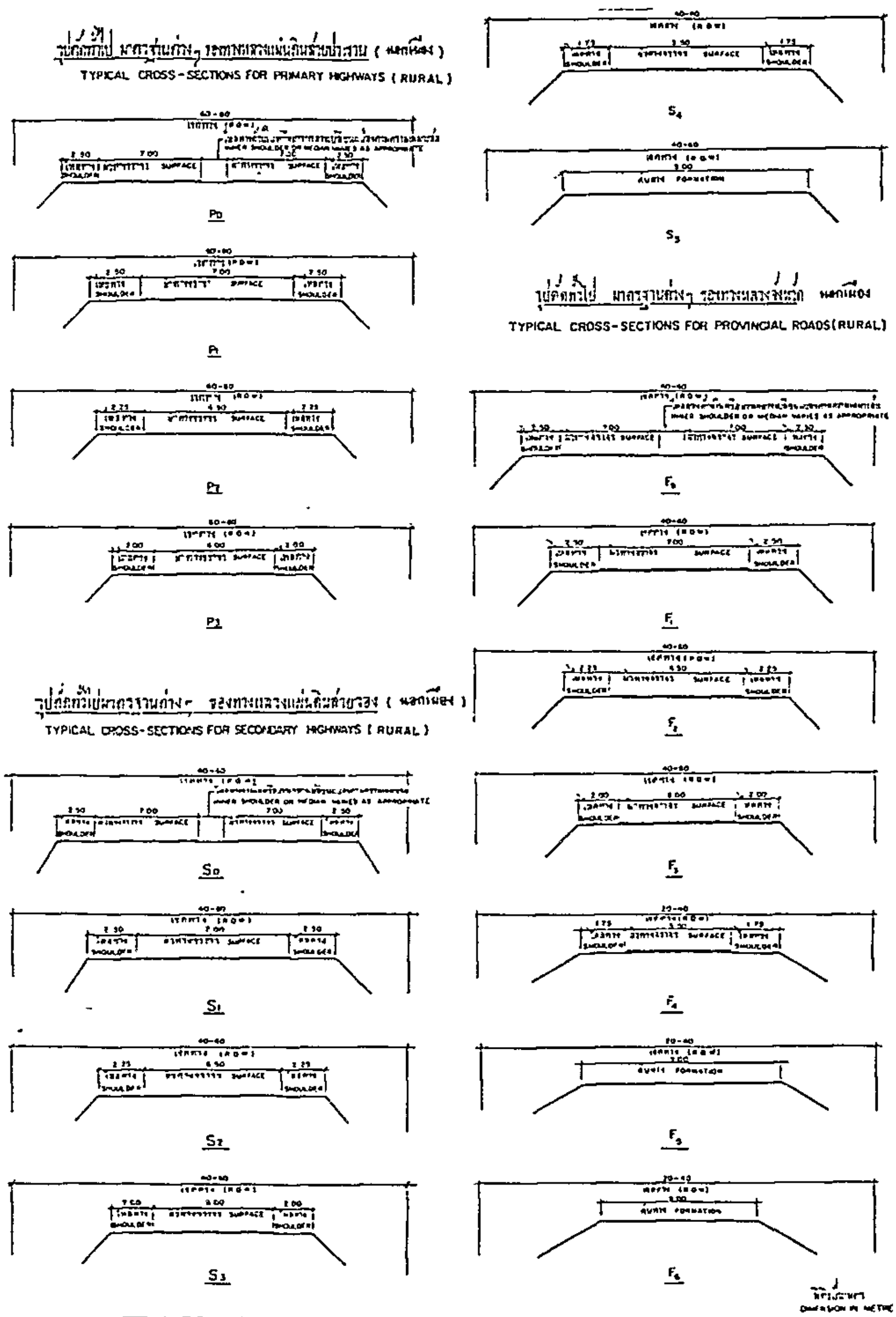
(5) Class F_D roads are required on the basis of a 7 year ADT projection or be justified by economic feasibility calculations. Class F_1 to F_3 roads are required on the basis of a 15-yeary ADT projection. Class F_4 roads have a projected ADT more than 300 in 7 years and more than 300 in 15 years. Class F_6 roads have a projected ADT less than 300 in 15 years.

Remark

In special cases, the Department may reduce the carriageway width to 3.5, 4, 4.5 or 5 m. on various roadbed width, i.e 4 m. on 8 m. roadbed width. Such the case the class of the road will be defined as class F_4 (4/8) If the geometric standard of the road section in the said case below than F_4 then the road class will be defined as F_4 (4/8)

DEPARTMENT OF HIGHWAY

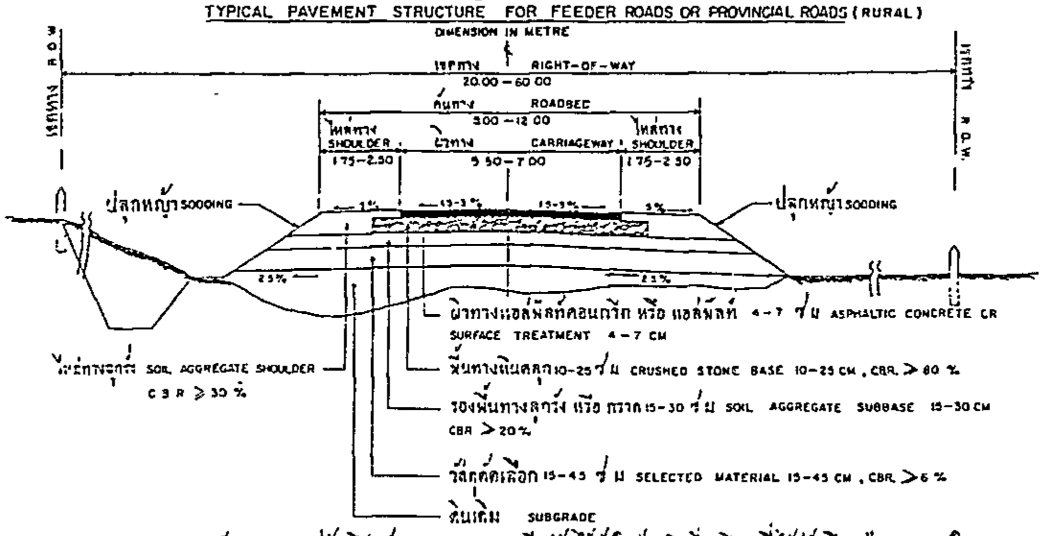
Fig. 6-3-3 Typical Cross Sections for Highways



DEPARTMENT OF HIGHWAY

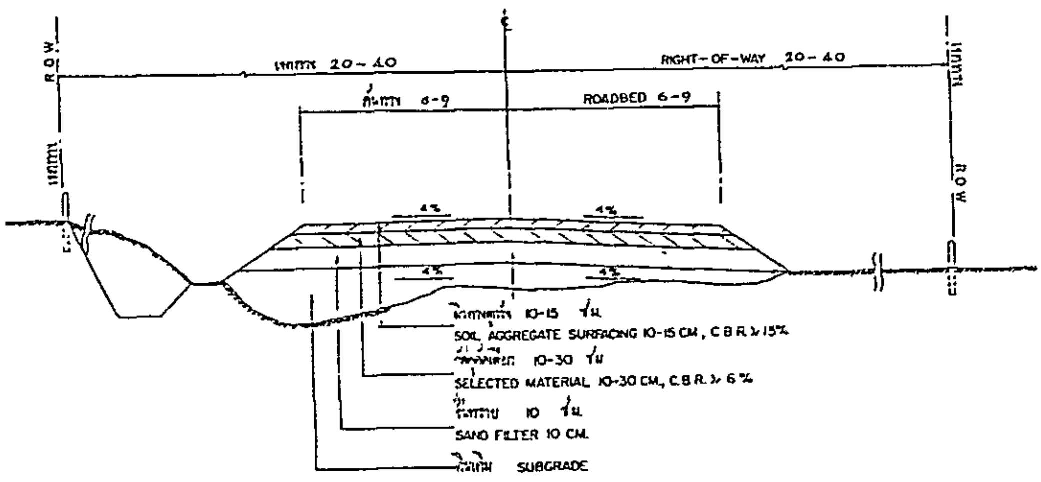
Fig. 6-3-4 Typical Pavement Structure for Feeder Roads or Provincial Roads (Rural)

รูปตัดทั่วไปของทางหลวงจังหวัด (นอกเมือง)
มิติเป็นเมตร
TYPICAL PAVEMENT STRUCTURE FOR FEEDER ROADS OR PROVINCIAL ROADS (RURAL)
DIMENSION IN METRE



หมายเหตุ คันทางอาจจะสร้างที่ตั้งอยู่กลางของเขตทาง หรือสร้างเบี่ยงไปด้านใดด้านหนึ่ง เพื่อเผื่อไว้สร้างอีก 2 ช่องทางจราจรในอนาคต
REMARKS THE ROADBED MAY BE CONSTRUCTED ALONG THE CENTER LINE OF THE RIGHT-OF-WAY OR ALONG THE EITHER SIDE, PROVIDING TWO MORE LANES CONSTRUCTION IN THE FUTURE

รูปตัดทั่วไปของทางหลวงจังหวัดผิว SOIL AGGREGATE
มิติเป็นเมตร
TYPICAL PAVEMENT STRUCTURE FOR FEEDER ROADS OR PROVINCIAL ROADS WITH SOIL AGGREGATE SURFACING
DIMENSION IN METRE



DEPARTMENT OF HIGHWAY

VI-4 Harbours

Outline of Bangkok port and Sattahip port, which are major commercial ports in the country, is summarized below based on the data from the Port Authority of Thailand.

VI-4-1 Bangkok Port

(1) Location

Bangkok port is located at 26km - 29km upstream from the mouth of the Chao Phraya river (the Menam river) as illustrated in Fig. 6-4-1.

