CEMENT
& LIME MANUFACTURE

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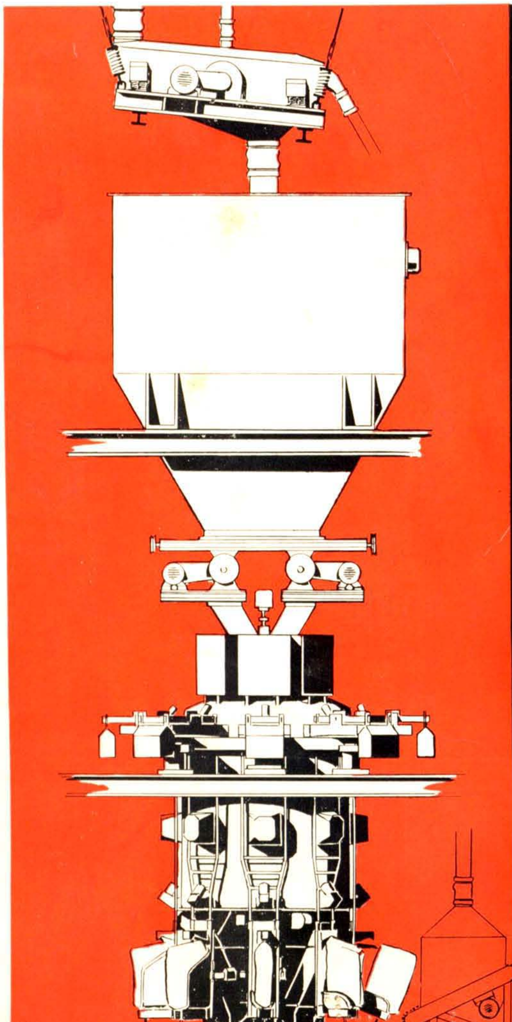

