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# IN-DEPTH SURVEY OF THE CEMENT INDUSTRY IN ECUADOR

SI/ECU/86/829/11-52

ECUADOR

Technical report: Diagnostic survey of Cementos Selva Alegre

Prepared for the Government of Ecuador by the
United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Harro J. Taubmann, cement expert

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United Nations Industrial Development Organization
Vienna

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## Explanatory notes

The monetary unit in Ecuador is the sucre (S/.).

References to dollars ($) are to United States dollars.

References to tonnes (t) are to metric tonnes.

References to gallons (gal) are to United States gallons (3.78543 l).

Besides the common abbreviations, symbols and terms, the following have been used in this report:

| | |
|---|---|
| CENDES | Centro de Desarrollo Industrial del Ecuador |
| IM | iron module |
| INEN | Instituto Nacional Ecuadoriano de Normalización |
| lgb | low-grade binder |
| LOI | loss on ignition |
| Lst | lime saturation standard |
| MPa | mega Pascal = $N/mm^2$ = 10 bar |
| SM | silica module |
| WG | water gauge |

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## ABSTRACT

Within the context of the project "In-depth study of the cement industry in Ecuador" (SI/ECU/86/829) for which the United Nations Industrial Development Organization is acting as the executing agency for the United Nations Development Programme, a team of three experts was fielded in order to carry out a diagnostic survey of all four cement plants existing in Ecuador and to recommend measures for their improvement or rehabilitation. The team, consisting of two cement experts and one economist, took up its assignment of two months during the last week of February 1987.

Upon request of the counterpart agency, the Centro de Desarrollo Industrial del Ecuador (CENDES), and due to the limited time and number of experts available, the two cement experts concentrated their efforts on only one cement plant each. Therefore the present report of the cement expert deals exclusively with Cementos Selva Alegre.

The factory, although producing the guaranteed tonnage of clinker, is facing financial problems due to its high debts. The main objective, therefore, was to find ways of cutting down production costs. After a careful study of the cement plant and the limestone quarry, the expert made the following main recommendations: (a) to reduce the excessive road transportation cost for limestone by erecting a 2-km belt conveyor, which could, in a second stage, be extended to 9-10 km; (b) to increase the workability of the cement by adding to the clinker gypsum and pozzolana respectively; (c) to diversify the production programme by including burnt and hydrated lime as well as a low-grade binder. The expert also elaborated detailed recommendations aiming at an improvement of the operation of the plant and submitted a programme for an increase of the clinker production up to 2,250 t/a.

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# INTRODUCTION

## A. Official arrangements

Within the context of the project "In-depth study of the cement industry in Ecuador" (SI/ECU/86/829) for which the United Nations Industrial Development Organization is acting as the executing agency for the United Nations Development Programme, a team of three experts was fielded in order to carry out a diagnostic survey of all four cement plants existing in Ecuador and to recommend measures for their improvement or rehabilitation. The team, consisting of:

Harald C. Boeck, cement expert and co-ordinator of the team
Jacques van Cutsem, economist
Harro J. Taubmann, cement expert

arrived at Quito on 21 and 25 February 1987 respectively.

The team reported to the counterpart agency, the Centro de Desarrollo Industrial del Ecuador (CENDES) and met their counterpart, Juan Viera P., Industrial Consultant and Director for Technical Assistance, CENDES.

Due to the limited time and number of experts available, CENDES decided that the team should carry out a diagnostic survey of only two cement plants, namely Empresa Industrias Guapan S.A. which was assigned to Harald C. Boeck and Cementos Selva Alegre which was surveyed by the author of this report.

On 4 March 1987, the experts travelled to their respective plants and proceeded according to a tentatively agreed work programme.

## B. Background

The present cement production of Ecuador is as follows:

| | t/a |
|---|---|
| La Cemento National | 1,365,000 |
| Cementos Selva Alegre | 340,000 |
| Cemento Chimborazo | 240,000 |
| Empresa Industrias Guapan | 85,000 |
| Total | 2,030,000 |

With the extension of La Cemento National and Empresa Industrias Guapan, the cement production is expected to reach 2,500,000 t/a in 1988, which covers more or less the needs of the country.

By 1990, the total cement consumption is expected to rise to 2,750,000 t/a, causing a shortage of 250,000 t/a, which could be compensated by increasing the production of Cementos Selva Alegre.

Cementos Selva Alegre is the second largest cement factory in Ecuador. Although it is producing the guaranteed tonnage of clinker, the factory is financially in a very difficult situation due to its debts. Further problems are:

(a) Excessive transport cost for limestone;

(b) Too high investment costs in relation to the production;

(c) The team of the responsible staff is not yet forged together, so as to be highly motivated and develop team spirit, although each of them is highly qualified and competent.

The most important objective for the management is to cut down production costs.

The purpose of the present report is therefore to provide solutions to the following problems:

(a) Outline the weak points of the factory and indicate remedies;

(b) Suggest how to reduce transport costs for limestone;

(c) Recommend strategies for an increase and diversification of the production in order to improve the pay-back situation for debts;

(d) Suggest cost-reducing measures.

The author of this report would like to thank the management and the staff of Cementos Selva Alegre for the open-minded discussions, the warm hospitality and the excellent co-operation extended to the expert, which enabled him to get an excellent insight into the plant situation and to obtain all necessary information and data for his work.

## RECOMMENDATIONS

1. In order to prove the probable reserves, further exploration by seismic investigation should be carried out.

2. ASTM type P cement should be introduced to the market. In order to increase the workability of the cement the addition of 5 per cent of limestone is recommended. The following two cement types should be produced:

| | | |
|---|---|---|
| INEN type 1 | : | 95% clinker, 5% gypsum or<br>90% clinker, 5% gypsum, 5% limestone; |
| ASTM type 1P | : | 75% clinker, 20% pozzolana, 5% gypsum. |

3. The production of burnt and hydrated lime for the sugar industry, the chemical industry, water treatment, construction and other applications should be taken up. Furthermore, the production of a low-grade binder with 50% clinker, 25% limestone, 28% pozzolana and 2% gypsum should be considered.

4. In order to save transport costs, the trucks should be loaded at the bottom of the limestone hill; before the new impact crusher is installed, the crushed limestone can be thrown down onto hoppers from which the trucks can be loaded. There are three options:

(a) No belt conveyor (saving about 7 km of road transport),

(b) A 250-m belt conveyor (saving 8 km of road transport);

(c) A-2 km belt conveyor (saving 12 km of road transport).

The expert recommends option (c), because this would be the first step for a later 9-10 km belt conveyor.

5. Based on a diagnostic analysis of the plant, the following improvements are recommended:

(a) The Hazemag impact crusher should be installed at a level of 1,620 m as soon as possible and combined with the 2-km belt conveyor. Trucks should be charged from a hopper, in order to avoid charging by shovel loader;

(b) When the Hazemag impact crusher is installed, the Cedar-Rapids hammer crusher should be used as secondary limestone crusher, in order to increase the raw mill capacity;

(c) The operation of the sonicool gas cooling tower should be improved in order to increase the retention time of the water droplets;

(d) The conical shaft of the preheater should be replaced by two cyclons in order to improve the efficiency of the preheater;

(e) The gas-outlet tubes of the existing preheater cyclones need to be repaired as they are deformed in a way that considerably reduces efficiency;

(f) The clinker production should be increased up to 1,500 t/d;

(g) The measuring and control equipment has to be checked and the indications and recordings to be adjusted;

(h) The production of pozzolana cement and low-grade binders should be started. A low-grade binder could be produced in the existing raw mill; in this case a new raw mill for the production of 2,500 t/d of clinker should be purchased and installed;

(i) To improve the efficiency of the main fans (No. 1, 2 and 3), the existing rotors with straight pallets should be replaced by highly efficient rotors with backward curved pallets;

(j) The co-operation of the team of operators should be enhanced through training and motivation;

(k) In order to avoid forseeable plant stops, the practical maintenance should be improved;

(l) As plant stops are most harmful for the overall plant efficiency, incentives (bounties) should be introduced for keeping the plant in continuous operation;

(m) To avoid the frequent granulometric segregation in the prehomogenization bed, a double-roller clay crusher should be installed;

(n) The existing multi-screw conveyor feeding the clay out of the clay hopper should be replaced by an apron conveyor.