(2) Port conditions

i) Width of approach channel
100m (straight portion) 250 m (curve portion)

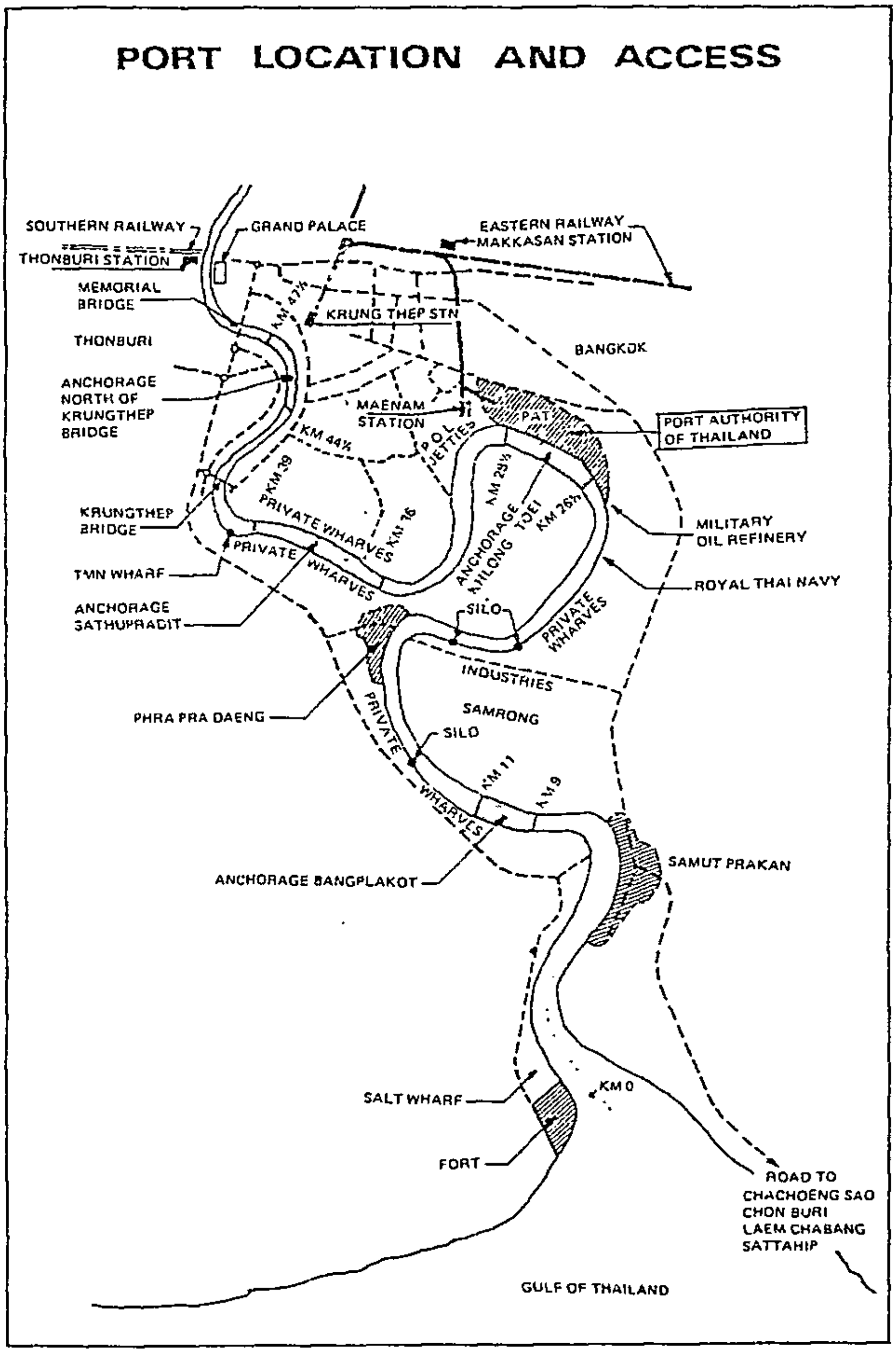
ii) Water depth
8.5m (Mean water level)

iii) Draft and length of vessels
Maximum draft and length of vessels for the port are 170m (565ft) and 10,000 DWT - 12,000 DWT respectively.

(3) Berth facility and cargo handling capacity

Facilities	No. of berths	Annual cargo handing capacity (million tons)
Old berth	10 berths	2.2
New east berth	8 berths	1.5
Dolphin	7 berths	1.1
Buoy	6 berths	0.5

Fig. 6-4-1 Port Location and Access of Bangkok Port



Source: The Port Authority of Thailand

VI-4-2 Sattahip Port

Sattahip port has been made available for commercial use since 1978, before then the port had been a naval port of the country.

(1) Location

The port is located at the Bay of Sattahip, 184km from Bangkok, along the east coast of the Gulf of Siam.

(2) Port conditions

i) Width of approach channel
100m

ii) Water depth
10m (Lower low water)

(3) Berth facility and cargo handling capacity

Facilities	Length of berth (m)	Annual cargo handling capacity (million tons)
West berth	540	1.0
North berth	350	

VI-4-3 Unloading of Construction Materials

Bangkok port is selected for unloading of construction materials required in the Project for the following reasons.

i) Superior port conditions and faciliies

ii) Unloading facilities

120t-floating crane is available at the Bangkok port, and unloading of construction materials for the project (EGAT project) similar to the Project was executed at this port.

iii) Better connection with inland transportation network, and shorter distance to the proposed plant site.

iv) Railway connection

VI-5 Communication Facilities

By the time implementation starts on the Project, communication facilities between the main cities and the proposed plant site and between the plant site and the quarry must be prepared.

At present, the Mae Sot area is connected with the capital Bangkok and main cities inside and outside of Thailand by a telephone system.

Therefore, there is no problem to carry out the Project, however, it is recommended to add telex services to the existing system in the future.

On the other hand, it is necessary to provide wireless communication equipment to connect between the quarry and the plant site by the account of the Project.

VI-6 Power Transmission Facilities

The substation in Tak is at present supplying electric power to the Mae Sot area through one circuit of overhead transmission line of 22 kV voltage.

As the power consumption in this area is estimated to reach an amount of about 10,000 MWh per year in the near future, some parts of the power demand in the area are planned to be supplied from the power plant of the Project and the power distribution equipment is needed to provide for this purpose.

Therefore, a power transformer with a capacity of 2,000 kvA, which is exclusively used for power supply to outside consumers, is designed to be provided in the proposed power plant. For the purpose of connection to the existing network in the Mae Sot area, a power distribution line with a length of approximate 10 km between the proposed power plant and the network shall be newly laid down. These cable installation cost should be borne by the PEA because the electric power supply to consumers in this area is generally limited to the PEA by the law.

SECTION VII CONCEPTIONAL DESIGN OF PLANT

VII-1 Outline of Process

VII-1-1 Selection of Process

In the Project, oil shale is planned to be utilized in multiple ways mentioned below. Cement and electric power are produced simultaneously utilizing the oil shale.

(1) To be utilized as a fuel for power generation

(2) Utilization of oil shale combustion residue as a mixing material for manufacturing oil shale cement

(3) Utilization of combustion residue as a raw material (clay-substitute) for manufacturing cement clinker

(4) To be utilized as a fuel for precalciner of cement kiln

(5) Utilization of combustion residue produced in (4) as a raw material (clay-substitute) for manufacturing cement clinker

(6) Utilization of power generated in (1) as an operating power for cement plant

It is, therefore, necessary to select an appropriate process meeting for the said conditions.

Process selection was made taking account of economic and technical conditions of the Project.

(1) Selection of boiler for power plant

As a boiler in which solid fuel with a low calorific value such as oil shale is completely burnt at low temperature generating ash of latent hydraulic property, a fluidized bed boiler is most suited and no satisfactory result seems to be obtained by boilers of other types. In a fluidized bed, a low grade solid fuel (oil shale) can be burnt homogeneously in a relatively narrow temperature range to produce a combustion residue having latent hydraulic property. Futhermore, combustion temperature can be controlled easily by in-bed tubes inserted in the bed.

(2) Selection of cement burning process

(i) Types of cement manufacturing process

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.

(a) Dry process
- Suspension type preheater kiln
- New suspension type preheater (precalciner type) kiln
- Long kiln
- Short kiln with waste heat boiler
- Shaft kiln
- Lepol Kiln

(b) Wet process
- Short kiln with waste heat boiler
- Long kiln
- Lepol kiln

(ii) Conditions in process selection

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

(a) Economic factors
   - Investment cost
   - Consumption of fuel, electric power and water
   - Personnel requirement
   - Area to be required for the plant

(b) Technical factors
   - Properties of raw material
   - Kind of fuel to be used
   - Quality of cement to be produced
   - Easiness of operation
   - Repair expenses
   - Capacity of kiln

(iii) Results of study

New suspension type preheater kiln process has been selected for the Project for the following reasons.

(a) In order to burn a solid fuel with a low calorific value such as oil shale effectively, use of precalciner is most suited.

(b) Fuel cost that occupies a great part in direct cost of cement manufacturing is considerably low.

(c) Alkali content and chlorine content of the raw materials to be used for the Project are considerably low. (refer to IV-2 Quality of Raw Material)

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

(d) Dry process with NSP kiln as well as SP kiln has such advantages as follows:

- Suspension preheater to be installed at the back of kiln has no movable parts.

  Therefore, the operation and maintenance of NSP is much easier than those of such machinery and equipment as boiler, Lepol grate, panpelletizer, etc., all of which may be incorporated in other processes.

- Dry process with NSP kiln has a big production capacity per kiln inside volume.

- Exhaust gas of high temperature from suspension preheater can be utilized for drying of limestone and clay.

(e) Dry process with NSP kiln is easy for operation and maintenance, next to dry process with long kiln.

(3) Selection of whole process

By conbining item (1) with item (2) mentioned above as an integrated process, the process shown in Fig. 7-1-1 is configurated.

In this integrated process, energy possessed by oil shale can completely be utilized and its burnt ash (combustion residue) is used for clay-substitute for cement manufacturing and for cement mixing material. That is, perfect utilization of oil shale can be achieved and thus the Project can manufacture cement at low cost and supply surplus electric power to neighboring area for regional development.

As raw mateirals except oil shale, limestone, iron ore (silica sand or marl), and gypsum are used.
As a fuel except oil shale, domestic coal is mainly used.

About 51% of the raw materials and about 75% (calorie basis) of the fuel are to be supplied by oil shale.

The similar process has been operated in commercial scale at Dotternhausen in Germany.

Since the combustion residue discharged from the fluidized bed boiler in power plant can be used as cement mixing material as it is, necessary amount of clinker can be reduced to about 70% of that required by conventional cement plant even in case only the cement equivalent to ordinary postland cement (Type I) is produced.

The construction cost can, therefore, be reduced and the total construction cost including the cost for power station with the fluidized bed boiler is almost the same as that of conventional cement plant for the same capacity.

Material balance of the process is shown in Fig. 7-1-1 and 7-1-2 respectively.

