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3.1 Present Situation of the Cement Industry

3.1.1 Outline of the Cement Industry

Cement industry in Yemen began with the establishment of Bajil plant which has 300,000 T/Y production capacity in North Yemen in 1976. In addition to Bajil plant, Amran 500,000 T/Y plant which was constructed in 1982 is now in full operation.

The production has covered 30% to 50% of the domestic demand and the balance has been supported by import.

Another 500,000 T/Y cement plant in Mafraq is now under construction and expected to be in operation in 1993.

3.1.2 Outline of Bajil Plant

Production Capacity	:	300,000 T/Y						
Production Process	:	Wet Kiln x 2 (100,000 T/Y, 200,000 T/Y)						
Cement Quality	:	Portland Cement						
Production Record								
Year	:	1985	1986	1987	1988	1989	1990	
Production (1,000 T/Y)	:	286	289	299	303	251	274	
Commercial Operation	:	1976						

3.1.3 Outline of Amran Plant

Production Capacity	:	500,000 T/Y
Production Process	:	Dry Kiln x 1
Cement Quality	:	Portland Cement
Production Record		

Year	:	1985	1986	1987	1988	1989	1990
Production (1,000 T/Y)	:	414	425	475	501	453	553

Commercial Operation : 1982

3.1.4 Outline of Mafraq Plant

Production Capacity	:	500,000 T/Y
Production Process	:	Dry Kiln x 1
Cement Quality	:	Portland Cement
Production Record	:	Nil
Commercial Operation	:	1992 (Planned)

3.2 Demand and Supply

3.2.1 Transition of Demand and Supply

The local production level in North Yemen has been at 700,000 to 800,000 T/Y after the completion of Amran factory in 1982 and the shortage has been supported by import.

South Yemen has had no cement factory and about 200,000 T/Y cement has been imported.

Cement demand growth in North Yemen was at high pace with the high economic growth of 1970's as shown in Table 3-1 and was intensified in 1984 and 1985 for the sake of restoration of earthquake damage in Dhamar. Thereafter it become slow down due to the decrease of import caused by the government's import restriction (Table 3-2). It is reported that the cement price has suddenly risen in 1987, which implies that this decline of consumption did not mean the decline of actual demand.

Therefore, the considerable potential demand which was far beyond the actual consumption must have existed.

Table 3-1 Transition of Cement Consumption

YEAR	TOTAL CONSUMPTION	North Yemen			South Yemen
		SUB TOTAL	PRODUCTION	IMPORT	
	1,000 TONS/Y	1,000 TONS/Y	1,000 TONS/Y	1,000 TONS/Y	1,000 TONS/Y
1973	129	129	45	84	
1974	112	112	65	47	
1975	465	465	65	400	
1976	965	965	65	900	
1977	1165	1165	65	1100	
1978	1015	1015	65	950	
1979	865	865	65	800	
1980	1070	1070	70	1000	
1981	1014	877	86	791	137
1982	1174	931	243	688	243
1983	1257	1035	623	412	222
1984	1569	1276	709	567	293
1985	1446	1224	698	526	222
1986	1366	1158	708	450	208
1987	1452	1261	786	475	191
1988	1380	1196	804	392	184
1989	1203	952	693	259	251
1990	1185	990	836	154	195

SOURCE : YCC
MOPD

Table 3-2
Transition of Trade Balance

YEAR	TRADE BALANCE 1,000 RIALS	EXPORT 1,000 RIALS	IMPORT 1,000 RIALS
1981	-7820400	47400	7867800
1982	-8764100	21600	8785700
1983	-8038000	44000	8082000
1984	-7459700	47500	7507200
1985	-7912300	61000	7973300
1986	-7820300	153000	7973300
1987	-12805600	497800	13303400
1988	NOT	AVAILABLE	
1989	-11532800	6765100	18297900
1990	-13797100	7066000	20863100

SOURCE : YEAR BOOK

3.3 Forecast of Future Demand

3.3.1 Demand Forecast Based on Correlation Analysis

In this study the correlation of the cement demand with the GDP and the population is studied then the future demand is forecasted. Both the GDP and the population are the most common parameters for the cement demand forecast. In this correlation analysis the past cement consumption data of North Yemen up to 1986 are used and the potential demand after 1986 is taken into account. In order to obtain consumption tendency five years moving average covering 18 years between 1973 and 1990, therefore, the moving average demand figure up to 1986 was used for the demand forecast. By this reason, the cement demand from 1987 through 1990 appears as a forecast, which figures, bigger than the recorded consumptions, imply unattended potential demand.

As for the ex-South Yemen area, due to unavailability of GNP data, simple demand forecast of anual 4% growth (past average growth of cement consumption is 4% in South Yemen) is applied.

(1) Demand Forecast Based on GDP

The transition of the GDP and the demand in North Yemen is shown in Table 3-3 and following shows the correlation.

Correlation Factor: 0.83
Y : Estimated annual cement demand (1,000 T/Y)
X : GDP (YR 1,000,000)
Y : 0.0365347X - 434.91701

The GDP growth record in North Yemen was 6.6%/Y under the second five years plan of which expected growth rate was 8.0%/Y. The latest growth record under the third five years plan up to 1991 is not available and the expected growth rate under the plan was also 8.0%/Y.

Therefore, the demand forecast is studied in following cases utilizing the above correlation formula.

- Case 1 : 6%/Y GDP growth rate
- Case 2 : 8%/Y GDP growth rate

The future cement demand based on the above GDP growth rate is forecasted as shown in Table 3-7 and the projected cement demand in 1998 when Mafraq expansion plant is expected to be in commercial operation is as follows;

- Case 1 : 2.345.000 T/Y
- Case 2 : 2,720,000 T/Y

Table 3-3

Transition of Cement Demand and GDP

YEAR	CEMENT DEMAND 1000 TONS/Y	5YEARS AVERAGE 1000 TONS/Y	GWOWTH RATE %	GDP 1000000 RIALS/Y	GROWTH RATE %
1973	129				
1974	112				
1975	465	567			
1976	965	744	1.31217		
1977	1165	895	1.20296	12679	
1978	1015	1016	1.13522	13859	1.09307
1979	865	998	0.98228	14669	1.05845
1980	1070	952	0.95391	15505	1.05699
1981	877	956	1.00420	15980	1.03064
1982	931	1038	1.08577	17523	1.09656
1983	1035	1069	1.02987	17951	1.02443
1984	1276	1125	1.05239	18558	1.03381
1985	1224	1191	1.05867	19402	1.04548
1986	1158	1223	1.02687	21217	1.09355
1987	1261	1158	0.94685	23708	1.11741
1988	1196	1111	0.95941	25273	1.06601
1989	952				
1990	990				

SOURCE : YCC
YEAR BOOK

(2) Demand Forecast Based on Population

The transition of the population and the demand in North Yemen is shown in Table 3-4 and following shows the correlation.

Correlation Factor: 0.85

Y : Estimated annual cement demand (1,000 T/Y)

X : Population (1,000,000 Persons)

$Y = 0.1505810X + 140.0826$

The latest record of the population growth in 1990 in Yemen was 3.1%/Y and the government target up to 2000 is 2.0%/Y. The demand forecast is studied in following cases utilizing the above correlation formula.

- Case 3 : 2%/Y Population growth rate
- Case 4 : 4%/Y Population growth rate

The future cement demand based on the above population growth rate is forecasted as shown in Table 3-7 and the projected cement demand in 1998 is as follows;

- Case 3 : 2,039,000 T/Y
- Case 4 : 2,253,000 T/Y

Table 3-4
Transition of Cement Demand and Population

YEAR	CEMENT DEMAND	5YEARS AVERAGE	GROWTH RATE	POPULATION	GROWTH RATE
	1000 TONS/Y	1000 TONS/Y	%	1000 PERSONS	%
1973	129				
1974	112				
1975	465	567			
1976	965	744	1.31217		
1977	1165	895	1.20296	6943	
1978	1015	1016	1.13522	7150	1.02981
1979	865	998	0.98228	7363	1.02979
1980	1070	952	0.95391	7582	1.02974
1981	877	956	1.00420	7695	1.0149
1982	931	1038	1.08577	7924	1.02976
1983	1035	1069	1.02987	8160	1.02978
1984	1276	1125	1.05239	8404	1.0299
1985	1224	1191	1.05867	8654	1.02975
1986	1158	1223	1.02687	8912	1.02981
1987	1261	1158	0.94685	9177	1.02974
1988	1196	1111	0.95941		
1989	952				
1990	990				

SOURCE : YCC
YEAR BOOK

3.3.2 Simple Demand Forecast Based on Actual Consumption

The theoretical demand forecast based on the correlation analysis was studied in Section 3.3.1, which result includes the potential demand, apart from the actual consumption.

In this study the simple demand forecast based on the actual cement consumption in 1990 is studied utilizing 6%/Y growth rate of cement demand in line with the past GDP growth rate of annual 6%.

Case 5 : 6%/Y Cement Demand growth rate Based on the actual cement demand in 1990

The future cement demand based on the above both demand growth rate and the consumption data is forecasted as shown in Table 3-7 and the projected demand in 1998 is as follows;

Case 5 : 1,889,000 T/Y

3.3.3 Cross Check

In order to corroborate the result of previous study the demand forecast in a sector of largest cement consuming industry is studied. Most of the cement consumption in Yemen is for housing and the demand in the housing sector is studied as a cross check.

GENERAL CEMENT USE IN YEMEN

- Housing Sector	:	80%
- Civil Construction Sector	:	18%
- Road Construction Sector	:	2%

Source: YCC

The averaged growth rate of the housing units between 1975 and 1986 in North Yemen is 4.365%/Y.