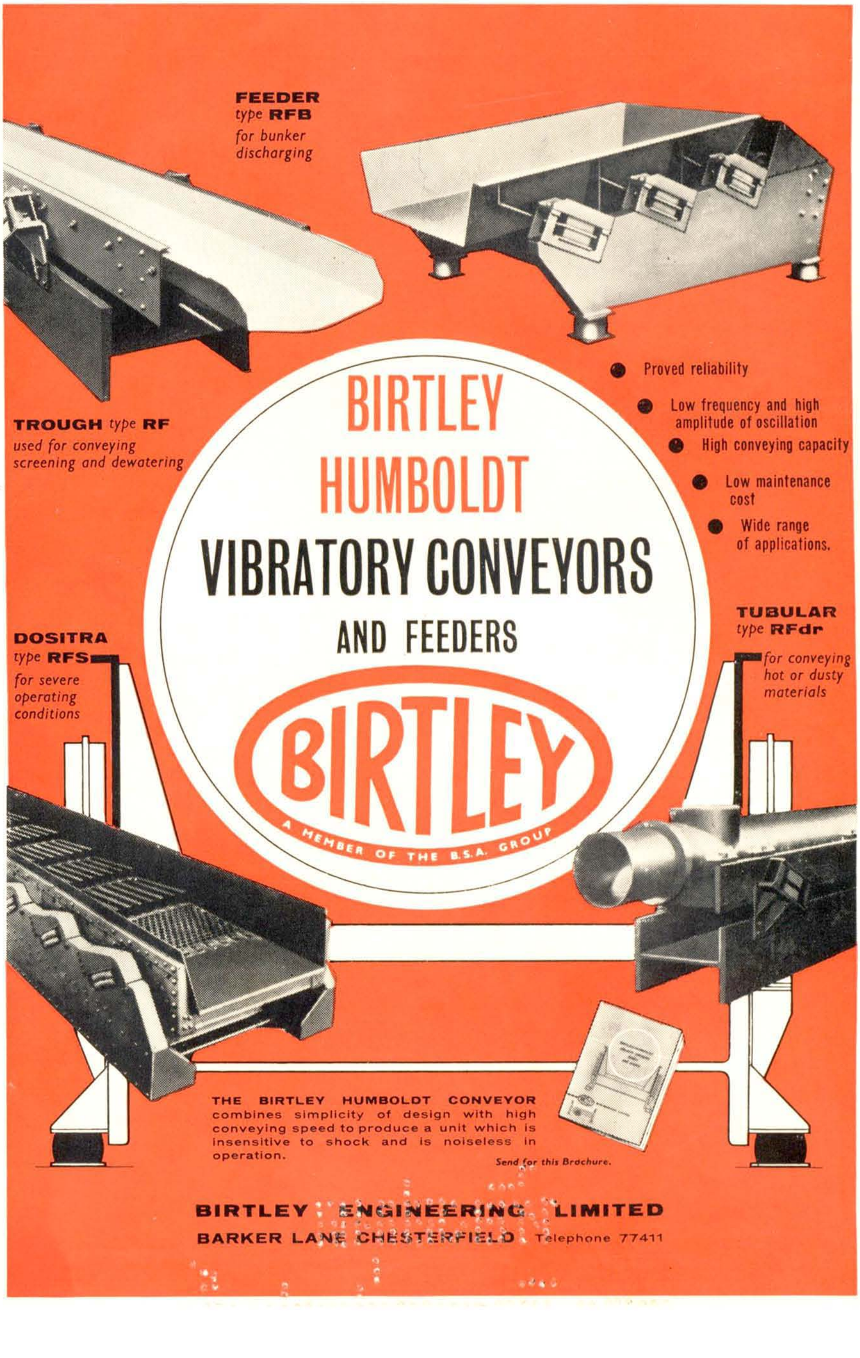
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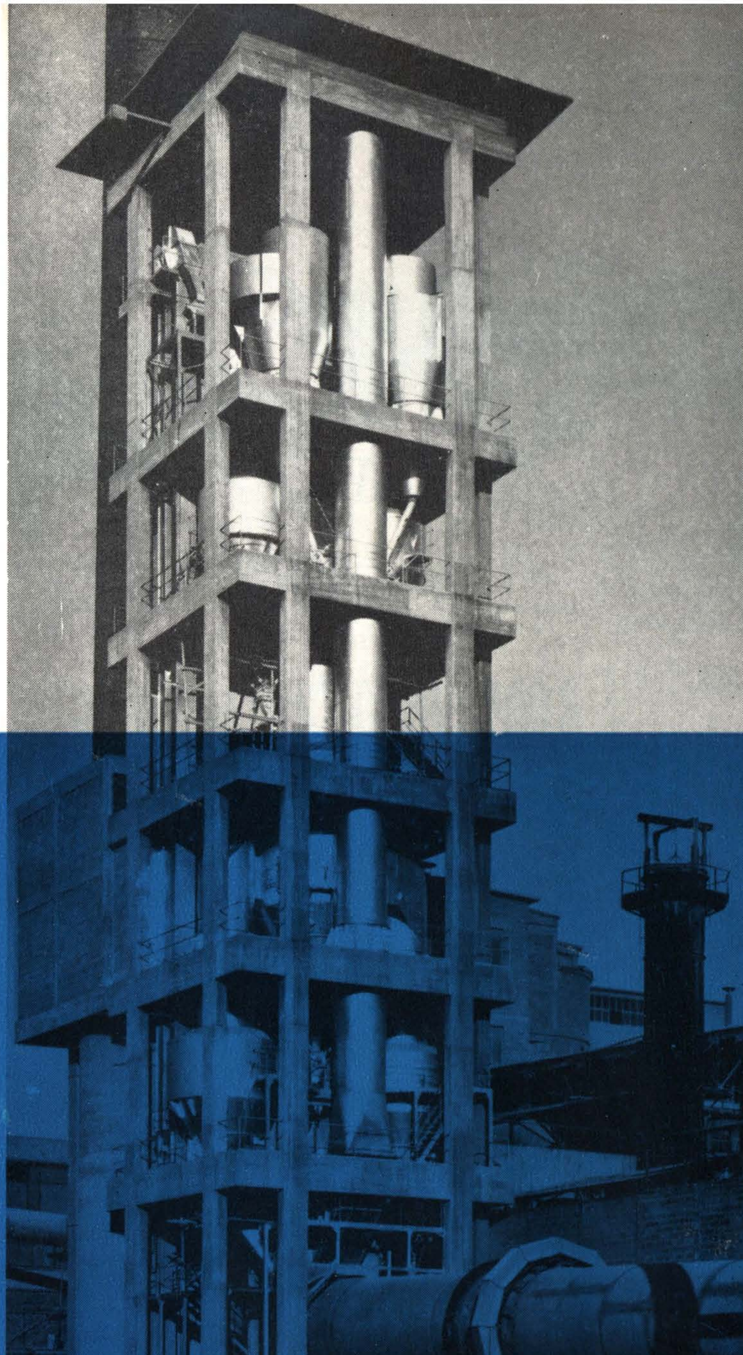

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VOLUME XL NUMBER 2 MARCH, 1967

A Small Cement Shaft-kiln in India

BY N. RAMACHANDRAD, B.SC. (ENG.), A.M.I.E.

THE new small cement shaft-kiln at Dalmiapuram is the first of its size to be established in India and is capable of producing 30 tons of clinker a day. It is therefore one of the smallest cement plants in the world, and has been in operation since August 1966. The thirty-seven cement works at present in India operate on the rotary-kiln process, with one exception, which is a Lurgi sintering plant having a daily capacity of 60 tons. The installation of a fully automatic continuous shaft-kiln has thus broken new ground in cement making in India and is the forerunner of several such plants, ranging in capacity from 30 to 150 tons per day, which are planned for the immediate future.

An operating plan of the works at Dalmiapuram is shown in *Fig.* 1 on page 18.

