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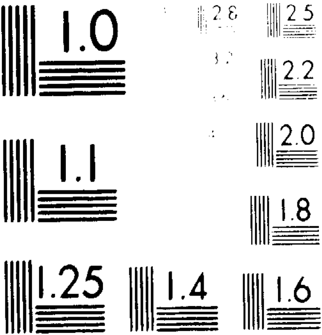

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CEMENT DEVELOPMENT AND RESEARCH CENTRE

DP/TUR/72/034

TURKEY

Technical report: Starting up of the research laboratory for the cement industry. Visits to plants and deposits at Bartin, Iskenderun, Pinarhisar and Elbistan

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

Based on a study by Mr. François Le Bel,
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United Nations Industrial Development Organization
Vienna

80-41065

Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit of Turkey is the Turkish lira (LT). During the period covered by the report, the value of the Turkish lira in relation to the United States dollar was $US 1 = LT 25.

Totals may not add precisely because of rounding.

References to "tons" are to metric tons.

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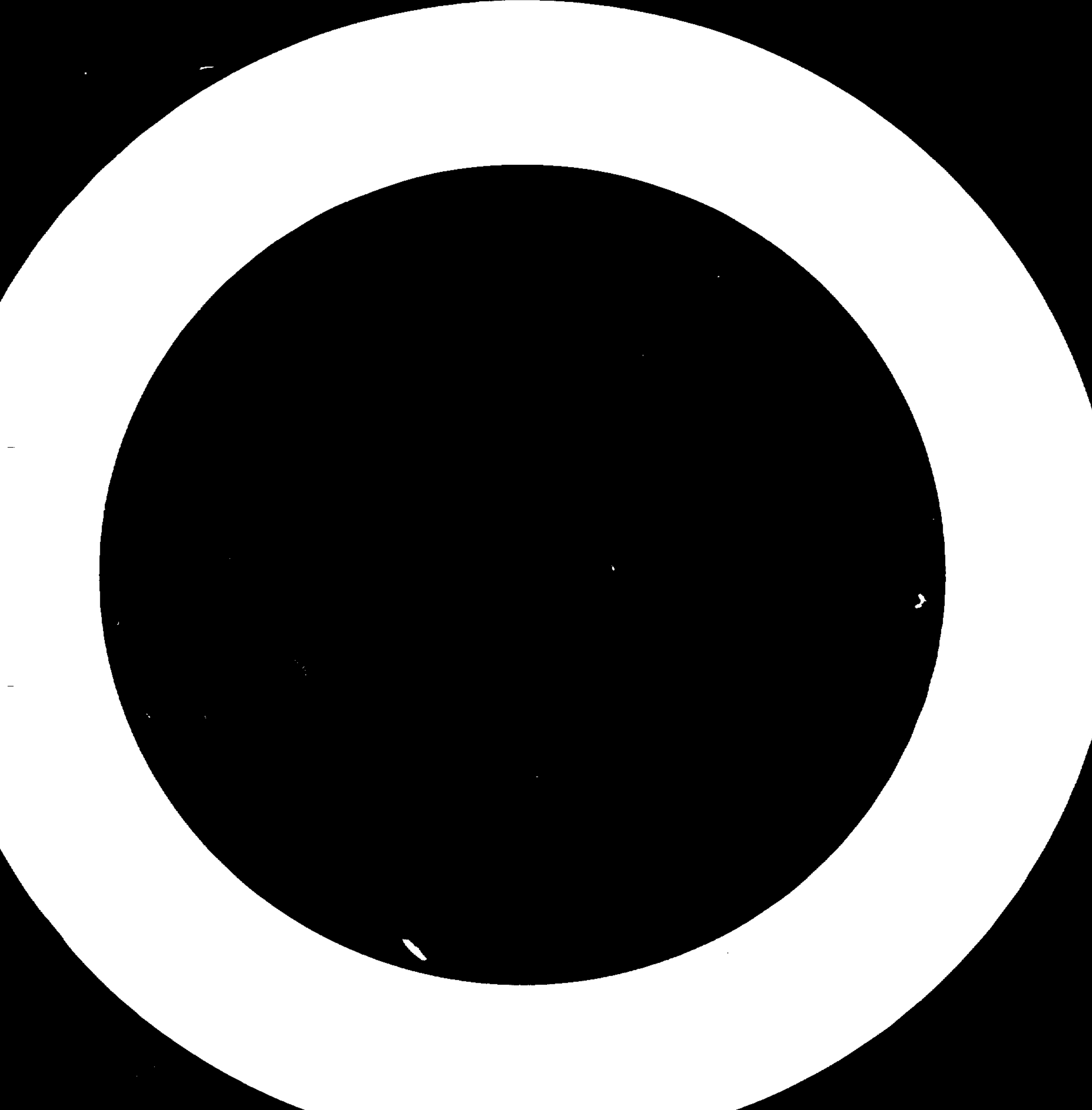
ABSTRACT

A mission to Turkey under project DP/TUR/72/034, "Cement Development and Research Centre", took place from 1 September to 15 October 1978. The mission was concerned with the starting up of the research laboratory for the Turkish cement industry, scheduled to take place during 1979, and especially with the savings of energy and money which might be made in this area through the use of reactive additives which are abundantly available in Turkey.

The expert visited plants at Bartin, Iskenderun and Pinarhisar and the lignite deposit at Elbistan, and submitted recommendations bearing on production, processes, strategy for the use of additives, etc.

The mission concluded with a meeting at Niğde attended by plant managers from the Turkish cement industry.



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INTRODUCTION

A mission to Turkey in connexion with project DP/TUR/72/034, "Cement Development and Research Centre", took place from 1 September to 15 October 1978, the United Nations Industrial Development Organization being the executing agency on behalf of the United Nations Development Programme.

The objectives were:

(a) The starting up of the research laboratory for the Turkish cement industry;

(b) Optimum use of domestic fuels for the firing of cement kilns;

(c) Potential energy savings.

Specific studies were carried out in connexion with a number of different regions of Turkey:

(a) At Bartin, Eregli and Karabük, with suggestions for a strategy for the Black Sea;

(b) At Iskenderun and Adana, with suggestions for a strategy for the Mediterranean coast and (possibly) Cyprus;

(c) At Pinarhisar and in Thrace;

(d) At Elbistan, where consideration was given to exploiting the fly ash from the thermal power station currently being erected.

The expert's visit to Turkey concluded with a meeting held at Nigde attended by most of the general managers and plant managers of the Turkish cement industry, the main theme being the whole range of problems connected with saving energy.

I. OBJECTIVES OF THE PROJECT

A. The research laboratory for the Turkish cement industry

It had been hoped that the research laboratory for the Turkish cement industry would be started up in 1978. In fact it will not become operational until the end of 1979, for a number of reasons:

(a) The civil engineering work will be completed towards the end of 1978;

(b) The installation of the equipment, studies of its operation and its adjustment will take place during 1979;

(c) The staff is largely trained but cannot begin work until the installation is completed.

To start with the simplest task (control of the products manufactured by plants), the laboratory should start operating during the course of the first quarter of 1979; the running-in period will probably take up the whole of 1979.

Recommendations

1. Make sure that the measurements taken are reliable.

2. By checking the measurements made in the central laboratory against those made in the laboratories of the plants, ensure that the measurements made in the latter are reliable.

3. Organize inter-plant control with the help of standard samples defined by the central laboratory.

4. Establish a quality label for the products which comply with official standards.

5. Introduce product quality control sanctions: "marking committee".[1/]

1/ The "marking committee" is constituted by some 15 persons: representatives of the cement industry, cement consumers (firms, administration), research laboratories concerned with cement and concrete. The chairman of this committee is a person of high standing who is familiar with cement problems and the physics and chemistry of cement. The committee pronounces on the results of cement quality control.

B. The Turkish cement industry and energy saving

The Turkish cement industry has not yet found its equilibrium as regards production and consumption, and the country's cement needs are still substantial.

Future investments will have to be examined very selectively, and the use of domestic fuels such as lignite must be given priority consideration. It should be mentioned that the Turkish balance-of-payments deficit is growing worse, so that a measure of this nature should have an influence in the right direction; putting up high-efficiency cement works is not necessarily the best solution, since in general the use of fuel oil, while not absolutely indispensable, is often highly desirable; Turkey possesses considerable deposits of reactive additives such as slag, pozzolana, and fly ash, whose use within reason (a maximum of 30 per cent additive for the moment, except in special cases) would make it possible to increase the country's cement production without large investments. Taking into account the reactivity of the additive products and transport costs, each plant would be in a position to optimize the choice of the deposits that are of interest to it.

Three over-all studies should be carried out by engineers who are competent in the field of cement, and who should be assisted by three good geologists and specialists from the central laboratory. They would call for:

(a) Complete familiarity with plants (raw materials; technology; processes; clinker quality);

(b) Complete familiarity with the reactive additives available in the neighbourhood of the plants (slag; pozzolana; fly ash; active silica);

(c) If these are not available close at hand, an economical distribution strategy should be instituted, involving in some cases the construction of grinding plants separated from the cement plants.

C. Potential energy savings

It is difficult to give an order of magnitude a priori for potential energy savings; it would nevertheless appear to be useful to consider the question - but without any guarantee as to the figures advanced.

Statistics for 1977, rounded, give us:

Cement sales: 13.8 million tons starting from 12.8 million tons of clinker.

If we suppose that 4 per cent gypsum is added to the clinker, we find:

13.5 million tons (clinker + gypsum) produce 13.8 million tons of cement. Additives used (in millions of tons):
13.8 - 13.5 = 0.4, a very low figure.
Average percentage of additives other than gypsum $= \frac{0.4}{12.8} = 3$ per cent, a very low figure.