HOUSING UNITS IN YEMEN

1975	:	856,049 Houses
1986	:	1,361,571 Houses

Source: YEAR BOOK

The cement required per averaged house (100 m^2) is as follows:

Concrete House	:	40 Tons/House
Concrete and Stones House	:	25 Tons/House
Traditional House	:	5 Tons/House

Source: F/S REPORT OF BCEOM, BS-ERI

As the housing data in South Yemen is not available, it is estimated based on the population then the growth rate of North Yemen is applied to the demand forecast. The cement demand forecast in the housing sector is shown in Table 3-5 and the projected demand in 1998 is 2,959,000 T/Y and is also far beyond the local production capacity.

Table 3-5
Cement Demand for Housing Sector

YEAR	HOUSING UNITS	NEW BUILT	CEMENT DEMAND
	HOUSES	HOUSES/Y	1000 TONS/Y
1990	2154293		
1991	2248337	94044	2194
1992	2346486	98149	2290
1993	2448919	102433	2390
1994	2555824	106905	2494
1995	2667396	111572	2603
1996	2783839	116443	2717
1997	2905365	121526	2836
1998	3032196	126831	2959
1999	3164563	132367	3089
2000	3302709	138146	3223
2001	3446885	144176	3364
2002	3597355	150470	3511
2003	3754394	157039	3664
2004	3918288	163894	3824
2005	4089337	171049	3991
2006	4267853	178516	4165
2007	4454162	186309	4347
2008	4648604	194442	4537
2009	4851534	202930	4735
2010	5063323	211789	4942

3.3.4 Regional Study of Mafraq Area

As the last step of the demand forecast, the local demand in Mafraq area is studied. The local production of Mafraq plant after the expansion will mainly cover the local demand in Taiz, Ibb and the south part (former south Yemen) according to YCC plan and the study of the projected demand in the above targeted area confirms the necessity of the expansion in Mafraq.

The past regional distribution of the cement consumption in 1990 is shown in Table 3-6(A) and the ratio of the targeted area accounts for 37.1% of the total. The projected demand distribution in 1998 is forecasted based on the same regional ratio as shown in Table 3-6(B). The projected demand in the targeted area in 1998 proves the necessity of the total production capacity of Mafraq existing and expansion plant.

Table 3-6 Regional Cement Demand

(A)

REGION	CEMENT CONSUMPTION IN 1990					
	PRODUCTION		IMPORT		TOTAL	
	%	T/Y	%	T/Y	%	T/Y
SA'DAH	7.46	62366	0	0	5.26	62366
HAJJAH	9.95	83182	0	0	7.02	83182
SANA'A	21.4	178904	30	46200	18.99	225104
HODEYDAH	9.95	83182	18	27720	9.36	110902
DAHMAR	6.32	52835	10	15400	5.76	68235
BAYDA	7.96	66546	0	0	5.62	66546
IBB *	10.45	87362	20	30800	9.97	118162
TAIZ *	11.19	93548	22	33880	10.75	127428
MA'RIB MAHWIT	15.32	128075	0	0	10.81	128075
NORTH YEMEN TOTAL	100	836000	100	154000	83.54	990000
SOUTH YEMEN TOTAL *	0	0	100	195000	16.46	195000
G. TOTAL		836000		349000	100	1185000
REGIONAL DEMAND IN MAFRAQ MARKET AREA(MARKED * TOTAL)					37.18	440590

(B)

%	Cement Demand in 1998				
	Case 1	Case 2	Case 3	Case 4	Case 5
	T/Y	T/Y	T/Y		
5.26	123347	143072	107251	118507	99361
7.02	164619	190944	143137	158160	132607
18.99	445317	516528	387211	427850	358726
9.36	219492	254592	190850	210880	176810
5.76	135072	156672	117446	129772	108806
5.62	131789	152864	114591	126618	106161
9.97	233796	271184	203288	224624	188333
10.75	252087	292400	219192	242197	203067
10.81	253494	294032	220415	243549	204200
16.46	385987	447712	335619	370843	310929
100	2345000	2720000	2039000	2253000	1889000
37.18	871870	1011296	758099	837664	702329

SOURCE : YCC

3.3.5 Result of the Demand Forecast

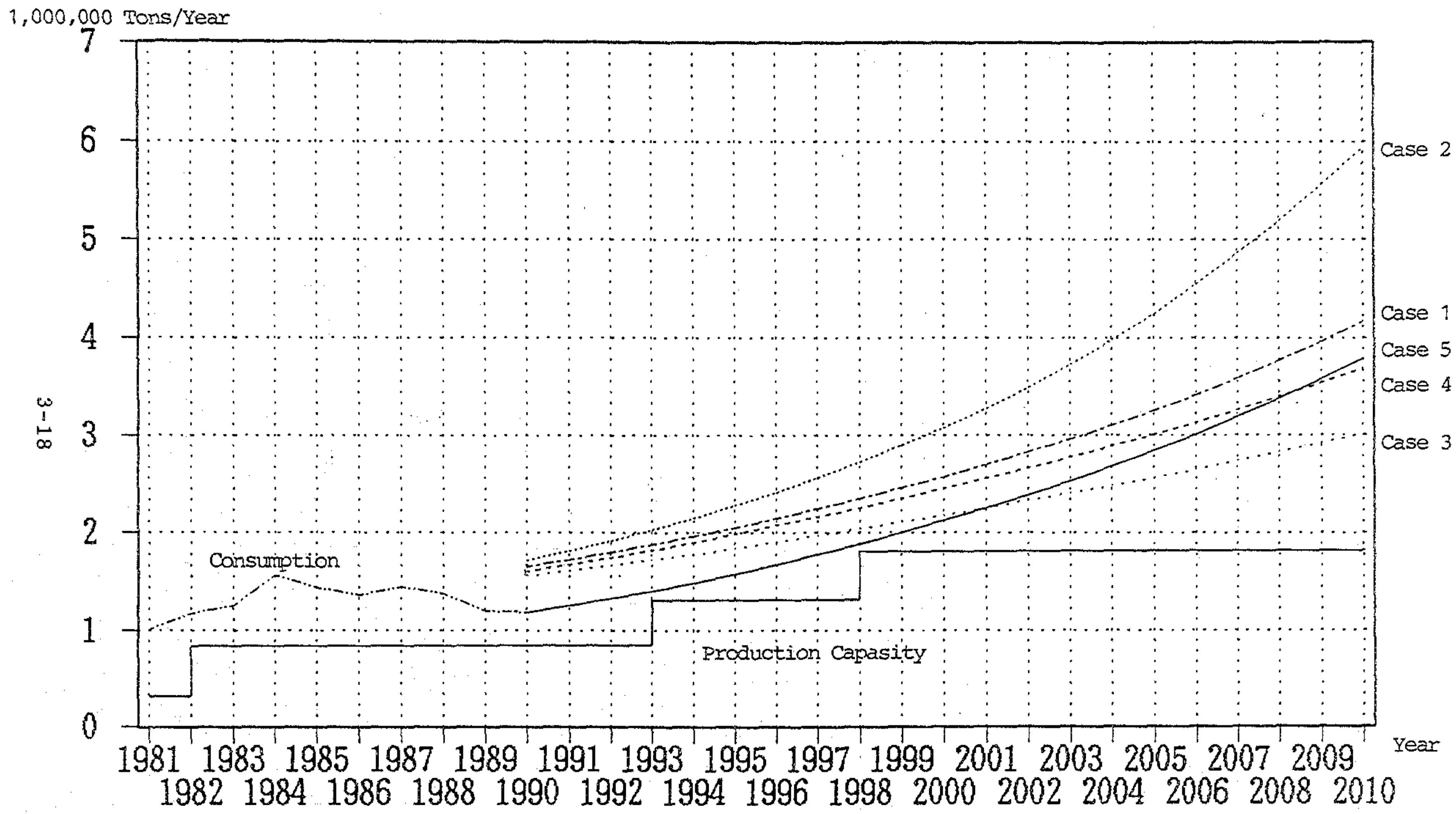
The projected cement demand which is beyond the local production capacity is forecasted in both correlation analysis based on the GDP and the population and even in the simple demand forecast based on the actual cement consumption in 1990 and the large cement shortage will continue and will increase even after the Mafraq expansion.

Future cement demand in previous studies in five cases is shown in Table 3-7 and Figure 3-1.

