THE FEASIBILITY STUDY REPORT

ON

THE ESTABLISHMENT OF THE INTEGRATED POWER AND CEMENT FACTORY USING OIL SHALE

IN

THE KINGDOM OF THAILAND

AUGUST, 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan decided to conduct a feasibility study on the Establishment of the Integrated Power and Cement Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to the Kingdom of Thailand a survey team headed by Mr. Ryo Toyabe from November 21 to December 25, 1982.

The team exchanged views with the officials concerned of the Government of Thailand and conducted a field survey in the Project-related areas including Bangkok, Chiang Mai and Tak. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that the report on the feasibility study will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

Tokyo, August 1983

Keisuke Arita
President
Japan International Cooperation Agency

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FOREWORD

– Purpose and Development of This Study –

The Kingdom of Thailand is located in the central part of Indochina Peninsula. In the east, Thailand adjoins Laos and Cambodia and in the west it adjoins Burma, while in the south it faces to the Siam Bay. In the southern west it extends to Malay Peninsula adjoining Malaysia.

Economy of Thailand was originally led by agriculture centering around rice, but after that it has developed smoothly through diversification of agriculture, assistance by and loan from the United States of America, acceptance of industrial investment from overseas countries. The economic development plan was commenced in 1961 as the first plan and the forth plan was completed in 1974. At present the fifth plan is being implemented.

During this period, the development of Thai economy was obstructed greatly by the first oil crisis started in 1973 and the second oil crisis broke out in 1979.

Under such circumstance Thailand as an importing country of energy has sincerely been grappling with development domestic energy resources.
As a part of the works since 1974 the Department of Mineral Resources (hereinafter referred to as DMR), Ministry of Industry has been investigating oil shale resources in the northern region including Mae Sot area and a deposit of oil shale whose reserves are 18.7 billion tons containing approximately five percent (weight) of oil has been confirmed.

In order to accelerate the development, the Thailand Government established the Oil Shale Committee in 1980.

The Committee is a development committee consisting of Minister of Industry as chairman and members from other related Ministries and Departments.

At first the Committee planned an oil extraction project from oil shale. However due to easing of oil crisis, the Committee postponed the oil extraction project and planned the project that is most realizable from technical and economic points of view as a present measure of oil shale utilization, that is, the project of establishing an Integrated Power and Cement Plant using oil shale (hereinafter referred to as the Project).

Based on this plan, the Thailand Government requested the Government of Japan to carry out the feasibility study on the plan for establishment of such plant in March, 1981.

In the response to the request of the Thailand, the Government of Japan performed a preliminary survey in July 1982 through Japan International Cooperation Agency (hereinafter referred to as JICA) and examined the Scope of Work that was agreed by both parties.

Based on the Scope of Work, JICA has carried out the survey during a period from November to December 1982. Accordingly the object of this investigation is quite clear.

That is, after grasping the overall background of the Project to carry out:

(1) market survey;

(2) investigation on raw materials, fuel, utilities, plant site, infrastructure, natural and social conditions;

(3) conceptional design of plant;

(4) environmental study;

(5) organization and manning plan;

(6) plant construction and operation plan;

(7) financial analysis and economic evaluation;

and then based on the overall consideration on the results obtained to judge the feasibility of the Project as well as to give recommendation for implementation of the Project.

The investigation was started with the departure of the raw material survey group from Japan on 21st November, 1982. Then market, financial, and economic study group and plant, environment, and infrastructure survey group departed from Japan on 6th and 11th December, 1982 respectively and commenced their works.

The field investigation progressed favourably throughout the whole period thanks to the positive cooperation extended by DMR and other Departments concerned and completed on 25th December. After returning home of the team, arrangement and analysis of the results of field investigation, laboratory test of samples collected at field and design of plant and quarries were carried out, and finally this report was completed in June 1983.

The field investigation is outlined as follows:

(1) Investigation of raw materials and fuels including oil shale

Investigation of oil shale deposit
Investigation of limestone deposit
Investigation of clay deposit
Investigation of additional raw materials
Chemical analysis in field
Investigation of mining and transportation of raw materials

(2) Site investigation

Investigation of proposed plant sites in Mae Sot area
Topographical survey at a favourable site

(3) Investigation of utilities

Investigation of electricity
Investigation of water

(4) Investigation of infrastructure

Investigation of roads and bridges
Investigation of harbour

(5) Environmental investigation

Investigation of environmental standard

(6) Market survey of cement and electricity
Investigation especially in the northern region

(7) Financial and economic study

Collection of necessary data and information

(8) Itinerary of Field Survey

The survey team carried out the field survey during a period of 35 days from November 21 to December 25, 1983.
The offices visited and places surveyed during the period are described as follows.

Remarks:

(1) Abbreviation of places

TY:	Tokyo,	BK:	Bangkok,	MS:	Mae Sot
TK:	Tak,	CM:	Chiang Mai,	LP:	Lam Pang
BT:	Ban Tak,	NS:	Nakhon Sawan,	PC:	Phichit
SB:	Sara Buri				

Day's order	Date	Day	Work description	Places
1.	Nov.21	(Sun)	Raw material survey group left Tokyo and arrived at Bangkok.	TY-BK
2.	Nov.22	(M)	Meeting at Japanese Embassy and JICA Bangkok Office	BK
			Meeting at Dept. of Mineral Resources (DMR)	BK
3.	Nov.23	(T)	1. Meeting with DMR on method for chemical analysis	BK
			2. Selection of oil shale sample for chemical analysis at DMR laboratory	BK
4.	Nov.24	(W)	1. Study of oil shale drilling core at DMR No.2 laboratory	BK
			2. Confirmation of oil shale sampling method for chemical analysis at DMR.	BK
5.	Nov.25	(Th)	1. Started sampling of oil shale sample from drilling core at DMR.	BK
			2. Members of raw material deposits survey proceeded to Mae Sot.	BK-MS
6.	Nov.26	(F)	1. Sampling of oil shale from drilling core (DMR)	BK
			2. Survey of limestone and oil shale deposits	MS
7.	Nov.27	(Sat)	1. Study of data	BK
			2. Survey of limestone deposit	MS

Day's order	Date	Day	Work description	Places
8.	Nov.28	(Sun)	1. Study of data	BK
			2. Chemical analysis of limestone	MS
9.	Nov.29	(M)	1. Sampling of oil shale from drilling core (DMR)	BK
			2. Survey of limestone deposit	MS
10.	Nov.30	(T)	1. Preparation of sample and chemical reagent (DMR)	BK
			2. Survey of limestone deposit	MS
11.	Dec. 1	(W)	1. Chemical analysis of oil shale ash (DMR)	BK
			2. Survey of limestone deposit	MS
12.	Dec. 2	(Th)	1. Chemical analysis of oil shale ash (DMR)	BK
			2. Survey of limestone deposit	MS
13.	Dec. 3	(F)	1. Chemical analysis of oil shale ash (DMR)	BK
			2. Survey of limestone deposit	MS
14.	Dec. 4	(Sat)	1. Chemical analysis of oil shale ash (DMR)	BK
			2. Survey of limestone deposit	MS
15.	Dec. 5	(Sun)	1. Study of data	BK
			2. Chemical analysis of limestone	MS
16.	Dec. 6	(M)	1. Market, financial, and economic survey group left Tokyo and arrived at Bangkok.	TY-BK
			2. Chemical analysis of oil shale ash (DMR)	BK
			3. Survey of oil shale deposit	MS

Day's order	Date	Day	Work description	Places
17.	Dec. 7	(T)	1. Meeting at Japanese Embassy, JICA Bangkok office, and DMR.	BK
			2. Chemical analysis of oil shale ash (DMR)	BK
			3. Survey of oil shale deposit	MS
18.	Dec. 8	(W)	1. Meeting at Statistical Dept., National Economic and Social Development Board, and Ceramic Material Division of DMR	BK
			2. Chemical analysis of oil shale ash (DMR)	BK
			3. Survey of oil shale deposit	MS
19.	Dec. 9	(Th)	1. Meeting at Association of Thailand Industries (Cement Association), Siam Cement Co., Ltd. (Bangkok Head Office), Office of the National Environment Board, and Japanese Embassy	BK
			2. Chemical analysis of oil shale ash (DMR)	BK
			3. Survey of oil shale deposit	MS
20.	Dec.10	(F)	1. Study of data	BK
			2. Arrangement of chemical analysis data	BK
			3. Chemical analysis of limestone	MS
21.	Dec.11	(Sat)	1. Preparation of chemical reagent at DMR laboratory	BK
			2. Chemical analysis of oil shale ash	BK
			3. Survey of silica sand deposit	MS
			4. Plant, environment, and infrastructure survey group left Tokyo and arrived at Bangkok.	TY-BK

Day's order	Date	Day	Work description	Places
22.	Dec.12	(Sun)	1. Study of data	BK
			2. Arrangement of chemical analysis data	BK
			3. Chemical analysis of limestone	MS
			4. Meeting of field survey	BK
23.	Dec.13	(M)	1. Members having stayed in Bangkok left Bangkok and arrived at Mae Sot.	BK-MS
			2. Survey of silica sand and clay deposits	MS
24.	Dec.14	(T)	1. General survey of raw material deposits, proposed plant site, and the Moei river basin	MS
25.	Dec.15	(W)	1. Meeting at Mae Sot Weather Station, Municipalty Office, and District Office	MS
			2. Survey of limestone deposit	MS
			3. Chemical analysis of oil shale ash	MS
26.	Dec.16	(Th)	1. Survey of oil shale deposit, Meeting at Sub Unit of Provincial Electricity Authority	MS
			2. Meeting at Mae Sot Weather Station, and Water Supply Office	MS
			3. Meeting at Provincial Office, Local Labour Office, Express Transportation Organization Tak Office, Irrigation Authority	TK
			4. A part team members proceeded to Chiang Mai through Tak.	MS-TK -CM

Day's order	Date	Day	Work description	Places
27.	Dec.17	(F)	1. Survey of silica sand deposit	MS
			2. Visit to and inspection of EGAT lignite quarry at Mae Moh	MS-LP
			3. Meeting at the North Part Dept. of Siam Cement Co. and a local contractor	CM
			4. Chemical analysis of oil shale ash	CM-BK
28.	Dec.18	(Sat)	1. Arrangement of data and packing of apparatus	MS
			2. Visit to Tak office of Thai Lignite Co., Ltd.	LP-TK
			3. Inspection of Ban Tak Stockyard of Thai Lignite Co., Ltd.	BT
			4. Visit to and inspection of Don Kui mine of Thai Gypsum Products Co., ltd., Phichit province.	PC-NS
			5. Inspection of the construction site in Chiang Mai	CM
			6. Chemical analysis of oil shale ash	BK
29.	Dec.19	(Sun)	1. Members of Mae Sot group proceeded to Bangkok.	MS-BK
			2. Inspection of Non Poh mine of Sitthickhok Mining Co., Ltd., Nakhon Sawan province	NS-BK
			3. Members of Chaing Mai group proceeded to Bangkok.	CM-BK
			4. Arrangement of chemical analysis data	BK

Day's order	Date	Day	Work description	Places
30.	Dec.20	(M)	1. Meeting at Financial Policy Office, Dept. of Highways, EGAT, and Bank of Thailand	BK
			2. Chemical analysis of oil shale ash	BK
			3. Inspection of oil shale drilling core at DMR No.2 laboratory	BK
31.	Dec.21	(T)	1. Meeting at Siam City Cement Co., Ltd. (Bangkok office), Port Authority, and JETRO Bangkok office	BK
			2. Meeting at Nam Sin Patana Ltd. Partnership, Thai Ohbayashi Corp., Ltd., Board of Investment, and NESDB, and Thai Lignite Co., Ltd. (Bangkok Office)	BK
			3. Chemical analysis of oil shale ash	BK
			4. Inspection of oil shale drilling core at DMR No.2 laboratory	BK
32.	Dec.22	(W)	1. Visit to Ta Luang plant of Siam Cement Co., Ltd.	SB
33.	Dec.23	(Th)	1. Meeting at DMR, Signing of the minutes of meeting	BK
34.	Dec.24	(F)	1. Meeting and reporting at Japanese Embassy, JICA Office, and DMR	BK
			Preparation for returning home	BK
35.	Dec.25	(Sat)	All the members left Bangkok and returned home	BK-TY

SECTION I GENERAL OBSERVATIONS

I-1 Premise for the Study

This report has been prepared under the following premises.

I-1-1 Cement Market

As cement market, domestic demand is considered to be main portion and a part of products is expected to be exported. It is assumed any change of affairs which reforms remarkably the present market conditions does not take place.

I-1-2 Raw Materials

As main raw materials, those occur in Mae Sot area are selected and as additional raw materials, those occur at places situated as close to Mae Sot as possible are chosen. The deposits mentioned below have been selected as deposits to be investigated.

(1) Limestone

Doi Din Chi deposit

(2) Clay

(i) Mae Sot deposit (oil shale and its overburden)

(ii) Deposit that occurs along the highway linking Mae Sot with Tak

(3) Siliceous material

Deposits that occur along the Moei river

(4) Iron ore

Non Poh deposit (Nakhon Sawan province)

(5) Gypsum

Don Kui deposit (Phichit province)

I-1-3 Fuel

(1) Oil shale

Mae Sot deposit

(2) Coal

Mae Ramat deposit

I-1-4 Utilities

(1) Electric power

The electric power necessary for the Project will be supplied from the power station which is planned to be constructed as an intergrated power plant in the Project, the excess electricity of which is distributed to general consumers in Mae Sot area through the Provincial Electricity Authority (PEA) in the Kingdom of Thailand.

(2) Water

The industrial water necessary for the Project is taken from the Moei river in the vicinity of the proposed plant site. Necessary piping facilities are provided by the budget for the Project.
The drinking water is supplied to the plant site by the Mae Sot Water Supply Office, Mae Sot.

I-1-5 Infrastructure

Roads

Access road to the plant from the provincial road and transportation road for limestone and oil shale are to be constructed in the Project.

I-1-6 Basic Data for Financial Analysis and Economical Evaluation

(1) Price and unit price

The price and unit price as of December 1982 have been used as the basis of calculation and no escalation has been taken into consideration.

(2) Financing

Loan/Equity ratio : 70/30

(3) Loan condition (long term)

Interest rate	10 %/yr
Repayment	12 years
Grace period	3 years
Construction interest	to be included in capital

(4) Loan condition (short term)

Interest rate	17 %/yr

(5) Project life 20 years

(6) Operation ratio of the plant

lst year	70 %
2nd year	80 %
3rd year	90 %
4th year and thereafter	100 %

(7) Annual working day 330 day/yr

(8) Taxes

(i)	Income tax	35 % of profit before tax
	Period of exemption	0 year
(ii)	Excise duty	6 % of net exfactory price
(iii)	Sales tax	10 % of excise duty

(9) Exchange rate

US$ 1 = Baht 23
US$ 1 = Yen 240

(10) Depreciation

	Double year (Yr)	Salvage value (%)
Civil and buildings	20	10
Vehicle and quarry equipment	5	0
Mechanical and electric equipment	10	10
Pre-operation expenses	10	0
Working capital	10	0

(11) Exfactory price of cement (bagged)

Oil shale cement	1,610 Baht/t
Mix cement	1,310 Baht/t

Note: Above prices include the excise duty and sales tax mentioned above:

That is:

(Exfactory price) = 1.066 x (Net exfactory price)

I-2 Summary of the Study

I-2-1 Cement Market and Power Demand and Supply

(1) Cement market

As for the cement market condition in the future, the domestic demand in Thailand seems to increase favourably by her development policy etc.

Increase of export can also be expected together with development of domestic energy resources.

Establishment of a cement plant meeting to the demand is required.

The demand in the northern region is about 10% of that of whole country. (Refer to II-1)

(2) Power demand and supply

All the electricity industries in Thailand is managed under the supervision of the Government.
Demand of electricity is expected to increase for 10 years' period from now on at an average rate of 9.2%/year, and based on this increase a long term electricity development plan has been made.

Per capita electricity consumption at Mae Sot is somewhat lower than the average value of whole country, but it is expected to reach the same in the near future.
At present electricity consumed in Mae Sot is supplied from a substation in the city of Tak. (Refer to II-2)

I-2-2 Natural and Social Conditions of Mae Sot

(1) Natural conditions

Mae Sot area is located on the west side of Tak province and adjoines the boundary with Burma.

The area is intermontane basin situated about 550 km to the north of Bangkok.

In the basin, streams are generally slow moving and in the mountainous areas, hard wood such as teak and yang predominates.

The climate of the area is tropical featured by the seasonal monsoons. (Refer to III-1)

(2) Social conditions

The northern region of the country is rather undeveloped area in the Kingdom of Thailand.

Among the region, Mae Sot has no large industries and is low in population density and thus remains to be one of the undeveloped areas.

The population of Amphoe Mae Sot is about 68,000. Main industry is agriculture. There are some stone crushing plants, rice-cleaning mills, saw mills etc. A zinc mine is under operation and the zinc ore will be supplied to a zinc refinery to be established in Tak in the near future. Many stores line the shopping district of Mae Sot town, and small-scale commerce is actively practiced in the area.

Electricity and water supply have been completed. As to the transportation, Mae Sot is linked with the city of Bangkok by a primary and secondary highway. (Refer to III-2)

I-2-3 Assessment of Raw Materials and Raw Materials Supply

(1) Assessment of raw materials

(a) Limestone

The limestone of Doi Din Chi diposit contains 53% of CaO (principal composition) on the average and the content of harmful compositions are lower than the allowable limit and so this limestone is of very good quality for manufacturing portland cement.

Minable reserves is 31.7 million tons which will last for about 51 years for the Project.

(b) Oil shale

The oil shale of Ban Huai Kalok deposit occurs in vast area and several layers.
Its calorific value at the proposed area for the Project is 700 kcal/kg on the average. Oil shale with a calorific value of about 940 kcal/kg, which is suitable as fuel for fluidized bed boiler and kiln precalciner, can be obtained by selective mining.

In the portion other than burnable portion, main components such as SiO_2, Al_2O_3, Fe_2O_3, CaO are contained in proper proportion and content of harmful components is low in quantity.

Oil shale ash generated by low temperature combustion in the fluidized bed boiler shows appropriate hydraulic properties for making good quality oil shale cement by mixing with cement clinker in a proper ratio.

It is very fine in particle size and high in reactivity and so suitable as clayey raw material.

Oil shale at Mae Sot area is reported to distribute extending over about 200 km^2 and have reserves of about 18.6 million tons.

Minable reserves of about 100 ha (1 km^2) at proposed Ban Huai Kalok area is 13.4 million tons which corresponds to requirement of 21 years of the Project. Oil shale deposited outside of or deeper part of inside of this area is considered as a future potential.

(c) Clayey material

Since oil shale itself is used as clayey material in the Project, no other clayey material is required at present.
According to investigation performed for reference, marl and calcarious stone occur mainly as overburden and intercalation of oil shale deposit and amount to about 50 million tons. In other area clayey materials also occur.

These clayey materials are suitable in quality as raw material of cement.

(d) Siliceous material

Silica sand scattered along the Moei river is suitable in quality as raw material of cement.
About 370 thausand tons of reserves were proved. In the Project, no silica sand is used at the initial stage.

(e) Iron ore

Hematite and magnetite deposits at Non Poh area in Nakhon Sawan province are suitable both in quality and quantity for the Project. Fe_2O_3 content in the ore exceeds 40%. For the Project, this iron ore will be procured.

(f) Gypsum

Gypsum deposit at Don Kui area in Pichit province is suitable both in quality and quantity for the Project. SO_3 content of gypsum is 46.5%. For the Project, this gypsum will be procured. (Refer to IV-1)

(2) Raw material supply

(a) Limestone

Doi Din Chi quarry is to be developed.
Limestone is exploited by drilling and blasting and after being broken down to small size, transported by dump trucks to the plant and then crushed.

(b) Oil shale

Ban Huai Kalok quarry is to be developed.
As described before, oil shale occurs in several layers under ground.
At first the deposit will be exploited to the depth of 30 m.

The overburden of about 20 m thick is removed at first and oil shale underlain is exploited by means of selective mining. Overburden and low quality oil shale are refilled into old pit directly or after piled up at a temporary dump area.

Oil shale of good quality is transported to the plant by dump trucks.
The exploitation is performed applying bench cut system.

(c) Iron ore and gypsum

Both materials are to be procured.

(d) Clayey and siliceous material

Although both of clayey and siliceous materials are not necessary, these materials are to be procured when necessary. (Refer to IV-3)

I-2-4 Assessment of Fuel

(1) Domestic coal (lignite)

Coal of Mae Ramat quarry is favourable in terms of quality, price, and transportation distance as fuel for kiln burning. The coal can be procured in the Project.

In order to make both quality and supply stable, partial use of imported coal is considered. (Refer to V-1)

(2) Oil shale

As described in I-2-3, oil shale of Ban Huai Kalok deposit is suitable as fuel for fluidized bed boiler for power generation and for kiln precalciner. (Refer to V-2)

I-2-5 Utilities and Infrastructure

(1) Electric power

All amount of the electric power necessary for the Project is generated and supplied by the industry-owned thermal power plant which is constructed within the integrated cement plant complex. The excess of generated power being assumed to be 1.5 MW is sold to general consumers in the Mae Sot area through the Provincial Electricity Authority.
The excess electric power is distributed to consumers in the Mae Sot area from the plant site with the same voltage as the existing distribution line of 22 kV. Since electric loads in the quarry are small, the diesel power generating equipment is installed in the quarry in stead of supplying

electricity from the plant site. In addition, the emergency diesel power generating equipment is installed in the industry-owned thermal power plant both for start-up and emergency. (Refer to VI-1)

(2) Water

The industrial water is taken from the Moei river, and the storing pond and cooling equipment for the industrial water is provided in the plant site, while the drinking water is supplied by the Mae Sot Water Supply Office. (Refer to VI-2)

(3) Road condition

In the Kingdom of Thailand, construction of road network has been implemented step by step and the road network is playing an important role in transportation both of passenger and cargo.
The courses Bangkok - Tak - Mae Sot and Mae Sot - Tak - Lam Pang -Chiang Mai are linked by national highways. Therefore the construction of short access road around the plant and transportation road of raw materials are all required in the Project. (Refer to VI-3)

(4) Harbours

Two ports, i.e. Bangkok port and Sattahip port are availabe in the kingdom of Thailand.
Unloading of machinery and equipment, construction material and raw materials for the Project is to be carried out at Bangkok port with sufficient facilities. (Refer to VI-4)

(5) Communication facilities

Communication between Mae Sot, nearby town of the plant, and Bangkok or other cities is available. (Refer to VI-5)

(6) Power distribution facilities

For the purpose of supply of the excess electric power to the Mae Sot area from the plant site, the feeder exclusively used for the purpose is provided in the power plant and one circuit of the power distribution line with the voltage of 22 kV to the Mae Sot area is to be constructed. (Total length is approx. 10 km)

Since the diesel power generating equipment will be planned to be provided in the quarry, no power distribution facilities are necessary. (Refer to VI-6)

I-2-6 Conceptional design of plant

Examining various factors in detail, conceptional design of the plant has been carried out as follows.

(1) Outline of process

The purpose of the Project is to produce cement while generating electricity with an effective use of oil shale. Power generating process consists of a fluidized bed boiler and a generator. Cement process is composed of a dry process kiln equipped with NSP (New Suspension Preheater) as main equipment.

Oil shale combustion residue discharged from the fluidized bed boiler is utilized as raw material for cement manufacturing and mixing material for cement.

In this process, oil shale is utilized efficiently and the process itself is of quite high efficiency. (Refer to VII-1)

(2) Production capacity

Taking account of various factors such as demand and supply of cement, reserves of raw materials, the capacity of the Project is set at 462,000 t/yr on clinker base and 808,500 t/yr on cement base including mix cement. The capacity of power generation is set at 12.5 MW. The future expansion of all the facilities has been taken into account in the plant layout. (Refer to VII-2)

(3) Selection of plant site

A hilly land situated in the suburbs of Mae Sot is selected as plant site. The place is located close to the limestone deposit and the oil shale deposit both of which are main raw materials, and the place is also convenient in shipping the products. (Refer to VII-3)

(4) Standards, laws and regulations

Standards and laws of the Kingdom of Thailand are to be observed. As to the standards of machinery and equipment, foreign standards internationally accepted may be used. (Refer to VII-4)

(5) Cement quality

The kinds of cement to be produced in the Project are oil shale cement and mix cement derived from on the oil shale cement. The former corresponds to Type I (ordinary portland cement) stipulated in TIS-15 (1974) and the latter mix cement stipulated in TIS-80 (2517).
The products of good quality can be produced with raw materials and through the process of the Project. Low strength cement that is used for road bed may be produced in the future. (Refer to VII-5)

(6) Supply plan of fuel

(a) Domestic coal

The domestic coal is to be procured from Thai Lignite Co., Ltd. The coal is transported from the Mae Ramat quarry by trucks through temporary storage to the plant.

(b) Imported coal

Coal imported from overseas countries is unloaded at Bangkok port and transported by trucks to the plant.

(c) Oil shale

Refer to I-2-3 Raw material supply. (Refer to VII-6)

(7) Distribution plan of products

The main market of the products of the Project is the northern region of Thailand.
The products are transported in bulk or bag by trucks to market place and delivered to users through dealers. (Refer to VII-7)

(8) Outline of plant design

The main equipment of the plant are selected considering and examining in detail such items as quality of raw material and fuel, process, and social and natural conditions of the Mae Sot area where plant is to be constructed. (Refer to VII-8)

(9) Specification of main equipment

The specification of main equipment are determined based on design philosophy mentioned above. (Refer to VII-9)

(10) Flow sheet and layout

(Refer to DWG. No. P-01, P-02, P-03 and VII-10)

(11) Plan for company house

Company houses of managing staff and engineers that accommodate 20% of all employee and welfare facilities are planned. (Refer to VII-11)

I-2-7 Environmental study

(1) Environmental Standards in Thailand

Environmental Quality Standards and National Environmental Quality Act are outlined. (Refer to VIII-1)

(2) Selection of pollution control equipment

Considering the standards mentioned above and other necessary conditions, the pollution control equipment are to be selected and designed.

I-2-8 Organization and Manning Plan

(1) Organization

The plant is managed by the board of directors.
The plant organization composed of four divisions i.e. production, mining, business, and administrative forms a standard organization. (Refer to IX-1)

(2) Manning plan

Manning plan is shown in Table 1-2-1. (Refer to IX-2)

Table 1-2-1 Manning Plan (persons)

Section	Man power requirement
Plant	341
Quarry	113
Total	454

I-2-9 Construction of Plant and Operation Plan

(1) Procurement and transportation of machinery and equipment and construction materials

The machinery and equipment should be procured taking account of their durabitily, interchangeability and standardization.
Almost all of construction materials are available in Thailand.
Among the machinery and equipment and construction materials, those to be imported are unloaded at Bangkok port and transported to the plant and those to be procured in Thailand are transported from Bangkok district to the plant.
No problems are foreseen in the transportation route. (Refer to X-1)

(2) Construction plan of plant

For the implementation of the Project, employment of a well experienced consultant is necessary.

Tentative schedule of the Project implementation.