5. In a second step the following modifications should be introduced:

(a) Equip the improved preheater with a precalciner, and implement a new gas-cooling tower;

(b) Increase the kiln production up to 2,250 t/d, which implies the upgrading of the oil-burner system; furthermore modify the cooler, either by installing a new cooler, or by adding to the existing cooler a g-type cooler;

(c) Erect a 9-10-km belt conveyor, in order to save further 25 km of road transport, including the climb;

(d) Install a further cement mill with new weigh-belt feeders of the same type as the old ones. Provide four feeders for clinker, gypsum, limestone and pozzolana;

(e) Erect a new raw-meal silo and substitute the existing homogenization system by the IBAU-type discharge system;

(f) Bring the raw mill capacity up to 200 t/h of dry raw meal, either by implementing a new mill of the same size as the existing one or by installing a 200 t/h mill and using the existing raw mill to produce the low-grade binder;

(g) Install a new electrofilter for the capacity of 2,500 t/d of clinker, i.e. 180,000 $Nm^3/h$, maximum temperature 180 °C, residual dust in the pure gas 50 $mg/m^3$;

(h) Install new, high-efficiency fans, corresponding to the higher gas volume which results from the 2,500 t/d kiln;

(i) Implement lime-burning facilities for 100 t/d, with a modern hydrating unit. For bagging, one of the existing four-spout bagging machines can be used;

(j) Implement a modern roto-pack machine for cement; use the existing four-spout machines for low-grade binder;

(k) In connection with the production increase of the kiln, renew the complete refractory lining. At the same time, provide better insulation.

In table 1 a synoptical review of the recommended improvements is presented, indicating investment costs and suggested timing. The costs are given in United Sates dollars on the basis of March 1987 exchange rates.

Table 1. Recommended plant improvements

| Step | Measures | Clinker | Cement | Raw meal | Fuel oil | Equipment | Investment cost (million dollars) | Timing (years) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Production of pozzolanic cement, low-grade binder (lgb), repair preheater | 1 250 t/d<br>400 000 t/a | 441 000 t/a* or<br>551 250 t/a** or<br>330 750 t/a* and<br>200 000 t/a lgb | 2 125 t/d<br>raw mill<br>97 t/h | 115 301 l/d<br>4 804 l/h<br>(1 269 gal/h) | 2 additional hoppers and 2 weigh-belt feeders for cement mill. Separate storage and packing facilities for different cement qualities; repair cyclone gas outlet tubes | 0.70 | 1 | Low-grade binder<br>50% clinker<br>24% limestone<br>24% pozzolana<br>2% gypsum |
| 2 | Production increase up to 1 500 t/d of clinker | 1 500 t/d<br>480 000 t/a | 529 200 t/a* or<br>661 500 t/a** or<br>441 000 t/a* and<br>160 000 t/a lgb | 2 550 t/d<br>raw mill<br>116 t/h | 138 361 l/d<br>5 765 l/h<br>(1 523 gal/h) | Substitute conical tower of preheater by 2 cyclones; increase volume of gas-cooling tower; increase raw mill capacity by secondary crushing of limestone | 0.8 | 2 | Cyclones to be produced in own workshop; change homogenization |
| 3 | Installation of Hazemag-crusher; improve limestone transport | 1 500 t/d<br>480 000 t/a | See step 2 | See step 2 | See step 2 | 2-km belt conveyor, civil engineering, charging hopper for trucks | 2.5 | 2 | |
| 4 | Production increase up to 2 250 t/d | 2 250 t/d<br>720 000 t/a | 793 000 t/a* or<br>992 250 t/a** or<br>any percentage of lgb | 3 825 t/d<br>raw mill<br>180 t/h | 207 542 l/d<br>8 648 l/h<br>(2 284 gal/h) | Precalciner, new cooler, new fans, new gas-cooling tower, new E-filter. Add further 10-km belt conveyor for limestone. Add storage silos for raw meal | 15 without belt conveyor; 23 with belt conveyor and tunnel | 4 | Use existing E-filter for cooling air from clinker cooler |
| 5 | Implement lime-burning facilities | 2 250 t/d<br>and 100 t/d<br>quick lime | See step 4 | See step 4<br>and 175 t/d<br>limestone<br>40-100 mm | 207 542 l/d<br>+ 10 309 l/d<br>217 851 l/d<br>9 077 l/h<br>(2 398 gal/h) | 1 or 2 lime kilns, hydrating unit, civil engineering, storage and packing facilities | 3 | 3 | Infrastructure of cement factory serves also for lime plant |

*Clinker + 5% gypsum + 5% limestone, Portland cement type No. 1.

**Clinker + 5% gypsum + 5% limestone : 25% pozzolana, pozzolanic cement type No. 1P.

# I. THE RAW MATERIAL BASIS

## A. General

One of the big problems of the Selva Alegre cement factory is the raw material basis. All the raw materials have to be brought from far away, with the exception of clay, the clay mine being on the territory of the factory itself. The distances from the mine to the factory are for:

| | |
|---|---|
| Limestone | 65 km |
| Sand (from Cotundo) | 280 km |
| Iron ore (from peninsula Sta. Helena) | 700 km |
| Gypsum | 850 km |
| Fuel oil | 500 km |

Therefore, the high transport costs are a big handicap for an economical production.

The proportion of the different raw materials in the raw mix is approximately the following:

| | Percentage |
|---|---|
| Limestone | 78.9 (2) |
| Clay | 18.4 (22-25) |
| Sand | 1.4 (12) |
| Iron ore | 1.3 (3) |

The raw material percentage refers to dry material; the values in parentheses are the average humidity content of the different products.

The most important raw material is limestone. The limestone mine is located near a village named Selva Alegre, which gave the name to the corporation.

The transport to the factory is difficult and costly, not only because of the long distance, but also due to bad roads and the difference in elevation. In order to reduce the transport cost, a feasibility study has been elaborated by Blue Circle Industries PLC Consultancy Services, in which it is recommended to replace the truck transport by a rope way. But the results of this study are not convincing.

A hybrid solution might be more economical, i.e. belt conveyors and truck transport. Two belt conveyors, one 2 km and the second 10 km long, would substitute the road transport of about 40 km and overcome the difference in altitude between 1,650 m and 3,200 m. At the end of the second belt conveyor a charging station with silos would be built, in order to facilitate the truck loading. But even with only the first belt conveyor installed, considerable advantages can be expected.

Furthermore, the existing two hammer crushers, type Cedar Rapids with a capacity of 130 t/h each, shall be replaced by one Hazemag impact-crusher, type APP 1615, with a capacity of 400 t/h.

The existing Cedar Rapids crushers are too flimsy for the heavy-duty operating conditions in a quarry for a cement factory. Taking a working period of 40 h/week, the capacity of 260 t/h is just enough for a production of 1,100 t/d of clinker, without reserves. Mostly the apron feeders are giving a high repair volume and furthermore the maximum grain size of feed rocks is only 400 mm, whereas the Hazemag impact crusher is equipped with a heavy-duty feeding conveyor and can digest rock pieces of up to 1,000 mm grain size.

The Hazemag crusher (for details see annex I) will be installed at an altitude of 1,620 m. From there the crushed stone is transported by a belt conveyor to the truck-loading station. There are two options: (a) a shorter belt conveyor of approximately 250 m; or (b) a 2 km belt conveyor. By implementing option (a) the road transport will be reduced by about 8 km, by implementing option (b) it will be reduced by about 12 km.

## B. Reserves of limestone

The limestone deposit is a hill in the shape of an elliptic cone (see annex I). The average limestone composition is the following:

| | Percentage |
|---|---|
| $SiO_2$ | 2.10 |
| $Al_2O_3$ | 0.41 |
| $Fe_2O_3$ | 0.19 |
| CaO | 54.00 |
| MgO | 0.78 |
| LOI | 42.40 |
| | 99.88 |

The analysis shows a very pure limestone, which can also be used for lime production. As it is coarse cristalline, it can be used as well for decorative purposes.