If we increase this additive from 3 per cent to 30 per cent, which is not inconceivable, the cement tonnage produced would increase from 13.8 to 16.6 million tons, a 2.8 million ton increase in tonnage with no additional expenditure of energy other than that required for drying the additives, which can be estimated at 418 kilojoules (kJ) per ton or product, taking the following values for average energy consumption in the Turkish cement industry:

Kiln heat consumption: 4,180 kJ/ton of clinker

Energy consumed for grinding, per ton of cement: 100 kW

Assuming that the total grinding energy for these products is roughly the same as that required for grinding the clinker,[2/] we find for this additional tonnage a saving of electricity necessary for the production of the clinker amounting to approximately:

60 kW/ton which, converted into joules, is: 630 MJ.

2/ Slag is more difficult to grind than clinker, while pozzolana and fly ash are much easier to grind.

The energy saved thus amounts to 4,830 megajoules (MJ) per ton of additives, or approximately 320,000 tons of heavy fuel oil (1 ton of heavy fuel is equivalent to 42,000 MJ).

Additional savings of energy could be achieved at the plants by means of:

Better functioning of the electric filters;

Better recovery of the sensible heat of the clinkers;

Better mixing of the raw materials.

It can be estimated that we save at least 209 MJ per ton of clinker, that is:

209 x 12.8 million tons of clinker: 2,675 million MJ

65,000 tons of heavy fuel oil

or, altogether, approximately 400,000 tons of heavy fuel oil.

The expert had no time to make a plant-by-plant examination of the quality of the fuels used; but it is in any case certain that a minimum of 50 per cent of lignite can be used with the fuel oil. At Bartin good results are being obtained by mixing 50 per cent lean coal from Zonguldak with 50 per cent lignite.

Studies could be carried out at every plant with a view to limiting the use of fuel oils; only an excessively high sulphur content in certain lignites might be an obstacle to their being used, especially in the case of cyclone preheater kilns such as the Humboldt exchanger of which 36 have already been installed in Turkey; with kilns of this kind, equipped with pre-calcinators, it becomes easier to solve the problem by installing (though this is costly) a suitable by-pass followed by electric dust-removal. The dust recovered is rich in sulphates and can advantageously replace the gypsum required in the cement mill.

This systematic additives policy has another interesting side-effect on investment: 2.8 million tons of pure Portland cement are equivalent to the production of 5 plants of 550,000 tons capacity each. The cost of each plant can be estimated at 1.8 billion Turkish pounds, giving:

5 x 1,800,000,000 = 9,000,000,000 Turkish pounds

whereas the provision of extra drying, grinding and silo installations in the existing plants would only cost a third of the above capital investment, or LT 3 billion.

This additional side-effect thus gives an appreciable saving, namely LT 6 billion.

These figures have only a relative value, but their magnitude shows how urgent it is to carry out these studies.

II. REPORT ON VISITS

A. Bartin plant

The plant is located on the Black Sea, 8 km from the port of Bartin (which can take ships of up to 10,000 tons); it is linked to the port by a serviceable road (trucks up to 25 tons) and a navigable river 3-5 m deep which is currently used by boats of up to 100 tons, but which could be developed for flat-bottomed barges of 500-1,000 tons.

It is an old plant, using the wet process; its maintenance, its management and the quality of its quarry, materials and products are excellent. The outlook for the plant's future appears good in the light of its exceptional situation on the Black Sea and the high quality of the quarry.

The characteristics of the plant are given below:

Original equipment: 1962 - Fives Lille Cail plant (turn-key contract)

Fives Lille Cail Principal equipment	Kiln: Ø 3.40 m. Length: 120 m. Production capacity: 200,000 tons/year (clinker) Additives: 50,000 tons/year of slag from Karabük

Cooler:	Fuller (France)
Cement mill:	1,100 kW
Raw-material grinder:	1,100 kW

Equipment added later: 2 Krupp 700 kW cement mills: these are not on the right scale for the plant: it would have been wiser for the future of this plant to choose a single 1,400 kW mill.

The raw materials come from two quarries:

One main quarry of proportioned marl: in one part the limestone content is between 75 and 77 per cent; elsewhere it is between 73 and 75 per cent. Reserves are unlimited; the percentages of acid products, i.e. SiO_2, Al_2O_3, Fe_2O_3 are constant; the silica is very fine and combined, and the raw materials are therefore highly reactive.

In case of correction, there is a quarry of pure limestone with an average $CaCO_3$ content of 99 per cent at a distance of 2 km from the plant.

See annex I for reference material for the visit to the Bartin plant. Included are analyses of raw materials, proportioned raw material, the coal used (half lignite, half Zonguldak), with upper and lower limits of its calorific value, clinker, and slag. There are also test reports on the mechanical characteristics of cements produced, PC 325 and CC 325, and an article on a slag cement called LEM, which is included for the information it provides on the development of such elements.

The Bartin plant produces two kinds of cement: a Portland cement with no additives other than gypsum - PC 325 - and a Portland cement to which is added 50 per cent Karabük slag - CC 325 - which is of excellent quality for the reasons mentioned above; moreover, the principal additive for the CC 325 is the Karabük slag, which has a high lime content and is highly reactive because of its alumina content and the quality of the granulation - slag quenched very energetically immediately after removal from the blast-furnace (at a distance of 30 m) - performed at high temperature (1,500° C) with a very large excess quantity of water. This slag, whose production is currently limited to 60,000 tons/year, comes from two blast-furnaces with a capacity of 300 tons/day (pig iron). The granulation plant is not yet installed on the largest of the furnaces (900 tons/day of pig iron), which could produce 90,000 tons/year of granulated slag.

In due course, the Karabük steel plant, located 80 km from Bartin, will be able to produce 150,000 tons/year of excellent slag, as is shown by the results obtained at Bartin.

A second steelworks on the Black Sea, 80 km west of Bartin, the Eregli plant, is being extended and will soon reach a production figure of 1 million tons of pig iron per year. This will be a second source of slag; granulation facilities are not yet installed but will be if the Turkish cement industry requests it. A good installation will provide an additional output of 300,000-350,000 tons of slag per year. This slag will be within reach of Bartin (80 km) by boat, which will reduce transport costs.

Bartin and Eregli will thus become two very important poles in the cement strategy for the Black Sea, from the Bosphorus to Trebizond (and even to Istanbul), since slag cements are preferable to Portland cements for off-shore use.

The laboratory experiments carried out at Bartin show that Bartin clinker can easily take an additive of 30-50 per cent of reactive slag, and this will be all the more true if the slag is ground separately.

Recommendations

Along with an over-all slag production (Eregli and Karabük) of 500,000 tons, approximately 1 million tons of clinker must be produced. This could be done at Bartin, for instance, with the installation of a production unit for 800,000 tons of clinker made by the dry process with the aid of a kiln equipped with pre-calcination facilities (daily capacity, 2,500 tons). The grinding installations could be located at Bartin, the Bartin port, Eregli and Karabük, but a very careful study of the market in northern Turkey will be necessary prior to a decision on their location.

The CP 325 at present being produced at Bartin is in fact a CP 400 (fineness, 3,500 Blaine); it would be interesting to mix it adjusting the gypsum content to 75 per cent of dry slag ground separately to increasing degrees of fineness (Blaine: 3,500, 4,000, 4,500, 5,000, 5,500, 6,000) and to determine compressive and tensile strength after 3, 7 and 28 days, after which the results would be compared with those for the present CP 325. This test should make it possible to find out more about the reactivity of Karabük slag (a priori, this seems excellent from its analysis and from the early strength of the CP 325, which is in fact a CP 400), and to know to what degree of fineness it should be ground to obtain the same resistances as a CC 400 and thus achieve maximum savings of energy, without forgetting to measure in each case the energy required for the additional grinding. The same experiments will have to be carried out when Eregli is able to deliver granulated slag.

Another very interesting source of additives is the fly ash from the thermal power stations in the Zonguldak region (Kulu power station); these are vitrecus and very rich in alumina (30 per cent); their activity is thus very high, and experiments carried out with Bartin clinker are revealing in this respect.

Generally speaking, all the Turkish clays are very rich in alumina, which is very advantageous for the cement industry; by analogy, the same will be true for the slag and fly ash, which are gangues of minerals contaminated by these clays or the schists from which they come.

B. Iskenderun plant

The grinding area is in the immediate proximity of the steelworks. The slag from the steelworks and the clinker from the Adana cement works are delivered to it. See annex II for reference material on this visit: a Rankin diagram, analyses, and strength curves of mortars made with slag cement.

Slag from the Iskenderun steelworks	Pig	Slag
	(in thousands	of tons)
One furnace operating	1 000	350
Two furnaces operating, within 1 year	2 000	700
Three furnaces operating, within 3 years	3 000	1 050

This very modern steelworks is situated on the sea, with a deep-water approach; iron ore can be delivered by sea from abroad, or by rail from the Sivas region.

The slag is granulated by the Soviet method; it is not completely quenched so that its remaining sensible heat evaporates the quenching water (i.e. not more than 3 m^3 of water is used per ton of slag).

Though the water supply to the granulating plant is constant, the tipping of the slag into the channel where the water circulates at high speed is not constant; this operation is carried out manually with no possibility of real control; since the quality of the quench is very variable, the quality of the slag is also, and this is detrimental to the operation of the grinding plant and therefore to the quality of the CP 325 manufactured.

Now it is very important for the plant that the quality of the slag should be uniform if not perfect; to achieve this, the following three recommendations are made:

Recommendations

The distance to be covered by the crucibles of slag coming from the blast-furnaces should be shortened to avoid cooling, which can affect quality; at present this distance is 4 km, but it will be reduced to 1 km when the two new blast-furnaces are working.

The quantity of quenching water should be increased so that this operation can take place more rapidly; this is essential to avoid the crystallization of a part of the slag and to obtain the maximum of glass (reactive part).

The quality of the slag produced must be made uniform by stocking it in a prehomogenization vat which could be located in the cement works behind the present storage shop, which is not very suitable for this operation.