Selection of consultant	:	about 9 months
Selection of contractor	:	about 1 year and 3 months
Construction works	:	about 3 years
Total	:	about 5 years

(Refer to X-2)

(3) Operation plan of plant

Operation ratio (i.e. capacity utilization) of the plant at first year, second year, third year, forth year and thereafter is assumed to be 70, 80, 90 and 100% respectively. (Refer to X-3)

I-2-10 Total Capital Requirement and Financing Plan

(1) Total capital requirement

The total capital requirement is shown in Table 1-2-2.

Table 1-2-2 Total capital Requirement

(1,000 Baht)

	Foreign portion	Local portion	Total
Fixed capital	1,936,568	1,159,800	3,096,368
Working capital	-	105,259	105,259
Total	1,936,568	1,265,059	3,201,627

(Refer to XI-1)

(2) Financing plan

Capital	:	30% of Total Fund
Long term loan	:	70% of Total Fund
Short term loan	:	to be borrowed when necessary

(Refer to XI-2)

I-2-11 Financial Analysis

(1) Premise of financial analysis

Refer to I-1 and XII-1

(2) Disbursement schedule of total capital requirement

Table 1-2-3 Annual Disbursement

(1,000 Baht)

Year	-3	-2	-1	Total
Amount	724,371	1,214,372	1,262,884	3,201,627

(Refer to XII-2)

(3) Sales plan

Production at full operation

Oil shale cement	323,400 t/yr
Mix cement	485,100 t/yr
Electric power	14,256,000 kWh/yr

(Refer to XII-3)

(4) Production cost

Table 1-2-4 Production Cost

Cost item	Baht/t-cement	Baht/yr
Direct cost	204.397	165,255,000
Fixed cost	150.757	121,887,000
Interest, Depreciation*	584.053	472,207,000
Total	939.207	759,349,000

Note: * Figure of 4th year

(Refer to XII-4)

(5) Financial analysis method

As method for profitability analysis, FIRR has been adapted. (Refer to XII-5)

(6) Results of financial analysis

Table 1-2-5 FIRR of Base Case

Financial internal rate of return	Result
FIRR on I (before tax)	19.8 %
FIRR on I (after tax)	15.0 %
FIRR on E	26.9 %

Judging from the above table, the profitability of the Project is high. (Refer to XII-6)

(7) Sensitivity analysis

Sensitivity analysis has been made on the following factors to the base case. Construction cost, Production cost, Operation ratio, Interest, Other expenses. (Refer to XII-7)

I-2-12 Case study - change in power plant capacity

Financial analysis has been carried out for the cases in which capacity of power generation etc. are changed.
The study shows that the base case is most profitable. (Refer to XIII-1)

I-2-13 Economic analysis

(1) Economic benefit and cost

Benefit: Increase of cement production, Increase of power supply, Construction of company house, Development of infrastructure, Increase of employment oportunity, Effect extended to local industries.

Cost : Initial expenses, Raw materials, Salaries and wages

(Refer to XIV-1)

(2) Economic internal rate of return (EIRR)

EIRR of the Project is calculated to be 21.4%. This value is higher than the cut-off rate of EIRR which is estimated to be 12 - 18% in Thailand. Thus the Project is quite favourable from economic point of view. (Refer to XIV-2)

(3) Tax

Through the implementation of the Project, expected tax income for 20 years amounts to 5.2 billion Bahts. (Refer to XIV-3)

(4) Impact of Project on foreign currency balance

The effect of the Project on foreign currency balance has been studied. (Refer to XIV-4)

I-2-14 Conclusion and Recommendation

(1) Conclusion

As a result of examination made based on premise described in I-1, the Project that is the establishment of an integrated power and cement plant using oil shale at Mae Sot is proved to be feasible in terms of technical and economic points. (Refer to XV-1)

(2) Recommendation

Recommendation is made on the following items. Construction fund, Land aquisition, Drilling, Pilot plant test of fluidized bed boiler, Topographic survey, Establishment of products standard, Negotiation for long term procurement, Employment of technical consultant, Estimation of construction cost, Arrangement for electricity supply, Project implementation body.

SECTION II CEMENT MARKET AND POWER DEMAND AND SUPPLY

II-1 Cement Market

II-1-1 Change in Cement Demand and Supply

(1) Kingdom of Thailand

At present, three cement companies, i.e. Siam Cement Co. (SCC), Jalaprathan Cement Co., (JCC) and Siam City Cement Co. (SCCC) have been producing cement in Thailand whose market share are 69%, 10% and 21% respectively.

In Thailand, the cement produced in its country was mainly used for local consumption and only in case of surplus it was exported.

However, during the year between 1970 and 1974 when cement price showed a steep rise in international market, each cement manufacturer was attracted by export market and concentrated on export.

Consequently, cement export amounted to, for example, record of 914,000 tons which caused the shortage of cement in domestic market and so a sudden rise in cement price. The successive Government controlled the cement market price as the countermeasure but in vain. In the second half of 1980, the Government announced the change of price control system.

In the meantime, the shortage of cement went on, and the country that had been exporting 20% of domestic product rolled down to cement importing country, and imported 3,000 million Baht of cement from 1978 to 1981.

But this import didn't solve the problem and finally the price control of cement had to be abolished.

As long term measures, policies that increase cement production capacity was studied.

Complying with the policies, the said three cement companies have commenced expansion of their production facilities and have come to own the capacity for exceeding domestic consumption.

This development is shown in Table 2-1-1 Production, Import, Export, and Consumption of Cement in Past years.

Table 2-1-1 Production, Import, Export and Consumption of Cement (No. 1)

[1,000 ton]

Year	Production	Import	Export	Consumption		
				Annual	Moving average	Per capita (kg)
1920	24	7	2	29	-	3
21	26	8	2	32	-	3
22	20	8	1	27	28	3
23	20	8	4	24	30	2
24	25	9	4	30	32	3
25	30	12	5	37	38	4
26	39	8	6	41	46	4
27	46	13	3	56	55	5
28	55	12	2	65	64	6
29	62	16	2	76	69	7
30	68	15	-	83	69	7
31	58	8	-	66	67	5
32	52	6	1	57	64	5
33	44	10	-	54	62	4
34	51	10	-	61	66	5
35	(60)	11	-	(71)	72	(5)
36	(75)	13	-	(88)	80	(6)
37	(80)	6	-	(86)	-	(6)
38	(90)	2	-	(92)	-	(6)
47	59	1	1	59	-	3
48	83	1	-	84	-	5
49	128	-	-	128	136	7
50	165	16	-	181	180	10
51	228	1	-	229	230	12
52	247	31	-	278	290	14
53	291	41	1	332	342	17
54	383	48	-	431	378	22
55	387	56	5	438	410	22
56	396	25	9	413	437	20
57	404	48	15	437	447	21
58	458	22	16	464	445	22
59	482	16	17	481	461	22

Table 2-1-1 Production, Import, Export and Consumption of Cement (No. 2)

[1,000 ton]

Year	Production	Import	Export	Consumption		
				Annual	Miving average	Per capita (kg)
1960	440	14	25	429	538	16
61	646	6	156	496	621	18
62	956	35	178	821	719	29
63	999	20	142	877	871	30
64	1,060	9	96	973	1,083	33
65	1,250	39	100	1,189	1,310	39
66	1,476	262	45	1,553	1,577	49
67	1,736	316	28	1,960	1,858	60
68	2,170	107	35	2,208	2,116	66
69	2,403	24	48	2,379	2,313	68
70	2,630	2	151	2,482	2,449	73
71	2,771	1	237	2,534	2,573	72
72	3,378	1	735	2,643	2,700	74
73	3,706	0	876	2,829	2,850	77
74	3,923	2	914	3,010	3,103	74
75	3,959	3	726	3,234	3,525	79
76	4,422	3	623	3,799	4,034	90
77	5,063	3	309	4,754	4,698	107
78	5,044	351	22	5,374	5,351	116
79	5,122	1,228	22	6,328	5,863	137
80	5,355	937	10	6,498	6,181	138
81	6,362	108	92	6,362	6,414	133
82	6,545	16	161	6,342		130
83	6,899	-	495	6,540		132

The operating rate of cement plants in Thailand is shown in Table 2-1-2.

Table 2-1-2 Operating Rate of Cement Plant in Thailand

(Capacity/production 1,000 t,
Operating Rate %)

Year	Capacity	Production	Operating Rate
1971	3,460	2,711	78.4
1972	3,460	3,378	97.6
1973	3,800*	3,706	97.5
1974	4,000*	3,923	98.1
1975	4,000*	3,959	99.0
1976	5,000	4,422	88.4
1977	5,000	5,063	101.3
1978	5,000	5,044	100.9
1979	5,100	5,122	100.4
1980	5,400	5,355	99.2
1981	7,150	6,362	89.0
1982	8,620	6,545	75.9
1983	8,880	6,899	77.7

Note: * shows the estimated capacity

Then, domestic consumption by region is shown in Table 2-1-3.

Table 2-1-3 Cement Consumption by Region

(1,000 t)

Year	Bangkok Metropolis	Central	Northern	North-eastern	Southern	Total
1981	3,050	1,273	679	724	636	6,362
1982	2,793	1,427	743	797	582	6,342
1983	2,872	1,473	762	823	610	6,540

Source: Siam Cement Co., Ltd.

Note * Estimated figures

(2) Northern region

Cement demand and supply in the northen region that is related to the Project specially is described hereinafter. At present no cement plant is operated in the northern region and the nearest plant to the northern region is Ta Kli plant of Jalaprathan Cement Co. located in Nakhon Sawan province. Therefore cement used in the region is transported from outside.

Market share in the northern region of the three companies in the last five years is shown in Table 2-1-4.

Table 2-1-4 Market Share in Northern Region

(%)

Company	1977 ~ 1981	1982
SCC	60	55
JCC	30	20
SCCC	10	20

As stated above, JCC, who has Ta Kli plant and is advantageous in transportation, has a relatively large share but SCC still has the highest share.

Next, the consumption in past years in northern region is shown in Table 2-1-5.

Discrepancy in figures both in Table 2-1-3 and Table 2-1-5 may be caused by the method in summing up.

Table 2-1-5 Cement Consumption in Northern Region

(1,000 t)

Year	1978	1979	1980	1981	1982	1983
Consumption	572	619	618	741	785	814*

* estimated consumption

Consumption in the northern region is shown by province and by users in Table 2-1-6 and Table 2-1-7 respectively.

Table 2-1-6 Cement Consumption by Province

(%)

Province	Chiang Mai	Nakhon Sawan	Lampang	Phitsanulok	Chiang Rai	Sukhothai	Others	Total
Share	30	15	15	8	6	5	1 ~ 3	100

Table 2-1-7 Cement Consumption by Users

(%)

End user	Share
Housings	60
Concrete products	25
Roads etc. (public)	15

II-1-2 Demand Forecast of Cement

II-1-2-1 Demand forecast of cement in Thailand

Demand forecast of cement was made by trend analysis, correlation analysis, estimation based on similar cases and the forecast prepared in Thailand.

(1) Trend analysis

Trend analysis is made by using the formula such as the linear exponential, Gompertz curve, quadratic, and cubic equations.

Respective equations and correlative coefficients are shown below, of which the most agreeable is the cubic equation.

As basic data for trend analysis, the moving average in five years of domestic demand during the period from 1960 to 1983 was used.

Note: Demand in 1983 is the estimated figure.

(i) The linear exponential equation

$y = 831.0791 \times 1.1136\ t$ ①

$r = 0.99163$

where, y: estimated annual cement consumption (tons in thousands)
t: years elapsed from 1962
r: correlative coefficient

(ii) The Gompertz curve equation

$y = 59.6496 \times 17.9563^{1.0256\ t}$ ②

$r = 0.98862$

(iii) The quadratic equation

$$y = 876.5275 + 51.8288\ t + 11.5587\ t^2 \qquad (3)$$

$r = 0.99068$

(iv) The cubic equation

$$y = 422.2336 + 283.6360\ t - 15.3758\ t^2 + 0.8551\ t^3 \qquad (4)$$

$r = 0.99326$

(2) Correlation analysis

Correlation analysis is carried out on the basis of the simple correlation between the moving average in five years of domestic demand and the real GDP (Gross Domestic Product) based on 1972.

$$y = -2545.62 + 30.0577\ x \qquad (5)$$

$r = 0.996227$

where, y: estimated annual cement consumption (tons in thousands)
x: real GDP (Baht in million)

According to the fifth five year plan, the real economic growth between 1981 and 1986 is estimated to be 6.6% p.a.

The annual cement consumption is estimated under the condition that this growth rate is maintained by 1992.

Actual records of GDP are shown in Table 2-1-8.

Table 2-1-8 Actual Record of GDP

Year	Population (person)	GDP present valve		GDP value of 1972		
		GDP (Baht)	per Capita (Baht)	GDP. (Baht)	per capita (Baht)	Growth rate (%)
1972	38,359,008	8,231*	213*	168,324	4,388	
1973	39,950,306	10,827*	273*	180,106**	4,508**	7.0**
1974	41,334,152	13,485*	331*	192,714**	4,662**	7.0**
1975	42,391,454	14,815*	354*	206,204**	4,864**	7.0**
1976	43.213,711	16,609*	387*	221,225	5,119	7.3
1977	44,272,693	19,652*	446*	237,173	5,357	7.21
1978	45,221,625	469,952	10,390	261,097	5,792	10.09
1979	46,113,756	556,240	12,060	276,907	6,005	6.06
1980	46,961,338	684,930	14,590	392,852	6,236	5.76

Note: * GDP in million US$
** Estimated value

(3) Estimation based on similar cases

It is very difficult to make a fair comparison when considering several different countries because they are not alike in terms of their stage of economic development, historical background and geological factors. However, to provide cement consumption growth data on similar case, we have selected some neighboring developing countries in Asia for ten year period from 1970 to 1980. Their annual average rate of cement increase was as follows:

People's Republic of China	10.6%
Hong Kong	12.2%
Republic of Indonesia	16.4%
Malaysia	11.6%
Republic of Korea	9.5%
Republic of Singapore	6.2%

According to the investigation made in Thailand so far, MOI (Ministry of Industry) estimated that average annual growth rate in the period from 1982 to 1990 is 5.3% and EGAT estimated that average annual growth rate in the period from 1982 to 1987 is 7.2%.

The demand forecast prepared by MOI and EGAT are shown in Table 2-1-9.

Table 2-1-9 Cement Demand Forecast in Thailand

(1,000 t)

Year	Forecast by Ministry of Industry	Forecast by EGAT
1982	7,118	8,450
1983	7,577	8,760
1984	8,036	9,540
1985	8,495	10,310
1986	8,954	11,030
1987	9,431	11,960
1988	9,872	
1989	10,331	
1990	10,791	

(4) Estimated results

From the above equations, future cement consumption can be estimated as shown in Table 2-1-10. (Please refer to Fig. 2-1-1 Cement Demand Forecast in Thailand.)

Fig. 2-1-1 Cement Demand Forecast in Thailand

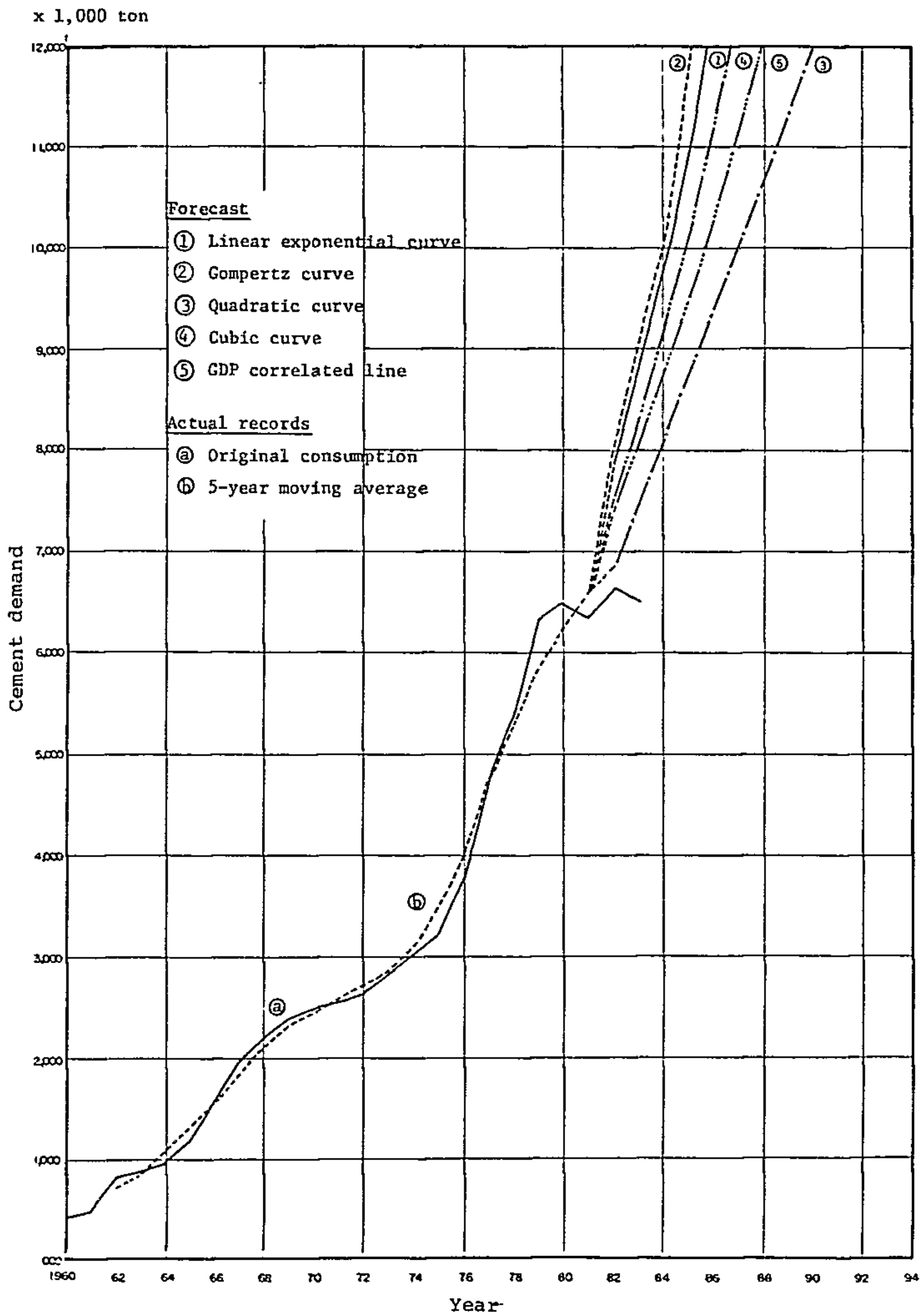


Table 2-1-10 Cement Demand Forecast by Respective Methods

(1,000 t)

	①	②	③	④	⑤	⑥ per capital (kg)
1982	7,954	8,076	7,062	7,517	7,457	144
1983	8,857	9,156	7,611	8,325	8,117	152
1984	9,863	10,415	8,183	9,216	8,821	160
1985	10,982	11,885	8,778	10,193	9,571	169
1986	12,230	13,608	9,396	11,264	10,371	177
1987	13,618	15,635	10,038	12,431	11,223	185
1988	15,165	18,029	10,702	13,702	12,132	193
1989	16,887	20,864	11,390	15,080	13,101	201
1990	18,804	24,236	12,100	16,571	14,134	209
1991	20,939	28,261	12,834	18,180	15,234	217
1992	23,317	33,085	13,591	19,912	16,408	225

Among the above estimation we have adopted the forecast calculated by the equation ③ as the basis for this report.

The reasons are as follows:

- Among the equations whose correlative coefficient (r) is greater than 0.99, the growth rate of equation ③ is the lowest which is rather conservative.

- According to the equation ③ the growth rate of ten years period from 1982 to 1992 is 6.8% on the average which is lower than or the same with those of last ten years in the neighboring countries.

- The growth rate is in the midway of demand forecast prepared by the concerned authorities in Thailand.

- Per capita consumption using equation ③ is calculated as shown in the column ⑥ of Table 2-1-10.

  This per capita consumption is not entirely unrealizable because it is the third highest in those of ASEAN countries and fairly lower than those of developed countries shown in Table 2-1-11.

II-1-2-2 Demand forecast of cement in northern region of Thailand

The demand forecast of cement in northern region was conducted mainly based on the trend analysis and the results of demand forecast in all region in Thailand are incorporated to the forecast.

(1) Trend analysis

Trend analysis is made by using the linear exponential, quadratic exponential, linear and quadratic equations.

Respective equations and correlative coefficients are shown as below.

As basic data for trend analysis, the cement consumption in northern region during the period from 1978 - 1983 was used. (see Table 2-1-4)

Note: The consumption in 1983 is the estimated figure.

(i) The linear exponential equation

$$y = 525.348 \times 1.079^{t} \qquad ①'$$

$$r = 0.91984$$

where, y: estimated annual cement consumption (tons in thousands)
t: years elapsed from 1978
r: correlative coefficient

(ii) The quadratic exponential equation

$$y = 527.432 \times 1.076^{t} \times 1.000^{t^2} \quad ②'$$

$$r = 0.89323$$

(iii) The linear equation

$$y = 508.400 + 52.314\ t \quad ③'$$

$$r = 0.92071$$

(iv) The quadratic equation

$$y = 523.400 + 41.064\ t + 1.607\ t^2 \quad ④'$$

$$r = 0.89742$$

(2) Results of forecast

From the above equations, the future cement consumption in the northern region is forecasted as shown in Table 2-1-12. (Please refer to Fig. 2-1-2 Cement Demand Forecast in Northern Region)

Fig. 2-1-2 Cement Demand Forecast at Northern Region in Thailand

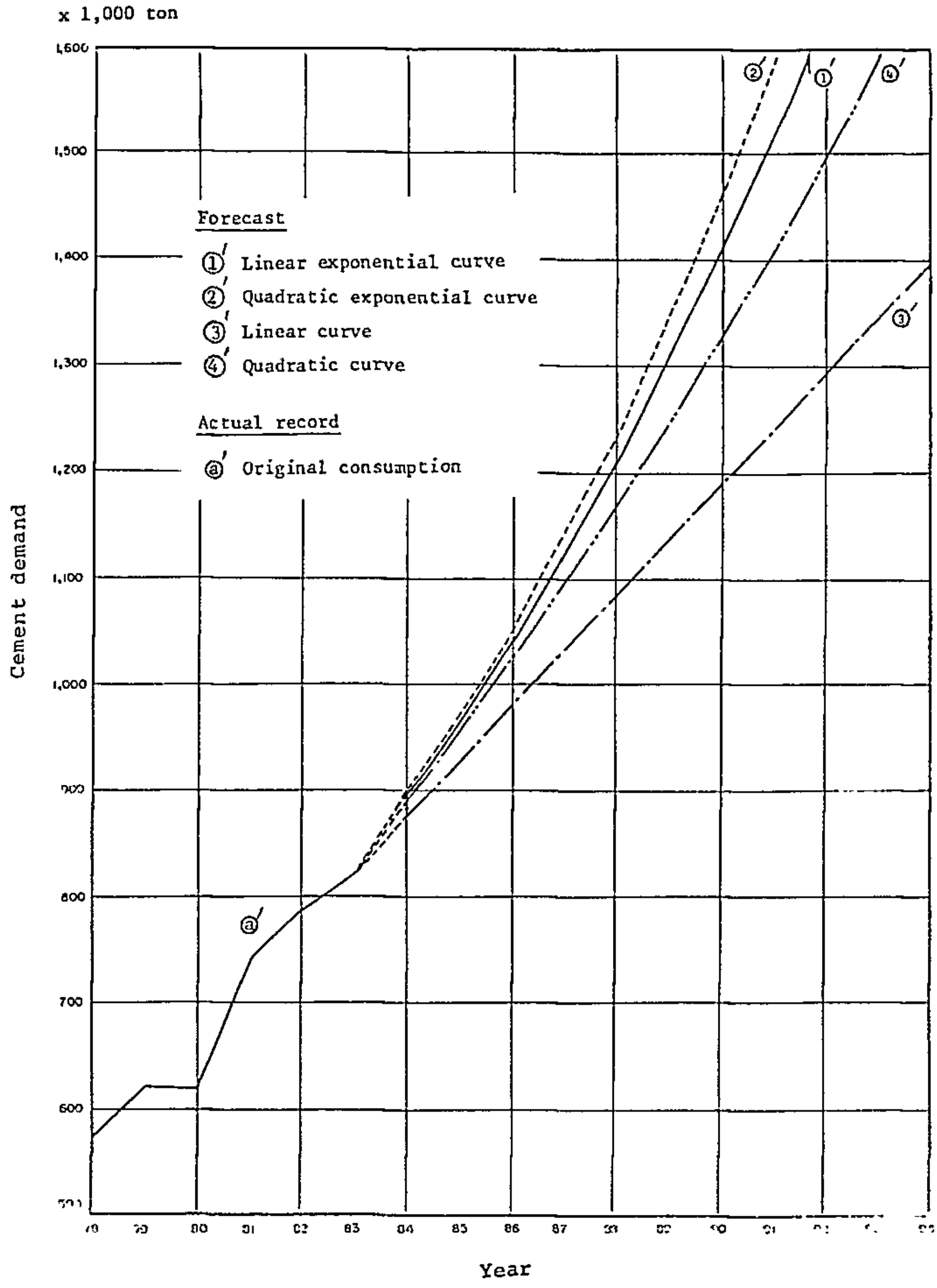


Table 2-1-11 Per capita Cement Consumption in Asian Countries

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Thailand	30	33	39	49	60	66	68	73	72	74	77	74	79	90	107	116	137	138	133	130
Indonesia	5	6	7	5	5	6	8	10	12	13	17	20	21	21	22	26	27	36	44	
Malaysia	94	98	92	74	62	70	65	66	103	117	130	141	159	151	160	180	203	227	-	
Singapore				203	370	451	366	372	426	504	514	541	549	646	557	544	582	587	682	
Philippines	40	44	50	52	67	75	70	66	67	73	71	66	823	81	73	73	77	80	72	
Hong Kong	286	328	350	285	167	163	190	221	321	289	289	301	272	357	445	512	473	643	650	
Taiwan	115	120	142	149	180	231	252	252	279	313	354	391	405	496	523	591	662	752	684	
South Korea	40	42	52	65	93	111	138	169	190	174	215	229	243	250	305	403	424	345	321	
Japan	290	319	313	361	401	447	477	528	544	616	715	639	547	572	608	689	705	704	659	
Nepal	4.2	4.4	7.9	8.7	3.4	6.1	6.6	8.7	7.6	7.8	8.9	12.9	17.1	12.1		8	9	10	-	
India	20	20	22	22	22	22	25	26	27	28	26	24	26	29	29	32	30	30	33	
Bangladesh							(9)	2	2	2	3	4	4	4	(5)	5	8	10	10	-
Pakistan	19	26	19	19	19	24	24	44	40	39	53	59	47	43	44	55	52	55	-	
Sri Lanka	26	24	25	29	25	34	34	31	32	31	35	34	26	27	28	40	45	65	-	
Afghanistan	6	9	11	11	8	5	4	6	5	4	5	4	4	7	15	15	26	-	-	
Burma	8	7	5	6	7	7	7	6	6	7	7	5	6	7	7	7	11	8	7	-
Laos				15	18	17	14	16	21	14	9	9	10			17	17			
Cambodia				33	42	26	24	18	5											
Vietnam	27	26	34	90	75	79	69	49	63	49	42	20	22			23	23	26		
China	12	15	22	24	26	29	34	39	47	53	49	44	54	64	68	73	78	80	80	
Burnei	120	186	208	337	375	420	474	450	465	484	397	545	798	644	726	490	310	458	458	
Macao	31	85	100	122	56	46	63	70	114	147	240	155	100	113	175	182	315	341	480	

Table 2-1-12 Cement Demand Forecast in Northern Region

(1,000 t)

	①'	②'	③'	④'
1984	894	898	875	890
1985	965	972	927	955
1986	1,041	1,053	979	1,023
1987	1,123	1,142	1,032	1,095
1988	1,211	1,239	1,084	1,170
1989	1,307	1,346	1,136	1,248
1990	1,410	1,463	1,188	1,329
1991	1,521	1,592	1,241	1,413
1992	1,641	1,734	1,293	1,501

Among the above forecast results, we have adopted the forecast calculated by the equation ①'.