Table 3-7 Demand Forecast

YEAR	CASE 1 GDP 6%/Y 1000 TONS/Y	CASE 2 GDP 8%/Y 1000 TONS/Y	CASE 3 POPULATION 2%/Y 1000 TONS/Y	CASE 4 POPULATION 4%/Y 1000 TONS/Y	CASE 5 GROWTH RATE 6%/Y 1000 TONS/Y	CEMENT CONSUMPTION 1000 TONS/Y
1981						1014
1982						1174
1983						1257
1984						1569
1985						1446
1986						1366
1987						1452
1988						1380
1989						1203
1990	1662	1721	1565	1609	1185	1185
1991	1731	1816	1618	1680	1256	
1992	1805	1919	1673	1752	1331	
1993	1883	2028	1729	1827	1411	
1994	1965	2147	1788	1906	1496	
1995	2052	2275	1848	1988	1586	
1996	2144	2412	1909	2073	1681	
1997	2242	2561	1973	2161	1782	
1998	2345	2720	2039	2253	1889	
1999	2455	2893	2107	2349	2002	
2000	2570	3078	2177	2449	2122	
2001	2693	3279	2250	2553	2249	
2002	2823	3494	2325	2660	2384	
2003	2959	3726	2402	2772	2527	
2004	3104	3977	2481	2888	2679	
2005	3257	4246	2563	3009	2840	
2006	3420	4537	2647	3135	3010	
2007	3592	4851	2735	3266	3191	
2008	3773	5189	2825	3403	3382	
2009	3966	5554	2918	3544	3585	
2010	4169	5946	3013	3691	3800	

Figure 3-1 Demand Forecast Graph

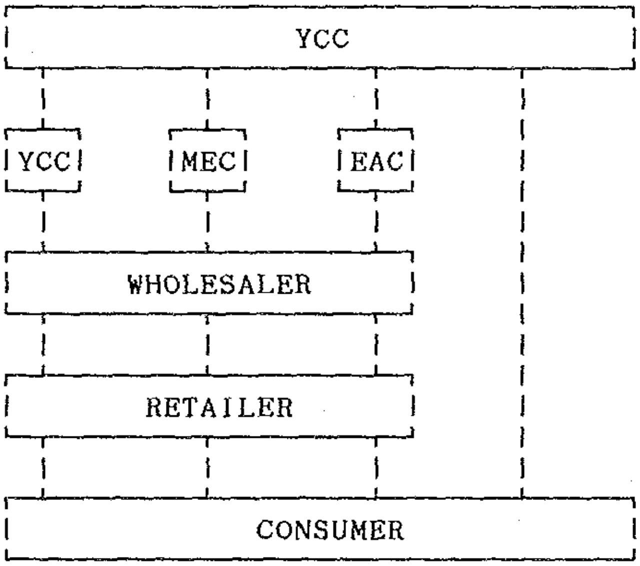


3.4 Cement Distribution System

The cement distribution system is distinct between the domestic production and the import.

As for the domestic production cement, there are two distribution flows as shown in Figure 3-2; one is supplied to consumers by way of wholesalers and retailers and the other is directly supplied to consumers.

The import cement is directly supplied to consumers at the port.



MEC: Military Economic Corp.
EAC: Employee's Association Corp.

Figure 3-2 Cement Distribution Flow (Domestic Production)

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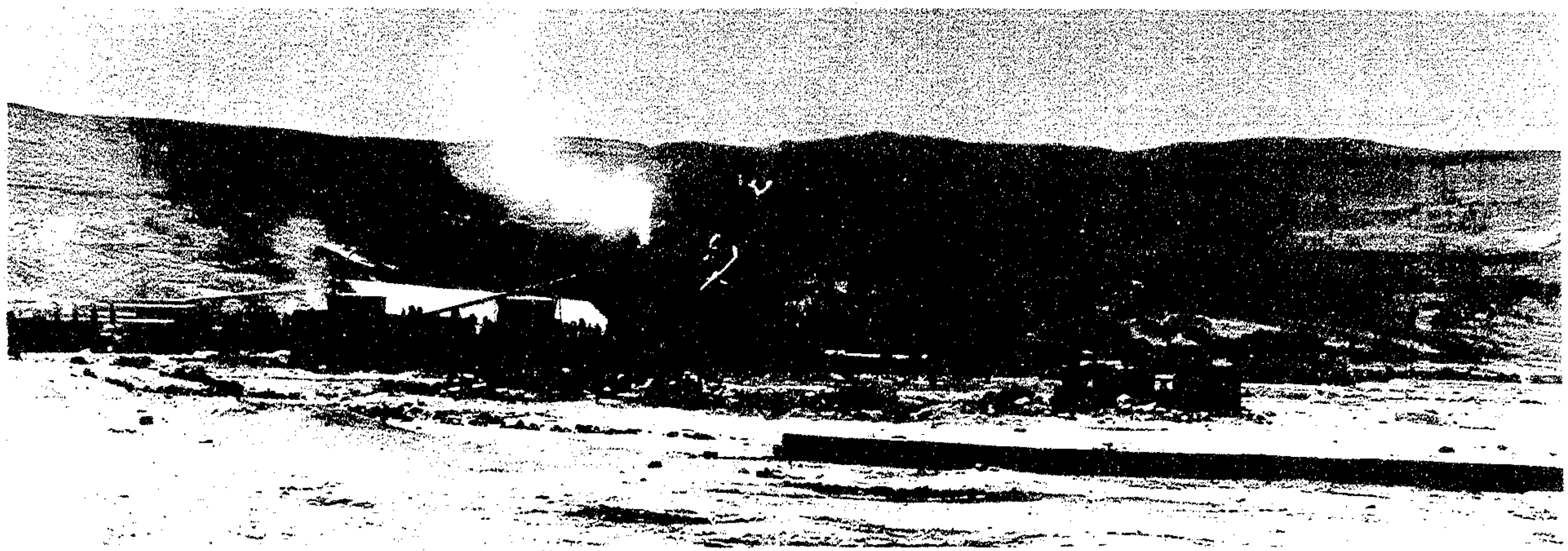

AMRAN CEMENT PLANT

BAJIL CEMENT PLANT


4.1 Amran Cement Plant

4.1.1 Outline of The Plant

1) General

Amran cement plant is located at Amran Basin 2,200m above sea level, about 55 km north from Sana'a, capital of Yemen Republic. The second cement plant following Bajil cement plant in the country was constructed in 1982 by Ishikawajima Harima Heavy Industry, Japan and financed by The Export-Import Bank of Japan (EXIM JAPAN).

The up-dated plant with 500 thousand tones annual capacity, was completed on schedule and started commercial operation in October, 1982.

The Japanese technical performance has been highly evaluated, since full capacity production was achieved in the first year of operation.

2) Quarry

(1) Limestone Quarry

The limestone quarry is on the hill about 1 km southwest from the plant. The limestone mined at the quarry is crushed and transported to the plant by a long conveyor-belt.

The quarry piled up limestone and marlstone mutually is estimated to have a reserve of 30 million tones as of 1992.

As the CaO content in the raw material, at 46 to 50% in limestone and 25 to 30% in marlstone, is relatively low compared with the Japanese types, clay material consumption can be reduced. The normal bench cut method is adopted in the mining. Mined stone is transported to an impeller breaker by dump trucks and crushed below 30 mm in size there before being fed to mix beds.

(2) Sandy Clay Quarry

Sandy clay, a kind of clay material is almost sand below 10 mm in size as its name suggests. The sandy clay used in Amran cement plant is loaded into dump trucks at Takuban in the middle of Sana'a and Amran and transported to the plant. The sandy clay contains about 80% SiO_2, its alkali contents is relatively low at about 0.7%.

Two kinds of cement raw materials are mixed in the proportions of 92 to 8 in Amran cement plant. One is the mixture of limestone and marlstone in the proportions of 9 to 1. The other is sandy clay.

(3) Gypsum Quarry

Gypsum transported from Kufraga, 40 km northeast from Sana'a has a purity of more than 95% ($CaSO_4 \cdot 2H_2O$).

Gypsum fed to the plant is broken below 30mm in size there by the crusher used for sandy clay.

3) Main Equipment

The layout of the plant, flow sheet and specifications of the main equipment are shown in Figure 4-1, Figure 4-2 and Table 4-1.

(1) Raw Material Preparation

After raw materials transported from quarries are stocked in each storage yard, they are mixed by weighers to get the proper content of raw mixtures.

A storage yard and a weigher for high grade limestone are installed to adjust the content between limestone and sandy clay.

The proportioned raw mixture with about 3% moisture is dried and ground at the same time by a ball mill with a cyclone separator, in which exhaust gas from a kiln is introduced.

The raw meal ground with about 10% residue over a 90 m sieve is fed to a homogenizing silo to be homogenized.

As an X-ray fluorescened analyzer is introduced for the proportioning of raw materials it is very easy to get precise analysis data with quickly.

(2) Clinker Burning

One kiln with New Suspension Preheater (NSP) is in stalled with a capacity of 1750 tones per day.

Since this NSP kiln has a higher burning capacity per unit kiln inside volume compared with other types of kiln, it is possible to prepare compact plant equipments.

Therefore, it has spread throughout the world rapidly since the early 1970's together with its excellent features of easy operation as well as lower fuel consumption.

There are some types of NSP kiln but the SF (Suspension-preheater with Flash Furnace) type, which is one of the most popular type of kiln, is installed in Amran cement plant.

C grade heavy oil is used as fuel and 60% of this is consumed in the Flash Furnace. Therefore, the heat load in the kiln can be saved, to contribute to extend the life of refractories inside the kiln, which reduces the cost of maintenance.

(3) Cement Grinding

Ordinary portland cement based on British standard 12-1978 is produced in Amran cement plant.

The clinker cooled in the clinker cooler after burning in the kiln is stored in silos. Clinker is ground together with about 3% gypsum by the ball mill, which is the same type for raw material grinding, and the final product, namely cement, is gained after coarser powder is separated by the cyclone separator.

Its fineness shall be about 3100 cm^2/g Blaine value.