Development of the cement plant

At the present time, the cement plant contains:

An uncovered slag heap, supplied by lorries (direct tipping), and therefore very small; this slag can be removed by a transporter crane feeding the hoppers of the (Humboldt) slag drier and those of the open-circuit cement mill (Schmidt - 1,600 kW).

The dried slag is stored in a silo which feeds the Schmidt mill; the clinker feeding the mill is supplied by the Adana plant, whose clinker production capacity is 1.5 million tons/year.

The quality of the equipment chosen is excellent, except that the electric dust-separation plant in the slag drier should have been preceded by cyclones which would have relieved the load of the electric dust-separator and improved its operation, which leaves something to be desired.

The quality of the cement is very variable because of the variable quality of the slag.

Analysis of the slag and the Adana clinker gives the following results:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Ignition loss
Clinker (Adana)	21.16	6.32	3.08	64.86	1.71	1.02	1.47
Slag (Iskenderun)	34.5	16.40	0.7	32.7	11.57		

The figures for slag are the following:

$$\frac{CaO + MgO + Al_2O_3}{SiO_2} = \frac{32.7 + 11.57 + 16.40}{34.5} = 1.75$$

These are excellent figures for a slag, provided that the quenching is energetic, i.e. that the proportion of glass is very high, which will be ascertained from laboratory studies now being carried out (e.g. diffraction of X-rays).

The CP 325 manufactured corresponds to the following mix, ground to a fineness of 3,500 Blaine:

	%
Slag	40
Clinker	57
Gypsum	3

The strength values are as follows:

3 days	7 days	28 days
160 - 190	200 - 280	310 - 400

whereas the objective sought by the customers is:

200	300	> 400

In view of the spread in early strength in particular (three days and seven days), it is not possible to satisfy customers' requirements.

If this slag is to be put to good use it is imperative that the three recommendations set out above should be implemented. It should be noted that, with the clinker and the slag being ground together, the slag is not being used to maximum advantage, because the slag is more difficult to grind than the clinker and the criterion of fineness of the mix does not ensure that the full potential of the slag is put to use; in view of the structure of this plant we are faced with a clear case for grinding the clinker and gypsum on one side and the slag on the other, and mixing them pneumatically or mechanically afterwards.

It is the expert's opinion that the customers' requirements would be very easily satisfied by a mixture of 55 per cent CP 325 (3,000 Blaine) and 45 per cent Iskenderun slag (4,000 Blaine).

This change in the manufacturing method could take place at the time of the proposed production increase, with the installation of a second mill equipped with a separator for grinding the slag alone, the present mill being used to manufacture CP 325 with Adana clinker; a group of 2 or 3 silos (whose capacity will depend on the production cycle of the mills) would stock the ground slag and the CP 325: an Eyrich mixer. for example, could provide adequate mixing after that, the mixture being then pumped to the delivery silos.

On the basis of these hypotheses a rapid calculation leads to the following conclusions:

The 1,600 kW mill could manufacture CP 325 (35 kW/t) (3,000 Blaine)

Mill output: $\frac{1,600}{35} = 45$ t/h 7,500 h/yr 45 x 7,500 = 340,000 t/yr

A 1,600 kW mill in closed circuit could grind the slag to 4,000 Blaine (50 kWh/t).

Mill output: $\frac{1,600}{50} \times \frac{130}{100} = 42$ t/h

7,500 h/yr 42 x 7,500 = 340,000 t/yr

Assuming the slag has been dried the outputs of ground slag and CP 325 are balanced.

Total production from Iskenderun in this case: 680,000 tons of CC 400.

Any other hypothesis may be examined, such as one involving greater use of slag and the manufacture of CC with the following characteristics:

30% CP 325 (3,000 Blaine)

70% slag (6,000 Blaine)

with the same quantity of Adana clinker, i.e. approximately: 330,000 tons.

One could manufacture 1 million tons of another CC 400 using nearly 800,000 tons of slag, or almost the entire Iskenderun slag output, provided it can be dried and ground; with a second slag drier this would present no problems; for the grinding it would be necessary to install a grinding capacity for slag alone of some 12,000 kW, i.e. three 3,300 kW mills with separators. Adjusting these is a delicate task, and the installation is very important.

At the present time the first solution is to be recommended.

How is the best use to be made of the Iskenderun production capacity of 700,000 tons in one case and 1,100,000 tons in the other case?

The sector to be covered by this plant is in principle restricted to the territory between the sea and the Syrian frontier, going towards Lahramaumaras, since the Adana plant is approximately at the same distance from that town; the Iskenderun tonnage will therefore substantially exceed the market.

Because of its deep-water location (steel plant port), the Iskenderun plant can export cement without high loading costs. This situation which is so favourable for export may also be useful in the supply of a large part of the Turkish market in an area which is developing rapidly, that is to say the Mediterranean coast from Antalya to Silifke, a tourist region where no cement plant is allowed to be erected but where good ports exist (Antalya, Alania, Silifke). Setting up unobtrusive silos on the wharves of these ports would make it possible to provide the coast with a regular supply by using 5,000-ton ships, for instance, to bring the Iskenderun cement to the silos; this solution has already been tried in the French West Indies, Canada (British Columbia), Greece and Norway, and should prove economic.

C. Pinarhisar plant

			Clinker	
Two furnaces	)	One wet line - 3 m x 90 m	100,000 t/yr	300 t/d
	)	35 per cent water - 6270 J/t of clinker (without electric dust separation)		
	)	One dry line (Humboldt) - 3.50 m -	280,000 t/yr	850 t/d
	)	4,180 J/t of clinker (electric dust-separation working badly)		

Raw materials

Limestone:

(a) An excellent quarry of pure limestone located near the plant;

(b) 3-4 km away there is another quarry of exceptional quality - pure limestone of astonishing whiteness ($CaCO_3$ = 100%).

Clay:

(a) For the wet line: very poor quarry; chosen because it permits reduction of the water content of the mix, and thereby of the calory consumption of the furnace; but it contains a large quantity of quartz. Its use is thus prejudicial for the continuous working of the furnace (dust, reduced life of the refractories in the burning zone, quality of clinker, etc.). It is recommended that the use of this clay material should be discontinued and that it should be replaced by the material used for the dry-line furnace (see below).

(b) For the dry line: there is an excellent quarry (1 km away) providing shale of very regular quality and free of quartz.

Recommendations

In view of the situation of this plant in Thrace, it should be competitive throughout the market represented by this province; it would therefore undoubtedly be more profitable to increase its production than to build other cement plants in the area, be it at Edirne, next to the frontier, or Sartroy next to the Sea of Marmara.

If it should prove impossible for other than technical reasons - political, for instance - to avoid erecting the latter two plants, they should in a first stage be limited to workshops for grinding the clinker (from Pinarhisar). This operation could prove very profitable if additive materials could be found locally, such as trass or fly ash (30 per cent additives). The clinker investment would be limited to the pre-calcining plant for the Pinarhisar Humboldt furnace. The quality and size of the quarries at this plant would make it easy to increase production from this line no matter what the production required, especially as the production can be diversified.

To diversify production, it is recommended that:

The quality of the white cement should be improved, as it could be excellent in view of the high quality of the limestone and kaolin (installation of a Lafarge cooler operating in a reducing atmosphere on the wet-line furnace used for this operation).

In view of the quality of the pure limestone, high-quality lime should be manufactured to supply the chemical industry.

A plant should be installed for supplying very pure limestone, very finely ground, to two important industries - paper and paints - and in general to all industries requiring very pure mineral supplies.

Ready-to-use white cement mortars should be prepared, of the kind generally known as "Premix":

	Percentage
Slaked white lime	10
White cement	20
White limestone sand of continuous grading for mortar (prepared from the pure limestone quarry)	70

all of this dried, mixed and bagged; this product is very useful for making high-quality white coatings.

D. Thermal power station and lignite deposit at Elbistan

The expert visited Alsin-Elbistan to obtain as much information as possible on how this project was progressing and on the operating conditions of the lignite deposit, on which depends the quality of the ash obtained; for the time being no one is interested, in spite of a suggestion made by the consulting engineers whose representative the expert met in Turkey. Some ideas were put forward in the basic report drawn up by that firm. (A list of persons with whom discussions were held is given in annex III.) The conclusion is not very optimistic; nevertheless, the proposals contained in the report DP/ID/SER.A/81 dated 18 January 1977 should be worked out in more detail as this project develops; it has fallen behind schedule and the first 340 MW unit will probably not be started up until 1982 instead of 1980. It must be said that this work site is enormous both in area and in terms of the size of the equipment installed and that, furthermore, it is far away from everything and necessitates planned operations employing nearly 7,000 people, most of them unskilled.

Open-cast working of the lignite mine is due to begin shortly. The removal of the top cover down to 80 m has been started. The expert went down a mineshaft to take samples of lignite and inert materials between the lignite beds; these will be examined at Ankara by the Cement Research Centre and in Paris by the Study and Research Centre for the Hydraulic Binder Industry.

The precise method for exploiting the usable part - 30 m thick on the average - has not yet been established and will probably vary over a period of time, meaning that the whole lignite seam will not be mined permanently over its entire height; the chemical composition of the ash from the power station will therefore vary over time; problems of storage and homogenization will consequently arise, but these can only be examined after a detailed operational plan is available, which is unlikely before the first unit has been started up and run in in 1982. We will therefore have to wait, especially as the SO_3 content of the core samples is very high (of the order of 14 per cent) and no one can say what proportion of the SO_3 will go up the chimney or how much will remain in the ash and affect its utilization. In any event, the ash will be of interest to the cement industry, but the choice of possible uses will have to be left until later.