The reasons are as follows:

- According to the equation ①', the yearly growth rate of 8 years period from 1984 to 1992 is 8.1 % on the average which is little higher than those of last 5 years which shows 7.3 % p.a.

- The demand of cement in northern region will be increased rapidly than the average growth rate in Thailand due to the fact that the northern region in Thailand will require more basic materials to achieve the economic development as composed with the average requirement in Thailand.

II-1-2-3 Export potentiality

As stated before, during the peak time from 1961 to 1977 Thailand was exporting more than 20% of her cement production. The cement export dropped later to meet the domestic demand, but the export potentiality will be recovered in case the production capacity in the country is expanded.

In addition to that, energy sources such as natural gas and petroleum which have been developed recently will increase the export competitive power in cement price together with the geographical advantage. Therefore it seems that at least 7% of cement production in Thailand can be exported.

The cement export in 1982 and 1983 (estimate) account for 2.5% and 6.6% of all the cement production respectively. (Refer to Table 2-2-1)

II-1-2-4 Others

(1) Demand for low strength cement

For construction of road, crushed stone layer is used for road base. In Thailand, especially in the northern region, the crushed stone is in short supply and in this case concrete layer is used in place of crushed stone layer. Low strength oil shale cement can be used as the cement for this concrete.

This low strength oil shale cement is prepared by mixing cement clinker and oil shale combustion residue from fluidized bed boiler in the ratio of 30 to 70 and is useful as road basis material. This kind of cement is sometimes called as "mortar binder".

The demand of this material in the northern region of Thailand is estimated as follows.

(i) Forecast for road construction in Thailand

According to the third five years plan for road construction (1982 - 1986) the road under planning is totally 12,000 km.

The amount of road constructed in the northern region is usually 37% of that in the whole country.

The road to be constructed in the northern region by the five years plan mentioned above is estimated to be:

12,000 x 0.37 = 4,440 km

The road standards of Thailand specifies three kinds of road, i.e. first class highway, second class highway, and provincial road, and the quantity of crushed stone layer requirement for the road construction is 1,400 m^3/km on the average.

(Width of road) x (Thickness of crushed stone layer) x (1,000 m)
= 7 x 0.2 x 1,000 = 1,400 m^3/km

In case concrete layer is substituted for the crushed stone layer, the quantity of low strength cement is about 60 kg/m^3 and per 1 km of road is:

Q = 1,400 x 0.06 t/km = 84 t/km

If 50% of road to be constructed in the northern region is constructed by this cement, the annual requirement is estimated to be:

$$4{,}400 \text{ km} \times \frac{1}{5 \text{ yr}} \times 84 \text{ t/km} \times 0.5 = 36{,}960 \text{ t/yr}$$

This quantity corresponds to about 5% of present cement consumption in the northern region and about 2 - 3% in the basis of ordinary portland cement.

The market of this cement is, therefore, not so large, but can be expected as a part of demand in the future.

(2) Cement demand for construction of dam

Large areas for hydropower generation are still underdeveloped in northern region of Thailand, and the investigation for the exploitation has been conducted. Accordingly, the construction of large multi-purpose dam will be possibly constructed in the near future.
The oil shale cement is a sort of mixed cement and shows the characteristics of low heat cement as well as those of the mixed cement. As the characteristics meets the requirement of the cement for mass-concrete in the use of dam constructibn, the consumption of oil shale cement is expected in this field.

II-1-3 Prospective Market Situation

As stated in II-1-2 (4), we have adopted the forecast given by the equation ③ as the basis for future domestic demand. Based on this equation, the projected supply and demand is shown in Table 2-1-13.

Table 2-1-13 Supply and Demand Forecast

(Tons in thousands)

Year	* Production	** Export	Domestic demand	Supply and demand gap	Mae Sot Cement Plant		Demand in nothern region
					*** Production	Gap	
1983	8,885	573	7,611	701	-	701	814
84	9,150	616	8,183	351	-	351	894
85	9,150	661	8,778	Δ289	-	Δ289	965
86	10,660	707	9,396	557	-	557	1,041
87	10,660	755	10,038	Δ133	-	Δ133	1,123
88	10,600	806	10,702	Δ848	566	Δ282	1,211
89	10,660	857	11,390	Δ1,387	647	Δ940	1,307
90	10,660	911	12,100	Δ2,351	728	Δ1,623	1,410
91	10,660	966	12,834	Δ3,140	809	Δ2,331	1,521
92	10,660	1,023	13,591	Δ3,954	809	Δ3,145	1,641

Note: 1) * It is assumed that no expansion project is implemented after 1986 by other companies.

2) ** Export is assumed to be 7% of total production. As to the reason for adopting this figure, refer to II-1-2-3 Export potentiality.

3) *** This production is possible in case the construction of plant is decided in 1983 and this is the earlist case.

II-1-4 Summary

In case the domestic demand and export are the same as shown in Table 2-1-13 and no remarkable change occurs in other circumstance, cement shortage will start after the year of 1987, and it becomes necessary to start the implementation of the Project immediately.
The cement production capacity is settled at 808,500 t/y as described in VII-2, and future expansion of capacity can be considered depending on demand situation. This capacity is approximately 1/2 of the demand for the northern region in 1992. (Please refer to Table 2-1-13)

II-1-5 Cement Price and Distribution

(1) Cement price

(i) Guideline price

As stated before, cement price was controlled by the Control Committee on Price Fixing and Anti-Monopoly (CCPFAM), but it has been abolished by now. The control price as of October 1, 1980 was 989 Baht/t for mixed cement and 1,194 Baht/t for ordinary portland cement as ex-facotry prices. At present, guideline prices have been established by kinds by each cement manufactures. This guideline price is based on Bangkok price and prices for other cities are calculated by adding transportation cost.

Recent guideline price (as of 9 March 1980, Bangkok) is shown in Table 2-1-14.

Table 2-1-14 Cement Guideline Price

(Baht) bagged

Company	Mix cement		Ordinary PC		High early strength PC	
	Brand	Price	Brand	Price	Brand	Price
SCC	Tiger	1,400	Elephant	1,705	Elephant head	1,860
JCC	Cobra	1,310	Green dragon	1,615	Red dragon	1,770
SCCC	Eagle	1,401	Diamond	1,701	Three diamond	1,860

Source: Ministry of Commerce, Commodity Research Division

Bangkok Weekly of 8 and 9 December 1982 reports that prices of Tiger, Elephant, and Elephant Head of SCC are 1,400, 1,705, and 1,800 Baht/t respectively, which is indicating that the cement price is stable recently.

(ii) Ex-factory price

Each cement manufacturer is selling its product at ex-factory price a little lower than the guideline price, and this ex-factory price changes depending on quantity and customers.

The ex-factory price includes cement tax. For example, the ex-factory price to dealer in cash differs from that to general customers.

Table 2-1-15 Ex-factory Price

(Baht/t)

		Mix cement	OPC	Source
Sale on cash to dealer	bag	1,241	1,544	The Association of Thailand Industries
	bulk	1,141	1,444	SCC
General	bag	1,310	1,610	SCC Chiang Mai Branch

In this report the latter is adopted as the basis.

(iii) Composition of cement sales price

Cement market price is composed of the ex-factory price mentioned above (which includes cement tax), transportation cost and warehouse charge.

Examples are shown in Table 2-1-16 and Table 2-1-17.

Table 2-1-16 Composition of Cement Market Price (1)

(Baht/t) bag

	Mix cement	Ordinary PC
Ex-factory price (incl. cement tax)	1,241	1 544
Cement tax	91	109
Warehouse charge + transportation cost	90 ∿ 205	90 ∿ 205
Ex-warehouse price	1,331 ∿ 1,446	1,634 ∿ 1,749

Source: Siam Cement Co., Ltd.

Table 2-1-17 Composition of Cement Market Price (2)

(Baht/t) bag

	Mix cement	Ordinary PC
Ex-factory price (incl. cement tax)	1,310	1,610
Transportation cost	165	165
Warehouse charge (incl. margin)	15	18
Exwarehouse price	1,490	1,790

Source: SCC Chiang Mai Branch

(iv) Retail price of cement

Retail cement price collected from dealers of various cities during field survey is shown in Table 2-1-18.

Table 2-1-18 Retail Cement Price

Kinds	Mix cement			Ordinary portland cement		
	Brand	Price		Brand	Price	
Cities		฿/bag	฿/t		฿/bag	฿/t
Mae-Sot	Cobra	75	1,500	Green Dragon	95	1,900
	Tiger	75	1,500			
Lamp Pang	Eagle	69	1,380	Diamond	85	1,700
	Tiger	70	1,400	Elephant	86	1,720
Bangkok	Tiger	72	1,440	Elephant	87.25	1,745

(v) Others

Retail price of white cement is shown as follows for reference. (as of August 1, 1982, Bangkok)

4,500 baht/t

(2) Distribution of cement

(i) Transportation of cement

Cement transportation in Thailand is carried out by trucks, trains, and barges.

Transportation of cement largely depends on trucks while transportation by train is little used due to higher cost.

Transportation to the northern region especially relies on trucks more than 90% in quantity. An example of transportation cost by truck is shown in Table 2-1-19.

Table 2-1-19 Cement Transportation Cost by Truck

(Baht/t)

Section	Distance	Cost
Saraburi - Chiang Mai	691	165

Each cement company is using pneumatic type car for transportation of bulk cement.

(ii) Distribution of cement

Each cement company has its branches at main cities and dealers at main consumption places. Concrete mixing plants are set at cities where a large amount of cement is used.

II-1-6 Cement Industry in Thailand

The outline of three cement companies in Thailand is described hereinafter.

(1) Production capacity

Table 2-1-20 Cement Production of Each Company

Company	Plant	Working day d/yr	Production		
			Clinker		Cement *
			t/d	t/yr	t/yr
Siam Cement Co., Ltd. (SCC)	Ta Luang Kiln No.5 Kiln No.6	 310 310	 4,000 4,000	 1,240,000 1,240,000	3,200,000
	Thung Song Kiln No.1 Kiln No.2 Kiln No.3	 340 340 330	 530 530 1,100	 180,000 180,000 363,000	900,000
	Kaeng Khd Kiln No.1 Kiln No.2	 300 300	 1,500 2,850	 450,000 855,000	1,700,000
Jalaprathan Cement Co., Ltd. (JCC)	Ta Kli Kiln No.1 Kiln No.2	 335 335	 500 500	 167,500 167,500	300,000
	Cha-am Kiln No.1	 295	 1,500	 442,500	420,000
Siam City Cement Co., Ltd. (SCCC)	Tab Kuang Kiln No.1 Kiln No.2	 295 295	 1,600 4,000	 472,000 1,168,000	2,100,000
Total		(306)	22,610	6,925,500	8,620,000

Source: Siam Cement Co., Ltd.

Note:1) * This figure shows the total production of all kinds of cement.

2) Schedule of kiln expansion.
   - No.1 kiln of Tab Kuang will be expanded to 3,000 t/d in February - April, 1983.
   - Cha-am plant will be expanded by setting up a new kiln of 4,000 t/d in middle of 1986.

3) No.1 - No.4 kiln in Ta Luang plant of SCC have been suspended because of wet process.
   These kilns are not included in Table 2-1-20.

4) Amphur Muang plant of Universal White Cement Co., Ltd. which is a white cement manufacturing plant is not included in Table 2-1-20.

(2) Location of cement plant

The location of cement plant of each company is shown in Fig. 2-1-3. According to this figure, almost all of plants are located in the vicinity of Bangkok except one plant in the southern region. No cement plant has been constructed in the northern and north-eastern region so far.

(3) Cement production in recent years by company

Cement production and market share are shown in Table 2-1-21.

Fig. 2-1-3 Location of Cement Plant in Thailand

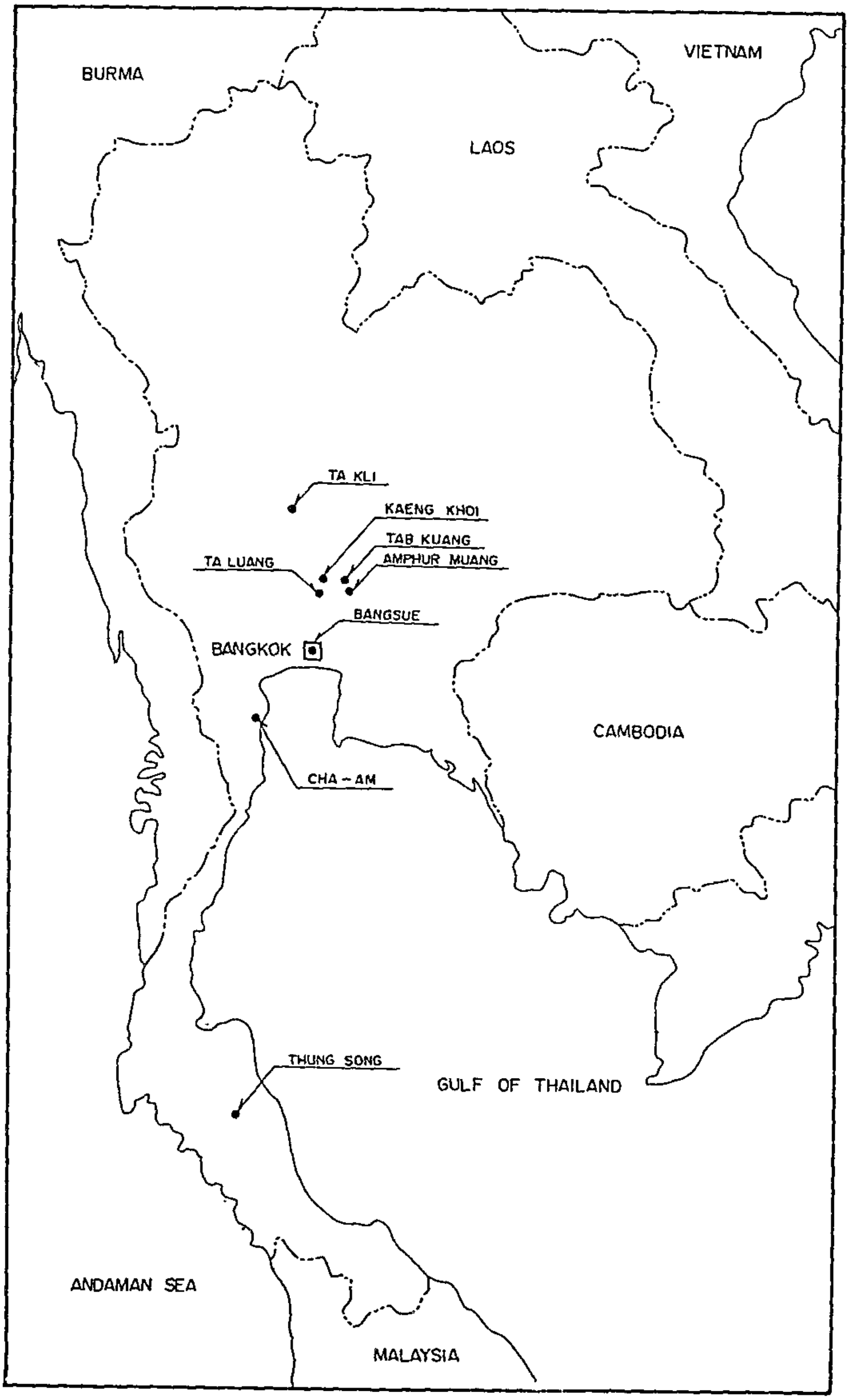


Table 2-1-21 Cement Production in Recent Years

year	1981		1982		1983	
Company	(10^6t)	(%)	(10^6t)	(%)	(10^6t)	(%)
SCC	4.671	73.4	4.500	68.8	4.759	69.0
JCC	0.713	11.2	0.701	10.7	0.670	9.7
SCCC	0.976	15.4	1.344	20.5	1.470	21.3
Total	6.362	100.0	6.545	100.0	6.899	100.0

Source: Siam Cement Co., Ltd.

(4) Operational data of cement plant

The operational data of representative cement plant in Thailand are shown below.

(i) Unit consumption of raw material

The unit consumption of raw material is shown in Table 2-1-22.

Table 2-1-22 Unit Consumption of Raw Material

(t/t-clinker)

Raw materials	Unit consumption
Limestone	1.27
Clay	0.33
Iron ore	0.017
Siliceous material	0.033
Total	1.65
Gypsum	4 ∿ 6%

(ii) Unit consumption of fuel

Heat requirement 800,000 kcal/t-clinker

(iii) Cement quality

Table 2-1-23 Cement Quality

Quality \ Kind	Mix cement	Ordinary portland cement
Fineness (Blane cm^2/g)	4,000±300	3,100±300
Strength (kg/cm^2)	120±20	150±15
Setting (min)	100	100

II-2 Power Demand and Supply

II-2-1 Electricity Supply System

The electricity had been supplied by private companies by the end of the Second World War in the Kingdom of Thailand, however all authorities concerning electricity supply are presently managed under the supervision of the Government.

(1) Electricity Generating Authority of Thailand (EGAT)

The Electricity Generating Authority of Thailand was established in May 1969 as a wholly-owned government corporation to rationalize and con solidate the functions and responsibilities of three independent enterprises namely the Yankee Electricity Authority (YEA), the North-East Electricity Authority (NEEA) and the Lignite Authority (LA), and its main business is to sell and distribute its generated electricity to the Metropolitan Electricity Authority, the Provincial Electricity Authority and nine large-scale industrial consumers in the country.

The EGAT also purchases surplus electricity from Laos and Malaysia.

(2) Metropolitan Electricity Authority (MEA)

The authority was formed in 1958 as a successor of the Electric Division and the Bangkok Electric Works in Bangkok which were under the supervision of the Home Affairs Ministry and is now called the Metropolitan Electricity Authority (MEA).

The MEA's main business includes the purchase of electricity from the EGAT and the sales of electricity to consumers in Nonta Buri, Samut Prakan and the Greater Bangkok areas. The MEA itself has no power generating palnt.

(3) Provincial Electricity Authority (PEA)

The authority was established in 1960 to rationalize the Provincial Electricity Organization (PEO) and is called the Provincial Electricity Authority (PEA).

The PEA's main business is to purchase the electric energy from the EGAT and sell it to consumers except those in the MEA's supply areas and in addition the PEA directly supplies the electric energy generated by themselves using diesel engines, to consumers in some rural provinces.

II-2-2 Electric Power Supply Facilities

(1) Power generating facilities

The total installed capacity of power generating facilities in Thailand excluding PEA's spare diesel power generating equipment of approximately 30 MW, is about 4,100 MW, and is classified in the following table.

Table 2-2-1 Records of Installed Power Generating Facilities

(MW)

Fiscal year	Hydro power plant	Thermal power plant			Total
		Steam	Gas turbine	Diesel	
1979	909.2	1,777.5	165	31.6	2,883.3
1980	1,269.2	1,777.5	165	29.6	3,241.3
1981	1,317.2	1,927.5	565	29.6	3,839.3
1982 *	1,380	1,927.5	745	29.6	4,082.1

Note: * Records are as of end April, 1982

As the figures as of end April, 1982 in the above table indicate, percentages of installed capacity by category are 33 % for hydro power plant, 47.2 % for steam power plant, 18.2 % for gas-turbine power plant and 0.7 % for diesel power plant.

Since the installed capacity of power generating facilities was 2,542.8 MW at the end of 1976 fiscal year, the increasing rate of the installed capacity of power generating facilities in Thailand is calculated to be an average figure of 8.6 % for the past five years.

(2) Load factor of power generating facilities

The load factor of power generating facilities in Thailand is shown in the table below.

Table 2-2-2 Records of Load Factor of Power Generating Facilities

(%)

Fiscal year	1976	1977	1978	1979	1980	1981
Load factor	65.1	66.7	67.2	60.7	69.7	68.5

Source: EGAT annual report

(3) Output capacity of principal power station

(i) Hydro power generating station

Hydro power resource in Thailand is estimated to be 24,000 MW, in which the amount already developed is 1,380 MW and the amount planned to be developed by the end of 1,990 is calculated to be 1,970 MW.

Output capacities of principal power stations are shown as follows:

Table 2-2-3 Output Capacity of Principal Power Stations (April, 1982)

Name of power station	No. of unit	Total output	Remarks
Bhumibol Dam	6	MW 420	
Sirikit Dam	3	375	
Srinagarind Dam	3	360	
Others	15	225	7 stations
Total	27	1,380	

(ii) Steam power station

Output capacities of principal steam power stations are listed in the following table.

Table 2-2-4 Steam Power Stations and Output (April, 1982)

Name of power station	No. of unit	Total output	Remarks
North Bangkok	3	MW 237.5	
South Bangkok	5	1,300	
Mae Moh	3	225	
Others	5	160	3 stations
Total	16	1,927.5	

(iii) Gas-turbine power station

Table 2-2-5 Gas-Turbine Power Station and Output (April, 1982)

Name of power station	No. of unit	Total output	Remarks
Bang Pakong No. 1	4	MW 240	
" No. 2	4	240	
South Bangkok	4	100	
Others	11	165	5 stations
Total	23	745	

(iv) Diesel power station

Diesel power stations are located at six places and numbers of unit are calculated to be 28 units of small-scale with a total capacity of 29.6 MW.

(4) Transmission lines

Power transmission lines owned by the EGAT are as shown in the attached DWG. No. E-01. There are secondary distribution networks owned by the MEA and the PEA with voltages of 33 kV, 22 kV and 11 kV.

The main power transmission lines consist of the networks connecting power generating stations and substations in the vicinity area of Bangkok, the basic route of 230 kV voltage connecting the three large hydro power stations of Bhumibol, Sirikit and Srinagarind dams, and the subroute of 115 kV together with other distribution lines of 69 kV voltage connecting the basic route with other hydro power stations in the Bangkok and the south and the central areas.

Total length of transmission and distribution lines is approximately 45,900 km.

Lengths classified by voltages are shown as follows:

Table 2-2-6 Length of Transmission and Distribution Lines (September, 1981)

Voltage (kV)	3.5	11	22	33	69	115	230
Total length (km)	187	5,817	23,248	4,931	1,362	7,127	3,210

Source: Annual reports of EGAT, PEA, etc.

The low voltage distribution is in standard 240/416 V with three phases four wires system at a frequency of 50 Hertz.

II-2-3 Supply and Demand Situation of Electric Power

(1) Amount of power generation

The peak and the total amount of power generation by the EGAT during the past 10 years are shown in table 2-2-7. The yearly increasing rate of the amount of power generation in the 1970s showed a remarkably high figure of an average 13 %, however the increasing rate in 1980s, due to the energy conservation policy by the Government and the increase of electric energy tariffs by the EGAT, approximately decreased to half of the 1970's.

Table 2-2-7 Records of the amount of power generation (including purchase from outside)

Fiscal year	Power generation at peak		Amount of power generation	
	MW	Increasing rate (%)	10^3 MWH	Increasing rate (%)
1972	1,028.8	17.9	5,711.2	19.2
1973	1,199.3	16.6	6,872.8	20.3
1974	1,256.3	4.8	7,258.6	5.6
1975	1,406.6	12.0	8,211.6	13.1
1976	1,652.1	17.5	9,414.5	14.6
1977	1,873.4	13.4	10,950.6	16.3
1978	2,100.6	12.1	12,371.7	13.0
1979	2,255.0	7.4	13,964.6	12.9
1980	2,417.4	7.2	14,753.7	5.7
1981	2,588.7	7.1	15,960.0	8.2

Source: EGAT annual report

In addition, Thailand purchased power energy of 658.9 x 10^3MWh in 1979, 752.9 x 10^3MWh in 1980, and 763.9 x 10^3MWh in 1981 from Laos and 31.2 x 10^3MWh in 1981 from malaysia.

(2) Breakdown of electric energy consumption

The electrification rate in Thailand is 76 % in the Greater Bangkok area and 34 % in rural areas including local cities, which means about 40 % on the average in the whole country. The annual electric energy consumption per capita is computed to be approximately 330 kWh.

Records of electric energy consumption by purposes are classified based on the PEA's data as in the following table. As shown in the table, the electric energy consumption for home-use has remarkably increased during the past five years.

Table 2-2-8 Record of Electric Energy Consumption by Purposes

Fiscal year	Home use MWH x 10^3	Home use Increasing rate (%)	Commercial use MWH x 10^3	Commercial use Increasing rate (%)	Industrial use MWH x 10^3	Industrial use Increasing rate (%)	Others MWH x 10^3	Others Increasing rate (%)
1977	804	-	797	-	1,542	-	30	-
1978	981	22.0	895	12.3	1,733	12.4	40	33.3
1979	1,177	20.0	1,020	14.0	2,006	15.8	51	27.5
1980	1,364	15.9	1,105	8.3	2,170	8.2	56	9.8
1981	1,582	16.0	1,066	-3.5	2,499	15.2	62	10.7

Source: PEA's annual report

II-2-4 Electricity Tariffs

The electricity tariffs of the EGAT have been recently revised 4 times in only one year due to the energy conservation policy, and since April 1981 the tariffs shown in Table 2-2-9 have been applied.

For reference, the actual records of average unit prices of electric energy inclusive of demand charge are shown in Table 2-2-10.

Table 2-2-9 EGAT's Electricity Tariffs

Consumer	Demand charge (Baht/kW)	energy charge (Baht/kWh) ∿100kWh	energy charge (Baht/kWh) 101∿300 kWh	energy charge (Baht/kWh) 301kWh∿
MEA-Normal rate	80	1.43	1.41	1.40
MEA-Special rate *1	74	1.39	1.39	1.39
PEA-Normal rate	67	1.13	1.10	1.07
PEA-Special rate *1	74	1.24	1.24	1.24
Industrial rate	87	1.50	1.48	1.45
Special rate *1	87	1.42	1.42	1.42

Note: Special rates are applicable to the following types of industry:

(i) Electric smelting industry
- o The minimum power demand is 3,000 kW or more.
- o The smelting industry using power and energy for production of finished product which shall not exceed the capacity of furnace contracted for.