(4) Cement Dispatch

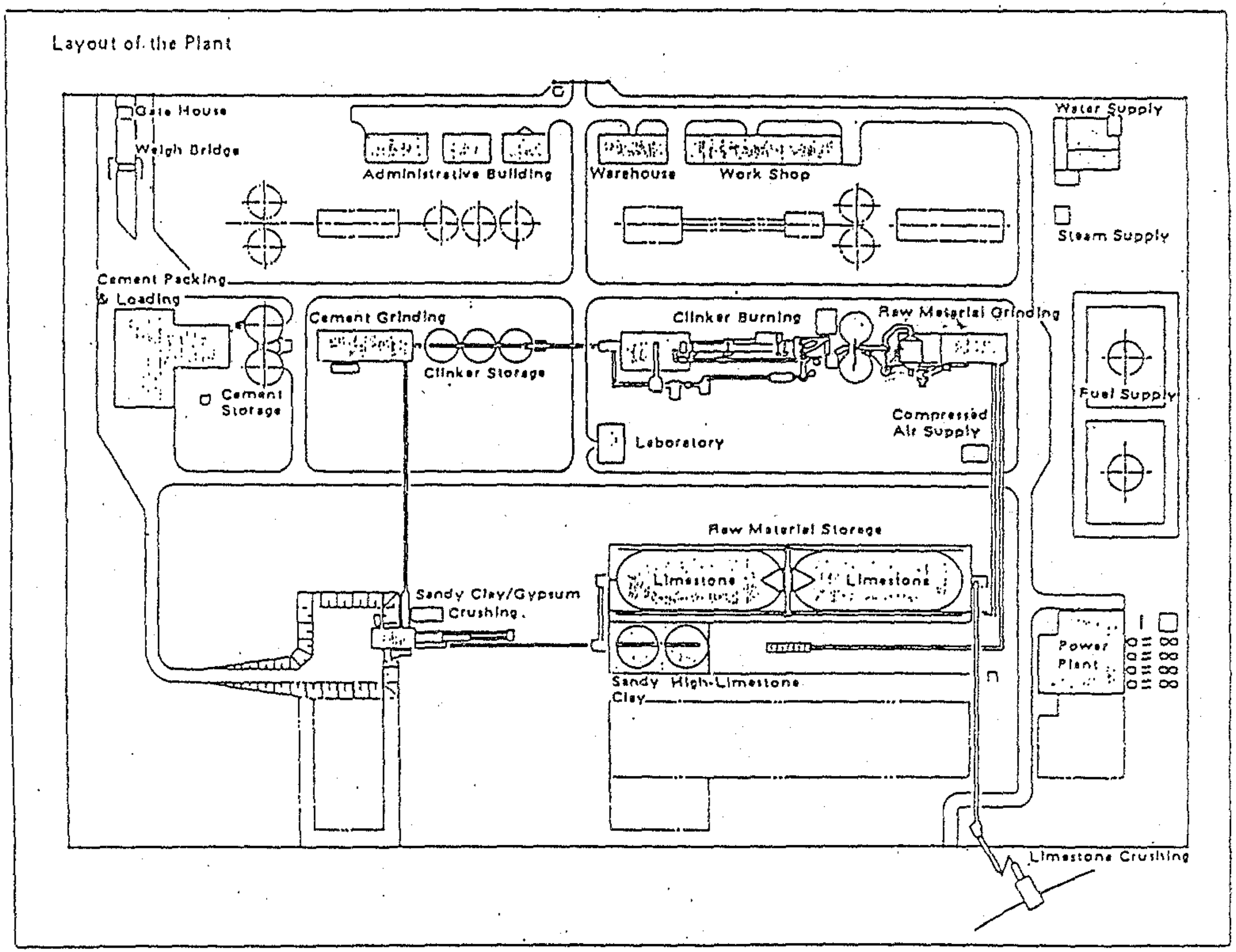
Cement is stocked in silos 75% of cement is delivered to consumers after being bagged by packers and the other 25% is loaded in bulk.

(5) Power Plant and Cooling Water

All electric power consumed in Amran cement plant can be supplied by a power plant which has four diesel generators. As power from the PEC (Public Electricity Corporation) is available, it was used for all power required in the cement plant at one time, but the power plant has been put into operation again because frequent trouble in the form of voltage drop occurred.

There are three wells of 200 m depth for cooling water used in the plant and drinking water for the employees housing area etc.

Figure 4-1 Layout of the plant



(Source:Amran Cement Plant)

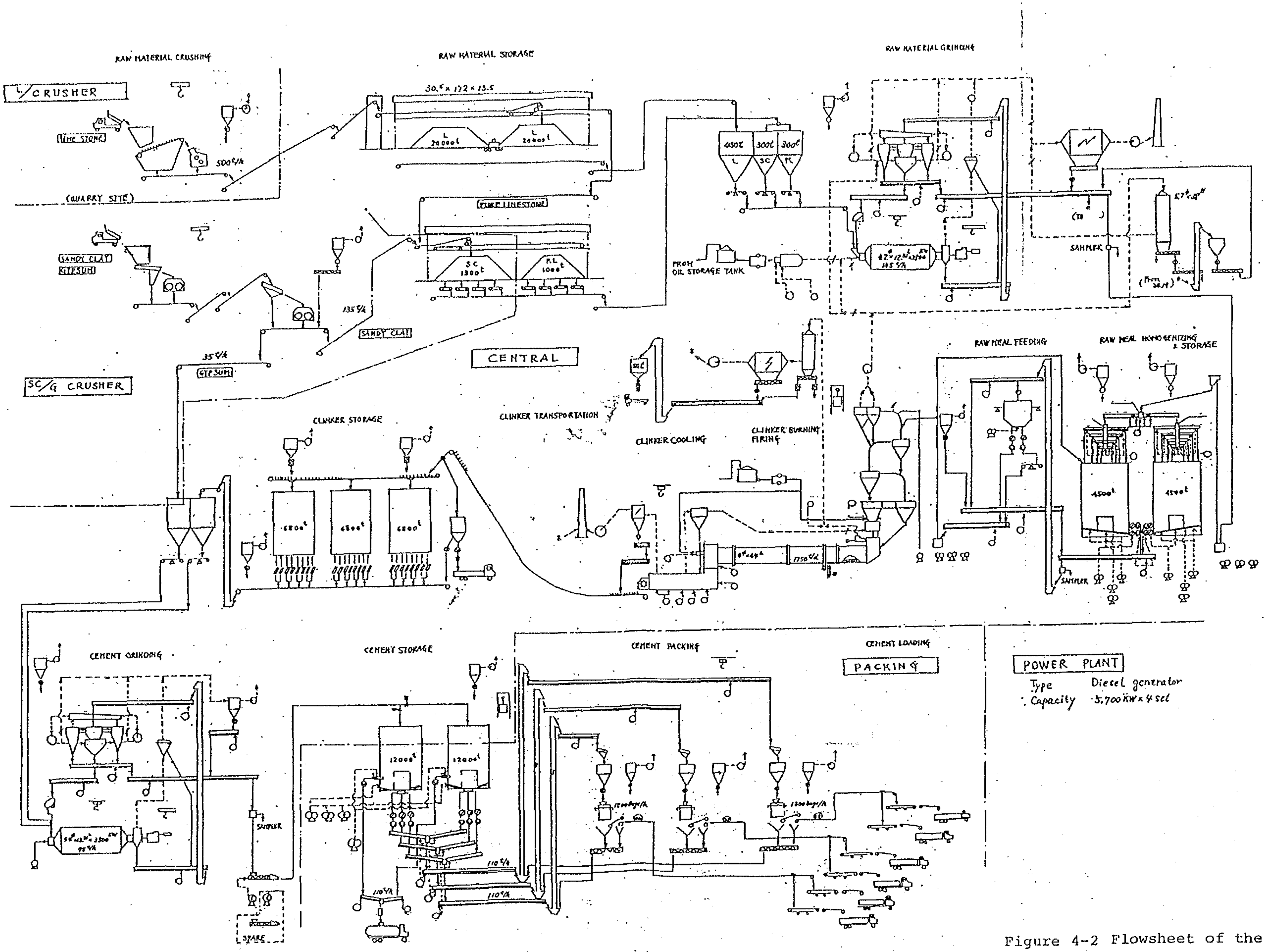


Figure 4-2 Flowsheet of the plant

(Source:Amran Cement Plant)

Table 4-1 Principal specification of the plant equipment

Equipment	System	Specification
Raw material crushing		
Limestone crusher	Compound impeller breaker	500 t/h, 600/800KW
Sandy clay/Gypsum crusher	Double roll crusher, 2 stages	135 t/h (Sandy clay), 35 t/h (gypsum)
Raw material storage		
Limestone	Chevron method mix bed with bridge scraper	20,000 t×2 piles, 220 t/h
Randy clay/hi-limestone	Open stock pile	1,300 t (Sandy clay), 1,000 t (hi-limestone)
Raw material grinding	Closed circuit compound mill with cyclone air separator	145 t/h, 4.2mφ×12.31ml, 2900KW, EP-dedusting
Raw meal homogenixing	Mixing chamber, concrete silo	4,500 t×2 silos~
Clinker burning	IHI-SF precalciner-kiln with 25%kiln gas by-pass	1,750 t/d, IHI-SF#129, 4.0mφ×60ml, EP-dedusting
Clinker cooling	Horizontal grate cooler	1,750 t/d, #FB2-22
Clinker storage	Concrete silo	6,800 t×3 silos
Cement grinding	Closed circuit compound mill with cyclone air separator	95 t/h, 4.4mφ×13.81ml, 3500KW, Bag filter-dedusting
Cement storage	Concrete silo	12,000 t×2 silos
Cement packing and loading	8-spout rotary packer	90 t/h (1,800 bags/h at 50 kg-bag)×3,
	with loader conveyors, and bulk loading spout	100 t/h for bulk loading
Power plant	Diesel engine-generator with radiator cooling system	5.7MW×4, IHI-SEMT 14PC2-5V engine,
		570KW aux. diesel generator
Cooling water supply	Closed circuit with cooling tower	300m³/h
Fuel storage	Cone-rool tank	4,000 kl×2 (Heavy oil and Diesel oil)
Steam Supply	Packaged boiler	2 t/h×2
Compressed air supply	Reciprocating compressor	26.5 m³/h (suction)×3

(Source:Amran Cement Plant)

4.1.2 Operating Conditions

1) Production

The amounts of clinker and cement produced since starting operation in July 1982 are shown in Table 4-2. Stable operation has been kept since then, except in 1985 and 86, when there were frequent stoppages due to the shortage of spare parts, heavy oil and diesel oil. Especially maximum production has recorded in recent two years by reason of spare parts were supplied sufficiently, so that the technical level of plant will be established highly.