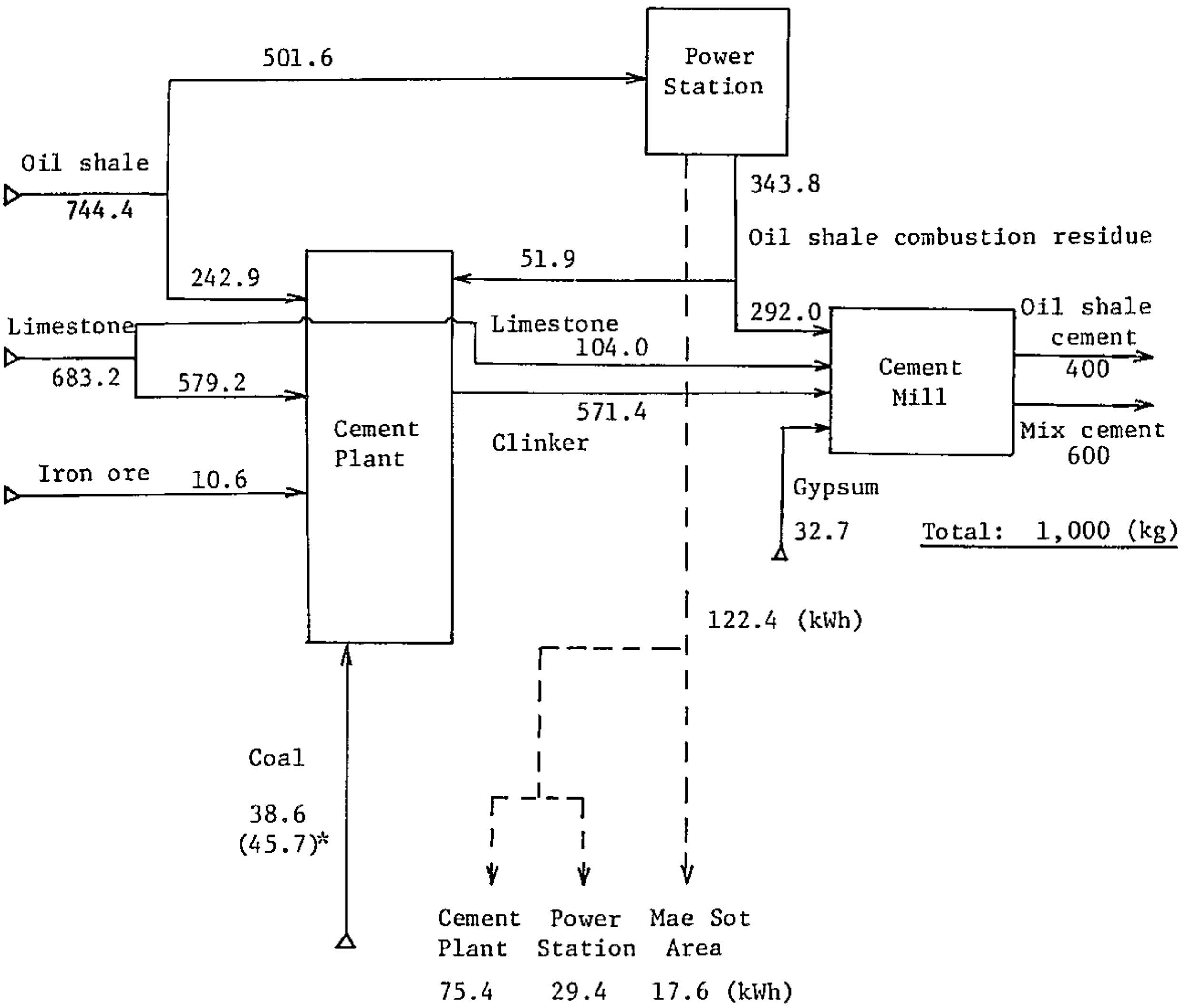
Fig. 7-1-1 shows 1st plan in which clayey materials necessary for clinker burning are supplied by oil shale and iron ore.

In this plan, the process is simplified and burnability of raw materials is improved. This is the reason why this plan has been adopted as 1st plan (design basis) in this report.

Fig. 7-1-2 shows 2nd plan in which clayey materials necessary for clinker burning are supplied by oil shale, silica sand, marl, and iron ore.

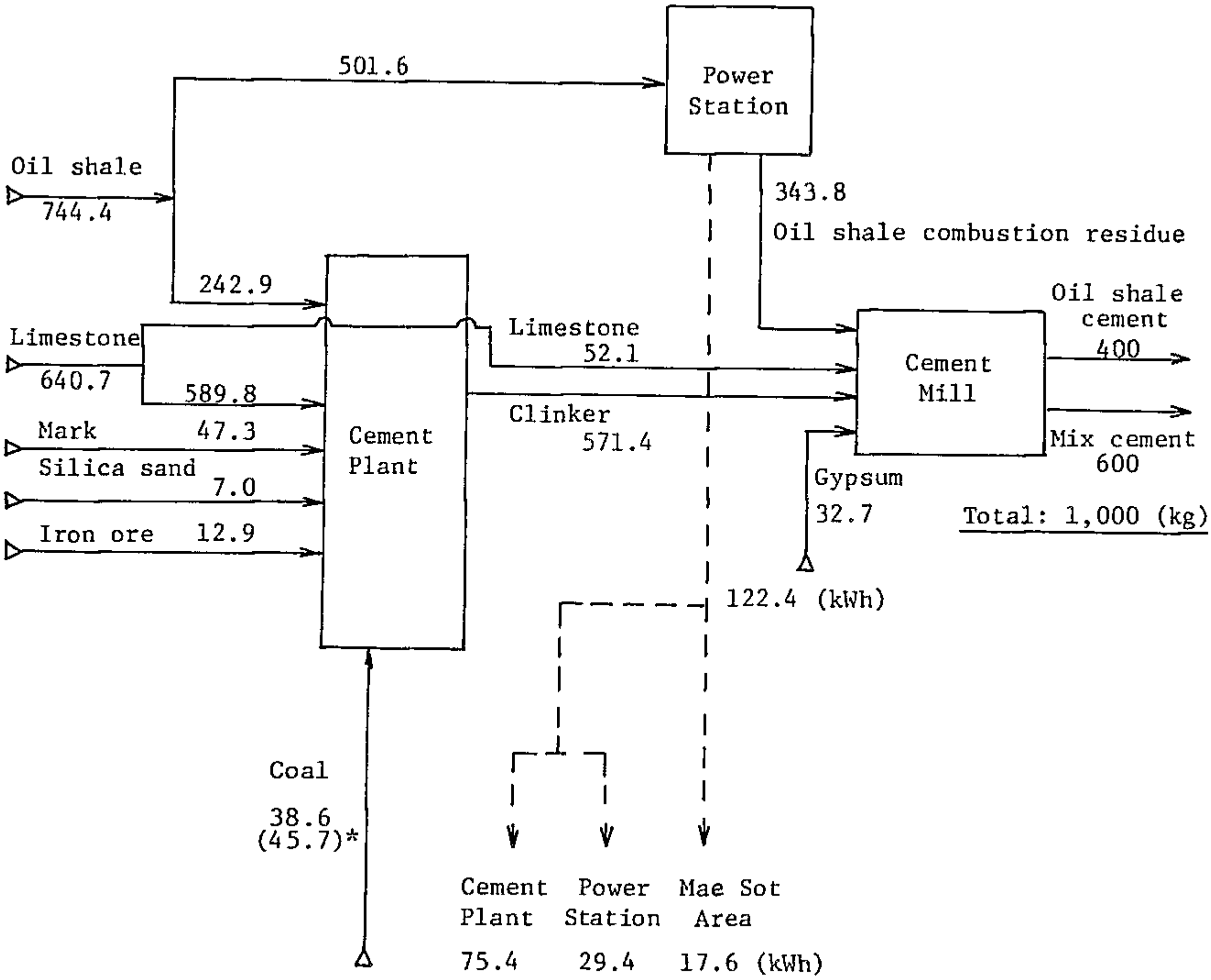
This plan is considered as a measure in case any change takes place in chemical composition of raw material and/or products in the future and is stated for reference.

Fig. 7-1-1 Material Balance (1st Plan)



Note: * The figure in the blacket shows the coal requirement in case calorific value of coal is 5,000 kcal/kg.

Fig. 7-1-2 Material Balance (2nd Plan)



Note: * Refer to the explanation in Fig. 7-1-1

VII-2 Production Capacity

Taking account of various factors such as relation between supply and demand of cement in the northern region of Thailand, reserves of oil shale and limestone in Mae Sot, infrastructure, production cost, plant site etc., the plant capacity of the Project is set as follows.

Clinker base	1,400 t/d
Cement base (including mix cement)	2,450 t/d

The capacity of power station is set at 12.5 MW.

The plant layout is to be made taking account of future expansion of the same capacity.

VII-2-1 Annual Production of Clinker and Cement

Table 7-2-1 Annual Production

Type of products	t/d	t/yr
Clinker	1,400	462,000
Oil shale cement	980	323,400
Mix cement	1,470	485,100
Total of cement	2,450	808,500

Note: Working day of kiln: 330 d/yr

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

Table 7-2-2 Annual Requirements of Raw Materials and Fuel

(wet basis)

	t/d	t/yr
Limestone	1,750.6	577,703
Oil shale	1,947.4	642,654
Iron ore	27.4	9,032
Gypsum	83.7	27,612
Coal	100.9	33,306

Note: Working day of kiln: 330 d/yr

VII-3 Selection of Plant Site

VII-3-1 Factors in Selection

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

(1) Availability of the calcareous and clayey materials within reasonable transportation distance from the site.

(2) Availability of minor raw materials such as silica sand, iron ore, gypsum

(3) Availability of utilities such as fuel, electricity, water

(4) Distance from market and distributing centers

(5) Transportation facilities to and from the site

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

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

(8) Surface condition (geology)

(9) Area and easiness of land preparation

(10) Environment

VII-3-2 Proposed Plant Site

Since in the Project the use of Mae Sot oil shale is necessary, the plant site is required to be in the vicinity of the oil shale deposit and limestone deposit that is another major raw material.

VII-3-3 Selection of Plant Site

After surveying the neighboring area of Mae Sot oil shale deposit and considering all the factors described in VII-3-1, it is recommended to select the site at the location shown in Fig. 7-3-1.

Reason:

(1) This site is situated close to oil shale deposit and limestone deposit. Since the consumption of oil shale is somewhat greater than that of limestone and refill of waste shale may be required, the site is selected to be closer to oil shale deposit.

(2) Infrastructure such as road is well developed around the site, and the length of access road to be constructed is short.

(3) Transportation of products and raw materials can be made without passing through the central district of Mae Sot town.

(4) Most of the site area consists of hilly land higher than surrounding rice fields, and land preparation work is easy. That is: the eastern side of site is a hill of about 210 m - 220 m above sea level. (The site is about 198 m above sea level.)

The northern and western side of the site is flat rice field. The southern side is low land and a small river of 3 m - 4 m wide is running to the Moei river. (refer to Fig. 7-3-1.)

(5) The Moei river has a record of flood in the past. However, the site will not be covered by flooded water, as it is located in a hilly land.

(6) In land preparation, the discharge of rain water from the site can easily be made to the nearby small river.

The water from hilly lands situated at both eastern and western sides of the site is dammed up by the stream intermittents (temporary river during rainy season) as shown in Fig. 7-3-1.

(7) Since most of the site area is in the hilly land except rice field that occupies a part of the site, the geological condition is acceptable.