(ii) Electrolytic process chemical industry
- o The minimum power demand is 1,500 kW or more.
- o The monthly load factor is 85 % or more.
- o The capital production cost of electricity is in excess of 20 % of the total production cost.

Table 2-2-10 Actual Records of Average Unit Prices of Electric Energy Including Demand Charge

(Baht/kWh)

Fiscal year / Unit price	1977	1978	1979	1980	1981
Based on EGAT's tariffs	0.46	0.56	0.52	0.75	1.30
Based on PEA's tariffs	0.69	0.84	0.84	1.05	1.62

Source: PEA annual report

II-2-5 Future Forecast of Supply and Demand of Electric Energy

(1) Forecast of electric energy demand

The future electric energy demand in Thailand is foreseen as shown in Table 2-2-11, and the yearly increasing rate of energy demand based on future forecast is assumed to be an average of 9.2 % for the coming 10 years.

Table 2-2-11 Forecast of Electric Energy Demand

Fiscal year	Peak demand		Electric energy consumption	
	MW	Increasing rate (%)	MWH x 10^3	Increasing rate (%)
1982	3,001	15.9	18,445	15.6
1983	3,433	14.4	20,570	11.5
1984	3,817	11.2	22,894	11.3
1985	4,195	9.9	25,252	10.3
1986	4,604	9.8	27,725	9.8
1987	4,968	7.9	29,944	8.0
1988	5,346	7.6	32,273	7.8
1989	5,742	7.4	34,693	7.5
1990	6,150	7.1	37,211	7.3
1991	6,581	7.0	39,816	7.0

Source: EGAT

(2) Development plan of electric resources

Based on the future forecast of electric energy demand shown in the above table, the EGAT has made a long term development plan of electric energy resources, and principal projects are shown in Table 2-2-12 and Table 2-2-13.

Table 2-2-12 Power Plant Projects Under Planning

Project name	Type	Unit No.	Unit capacity (MW)	Scheduled commissioning date
Bhumibol	Hydro	No. 7	133	1982.11
Khao Laem	Hydro	No. 1~3	100 x 3	1984.3
Bang Pakong 1	Steam	-	120	1982.10
Bang Pakong 2	Steam	-	120	1983.4
Bang Pakong GT-CS	Gas-turbine	No. 1	550	1984.1
Bang Pakong GT-CS	Gas-turbine	No. 2	550	1984.8
Mae Moh	Steam	No. 4	150	1984.5
Mae Moh	Steam	No. 5	150	1984.11

Source: EGAT annual report

Table 2-2-13 Power Plant Project Approved by the Government

Project name	Type	Unit No.	Unit capacity (MW)	Scheduled commissioning date
Sirindhorn	Hydro	No. 3	12	1984.10
Srinagarind	Hydro	No. 4	180	1985.7
Mae Nagat	Hydro	No.1, 2	4.5 x 2	1985.11
Chulabhorn	Hydro	No.1 ~ 3	80 x 3	1987.6
Mae Moh	Steam	No. 6	150	1985.9
Mae Moh	Steam	No. 7	150	1986.3

Source: EGAT annual report

Other projects including both 14 plants of hydro power generation with an estimated capacity of 1,096.8 MW and of thermal power generation with a planned capacity of 2,340 MW are now in the stage of feasibility study.

II-2-6 Supply and Demand of Electricity Energy in the Mae Sot Area

(1) Power generating facilities

The electric energy is supplied to consumers in the Mae Sot area from the substation in Tak through an overhead power distribution line of 22 kV voltage with a cross section area of 185 mm^2.

Tak substation receives 153 kV high voltage electricity and reduces to 22 kV for further distribution.

(2) Breakdown of electric energy consumption

Breakdown of electric energy consumption in the Mae Sot area is shown in Table 2-2-14.

The annual electric energy consumption per capita in the area is 293.8 kWh/yr in 1981 which is 10 % lower than that of national average (333.3 kWh/yr).

Table 2-2-14 Breakdown of Electric Energy Consumption in Mae Sot

Fiscal year	Electric Energy Consumption (MWH)					Per capita consumption (kWh/yr)
	Houses	Commerce	Industry	Others	Total	
1980	3,316.8	2,542.0	195.5	125.8	6,180.1	247.2
1981	3,884.4	2,207.5	1,119.9	133.9	7,345.7	293.8

Source: PEA Mae Sot Office

(3) Demand forecast of electric energy in Mae Sot

No forecast has been made by the concerned authorities on the future demand of electric energy in Mae Sot. Thus, in this study the increase rate of per capita electric energy consumption in the area is assumed to be equivalent to that of national average increase rate shown in Table 2-2-15. On this assumption, the electric energy demand in the area is calculated to be 14,840 x 10^3 kWh/yr in 10 years from now, which is about twice as much as the current demand. Furthermore, the demand in 10 years is expected to reach 18,450 x 10^3 kWh/yr provided that the population of the area increases at 2.2 % p.a. rate as shown in Table 3-2-3.

Table 2-2-15 Demand Forecast for Per Capita Electric Energy Consumption

Fiscal year	Total electric energy demand (10^3 MWH)	Population (10^3 person)	Electric demand per capita	
			kWh/person	Grouth rate (%)
1982	18,445	48,890	377.3	13.2
1983	20,570	49,927	412.0	9.2
1984	22,894	50,986	449.0	9.0
1985	25,252	52,067	485.0	8.0
1986	27,725	53,171	521.4	7.5
1987	29,944	54,298	551.5	5.8
1988	32,273	55,449	582.0	5.5
1989	34,693	56,625	612.7	5.3
1990	37,211	57,825	643.5	5.0
1991	39,816	59.051	674.3	4.8

Note: 1) The demand forecast for electricity is forecasted based on the data and information from EGAT.

2) The population is forecasted based on the data and information from the Statistic Office in Thailand.

SECTION III NATURAL AND SOCIAL CONDITIONS OF MAE SOT

Mae Sot, the proposed plant site, is located in Tak province, north-west part of Thailand. Natural and social conditions prevailing in the area are described in this SECTION.

III-1 Natural Conditions

The area administratively involved in the county of of Mae Sot (Amphoe Mae Sot) is located on the west side of Tak province, and is about 87 km west from Tak, which is located about 420 km north from Bangkok.

Amphoe Mae Sot, more precisely, is located at longtitude 16° 42' 42" north, and longtitude 98° 34' 42" east. Amphoe Mae Sot is sorrounded by Amphoe Mae Ramat to the north, Amphoe Tak to the east and Amphoe Umphong to the south respectively, and to the west the Moei river makes the natural boundary between Thailand and Burma. Amphoe Mae Sot has an area of 2,121 km^2.

The Indo-China mountains, a prolongation of the Himaraya mountains, lies on the border area between Thailand and Burma, which ends at the south, forming pallarel mountain ridges runing north-south direction. The area of Mae Sot is characterized by this pallarel mountain ridges trending north-northeast and stream valleys between the mountain ridges. A prominent feature of the area is the occurrence of elongated leveled floor intermontane basins along the large valleys separated by gorges. Within the larger basins, streams are generally slow moving, and meander over narrow flood plains. The altitude of Mae Sot Basin is about 210 m above sea level. In the mountainous areas, hardwood such as teak and yang predominates together with a large variety of luxuriant undergrowth.

The town of Maé Sot is located at the center of the basin, and the oil shale deposit for the project is underlying beneath the basin. The limestone deposit for the Project is also found in the basin, at the north-west direction from the town of Mae Sot.

The meteorological data of the area has been recorded at the meteorological station next to the small airport in the town of Mae Sot. The climate of the area is tropical featured by the seasonal monsoons, and the seasons of the year may be divided into three seasons, namely, summer season, rainy season and winter season. The summer season (Feb. to April) is characterized by the high temperature and the rainy season (May to Oct.) by the south-west monsoon, with the remaining period (Nov. to Jan.) being classified as the winter season. Further discussion on meteorological conditions in the area based on the data obtained from the meteorological station is made below.

(1) Temperature and humidity

The temperature in the area peaks from the summer season to the beginning of rainy season with the monthly average maximum temperature of 38-39°C. Although the temperature is relatively high throughout the year, in the winter season it becomes rather lower with the minimum temperature of 10°C range. The yearly average temperature in the area is 26.1-26.6°C.

The humidity is high ranging from 70% to 90% in the rainy season. It becomes lower in the summer and winter seasons with average range being 60-80% and 50-70% respectively. The yearly average relative humidity in the area is 73.4-75.5%.

(2) Rainfall

The rainfall in the area generally concentrates in the rainy season with some yearly fluctuation, and no appreciable rainfall is observed in the summer and winter seasons. The rainfall in the rainy season varies considerably year by year, it appears that the heaviest rainfall occurs in August. The yearly average total rainfall has a tendency to increase in the past five years, and 1,793 mm and 1,151 mm of precipitation have been observed in 1982 (excluding precipitation in Dec.) and 1981 respectively. The average rainfall-days per year is about 110-150 days.

(3) Wind direction and speed

The west-east direction wind predominates throughout the year in the area except the adverse east-west direction wind observed in the winter season. The wind speed is generally slow, but strong wind of 33 kts range is sometimes observed in the area.

(4) River discharge

No river discharge data in the area is available, however, the water level data of the Moei river (the natural boundary between Thailand and Burma) is available as shown in Table 6-1-1.

(5) Earthquakes

No earthquake data in the area has been obtained, but no significant earthquake has been reported in the past in this area.

Meteorological data (Temperature, Humidity, Rainfall, Wind Direction and Speed) are shown in Table 3-1-1, 3-1-2, 3-1-3 and 3-1-4 respectively.

Table 3-1-1 Temperature

(°C)

Year / Month	1978			1979			1980			1981			1982		
	max.	min.	ave.	max.	min.	ave.	max.	min.	ave.	max.	min.	ave.	max.	min.	ave.
January	33.4	8.6	23.4	34.1	13.3	24.4	32.1	11.2	22.4	33.3	10.2	22.2	31.8	12.5	21.8
February	35.2	11.4	25.6	35.4	13.7	25.9	35.3	10.9	24.5	35.7	11.6	25.2	36.0	10.9	23.8
March	38.3	14.1	27.2	38.8	12.9	27.8	38.2	13.9	28.4	38.0	17.1	27.8	37.9	15.3	27.8
April	38.6	18.5	29.8	38.7	21.0	29.7	38.4	21.8	30.4	39.0	20.3	29.6	36.4	20.6	29.0
May	38.9	23.2	29.6	39.2	22.5	22.9	38.9	23.0	30.2	38.8	21.7	29.0	36.8	22.0	28.7
June	34.8	21.8	27.5	34.7	23.1	28.1	33.6	21.8	27.7	31.8	22.2	26.6	33.5	22.0	26.9
July	32.7	22.5	26.7	33.6	22.4	27.4	32.2	22.0	26.9	32.6	21.3	26.5	32.7	20.9	26.1
August	32.0	22.1	26.0	33.2	22.0	26.2	-	22.2	26.5	30.9	21.2	25.6	31.4	21.5	25.3
September	33.3	21.8	26.6	34.5	21.8	27.6	32.2	22.4	26.1	35.8	21.8	27.2	32.1	21.5	26.5
October	34.1	14.2	26.6	33.9	17.6	26.6	34.0	17.2	27.2	33.5	20.4	26.8	33.1	20.2	27.0
November	33.8	14.2	25.1	33.3	14.3	23.9	32.8	17.0	25.6	33.0	16.0	25.2	33.4	18.4	26.0
December	33.2	8.7	22.7	33.5	11.1	22.4	32.8	11.7	23.6	32.0	9.8	21.5			

Measured at Mae-Sot Weather Station

Table 3-1-2 Humidity

(%)

Year / Month	1978			1979			1980			1981			1982		
	max.	min.	ave.	max.	min.	ave.	max.	min.	ave.	max.	min.	ave.	max.	min.	ave.
January	98.0	17.0	69.0	96.0	29.0	70.0	98.0	24.0	70.0	97.0	25.0	68.0	98.0	35.0	77.0
February	97.0	22.0	68.0	92.0	22.0	62.0	95.0	21.0	59.0	93.0	20.0	64.0	96.0	23.0	64.0
March	91.0	22.0	54.0	95.0	19.0	56.0	94.0	21.0	60.0	89.0	18.0	52.0	95.0	20.0	59.0
April	91.0	21.0	59.0	95.0	29.0	64.0	96.0	33.0	63.0	96.0	19.0	58.0	92.0	33.0	64.0
May	96.0	28.0	73.0	96.0	30.0	74.0	97.0	38.0	70.0	97.0	24.0	74.0	97.0	37.0	77.0
June	97.0	90.0	82.0	98.0	50.0	81.0	96.0	55.0	83.0	98.0	64.0	86.0	97.0	58.0	86.0
July	97.0	56.0	85.0	96.0	57.0	83.0	97.0	63.0	85.0	97.0	60.0	86.0	97.0	61.0	85.0
August	97.0	55.0	87.0	97.0	56.0	86.0	97.0	59.0	85.0	98.0	66.0	89.0	97.0	64.0	89.0
September	97.0	55.0	86.0	97.0	52.0	84.0	98.0	58.0	87.0	97.0	37.0	85.0	97.0	57.0	86.0
October	98.0	34.0	80.0	97.0	43.0	79.0	97.0	44.0	83.0	97.0	52.0	84.0	99.0	47.0	84.0
November	97.0	34.0	74.0	98.0	35.0	72.0	97.0	41.0	78.0	98.0	47.0	83.0	97.0	46.0	80.0
December	99.0	28.0	71.0	96.0	29.0	70.0	98.0	36.0	74.0	98.0	38.0	77.0			

Measured at Mae-Sot Weather Station

Table 3-1-3 Rainfall

(mm)

Month \ Year	1978	1979	1980	1981	1982
January	1.4	-	-	-	-
February	32.6	-	-	-	-
March	-	-	6.4	-	3.0
April	19.7	54.1	52.9	53.0	28.6
May	107.8	137.1	283.0	115.9	228.2
June	168.9	224.8	136.8	331.5	329.3
July	205.0	138.6	216.8	307.7	426.5
August	346.1	389.8	151.3	473.5	507.7
September	207.0	209.1	251.0	159.1	185.0
October	61.8	26.7	108.0	84.8	79.0
November	-	-	2.3	79.8	5.5
December	0.3	-	0.1	0.6	

Measured at Mae-Sot Weather Station

Table 3-1-4 Wind Direction and Speed

Year / Month / unit	1978			1979			1980			1981			1982		
	Direction		Speed	Direction		Speed	Direction		Speed	Direction		Speed	Direction		Speed
	deg.	from/to	kts	deg.	from/to	kts	deg.	from/to	kts	deg.	from/to	kts	deg.	from/to	kts
January	270	W/E	10-14	240	WSW/ENE	10-16	250	WSW/ENE	5-10	090	E/W	10-17	290	WNW/ESE	10-16
February	270	W/E	10-20	270	W/E	5-10	270	W/E	10-20	270	W/E	10-17	270	W/E	10-16
March	270	W/E	5-12	240	WSW/ENE	10-17	270	W/E	10-16	130	SE/NW	10-16	270	W/E	10-16
April	270	W/E	10-30	270	W/E	5-12	270	W/E	5- 7	270	W/E	5- 8	270	W/E	5-10
May	180	S/N	10-14	270	W/E	10-16	270	W/E	10-20	270	W/E	10-16	270	W/E	5-14
June	290	WNW/ESE	10-30	270	W/E	10-23	270	W/E	10-30	270	W/E	10-22	270	W/E	5-10
July	270	W/E	10-15	270	W/E	10-16	270	W/E	10-16	270	W/E	10-20	270	W/E	10-18
August	240	WSW/ENE	10-16	270	W/E	10-20	270	W/E	10-20	180	S/N	10-20	270	W/E	10-20
September	270	W/E	5-10	270	W/E	10-16	090	E/W	10-20	220	SW/NE	10-24	270	W/E	10-23
October	090	E/W	10-16	040	NE/SW	10-20	090	E/W	10-15	090	E/W	10-19	090	E/W	10-20
November	090	E/W	5-10	090	E/W	10-16	090	E/W	10-17	090	E/W	10-16	090	E/W	10-17
December	090	E/W	10-22	360	N/S	10-19	090	E/W	10-16	090	E/W	10-17	-	-	-

Max. Wind Velocity : 33 kts in April 1980

Measured at Mae-Sot Weather Station

III-2 Social Conditions

The north part of country, along with the north-east part, is rather undeveloped area in the Kingdom of Thailand. Statistical data on GRP (Gross Regional Product) of Thailand for the past four years is summarized in Table 3-2-1.

Table 3-2-1 Gross Regional Products (1977-1980)

(1,000,000 Baht for total, Baht for per capita)

		1977	1978	1979	1980
The Kingdom of Thailand	Total per capita.	- -	257,043 5,699	269,897 5,849	284,573 6,126
Bangkok Metropolis	Total per capita.	74,939 16,298	82,005 17,149	92,715 18,674	100,270 19,462
Central	Total per capita.	16,992 6,033	17,444 6,140	19,082 6,666	20,334 7,060
East	Total per capita.	30,878 10,209	35,046 11,197	33,659 10,383	35,701 10,629
West	Total per capita.	23,796 7,664	25,551 8,132	24,653 7,757	25,126 7,828
North-East	Total per capita.	32,908 2,143	36,694 2,334	39,990 2,487	42,494 2,616
North	Total per capita.	32,125 3,509	36,731 3,937	37,919 3,991	38,191 3,951
South	Total per capita.	25,536 4,739	27,626 5,012	28,889 5,128	30,236 5,255

Note: 1972 constant price basis.

Regional area and population in 1981 are shown in Table 3-2-2.

Table 3-2-2 Regional Area and Population

	Area (km²)	Population			Density of Population*
		Total	Male	Female	
The kingdom of Thailand	513,115.0	47,875,002	24,067,597	23,807,405	93
Bangkok Metropolis	1,565.2	5,331,402	2,704,284	2,627,118	3,406
Central	18,741.6	3,293,052	1,636,906	1,656,146	176
East	37,506.6	3,502,247	1,776,458	1,725,789	93
West	46,087.8	3,706,111	1,859,799	1,846,312	80
North-East	168,854.3	16,393,356	8,211,335	8,182,021	97
North Tak province Mae Sot Country	169,644.3 (16,406.6) (2,121)	9,714,135 (284,442) (68,148)	4,891,571 (144,135) (34,943)	4,822,564 (140,307) (33,214)	57 (17) (32)
South	70,715.2	5,934,699	2,987,244	2,947,455	84

Note: * per km^2

Mae Sot county (Amphoe Mae Sot) administratively included in the North region of the country, is located in the boundary area between Thailand and Burma, thinly populated and having no major industries remains as one of the undeveloped area in the country.

The social conditions prevailing in Mae Sot area is discussed below.

(1) Manpower in Mae Sot

(i) Population of Mae Sot town

The population of Mae Sot county is 68,147 consisting of 34,943 male population and 33,214 female population. In the population, foreigners (Chinese, Indian, Pakistani, Japanese, French, British, Burmese, American) and 1,150 of of mountain tribes are accounted for.

The town of Mae Sot having wide-spread urban district, forms a center of the Mae Sot county. The population of the town is shown in Table 3-2-3.

Table 3-2-3 Population of Mae Sot Town

Year	1975	Nov. 1982
Population	16,457	19,262
- male	8,554	9,907
- female	7,903	9,355
No. of families	3,571	3,589
No. of houses	3,285	4,420

(ii) Manpower requirement for the Project

Manpower requirement for the Project is estimated to be several hundreds labors, and as far as unskilled labor requirement is concerned, it can be recruited easily in the area allowing for minor relocation within the area. As for skilled labors and engineers required for the Project, no sufficient manpower is available in the area and country-wide recruitment is necessary.

(2) Industries

Major industry of Mae Sot area is agriculture, and principal products includes rice, corn, sugar cane, garlic and etc. Although water baffaloes and pigs are raised in the area, there exists no exclusive stock-farming activity. There is no appreciable fishery activity observed in the area. As for mining activity one zinc mine is under operation and the zinc ore will be supplied to a zinc refinery plant to be established in Tak in the near future, and small-scale rubble production is currently being done at the limestone deposit which is planned to be developed in the Project. Manufacturing industries in the area includes six large-scale rice mills, 38 small-scale rice mills, one lumber mill, one ice plant, one woodworking shop, one stonemason shop and one noddle-making plant. Many stores line the shopping district of Mae Sot town, and small-scale commerce is actively practiced in the area. There are five joint-stock corporations and twenty-two partnership companies registered in the town.

(3) Utilities

(i) Electric power

- reference is made to IV-1.

(ii) Water supply

Running water is taken from the Moei river, which is the natural boundary between Thailand and Burma. Outline of water supply system in Mae Sot is shown below.

(a) Water treatment flow chart

Fig. 3-2-1 shows water treatment flow chart.

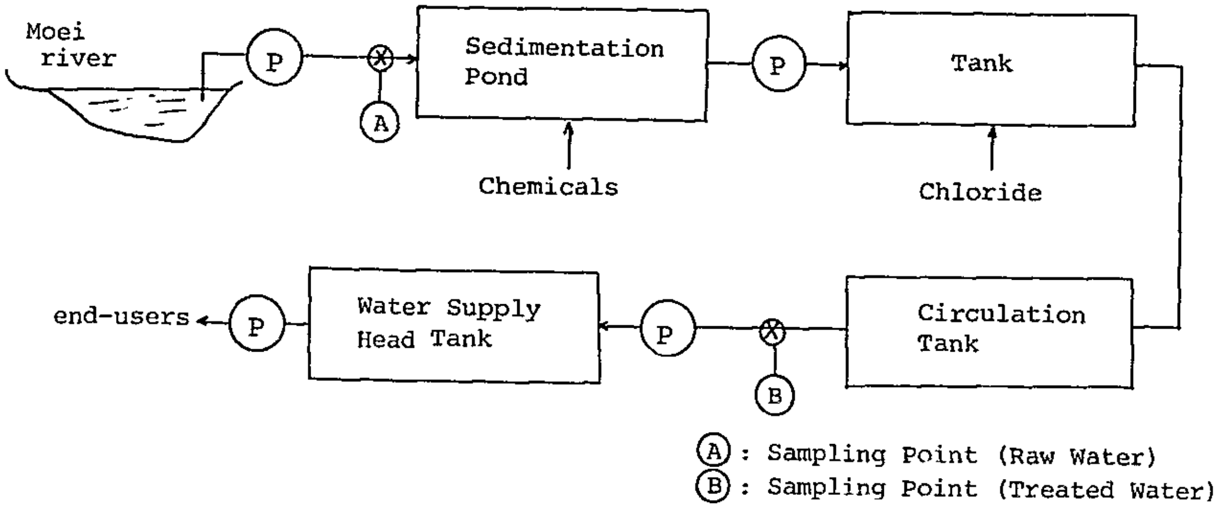


Fig. 3-2-1 Water Treatment Flow Chart

(b) Major facilities of Moei river pumping station

	Rating	Quantity
Pump (Motor)	250 m^3/hr	1
"	150 m^3/hr	2
"	100 m^3/hr	1
Pump (Engine)	150 m^3/hr	1
"	100 m^3/hr	1

Water Intake Rate (current rate) : 250 m^3/hr

(c) Water supply rate

Water Supply Rate : approx. 90,000 m^3/month (includes supply to outside of Mae Sot county)

(d) Water price

Water price is classified into nine ranks depending upon the size of supply pipe diameter (1/2"ϕ - 6"ϕ), and ranges from 2.0 Baht/m^3 to 5.03 Baht/m^3.

(e) Water quality

Quality of water is shown in Table 3-2-4.

Table 3-2-4 Water Quality

Items	Raw Water	Filtrated Water	
	1982.8.4	1982.8.5	1981.5.4
Color	N.D.	N.D.	N.D.
Odor	N.D.	N.D.	N.D.
Taste	N.D.	N.D.	N.D.
Turbidity SiO_2 (ppm)	72	3.7	1.0
pH	7.8	7.9	7.8
Electric Conductivity 20°C (mΩ/cm)	180	210	450
Total Hardness $CaCO_3$ (ppm)	120	140	196
Carbonate Hardness (ppm)	98	98	178
Non-Carbonate Hardness (ppm)	22	42	18
Nitrate (ppm)	0.0090	0.0051	0.0056
Cl (ppm)	6.0	9.0	7.0
Total Fe (ppm)	0.003	0.085	0.175
Mn (ppm)	0.07	nil	nil
Cu (ppm)	0.105	0.2084	0.093
Zn (ppm)	0.494	0.560	0.210
Pb (ppm)	N.D.	N.D.	N.D.
Mg (ppm)	7.2	7.7	19
SO_4 (ppm)	1.0	2.1	11
F (ppm)	0.01	0.1	0.23
Alkali	N.D.	N.D.	N.D.
Suspended Solid	-	-	-
Evaporation Residue	-	-	-

N.D. : Not Detected

(4) Transportation

The primary national highway connects Tak and Bangkok, and the 87 kw length concrete-paved highway (secondary highway) starts from Tak towards west direction ends at Mae Sot. Other local highways and roads (latelite paved) connected with this highway makes road network in the area. Traffic of the roads in the area is not heavy at present, indicating considerable surplus capacity for the future increase of traffic.

As for communications, buses, both ordinary and air-conditioned, commute between Bangkok and Mae Sot daily. The cost per person is about 57 Baht for ordinary bus, and 110 Baht for air-conditioned. Buses and taxis from Tak to Mae Sot cost 13 and 25 Baht respectively. At present, the area is not directly accesible by train. There is a small commercial airport in the town of Mae Sot, however no regular commercial flight is available except chartered flights.

(5) Medical facilities

The following medical facilities are currently available in Mae Sot area.

Facilities	Numbers
Hospital	1 (202 beds)
Health Center	8
Maternity Clinic	1
Medical Office	5
Pharmaceutist	11

(6) Accomodation and others

The following facilities are currently available in Mae Sot area.

Facilities	Numbers
Hotel	4
Movie	3
Bank	6
Restaurant	many

SECTION IV ASSESSMENT OF RAW MATERIALS AND RAW MATERIALS SUPPLY

The raw materials for the ordinary portland cement are mainly limestone and clay, and as additives siliceous material and ferrous material are used. These materials are mixed based on the raw mix design, then ground by the raw mill. The clinker is a product of burnt raw mixture through the kiln. The ordinary portland cement is manufactured by mixing the clinker with 3 - 4% of gypsum, and then finely ground to the final product through the clinker mill. In case of the oil shale cement, however, oil shale is used as a cement raw material instead of clayey material, and also used as a fuel for the power station. Furthermore, oil shale ash (combustion residue) from the power station is used for mixing material of the cement.

The site investigation and study were conducted taking energy balance and material balance into consideration because their balance is important factor for the Project.

The main raw materials for the Project are oil shale and limestone, and the additive materials are ferrous material and gypsum.
Siliceous material and clayey material are not required for the Project, but these materials were also investigated considering that these materials may be required in the future.

The study on the existing investigation reports, the site investigation and analysis of the data obtained, were carefully carried out. Especially for the main raw materials, two third of the total study schedule was consumed.

As for oil shale deposit at Mae Sot area, DMR (Department of Mineral Resources) and others have carried out detailed geological survey and topographical survey, and also the geology of the Mae Sot Basin was described in several reports.