The proved reserves are approximately 28 million t. The most probable reserves are 61.2 million t, but of course, these reserves need further exploration. The expert suggests to use seismic exploration, and for confirmation one or two bore holes.

Up to now approximately 1.4 million t of the proved reserves have been used. Therefore, supposed the probable reserves can be transformed by exploration into proved reserves, a volume of approximately 88 million t is still available; i.e. with a daily clinker production of 2,500 t/d, a lifetime of the reserves of 75 years can be envisaged.

Whether the lower strata can be proved as limestone is very uncertain. This lower portion would represent another 86 million t; but the expert's suggestion is to consider only the two portions, proved and probable and to proceed as soon as possible with further explorations.

The above-mentioned longevity considerations do not take into consideration a possible lime production, which would add about 60,000 t/a to the consumption figures.

## C. Road transport of limestone

One of the big problems of Cementos Selva Alegre is the long distance between quarry and factory. The road is 64.5 km long, of which only approximately 20 km are tarred. The rest is a relatively wide aggregate road with a great number of curves. An additional handicap is the difference in altitude: the trucks start in the quarry at an altitude of 1,900 m, then have to go down to 1,650 m (9 km), climb up to 3,400 m (35 km) in order to go down again to the factory at 2,700 m (20 km).

The straight line between quarry and factory is only 24 km. This is the reason why various attempts have been made to substitute the truck transport by other means such as rope way or belt conveyors. But for the total distance both systems are too expensive and they can not be amortized within a reasonable period. A feasible solution seems to be a combination of belt conveyors and truck transport.

However, the trucks should be loaded down the hill at a level of 1,700 m and preferably out of a silo. This is independent of the installation of the Hazemag impact crusher, type APP 15/16; (rotor diameter 1,600 mm, rotor width 1,500 mm, motor 400 kW (525 hp)). Even with the two Cedar Rapids crushers the crushed material could be thrown down the hill and stored in silos.

Later, when the Hazemag is installed, the coarse limestone, as mined (rom) will be thrown down from the top of the mine to an intermediate storage from where the limestone is taken by a shovel loader and transported to the crusher, the implementation of which is shown in annex I.

The substantial advantage of loading the trucks down the hill is a saving of about 9 km of road transport, which means a reduction of the transport cost by approximately 14%. The expert's suggestion to install a belt conveyor would mean a further reduction of road transport by 3.5 km. In total 12.5 km of road and a transport cost of approximately 20% could be saved. At the end of the second belt conveyor a silo should be erected, from which the trucks would be loaded directly, without shovel loader, which means another saving of S/.40/t.

At present 96 trucks are required to transport the limestone for a production of 1,250 t/d of clinker. By implementing both belt conveyors, the number of trucks could be reduced to 30 for a production of 1,500 t/d and to 43 for 2,250 t/d of clinker. For a feasibility study it has to be considered that the transport cost will soon increase from at present S/.715/t to about S/.840/t.

For the following calculation a transport cost of S/.800 + 40 = S/.840/t has been adopted:

| | | | Million $ |
|---|---|---|---|
| Investments: | Belt conveyor | | 1.0 |
| | Civil work | | 0.6 |
| | | Total | 1.6 |

Savings: 20% of 840 = S/.t 168/t = $1.12/t

With 500,000 t being transported per year, the savings are $560,000/year - 5% interest $80,000/year i.e. for pay back available $480,000/year

Pay-back time: $\frac{1,600,00}{480,000}$ = 3.33 years

This pay-back time is so attractive that implementation of the first step should start now and have priority No. 1. It could be completed within eight months. As the installation of the Hazemag crusher will take at least two years, it is an advantage to realize the intermediate step with the crushed material; the belt conveyor can be adapted later to the Hazemag crusher.

In a second step, possibly together with the production increase of the plant to 2,250 t/d of clinker, a second 10-km belt conveyor should be installed, reducing the road transport to 28 km and lowering the production cost to 43% of the present cost per tonne. As the quantity for the transport will double, again a very interesting pay-back time can be expected:

| | |
|---|---|
| Total investment cost | $8.5 million |
| Savings | 0.56 x (840-168) = S/.376/t = $2.51/t = $2,510,000/year |
| - 5% interest | $ 425,000 |
| | $2,085,000 |

Pay-back time: $\frac{8,500,000}{2,085,000}$ = 4.1 years.

This hybrid solution seems to be so attractive, that a detailed feasibility study for the long belt conveyor should be initiated.

The expert recommends to install the belt conveyor in a tube of 2.8 m diameter that is protection and structure all in one.

## II. PRESENT PLANT SITUATION

### A. General

One of the most important factors in achieving a low production cost is continuous operation, i.e. the avoidance of all foreseeable plant stops resulting in kiln stops. This is a question of:

(a) Availability of spare parts;

(b) Preventive maintenance.

Those two items are interrelated. Rarely parts of equipment fail suddenly. In most cases a breakdown can be foreseen, either because of the lifetime of the part concerned, or because of progressive wear and tear. Although there are definite improvements to be noted, haphazard plant stops are too frequent.

A critical investigation has to be made as to which parts can cause a standstill of the kiln. Those parts should under all circumstances be on stock, even if they are second-hand, in order to reduce cost. (For example, the failure of the 1,500 hp fan motor.) In that context the following rule should be observed: a somewhat lower but continuous production is better than forced hazardous operation.

A fact sheet of the cement plant is contained in annex II, and a detailed description of the plant and its operation is given in annex III.

It should be mentioned that Cementos Selva Alegre has an almost perfect system of recording production figures, based on a set of forms, including daily, weekly, monthly, yearly and special reports.

### B. Limestone crushing

The mined limestone with a maximum grain size of 400-500 mm is transported by rubber-tyred vehicles (capacity 30 t) to two double-wheel hammer crushers, type Cedar-Rapids (capacity 130 t/h each). Bigger rocks are rejected and thrown down the hill, because the apron feeders of the crushers do not admit pieces bigger than 400-500 mm. The crushed limestone having a grain size of 0-100 mm, with occasional pieces up to 200 mm, is stockpiled near the crushers. The crushers are located at an altitude of 1,900 m above sea-level.

A new Hazemag impact crusher is available at the warehouse; it should be installed as soon as possible at an altitude of about 1,650 m above sea-level.

### C. Limestone transport to the plant

The limestone transport over 65 km is carried out by 96 trucks having a capacity of 15.5 t; 12 are owned by Selva Alegre, 84 are owned by contractors. The 12 Selva Alegre trucks are travelling twice per day, five days a week; the contractors' trucks are doing only one and a half trips per day. The total transport volume is 11,625 t/week; this is very close to the 11,900 t/week theoretical consumption, when the plant is continuously running at a capacity of 1,250 t/d of clinker. At present the transport cost is S/.715/t with a tendency to increase.

### D. Limestone preblending and transportation to the raw mill

The limestone at Selva Alegre plant is of a very uniform quality. It is high in $CaCO_3$, namely 96.5% with minor variations; therefore the limestone deposit at the plant site of approximately 90,000 t is more a storage than a preblending bed, although the existing staker and four discharge vibrating feeders could equilibrate variations in the chemical composition. From the deposit the limestone is transported to the hopper before the raw mill by a belt conveyor, equipped with a weighing scale, which is out of operation. But there is a weigh-bridge for the arriving trucks, so that the total limestone quantity delivered is known and recorded.

### E. Clay preblending and transportation to the raw mill

The clay is taken from a deposit which is only a few hundred metres away from the plant site. The 20 t trucks delivering the clay are weighed on another weigh-bridge and then take the clay to the covered clay deposit, which has a storage capacity of 10,000 $m^3$. From that deposit the clay is transported by dumpers and belt-conveyors to the boom stacker of the blending bed. The blending bed is operating by the Windrow stacking method.

As the originally installed hammer crusher for clay has been removed because it never operated satisfactorily, there is no clay crusher in operation; therefore, granulometric segregation takes place in the blending bed. The reclaimer is a bridge-type scraping reclaimer with harrow attachment. The blending bed, also under cover, has a storage capacity of 20,000 $m^3$. The total clay storage capacity is therefore approximately 45,000 t.