SiO_2	Fe_2O_3	MgO	SO_3	P_2O_5	$Al_2O_3 + TiO_2$	CaO
23.18	4.26	2.15	13.76	0.48	9.56	47.70

$Na_2O + K_2O$	MnO
0.46	0.18

This presupposes that all the sulphur from the coal remains in the ash in the form of SO_3. In theory a good part of the SO_3 will go up the chimney, but experience alone will tell us the proportion; it will therefore be necessary to wait until 1982 or 1983. This being the case, if we exclude this SO_3, the ash in its average composition can be regarded as a raw material with the right proportions for use by cement works, and if the temperature of 900° planned for the lignite flame allows decarbonation of $CaCO_3$ in the ash, the latter, after the grinding and hydrating of the lime, will be hydraulic. Its quality could be improved by adding pozzolana or very finely ground slag (cf. the use in cement works of lime-rich fly ash from the thermal power station at Gardanne near Marseilles, France.)

Utilization of power station ash

The ash of lignite-fired steam- or heat-generating plants can be utilized for the following purposes depending on its chemical composition, which varies widely:

Hydraulic adhesive cement

Building materials (gutter-stones, aero-concrete)

Road construction (filling and compaction material)

Fertilizer

Miscellaneous (sand-blast material)

The utilization of ash is also tightly connected with the market and cost situation for civil construction materials. Many projects for utilization of lignite ash have had to be discontinued for economic reasons.

For Elbistan lignite, only that from borehole 806 has been analysed, and the composition of the fly ash has not finally been determined. The compositions of the lignite and its ash are of course related to each other and that of the fly ash depends on the behaviour of the combustion systems of the boilers. Therefore it is impossible at this time to give precise suggestions for utilization of Elbistan lignite ash, and the following comments are limited to the kinds of utilization that seem possible based on the available ash analyses, which yield the following data:

	Percentage	
	Range	Average
SiO_2	7.0-56.0	29.6
$Fe_2O_3 + Al_2O_3$	3.4-44.9	17.4
CaO	6.2-78.2	30.8
MgO	0.0-3.9	2.8
SO_3	3.8-22.4	14.3

If this composition is representative, there is almost no possibility to use Elbistan lignite ash for hydraulic adhesive cement because it will not meet the specifications of Turkish standards TS 639 and 640.

The utilization of fly ash as fertilizer is feasible only when it has a CaO content of more than 45 per cent and very little SO_3. As these conditions are met by only very few of the samples, it is not probable that Elbistan lignite ash can be used as fertilizer.

The utilization of this fly ash for the other purposes listed is not commercially important.

To use lignite ash for civil construction materials such as gutter-stones or aero-concrete, it must have the following composition:

	Percentage
SiO_2	27-58
CaO	22-48
free CaO	up to 10
$Fe_2O_3 + Al_2O_3$	6-17
MgO	6
SO_3	up to 14
C	up to 5

The figures show that Elbistan lignite can be used economically for aero-concrete only if it is supplemented with SiO_2 and CaO. Additionally, the compressive strength of the operational Elbistan fly ash has to be determined experimentally to see whether the Turkish standards can be met. In any case, it would be necessary to blend the ash and closely monitor its composition. In these circumstances, it is useless to consider the economic aspects of the market situation for construction materials in Turkey until after the exact long-term composition of the lignite ash is known.

The use of Elbistan lignite ash as a supplement to asphalt for road filling should be possible. For soil compaction, it may be used only within certain limits imposed by its composition and grain size distribution, which have yet to be determined.

To summarize: It is necessary to obtain data on the operational ash over a long period to decide how best to utilize the ash. For the time being, there is not enough information; for example, the SO_3 content in the ash is very uncertain because it is unknown how much sulphur is retained in the furnace hopper ash. Therefore, all statements regarding the utilization of Elbistan lignite ash must be preliminary, but it can be said that Elbistan ash can be used, within certain limits, as road-filling material and, with supplements of SiO_2 and CaO, in aero-concrete. The economics of utilization will depend on the market price of construction materials.

III. CONCLUSIONS

The participants met at Nigde (see annex IV) in order to study the conclusions of this further visit to Turkey, some of which have already been set out in this report, but without mentioning certain conclusions of a fundamental nature on which a Turkish policy of energy saving must be based:

Additives

1. Average analyses of clinkers, slags, pozzolanas, fly ash.

2. Explanation of the technical reasons for their mineralogical compositions or textures, which affect their activity.

Reactivity of glass due to:

The anarchic presence of free SiO_4 ions;
The alumina content;
The presence of hydraulic products in the slag;

Position of Bartin and Iskenderun clinkers among other clinkers;
Position of Karabük and Iskenderun slags among slags;
The Kulu fly ash and fly ash in general.

3. The position of these products in the Rankin diagram (annex II).

4. The reason for the particularly high reactivity of the Karabük slag and the Kulu ash.

Their exceptional alumina content makes it possible to add them to clinker in a higher-than-normal proportion without reducing early strength (three days); the latter is maintained at a high level by the rapid hydration of calcium trisulpho-aluminate.

The free silica combines more slowly with the hydration lime of the clinker part.

The reactivity is improved by separate grinding of the clinker and additives.

In Turkey the use of additives will go through several stages:

Increasing from 5 to 20 per cent additives on average;
From 20 to 50 per cent;

In certain cases (high reactivity), going as far as 70 per cent, thereby effecting savings of both energy and money.

With 30 per cent additives:

Energy saving - 400,000 tons of heavy fuel oil
Saving of money - LT 6 billion

<u>Strategy for the maximum use of local fuels and, in particular, lignite</u>

Attention has to be given to the percentage of SO_3 because of its effect on the choice of processes (use of the suspension preheater process requires careful thought).

The Bartin-Iskenderun-Pinarhisar-Elbistan (Alsin) plants show particular features.

This strategy implies team work between members of the following departments: Research - Laboratory - Planning - Works Management - Finance.

It is high time to develop a small engineering team (three or four young engineers) to avoid having to depend on equipment manufacturers and to allow the best choice to be made in the context of studies on the following:

Location: markets, raw materials, fuels, additives; plant siting, production capacity;

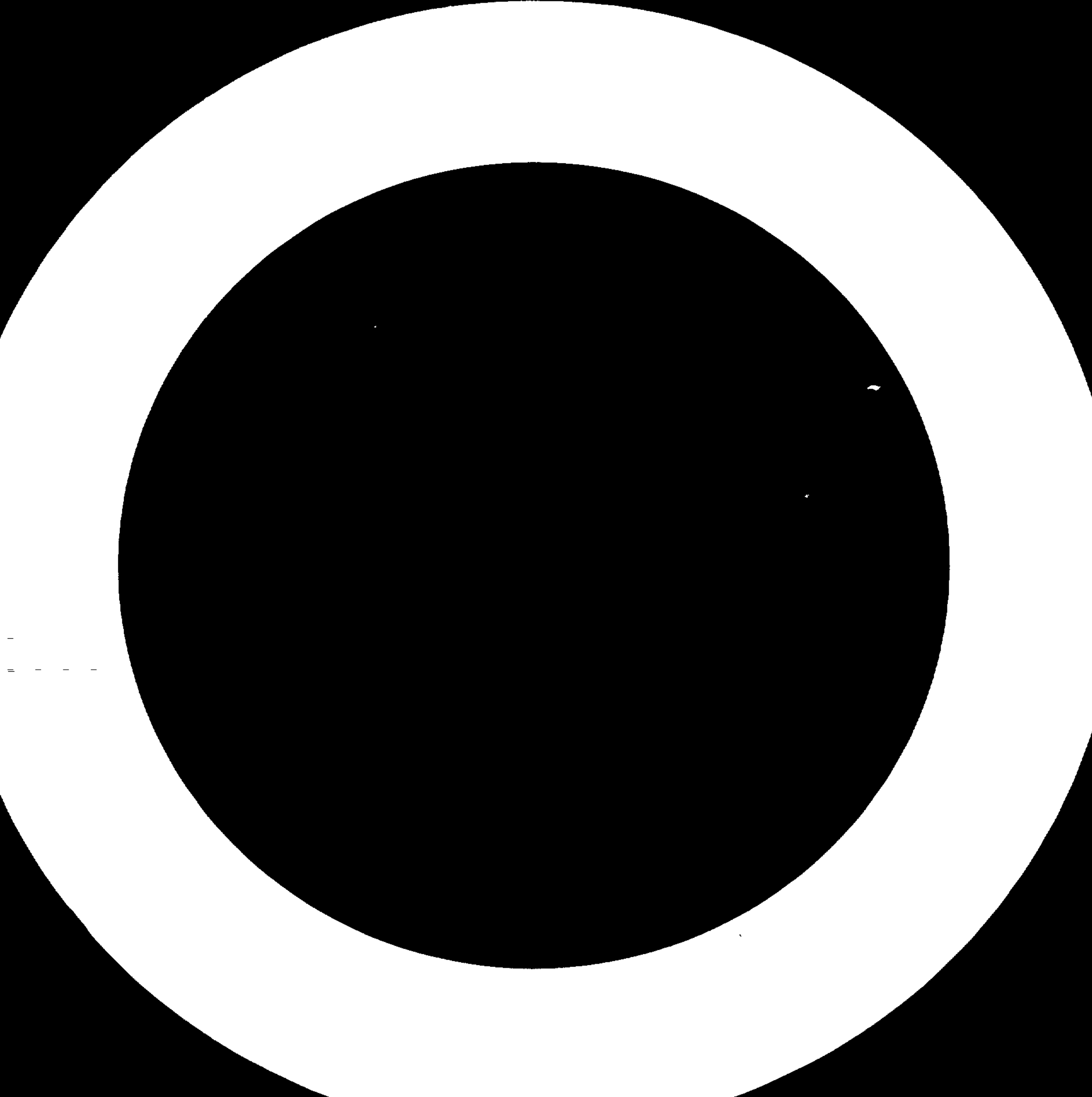
Calculation of the optimum raw mix: clinker formation tests;

Choice of process;

Consultations;

Choice of manufacturers, etc.

It may be noted that the central laboratory plays a fundamental role in these studies; it should therefore be managed by someone who is very conscious of cement problems, whose diverse nature is well known.