Klockner Industries and Lurgi Co. of Federal Republic of Germany, dispatched oil shale experts from January to August, 1982 in order to carry out preliminary feasibility study, including core boring on oil shale deposit at Ban Huai Kalok area. The result of core boring was also utilized for preparing this report.

The limestone deposits occur at the western and eastern areas of the town of Mae Sot.

The limestone deposit of the western area, which is called to be Doi Din Chi deposit, was surveyed for the Project in detail on the deposit surface from the geological and mining points of view. In the period of site survey, the quality of the raw material was checked visually based on the accumulated experience, and at the same time the grab samples collected from the deposit surface were chemically analyzed on CaO and MgO contents at the temporary laboratory at Mae Sot.

Ferrous material and gypsum were geologically surveyed at Nakhon Sawan province and Phichit province respectively because there is no source of these raw material deposits in Mae Sot.

- Outline of geological survey work in Thailand, in cooperation with DMR.

(1) Limestone material

- General geological survey of Doi Din Chi limestone deposit.
- Collection of samples from the deposit surface.
- Site survey for study on quarry development and raw material transportation.
- Chemical analysis of limestone samples collected (32 pieces).

(2) Oil shale material

- General survey of oil shale deposit at Mae Sot.
- Confirmation at field of boring points carried out so far at Ban Huai Kalok
- General geological survey of Ban Huai Kalok.
- Study on the previous reports and boring data.
- Collection of representative samples for laboratory test.
- Site survey for study on quarry development and raw material transportation.
- Chemical analysis of core samples of oil shale (34 pieces).

(3) Clayey material

- General geological survey of Ban Huai Kalok area.
- Collection of clay samples.
- Study on boring core.
- General geological survey of the area along Tak - Mae Sot Highway, and sampling of clay.
- Chemical analysis of boring core of claystone, marl, shale etc. (12 pieces).

(4) Siliceous material

- General survey of the area along the Moei river.
- Collection of silica sand samples.

(5) Ferrous material

- General geological survey of iron deposit at Non Poh, Nakhon Sawan province.
- Collection of samples

(6) Gypsum material

- General geological survey of gypsum deposit at Don Kui, Phichit province.

IV-1 Geological Survey

IV-1-1 General Geology of Mae Sot Area

The general geology of Mae Sot area is mentioned hereinafter in relation with the raw material deposit for the Project.

The stratigraphical sequence of Mae Sot area is considered as shown in Table 4-1-1.

The geology of Mae Sot area is divided, in descending order, into : the Quaternary Bed and Tertiary Formation of the Cenozoic, the Triassic Formation of the Mesozoic, and the Permian Formation of the Paleozoic.

These formations lie in unconformable contact with each other.

Oil shale is one of the main raw materials for the Project. The Mae Sot Basin is geologically composed of the Tertiary Formation which consists of an alternation of oil shale, shale, marl etc.

The Mae Sot Basin which is situated along the Thai-Burmese border, about halfway between Tak in Thailand and Moulmein in Burma, is about 50 km in length (north-south direction) and is about 30 km in width (east-west). The town of Mae Sot is at about the center of the basin. One third of the basin is in Burma and two thirds in Thailand.

Limestone is another main raw material for the Project, and limestone deposits occur in the Mesozoic which is situated west of the Mae Sot town, and in the Paleozoic which is east of the Mae Sot town.

For the Project, the Triassic limestone of the Mesozoic was geologically surveyed, and this limestone distributes along the Moei river, contacting with conglomerate, sandstone etc.

On the other hand, at the eastern area of Mae Sot town, shale, sandstone, chert etc of the Paleozoic distribute along Tak - Mae Sot highway. At further eastern area, dolomitic limestone, dolomite and limestone belonging to the Paleozoic distribute widely of steep slope or perpendicular feature. These carbonate rocks are not suitable for the Project due to high MgO content.

Clayey material and siliceous material were also surveyed for possible future use, although these raw materials are not required for the Project according to the raw mix design. As clayey material, shale, marl and the like which alternate with or overlie oil shale are suitable, and an alternation of shale and sandstone along Tak - Mae Sot highway is also suitable for cement raw material.

As for siliceous material, silica sand deposits of the Alluvium are found in places along the Moei river. These silica sand deposits are suitable for cement raw material.

The additives such as ferrous material and gypsum are not found at Mae Sot.

Table 4-1-1 Geological Stratigraphy of Mae Sot Area

Geological age		Series	Formation	Raw material for cement
Alluvium, Quaternary		* Mae Ramat Graval	Clay, sand gravel River deposit	Siliceous material (Silica sand)
		unconformity		
Cenozoic	Pliocene to Miocene, Neocene, Tertiary	(Mae Sot Series) * Mae Sot Oil Shale	-The Fourth Member shale alternating with oil shale and calcareous shale. less than 300m thick -The Third Member sandy shale, sandy marl alternating with siltstone, sandstone and oil shale. more than 500m thick -The Second Member marlstone, alternation of oil shale and shale. more than 900m thick. -The First Member argillaceous limestone alter-nating with sandstone and shale. 600m or more	Oil shale material and clayey material
		unconformity		
Mesozoic	Triassic	* Mae Moei Group	Conglomerate, limestone guartz-sandstone limestone, shale	Limestone material
		unconformity		
Paleozoic	Permian		dolomitic limestone, alternation of shale and sandstone, quarty-sandstone.	Clayey material

(* by Von Braun and Jordan)

The following reports and maps were referred to for preparation of the report.

1. DRM (1976): Geological Map of Amphoe Mae Sot (1/20,000)

2. DMR (1978): Mae Sot Oil Shale Exploration

3. DMR (1979): Reserve Estimation of Oil Shale Source, Amphoe Mae Sot, Tak Province

4. Royal Thai Survey Department (1979): Topographical Map of Oil Shale Potential Amphoe Mae Sot, Changwat Tak (1/15,000)

5. DMR (1979): Geological Map of Amphoe Mae Sot, Changwak Tak (1/30,000)

6. Subcommittee on Oil Shale (1981): Mae Sot Oil Shale Development

7. Chiang Mai University (1981): Oil Shale Resources at Ban Huai Kalok, Mae Sot District

8. DMR (1976): Phichit Gypsum Deposit, Central Thailand

IV-1-2 Limestone Material (Doi Din Chi Deposit)

(1) Previous investigation and methodology

The Mesozoic and Paleozoic of Mae Sot area were surveyed by Von Braun and Jordan in 1976 along Tak - Mae Sot highway. Prior to this investigation, DMR started core boring on oil shale deposit in 1973, and at the same time DMR started geological survey and topographical survey of Mae Sot area.

DMR prepared a report and a map titled "Mae Sot Oil Shale Exploration" in 1978 and "Geological Map of Amphoe Mae Sot, Changwat Tak" in 1979. In this report and map, the Mesozoic and the Paleozoic were also outlined. The limestone deposit which is situated at Doi Din Chi, east of the Moei river, was surveyed for cement raw material. DMR also surveyed roughly and prapared the geological map of 1:20,000 scale in 1976, and the same of 1:30,000 in 1979. The result of chemical analysis of 21 limestone samples was given by DMR. Among them, 5 samples were from Doi Din Chi deposit, and the rests were from eastern deposit of Mae Sot town.

- Site work of JICA's (Japan International Cooperation Agency) survey team in cooperation with DMR.
  - Geological mapping by the scale of 1:2,000 : approx. 300 ha.
  - Sampling for correlation and chemical analysis : 219 pieces
  - Sampling for burnability test : 11 kg
  - Chemical analysis of grab samples : 32 pieces

(2) Location and accessibility

Doi Din Chi limestone deposit is situated about 8.5 km north-west from Mae Sot town, in other words the deposit is about 2 km from the Moei river which is running on the Thailand - Burma border.

It is easy to approach to the deposit from Mae Sot town as shown in Fig. 4-1-1.

The route to approach to the deposit is as follows:

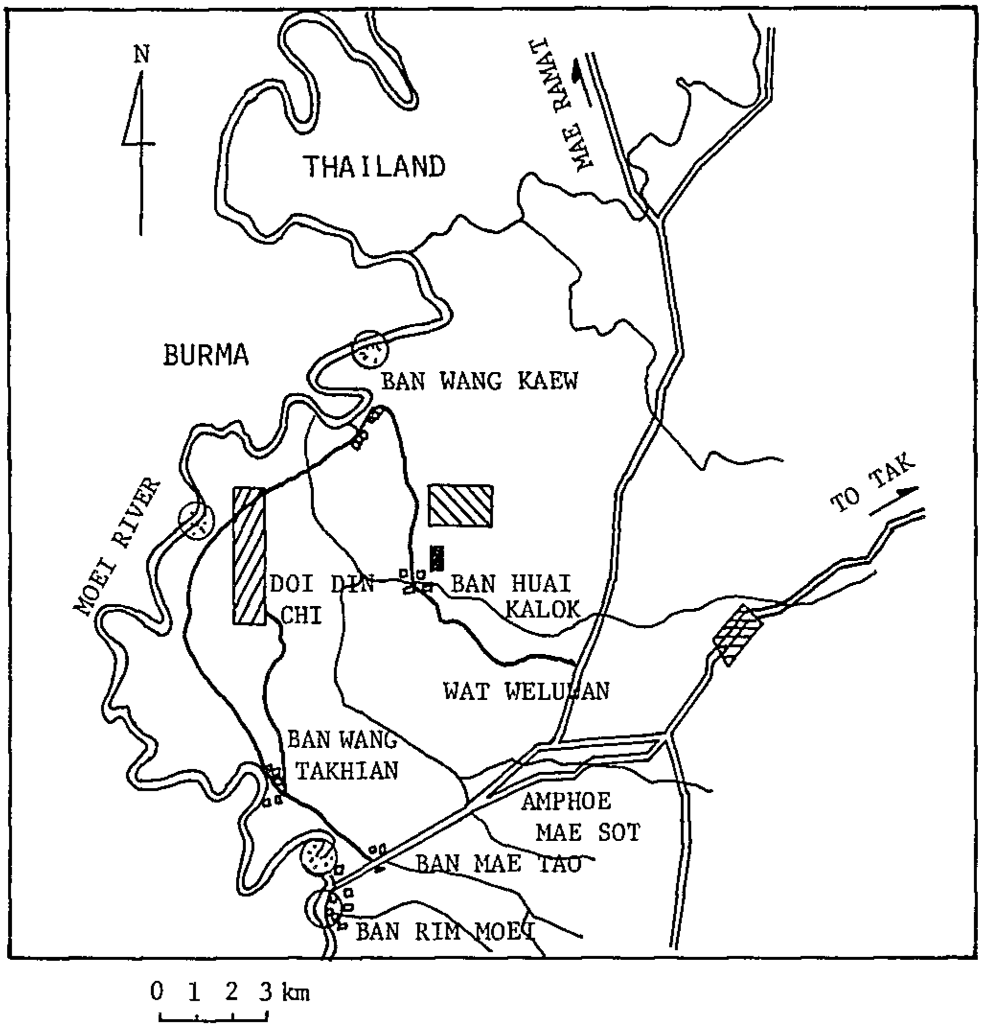
[Mae Sot town] — paved road, about 5 km → [Ban Mae Tao] — non-paved road, about 2.5 km →

[Ban Wang Takhian] — non-paved road, about 4.5 km → [Doi Din Chi deposit]

The transportation distance of limestone material is about 5.5 km from the proposed quarry to the proposed plant site. It is necessary to construct a new transportation road between the proposed quarry and the plant site.

Local contractor is working to produce crushed stone for construction material at the southernmost area of the deposit which extends with the direction of north-south. That limestone quarry produces about 500 m^3/month of limestone crushed-stone, and is being operated by inclined stoping.

Fig. 4-1-1 Location Map of Raw Material Deposit at Mae Sot



SCALE APPROX. 1 : 200,000

Index

- Limestone deposit
- Oil shale and clay deposit
- Clay deposit
- Silica sand deposit
- The proposed plant site

(3) Topography and Vegetation

Doi Din Chi limestone deposit is situated at the west of Mae Sot town which is approximately 200 m above sea level (S.L.). The mountain range composed of the deposit lies independently with the direction of north-south. The highest point of the range indicates 435 m S.L. and the level of the existing road to the west of the range is 200 m S.L.. The level of the existing quarry at southernmost of the deposit area is 240 m S.L..

The limestone deposit of the northern area distributes across the north-south range with low angle, but at the southern area the limestone deposit forms the top of the range. The lowest level in the limestone deposit is about 200 m S.L. at the road on the north area of the deposit, and the highest level is 400 m S.L. at the top of the central area. Accordingly, the maximum elevation is 200 m at the limestone deposit.

The slope of the area formed by limestone has 20° - 40° inclination on the average. However, there are in places very steep slope and perpendicular cliff of limestone. Especially, at the eastern slope of the central range, it is impossible or very difficult to approach to the slope. In the area surveyed, cultivated area is found at the gentle land to the east of the existing quarry, and to the west of the range.

As for the vegetation of the range, the area is covered with bamboos, bushes, grass, and rarely tall trees. The vegetation of the area is not so dense.

Top soil covering the deposit, in general, is thin and so limestone is well-outcroped.

(4) Geology and Deposit

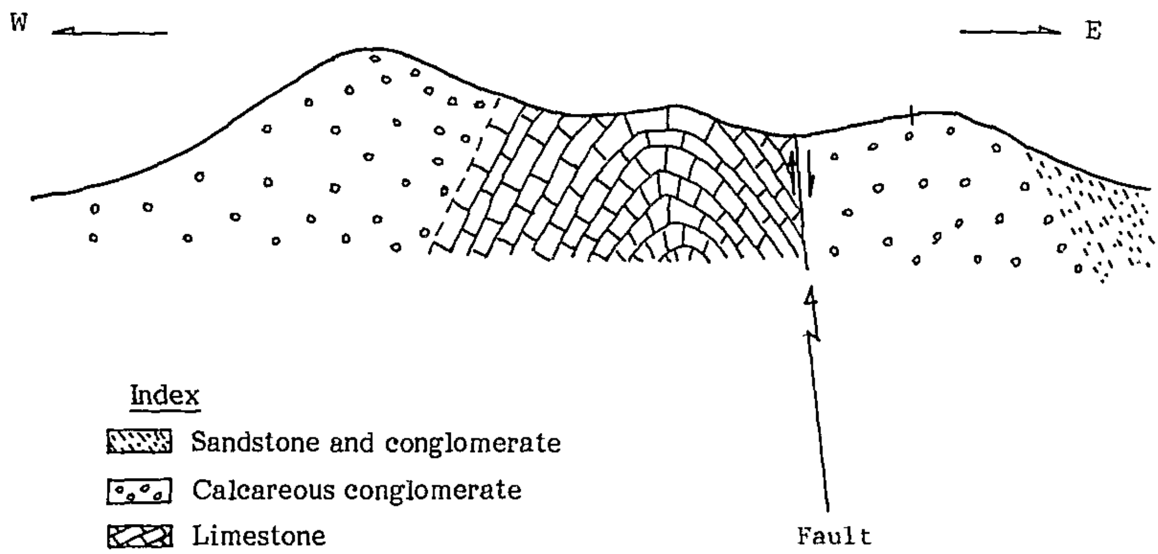
The geology of Doi Din Chi area and the neighbouring area is composed of limestone formation, limestone conglomerate formation, and sandstone and conglomerate formations from the bottom to the top in order.

In general, the formations strike NS or NW and form probably anticline structure. Accordingly, the formations dip east at the eastern slope and dip west at the western slope.

According to the classification made by Von Braun and Jordan (1976), these formations belong to Mae Moei Group of the Triassic, and these are equal to the Kamawkala Limestone named after by Cotter (1924).

The schematic geological section of the area is shown in Fig. 4-1-2.

Fig. 4-1-2 Schematic Geological Section of Limestone Deposit



(i) Limestone formation

The limestone formation extends with the direction of north-south, having about 3,800 m elongation and 200 m - 600 m width. Swelling and pinching in the limestone formation are observed.
The limestone formation is cut by ENE-N wrench fault at about 40 m south of the independent top of 424 m S.L.. The limestone formation appears to be moved laterally along wrench fault. In this report, the southern formation divided by the fault is referred to as "south limestone deposit", and the northern as "north limestone deposit".
As for the south deposit, it extends about 1,100 m with the derection of north-south, and it is exposed in width of 200 m - 600 m but diminishing at the southern end. The limestone formation, in general, is massive, has few bedding planes, but the bedded limestone occurs in places. The bedded limestone strikes N25°W-N25°E and dips 50°-60° west at the western slope, 50°-60° east at the eastern slope. As shown in geological map (attached DWG. No. G-03), the south deposit lies in unconformable contact with sandstone and conglomerate, although a part of the deposits contacts with calcareous conglomerate conformably.

On the other hand, the north deposit distributes with elongation of about 2,700 m and width of 200 m - 500 m. The north deposit is cut by wrench fault and extends to further north.
The north deposit extends with the direction of NE-SW. The bedded limestone strikes N30°-50°W and dips 60°-70° west at the western slope, 60°-70° east at the eastern slope.
The eastern boundary of the north deposit is in fault contact with sandstone, conglomerate and calcareous conglomerate, and the western boundary is in conformable contact with calcareous conglomerate.

As mentioned before, the near central belt appears to form an axis of anticline.

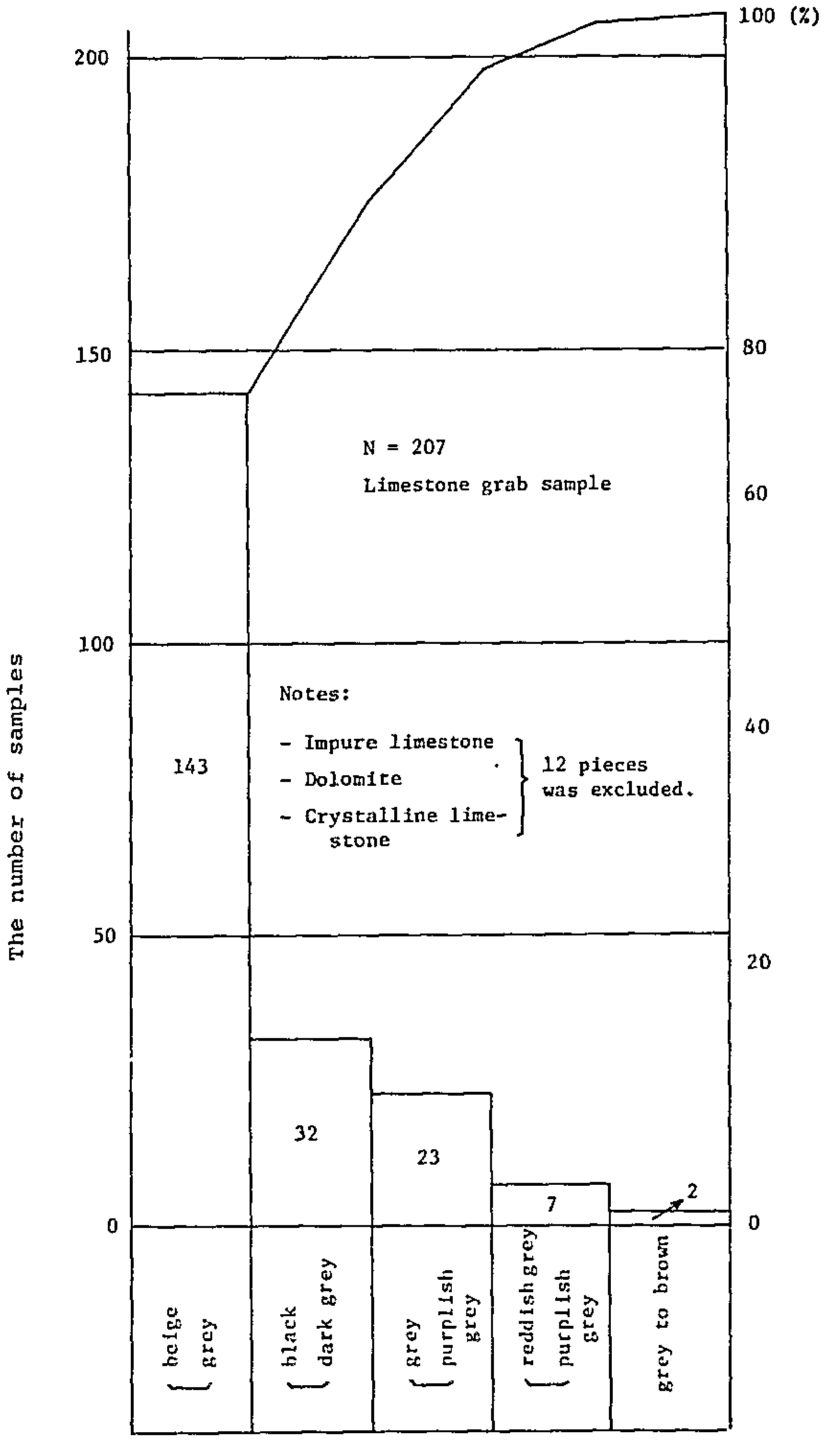
The limestone is generally cryptocrystalline, hard, compact in lithological characteristics. Fig. 4-1-3 shows the result of classification of limestone samples based on visual observation. According to Fig. 4-1-3, light beige to grey limestone occupies 70% of total, light grey to black limestone and purplish grey occupy 15% and 11% respectively, and the rest of 4% is purplish grey to pinkish grey, greyish brown etc.

There is no close relation between limestone colour and chemical composition.

Calcite veins of 0.5 mm - 5.0 mm width cross frequently limestone formation forming network structure. Especially along and around the fault, crystalline limestone composed of calcite vein of several mm size occurs occasionally but in small scale in width and extension. And particular type of limestone with red network structure, which is similar to conglomerate or brecciated limestone in texture, occurs locally along and around the fault and geological boundary. This type of limestone is also suitable for cement raw material.

Waste rocks as intercalation, which are reddish marlstone and dolomite, are rarely found in limestone formation. The reddish marlstone of 1 m to 2 m thick is intercalated at two places in the south deposit, but its size is very small. Dolomite and dolomitic limestone show an elephant skin structure on the weathered surface of outcrop. These dolomitic rocks occur in shape of lense or nodule within 1 m in size. It is easy to distinguish the dolomitic rock from limestone by the characteristics of its particular fracture and the eleplant skin structure.

Fig. 4-1-3 Classification of Limestone Samples Based on Colour



These intercalations can be used as cement raw material by mixing them with limestone of good quality, because their localities are limited locally and their size is small. The top soil covering limestone deposit is thin, about 1 m on the average, so a part of top soil can be used as raw material by mixing with limestone. In dry season, there is no water flow along valley in the deposit area, but the calcareous-sinter deposited along valley indicates considerable water flow in rainy season.

Judging from the geological, topographical and mining conditions, the northern area of the existing quarry in the south deposit is proposed for limestone quarry for the Project.

(ii) Calcareous conglomerate formation

Calcareous conglomerate overlying limestone lies in conformable contact with limestone at the western boundary of the north deposit, and at a part of the western boundary of the south deposit. But at the eastern boundary of the north deposit this conglomerate is in fault contact with limestone.

Calcareous conglomerate distributes widely at the central peak and north area of the surveyed area. This conglomerate is mainly composed of the rounded and angular gravel, pebble and cobble of limestone, sandstone, quartzite and rarely chert in calcareous or marly matrix. The matrix is generally raddish in colour, but occasionally grey.

This formation has no bedding plane and is impossible to get the figure of the strike and dip.

(iii) Sandstone and conglomerate formation

Sandstone and conglomerate overlying calcareous conglomerate distributes widely at the south area, northernmost area,east area of the surveyed area, and Doi Yao area of east to the surveyed area. In the south area of the surveyed area, sandstone lies in unconformable contact with limestone. Sandstone is fine, compact, grey in colour, but generally weathered into yellowish brown to whitish grey. In other area except the south area of the surveyed area, conglomerate and siliceous rock are dominant and sandstone is rare.

Generally, conglomerate is composed of the rounded and angular gravel, pebble and cobble of sandstone in sandy matrix.

This conglomerate is very hard.

Siliceous rock, some of which is flinty, is very hard, and its color is reddish brown to yellowish brown.

This formation has no bedding plane and is impossible to measure the strike and dip.

(5) Limestone reserves

Limestone reserves were calculated based on the result of geological survey. (Refer to attached DWG. No. G-06 and G-07).

(i) Basic condition for calculation

(a) Limestone deposit is divided into the south deposit and the north deposit.

(b) The area calculated in the surveyed area:
The south deposit 16.0 ha.
The north deposit 24.7 ha.
Total 40.7 ha.

(c) The topographical map used:
1/2,000 (enlarged map of 1:15,000 topographical map made by the Royal Thai Survey Department)

(d) The final angle of faces:
60^o to the horizontal plane.
Notes: 1) Border between the south deposit and the north deposit: 90^o
2) North border of the north deposit: 90^o

(e) The proposed quarrying level: 230 m S.L.

(f) Formula used: Simpson's Formula
In case section number is odd,

$$V = \frac{1}{3} \quad a_1 + a_n + 4 \times (a_2 + a_4 + \ldots) + 2 \times (a_3 + a_5 + \ldots)$$

In case section number is even,

$$V = \frac{1}{3} \quad a_1 + a_{n-1} + 4 \times (a_2 + a_4 + \ldots) + 2 \times (a_3 + a_5 + \ldots) + L \times \frac{a_{n-1} + a_n}{2}$$

where V: whole volume (m^3)
L: interval between each vertical section (m)
a_i: area of cross section (m^2)

(g) The list of the area of each cross section: shown in Table 4-1-3.

(h) Apparent specific gravity: 2.68

(i) The safety factor for the accuracy of survey/calculation, and recovery ratio: 0.95 and 0.9 respectively.

(j) The accuracy of reserves:
Judging from the geological condition and geological structure, calculated reserves are considered to be between the proven reserves and the probable, but before implementation of the Project in future, core boring should be carried out for quarry development.

(k) The thickness of top soil:
estimated to be 1 m on the average.

(1) Limestone production required:
577,703 t/yr

(ii) The result of reserves calculation

The calculation result is summarized in Table 4-1-2. The limestone reserves of the south deposit and the north deposit are 13.0 million tons and 18.7 million tons respectively, and total reserve amounts to 31.7 million tons.

The life of the limestone reserves is 22 year at the south deposit, and 32 years at the north deposit respectively for the Project.

Table 4-1-2 Limestone Reserves and Top Soil Volume

Deposit	Limestone		Top soil (m^3)
	Available reserves (t)	Life (yr)	
South deposit	13,030,000	22	160,000
North deposit	18,680,000	32	247,000
Total	31,710,000	54	407,000

Note: 1) In addition to the limestone reserves listed above, other limestone reserves can be expected in the northern area adjacent to the north deposit.

2) A part of top soil can be used as raw material by mixing with limestone.