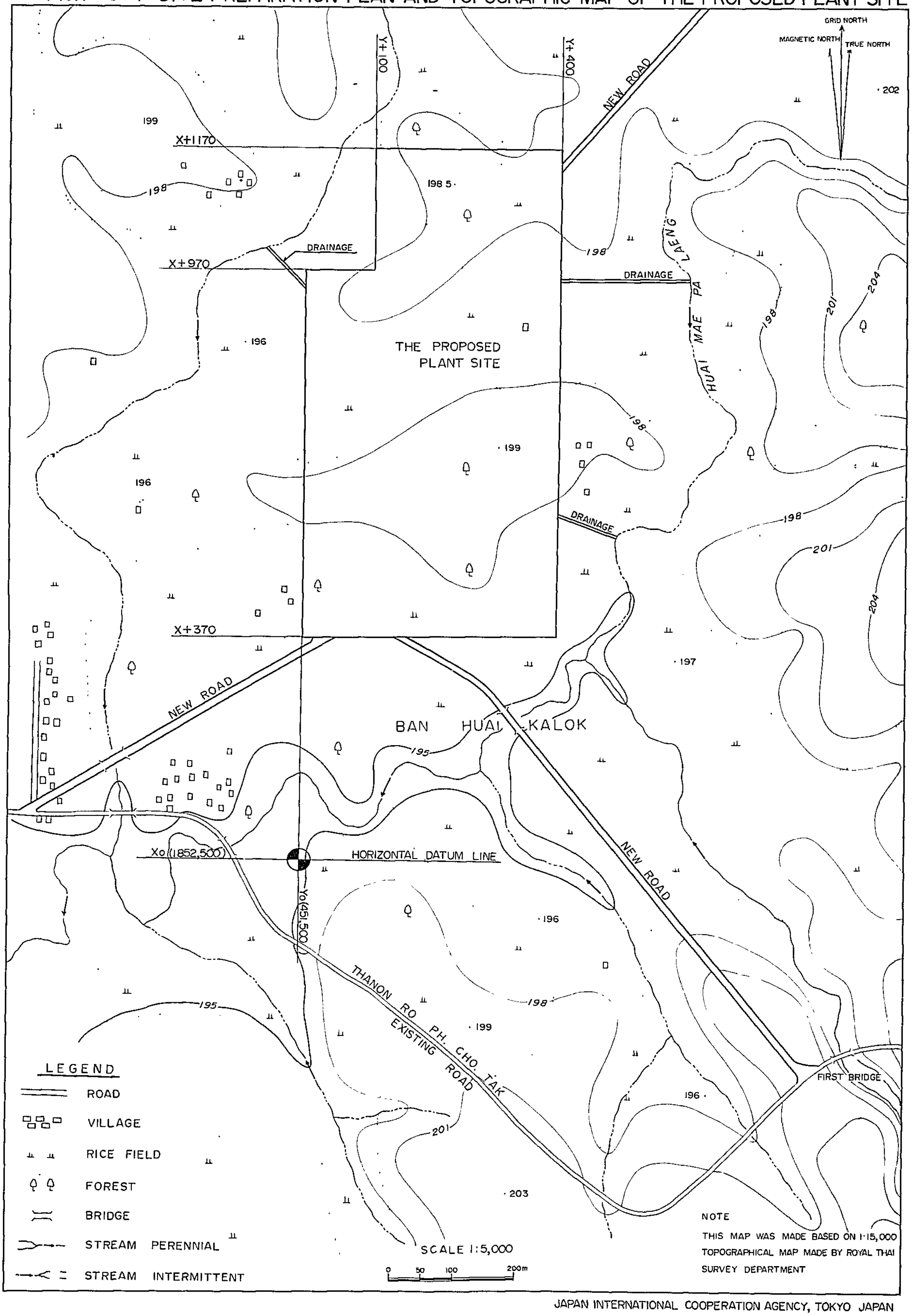
An oil shale layer situated at -4.0 - -4.5 m from the surface can be used as a supporting layer.

(As to detail further investigation is required)

(8) Sufficient area for plant site is obtained.

(9) It is located far from Mae Sot town which is favorable from environmental points of view.

FIG.7-3-1 SITE PREPARATION PLAN AND TOPOGRAPHIC MAP OF THE PROPOSED PLANT SITE



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VII-4 Standards, Laws and Regulations

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

VII-4-1 Standards

(1) Civil and building

(a) General

Thailand Industrial Standards (TIS)

(b) Specification of roads and road bridges

AASHO (American Association of State Highway Officials)

(2) Mechanical

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

(3) Electrical

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) Environmental quality standards

Thailand Environmental Quality Standards 1980

(5) Cement quality

Thailand Industrial Standards (TIS)

Ordinary portland cement TIS 15 (1974)

Mix cement TIS 80-2517 UDC·691·544

VII-4-2 Laws

(1) Civil and building

a. Architectural

- Building Control Act 1979
- Bye-Laws of the Construction of Buildings 1979

b. Civil

- Law on Highways

(2) Factory law

Factories Act 1979, 1969

(3) Environment law

National Environmental Quality Act

VII-5 Cement Quality

VII-5-1 The Quality of Cement to be Produced

It is assumed that the type of cement to be produced in the Project is oil shale cement and mix cement. Oil shale cement is produced by mixing ordinary portland cement clinker burnt in kiln with oil shale ash burnt in the fluidized bed boiler. Mix cement is produced by mixing the above mentioned oil shale cement with inert materials.

Since the raw materials available in Mae Sot area of suitable quality for manufacturing ordinary portland cement as described in IV-2, it is possible to produce ordinary portland cement clinker of good quality. Oil shale combustion residue which is used as mixing material can produce oil shale cement of good quality when mixed with ordinary portland cement clinker.

Furthermore, the quality of oil shale cement is by no means inferior to ordinary portland cement.

The representative standards of ordinary portland cement are shown below.

All cements which complies with any one of these standards can be produced from the raw materials available in this district.

Country	No. of standards	Name of cement
UK	BS 12 (1978)	Ordinary portland cement
USA	ASTM C-150 (1980)	Type I
Thailand	TIS : 15 (1974)	Type I
Germany	DIN 1164 (1978)	PZ 350 L
Japan	JIS R 5210 (1979)	Ordinary portland cement

Furthermore, the mix cement is produced and sold in the Kingdom of Thailand.

Thai specification TIS-80-2517 is specified for mix cement.

As described in chapter IV-2-2, the raw materials of Mae sot district have suitable quality to produce the cement that satisfies this specification.

VII-5-2 Preparing Proportion of Raw Materials

(1) Moduli of cement

The moduli of cement clinker 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 clinker to be produced in the Project are designed as follows:

HM (Hydraulic modulus)

$$= \frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3} = 2.08$$

SM (Silica modulus)

$$= \frac{SiO_2}{Al_2O_3 + Fe_2O_3} = 2.2$$

IM (Iron modulus)

$$= \frac{Al_2O_3}{Fe_2O_3} = 2.4$$

(2) Chemical composition of raw material

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

(i) Limestone

Grab sample of Doi Din Chi deposit   10 samples

(ii) Oil shale

Drilling core sample of Ban Huai Kalok deposit	34 samples

(iii) Marl

Grab sample of Ban Huai Kalok deposit	2 samples

(iv) Silica sand

Moei river silica sand	2 samples

(v) Iron ore

Non Poh iron ore	2 samples

(vi) Coal ash

Ash of Mae Ramat coal	1 sample

The average chemical composition of each raw material are shown in Table 7-5-1.

Table 7-5-1 Chemical Composition of Raw Materials (Average)

		Lime-stone	Oil shale	Marl	Silica sand	Iron ore	Coal ash
Chemical composition (wt % on dry basis)	L.O.I.	42.8	28.8	22.5	1.0	6.2	1.7
	SiO_2	2.0	31.8	36.0	86.4	43.6	49.1
	Al_2O_3	0.5	10.1	14.2	7.4	9.0	40.4
	Fe_2O_3	0.2	3.4	3.8	0.6	39.7	3.4
	CaO	53.8	17.2	18.1	0.4	1.1	2.1
	MgO	0.4	3.6	2.5	0.2	0.4	1.2
	SO_3	0.0	2.4	0.0	0.0	0.0	-
	Na_2O	0.00	0.73	0.25	0.79	0.06	-
	K_2O	0.01	1.40	2.48	3.50	0.04	-
	Total	99.71	99.43	99.83	100.29	100.07	97.9
	P_2O_5	0.02	0.12	0.16	0.04	0.04	-
	Cl	0.000	0.002	0.000	0.000	0.020	-

(3) Combination of raw materials

When ordinary raw materials are used, the proportioning percentage of raw materials is unequivocally determined by chemical composition of clinker to be produced. In the Project, raw meal can be made from limestone, oil shale and iron ore depending on chemical composition of clinker. Besides the above mentioned materials, chemical composition of coal ash is also added in the chemical composition of the produced clinker.

However, in the Project, oil shale shall be used not only as raw material, but also as fuel. Calorific value of oil shale is intended to be used effectively in suspension preheater which includes precalciner. But in oil shale burning experience at cement plant, the calorific value to be able to be used in the precalciner is no more than 50% of total heat consumption for clinker burning. Therefore, the amount of oil shale is determined by this heat consumption and, thus determined amount has higher priority than the amount determined by the raw material proportioning.

In the Project, the amount of oil shale determined by the raw material proportioning is more than that determined by the heat consumption, so the remaining amount needs to be compensated for by other materials, in order to satisfy the required clinker chemical composition.

In this report, two combinations of materials (1) oil shale combustion residue and (2) marl and silica sand are studied respectively.

The standard combination and other 3 combinations are shown in Table 7-5-2 together with moduli of clinker.

Table 7-5-2 Combination of Raw Materials

Combination		No.1	No.2	No.3	No.4
Limestone		o	o	o	o
Oil shale		o	o	o	o
Oil shale ash		o	o		
Marl				o	o
Silica sand				o	o
Iron ore		o	o	o	o
Moduli of	HM	2.08	2.08	2.08	2.08
clinker	SM	2.2	2.1	2.2	2.3
(planned)	IM			2.3	2.3

(4) Preparing proportion of raw materials

The preparing proportion of raw materials (dry basis), the chemical composition of raw meal, chemical composition of clinker and the mineral composition of clinker are shown in Table 7-5-3 - 7-5-6 respectively.

Table 7-5-3 Preparing Proportion of Raw Materials

(wt % on dry basis)

Combination	No.1	No.2	No.3	No.4
Limestone	65.47	65.99	65.55	66.07
Oil shale	27.46	27.36	26.99	27.01
Oil shale ash	5.87	4.52		
Marl			5.25	3.97
Silica sand			0.77	1.54
Iron ore	1.20	2.13	1.44	1.41
Total	100.00	100.00	100.00	100.00

Table 7-5-4 Chemical Composition of Raw Meal

Combination		No.1	No.2	No.3	No.4
Chemical composition (wt.% on dry basis)	L.O.I	36.0	36.2	37.1	37.1
	SiO_2	13.2	13.0	13.1	13.3
	Al_2O_3	4.0	3.9	4.0	3.9
	Fe_2O_3	1.8	2.1	1.8	1.8
	CaO	41.4	41.3	40.9	41.0
	MgO	1.6	1.5	1.4	1.3
	SO_3	0.9	0.8	0.6	0.6
	Na_2O	0.26	0.25	0.22	0.22
	K_2O	0.50	0.48	0.55	0.54
	Total	99.66	99.53	99.67	99.76
	P_2O_5	0.05	0.05	0.05	0.05
	Cl	0.000	0.000	0.000	0.000
Moduli of raw meal (calculated)	HM	2.15	2.14	2.14	2.14
	SM	2.3	2.2	2.3	2.3
	IM	2.2	1.9	2.2	2.2

Table 7-5-5 Chemical Composition of Clinker

Combination		No.1	No.2	No.3	No.4
Chemical composition (wt.% on dry basis)	SiO_2	20.9	20.6	21.1	21.4
	Al_2O_3	6.6	6.5	6.7	6.5
	Fe_2O_3	2.8	3.3	2.9	2.8
	CaO	64.1	64.2	64.4	64.4
	MgO	2.4	2.3	2.2	2.2
	SO_3	1.3	1.3	1.0	1.0
	Total	98.1	98.2	98.3	98.3
Moduli of clinker (calculated)	HM	2.08	2.08	2.08	2.08
	SM	2.2	2.1	2.2	2.3
	IM	2.4	2.0	2.3	2.3

Table 7-5-6 Mineral Composition of Clinker

Combination		No.1	No.2	No.3	No.4
Mineral component	C_3S	50	49	47	46
	C_2S	22	22	25	27
	C_3A	13	12	13	12
	C_4AF	9	10	9	9
L.S.F.		0.92	0.93	0.92	0.92

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 coal ash to be mixed in clinker was calculated as follows.