The transport from the blending bed to the corresponding raw mill hopper is by belt conveyors; here too the weighing scale on the belt is out of operation.

It is recommended to install a double-roller clay crusher in order to avoid segregations.

### F. Storage of correctives and gypsum, and their transport

At the raw material storage not only limestone and clay are stored, but also the correctives, i.e. sand (5,000 t), iron ore (6,000 t), and gypsum (4,500 t).

The transport to the corresponding raw mill hopper is by belt conveyors which are fed by a shovel loader. The gypsum, before reaching the cement mill hopper, is crushed by a hammer crusher, type Williams, which is fed by a vibrating feeder from a hopper, charged by the shovel loader. The crushed gypsum is transported by a bucket elevator and a belt conveyor into the feeding hopper of the cement mill.

### G. Raw meal preparation

The raw meal, namely:

| | t/h | Humidity (%) |
|---|---|---|
| Limestone | 80.5 | 2 |
| Clay | 27.7 | 23.5 |
| Sand | 1.57 | 12 |
| Iron ore | 1.34 | 3 |
| Total | 106.10 | 6.1 |

is fed to the raw mill by weigh-belt feeders from the raw material hoppers. The clay feeder is charged by a multi-screw conveyor, having a very high rate of wear and tear. The above-mentioned feeding rate refers to dry raw meal.

The raw mill is a vertical roller mill, type MPS, licensed from Pfeiffer. The maximum performance indicated by the supplier, Allis Chalmers, namely 120 t/h, cannot be reached under present conditions with the coarse limestone. The maximum capacity reached is 100 t/h, and that limits the kiln production to 1,250 t/d of clinker.

The raw mill is heated with the flue gases from the preheater of the kiln. Before entering, the gases are conditioned in a Sonicool cooling tower, the performance of which is poor because the resident time of the droplets in the tower is not enough for their evaporation.

The produced raw meal is stored in concrete silos with a capacity of 4,140 t and 1,880 t respectively. Above these silos a 962 t homogenization silo is located. Due to the arrangement of the air inlets, granulometric segregation takes place.

The discharge from the silos is carried out by airslide conveyors, which feed a Fuller pump for the raw-meal transport to the kiln preheater. Between the airslide conveyor and the Fuller pump a proportioning weigh-belt feeder is located.

The average of raw meal analyses carried out in February 1987 is the following:

| | Percentage | Moduli | |
|---|---|---|---|
| LOI | 33.5 | Lst | 98.4 |
| $SiO_2$ | 13.7 | SM | 2.44 |
| $Al_2O_3$ | 3.7 | IM | 1.87 |
| $Fe_2O_3$ | 2.0 | | |
| CaO | 43.2 | | |
| MgO | 1.5 | | |
| $Na_2O$ | 0.74 | Fineness | |
| $K_2O$ | 0.23 | Residue on 200-mesh | |
| $TiO_2$ | 0.28 | screen (74 $\mu$m) 16% | |
| $CaCO_3$ | 75.7 | | |
| Humidity | 0.4 | | |

The grindability is 18 kWh/t.

## H. Pyroprocessing

The clinker is produced in a rotary kiln, having an inside diameter of the shell of 4.42 m and a length of 62.3 m equipped with a MIAG-type preheater with one conical shaft and three cyclone stages. The active volume of the kiln, inside the refractory lining, is 779 $m^3$. Therefore the theoretical production with preheater could be 1,500 t/d of clinker and with precalciner 2,250-2,500 t/d of clinker.

As the preheater is not working well, the degree of calcination of the raw meal entering the kiln is below 20%, and most of the decarbonatization takes place in the rotary kiln. Therefore too much dust that is not bound in nodules enters the burning zone, causing an excessive amount of dust entering the cooler from which it is blown back into the kiln and hampers the radiation of the flame.

The raw mill performance and the poor preheater efficiency are the reasons why the actual production of the kiln is limited to 1,250 t/d of clinker, which is still 14% more than guaranteed. The specific production figures of the existing kiln are:

| t/d | t/h | $t/d/m^3$ |
|---|---|---|
| 1,250 | 52 | 1.6 |
| 1,500 | 62.5 | 1.93 |
| 1,750 | 73 | 2.25 |
| 2,000 | 83.3 | 2.57 |
| 2,250 | 93.8 | 2.89 |
| 2,500 | 104.2 | 3.21 |

It is evident that the kiln can produce much more than defined in the specifications. One of the critical points of the overall engineering is that the individual pieces of equipment are not optimized as a system. As a consequence, the plant is at least 30% too expensive for the guaranteed performance.

In table 2 production data for different kiln performances are given. It shows clearly where investments are necessary to increase the production of the plant. For the computation of fuel-oil consumption and gas volume, 850 kcal/kg clinker has been assumed; for the calculation of the cement quantity it has been assumed that clinker + 5% gypsum + 5% limestone or pozzolana are ground; and for the mill capacities, actually obtained tonnages are used.

The average clinker characteristics (analysis of February 1987) are as follows:

| | Percentage | Moduli | |
|---|---|---|---|
| LOI | 0.3 | LSt | 92.6 |
| $SiO_2$ | 21.3 | SM | 2.35 |
| $Al_2O_3$ | 5.8 | IM | 1.78 |
| $Fe_2O_3$ | 3.3 | | |
| CaO | 64.8 | Liquid phase | |
| MgO | 2.1 | 27.7% | |
| $SO_3$ | 0.61 | | |
| $Na_2O$ | 0.99 | Mineralogy | |
| $K_2O$ | 0.37 | $C_3S$ | 52.5 |
| $TiO_2$ | 0.53 | $C_2S$ | 20.9 |
| | | $C_3A$ | 9.8 |
| Free lime: 1.4% | | $C_4AF$ | 9.9 |

## I. Cement grinding

The cement mill is a two-chamber ball mill, with an air separator. Its effective capacity is 72 t/h of Portland cement No. 1. This cement corresponds to INEN 152, similar to ASTM 152. The cement has 3,300 to 3,400 Blaine.

A typical compression-strength distribution is the following:

Table 2. Production data for different kiln performances

| Clinker production t/d | Clinker production t/h | Clinker production t/y a/ | Raw mill capacity b/ Necessary (t/h) | Raw mill capacity b/ Installed (t/h) | Theoretical cement production c/ (t/y) | Cement mill capacity Necessary (t/h) | Cement mill capacity Installed (t/h) | Flue gas $m^3$ B/h (180 °C) | Flue gas $m^3$ N/h | Fuel oil d/ kg/h | Fuel oil d/ l/min |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 000 | 41.7 | 320 000 | 77.3 | 100 | 352 000 | 58.5 | 72 | 112 095 | 67 554 | 3 731 | 64.1 |
| 1 100 | 45.8 | 352 000 | 85 | 100 | 388 080 | 64.3 | 72 | 123 116 | 74 196 | 4 098 | 70.4 |
| 1 250 | 52.0 | 400 000 | 96.4 | 100 | 441 000 | 73.0 | 72 | 139 783 | 84 240 | 4 653 | 80.0 |
| 1 500 | 62.5 | 480 000 | 116 | 100 | 529 200 | 87.7 | 72 | 168 008 | 101 250 | 5 592 | 96.0 |
| 1 750 | 73.0 | 560 000 | 135 | 100 | 617 400 | 102.4 | 72 | 196 233 | 118 260 | 6 532 | 112.0 |
| 2 000 | 83.3 | 640 000 | 154 | 100 | 705 600 | 117.0 | 72 | 223 921 | 134 446 | 7 453 | 128.0 |
| 2 250 | 93.8 | 720 000 | 174 | 100 | 793 800 | 132.0 | 72 | 252 147 | 151 936 | 8 393 | 144.0 |
| 2 500 | 104.2 | 800 000 | 193 | 100 | 882 000 | 146.0 | 72 | 280 163 | 168 840 | 9 323 | 160.0 |

a/ 320 days per year; 1.7 raw meal proportion: 1 clinker.

b/ 154 h/week.

c/ 132 h/week.

d/ $H_u$ = 9,500 kcal/kg.

| Days | MPa |
|---|---|
| 1 | 10 |
| 3 | 19 |
| 7 | 24 |
| 28 | 32 |

An analysis of the bagged cement (average of February 1987) gave the following results:

| | Percentage |
|---|---|
| LOI | 1.5 |
| $SiO_2$ | 20.6 |
| $Al_2O_3$ | 5.9 |
| $Fe_2O_3$ | 3.2 |
| CaO | 62.3 |
| MgO | 2.1 |
| $SO_3$ | 2.6 |
| R | 1.8 |
| Free lime | 1.2 |

The cement is transported from the mill to the storage silos by a Fuller pump. It is stored in two silos of 5,450 t each, from where it is discharged by airslide conveyors and transported by a bucket elevator to the bagging station and the bulk loading bay respectively. Most of the cement (85%) is dispatched in 50-kg bags, the rest (15%) is sold in bulk.