(iii) Detail of calculation (Refer to Table 4-1-3)

- The south deposit

Whole volume

$$V_S = \frac{50}{3}\{a_1 + a_{13} + 4 \times (a_2 + a_4 + a_6 + a_8 + a_{10} + a_{12}) + 2 \times (a_3 + a_5 + a_7 + a_9 + a_{11})\}$$

$$\doteqdot 5,850,000 \ (m^3)$$

Top soil volume

$$V_S' = 160,000 \ m^2 \times 1 \ m = 160,000 \ m^3$$

Available limestone reserves

$$M_S = (V_S - V_S') \times 2.68 \times 0.95 \times 0.9 \doteqdot 13,038,000 \ (t)$$

- The north deposit

Whole volume

$$V_N = \frac{50}{3}\{a_{14} + a_{28} + 4 \times (a_{15} + a_{17} + a_{19} + a_{21} + a_{23} + a_{25} + a_{27}) + 2 \times (a_{16} + a_{18} + a_{20} + a_{22} + a_{24} + a_{26})\} + \frac{a_{28} + a_{29}}{2} \times 50 \doteqdot 8,403,000 \ (m^3)$$

Top soil volume

$$V_N' = 247,000 \ m^2 \times 1 \ m = 247,000 \ m^3$$

Available limestone reserves

$$M_N = (V_N - V_N') \times 2.68 \times 0.95 \times 0.9 \doteqdot 18,688,000 (t)$$

Table 4-1-3 Area of Cross Section

Section No.	Sign	The south deposit (m^2)	The north deposit (m^2)
1	a_1	960	
2	a_2	4,400	
3	a_3	9,880	
4	a_4	12,040	
5	a_5	13,360	
6	a_6	17,000	
7	a_7	24,360	
8	a_8	17,480	
9	a_9	10,800	
10	a_{10}	5,000	
11	a_{11}	2,640	
12	a_{12}	1,000	
13	a_{13}	320	
14	a_{14}		1,000
15	a_{15}		1,560
16	a_{16}		2,160
17	a_{17}		2,400
18	a_{18}		2,880
19	a_{19}		3,040
20	a_{20}		4,400
21	a_{21}		6,200
22	a_{22}		11,480
23	a_{23}		15,000
24	a_{24}		18,400
25	a_{25}		20,400
26	a_{26}		22,520
27	a_{27}		23,520
28	a_{28}		23,360
29	a_{29}		21,760

Note: Section No. corresponds to that of attached DWG. No. G-06.

Fig. 4-1-4 Classification of Limestone Samples Based on CaO Content

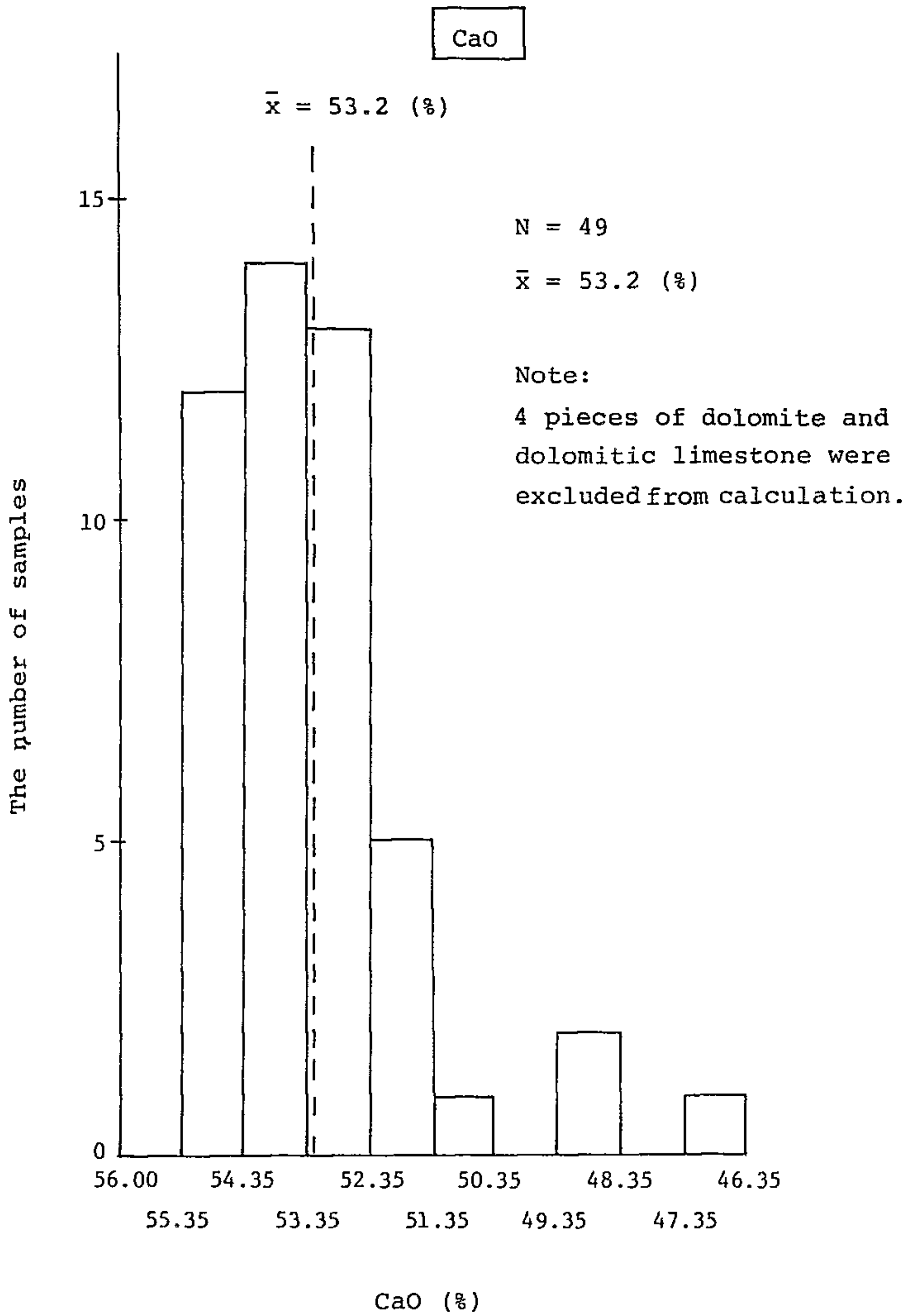
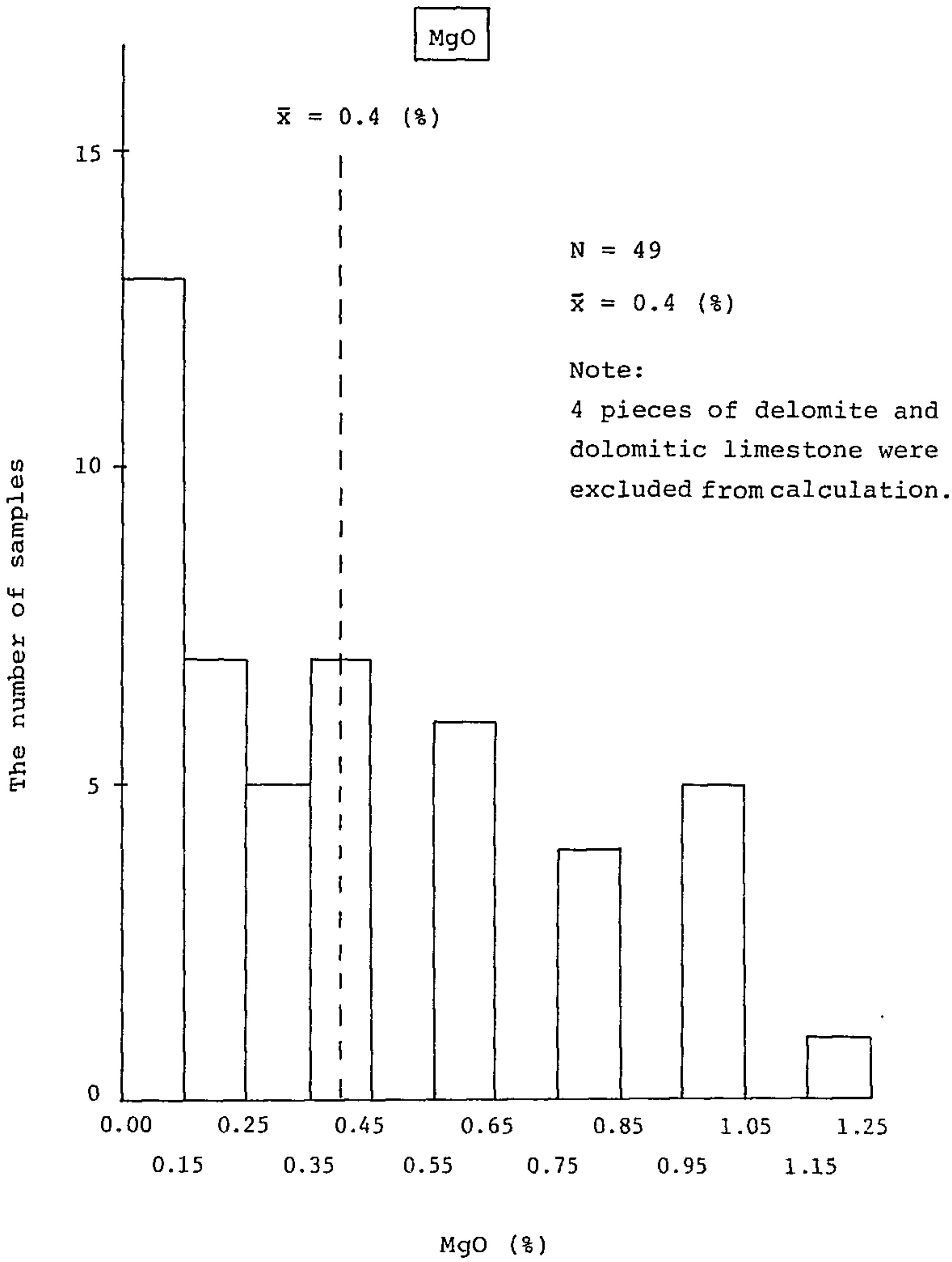


Fig. 4-1-5 Classification of Limestone Samples Based on MgO Content



(6) Outline of quality

The average chemical composition of 49 limestone samples except for 4 dolomitic samples is as follows:

CaO	:	53.2 %
MgO	:	0.4 %

The classification of limestone smaples is shown in Fig. 4-1-4 based on CaO content, Fig. 4-1-5 based on MgO content.

Doi Din Chi limestone contains high CaO and low MgO contents which can meet requirements for the Project in quality.

MgO content in dolomitic rocks of lense or nodule varies from 8% to 17%, but it does not give the influence on the quality of limestone material because the ratio of dolomitic rock to limestone is negligibly small.

The detail of limestone quality is mentioned in IV-1-2.

IV-1-3 Oil Shale (Mae Sot deposit)

(1) Previous investigation and methodology

The Cenozoic formation of Mae Sot area was described as the Mae Sot Series by Brown et al. (1951). Von Braun and Jordan (1976) used the name of the Mae Sot Group. After that, some private company carried out core boring at 10 points in oil shale reserve area for feasibility study.

Active exploration and research of oil shale at Mae Sot was started after the first energy crisis. In the end of 1973, the oil price was getting high because of the energy crisis, and then Thailand Government foresaw the importance and necessity to develop the Mae Sot oil shale resource as a substitute energy for oil.

DMR carried out exploration and research including core boring during the period from February 1974 to the end of 1978. After that, Chiang Mai University (1981) and Lurgi Company (1982) executed exploration and research of oil shale deposit.

Outline of the previous work is summarized as follows:

1974:

- Preparation of geological map of 1:20,000 scale.
- Preparation of Bouguer Anomaly map of Mae Sot basin. (modified in 1979)
- Core boring at 10 points (3,044 m ... 9,986 ft)
- γ-ray logging, resistivity and SP logging.

1975:

- Core boring at 25 points (5,472 m ... 17,953 ft)

1976:

- Start of analytical work (modified Fischer assay and chemical analysis)
- Shallow core boring at 2 points } at Ban Huai Kalok area
- Deep core boring at 51 points } (8,350 m ... 27,396 ft)
- Exploration and study on depositional environment of oil shale by experts of the Union of Soviet Socialist Republics.

1977:

- Core boring at 50 points (8,174 m ... 26,819 ft)
- Topographical survey.
- Preparation of topographical map of 1:15,000 scale.

1978:

- Core boring at 13 points (1,194 m ... 3,917 ft)

1981:

- Study on suitability of oil shale for mining as a fuel source for electricity generation at Ban Huai Kalok area.

1982:

- Preliminary feasibility study on oil shale at Ban Huai Kalok area by experts of Lurgi Company, including core boring at 21 points. (2,100 m ... 6,890 ft)

In short, DMR and other organizations carried out core boring at 176 points and total length amounts to about 28,350 m since 1974.

Oil shale smaples obtained from bore holes were tested on contents of oil, moisture, gas, sulfur, ash, etc., and measurement of calorific value and specific gravity was made. The physical properties of oil shale were tested, and also oil shale ash was chemically analyzed.

The area of 350 km^2 was surveyed geologically and topographically.

The following is the result of classification based on drilling depth. (Refer to attached DWG. No. G-08)

less than 300 ft (91 m)	:	70 bore holes
300 ft (91 m) - 500 ft (152 m)	:	72 bore holes
500 ft (152 m) - 1,000 ft (305 m)	:	13 bore holes
1,000 ft (305 m) - 1,500 ft (457 m)	:	10 bore holes
1,500 ft (457 m) - 2,000 ft (610 m)	:	9 bore holes
more than 2,000 ft (610 m)	:	2 bore holes
Total	:	176 bore holes

- Site work of JICA(Japan International Cooperation Agency)'s survey team, in cooperation with DMR.

  - General survey of oil shale area.
  - Selection of the proposed oil shale quarry based on the existing boring data.
  - Confirmation of boring points at Ban Huai Kalok area. (19 bore holes).
  - Rough geological survey of the proposed oil shale quarry.
  - Study on the boring data and observation of boring cores carried out at Ban Huai Kalok area.

- Study on previous reports etc.
- Collection of the representative oil shale samples
  - 120 kg from test pit near bore hole No. LK2 (Sample No. OSH-LK2')
  - 120 kg from test pit near bore hole No. DDH4-6 (Sample No. OSH-DDH4-6)

(2) Location and accessibility

From the result of exploration, oil shale was found to cover the area of approximately 200 km^2. The area was divided into 2 sections, north and south of Mae Sot town. The area surveyed (the proposed oil shale quarry of Ban Huai Kalok) is situated about 6 km north of Mae Sot town, in other word about 1.5 km northeast of Ban Huai Kalok.

It is easy to approach to the proposed oil shale quarry from Mae Sot town as shown in Fig. 4-1-1. The route to approach to the area surveyed is as follows:

Mae Sot town → paved road, about 4 km → Wat Weluwan → non-paved road, about 4.5 km →

Ban Huai Kalok → non-paved road, about 4.5 km → West of the area surveyed.

The area surveyed this time is situated within 3 km east from the road. And this area of about 3 km^2 is nearly the same as the area surveyed by Lurgi Company in 1982.

It is necessary to construct a transportation road between the proposed plant site and the proposed oil shale quarry. Transportation distance of oil shale material is less than 2 km, and 700 m at shortest.

Temporary road to the temporary waste dump area is required for transportation of waste materials.

(3) Topography and vegetation

The area surveyed is topographically gentle with undulation. The elevation of the area increases towards the east.

The highest level is 227 m S.L., eastern hill of bore hole LK15, and the lowest is 198 m S.L., around bore hole LK2. Accordingly the maximum elevation is about 30 m in the area surveyed. But the maximum elevation at the proposed quarry is about 20 m.

In the west of the area surveyed, rice field is found here and there, but in the east, the area is formed mainly by low hill and the rice field is rare.

As for the vegetation of the area, the hilly area is covered with teaks, other trees, bushes, and grass, but it is not so dense.

The proposed quarry site is hilly area and no rice field is found.

Several rough roads of 2 m - 3 m width are running in the area surveyed. Jeep can go through the roads.

(4) Geology and deposit

(i) Mae Sot Area

The geology of the Mae Sot Basin is composed of the Mae Sot Group (named by Von Braun and Jordan, 1976) of the Cenozoic formation. The Mae Sot Group is sub-divided into the Mae Sot Oil Shale of the Tertiary age which is equal to Mae Sot Series named by Brown et al., and the Mae Ramat Gravel of the Tertiary age.

Mae Sot Oil Shale is considered to be fluvial and lacustrine deposit of the Pliocene to the Miocene of the Tertiary age.

The Mae Sot Oil Shale (Mae Sot Series) can be devided roughly into 4 sub-divisions, from the lowermost to the uppermost part, as follows:

- The First Member (more than 600 m in thickness): yellow-brown argillaceous limestone alternating with sandstone and shale.
- The Second Member (more than 900 m in thickness): grey-green marlstone, in upper part alternating with oil shale and shale.
- The Third Member (more than 500 m in thickness): sandy shale, sandy marlstone alternating with siltstone, sandstone and oil shale.
- The Fourth Member (less than 300 m in thickness): laminated grey-green shale alternating with oil shale and dense non-laminated calcareous shale.

The outcrop of oil shale is rare at hilly and flat area, but along streams oil shale outcrop is occasionally found. Oil shale beds were found at 26 levels through boring survey and their average thickness is 1.2 m to 30.2 m (4 ft to 99 ft).

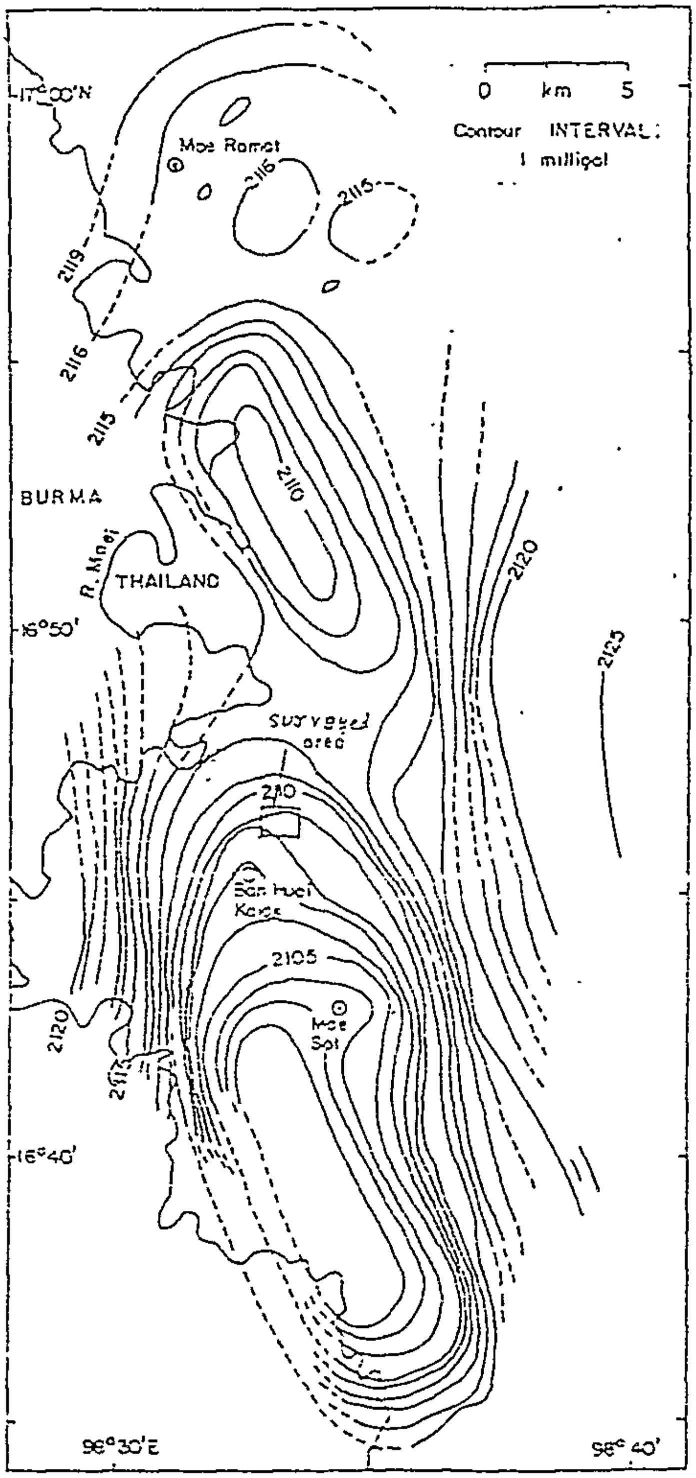
Oil shale bed varies in thickness, and is swelling and pinching as shown in Fig. 4-1-8 and attached DWG. No. G-10.

Oil shale is found in the area of 200 km^2 extending from north to south.

Bouguer anomaly map (Fig. 4-1-6) shows that Mae Sot Basin consists of two sub-basin.

The surveyed area is located at the northern margin of the south sub-basin.

Fig. 4-1-6 Bouguer Anomaly Map of Mae Sot Basin



Bouguer anomaly map of Mae Sot basin Modified from Mineral Fuels Division (1979)

(ii) Ban Huai Kalok area

Oil shale occurs in shallow level in the surveyed area, northeast of Ban Huai Kalok. This area, therefore, is judged to be suitable for open pit mining, as compararеd with other area. In the surveyed area, oil shale is seldom exposed due to the overburden of shale etc. and top soil. Marlstone, shale and standstone are found at test pit excavated by DMR.

Oil shale outcrops at southern area of bore hole LK2, distributing about 80 m long with the direction of north-south. This oil shale is black to dark brown in colour, bedded, and high grade. This outcrop strikes N35°E to N35°W and 15°-25° westward. The correct correlation of oil shale beds is not completed yet in the surveyed area, although core boring has been carried out at 20 points in the area. Attached DWG. No. G-10 is tentative geological section of the area based on the assumption that 8 or 9 levels of oil shale beds exist. The proposed oil shale quarry of about 100 ha. is located in the surveyed area, considering the suitability for open pit mining. Fig. 4-1-7 shows the said area and the oil shale reserves have been calculated for the same area.

According to the observation of boring core, the geology of the area mainly comprises of non-laminated and laminated green shale alternated with oil shale, and among them dark grey to yellowish grey, fine-grained sandstone and yellowish white marlstone beds are interbedded. Thickness of the beds varies from few centimeters to several meters.

- Description of the representative sample for this study

  Oil shale samples for laboratory test were collected about 60 m south of bore hole LK2. The samples were taken from the test pit of about 3 m deep by channelling from the top to the bottom. The collected samples were reduced to 120 kg of required quantity by the quatering method. The stratigraphy of the test pit is as follows.

The upper part comprises mainly black to dark brown oil shale of high grade. The middle and the lower parts are mainly composed of grey to greyish green, laminated oil shale which is medium to low grade. The greyish green calcareous shale appears at the bottom of the pit.

The representative oil shale sample collected lies upper level than those in the proposed quarry site, and about 1.2 km west of the same site. However, the property of oil shale is similar to each other.

(5) Reserves

(i) Mae Sot area

As mentioned before, the survey and study conducted so far revealed that oil shale covers about 200 km^2 in the northern and southern sections of Mae Sot town. DMR estimated the reserves of oil shale as shown in Table 4-1-4.

Table 4-1-4 Reserves of Mae Sot Oil Shale

Section	Area for estimation (km^2)	Oil shale reserves (10^6 t)	Shale oil reserves	
			(10^6 ℓ)	(10^6 bbl)
Northern Section	24	7,797	364,752	2,293
Southern Section	29	10,871	589,190	3,703
Total	53	18,668	953,942	5,996

Oil shale reserves were estimated to be 18,668 million tons in the area of 53 km^2, and shale oil reverses were calculated to be 953,942 million liters or 5,996 million barrels. This reserves were calculated to cover the reserves down to 600 m depth.

(ii) Ban Huai Kalok area

For the Project, oil shale is used as a cement raw material and a fuel for power station without retorting. Further, oil shale ash (spent shale, combustion residue) is also used as a part of cement raw material and mixing material of cement.

Oil shale reserves and overburden volume were calculated on the condition that oil shale is quarried by open pit mining.

In calculation, boring logs of oil shale were used as a basic data.

(a) Basic condition for calculation

(1) The area calculated: approximately 100 ha.
(Refer to Fig. 4-1-7)

(2) The proposed quarrying level: 30 m below ground level

(3) The thickness of oil shale: 10.4 m on average

- The total thickness of oil shale beds from the surface to 30 m depth is as follows at each bore hole.

LK7: 5m	LK13: 12m	LK14: 12m
LK16: 8m	LK17: 17m	LK18: 8m
LK19: 12m	LK20: 10m	DDH5-8: 10m

Average: 10.4m

(4) The thickness of overburden: 19.6 m on average.

(5) Apparent specific gravity: assumed to be 2.06
(result of measurement)

(6) The safety factor for the accuracy of survey/calculation, and recovery ratio: 0.9 and 0.77 respectively

(7) Oil shale production required: 642,654 t/year

(b) Result of calculation

The available reserves of oil shale, and the waste (overburden and intercalation) volume are estimated to be 14,800 thousand tons and 21,990 thousand cubic meters respectively in the proposed quarry. W/O ratio (waste volume/oil shale volume) is 2.8. These reserves which were calculated to 30 m depth are sufficient for 23 years operation for the Project.

As mentioned before, oil shale distributes outside of the calculated area as well, and the reserves are also sufficient for the operation even after 23 years. However, the outside area is inferior to the proposed site in quarrying condition due to thicker overburden.

Oil shale is also found below 30 m depth down to 100 m depth in the proposed site. This reserves between 30 m depth and 100 m depth should be taken into consideration in future.

(c) Detail of calculation

- Available reserves of oil shale.

1,000,000 m^2 x 10.4 m
(area) (average thickness)
x 2.06 (t/m^3) x 0.9
(apparent specific gravity) (safety factor)
x 0.77 ≒ 14,800,000 t
(recovery ratio)

- Life of the reserves for the Project.