Calorific value (net of coal	5,924 kcal/kg
Ash content of coal (dry basis)	14.2%
Heat consumption of clinker	400,000 kcal/t-clinker
Quantity of ash to be mixed in clinker	9.589 kg/t-clinker

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 7-5-7.

Table 7-5-7 Unit Consumption of Raw Materials (Theoretical Value)

(t-raw materials on dry basis/ t-clinker including coal ash)

Combination	No.1	No.2	No.3	No.4
Limestone	1.0136	1.0254	1.0322	1.0396
Oil shale	0.4251	0.4251	0.4251	0.4251
Oil shale ash	0.0908	0.0703		
Marl			0.0827	0.0625
Silica sand			0.0122	0.0242
Iron ore	0.0185	0.0331	0.0226	0.0222
Total	1.5480	1.5539	1.5748	1.5736

(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 7-5-8.

Table 7-5-8 Unit Consumption of Raw Materials (Actual Value)

(t-raw materials on dry basis/ t-clinker including coal ash)

Combination	No.1	No.2	No.3	No.4
Limestone	1.0389	1.0510	1.0580	1.0656
Oil shale	0.4357	0.4357	0.4357	0.4357
Oil shale ash	0.0931	0.721		
Marl			0.0848	0.0641
Silica sand			0.0125	0.0248
Iron ore	0.0190	0.0339	0.0232	0.0228
Total	1.5867	1.5927	1.6142	1.6130

VII-6 Supply Plan of Fuel

Principal fuels used in the Project are, as mentioned previously, domestic coal and oil shale, Imported coal if necessary, can also be used as a supplmentary fuel.

VII-6-1 Domestic Coal

(1) Coal mine

Mae Ramat coal mine is selected as a coal supply source for the Project as mentioned previously, and the coal is planned to be purchased from Thai Lignite Company.

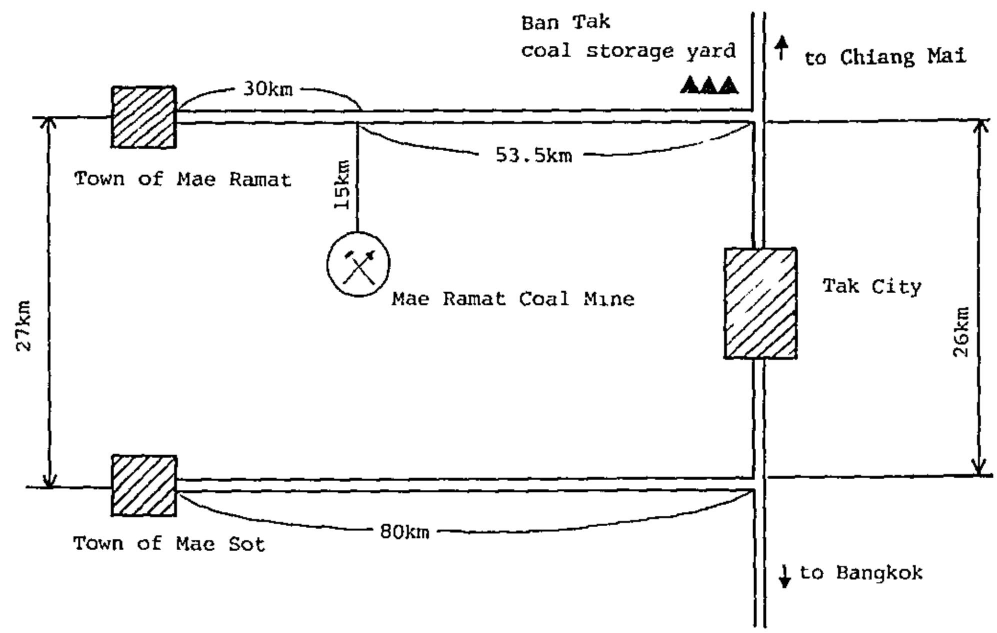
(2) Transportation

In Mae Ramat coal mine, coal is mined and stored in the coal storage yard during the dry season (including winter season), since the mine is not accessible in the rainy season due to road conditions. And the coal storage yard of Mae Ramat coal mine is located in Ban Tak.

Thai Lignite Company is recommended to handle the transportation (including storage) of coal from the mine to Mae Sot on behalf of the Project owner during the initial stage of the Project, since this company, currently supplying coal to the private cement company, is believed to have sufficient experience in this field. (refer to V-1) Construction of new road and new coal storage yard should be studied in the future to take advantage of very short direct distance between Mae Sot and Mae Ramat.

Transportation route of Mae Ramat coal is illustrated in Fig. 7-6-1.

Fig. 7-6-1 Transportation Route of Mae Ramat Coal



(3) Supply capability

Thai Lignite Company currently supplies 120,000 tons of coal annualy. Although the probable reserve of the Mae Ramat mine is 2,000,000 tons, it is reported that 100,000 tons range of coal can be supplied to the Project (actual coal requirement for the Project is 37,000 t/yr), as there exist undeveloped coal mines in the vicinity of the existing mine. It is recommended that a detailed study on coal mines including those in other areas be carried out in the next stage of the Project.

(4) Price

At Ban Tak coal storage yard	600 Baht/t
Transport cost (Ban Tak - Mae Sot)	100 Baht/t
Total	700 Baht/t

VII-6-2 Imported Coal

(1) Needs for imported coal

In this Project, Mae Ramat coal is planned to be used as a principal fuel for clinker burnning. The use of imported high-quality coal as a supplemental fuel is also suggested for the purpose of securing stable supply and constant quality (calorific value). Australia and China are possible imported coal sources.

(2) Transportation of imported coal

Imported coal is unloaded at the Bangkok port and then transported to Mae Sot by truck. Transportation of the imported coal can be carried out effectively by trucks owing to the completely paved highways throughout the route. It may also be possible to transport the imported coal by railway between Bangkok and Sawan Kalok, however transshipment at Ban Dara should make this route more costly.

(3) Price of imported coal

Australian Coal: 1,500 - 1,700 Baht/ton (CIF Mae Sot)

VII-6-3 Oil Shale

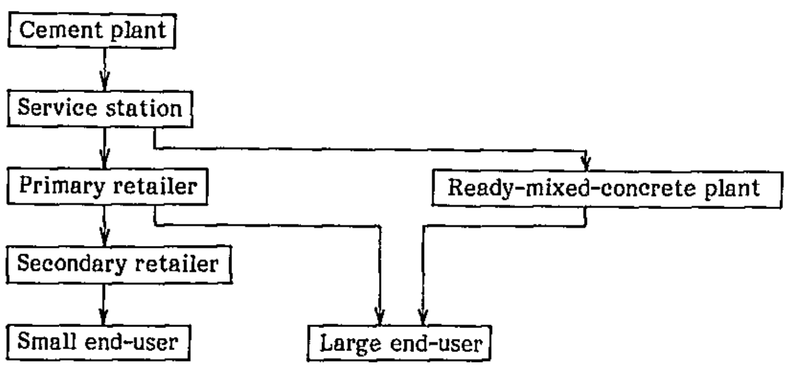
Supply of oil shale is discussed in detail in IV-3 of this report.

VII-7 Distribution Plan of Products

VII-7-1 Marketing Routes

A special consideration is required in marketing cement products, because cement is marketed in large volume and weight for its inexpensive price per volume, and is very difficult to be stored for a long period of time for its physical and chemical instability. A typical marketing route of cement is illustrated in Fig. 7-7-1.

Fig. 7-7-1 Typical Cement Marketing Route

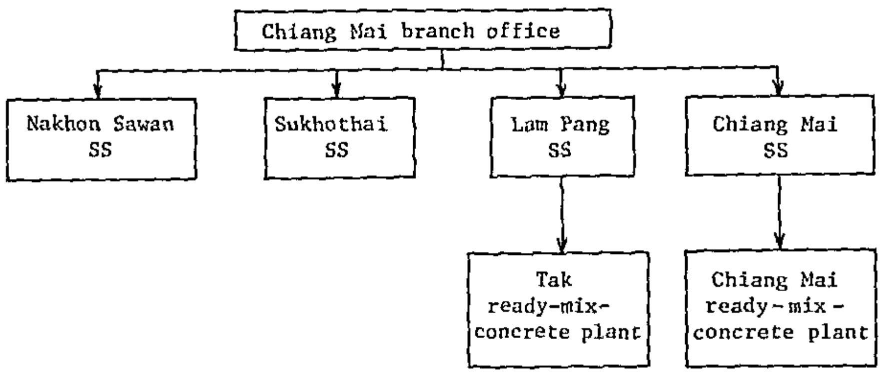


The actual marketing route of cement may become more complexed than the route illustrated, as the intermediary steps are often omitted in the actual practice depending upon the market situation. However, the current marketing route in the Kingdom of Thailand is very similar to that illustrated above. In Thailand, cement service stations are distributed in major cities, which then supplies cement to retailers in the city. The size of retailers commensurates with market sizes of the city. The retailers are affiliated by the individual cement companies. Ready-mix-concrete plants are distributed in larger cities of the country.

In Thailand, the service stations, generally small-sized, stores bag-cement in their storage, and are not equipped with silo-packer facility.

Fig. 7-7-2 shows a marketing organization for the north part of country operated by a certain private cement company.

Fig.7-7-2 Marketing Organization for North Market



Organization similar to Fig.7-7-2 must be established for the Project, since the north part of country is also considered as principal market for the Project (VII-7-2 is refered to). However, the Project having its manufcturing plant in the north part of country should have advantage in responding demand changes in the north market over other cement companies.

VII-7-2 Marketing Area

Transportation cost of cement accounts for a important portion of cement retail price because of its large volume and weight being marketed.

Therefore, distances between the market and the manufacturing plant determine the market for the plants, provided that manufacturing costs are equivalent in each plant.

At present, the Takli plant of Jalaprathan Cement Co. is the cement plant operating in the most northern part of the country. However, because of the small capacity of this plant (335,000 t/yr), the cement plants operating in Saraburi area should be considered as the competing cement supply sources in order to investigate the potential cement market for the Project. Accordingly, the boundary point between the market for the existing cement plants in Saraburi and the market for the Project plant is considered to be the point where the transportation distances from both plants equalize. On a highway map, this boundary point can be located at the point a short distance north from Nakhon Sawan on the northwards highway from Saraburi.

VII-7-3 Transportation Method

In the north part of Thailand, cement can be transported by either truck or railway. However, most of (more than 90%) cement is currently transported by truck due to high cost of railway transportation. Railway transport is practiced only in the summer season, when many trucks are used for the transport of sugar cane in the south part of country.

Bag-cement and bulk-cement are both currently transported by truck in the area, and bag-cement accounts for 70%-80% of total transport. In the Project, the use of larger trucks and the increase of bulk transport are recommended to reduce the transportation cost of products cement.

The present transportation cost of cement for example from Saraburi to Chaing Mai is 165 Baht/t by truck.