It is highly recommended to add 5% of limestone to the mixture of clinker and gypsum. Furthermore, the production of pozzolanic cement with up to 25% of pozzolana should be envisaged, particularly as several pozzolana deposits of good quality are available in the vicinity of the factory. In order to increase the income, it is also recommended to produce a low-grade binder, composed as follows:

50% clinker
24% limestone
24% pozzolana
2% gypsum

It could be sold under the trade mark

| Morterello Selva Alegre |
|---|

or any other attractive name.

J. Laboratory and quality control

The laboratory is equipped with all necessary apparatuses, devices and appliances to carry out routine analyses for operation and quality control. A certain volume of research work for new binders and other construction materials on the basis of cement and lime is also possible.

The routine tests include chemical and physical analyses of raw materials, partially processed materials and final products. The following sampling frequency is in use:

| | |
|---|---|
| Limestone | 1 time/day |
| Clay | 2 times/day |
| Sand | each truck |
| Iron ore | each truck |
| Gypsum | each truck |
| Raw mill | every hour (automatic sampler) |
| Raw meal (kiln feed) | every 2 hours |
| Clinker (screened 3-10 mm) | every hour |
| Cement from mill | every 2 hours |
| Cement for bagging | 1 time/day |
| Gypsum for cement mills | 1 time/day |

For chemical tests the following methods are applied: gravimetric, volumetric, complexometric, X-ray fluorescence, flame fotometric and conductrimetric analysis.

The physical tests include: density, apparent volume, normal consistency, fineness, grain size analysis, Blaine test, compression and shrinkage tests.

The laboratory equipment consists of: Orsat gas analyzer, precision scales, heaters, mufflers and driers, crushers, mills, presses, colorimeter, spectrophotometer, X-ray analyzer, computer, viscosimeter, densimeter, glassware, Vicat needle and chemicals.

## III. STRATEGIES TO IMPROVE THE PERFORMANCE OF THE PLANT

One of the most important objectives is to instill in the leading team cost-mindedness and motivation to achieve improvements. In that connection information and training are essential.

Before developing improvement strategies, the weak points of the plant will be summarized.

### A. Summary of deficiencies

**Raw materials**

Limestone

- Mining is still chaotic;
- Crushing on mining level; road transport to be shortened by 9 km;
- Grain size of crushed limestone too big;
- Limestone crushers too weak; maximum feeding size of rocks with 400-500 mm too small;
- Limestone transport to the factory very tedious and costly;
- Belt-weighing scale inside the plant out of order.

Clay

- No clay crusher operating;
- Belt-weighing scale inside the plant out of order.

**Raw milling**

- Multi screw-conveyor feeder for clay weigh-belt feeder showing heavy wear and tear;
- Feeding valve of roller mill tends to jam (now replaced by triple flap valve);
- Raw-mill capacity due to coarse limestone too small;
- Homogenization system does not prevent granulometric segregation, which means from time to time too coarse raw meal.

**Pyroprocessing**

- Installed MIAG-type preheater not very efficient; raw meal entering the rotary kiln is too cold; gas outlet temperature up to 460 °C;
- Gas outlet tubes of the cyclones partly bent, i.e. no uniform heat distribution in the cyclones;
- Gas cooling tower too small;
- First clinker cooler fan too small; should have 1,500 $m^3$/min instead of 340 $m^3$/min;

- Distribution chute on the top of the clinker storage bay does not work, therefore clinker is not distributed uniformly;

- Only three discharge vibratory conveyors are provided in the clinker storage bay, therefore too much dead storage;

- Indications on the control panel are not correct.

Cement milling

- Weigh-belt feeders do not indicate performance correctly;

- Weighing scale for bulk-loaded cement is not operating;

- Packing capacity far too small; when from the total of 9,625 t/week to be dispatched, 85%, i.e. 8,181 t have to be bagged, then 102 h/week or 17 h/day are required to do the job.

## B. Suggested improvements

From the above, strategies as to how to improve the plant can be deduced. Of course, the first and most important decision to be taken is the following: which is the desired maximum capacity of the plant and in what time should it be realized?

Notwithstanding the answer to the above question, the following measures are decisive to achieve a cost reduction and are therefore strongly recommended.

Quarry

The distance of road transport of the limestone should be reduced as much as possible. Therefore, truck loading at the base of the hill, i.e. at about 1,650 m above sea-level, should be realized under task force conditions. The expert recommends to install a 2-km belt conveyor in order to save 12 km of road transport. The trucks should be loaded by a charging hopper.

Furthermore it is most important to install the Hazemag impact crusher. The belt conveyor and the charging hopper have to be used as well.

It should be stressed that, in case the clinker production is increased up to 2,250 t/d, a further belt conveyor of about 10 km length is compulsory, because the transport of some 1.7 million t/a of limestone by truck over 52 km on the existing road would be nearly impossible.

Production increase to 1,500 t/d of clinker

The only way to reduce the pay-back period of the debts is by increasing the production. It is, therefore, recommended to push the kiln output up to 1,500 t/d, which will yield the following quantities of cement:

| | |
|---|---|
| Under present conditions | 1,575 t/d |
| With 5% limestone | 1,654 t/d |
| As pozzolanic cement | 2,067 t/d |

This can be achieved by proceeding as follows:

(a) Reduce the grain size of the crushed limestone, i.e. implement the Hazemag impact crusher and use one of the Cedar-Rapids crushers for secondary crushing. That will bring the raw mill capacity up to 120 t/h;

(b) Enlarge the gas cooling tower by increasing the cylindrical portion as planned and install new atomizing nozzles;

(c) Substitute the conical shaft of the preheater by two cyclones having the same dimensions as the cyclones of stage one, i.e. directly after the conical shaft. Repair the gas outlet tubes of the existing cyclones and reinforce the inlet in order to avoid deformation;

(d) Substitute the clinker cooler fan No. 1 by a 1,500 $m^3$/min fan. The cooling air distribution for a 1,500 t/d kiln production should be as follows:

| Fan No. | Air volume $m^3$ N/h | Air volume $m^3$/min |
|---|---|---|
| 1 (OA) | 66,500 | 1,487 |
| 2 (OB) | 44,563 | 743 |
| 3 (OC) | 29,094 | 520 |
| 4 (OD) | 37,406 | 669 |
| 5 (OE) | 24,938 | 446 |

(e) Increase the oil pressure of the burner;

(f) For cement milling there are several options; the decision is, of course, dependent on the desired final capacity. However, it is necessary to provide four hoppers and the corresponding weigh-belt feeders for clinker, gypsum, limestone and pozzolana.

> Option I: Maximum performance of the plant based on a production of 1,500 t/d of clinker: use the existing raw mill for pregrinding the cement, then the ball mill capacity will go up to 130 t/h or a maximum of 20,000 t/week of cement. This option implies a new raw mill.
>
> Option II: The finally envisaged performance of the factory is based on a daily clinker production of 2,250 t or 2,500 t, respectively. In this case, even for the first step, it is recommended to install a second cement mill, identical to the existing one, but with four feeding hoppers and four feeders.

In any event, the existing cement-storage facilities have to be doubled by putting the existing silos into operation. Furthermore, even for the 1,500 t/d step, it is necessary to install a new high-performance Rotopack bagging machine.

Production increase to 2,250 t/d of clinker

In that case the corresponding cement quantities would be:

| | |
|---|---|
| Cement No. 1 | 2,363 t/d |
| With 5% limestone | 2,481 t/d |
| As pozzolanic cement | 3,100 t/d |

As this option involves a rather long-range programme, only the major modifications of the plant have been indicated, without presenting details.