14,800,000 t ÷ 642,650 t/y
(available reserves) (annual production)
≒ 23 years
(life)

- Waste volume (volume of overburden and intercalation)

(1,000,000 m^2 x 19.6 m)
(area) (average thickness)
+ (1,000,000 m^2 x 10.4 m
(area) (average thikness of oil shale)
x 0.23) ≒ 21,990,000 m^3
(intercalation)

- W/O ratio

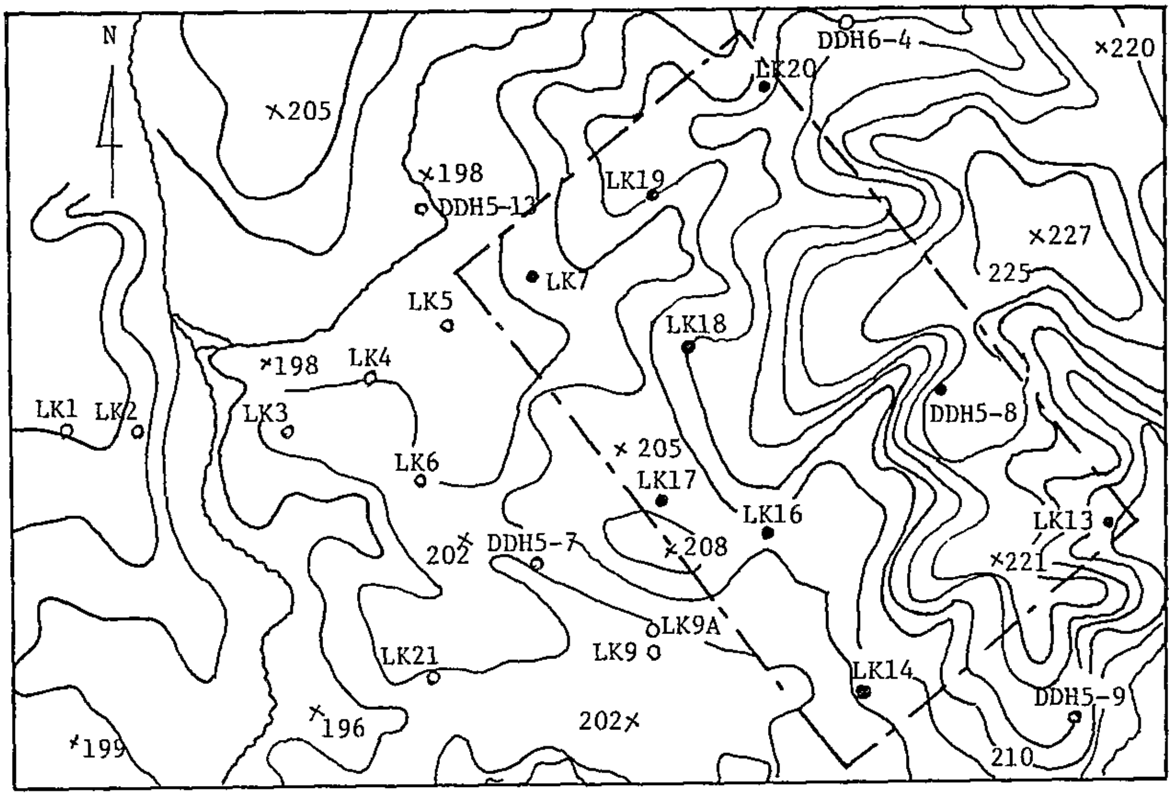
21,990,000 m^3 ÷ (1,000,000 m^2 x 10.4 m x 0.77) = 2.8
(waste volume) (Oil shale volume)

Notes:

(1) Intercalation/Oil shale was estimated to be 0.3 from boring core. Accordingly, recovery ratio that is, Oil shale/Oil shale plus intercalation is calculated to be 0.77.

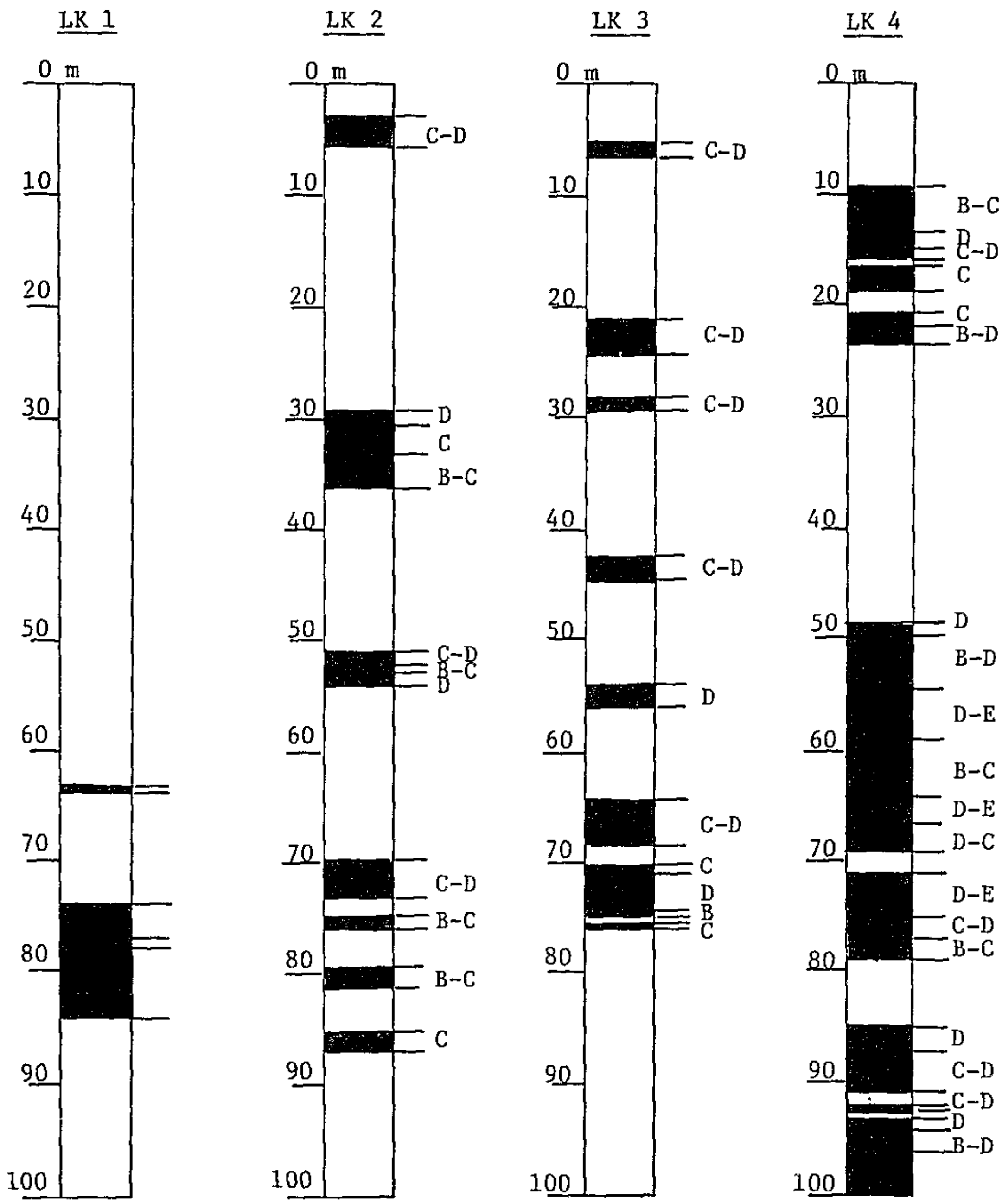
(2) Intercalation described in this chapter means mainly low grade oil shale.

Fig. 4-1-7 Location Map of The Proposed Oil Shale Quarry
(Map for Reserves Calculation)



Scale 1 : 15,000

Fig. 4-1-8 (1) Simplified Boring Log at Ban Huai Kalok Area



A, B : high grade oil shale

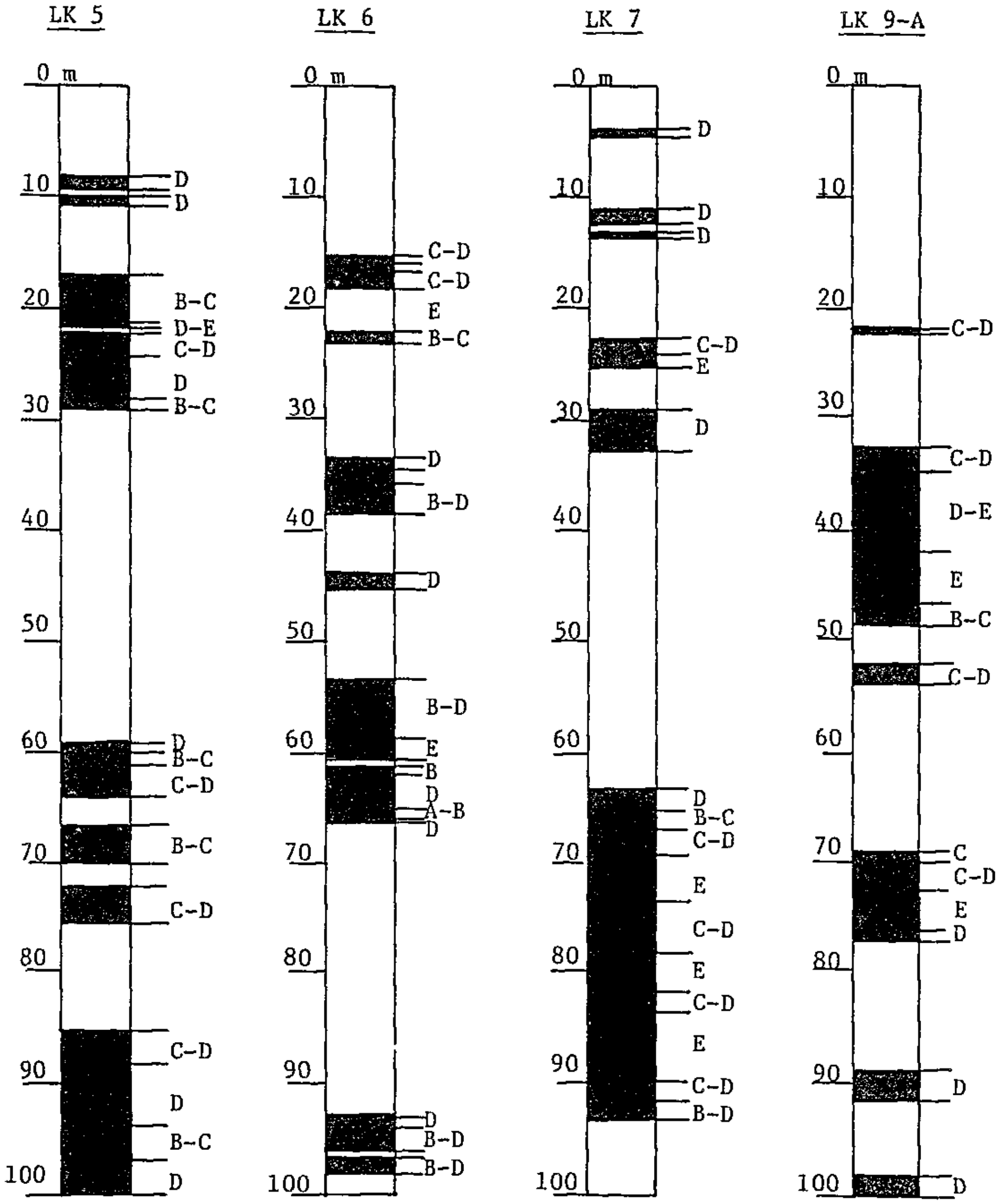
C : medium grade oil shale

D, E : low grade oil shale

Note: 1) These simplified boring logs were made from boring logs prepared by DMR.

2) Oil shale grade accords with DMR's classification.

Fig. 4-1-8 (2) Simplified Boring Log at Ban Huai Kalok Area

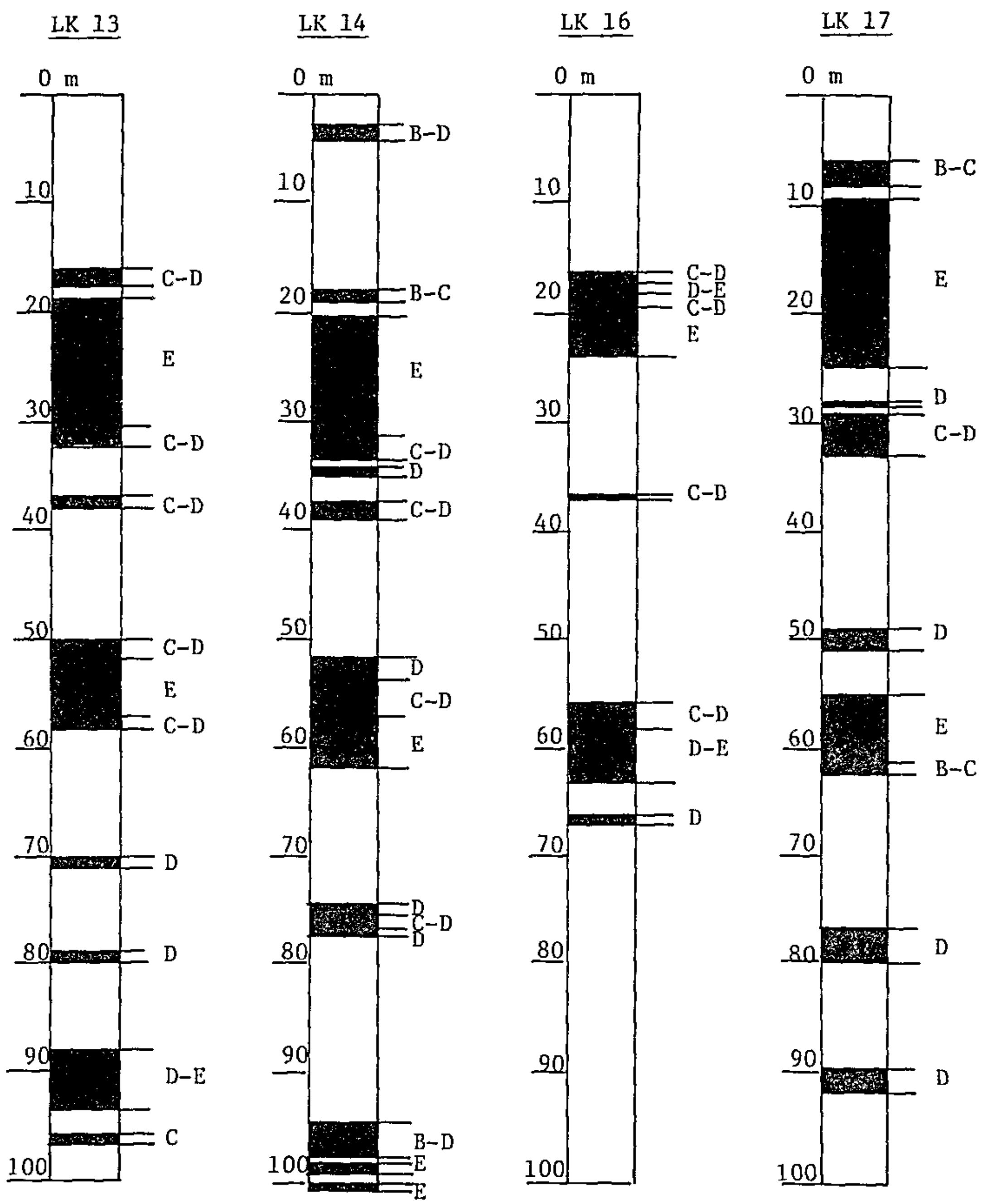


A, B : high grade oil shale

C : medium grade oil shale

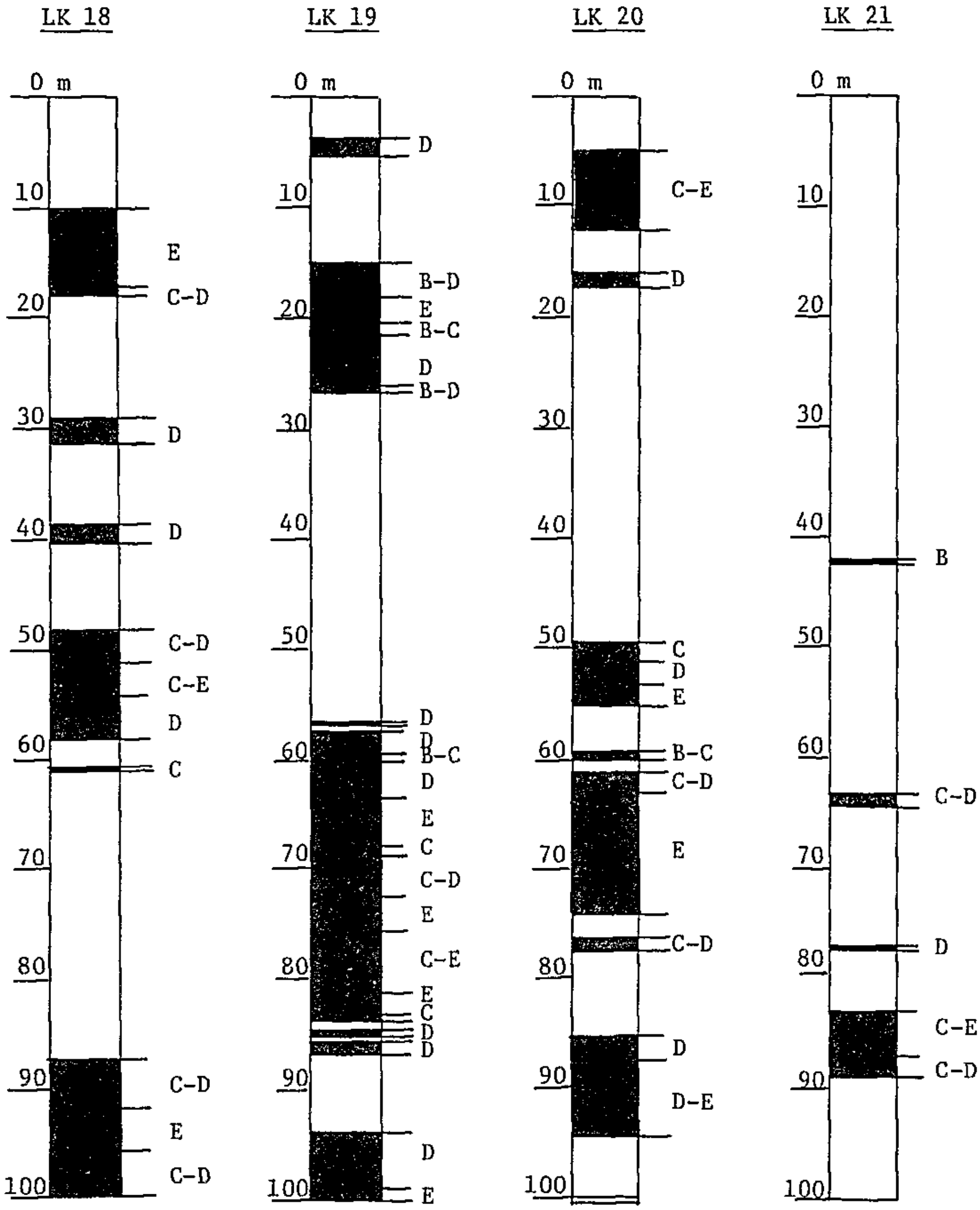
D, E : low grade oil shale

Fig. 4-1-8 (3) Simplified Boring Log at Ban Huai Kalok Area



A, B : high grade oil shale
C : medium grade oil shale
D, E : low grade oil shale

Fig. 4-1-8 (4) Simplified Boring Log at Ban Huai Kalok Area

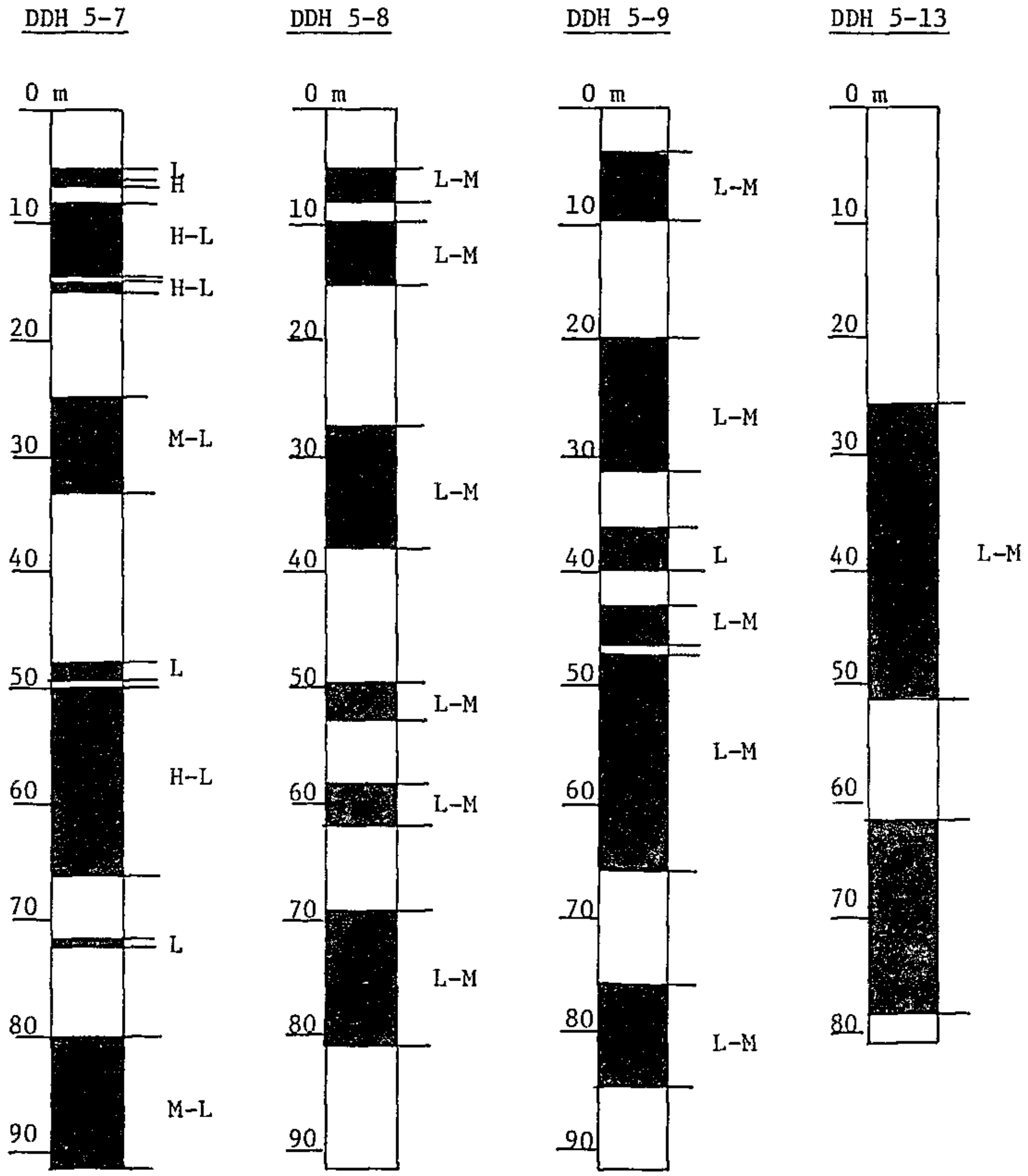


A, B : high grade oil shale

C : medium grade oil shale

D, E : low grade oil shale

Fig. 4-1-8 (5) Simplified Boring Log at Ban Huai Kalok Area

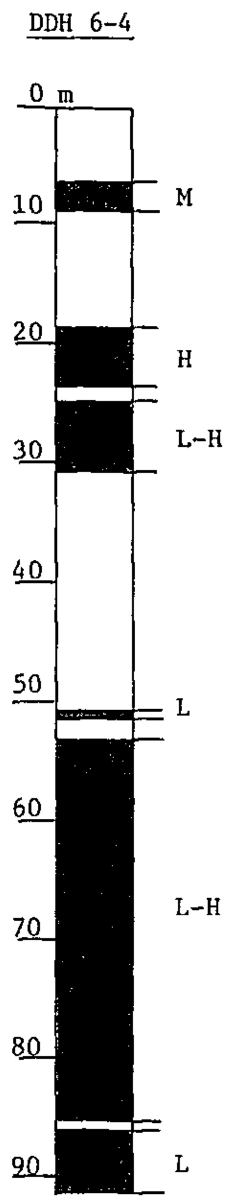


H : high grade oil shale

M : medium grade oil shale

L : low grade oil shale

Fig. 4-1-8 (6) Simplified Boring Log at Ban Huai Kalok Area



H : high grade oil shale

M : medium grade oil shale

L : low grade oil shale

(6) Outline of quality

DMR reported the following oil shale properties through modified Fischer assay analysis for 20,000 samples.

- Oil content : 1 - 26%/t-oil shale in weight.
- Average oil content : 5%/t-oil shale in weight or 50 liters/t-oil shale or 12 gallons/t-oil shale.
- Average calorific value : 1,187 kcal/kg-oil shale
- Average specific gravity : 1.83
- Sulfur content : 0.62%

Property of shale oil is as follows

- Average specific gravity : 0.89
- Average calorific value : 11,000 kcal/kg

For the Project, oil shale of the proposed quary can be used as a fuel for power station as it is, and also used as a cement raw material. Oil shale ash (combustion residue) can be used as a part of raw material as well as mixing material. As shown in Fig. 4-1-8 and attached DWG. No. G-10, oil shale bed varies in thickness considerably. From the quality viewpoint, oil shale varies from high to medium and further to low grade. Before the Project is realized, the occurrence of oil shale should be surveyed in more detail by supplementary core boring. Also after the Project is realized, it is indispensable to control the quality of oil shale strictly at quarry by selective mining.

IV-1-4 Clayey Material

The ordinary clayey material is not required for the Project according to raw mix design because oil shale and oil shale ash can substitute for clayey material. But two areas of clay deposit were investigated for possible future use.

(1) Ban Huai Kalok area

In excavation of oil shale, waste material which is about 2.8 times as much as oil shale has to be dumped. This waste material will be refilled in the mined oil shale pits after dumping to the waste dump area temporarily, but this waste material composed of marlstone, shale, sandstone etc. can be used as clayey material for cement raw material if required in future.

The volume of the waste is about 50 million tons (22 million m^3).

Location, topography and geology of the area are mentioned in IV-1-3.

(2) Area along Tak - Mae Sot highway

As shown in Fig. 4-1-1 and attached DWG. No. G-02, the area along Tak - Mae Sot highway was survey in search for clayey material. An alternation of shale and sandstone belonging to the Jurassic of the Mesozoic age is found about 6 km northeast of Mae Sot town.

The alternation is grey, dark grey and reddish brown in colour, hard, and not well-weathered. Unit layer of sandstone and shale is few centimeters to less than 1 meter in thickness, and both beds of alternation occur half and half in ratio. The general trend of the alternation is NS to N25°W, dipping 30° to 40° westward.

This alternation is suitable as clayey material in future, and the reserves are abundant. However, the alternation of this area will not be probably required even in future because clayey material can be expected sufficiently at Ban Huai Kalok area.

IV-1-5 Siliceous Material

According to raw mix design, siliceous material is not required for the Project. However, it is possible to use siliceous material in future for adjustment of Silica Modulus (SM ..: $\frac{SiO_2}{Al_2O_3+Fe_2O_3}$). For that purpose, silica sand deposit was surveyed in the areas along the Moei river.

The Moei river meanders from south to north and joins with the Salween River.

The Moei river flows with the width of less than 100 meters, and at some places of the riverbank where the river water is slowly running, silica sand lies with the thickness of less than 2 meters.

Six sources of silica sand deposit were investigated and the result is summarized in Table 4-1-5. Silica sand is generally composed of fine to medium-grained quartz, but in some places coarse-grained quartz is also found.

Other minerals except quartz are feldspar and muscovite, and gravels of sandstone, and shale are rarely scattered on the deposit surface.

SiO_2 content in silica sand is more than 85% and such quality is suitable as siliceous material for cement manufacturing.

The reserves of silica sand are estimated to be 370 thousand tons. The silica sand sources are shown in attached DWG. No. G-02, and there is potentiality to increase silica sand reserves by additional geological survey.