VII-7-4 Container

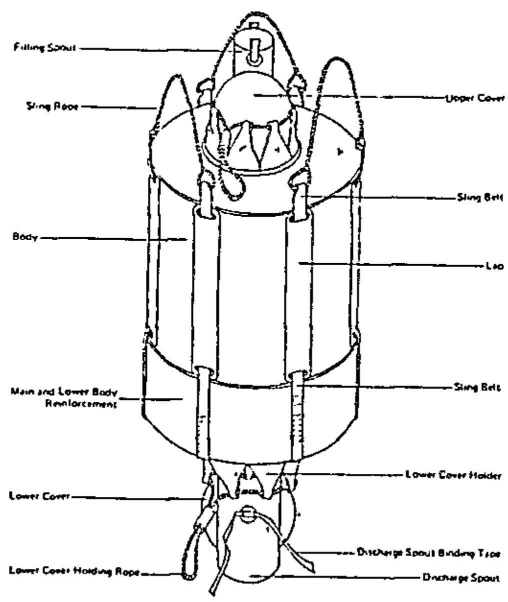
At present, 70%-80% of cement products is transported as 50kg bag-cement in the country, and 4-ply craft paper bags are of common use. The same paper bags may be used during the initial period of the Project, however, bulk-cement should be increased in the future in order to reduce the transportation cost and keep the quality of product cement. Furthermore, the use of flexible containers (illustrated in Fig. 7-7-3) which have cost advantage over the paper bags is planned in the Project for larger end-users.

Two types of flexible containers, running type and one-way type, are available, and their specifications are shown in Table 7-7-1.

Table 7-7-1 Specification of Flexible Container

	Running type		One-way type
Volume	2.0 ton 1,800 ℓ	1.5 ton 1,300 ℓ	1.0 ton 900 ℓ
Size	1,200ø x 1,610 h	1,150ø x 1,260 h	1,100ø x 950 h
Repeat uses	appx. 100		1
Material	Nylon fiber - synthetic rubber Coating		PP fiber - resin coating
Heat resisting Characteristics	100°C		max. 60°C
Water proof characteristics	good		good
No. of stacks	max. 3		max. 3
Price (Baht/Bag)	6,018	4,646	402

Fig. 7-7-3 Flexible Container



VII-8 Outline of Plant Design

VII-8-1 Selection of Main Machinery and Equipment of the Plant

In the selection of main machinery and equipment of the plant, the following items are generally to be investigated.

(a) Quality of raw materials and fuel

Physical and chemical properties of raw materials determine the type of process to be applied and consequently determine the type and specification of machinery and equipment.
The same can be said for the properties of fuel.

(b) Procurement conditions for raw materials and fuel

Type and specification of receiving/transportation facilities are principally determined by the procurement conditions for raw materials and fuel to be used in the plant.

(c) Process

The type of process to be used is determined considering the factors as described in (a) and etc., and main machinery and equipment are selected to meet the process requirements.
(refer to VII-1)

(d) Social and natural conditions of the proposed plant site

Social and natural conditions of the proposed plant site must also be considered in selecting main machinery and equipment of the plant.
Social conditions to be considered are labor availability, labor quality, activity of related industries in the area, environmental quality standards and etc, while natural conditions to be considered may include meteorological conditions, water availability, and etc..

Investigation results of the above items are briefly summarized below. For the specification of main machinery and equipment, VII-9 is referred to.

(1) Raw material storage

(i) Limestone, iron ore and gypsum

It is expected that limestone mining can be continued even during the rainy season, except in extremely heavy rain.

Considering the above, limestone storage with a capacity for eight (8) days operation will be sufficient.

Iron ore and gypsum are procured from nearby mining companies.

Limestone, iron ore and gypsum are stockpiled in one storage yard, because consumption of iron ore and gypsum is very small.

These raw materials are reclaimed by one portal scraper which is for common use.

Respective storage capacity of iron ore and gypsum are for four (4) months and for twenty-two (22) days respectively.

(ii) Oil shale storage

The composition of the oil shale and thus also the calorific value, depending upon the layer depth, show great flucluations. Therefore an efficient mixing before combustion in the fluidized bed combustor is necessary.

This efficient mixing is achieved in a circular storage mixing bed, by building up an oil shale stockpile and reclaiming this stockpile at the front end by means of a horizontally and vertically working scraper device.

The storage capacity of the oil shale is for approximately seven (7) days of operation.

(iii) Oil shale silo

The oil shale homoginized in the circular storage mixing bed is partly fed to the fluidized bed combustors of the power plant and partly to the cement plant through oil shale silo.
The storage capacity of the oil shale silo is for 1.4 days of the raw mill capacity.

(2) Ash silo

Collected ash (combustion residue) from the fluidized bed combustor is to be used for raw mix and mixing material of cement.
The storage capacity of the ash is for 3.5 days operation.

(3) Coal storage yard

Coal is procured from a nearby coal mining company. Coal storage is to be provided with an adequate roof in order to minimize the increase in moisture content during the rainy season.
In order to prevent spontaneous ignition, coal layer is to be trodden down by a sheep foot roller or equivalent means, and stockpile height should not exceed 4 m. The storage capacity of the coal is approximately for half (0.5) month operation.
The coal is to be discharged into the feed hopper by a wheel loader.

(4) Raw material and oil shale grinding and drying

Raw materials and oil shale are to be ground and dried simultaneously by a vertical roller mill. The mill operating time ratio between raw mix and oil shale is approximately 2:1.
Exhaust gas from suspension preheater can be utilized as a heat source for material drying, however, hot gas generator using heavy oil or diesel oil should be provided for start-up of the mill or emergency such as in case of extremly high moisture content materials.

(5) Raw meal blending and storage

In general, chemical composition and fineness of raw meal after grinding process still fluctuates because of the fluctuation in quality of each raw material, deviation in mixing process, mill operating condition, etc.

In order to operate the kiln stably and to produce clinker of uniform quality, it is necessary to blend raw meal in the blending silo provided before the raw meal silo.
Total capacity of blending silo and storage silo is for four (4) days kiln operation.

(6) Ground oil shale blending silo

It is necessary to blend the oil shale in the silo by the same reason mentioned in the preceding clause. The silo is to be used both for blending and storage. The storage capacity of oil shale is for 5 days operation.

(7) Kiln and cooler

Type of kiln is to be of new suspension preheater type kiln as mentioned in VII-1.
In regard to the type of cooler, the horizontal grate cooler is recommended, because it is quite reliable for the reasons as follows:

(i) Air for kiln burning obtained from this type of cooler has higher temperature.

(ii) Temperature of cooled clinker is relatively low and stable.

(8) Clinker storage

In general, silos and storage yards are adopted for clinker storage.

For this plant, clinker silo is recommended, considering prevention of dust emmission during clinker storing, simplification of machinery and equipment and easiness of its operation and control.
Clinker storage silo should have a total capacity sufficient for ten (10) days clinker production.

(9) Cement grinding

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

(10) Cement storage

Two kinds of cement are to be stored independently in 2 sets of silos. The storage capacity of cement is for eight (8) days cement production.

(11) Cement packing

Rotary packer is to be provided for cement packing. Some quantity of cement is to be shipped by bulk loading by air slide conveyor system.

(12) Coal grinding

Coal is to be ground by a vertical roller mill equipped with simultaneous drying device.
A part of the hot air from clinker cooler is to be utilized for coal drying.

VII-8-2 Outline for Design and Construction of Building and Civil Engineering Work

(1) Site development

(i) Location and layout (refer to Fig. 7-3-1)

The plant site is proposed to be located near the oil shale deposit as described in Section VII-3.

Layout is proposed to be on the North to South axis.

The reasons are as follows:

(a) The proposed plant site and the planned new road is conveniently located from the viewpoint of transportation of raw materials, fuel, and products.

(b) The plant site on a tableland has geological and topographical advantages, for instance, good soil condition and easiness of land preparation.

(c) A branch of the Moei river flows around the plant site, therefore, it is advantageous for discharging of rain water from the plant site.

(ii) Area

Area ..... 300,000 m^2

(East to West ...... 300 to 400 m long)
(South to North ... 600 to 800 m long)

(iii) Outline of site development

The ground level of the plant site is 198 meters above sea level and approximately 1 to 2 m higher than the level of surrounding rice fields.

The level has been so determined that the volume of earth cut and fill will be the same from an economical view point, and furthermore its level has been decided to take advantage of rainwater drainage and construction of structure foundations.

Estimated volume of earth work is as follows:

a.	Earth cut	150,000 m^3
b.	Earth fill	160,000 m^3
c.	Slope protection	4,000 m^2
d.	Drain-ditch	400 m

(2) Outline of access road

(i) Section

Its distance is about 5 km between the fork on the rural road Route No. 1085 (Mae Pa Tai village) and the proposed plant site.

(a) Mae Pa Tai to the first bridge
..... The existing road, which is required to be improved.

(b) The First Bridge to the plant site
..... A new access road will be constructed

(ii) Route

The new access road will be constructed along a brook, considering rainwater drainage.

(iii) Design

Design conditions are as follows:

(a) It shall be designed to bear with transport of large and heavy cargoes required for the plant construction.

(b) After completion of the plant, it shall have necessary dimensions and capacities to transport conveniently and smoothly raw materials, fuels and products.

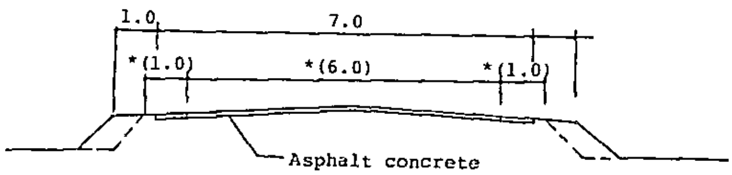
(c) It shall satisfy the above mentioned items (a), (b) and, judging from the road condition in Thailand, it shall conform to the specification of rural roads by the Highway Department. (refer to Section VI-3) Outline of access road is shown in Table 7-8-1, Fig. 7-8-1.

Table 7-8-1 Specification of Access Road

	(a) Improved road	(b) New road
Route	From Mae Pa Tai To the first bridge	From the first bridge To the plant site
Approximate length	4 km	1 km
Effective width	7 m	7 m
Carriageway width Pavement*	Asphalt concrete	Asphalt concrete
Minimum radius of horizontal circular curve	15 m	15 m

Note: * Existing pavement of road (a) is macadom.

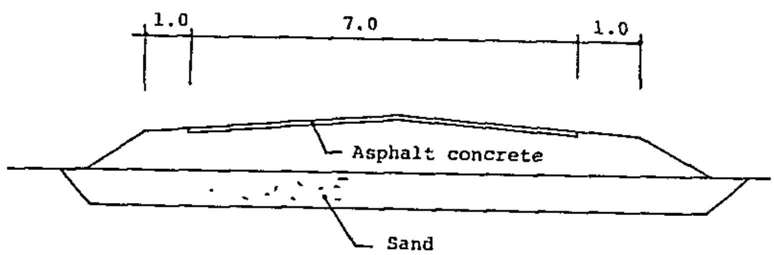
Fig. 7-8-1 Standard Cross Section of Access Road



(a) Improved road

Unit: m

* These figures are those of the existing road.