(a) Raw-meal production:

- New raw mill of the same performance as the existing roller mill, or a new 200-210 t/h roller mill;

- One new raw-meal silo;

- Eliminate the actual homogenizing system and equip all three silos with IBAU-discharge;

- Increase transport capacity;

(b) Pyroprocessing:

- New gas conditioning tower;

- Provide precalciner with tertiary air duct;

- New clinker cooler, or add to the existing cooler, which must be equipped with new fans and a g-type cooler; in this case substitute the clinker crusher;

- New high-efficiency fans for flue gas conveying;

- New electro-filter; use the existing filter for cooler;

- Increase capacity of oil burner;

- Overhaul the whole plant;

(c) Cement milling:

Same as under (f) above.

## IV. OPTIMIZATION OF PERFORMANCE

On top of the nominal output of the production equipment, additional output can be achieved by optimizing the plant performance. Optimizing the plant performance, in this context, is understood to include the following:

(a) Optimum maintenance of equipment (including an efficient preventive maintenance system, as far as practicable under existing conditions) to ensure highest plant availability over the year. Computer programs are not enough; it is important that the respective maintenance work is carried out in the foreseen time;

(b) Optimum operation of the equipment to ensure that the plant is permanently operated at highest efficiency. This is particularly valid for the kiln operation;

(c) A production-minded and motivated team of operators that makes an effort to yield extra tonnes and to save production costs.

The achievement of the above points calls for the implementation of a comprehensive and ongoing training programme. Such a programme has been initiated.

## Annex I

## QUARRY SITUATION

### A. Layout

The quarry is exploited between 1,900 and 2,000 m above sea-level. The two primary crushers are also located at that level. The mined limestone is thrown down on three chutes to the corresponding stockpile, from where it is taken by loaders and transported to the Hazemag crusher. A belt conveyor for the crushed limestone and auxiliary buildings are also provided. Figure I shows the reserves of limestone.

### B. Quarry equipment

The quarry is equipped with the following:

- 2 truck drills, ATLAS COPCO;
  one type 301; the second type 601;
  those drills are operated by diesel-motor
  driven compressors, type XA 750;
- 3 pneumatic hand-hammers, ATLAS COPCO, type RH 561
  without compressors.

For transport in the quarry two heavy trucks, CATERPILLAR type 769, with a capacity of 30 t are used.

Furthermore there are available:

- 1 crawler loader, CATERPILLAR type D 9 L
- 1 wheel loader, CATERPILLAR type 988B, shovel 5 $m^3$
- 2 wheel loaders, CATERPILLAR type 966B, shovel 3 $m^3$

A camp has been put up for the 40 operators working in the quarry and there is a medical service, a cafeteria, an automotive workshop and a photographic office.

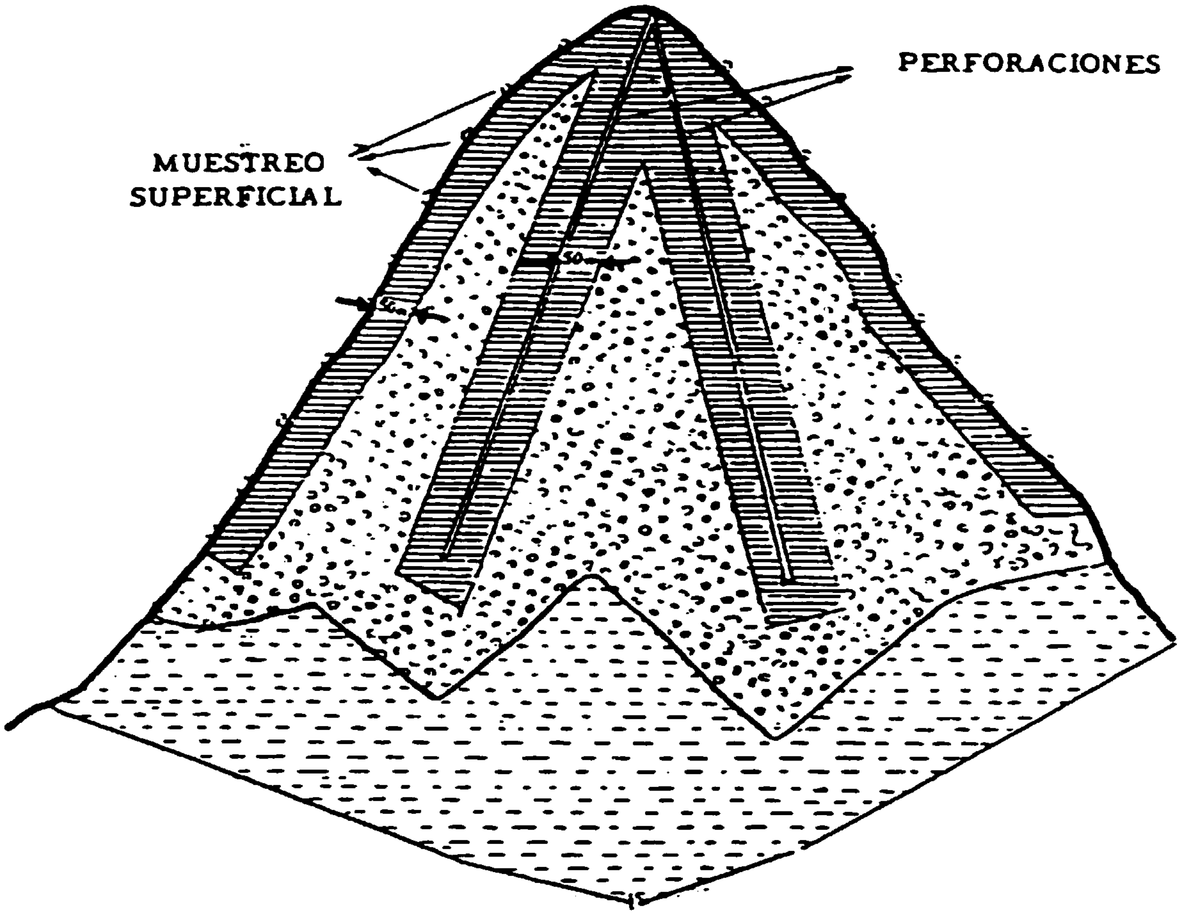
The quarry has its own water supply of 12 $m^3/h$; 80% is used for the camp; purification equipment is available; the other 20% are used for the equipment.

The working hours are 5 days at 8 h, i.e. 40 h/week.

The explosive consumption is rather high with 360 g/t of limestone; no secondary blasting is used. The reason for the high explosive consumption is that the actual exploitation is rather chaotic; the development of exploitation floors is under preparation.

### C. Hazemag impact crusher

The new Hazemag impact crusher will be implemented at a level of 1,620-1,650 m above sea-level. Figure II shows the implementation details.




| | | |
|---|---|---|
| | Reservas Medidas | 28'039.000 Tn. |
| | Reservas indicadas | 61'217.000 Tn. |
| | Reservas inferidas | 86'045.000 Tn. |
| | TOTAL | 175'301.000 Tn. |