Table 4-1-5 Sources and Reserves of Silica Sand

Deposit No.	Location	Area	Reserves
No. 1	1.4 km north of Ban Wang Kaew	14,800 m^2	47,000 t
No. 2	1.2 km northwest of Priest Resident at Doi Din Chi	43,600	139,000
No. 3	0.7 km northwest of Ban Rim Moei	5,000	16,000
No. 4	Ban Rim Moei	7,000	22,000
No. 5	Ban Lakhon	15,600	49,000
No. 6	Ban Mae Kong Ken	30,000	96,000
Total		116,000	369,000

Note:

1) The average thickness of silica sand : 2 m
2) Apparent specific gravity : 2.0
3) The recovery ratio : 0.8
4) No. 1 deposit is being taken as construction material.

IV-1-6 Ferrous Material

Ferrous material was investigated at iron mine of Sitthickhok Mining Co., Ltd., Non Poh, Nakhon Sawan province. This quarry is situated 53 km by road southeast of Nakhon Sawan. Fourty-four km of 53 km is paved road and the rest of 9 km unpaved road runs to the east from the said paved road.

It is easy to transport this ferrous material to Mae Sot by truck, although 9 km of the non-paved road requires partial repairing work. The transportation distance is about 290 km from Non Poh area to Mae Sot.

Iron deposit looks to occur horizontally in nearly flat area with thickness of less than 2 - 3 meters. It is difficult to delineate the deposit area exactly, but the deposit area is not likely to be so narrow, and expected to extend in the dimension of 300 m x 300 m.

This iron mine seems to operate irregularly depending upon the market demand, and not operate all the year. The working and mined area is 50 m x 100 m. Outcrop and moved rock such as limestone are found at the mined area.

X-ray diffraction analyses of two iron ore samples proved the existence of hematite. The same samples were chemically analyzed and the Fe_2O_3 content was determined to be 40 %.

At this deposit, magnetite ore is also found in addition to hematite.

Ripping method is probably practicable to mine the iron deposit without blasting because big lump of iron ore is rare at deposit area.

The required quantity of ferrous material is about 9,000 tons annually for the Project. The reserves are expected to be for more than 20 years operation for the Project and the quality of ferrous material can meet requirement. It is said that in this area there is another iron deposit similar to this deposit.

IV-1-7 Gypsum Material

Gypsum was investigated at the open pit of Thai Gypsum Co., Ltd. which is situated at Doi Kui area, Phichit province.

Approach to this pit is as follows:

Tak → (to southeast, 45 km) → Kam Phang Phet → (to east, 70 km) → Phichit

→ (to southeast, 70 km) → Doi Kui. (whole road is paved)

The transportation distance is about 270 km from Doi Kui area to Mae Sot.

Gypsum deposit is being quarried below ground level because the deposit lies in flat land.

The oval-shaped open pit has about 10 meters depth and 50 - 100 meters diameter.

The production capacity of this pit is said to be 100 thousand tons monthly and 20% of gypsum product is for domestic consumption and 80% is for export.

Thai Gypsum Co. is supplying gypsum to Siam City Cement Co.

The geology of the gypsum area consists of Kanchanaburi Series of the Paleozoic age.

Gypsum is massive in occurrence, white to greyish white in colour, and medium to coarse grained. Bedding plane is not found in gypsum deposit but in parts grey band is recognized in white gypsum.

The quality of gypsum product is being controlled to maintain more than 95% of $CaSO_4 \cdot 2H_2O$. At quarry face anhydrite ($CaSO_4$), which is not suitable for cement retarder, is rarely found but other intercalations are not found.

Anhydrite is nearly the same colour as gypsum, but heavier than gypsum.

The boring survey conducted so far proved that gypsum bed changes to anhydrite at deeper part from the ground level.

At present, anhydrite is rejected so as not to degrade the quality of gypsum product.

The sample collected was chemically analyzed and SO_3 content was 46.5%. The quality of this sample can meet the specification required. Thai Gypsum Co. owns four mining concessions of gypsum at Phichit. Gypsum occurs in the said mining concession area in a size of 250 m - 500 m wide and 2,500 m long. The depth of the deposit was confirmed to be 20 m - 30 m by boring.

Accordingly the reserves of gypsum are estimated to be more than 30 million tons. The requirement of gypsum is 20,000 tons annually for the Project.

A report on gypsum deposits in Phichit was prepared by DMR (1967).

IV-1-8 Conclusion and Recommendation

(1) Limestone material

The limestone deposit is situated west-southwest of the proposed plant site in Ban Huai Kalok area. The limestone deposit distributes with the direction of north-south. The limestone reserves in 41 ha. were calculated to be 31,700 thousand tons, and these reserves are enough for 54 years operation for the Project. The south deposit is proposed for limestone quarry, and the limestone reserves in south deposit are 13,000 thousand tons which are for 22 years operation.
The additional limestone reserves can be expected in the northern area adjacent to the north deposit.
The topography of the area is simple and easy for quarring. Especially the area above 240 - 250 S.L. is superior in quarring condition with thin top soil.

It is necessary to construct a transportation road of 5.5 km between the proposed quarry and the plant site. As the topography along the proposed route is gentle and simple, it is easy to construct the road.

(i) The quality of limestone can meet the specification required for the Project. Average CaO and MgO content is 53.2% and 0.4% respectively. The intercalations such as marlstone and dolomite are rarely interbedded in limestone, but they are small in size and negligible.

(ii) As a result of geological survey on surface, the limestone thickness was confirmed to be about 100 meters at the existing quarry. The limestone thickness is presumed to be more than 100 meters, accordingly the reserves calculation was made based on 150 meters thickness in some sections. In this meaning, the accuracy of the reserves can be defined between the proved reserves and the probable one.

Before the Project is realized, core boring of 100 - 150 meter depth at a few points is recommended to further confirm the reserves and geological structure.

(2) Oil shale material

(i) Oil shale covers the area of approximately 200 km^2 in Mae Sot area. Oil shale reserves were reported to be 18,668 million tons in the area of 53 km^2, and shale oil reserves were 5,996 barrels according to DMRs' survey.

(ii) Oil shale reserves in Ban Huai Kalok area of approximate 100 ha. (1 km^2) where open pit mining is adoptable are calculated to be 14,800 thousand tons. These reserves are enough for 23 years operation for the Project. Although the outside area is inferior to the proposed quarry in quarring condition and the deeper part below 30 meters is also inferior, oil shale reserves in those area are sufficient for the operation even after 23 years.

(iii) The quality of oil shale is not high grade on the average, but oil shale can be used as a cement raw material and also as a fuel for power station without retorting. Oil shale ash from power station can be used as a part of cement raw material, and mixing material for cement manufacturing.

(iv) Oil shale beds are presumed to be 8 or 9 levels in the survey area at Ban Huai Kalok, and varies in thickness considerably.

The occurrence and quality of oil shale should be studied in more detail by supplementary boring and trenching before the Project will be realized.

(3) Clayey material

Clay deposit was investigated for possible future use although the ordinary clayey material is not required for the Project.

Overburden and intercalation of oil shale, which are waste materials, can be used as clayey material because they are marlstone, calcareous shale etc.. The reserves of these material are about 50 million tons in the proposed oil shale quarry site.

This type of clayer material also distributes outside of the proposed site.

The reserves and quality can meet requirement for the project.

(4) Siliceous material

Silica sand lies with the thickness of less than 2 meters at some places of the riverbank of the Moei river.

The reserves of silica sand are estimated to be 370 thousand tons.

Silica sand is suitable in quality for the Project, but silica sand is not required for the Project according to the raw mix design.

(5) Ferrous material

Ferrous material has to be transported for a long distance because there is no source of it in Mae Sot area. Iron deposit at Non Poh, Nakhon Sawan province, can meet requirements for the Project both in the reserves and quality.

Fe_2O_3 content in iron ore at Non Poh area is more than 40 %.

(6) Gypsum material

Gypsum material has to be transported from Doi Kui area, Phichit province because there is no source of it in Mae Sot area. Gypsum deposit can meet requirements for the Project both in the reserves and quality.

Gypsum product of Thai Gypsum Co., Ltd. is mostly composed of gypsum and mixed with a bit of anhydrite.
The mixed ratio of anhydrite to gypsum is very low, and the mixed anhydrite can be neglected for the Project.

IV-2 Quality of Raw Materials

IV-2-1 Characteristics of Raw Materials

The characteristics of raw materials proposed for the Project are described and discussed hereinafter, based on the test results stated in IV-2-2.

(1) Limestone (Doi Din Chi deposit)

Doi Din Chi limestone deposit to be used for the Project is of high purity for calcareous raw material of portland cement as a whole. It contains CaO of about 53 % as principal component and also contains MgO of about 0.4 % on the average.

The amount of minor component such as Na_2O, P_2O_5 and K_2O, Cl is about 0.00 %, 0.03 % and less than 0.01 and 0.001 % respectively.

This limestone is composed of calcite as a principal mineral component, and of small amount of quartz. The calcite crystal is relatively fine crystallined and its shapes are round having a size of about 100 - 200 micron on the average. Both specific gravity and apparent specific gravity are about 2.7 and therefore this limestone is compact and rather hard to be ground.

(2) Oil shale (Ban Huai Kalok deposit)

The calorific valùe of Ban Huai Kolok oil shale is high in black color parts but relatively low in light brown color parts and its variation is rather high.

In the range of 10 m - 20 m depth from ground in mining area to be used for the project, the apparent mean calorific value of these oil shale is 530 cal/g and final calorific value is corrected to 680 cal/g by adding the calorific value of about 150 cal/g depending on carbonate decomposition.

But as the amount of oil shale to be used for the Project is not so much, it can be expected to get oil shale having sufficient calory (940 cal/g) for the Project by severe selective mining.

The amount of main chemical component besides combustible element, such as SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO is about 30 %, 10 %, 3.5 %, 17 % and 3.5 % on the average respectively. It can be said that this oil shale is well balanced.

The amount of minor component of Ban Huai Kalok oil shale such as Na_2O, K_2O, P_2O_5 and Cl is 0.73 %, 1.36 %, 0.12 % and 0.002 % on the average respectively.

The amount of SO_3 is 2.5 % which is considerably higher than that normal clays.

As for the mineral composition, dolomite, zeolite, calcite and quartz are contained in this oil shale. The size of quartz crystal varies from 10 micron to 20 micron. The size of dolomite is 10 micron - 20 micron too.

The apparent specific gravity is about 2.06. The oil shale is rather compact and its moisture content is relatively small.

(3) Silica sand (Moei river deposit)

The composition of silica sand deposited in the basin of Moei river varies to a certain extent depending on the places.

Its SiO_2 content varies in the range of 80 % - 90 % and mica content varies too.

Silica sand sample collected from the basin of the river for the Project is of average quality having the following chemical composition.

(%)

SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O
86.4	7.4	0.6	0.79 %	3.50

Moei river silica sand mainly consists of such minerals as quartz, feldspar, mica. The specific gravity is 2.31.

Judging from its quality, this silica sand is suitable as siliceous additive for manufacturing portland cement.

(4) Ferrous raw material (Non Poh iron ore)

Iron ore of Non Poh deposit, to be used for the Project, mainly consists of the following composition and is of middle purity.

(%)

Fe_2O_3	SiO_2	Al_2O_3
40 - 45	40 - 50	8 - 9

As for the mineral composition, hematite is principal component with small amount of quartz.
Judging from its quality, Non Poh iron ore is suitable as ferrous additive for manufacturing portland cement.

(5) Marl (Ban Huai Kalok deposit)

The upper part of oil shale deposit at Ban Huai Kolok area is marly raw material. The amount of chemical component such as SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO is 25.7, 9.7, 3.2, 22.2 and 5.3 % respectively, and CaO and MgO content in marl is more than those in oil shale.
But the superficial part of marl contains lower CaO and MgO content as follows.

CaO	MgO
18.1 %	2.5 %

Also the amount of chemical component such as Na_2O, K_2O is 0.25 and 2.48 % respectively, and so this material can be used as clayey material for the Project.
Apparent specific gravity is 1.92 - 2.20 which is nearly same value as oil shale.

(6) Raw meal

In case ordinary portland cement is produced from the raw materials mentioned above, judging from chemical composition and its dispersion of each raw material, it is easy to prepare the raw meal having desired composition.
The content of impurity such as Na_2O, K_2O and Cl in the raw meal is 0.26, 0.50 and less than 0.001 % respectively and therefore the dry process with a new suspension preheater system can be adopted for the Project.

The burnability of the raw meal is a little inferior to that of the raw meal used in the cement plant in Japan while the grindability of the former is a little lower than the latter.
Generally speaking this raw meal is suitable for manufacturing ordinary portland cement.

(7) Gypsum (Phichit deposit)

As cement retarder, Phichit gypsum is scheduled to be used. The test results of two samples show that the gypsum consists of 32.3 % of CaO and 46.5 % of SO_3 and the purity calculated from SO_3 content is 100 %.
Principal mineral is $CaSO_4$, $2H_2O$ and a few quantity of anhydrite may be contained in it.
This gypsum is suitable as retarder of portland cement.

(8) Coal (Mae Ramat)

As fuel, Mae Ramat coal is scheduled to be used. The test result of sample is as follows.

Calorific value (Gross)	5,440 Kcal/kg
Ash	12.4 %
Volatile matter	33.6 %
Fixed carbon	41.4 %

Chemical composition of ash	SiO_2	49.1%
	Al_2O_3	40.4 %
	Fe_2O_3	3.4 %
	CaO	2.1 %
	MgO	1.2 %

This coal can be used for clinker burning process satisfactorily.

IV-2-2 Test Results of Raw Materials

The samples of each raw material taken and/or obtained by the study team in the field were tested mostly in Japan except a part of samples tested in the field laboratory.

(1) Chemical analysis

(i) Samples

Kind and number of sample tested, number of composition tested, the Table number for each test are described in Table 4-2-1.

(ii) Testing method

The samples for chemical analysis were prepared through the processes such as drying,crushing and grinding.
The following methods were used for chemical analysis.

Method		Composition analyzed
- Gravimetric analysis	:	SiO_2, Al_2O_3, Fe_2O_3, SO_3
- Volumetric analysis	:	CaO, MgO, Cl
- Flame photometric analysis	:	Na_2O, K_2O
- Colorimetric analysis	:	P_2O_5, Fe_2O_3

(iii) Results of chemical analysis

The results of chemical analysis are shown in Table 4-2-2 - 4-2-12.

Table 4-2-1 List of Analyzed Samples

Sample		Quantity of analyzed samples	Quantity of analyzed components	Table of results to be referred	Place carried out
Limestone (Doi Din chi)	Grab sample	39 pcs	2 components	Table 4-2-2	at site
		10 pcs	11 components	Table 4-2-3	in Japan
Oil shale (Ban Huai Kalok)	Drilling sample	39 pcs	6 components	Table 4-2-5	at site
		6 pcs	11 components		in Japan
	Grab sample	2 pcs	11 components		
Marl (Ban Huai Kalok)	Drilling sample	15 pcs	6 components	Table 4-2-6	at site
	Grab sample	2 pcs	11 components		in Japan
Silica sand	(Moei river)	1 pc 1 pc	7 components 11 components	Table 4-2-7	in Japan
Iron ore	(Non Poh)	1 pc 1 pc	6 components 11 components	Table 4-2-8	in Japan
Gypsum	(Phichit)	1 pc 1 pc	3 conponents 6 conponents	Table 4-2-9	in Japan
Coal ash	(Mae Ramat)	1 pc	6 components	Table 4-2-10	in Japan

Table 4-2-2 Chemical Analysis of Doi Din Chin Limestone
(Grab Samples, Analyzed at Site)

(wt.% on dry basis)

Sample No.	CaO	MgO	Sample No.	CaO	MgO
L-01	55.0	0.3	L-30	52.8	0.6
L-02	53.3	1.0	L-33	51.5	0.4
L-03	52.2	0.8	L-34	53.9	1.0
L-04	49.2	0.4	L-35	54.7	0.0
L-05	52.3	0.3	L-36	(35.0	17.2)
L-06	52.6	0.4	L-37	53.2	0.1
L-08	50.4	0.2	L-39	53.3	0.1
L-09	54.5	0.6	L-40	(38.2	14.2)
L-11	55.3	0.6	L-41	53.3	0.5
L-12	55.5	0.3	L-42	(32.4	19.3)
L-15	46.4	1.0	L-43	52.6	0.4
L-16	52.0	0.6	L-44	53.4	0.1
L-18	53.6	0.4	L-45	52.6	0.8
L-19	51.5	1.0	L-46	54.7	0.0
L-21	53.9	0.2	L-47	53.4	0.2
L-22	52.8	0.3	L-48	53.5	0.1
L-23	54.5	0.4	L-49	53.5	0.1
L-24	49.0	1.0	L-50	54.7	0.0
L-25	53.1	0.4	L-51	53.1	0.0
L-26	54.2	1.2	L-52	55.0	0.0
L-27	54.2	0.6	L-53	(43.5	8.5)
L-28	54.2	0.1			

AVERAGE	53.0	0.4

Table 4-2-3 Chemical Analysis of Doi Din Chi Limestone
(Grab samples analyzed in Japan)

(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
L-07	43.3	1.5	0.4	0.1	54.7	0.2	0.0	0.00	0.01	100.2	0.02	0.000
L-10	43.3	1.2	0.2	0.4	53.4	0.6	"	"	"	99.1	"	"
L-13	41.8	3.9	0.5	0.1	52.8	0.2	"	"	"	99.3	0.04	"
L-14	42.8	2.6	0.7	0.2	53.4	0.8	"	"	"	100.5	"	"
L-17	43.3	1.0	0.4	0.1	54.5	1.2	"	"	"	100.5	0.02	"
L-20	42.2	2.6	0.7	0.1	53.4	0.3	"	"	0.00	99.3	0.03	"
L-29	42.5	2.4	0.7	0.3	53.0	0.8	"	"	0.01	99.7	0.02	"
L-31	42.6	0.9	0.7	0.1	55.0	0.0	"	"	"	99.3	"	"
L-32	42.9	0.9	0.7	0.1	53.6	0.2	"	"	0.03	98.4	0.01	"
L-38	43.2	1.4	0.3	0.1	54.6	0.1	"	"	0.02	99.7	0.04	"
Ave.	42.79	1.84	0.53	0.16	53.84	0.44	0.0	0.00	0.01	99.63	0.03	0.000

Table 4-2-4 Brief Description of Limestone and Dolomite Samples

Sample No.	Locality	Classification	Colour	Remarks
L-01	South deposit	limestone	light grey	compact, calcite veinlet
L-02	do	do	light purplish grey	compact
L-03	do	do	do	compact, calcite veinlet
L-04	do	do	grey, but yellowish brown on surface	compact
L-05	do	do	light purplish grey	compact, calcite veinlet
L-06	do	do	grey	do
L-07	do	do	do	do
L-08	North deposit	do	light purplish grey	compact, calcite veinlet and reddish brown patch
L-09	do	do	grey	compact, calcite veinlet
L-10	do	do	light purplish grey	do
L-11	do	do	grey	do
L-12	do	do	do	do
L-13	South deposit	do	light purplish grey to grey	compact, calcite veinlet and reddish brown vein
L-14	do	do	grey	compact, calcite veinlet
L-15	do	do	light purplish grey to grey	compact, reddish brown vein
L-16	do	do	grey	compact, re-crystallized calcite patch
L-17	do	do	grey, in part light purplish grey	compact, calcite veinlet
L-18	do	do	grey to light yellowish brown	compact, calcite veinlet and light yellowish brown vein
L-19	do	do	dark grey	compact
L-20	do	do	grey	compact, calcite veinlet and re-crystallized patch
L-21	do	do	light purplish grey	compact, calcite veinlet

(continued)

Sample No.	Locality	Classification	Colour	Remarks
L-22	South deposit	limestone	greyish brown	compact, calcite veinlet and yellowish brown vein, micro-fossil
L-23	do	do	grey	compact, calcite veinlet
L-24	North deposit	do	dark grey, in part light purplish grey	compact, calcite veinlet
L-25	do	do	grey to light purplish grey	do
L-26	do	do	grey to light yellowish brown	compact, calcite veinlet and yellowish brown vein
L-27	do	do	do	do
L-28	do	do	do	do
L-29	do	do	dark grey	compact, calcite veinlet
L-30	South deposit	do	greyish brown	micro-crystalline, micro-fossil
L-31	North deposit	do	grey to light yellowish brown	compact, calcite veinlet and yellowish vein
L-32	do	do	do	compact, calcite veinlet
L-33	do	do	dark grey	do
L-34	do	do	grey to light purplish grey	compact, reddish brown vein
L-35	do	do	grey	compact, re-crystallized calcite patch, micro-fossil
L-36	do	dolomite	grey to dark grey	compact, yellowish brown vein
L-37	do	limestone	grey to light purplish grey, in part reddish grey	compact, calcite veinlet
L-38	do	do	grey to light yellowish brown	compact
L-39	do	do	grey to light yellowish brown, in part light purplish grey	compact, calcite veinlet and yellowish brown vein

(continued)

Sample No.	Locality	Classifi- cation	Colour	Remarks
L-40	North deposit	dolomite	grey to light pur- plish grey	compact, calcite veinlet
L-41	do	limestone	dark grey	do
L-42	do	dolomite	grey to light pur- plish grey	compact, reddish brown vein
L-43	do	limestone	grey to light yel- lowish brown	compact, calcite veinlet and reddish brown vein
L-44	do	do	do	compact, calcite veinlet and yellow vein
L-45	do	do	do	compact, calcite veinlet, re-crystal- lized calcite patch
L-46	do	do	do	compact, calcite veinlet, micro- fossil
L-47	do	do	do	compact, calcite veinlet
L-48	do	do	do	compact, calcite veinlet and yellow- ish brown vein
L-49	do	do	grey to dark grey	do
L-50	do	do	grey to light yel- lowish brown	compact, calcite veinlet
L-51	do	do	do	compact, calcite veinlet and yellow vein, micro-fossil
L-52	do	do	do	compact, calcite veinlet and greyish black vein
L-53	do	dolomitic limestone	dark grey, in part brown	compact, calcite veinlet

Note: Sample No. corresponds to that of Table 4-2-2, 4-2-3, and that of attached DWG. No. G-03, G-06.

Table 4-2-5 Chemical Analysis of Ban Huai Kalok Oil Shale
(Drilling Core Sample) - (1)

(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
OSHLK1301	32.8	28.1	10.9	4.0	14.1	5.1						
1302	30.4	21.2	7.0	3.3	19.8	5.3						
1303	30.2	28.7	8.3	3.4	19.4	5.1						
1304	26.6	44.0	5.0	2.9	14.9	1.6	3.5	0.73	0.81	100.0	0.10	0.000
1305	32.5	27.2	6.8	3.2	20.3	4.4						
1306	30.2	31.3	5.3	2.6	22.3	2.6						
1307	29.9	28.7	6.4	2.6	23.4	2.0	1.8	0.81	1.16	96.8	0.12	0.000
1308	31.4	30.1	8.6	3.5	17.9	3.6						
1309	32.1	28.3	10.5	4.3	12.9	6.0						
OSHLK1401	31.6	26.7	13.3	4.4	14.8	5.3						
1402	32.4	27.7	10.4	3.0	19.1	5.1						
1403	27.2	38.6	8.0	2.7	19.5	2.1						
1404	25.4	45.2	5.8	2.8	15.2	1.2						
1405	30.3	29.2	11.2	3.3	18.1	3.6						
1406	29.3	30.4	8.6	2.4	21.1	2.1						
1407	30.2	28.7	9.0	2.6	21.8	2.1						
1408	31.3	30.5	10.9	3.5	13.8	3.6	1.7	0.98	1.88	98.2	0.13	0.000
1409	30.8	28.2	13.0	4.1	12.0	6.2						

Table 4-2-5 Chemical Analysis of Ban Huai Kalok Oil Shale (Drilling Core Sample) - (2)

(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
OSHLK1601	24.5	33.2	14.8	4.3	12.6	5.5						
1602	28.1	30.7	12.4	3.2	16.3	4.0						
1603	28.6	32.3	10.6	2.6	17.5	3.0						
1604	26.1	36.6	7.6	2.2	20.8	1.0						
1605	28.0	32.2	11.0	3.1	16.9	3.6						
OSHLK1801	29.3	31.7	13.0	4.1	14.1	4.1						
1802	31.7	28.7	10.2	3.4	18.6	2.1	2.4	0.56	1.63	99.3	0.14	0.01
1803	28.0	35.1	7.7	2.6	19.9	3.6						
1804	28.0	35.3	12.7	4.0	15.2	2.9						
OSHLK 401	26.7	32.6	13.6	4.1	13.8	2.2						
402	26.6	37.2	12.1	4.1	13.3	3.2						
403	27.4	35.1	6.8	2.7	22.5	2.3						
404	28.6	29.4	9.9	3.8	16.9	4.3						
405	25.5	30.5	13.0	4.5	16.2	5.6						
406	23.7	32.8	14.9	4.7	13.6	6.1						
407	27.6	33.3	13.1	4.0	11.3	5.7						
OSHLK2001	25.0	31.9	15.4	4.5	14.0	2.8						
2002	28.0	32.3	11.7	3.6	21.0	3.4						
2003	30.3	32.9	9.4	3.2	15.4	3.6	2.9	0.56	1.32	99.58	0.13	0.000
2004	27.2	35.2	7.7	3.4	17.6	2.5						
2005	28.7	27.2	12.5	3.6	16.1	6.7						
Average	28.77	31.90	10.23	3.44	17.03	3.72	2.42	0.73	1.40	99.64	0.12	0.002

Table 4-2-6 Chemical Analysis of Ban Huai Kalok Marl
(Drilling Core Sample and Grab Sample)

(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
MLK1301	31.5	19.7	7.3	2.4	27.8	5.9				94.6		
1302	32.3	20.0	8.8	2.4	24.0	6.3				93.8		
1303	30.1	24.6	8.4	3.1	24.5	6.8				97.5		
MLK1401	30.4	29.2	12.4	4.0	13.7	6.1				95.8		
1402	28.5	24.7	10.9	3.2	22.3	5.5				95.1		
1403	31.7	19.7	6.5	3.1	26.9	5.6				93.5		
1404	29.7	26.4	12.5	3.7	18.2	6.6				97.1		
MLK1601	29.9	23.8	9.1	2.5	27.6	3.6				96.5		
1602	32.3	19.6	7.4	1.8	31.7	3.8				96.6		
1603	28.3	26.3	10.8	3.1	21.8	5.3				95.6		
MLK1801	27.8	26.0	10.4	3.2	22.2	5.3				94.9		
1802	28.3	28.3	11.2	3.9	16.9	5.8				94.4		
MLK2001	25.7	30.1	13.7	4.4	15.1	5.4				94.4		
MLK 401	18.7	39.9	11.1	3.3	18.1	2.1				93.2		
402	25.6	27.3	11.4	4.3	21.5	5.1				95.2		
Average	28.9	25.7	9.7	3.2	22.2	5.3				95.0		
M01	20.9	37.8	13.3	3.7	18.9	2.0	0.0	0.37	2.73	99.7	0.08	0.000
M02	24.1	34.1	15.1	4.0	17.3	3.0	0.0	0.13	2.22	100.0	0.24	0.000
Average	22.5	36.0	14.2	3.8	18.1	2.5	0.0	0.25	2.48	99.8	0.16	0.000