Annex I

LEM SLAG CEMENT

General observations

The Sociétě Thionvilloise de Ciments et la Société des Ciments Portland de Lorraine, both located in the Lorraine steel-making basin, have for more than half a century devoted their main efforts to improving the use made of granulated blast-furnace slag in cement production.

When the ground slag is activated by a base (the lime derived from a clinker, for instance) in well-defined proportions, the mix becomes a hydraulic binder with very useful characteristics.

After Electricité de France (EDF), cement producers are the country's largest consumer of fossil fuels. In the world economic context, the authorities are bound to encourage cement producers to reduce their consumption of energy and, for example, to make as much use as possible of a national product such as granulated slag, the making of which requires no energy.

In view of this situation a team of researchers from our companies was charged with finding a cement with a high slag content which, apart from its other well-known qualities, would in addition possess those of an artificial Portland cement.

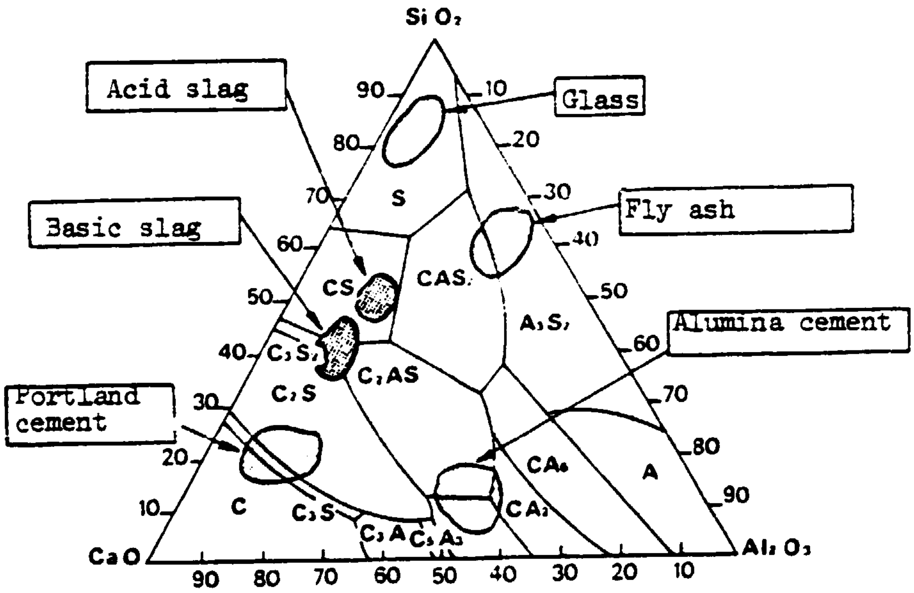
Their research has resulted in perfecting a new slag cement which satisfies the above criteria. It is the "Maximum Energy" Binder, giving maximum energy for minimal energy consumption: LEM.

Balance-sheet of advantages and shortcomings of conventional slag cement

The data contained in this summary come from a lengthy inquiry among users of various types of cement: contractors, laboratories, concrete makers, etc.

Advantages

Basic Lorraine slag is extremely reactive and possesses a high lime content of the order of 44 to 45 per cent (see the Rankin diagram below); the content of artificial Portland cements is approximately 63 to 64 per cent.



In a cement of high slag content there is no trace, after the hydration reactions, of portlandite, $Ca(OH)_2$, dissolved by pure water, nor of tricalcium aluminate (C3A), attacked by aggressive water. Consequently slag cements show good resistance to:

Pure water: pure water tends to dissolve the lime in conventional artificial cement, which may lead to deterioration of the concretes with time;

Sulphates: selenitic water, sea water;

Chlorides: sea water, anti-ice salt, saliferous and potassic soils;

Waste water: drain water, fermentable liquids;

It is also well-known that slag cements offer:

Excellent performance under conditions of humidity and thermo-activation;

Very good long-term mechanical performance;

Low heat of hydration;

Good resistance to frost.

Cements with a high slag content are recommended for massive work and the tr'atment of road beds.

Shortcomings

Compared with artificial Portlands, traditional high-slag cements are criticized for such shortcomings as:

Low initial resistance,

Sensitivity to desiccation and cold,

Reduced workability of the concrete,

which in certain cases limit their uses.

A thorough study of these shortcomings has shown that they are due not to the components of the cement but to the method of treatment. In the usual process of manufacture by simultaneous grinding, the slag, a product with different characteristics from clinker, is treated in the same way as the latter. The clinker is too finely ground, which causes certain defects to appear, whereas the slag, which is harder to grind, is not broken up enough for all its qualities to be utilized to advantage.

Characteristics and performance

In terms of standard NF P 15.301 registered on 12 August 1976, LEM comes under category CLK 450 R. It also satisfies the German DIN 1164 standard, in class 45 F NW - HS - NA.

Patent application No. 77.31 345 has been submitted for LEM.

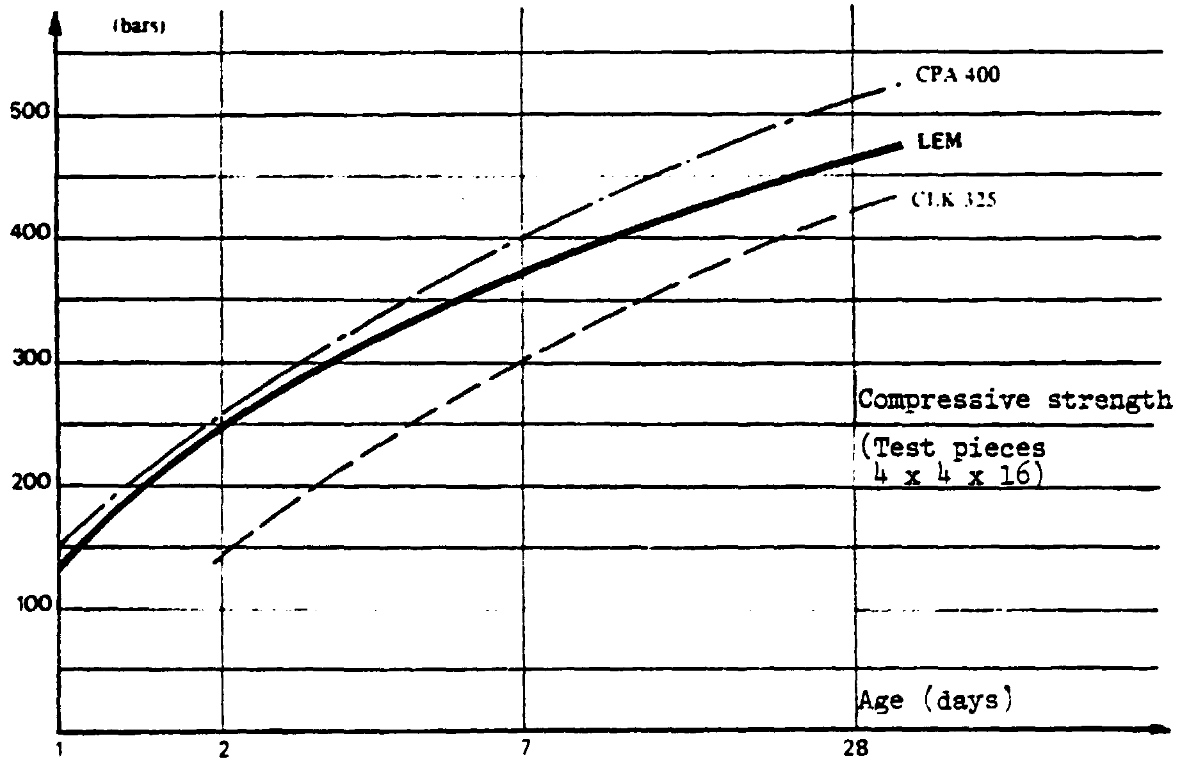
LEM's remarkable attributes come from the slag's having been broken down well, owing to its separate milling. The slag, made highly reactive by this treatment, is mixed with a low quantity of clinker.

LEM offers the following characteristics:

(1) Mechanical tests

Compression

The following graph shows the results of tests on normalized mortar:

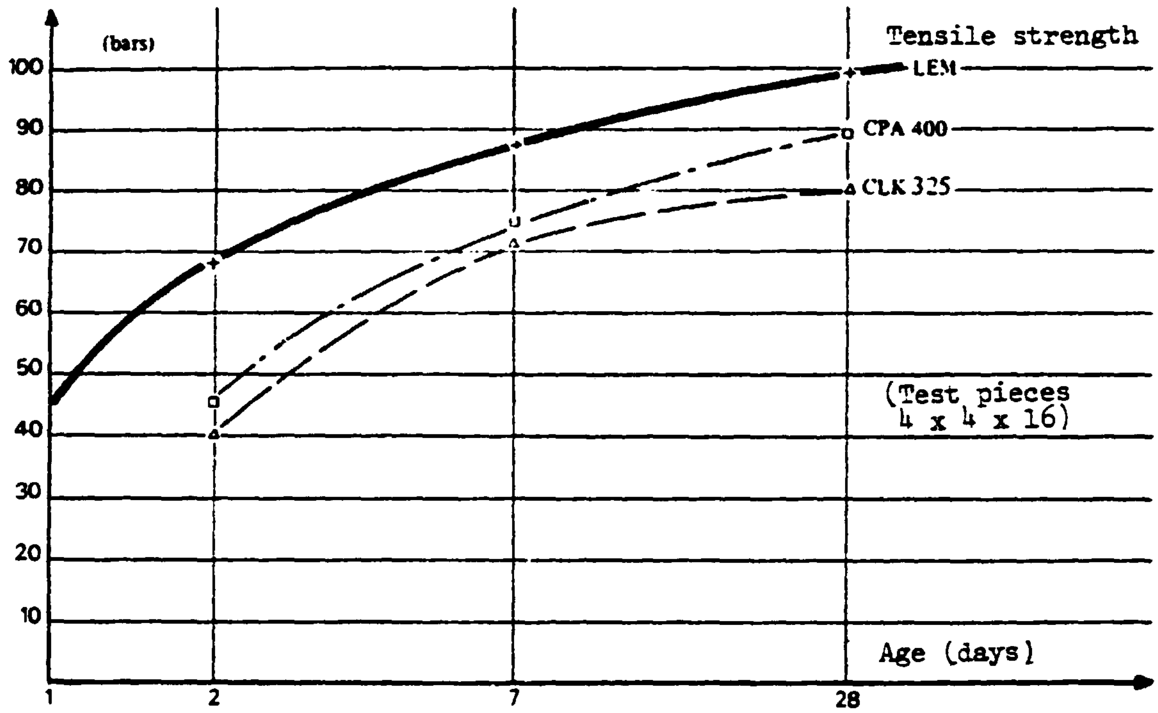


After shorter periods the performances of LEM are on a par with those of CPA 400.