(b) New road

Unit: m

(3) Outline of bridges

(i) Existing bridge (refer to Fig. 7-8-1)

According to the site investigation for the Project, the First Bridge was under preparation for construction in December, 1982 and will be completed in 1983 according to its schedule, the Second Bridge was under construction, and the Third Bridge was completed by December, 1982.

Judging from the information which were obtained from the contractor of the Second Bridge and our site investigation, these bridges have adequate dimensions and capacities for the transportation of raw materials, fuel, and products of the Project after the completion of the plant, however, it is presumed that reinforcement of existing components will be required in consideration of the transportation of heavy cargo necessary for the plant construction. (Further detailed investigation and study is required in order to reconfirm the reinforcement.)

For reference, outline of the Third Bridge (completed) is as follows:

The superstructure is composed of 3 spans of 7.5 m long concrete slab each with both ends simply supported by piers of square-type RC piles.

(ii) Proposed bridge

This bridge shall comform to the specification of road bridge as mentioned in Section VI-3-3.

Detailed hydrologic investigation of river, topographic and geologic investigation are required in order to determine the position of piers and to design structures of piers.

(4) Design for structure and building

(i) Design standards

Building Control Act of the Kingdom of Thialand and Bye-Laws of the Bangkok metropolis Re; Control of the Construction of Buildings should be adopted.

(ii) Design load

(a) Wind load

In case that wind load is estimated based on the standard of the Architectural Institute of Japan (AIJ) and the wind record at the Mae Sot district, the design wind speed and the dynamic pressure are calculated to be about 18 m/s and about 20 kg/m^2, respectively. The calculated figures are smaller than 50 kg/m^2 of minimum design dynamic pressure that is required by Bye-Laws of the Bangkok metropolis. The reason is due to the topographical fact that the area of the proposed plant site is surrounded by mountains.

Therefore, the following shall apply to the design of the Project, in consideration of safety, etc.:

Height of a building or any part of a building	Minimum wind pressure (kg/m^2)
Any part of a building that is under 10 metre high	50
Any part of a building that is between 10 and 20 metre high	80
Any part of a building that is between 20 and 40 metre high	120
Any part of a building that is over 40 metre high	160

(b) Seismic load

Seismic load is not necessary to be considered at Mae Sot area.

(c) Live load

The design live load except the following items shall be in accordance with the usually recognized live load for design of cement plant.

- Machine foundation shall be designed to consider the effect of vibration or impact.

- Burner floor of burning house, where fire bricks will be piled temporarily, shall be designed to resist a uniformly distributed load of 3,000 kg/m^2 or so.

- Bag store floor of packing house shall be designed to resist a uniformly distributed load of.900 kg/m^2 or so.

(iii) Soil investigation and design of foundations

(a) Foundations sensitive to differential settlement (those for kiln, mill, cooler, turbine, etc.)

Where a hard and strong stratum (equivalent to, or more than a dense gravel layer) exists within a shallow depth, the foundations should be placed directly on it, or on lean-mix cobble concrete which replaces the soil overlaying the said stratum.

Where the soil condition is otherwise, point-bearing piles shall be used to support the foundations.

(b) Foundations except mentioned in (a)

Where the soil has enough bearing capacity, the foundations may be placed directly on it. Where the soil condition is otherwise, the foundations shall be supported by piles or gravel beds to replace the upper weak soil.

(c) Soil investigation

At least the following soil investigation are necessary to make judgements with regard to the cases mentioned in the foregoing sections, (a) and (b).

- Boring test (at least one for each main structure)

- Standard penetration test (BS-1377 TEST 19 or ASTM-D1586)

- Other tests necessary for estimating the strength and the settlement, depending upon actual soil conditions.

Such detailed soil investigation, however, has not been carried out by the study team during the site survey period at the proposed plant site.
Therefore, the said investigation is required prior to the commencement of the Project in order to improve accuracy of construction cost estimate, and furthermore, to complete a detail design of foundations of structures and buildings.

Oil shale stratum has been found at the depth of 4.0 m to 5.0 m below the ground surface by the boring test for oil shale research.
Oil shale stratum is, in general, seemed to be adoptable as bearing layer for structures and building.

However, due to limited data, it is difficult to make a final judgement whether this oil shale stratum can be adopted as the bearing layer for the cement plant.

(iv) Structure

From the standpoint of durability and fire-proofing, underground substructures shall be constructed of reinforced concrete and super-structures shall be constructed of reinforced concrete or structural steel, while light and minor structures may be constructed of reinforced concrete block or masonry.

Considering the building construction situation in Thailand and the aforesaid design requirements, it is recommended that most part of the structure be, in general, constructed of reinforced concrete, unless otherwise specified.

(v) Requirements for design of main structures

Note: Whenever the indication "drawing", appears at the last of any heading line of the following sub-sections, it means that a drawing of the structure represented by the heading is attached to the last part of this report.

(a) Limestone, iron ores, gypsum storage (drawing)

From the viewpoint of quality control for each material in storage, the storage shall be covered with roof.
Design of such super structure shall be considered to satisfy economic and safety conditions.

Therefore, such storage shall be of steel structure.
The storage shall be furnished with accessory foundation mentioned below.

- Foundation for B.C. bridges
- Foundation for portal scraper rails

(b) Oil shale silo and ash silo

The shells shall be constructed of reinforced concrete, and the roofs shall be constructed of steel structure or reinforced concrete, the silos shall be waterproof.

(c) Raw material weighing hopper

Four hoppers are to be provided, one each for limestone, oil shale, oil shale combustion residue and iron ore. The structure shall be constructed of reinforced concrete. For the hoppers, more abrasion allowance shall be considered than for the others.

(d) Raw mill house (drawing)

Main structure of raw mill house shall be constructed of reinforced concrete or steel structure, and the roof shall be constructed of steel structure, and ventilation shall be considered.

The electric room shall be dust-proof, and shall be air-conditioned.

(e) Blending silo and raw meal silo

In addition to the description in (b), pressure raised by the blending-equipment in silo shall be taken into account in designing the shell.

(f) Burning house (including clinker cooler room) (drawing)

It is recommended that most part of this building be constructed of reinforced concrete, and the roof be constructed of steel structure.

Live load described in (ii)-(c) and high temperature of kiln, shall be considered in designing the structure.

(g) Clinker silo and unburned clinker silo (drawing)

In addition to the description in (V)-(b), thermal stress shall be taken into account in designing the shell, because this silo often receives hot clinker.

(h) Cement mill house (drawing)

The separator floor and the portion below this level of the mill house should be constructed of reinforced concrete to increase the rigidity against vibration.

The structure above the separator floor shall be constructed of structural steel.

The mill motor room shall be dust-proof, and shall be provided with ventilation-equipment considering temperature in the house, and shall be provided with crane girder for maintainance of mill motor.

This house shall contain electric room and space for maintainance of mill.

(i) Cement packing house (drawing)

It is recommended that most part of this building be constructed of reinforced concrete or steel structure, and the roof be constructed of steel structure, and the cladding be covered with concrete block, asbestos cement sheet or galvanized steel sheet.

This building shall be designed in consideration of live load described in (ii)-(c) and water-proof, and shall contain a bag store, a control room and an electric room.

(j) Cement loading room (drawing)

This building shall be of "pilot" type, with a ground floor designed so that trucks can be loaded there with bagged cement and after being loaded go out through the building.

Three loading lines shall be provided.

(k) Coal storage

It is recommended that most part of this building be constructed of reinforced concrete, and the roof be constructed of steel structure. The coal transported by trucks to the storage shall be placed in uniform thickness and compacted by means of bulldozer, sheep's foot roller, and the like to prevent spontaneous ignition of the stored coal, and shall be provided with sprinkler.

(l) Coal mill house

This building can be constructed of reinforced concrete or steel structure. However, it is recommended that this building be of reinforced concrete, considering the spontaneous ignition by accumulated coal-dust on structural members.

Furthermore, an outdoor main staircase and sufficient natural ventilation device shall be provided with.

(m) Oil shale homogenizing storage (drawing)

From the viewpoint of quality control for oil shale and antipollution measures such as reducing dust emmission, the storage shall be provided with roof.

The type of storage shall be a circular-storage type for using stacker and reclaimer.

Main structure shall be constructed with arched domes or elliptical domes from the viewpoint of above mentioned reason.

The storage shall be provided with accessory structure and foundation listed below.

- Foundation for post of stacker and reclaimer

- Foundation for stacker rails

- Tunnel for discharging belt conveyor

(n) Power plant

Power plant shall need the following buildings, turbine house, boiler house, auxiliary equipment room, transformer room, electric room, control room, etc.

These buildings shall be of steel structure or reinforced concrete structure.

The turbine foundations shall be structurally separated from the structure of the house for preventing transmission of vibration.

The house shall be provided with crane girder and space for maintainance of turbine, and shall be designed considering ventilation and dust-proof.

(o) Central control house

This building shall contain control room, electric room and woker's room, etc., and shall be designed cosidering dust-proof, space for electrical cable, air conditioning, etc.

(p) Workshop (drawing)

The following shops shall be included in this building.

- Mechanical shop (including a blacksmith shop)
- Electrical shop (including motor drying room)
- Car repair shop
- Tool room
- Shop office and rest room.

An overhead crane shall be provided for carrying heavy items.

(q) Warehouse

Warehouse shall be provided for storing spare parts of the mechanical and the electrical equipment, consumables (such as lubricant oil, fire bricks, mill balls, mill liners, etc.) and repair material (steel, for example), and also it shall provide space for worker's room.

The number of the warehouses is not necessarily limited to one and may be several, and all of the warehouses shall be designed to different specifications in accordance with the respective kinds of materials to be stored.

There may be some materials which can be stored temporarily in the open air. For this purpose, an open storage should be provided in the vicinity of the warehouses.

(r) Laboratory and production section office

This building shall be constructed of reinforced concrete or reinforced concrete block.

The laboratory shall be divided into the following sections:

- Physical testing room (including a constant temperature and humidity room)

- Chemical testing room (including chemical balance room)

- Laboratory office.

Production section office will accommodate production division described in chapter IX.

(s) Ancillary building

The following buildings will be needed in addition to the aforementioned.

- Administration office

- Garage (for company cars)

- Canteen

- Welfare facilities (clinic, locker room, shower room, lavatory, library)

- Shed for bicycle

- Guard house (one for each gate)

- Toilet blocks (about 5 blocks in the plant where necessary)

(t) Pavement

The pavement in the plant shall be of cement concrete of 20 cm thick or more, to stand up to the heavy traffic and to be durable.

The carriageway width shall be 8 m wide for main road and 4 m or 6 m wide for others.

From an ecomical point of view, the roads in the plant may be paved only with crushed stone at the time of the plant operation commencement, and afterwards be gradually paved with concrete using the produced cement.

(u) Drainage system

Where it is anticipated that heavy traffic will cross over a drainage channel or pass along it, such channel shall be constructed of reinforced concrete to resist the heavy traffic load.

Other channels except the aforesaid may be constructed economically of brick or stone masonry.

Drainage system should be designed based on the rain-fall expected in rainy season. Discharge of collected water to the surrounding rice fields should also be considered in the design.