Table 4-2 Clinker and cement production

	Clinker production (t)	Cement production (t)	Capacity ratio (%)
1982	168,300	154,700	(-)
1983	504,600	529,300	106
1984	505,400	519,100	104
1985	434,600	412,500	83
1986	357,800	418,100	84
1987	468,600	475,500	95
1988	462,000	501,400	100
1989	453,000	453,700	91
1990	514,600	553,800	111
1991	555,500	553,100	111

Capacity ratio(%) = annual cement production (t) / 500 thousand(t) x 100

(Source: Amran Cement Plant)

2) Cement Quality

Cement quality shown in Table 4-3 is satisfactory according to British Standards. The most important figure showing cement properties; i.e., 28 days compressive strength is 54.6 N/mm^2 average, and it corresponds to about 380 Kgf/cm^2 in the Japanese Industrial Standard.

It is thought to be at a more than average level in the world, in spite of being less than that in the Japanese market; 410 Kgf/cm^2.

As the fineness of cement is becoming coarser year by year, it is thought the ball arrangement in the cement mill is changed. In other words, it is supposed the shortage of spare parts due to the above condition is still continued.

3) Operation

The operation chart of the kiln and operating results of the main equipment are shown in Figure 4-3 and Table 4-4 respectively.

Following are the analysis results of kiln failure and stoppage since the commercial operation of 1982.

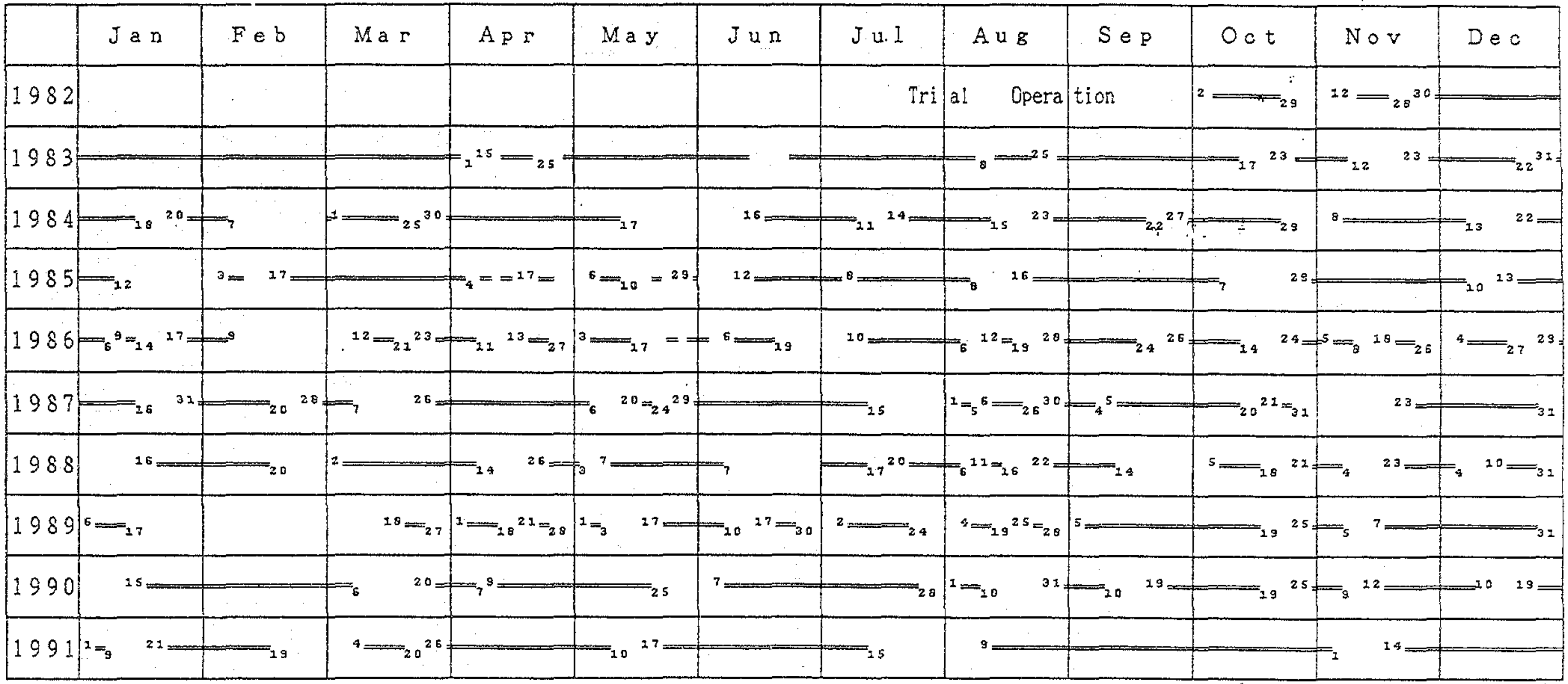
(1) Operation in 1982 and 83
Troubles such as preheater clogging which is one of the weak points of NSP kiln, occurred many times.

Table 4-3 Quality of cement

		B S	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Ig.loss	(%)	3.0 max	0.6	0.7	0.6	0.7	0.9	0.7	0.8	0.9	0.9	0.9
Insol.	(%)	1.5 max	0.3	0.3	0.3	0.4	0.5	0.5	0.5	0.6	0.5	0.4
SiO_2	(%)		21.5	21.0	21.1	22.0	21.5	21.4	22.1	21.2	21.2	21.0
Al_2O_3	(%)		5.5	5.7	5.6	5.5	5.0	5.1	5.2	5.7	5.6	5.0
Fe_2O_3	(%)		3.1	3.3	3.3	3.1	2.9	2.6	2.8	3.1	3.0	3.0
CaO	(%)		63.2	63.2	62.6	61.9	61.4	62.0	61.2	60.9	61.7	61.5
MgO	(%)	4.0 max	1.8	2.0	2.6	2.9	2.9	2.1	1.8	2.3	2.3	2.1
SO_3	(%)	3.0 max	1.9	2.1	2.0	2.1	2.0	1.7	1.6	1.9	2.1	2.1
Na_2O	(%)		0.14	0.34	0.26	0.21	0.23	0.26	—	—	—	—
K_2O	(%)		1.00	0.98	0.91	0.88	0.81	0.88	0.90	0.97	0.79	0.88
Total	(%)		99.0	99.6	99.3	99.3	97.7	97.3	96.9	97.4	97.5	96.0
HM			2.06	2.06	2.04	2.00	2.06	2.09	1.98	2.00	2.04	2.07
SM			2.5	2.4	2.4	2.7	2.7	2.7	2.7	2.4	2.6	2.6
IM			1.8	1.8	1.8	1.7	1.8	1.9	1.9	1.9	1.7	1.7
LSF		0.66～1.02	0.90	0.91	0.90	0.87	0.89	0.90	0.86	0.87	0.89	0.90
F-CaO			1.1	1.0	1.2	1.0	0.9	—	0.7	0.7	0.6	0.6
Fineness	Blaine(cm^2/g)	2250 min	3130	3180	3200	3190	3220	3080	3020	3230	3120	3100
	88 μR (%)		1.2	1.1	1.2	1.2	1.8	2.1	2.9	2.6	2.3	2.3
	44 μR (%)		10.7	11.8	12.6	12.6	15.1	17.0	16.8	28.2	15.9	15.3
Setting time	Initial(h-min)	45 min min	2—16	2—25	1—09	2—20	2—33	2—00	2—35	2—34	2—25	2—40
	Final (h-min)	10 hours max	3—19	3—11	2—04	2—52	3—28	2—90	3—45	3—33	3—27	3—31
Soundness												
Compressive	3 days(N/mm^2)	23 min	30.2	31.9	29.1	30.8	26.3	27.4	26.2	26.7	25.1	30.6
	7 days(N/mm^2)		39.6	40.9	38.6	39.4	37.2	39.6	39.9	39.1	—	—
	28 days(N/mm^2)	41 min	53.7	54.3	49.6	53.0	52.6	54.0	57.1	53.1	57.8	59.6

(Source:Amran Cement Plant)

Figure 4-3 Operation Chart of kiln



(Source:Amran Cement Plant)

Table 4-4 Operating results of main equipment

		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Raw Mill	Operation hour (h)	2162	6391	6255	5671	4873	6942	6043	5726	6130	6660
	Run factor (%)	73.4	73.0	71.4	64.7	55.6	79.2	69.0	65.4	70.0	76.0
	Output (t/h)	124.4	125.3	125.7	118.2	118.1	143.8	140.4	127.9	134.6	135.1
Kiln	Operation hour (h)	2527	6979	6676	6156	5401	7229	6081	5985	6463	7060
	Run factor (%)	85.7	79.7	76.2	70.3	61.7	82.5	69.4	68.2	73.5	80.6
	Output (t/h)	66.6	72.3	75.7	70.6	66.2	74.8	75.9	76.0	79.7	78.8
Cement Mill	Operation hour (h)	1646	5698	5959	5187	5052	6740	5463	5116	5920	5568
	Run factor (%)	55.9	65.0	68.0	59.2	57.7	76.9	62.4	58.4	67.6	63.5
	Output (t/h)	93.9	92.9	87.1	79.1	82.8	92.2	90.2	88.7	93.5	99.3
Fuel consumption (ℓ/t)		89.7	86.8	86.6	90.3	93.0	89.1	91.8	93.4	86.7	88.8
Specific power Consumption (KWH/t)		172.6	154.7	149.5	157.1	153.5	138.4	149.2	143.2	137.0	133.1

$$\text{Run factor} = \frac{\text{Operation hour}}{\text{Total hour per year}}$$ (including periodical maintenance and stock adjustment)

(Source:Amran Cement Plant)

It happened because of alkali materials sticking on the cyclone wall due to condensation of vaporized alkali in the raw meal. The coating material sometimes fell down due to temperature changes and clogged cyclone chutes. However, it was gradually solved by installing a high pressure air blasting system developed recently.