In accordance with the objective sought, LEM already satisfies the requirements of the new standards at 28 days, which explains the gap between it and the CPA 400 at that interval.

Tensile strength

The following graph shows the results of tests on normalized mortar:



The tensile and bending performances of LEM are remarkable.

Setting time

Measuring was carried out with pure mix, using an automatic setting tester, CERILH type:

Start of setting: 3 h.

End of setting: 6 h.

(2) Sweating and desiccation

The extra fineness of the slag in LEM makes it possible drastically to reduce the capillary network, and therefore porosity, a cause of desiccation. The following are the results of sweating measurements, expressed in litres of water per 100 kg of cement:

CLK 325 : 3.60 litres/100 kg
CPA 400 : 2.70 litres/100 kg
LEM : 0.70 litres/100 kg

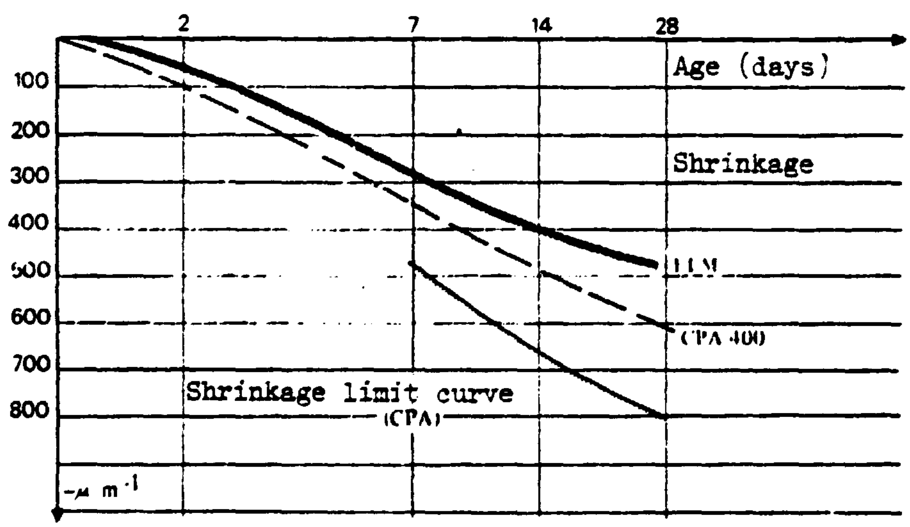
Observations on concrete confirm the measurements made on mortar.

(3) Shrinkage and distension

Shrinkage

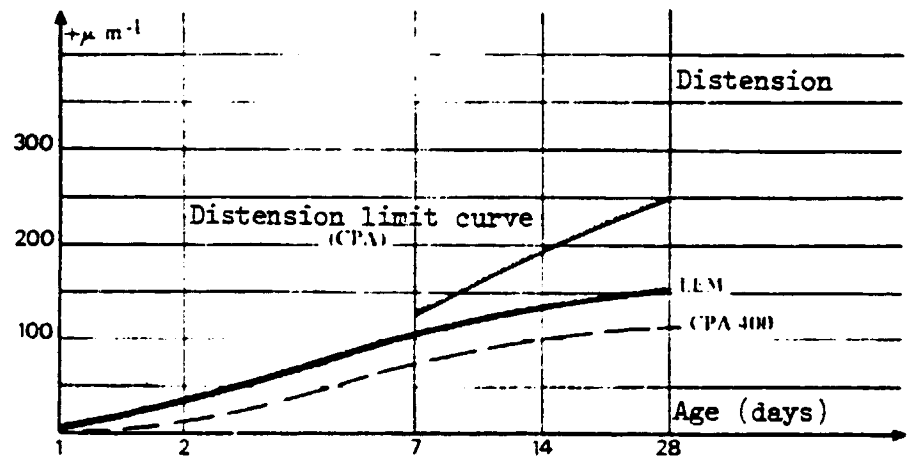
Hydraulic shrinkage of LEM is remarkably low, of the order of 500 μ/m at 28 days. See graph below.

This finding calls in question the opinion, wide-spread in the cement literature, that "shrinkage increases with the quantity of fine elements".



Distension

The measurements of distension carried out on LEM (see graph below) show a very good level, the values being well below the limits fixed by the SNCF standards or recommended by new standards for certain cases.



Ring fissuring

The times measured for fissuring substantially exceed 15 hours and thus conform to SNCF specifications.

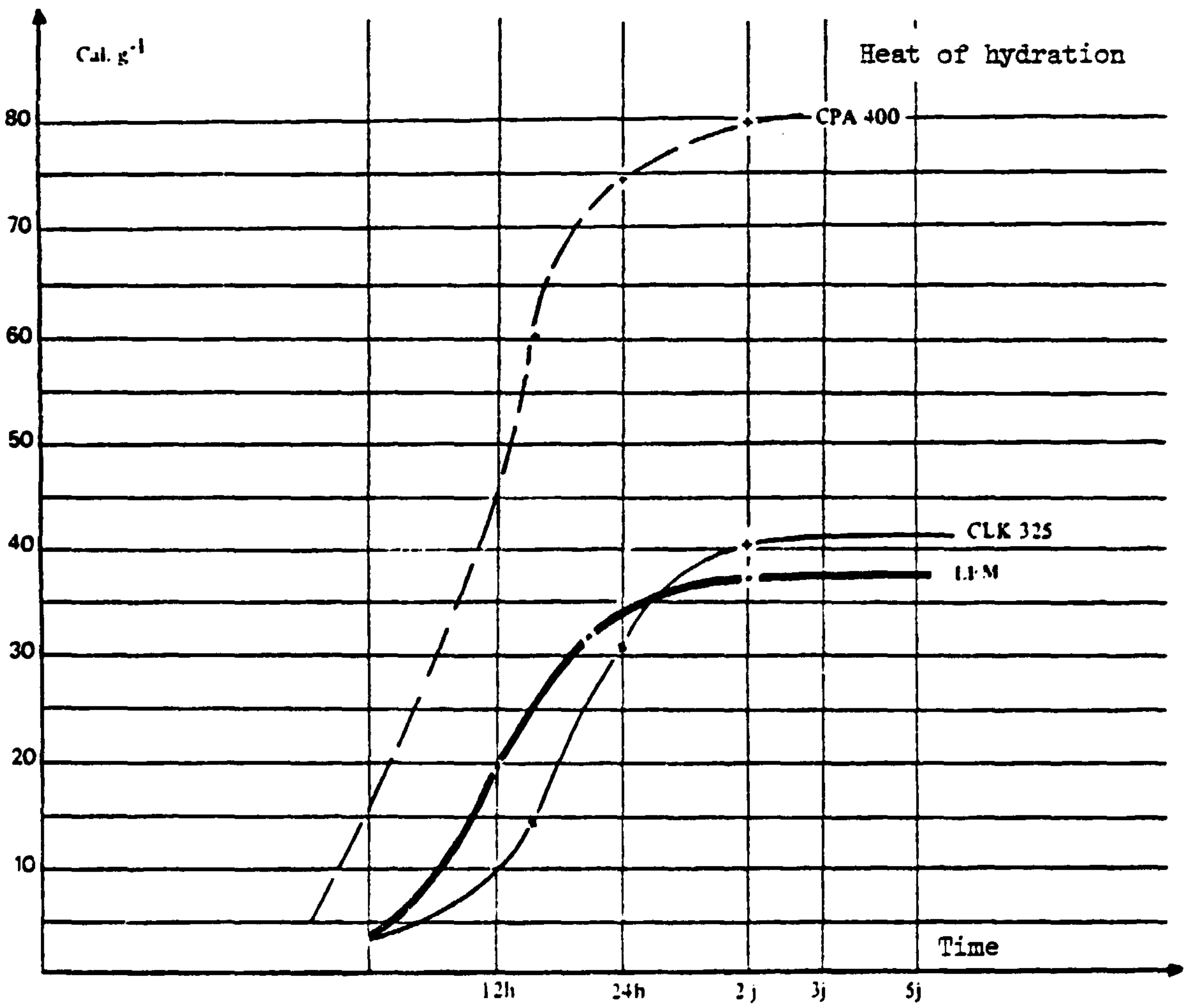
Sensitivity to cold

This notion is linked to the heat of hydration of the cement. The hydration reaction is exothermic and itself depends on the degree of break-up of the material.