VII-9 Specification of Main Equipment

VII-9-1 Main Machinery and Equipment of the Plant

(1) Crusher for limestone and iron ore

No. of sets	:	1
Type of crusher	:	Impact crusher
Feed size	:	Max. 800 mm
Product size	:	Less than 50 mm
Capacity	:	250 t/hr
Motor	:	500 kW
Operating time	:	10 hours per day

(2) Limestone, iron ore and gypsum storage

No. of sets	:	1	
Type of storage	:	Layered stockpile, sheltered type	
Type of discharger	:	Portal scraper	
Dimensions of stockpile	:	Limestone	25mW x 90mL x 10mH
		Iron ore	25mø x 10mH (cone)
		Gypsum	25mø x 10mH (cone)

(3) Limestone, iron ore and gypsum reclaimer

No. of sets	:	1
Type	:	Portal scraper
Capacity	:	Max. 400 t/hr
Operating type	:	24 hours per day

(4) Oil shale silo

No. of sets	:	1
Type	:	Concrete structure
Dimensions	:	15mø x 15mH
Capacity	:	3,000 t

(5) Ash silo

No. of sets	:	1
Type	:	Concrete structure
Dimensions	:	17mø x 20mH
Capacity	:	3,000 t

(6) Raw mill

No. of sets	:	1
Type	:	Vertical roller mill
Dimensions	:	5mø x 11.8mH
Feed size	:	Max. 50 mm
Product fineness	:	15% residue on 88 micron sieve
Capacity	:	Raw mix 130 t/hr
		Oil shale 100 t/hr
Motor	:	1,400 kW

(7) Raw meal blending silo

No. of sets	:	1
Type	:	Concrete structure
Dimensions	:	13mø x 25mH
Capacity	:	2,000 t

(8) Raw meal storage silo

No. of sets	:	1
Type	:	Concrete structure
Dimensions	:	18mø x 25mH
Capacity	:	5,000 t

(9) Oil shale blending silo

No. of sets	:	1
Type	:	Concrete structure
Dimensions	:	15mø x 25mH
Capacity	:	3,000 t

(10) Kiln

No. of sets	:	1
Type	:	New suspension preheater kiln
Dimensions	:	3.5mø x 53mL
Capacity	:	1,400 t/d
Operating time	:	24 hours per day 330 days per year

(11) Clinker cooler

No. of sets	:	1
Type	:	Horizontal grate cooler
Capacity	:	1,400 t/d
Operating time	:	24 hours per day 330 days per year

(12) Clinker silo

No. of sets	:	1
Type	:	Concrete structure
Dimensions	:	25mø x 30mH
Capacity	:	15,000 t

(13) Cement mill

No. of sets	:	2
Type	:	Two compartment tube mill, closed circuit with separator
Dimensions	:	3.35mø x 9.6mL
Feed size	:	Max. 25 mm
Product fineness	:	Specific surface 4,000 cm^2/g
Capacity	:	63 t/hr
Motor	:	1,600 kW
Operating time	:	20 hours per day

(14) Cement silo

No. of sets	:	4
Type	:	Concrete structure
Dimensions	:	15mø x 30mH
Capacity	:	5,000 t

(15) Packer

No. of sets	:	3
Type	:	Rotary packer
Capacity	:	100 t/hr
Operating time	:	10 hours per day 6 days per week

(16) Coal storage

No. of sets	:	1
Type of storage	:	Stockpile layered and trodden sheltered type
Type of discharge	:	Wheel loader
Dimensions of stockpile	:	20mW x 30mL x 4mH
Capacity	:	1,500 t

(17) Coal mill

No. of sets	:	1
Type	:	Vertical roller mill
Dimensions	:	1.4mø x 3.15mH
Feed size	:	Max. 30 mm
Product fineness	:	15% residue on 88 micron sieve
Moisture content of feed	:	Max. 4%
Capacity	:	6 t/hr
Motor	:	150 kW
Operating time	:	20 hours per day

(18) Primary crusher for oil shale

No. of sets	:	1
Type	:	Jaw crusher
Feed size	:	Max. 600 mm
Product size	:	Less than 75 mm
Capacity	:	200 t/hr
Motor	:	95 kW
Operating time	:	10 hours per day

(19) Secondary crusher for oil shale

No. of sets	:	1
Type	:	Impact crusher
Feed size	:	Max. 200 mm
Product size	:	Less than 20 mm
Capacity	:	250 t/hr
Motor	:	350 kW
Operting time	:	10 hours per day

(20) Oil shale homogenizer

No. of sets	:	1
Type	:	Circular storage mixing bed, sheltered type
Storage capacity	:	8,000 t
Stock piling capacity	:	250 t/hr
Discharging capacity	:	300 t/hr
Distance between rails	:	55 m

VII-9-2 Electrical Equipment of the Plant

Refer to the attached DWG. No. E-02 Single Line Diagram.

(1) Sub-station equipment

(i) Extra-high voltage switchgear

Quantity : 1 set

Type : Indoor type

Consisting of :

1 - Disconnecting switch (isolator), remotely air-operated

1 - Gas circuit breaker

1 - Set of current transformer

1 - Metering outfit for power sales

1 - Lightning arrestor

1 - Air compressor unit

(ii) Extra-high voltage transformer

Quantity : 1

Type : 3 phase, outdoor, oil-immersed, self-cooling with on-load tap-changer

Rating : Primary voltage 22 kV
Secondary voltage 6.6 kV

Capacity : 2,000 kVA

(iii) High voltage power distribution equipment

Quantity : 1 set

Type : Indoor, enclosed cubicle type switchboard

Main specification:

Bus duct - Outdoor type (between extra-high voltage transformer and main switchboard)

Circuit breaker - Magnetic - blast type 1000 MVA

Main services:

1 - Main transformer cubicle
2 - Generator cubicle
1 - Emergency diesel generator cubicle
8 - Station service cubicle
15 - Feeder cubicle
1 - Lightning arrestor cubicle
1 - Capacitor cubicle

(iv) Control board

Quantity	:	1 set
Type	:	Indoor, benchboard type, inclusive one set of relay panels

(v) Electrical equipment for station service

Quantity : 1 set

Consisting of :

1 - DC power supply apparatus
8 - High voltage motor stator
1 - Low voltage motor control center

(vi) Emergency power generating equipment

Quantity	:	1 set
Type	:	Diesel engine generating set
Main Specification	:	Stational four-cycle engine with super changer, 3 phases, 4 poles, 6.6 kV, AC generator
Capacity	:	1,750 kVA

(2) Power generating equipment

(i) Steam boiler

Quantity	:	2 sets
Type	:	Fluidized bed type natural circulation boiler

Capacity	:	28 t/hr	
Steam temp.	:	495°C	
Steam pressure	:	62 kg/cm^2	
Heat transfer surface area	:	Economizer	1,600 m^2
		Evaporator	1,100 m^2
		Superheater	680 m^2

(ii) Turbine-generator

Quantity	:	2 sets
Type	:	Condensing type turbine-generator directly conbined with excitor
Capacity	:	9,000 kVA/set
Voltage	:	6,900 V
Power factor	:	0.8 (lag)
Frequency	:	50 Hz
Rotation speed	:	1,800 rpm

(iii) Steam condenser

Quantity	:	2 sets
Type	:	Steam ejector type
Condensate pressure	:	0.07 kg/m^2
Condensate temp.	:	39°C

(3) Power distributing equipment

(i) Major equipment

1 - High voltage switchgear

1 - Power transformer: 6,600/ 415 V

1 - Lighting transformer: 6,600/ 415/ 230 V

1 - Low voltage distributing board

1 - Motor control center

(ii) Installation place

1 - Electric room for Raw Material Unloading Dept.

1 - Electric room for Raw Material Grinding Dept.
1 - Electric room for Clinker Burning Dept.
1 - Electric room for Finish Grinding Dept.
1 - Electric room for Workshop

(4) Motors

Quantity : 1 lot

Main specification :

Protection - Totally enclosed, fan cooled, dust proof type

Voltage - 6.6 kV for motors exceeding 200 kW
230 V for motors 200 kW or smaller
203 V for single phase small motors
and for control motors

Insulation class - class-B for high voltage motors
class-E for low voltage motors

Temperature rise - The design ambient temperature is 45°C.

Standards - IEC standards

Motors for special purposes -
DC motor, for kiln drive
Induction synchronous motor, for mill drive
Induction motor with eddy current coupling, for variable speed drive
General motor, for low speed drive

Note: The capacity of large motors shall be determined in consideration of both the capacity of the power plant and the voltage regulations at its start-up. (In the Project, it is recommendable to limit the maximum unit capacity to be 1,600 kW)

(5) Process control equipment (Including instruments)

(i) Central control switchboard

Quantity : 1 set

Type : Indoor-use, dust proof, benchboard type

Inclusive of instruments, graphic panel, lamps, alarms, etc.

(ii) Local control switchboard

Quantity : 1 lot

Type : Indoor-use, dust-proof, wall-mounting type

Inclusive of push buttons, lamps, etc.

(iii) General instruments

Quantity : 1 lot

Type : Indoor or outdoor use, dust-proof

Common specification : Power source - AC 100 V, single phase, 50 Hz

Note: This power shall be supplied from the control power line (AC 230 V, single phase) through a exclusively used transformer.

Output signal - DC 4 - 20 mA

(6) Lighting equipment

(i) Guide for illumination level

Indoor (on working surface)

Control room	250 - 600 lx.
Working places	more than 100 lx.
Outdoor working places	more than 50 lx.
Roads, storage	more than 10 lx.

(ii) Main specification

Distribution board	-	Sheet metal mode, wall-mounting type, AC 230 V, 50 Hz
Mercury vapour lamp	-	Improved-power-factor type, AC 230 V, 50 Hz, 200 - 1,000 W, for outdoor illumination and for indoor illumination in high - ceiled rooms
Fluorescent lamp	-	Improved-power-factor type, AC 230 V, 50 Hz, 20 - 60 W, for indoor general and emergency illumination
Incandescent lamp	-	AC 230 V, 50 Hz, 100 - 300 W, for spot illumination

Distribution board for repairing works -
Sheet metal made, wall-mounting type, AC 415/230 V, 50 Hz

Socket and outlet - 2P 15A, 3P 63A or more

(7) Communication facilities

Quantity	:	1 set
Type	:	Automatic exchange, dial type telephone
Capacity	:	Outward trunk line - max. 10 lines Extension - max. 100 lines mounted 50 lines
Power source	:	Battery with a floating charger

(8) Wiring and piping works

(i) Cables

Main specification:

High tension cables	-	6.6 kV cross-linked polyethylene insulated PVC sheathed cables with 22 mm^2 or more
Low tension cables	-	600 V cross-linked polyethylene insulated or PVC insulated PVC sheathed cables with 3.5 mm^2 or more
Control cables	-	600 V PVC insulated PVC sheathed cables
Communication cables	-	600 V PVC sheathed cables
Grounding wires	-	600 V PVC insulated wires

(ii) Outdoor wiring system

Main specification:

Main route	-	Cable rack system on steel lattice structure (5 m or more above ground level)
Branch route	-	Underground concrete trough system or directly buried conduit system

(iii) Indoor wiring system

Main specification:

Main route	-	Cable rack system or cable pit system on the floor
Branch route	-	Conduit system

(iv) Grounding circuit

Main specification:

Loop system consisting of copper grounding rods and wires network