(2) Operation in 1984 and 85

Troubles on clinker cooler were common. These were caused by the falling off of cooler plates or the tripping of the spillage claim conveyor, but thought to be due to poor maintenance because of the shortage of spare parts.

(3) Operation in 1986

Operation ratio was at its lowest;(78.5%), due to an insufficient supply of limestone and a shortage of spare parts for quarry vehicles. And the plant stopped many times due to a lack of heavy oil for clinker burning and diesel oil for the power station.

(4) Operation in 1987 and 88

Clogging in the raw material hopper pointed out by a Rumanian technical adviser was caused due to sticky limestone in the rainy season.

Clogging in hoppers under the clinker cooler also happened, therefore drastic measures were required to prevent repeated troubles.

(5) Operation in 1989

Public electric power was supplied by PEC, however, cement plant equipment stopped often due to frequent voltage drops. It was impossible for the cement plant side to solve it because earthing happened on the transmission line from the substation.

(6) Operation in 1990 and 91

Diesel generators were restarted to prevent frequent power trouble such as voltage drops. Kiln failure or stoppage was reduced remarkably since troubles with the clinker cooler were solved.

In the future, it is pointed out that keeping sufficient spare parts and completing periodical maintenance is important.

4) Organization and Number of Employees

(1) Technical Assistant

Commercial operation started in October, 1982 and complete production was achieved within the year under the guidance of 15 Japanese experts dispatched for management services.

In the second and third year, technical transfer was done by 8 and 4 Japanese experts respectively. Technical assistance by Rumanians has been tried since 1986, so that 3 engineers are staying in charge of mechanic, process and electricity respectively.

(2) Philippine Experts

Although the plant is mainly operated by Yemenees, superior skilled maintenance workers were not sufficient in this country which doesn't have having large industries. Therefore, a total of 16 Philippine experts (14 for maintenance and repair, 1 for electricity and 1 for maintenance of quarry vehicles) were employed at the beginning, but in accordance with the improvement of yemenees skill a total of 7 experts (5, 1 and 1 in each above field) are engaged as of March, 1992.

(3) Plant Employees

The entire operation, maintenance and management except for 3 Rumanian technical assistants and 7 Philippine experts for maintenance, is performed by Yemeness.

The number of employees is shown below, but it is increasing gradually from the 430 employees at the beginning for the purpose of employment security in accordance with government policy.

Quarry	96	Administration	41
Quarry work shop	30	Finance	78
Packer	72	Utility	64
Maintenance	64	Guard	46
Production	80		
Laboratory	27		
Electricity	34		
Power station	30		
Total	433	Total	229

Grand Total 662

(Source: Amran Cement Plant)

4.2 Bajil Cement Plant

4.2.1 Outline of the Plant

1) General

Bajil cement plant is located at Bajil city, about 120 km east from Sana'a, along Sana'a-Hodeidah road.
The plant was constructed in 1973 as the first cement plant in Yemen by the financial and technical assistance of the Soviet Union.
The plant have two wet process kilns, each capacity is 670 T/D and 330 T/D respectively, and 300,000 tons annual cement production.

2) Raw Material

Raw materials used for the plant are 80% of limestone and 20% of clay.
Both materials are mined and transported to plant from each quarry located about 4 km away from the plant.
5% gypsum and 8% pozzolan are also used as additives of cement.

3) Main Equipment

Main specification of the plant are as follows.

Limestone Crusher	: 120 T/H x 1
Raw Material Grinding	: 40 T/H x 2
Rotary Kiln	: Wet Process Long Kiln
	4m dia. x 150 mL 670 T/D
	2.5m dia. x 75 mL 330 T/D
Cement Grinding	: 25 T/H x 2, 9 T/H x 1
Cement Packing	: Rotary Packer 800 bag/H x 2
	Inline Packer 600 bag/H x 1

Utilities Supply

- Water : Supplied from 6-wells near plant site
  Average Consumption: 1400 T/D
- Electric Power : Diesel Generator and public electricity source
  3000 kW x 4 sets
  Average Consumption: 7.5 MW
- Fuel : Heavy Oil
  Average Consumption: 150 T/D

4.2.2 Plant Operation

1) Clinker and Cement Production

Plant is operated about 650 personnel including 15 engineers and 20 supervisors, and 12 - 13 Russian advisors.
Clinker and Cement Production of 1990-1991 are mentioned in Table 4-5 Clinker and Cement Production

2) Cement Quality

Russian standard is applied for this cement quality.
Qualities of raw materials and cement are shown in Table 4-6.
Chemical analysis of cement is almost satisfied.
However it is unknown of physical characteristics.

Table 4.5 Clinker and Cement Production 1990 - 1991

MONTH	1990		1991	
	CLINKER	CEMENT	CLINKER	CEMENT
JAN	28,923,00	30,163,75	24,254.00	25,207.65
FEB	14,919.00	20,114.85	22,424.00	26,074.35
MAR	16,352.00	16,498.56	25,732.00	27,708.30
APR	29,028.00	27,860.70	16,537.00	21,564.00
MAY	29,529.00	32,446.70	11,683.00	13,317.85
JUN	25,180.00	26,006.10	27,048.00	24,826.70
JUL	25,292.00	20,919.75	24,216.00	19,302.70
AUG	26,093.00	23,518.00	15,598.00	20,373.50
SEP	6,000.00	20,638.15	16,635.00	31,297.05
OCT	13,962.00	12,975.40	18,525.00	29,206.00
NOV	20,500.00	21,902.44	20,752.00	25,703.30
DEC	28,793.00	28,209.95	23,005.00	29,131.05
TOTAL	264,571.00	281,254.85	246,409.00	293,712.45

Source: Bajil Cement Factory (Unit: tons)

Table 4-6 Quality of Raw Materials and Cement

	Ig-loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total	LSF	SM	IM	C_3S	C_2S	C_3A	C_4AF
Limestone	32.26	16.30	4.18	5.44	39.78	1.56	99.52							
Limestone	40.19	2.27	0.38	0.25	55.63	0.77	99.93							
Clay	11.89	53.84	11.88	7.05	9.95	3.57	98.18							
Slarry	33.85	14.01	3.63	2.72	42.83	1.52	98.53	0.91	2.2	1.4				
Clinker	0.0	21.24	5.58	3.98	64.24	1.95		0.90	2.2	1.4	56.6	18.3	8.0	12.1
"	2.2	21.07	5.54	3.99	64.24	2.08		0.91	2.2	1.3	58.5	16.3	7.9	12.1
Gypsum		6.0	1.08	0.56	32.0	0.54								
Add	5.95	69.05	10.56	2.80	9.94	0.24	98.27							
Cement	1.98	21.85	5.68	3.85	59.30	2.50								
Cement		22.83	5.58	3.95	59.70	2.0								

5

5

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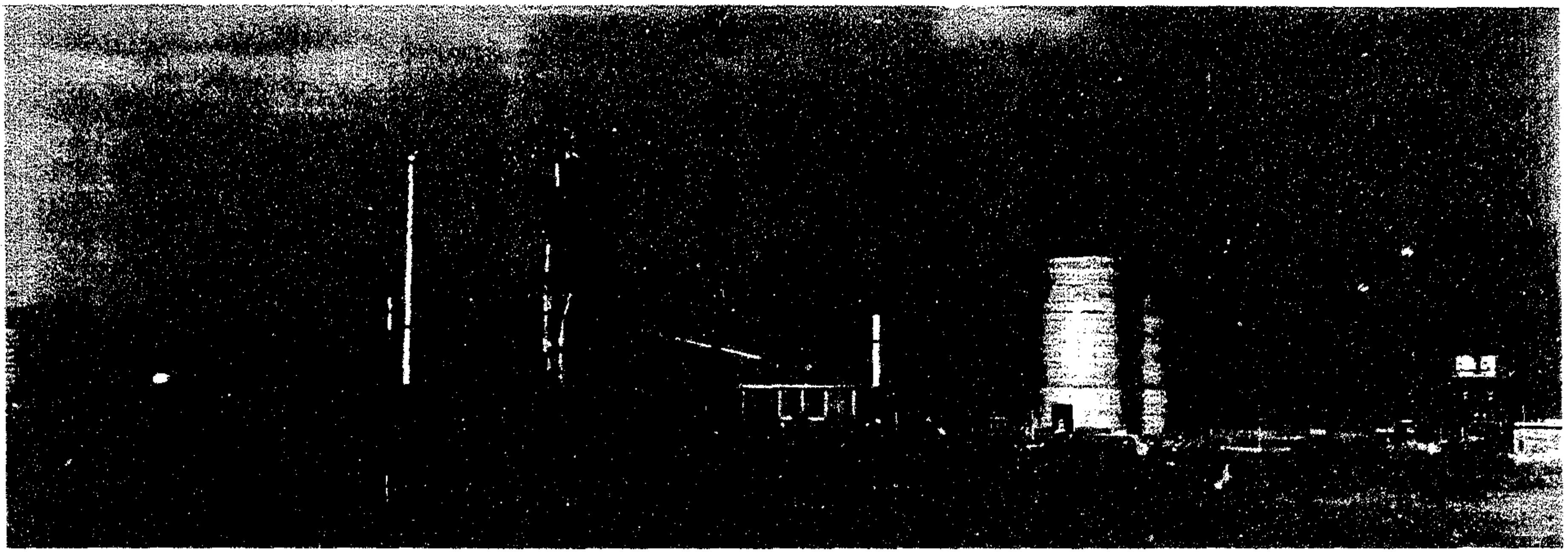