**Figure I. Yacimiento de calizas**
**Diagrama de las perforaciones y calculo de reservas**

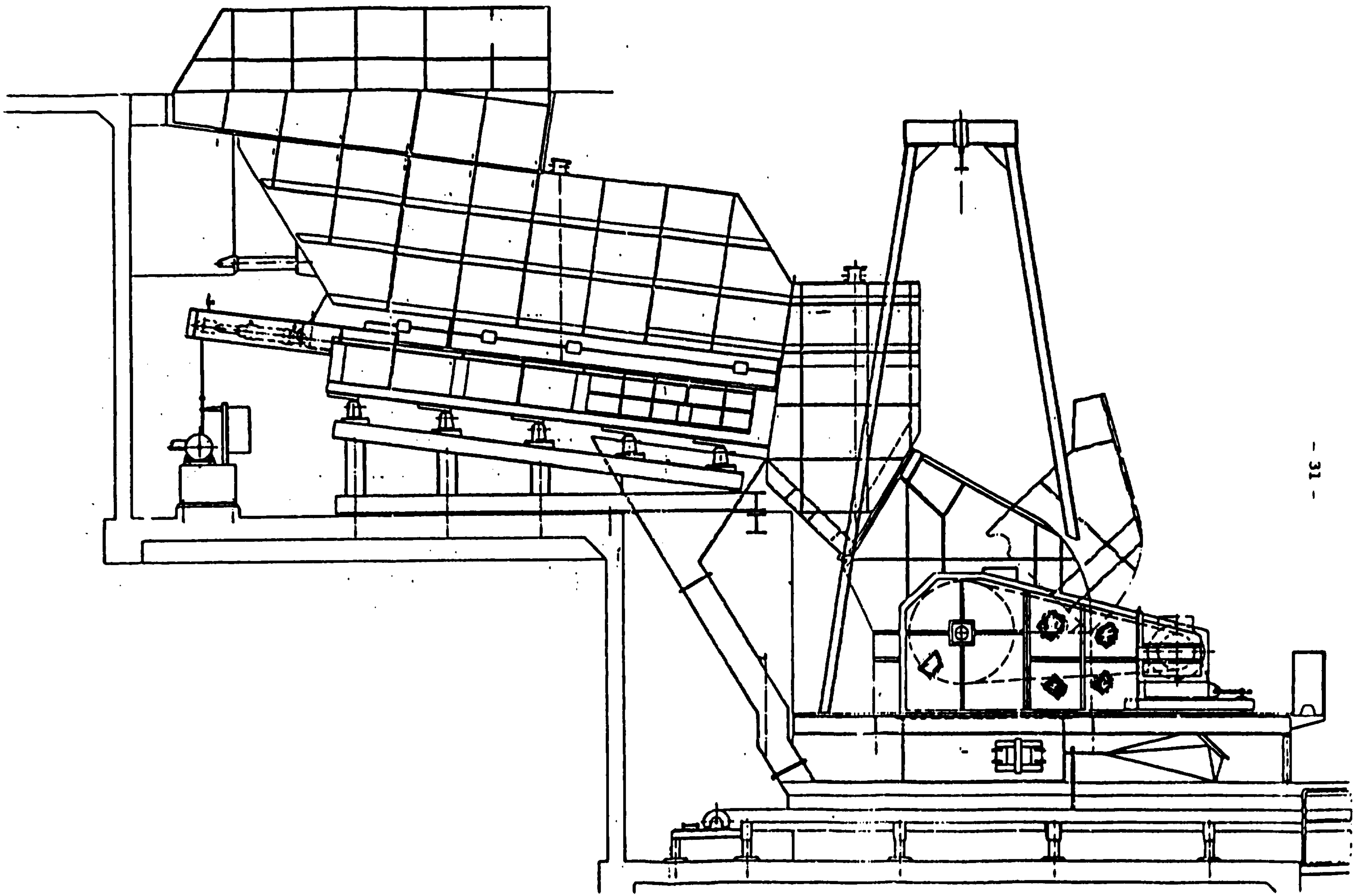


Figure II. Implementation of the Hazemag impact crusher

Annex II

## FACT SHEET OF CEMENT PLANT

### Plant location

The plant is located 7 km west of Otavalo, on the road to Selva Alegre, Province of Imbabura, Ecuador.

### Elevation

2,700 m above sea-level.

### Climate

Tropical, average temperatures: day 21 °C, night 8 °C.
Rainfall: Very little in the dry season. Occasional rainfalls, partly very heavy, in the wet season (January-May).

### Road conditions

Good paved road between the factory and Otavalo (7 km). From the 65 km between the limestone quarry and the factory only 20 km are paved. The road to Quito (140 km) is a good tarred road (Panamericana).

### Railway connections

There is no railway connection.

### Market areas

Provinces of Imbabura, Quito and Esmeralda.

### Distribution terminals

One at Quito, bag storage only.

### Method of cement transport

100% by trucks, of which 85% in bags and 15% in bulk.

### Production capacity

Rated capacity: 1,100 t/d clinker
Actual capacity: 1,100-1,250 t/d clinker

### Type of process

Dry process; kiln with preheater.

### Size of main equipment

Rotary kiln with MIAG-type preheater;
Dia = 4.42 m; L = 63 m; Fuller-type cooler 38 $m^2$; capacity 1,100-1,250 t/d clinker;

Raw mill: roller mill, PFEIFFER type, operating as dryer mill, capacity 90-100 t/h;

Cement mill: 2 chamber ball mill with air separator,
Dia = 3.96 m; L = 11.89 m; capacity 56 (70) t/h.

Staff

Plant: 300; office: 100; total: 400 (including 40 quarry operators)

Quito office: 20

Quito distributing station: 10

Raw material reserves

(a) Limestone: proved reserves 28 million t
probable reserves 61 million t
possible reserves 86 million t
Distance between quarry and factory 65 km by road;

(b) Clay: unlimited, supplied from sites near the plant;

(c) Sand: unlimited, distance 280 km;

(d) Iron ore: unlimited, distance 700 km;

(e) Pozzolana: unlimited, in the surroundings of the plant;

(f) Gypsum: 20 years, distance 850 km.

Raw material mixture

| | |
|---|---|
| $CaCO_3$ | 78.9% |
| Clay | 18.4% |
| Sand | 1.4% |
| Iron ore | 1.3% |

Plant history

| | |
|---|---|
| 1972 | First ideas for a cement factory on the basis of limestone deposits near Selva Alegre |
| 1973 | Order to SNC for planning |
| 1974 | Order for supply to ALLIS-CHALMERS, Canada |
| 1976-1980 | Erection by SADE, Colombia; Civil engineering: SEMAICA, Ecuador |
| 1980 | August start up of the factory. |

## Annex III

## PLANT DESCRIPTION AND OPERATION

### A. General impressions

The factory can produce 350,000 t/a of clinker, i.e. 400,000 t/a of cement by adding 4% gypsum, 5% limestone and 5% pozzolana. In order to reach this result it is necessary that continuous operation is maintained and that stops are reduced to a maximum of 1,000 hours per year.

The production figures of the different production units are not synchronized; the kiln production, for instance, can be increased to 1,500 t/d, in which case the quarry crushers, the raw mill and the fans of the clinker cooler are not sufficient.

The plant is operated from the control room and the control panel. Each of the engineers and operators in production, laboratory, maintenance and engineering is highly qualified; but the expert got the impression that there is a lack of motivation, co-ordination and team spirit, although technical meetings at different levels are held regularly.

The indicators and recorders on the control panel do not show the real values, therefore a system of correction coefficients has been developed.

Many of the installed pieces of equipment do not correspond to the actual technical level and were already obsolete when the plant was planned (e.g. the proportioning scales).

The consulting engineer, Surveyor, Nenninger & Chenevert Inc. (SNC), Montreal, Canada, were not very experienced with cement factories.

### B. Plant layout

Although the plant layout is not optimal, there is nothing which would hamper a smooth operation.

The limestone deposit has a capacity of about 30,000 t, i.e. with the actual production rate there is a stock for 18 days.

The total clay storage capacity in the covered stockyard and in the prehomogenization mixing bed, type BUEHLER-MIAG, is approximately 32,000 t, which means a stock for 100 days of kiln operation. The storage capacity and the operation time for the other components are:

| | | |
|---|---|---|
| Sand | 5,000 t | 200 days |
| Iron ore | 6,000 t | 250 days |
| Gypsum | 4,500 t | 75 days |

Those capacities should be sufficient, even if the long distances for transport are taken into consideration.

One weak point is the belt conveyor for clinker, connecting the clinker storage bay to the cement-mill hopper.

The plant is erected on three different levels. The layout of the plant itself and that of other buildings, such as administration, laboratory, workshop and warehouse, is reasonable. Sufficient space for open-air storage is provided. All storage points in the plant are easily accessible.

The road to Otavalo on the Panamericana is an excellent tarred road. The most important distances are:

| | |
|---|---|
| To Otavalo | 7 km |
| To Ibarra | 30 km |
| To Quito | 140 km |

For the transport of personnel buses are available; the leading crew is equipped with trooper cars.