Hydration heat

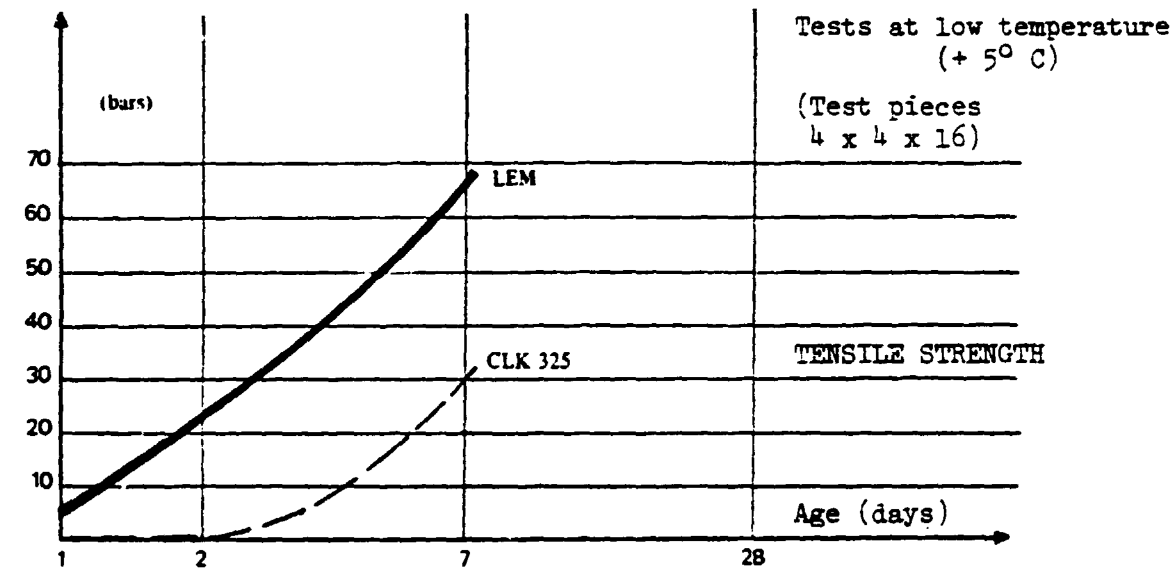
The hydration heat of LEM is close to that of a conventional CLK: like CLK it is thus excellently suited to massive work. On the other hand, this heat of hydration is released much more rapidly, which improves the resistance of LEM at low temperature.

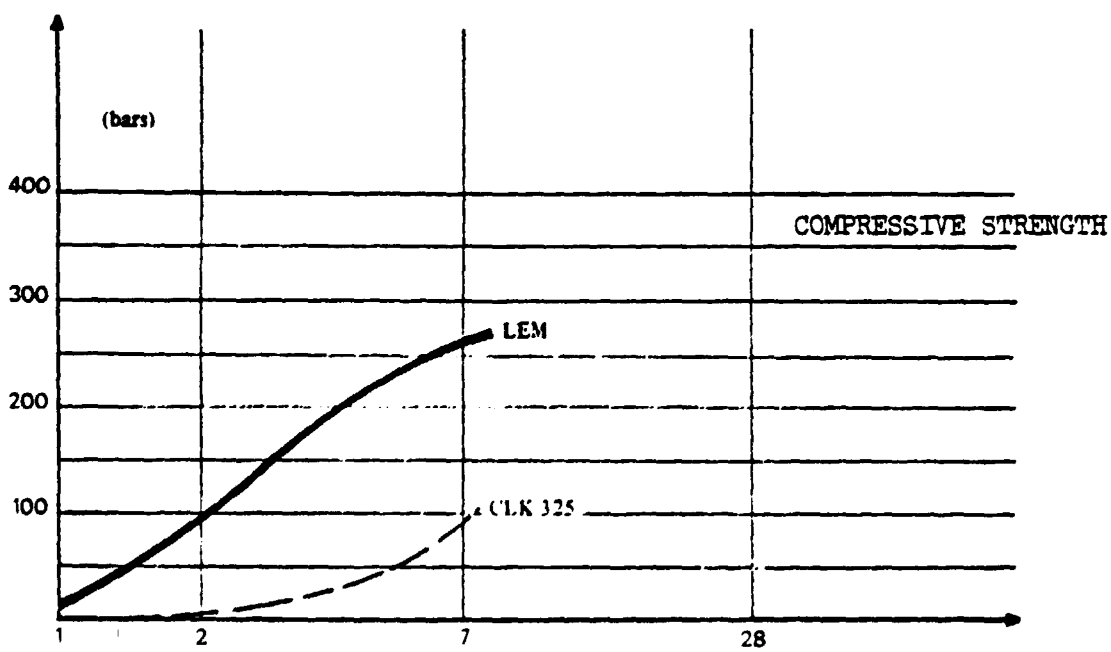
In view of its low heat of hydration, LEM offers very promising possibilities for use in road concrete.



Resistance at low temperature

Conventional cements of high slag content do not always develop sufficient initial resistances at low temperature and it sometimes becomes necessary to add a setting accelerator (chlorides, for instance), which, however, has the disadvantage of increasing shrinkage. With LEM, performance is very different because, as indicated in the preceeding paragraph, hydration heat is released from the very first hours.





Workability and stiffening

This relates to the aptitude of a mortar or of a concrete to position itself correctly. In fact, it involves a number of rheological characteristics which cause mortar and concrete to flow more or less well.

Thanks to its high specific area LEM wraps the granules effectively and to some extent plays the part of a lubricant.

Workability

Measurements with an LCPC mortar workability tester of the flow time for a normalized mortar give the following results:

CLK 325 : 16 seconds
CPA 400 : 12 seconds
LEM : 6 seconds

Compared with conventional CLK and even CPA, the workability of LEM is quite remarkable.

Stiffening

Stiffening of LEM, measured by the Tusschenbroeck method, is nil.

Manufacturing energy balance

The unit of energy adopted is the therm, it being borne in mind that for manufacturing purposes 1 kWh requires approximately 2.5 therms of fuel.

CPA 400

Composition: 95 per cent clinker.1/

Produced at a high temperature, $1{,}450^{\circ}$ C, the clinker, from the quarry to the furnace, requires approximately 1,120 therms, of which 980 come from fuel2/ and 140 from electricity, i.e. for CPA 400:

Clinker	0.95	x 1,120	=	1,064	therms
Grinding	35 kWh	x 2.5	=	87	therms
Total				1,151	therms

LEM

Blast-furnace slag, collected before casting of the molten metal, needs practically no specific addition of heat.

When the sensible heat of the smoke from the furnaces is not recovered, drying in the factory consumes at most 100 therms per ton. This figure will be adopted.

The energy required to make an LEM containing 20 per cent clinker1/ may be calculated as follows:

Clinker	0.20	x	1,120	=	224	therms
Drying of slag	0.75	x	100	=	75	therms
Grinding	100	x	2.5	=	250	therms
Total					549	therms

The energy required to manufacture LEM, a class 450 R cement, does not come to half of what is needed to produce a CPA 400.

1/ With the addition of calcium sulphate as setting control agent.

2/ Objective of the Cement Profession in the sectoral energy-saving contract for 1980.

Conclusion

With LEM, the market now has available a cement of high slag content offering very wide possibilities for use in construction work below ground and above ground, for massive work and for thin walls, at building-sites and in prefabrication.

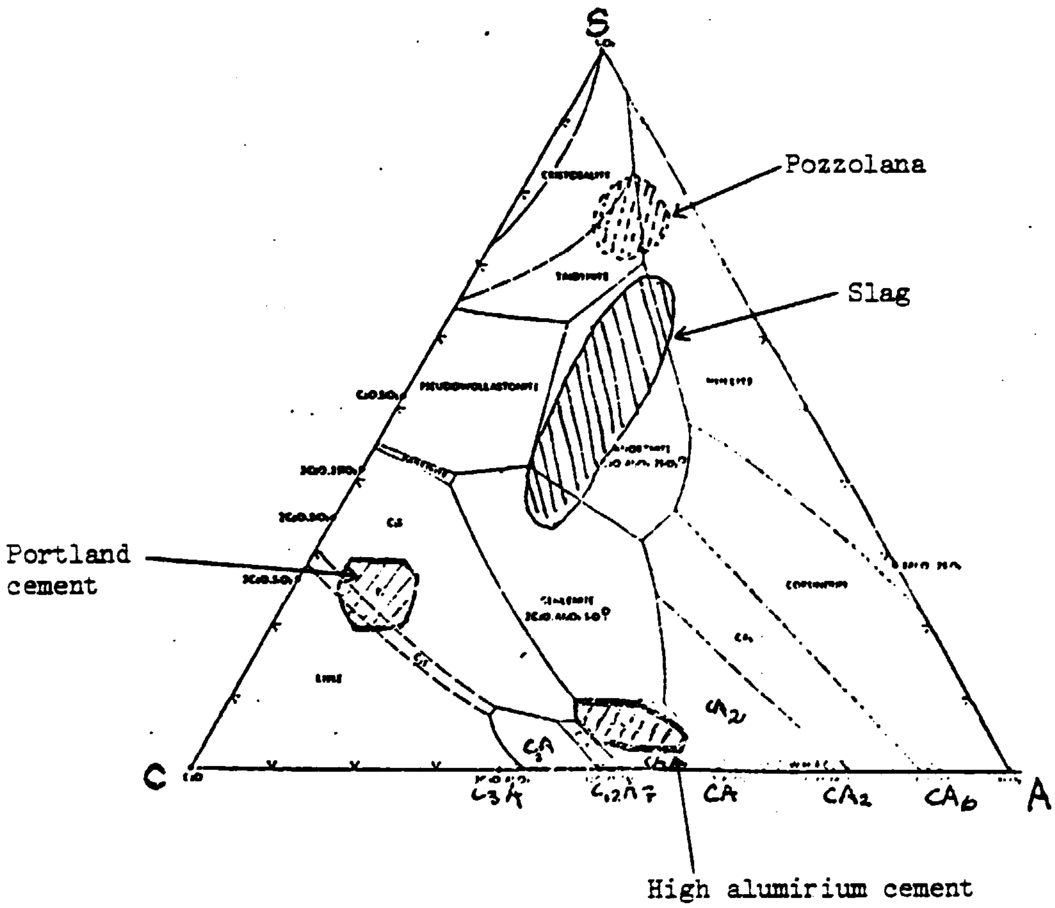
A new cement of the future 450 R class, LEM combines the qualities of a Portland cement of the same class with those of a slag cement. It offers high initial resistances, a low degree of shrinkage, a high level of workability, good water retention and low desiccation sensitivity, low heat of hydration, good resistance to frost and very high resistance to aggressive agents.