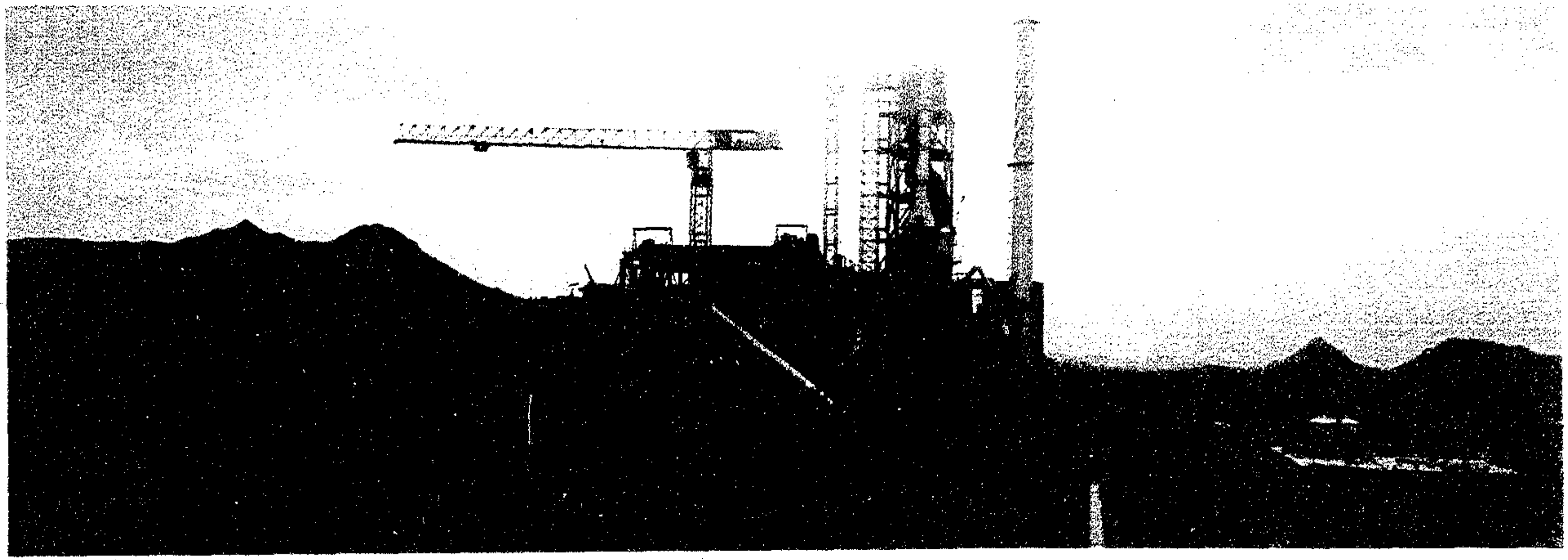

MAFRAQ CEMENT PLANT
(UNDER CONSTRUCTION)

5.1 Outline of Mafraq Cement Plant

5.1.1 Plant Site

The Cement Plant shall be located about 40 km south west from Taiz, along the Taiz - Mukha road.

The selected terrain of the plant site is an almost flat terrace located in front of the limestone deposit.

The selected plant site is shown in Figure 5.1 "Plant Site".

5.1.2 Local Conditions

Climatic conditions of the plant are given hereafter.

- Temperature : min. 15 Deg.C, max. 45 Deg.C
- Relative humidity: min. 30%, max. 100%, average 50%
- Average barometric pressure: 730 mmHg
- Wind:
  For calculation purposes, the maximum wind velocity shall be taken as equal to 130 km/h. Prevailing winds are from W.S.W direction.
- Rainfall : 40 mm per day, and occasionally 25 mm in an hour
- Altitude : 650 meters above mean sea-level

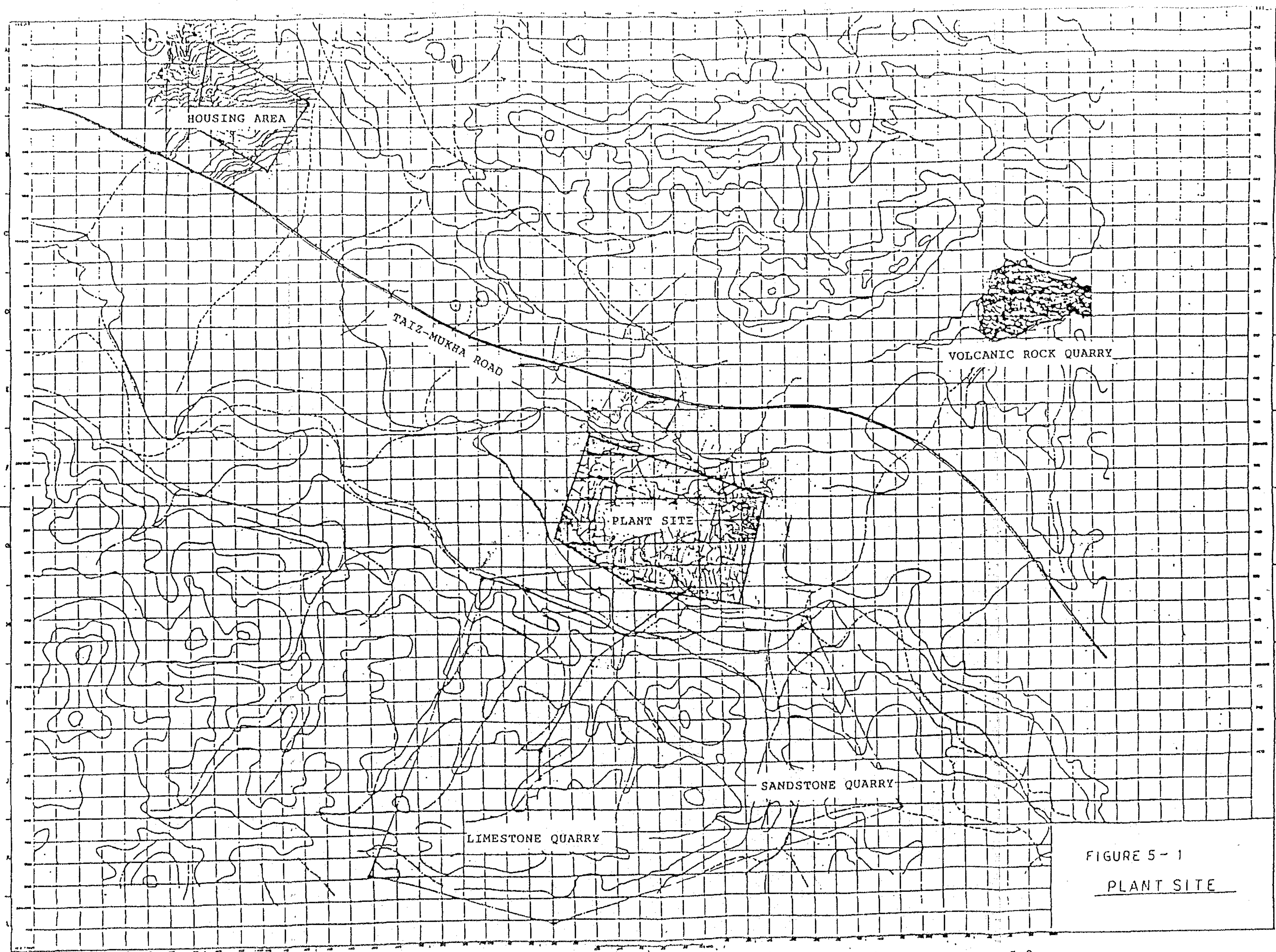

FIGURE 5-1

PLANT SITE

5.1.3 Plant Capacity

Production capacity of existing Mafraq Cement Plant is planned to 1700 tons per day clinker production and rated annual cement production is 500,000 tons per year.

The plant shall be capable of producing Ordinary Portland Cement according to ASTM C-150-82, Type I.

Type I clinker composition may be close to the following:

SiO_2	:	approximately	22.2
Al_2O_3	:	"	4.9
TiO_2	:	"	0.6
Fe_2O_3	:	"	2.9
Mn_2O_3	:	"	0.1
CaO	:	"	64.0
MgO	;	"	3.5
LSF	:	"	0.91
SM	:	"	2.6
AM	:	"	1.83

5.1.4 Description of the Equipment

The process adopted for manufacturing clinker is essentially the dry process using a precalcination system. Plot plant and principal specification of the plant are shown in Figure 5-2 "Plot Plan", 5-3 "Flow Sheet" and table 5-1 "Principal Specification".
lant equipment is classified into the following sections.

SECTION 10 - RAW MATERIALS QUARRYING

Sub-section 101 - Limestone quarry

The quarry is opened on the eastern side of the northern end of the limestone range.
In order to feed the plant, about 18,000 tons of limestone per week (of 6 days) have to be extracted.

After blasting, the limestone is loaded by front-end loaders and directly fed to the mobile crusher installed in the quarry.

Sub-section 102 - Volcanic rocks quarry

Located at about 2 km north west from the plant, the volcanic rocks quarry normally do not require blasting for its exploitation.

The average weekly production is close to 1,500 tons.
The rock is ripped by bulldozer, dumped on trucks with front-end loaders and conveyed to the additives crusher.