## C. Maintenance

The company has good maintenance facilities consisting of the following departments:

Mechanical workshop
Automotive repair shop (in the plant)
Automotive and mechanical repair shop (in the quarry)
Sheet-metal shop
Electrical shop
Carpenter shop
Lubricant storage and office
Separated tool storage and distribution
Maintenance office

### Mechanical workshop

That workshop is well equipped. Most of the routine repairs in the plant can be performed effectively, provided that the required spare parts are available. Although the situation has improved during the last year, there is still a good number of spares which should be purchased soon. It is cheaper to invest in spare parts than to stop the plant and purchase the missing parts in a rush.

Fabricated or machined parts can be made in-house when needed for maintenance, modification or improvement of existing equipment.

The mechanical workshop is equipped with the following machine tools:

1 boring machine, horizontal type
3 lathes
2 grinding machines
1 radial drilling machine
1 universal milling machine
1 shaping machine
2 hydraulic presses
1 thread cutter
2 cutting machines
1 rolling machine
1 pipe bender
4 drilling machines
1 saw for metals
1 oxygen cutter
various welding places, electric and by gas

Furthermore, a 10 t travelling crane and a 2 t one-rail crane are available. The mechanical workshop also has a tyre balancing machine.

The shop is clean and well maintained. It is spacious and can handle large pieces of equipment.

For annealing and rectifying work, a heating furnace would be helpful.

Automotive workshop

The automotive workshop has four bays under roof and two in the open air and is provided with service pits and mechanics' tools. It has its own drilling machine, welding equipment and a grinding machine for brake drums. There is also a tyre balancing machine available.

As no travelling crane is available, heavy lifting is done by a mobile crane. The large, heavy equipment is generally repaired or serviced outdoors. A battery-charging station is located in a separate room. In another separate room there is also a stock of lubricants for the automobiles.

In the workshop at the quarry, minor routine maintenance is being performed.

Sheet-metal shop

The sheet-metal shop deals mainly with thin sheet-metal work. Heavy equipment is handled in the large mechanical workshop where the heavy machine tools are located.

Electrical shop

The electrical shop is equipped with the usual tools such as multimeter, tachometer, voltmeter, clamp-on amperemeter, MEGGER, oscilloscope, insulation tester, mV/degC-meter, stroboscope and balancing equipment, Butronik calibrator and various hand tools.

The electrical work includes the inspection and maintenance of electrical equipment, such as power generators, power transmission, motors, transformers, breakers and switches; and the maintenance and calibration of the control system, including weighing scales, instrumentation and communication system.

Because the instrumentation does not show the correct figures, correction coefficients are used to homologize the indicated figures with the reality. A complete check-up of the control panel is therefore necessary, and this work has already started.

Carpenter shop

This shop has facilities to fabricate or repair any carpentry work normally occurring in a cement factory. It is equipped with a band saw, a table saw, a planer and a lathe, as well as with working tables and hand tools.

Lubricant storage area

It is located in front of the administration building. Most of the oil drums are kept in the open air, but there is also a hut for the storage of special products.

Maintenance office

That office is located in the administration building. The different maintenance programmes, which are prepared with the help of a computer, include the following:

(a) An annual programme, which is co-ordinated with the planned production programme and which covers the purchase of the necessary spare parts. Due to financial problems the spare-parts programme had been neglected until 1985 and this is the reason, why essential parts are missing;

(b) Monthly programmes;

(c) Task-force programmes, which are executed when a standstill occurs. In that case the daily work is co-ordinated and adapted to the standstill envisaged;

(d) Programmes for the workshop; all operational instructions are given in printed form;

(e) Inspection programmes for the different departments of the plant. During such inspections, wear and tear is controlled, temperatures, vibrations and noise are measured.

Theoretically the organization is excellent, but there are practical problems such as the lack of spare parts and the under- or overestimation of the real working hours required.

Part of the maintenance office, where a draftsman prepares workshop drawings, is also a documentation centre, which is administered in an excellent manner. All drawings and descriptive notes are available and can be quickly retrieved by means of a card index. There is also a special library and a collection of catalogues of suppliers. In addition to the available documentation, it is recommended to subscribe to Pit and Quarry and Rock Products, as well as to Zement-Kalk-Gips which contains many articles in English.

## D. Warehouse

The warehouse has a good selection of all consumables; but there is still a lack of spare parts for the production equipment, although considerable efforts have been made within the last two years to complete the spare-parts store.

Here too, the management is perfect. There is a catalogue in which all pertinent data are recorded.

The warehouse is clean and in good order and the parts are clearly arranged in racks.

## E. Consumables

### Electric power

There are two sources of power supply:

(a) Empresa Electrica del Norte (EMELNORTE) providing 60% of the required energy; supply 34,000 V; inside 4,160 V;

(b) Diesel generators at the plant, providing 40%; voltage 4,160 V; used for minor motors below 500 hp (480 V) and lights and administration (115 V).

Three diesel-generator sets, type Fuji-Electric, are installed, for 4.0 kW each, operating with Bunker-C fuel oil, the same as used for the kiln. The specific fuel consumption is approximately 200 g/kWh, giving a daily consumption of 5,400 gallons, equivalent to 19,826 kg.

In 1986 the diesel-generator sets produced 15,748,460 kWh, minus their own consumption of 732,000 kWh; they supplied to the factory 15,016,460 kWh.

EMELNORTE supplied 32,430 kWh in 1986
Total consumption 47,446,460 kWh
Cement production 346,126 t/a
Specific power consumption 137 kWh/t of cement

Fuel oil

Two types of fuel oil are used in the factory:

(a) Bunker-C for kiln and power station. Consumption 1986· 885,518 gal = 3,251,504 kg;

(b) Diesel for the automotive park. Consumption 1986: 293,737 gal = 1,111,921 l.

Gasoline is used for cars.

The fuel-oil storage capacity is:

2 tanks of 1,900 $m^3$ each for Bunker-C and
76 $m^3$ for daily consumption.

Furthermore, the following can be stored:

50,000 l diesel and
20,000 l gasoline in the factory; and
20,000 l diesel and
20,000 l gasoline in the quarry.

Bunker-C fuel oil has the following specifications:

$\gamma$ = 0.97 kg/l
H = 9,500 kcal/kg
Working temperature 130 °C

Water

Both, factory and quarry have their own water supply and in both places filters are installed. For the consumption of the personnel, drinking water is made available by the company.

Compressed air

The plant is served by individual compressors, located in the areas where air is required.

There is also a central compressor room, located inside the raw-meal silos with four Gader-Dember screw-type compressors, for a total air volume of 37.4 $m^3$/min at 8 bar.

As this air quantity is obviously insufficient, two new compressors, producing at least 16 $m^3$/min, should be installed.

## F. Packing plant

The packing plant is located next to the two cement silos, each having a capacity of 6,449 t. The silos are fed by a pneumatic conveyor, type Fuller, with a capacity of 105 (120) t/h. Silo selection is manual. Withdrawal from the silos is made by air-slide conveyors feeding a bucket elevator, type Rexnord, having a capacity of 110 (125) t/h. To keep the flow going, the two cement silos are vented from the bottom by means of textile hoses.

From the bucket elevator the cement is distributed either onto the feed hopper of the packing machines or to the bulk dispatch silo. From the feed hopper the two packing machines are fed by rotary valves.

Each of the two four-spout Haver & Boecker packing machines has a guaranteed capacity of 1,000 (1,200) bags/h, but in practice only 900 bags can be achieved. However, as only 800 bags can be loaded on one truck, the real output is only 800 bags/h and machine.

There are three channels provided, two for bagged cement (85%) and one for loose cement (15%). All cement is transported by truck. The bags are loaded by belt conveyors which can be adapted to the trucks to be loaded.

Due to the slow-down system of the bags on the chute some bags break, accounting for a total loss of approximately 1%. Most of it is recuperated.

The bagging and loading system is effectively dedusted.

The paper bags are supplied by Papelera Nacional de Guayaquil.

## G. Cafeteria

The cafeteria, situated in the administration building, is serving lunch to all plant personnel on two shifts, seven days a week. There is also a cafeteria at the quarry site.