This excellent performance is due to the high degree of break-up of the slag obtained by an original technique and the optimization of the physico-chemical parameters of the constituents.

LEM requires for its manufacture half the energy needed for the production of an artificial Portland cement of the same class.

Annex II

REFERENCE MATERIAL ON ISKENDERUN PLANT



Rankin Diagram

Analyses

	CaO	SiO_2	Al_2O_3	MgO	Fe_2O_3	MnO	S	Na_2O	K_2O	SO_3
SLAGS										
France (Basic)	40-48	29-36	13-19	2-8	0.5-3.8	0.1-1	0.4-1.5			
USSR	29-48	34-35	5-23	0-18	0.3-2.4	0.1-2.1	1			
United States	36.45	33.42	10.16	3-12	0.3-2	0.2-1.5				
Karabus	37.06	36.76	19.23	4.67	0.52					
Iskenderun	38.93	35.93	18.51	7.64	0.24	(variation of CaO = 4 points)				
POZZOLANA										
Rhenish Trass	3.8	54.6	16.4	1.9	3.8			5.1	3.9	0.4
Santorin Earth	3.2	65.2	12.9	1.9	6.3			2.6	4.2	
Rome = Segni	12	44.1	17.3	2	10.7			1.4	3.1	
FLY ASH										
Kulu	2.32	57.29	30.49	1.89	5.53					0.24
Other	7	47.1	18.2	1.1	19.2				3.95	2.8
CLINKER										
La Malle (France)	65.75	21.50	5.95	2.10	2.25		0.23	0.17	0.88	0.75
Port La Nouvelle	65.90	22.70	4.65	1.05	3.20		0.01	0.11	0.90	0.35
Bartin	64.86	20.73	5.54	2.96	3.79					0.77
Adana	66.70	20.71	4.35	2.22	2.85					0.36

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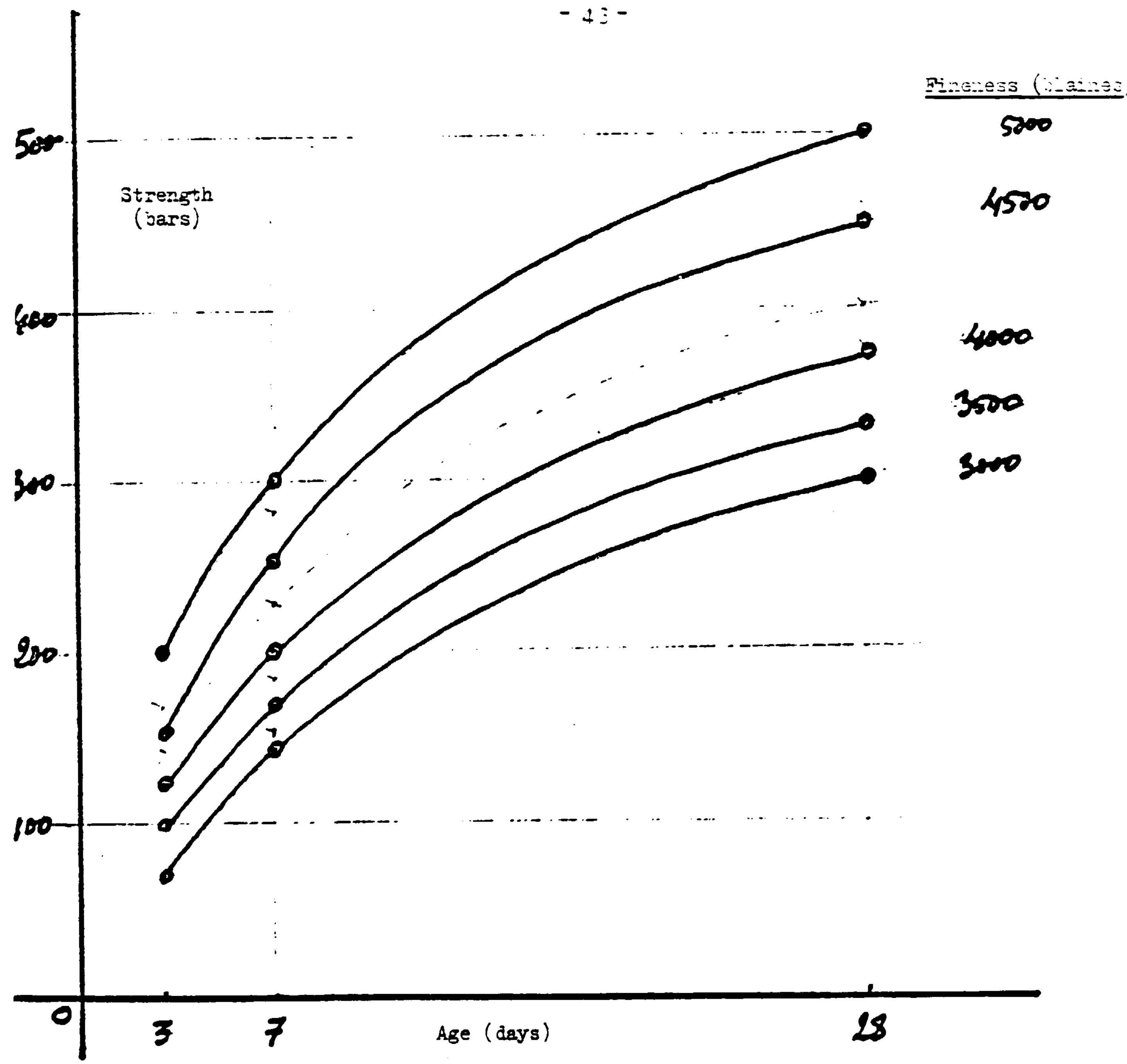

Compressive strength of mortars made from cement (3000 blaines) with 75% slag of varying fineness (cement and slag ground separately)

Source: F. Schröder, Tokyo, 1968.

Annex III

LIST OF PERSONS MET AT ELBISTAN

Tuncer Yakut	President of the department Alsin-Elbistan - TEK Ankara
Turan Ozturk	Research Planning - Projects and installations works department - TCE Ankara
Ar Buchananc	Fichtner Consu ting Engineers - Ankara
Arna Pagel	Alsin - Elbistan
Meamet Duygulu	Delegate of TEK at Alsin - Elbistan
Ahmet Cetin	Delegate of TCE at Alsin - Elbistan
Yves Haller	Chief Engineer at Alsin - Elbistan - Sofrelec

Annex IV

LIST OF PARTICIPANTS AT THE NIGDE MEETING

Ruhi Özmelek, Plant Manager
Afyon Çimento Fabrikasi Müdürü, Afyon

Abdulkadir Ciğerli, Plant Manager
Balikesir Çimento Fabrikasi Müdüru, Balikesir

Hikmet Dizdar, Plant Manager
Çorum Çimento Fabrikasi Müdürü, Çorum

Nihat Al, Plant Manager
Bartin Çimento Fabrikasi Müdürü, Bartin

Cemal Kaşarcioğlu, Plant Manager
Niğde Çimento Fabrikasi Müdürü, Niğde

Orhan Civelek, Plant Manager
Söke Çimento Fabrikasi Müdürü, Söke

Erbay Aksoy, Plant Manager
Pinarhisar Çimento Fabrikasi Müdürü, Pinarhisar

Yilmaz Külcü, Plant Manager
Elaziğ Çimento Fabrikasi Müdürü, Eleziğ

Müfit Güler, Plant Manager
Kars Çimento Fabrikasi Müdürü, Kars

Hasan Uzun Osmanoğlu, Plant Manager
G. Antep Çimento Fabrikasi Müdürü, G. Antep

Neşet Bellikli, Plant Manager
Van Çimento Fabrikasi Müdürü, Van

Lütfi Kömürlü, Plant Manager
Iskenderun Çimento Fabrikasi Müdürü, Iskenderun

Burhan Evcil, Plant Manager
Trabzon Çimento Fabrikasi Müdürü, Trabzon

Yaşar Adakoğlu, Plant Manager
Aşkale Çimento Fabrikasi Müdürü, Aşkale

Muhlis Sancaktar, Plant Manager
Adana Kağit Torba Fabrikasi Müdürü, Adana

Fevzi Saatcioğlu, Plant Manager
Çokurova Adana Çimento Fabrikasi Müdürü, Çukurova-Adana

Mustafa Filizel, Plant Manager
Konya Çimento Fabrikasi Müdürü, Konya

Ayduk Çelenk, Plant Manager
Akçimento Fabrikasi Müdürü, Istanbul

Yüksel Inan, Plant Manager
Baştaş Çimento Fabrikasi Müdürü

Necati Nemutlu, General Manager
Genel Müdür, T. Çim. San. T.A.Ş.
Atatürk Bulvari 211, Kavaklidere-Ankara

Erol Kadioğlu, Deputy General Manager
Genel Müdür Muavini, T. Çim. San. T.A.Ş.
Atatürk Bulvari 211, Kavaklidere-Ankara

Güner Alkan, Director of Operations Dept.,
Işletmeler Müdürü, T. Çim. San. T.A.Ş.
Atatürk Bulvari 211, Kavaklidere-Ankara

Fikret Tüzün, Director of Erections Dept.,
Tesis Müdürü, T. Çim. San. T.A.Ş.
Atatürk Bulvari 211, Kavaklidere-Ankara

Faruk Yağiz, Director of Research and Planning Dept.,
Planlama Müdür, Ömür Sok. No. 26,
Aşaği Ayranci, Ankara-Turkey

Muammer Zeybek, Deputy Manager
Bartin Çimento Fabrikasi Müdürü Mv., Bartin-Zonguldak