Sub-section 103 - Sandstone quarry

Located at about 2 km East to the plant, the sandstone is blasted, loaded on trucks and despatched to the stockpiles of the plant.

The average weekly needs are of the order of 400 tons.

Sub-section 104 - Gypsum storage

Gypsum in 0 to 300 mm size, is supplied by trucks to the plant and stockpiled (about 7,500 tons) near the gypsum crushing section.

This stockpile is partly covered by an open-sided structure under which front-end loader is to operate.

Sub-section 105 - Other materials supplies and storage

Other materials, if any, are received by trucks and dumped separately on respective bulk open storage piles.

SECTION 11 - RAW MATERIALS CRUSHING, STORAGE AND HANDLING

Sub-section 111 - Limestone crushing and handling

Capacity: 500 tons/hour

Limestones from the various limestone quarry faces are crushed to max. 70 mm in an electric operated mobile crushing section, prior to being transported by a belt conveyor system to the plant.

The crushed limestones are led through a system of belt conveyors onto either of the two piles of the mixed bed for pre-homogenization after having passed over a weighing belt and through an automatic sampling station.

Sub-section 112 - Additives crushing and handling

Capacity: 100 tons/hour

Volcanic rocks, sandstone and other raw materials are received in the plant by trucks and stockpiled. Reclaiming is effected by front-end loader, and the material is fed through a hopper made out of concrete and grizzly feeder into an impact crusher. The 0 to 60 mm product is discharged on a belt conveyor and carried on a vibrating inclined screen of about 15 mm opening.

The oversized material is directly fed to a cone crusher and the product of the latter, to the raw materials hoppers through bucket elevator and conveyors system.

Sub-section 113 - Limestone mixed bed

Mixed beds	:	2 x 20,000 tons
Stacking capacity	:	500 tons/hour
Reclaiming capacity	:	0 to 300 tons/hour

The crushed limestones are discharged through a programmed stacking equipment on the mixed bed stockpiles.

The mixed beds system is also equipped with a reclaimer which, through a series of belt conveyors, permits to extract the mixed material and feed it to the corresponding service hopper of the raw meal grinding section.

Sub-section 114 - Additives handling

Volcanic rocks, sandstone and other material, if any, is fed in sequence by means of a front-end loader to their respective service hoppers of the raw meal grinding section through additives crushing section.

Sub section 115 - Gypsum crushing and handling

Capacity	:	20 tons/hour
Product size	:	max. 50 mm with max. 10% oversize up to 80 mm

From the covered stockpile, by means of front-end loader, gypsum is fed through a receiving hopper made out of concrete into the corresponding 20 tons per hour crusher.
The 0 to 50 mm product is conveyed and fed into a gypsum bin before the cement mill by means of a belt conveyor and an elevator.

SECTION 12 - RAW MEAL PREPARATION

Sub-section 121 - Raw meal grinding and drying

Capacity : 135 tons/hour
Fineness : 22% retain on US 170 mesh sieve

The various raw materials are fed to the raw grinding vertical mill through the service hoppers weighing feeders and the belt and bucket elevator conveyor system
The material in the mill is dried whenever necessary by using a hot gas generator.
The ground raw meal is drawn out of the mill by the mill system fan suction and collected by a cyclone and an electrostatic precipitator (EP).
From there, the raw meal is transferred to the storage silos using an elevator.

The raw meal, on its way to the storage silo, is automatically sampled and the samples conveyed to the laboratory for analysis on the online automatic X-Ray analyzer which is turn activates a computerized raw mill feed control.

Sub-section 122 - Raw meal homogenizing and storage

Storage silos : 2 x 2,800 tons
Homogenizing silo : 1,200 tons

The material from the grinding mill after having been sampled for quality control is sent through an elevator into either of the two storage silos.

Material from the silos is withdrawn by air extraction from the lower part of the silos and sent to the continuous homogenizing silo.

The homogenized raw meal is led through two air slide systems either into the kiln feed system or recycled into either of the two storage silos.

Dust from kiln EP is also returned to the continuous homogenizing silo.

The homogenized raw meal is automatically sampled on its way to the kiln feed system and samples are conveyed to the laboratory for an automatic X-Ray analysis.

SECTION 20 - CLINKER BURNING AND HANDLING

Sub-section 201 - Clinker burning

Capacity : 1,700 T/D of clinker.

The raw meal (which also includes the E P dust) is sent to the kiln feed system via an air slide. The kiln feed weighing system includes also for emergency cases, a manually remote controlled flow gate. From the feed weighing, raw meal is conveyed through air slide and an airlift to the preheater.

The raw meal is led into the five stage preheater system and precalcinator where roughly half or more of the heat input is taken to calcine the meal to approximately 85%.

Exhaust gases from the preheater are led through a spray tower to an electrostatic precipitator, and the dust collected is recycled into the homogenizing system and/or discarded.

Hot air for the burning operation in the precalciner is fed from the grate cooler after passing through a settling chamber for dedusting of the clinker particles.

The remaining part of the cooler gases is dedusted in a gravel bed filter and discarded.

The material from the five-stage preheater enters the kiln where clinkering is completed in the conventional manner and it is discharged into the grate cooler where it is cooled down to 65 Deg.C above ambient temperature.

If required, part of the exhaust gases from the kiln may be deviated through a 20% capacity by-pass duct into a water spraying tower and an electrostatic precipitator.

The dust collected from this precipitator is discarded through a series of screws and a dust bin equipped for loading the dust transport truck.

Heavy fuel oil is used for the kiln firing.

Sub-section 202 - Clinker crushing storage and handling

Capacity : 2 x 8,500 tons

Clinker from the kiln after having been cooled down in the grate cooler to a temperature not exceeding 65 Deg.C above ambient temperature and crushed at the outlet of the grate cooler to 0 to 25 mm to suit cement mill requirement, is conveyed by means of a series of deep bucket conveyors to the top of two clinker storage

silos.
Alternatively, the clinker from the kiln may be fed into a bulk loading bin in order to dispose of it, when desired, prior to reaching the storage silos.

A clinker hopper installed over a belt conveyor, permits to recycle any clinker stored outside the silo to the clinker hopper of the cement grinding section.

From the two clinker storage silos, the clinker is extracted and fed into the clinker hopper of the cement grinding mill through heat resistant belt conveyor.

SECTION 21 - CEMENT GRINDING

Sub-section 211 - Cement grinding

Capacity : 90 tons/hour of type I cement
Fineness : 320 m^2/kg

Clinker from the hopper and gypsum from the crushed gypsum hopper are both discharged and proportioned by weighfeeders before being fed into the cement grinding mill.

The ground product of this mill is conveyed through an elevator into a mechanical air separator from where the coarse material is returned to the mill while the finished cement collected by a series of cyclone and bag filter is led out of the system by a pneumatic pump.

For cooling the cement, water is sprayed in the second chamber of the mill.

An additive material service hopper is also installed for possibly producing pozzolanic type cement.

Sub-section 212 - Cement handling and storage

Capacity : 4 x 7,000 tons

The finished cement from the grinding mill is conveyed through a pneumatic pump to any of the four cement storage silos.

SECTION 22 - CEMENT DELIVERY

Sub-section 221 - Empty bags storage and handling

A store is installed for housing the empty cement bags for six months deliveries.

It is situated in the cement packing building and it is equipped with a humidifier and sprinkler system.

The store is equipped with two electric hoisting monorail and travelling trolleys facilitating truck unloading.

Three toboggans (one for each bagging machine) are installed for delivery of empty bags to the level of the bagging machines.

Sub-section 222 - Cement packing

Capacity : 3 x 100 tons/hour

The stored cement in the four silos can be extracted and conveyed by means of air slides into three elevators which discharge the cement onto vibrating screen for removal of scrap iron fragments and then through intermediate hoppers into three cement bagging machines, and it is packed in 50 kg bag.

Each packing machine shall be equipped with automatic bags weight controlling and adjusting equipment for keeping the weight of the bags within the tolerance limits.

Cement spillage from each packing line is returned to the corresponding elevator for recirculation.

Sub-section 223 - Cement delivery in bags

The bagging machines through a system of belt conveyors can deliver the 50 kg cement bags to any of the five loading lines.
Two of the loading lines are each equipped with an extendible and height adjustable belt conveyor to allow for free access to any part of the truck. The three other loading lines are each equipped with automatic truck loading machines.

Collected cement spilled at ground level will be recycled to the packing plant through a feeding hopper equipped with a grid for discarding pieces of paper, etc. From this hopper, a system of screw conveyors will transfer this cement to one of the bucket elevators.

Sub-section 224 - Cement delivery in bulk

Bulk cement can be loaded directly from the concerned two storage silos, each equipped with a 100-ton per hour delivery point.

Load cells to be provided to control the feeding of the trucks.

SECTION 30 - AUXILIARIES

Sub-section 301 - Water storage, treatment and distribution system

1. Raw water

Raw water is supplied to the raw water storage tank at the plant site. Two separate water treatment plant designed according to the water analysis, provide the necessary quantity of drinking and process waters. Water for fire-fighting is directly taken from the main raw water tank.

2. Water treatment plant

2.1 Water treatment plant for process water production

This unit produces the necessary quantity of process water with a TDS not exceeding 250 ppm. Its capacity is min. 40 cu.m/h. The treated water shall be stored in a storage tank.

2.2 Water treatment plant for drinking water production

This unit produces drinking water in accordance with WHO recommendations with a TDS of about 500 ppm.

The capacity of this plant is minimum 8.5 cu.m/h of drinking water.

3. Drinking water

Drinking water coming from the drinking water tank is distributed to the following buildings:

- Administration building, canteen and shower-room
- Workshops, garage, laboratory and control room
- Emergency power plant, warehouse and toilet