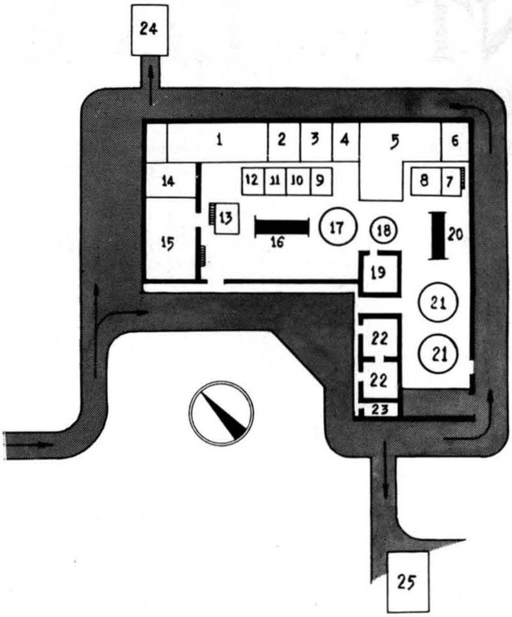
Raw Materials

The main raw materials are limestone and clay, but a small quantity of laterite is added at times as a corrective material to make up the deficiency in iron oxide in the raw meal. The limestone is obtained from a quarry three miles from the works. Dumper lorries of 7-tons capacity transport the limestone from the quarry to the works, and deposit it in the common storage hall. Clay is brought in by lorries from deposits within two miles of the works.

Storage Hall

The storage hall, which is 130 ft. long and 30 ft. wide, is used for the clinker and gypsum, as well as for the raw materials, the various materials being separated by reinforced concrete walls. The hall is provided with an electric overhead travelling grab-crane of $\frac{3}{4}$-cu. yd. capacity. The raw-material bins are along the long side of the hall; thus the crane is able to pick up these materials from the heaps and deposit them in the appropriate bins, from which they are recovered for further processing.

B



1. Limestone Store
2. Clay Store
3. Coal Store
4. Correction-material Store
5. Clinker Store
6. Gypsum Store
7. Gypsum Bin
8. Clinker Bin
9. Correction-material Bin
10. Coal Bin
11. Clay Bin
12. Limestone Bin
13. Raw Mix Bin
14. Jaw Crusher
15. Office
16. Raw-mill
17. Homogeniser and Storage Silos
18. Vertical Shaft-kiln
19. Roots Blower
20. Cement Mill
21. Cement Silo
22. Laboratory
23. Toilet and Lockers
24. H. T. supply Room
25. Stores and Workshop

Fig.1.—Plan of Cement Works at Dalmiapuram

Preparation of Raw Meal

Four weigh-batchers are installed below the raw-material bins (*Fig.* 2). By opening manually the quadrant gates below the bins, the materials are fed directly into the weigh-batchers for proportionate weighing. A belt-conveyor runs below the weigh-batchers and, after weighing, the raw materials are allowed to drop on to the moving belt for transportation to a mixer.

Pre-mixing of the raw materials and fuel is carried out in a mixer of special design. After thorough mixing, the raw meal falls from the mixer into the boot of an elevator by which it is discharged into a hopper capable of storing one day's requirements.

The dry grinding of the raw meal and fuel is done in a fine-roller Raymond mill provided with a 65-h.p. motor for the blower and a 60-h.p. motor for the main drive. The feeding to the mill is automatically controlled to match the output of the mill. When the raw meal has been ground to a fine degree (170 to 200 mesh), it is removed from the mill by means of circulating air provided by the blower, and the product is collected in a cyclone. For small cement plants, the type of mill used has been found to be suitable for grinding raw meal in view of its ability to provide close adjustments in the fineness of the product.

The raw meal, which is now ready for blending, is conveyed by means of a bucket-elevator to a blending silo (*Fig.* 3) which is 11 ft. 2 in. in diameter. Intimate

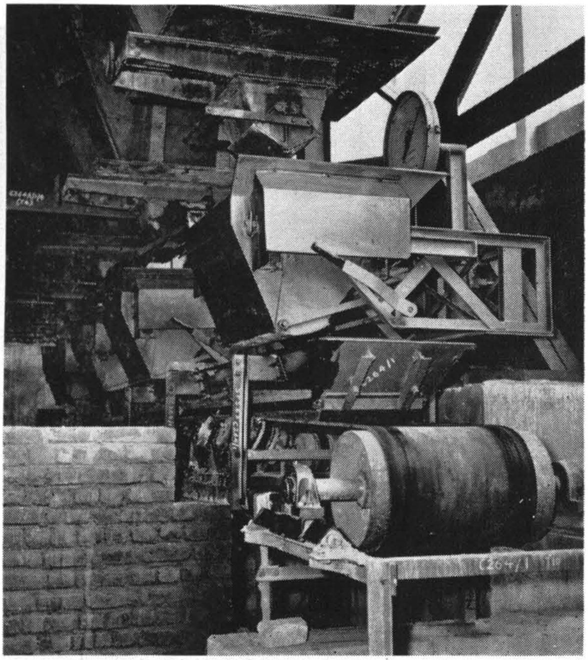


Fig. 2. Weigh-batchers under storage bins

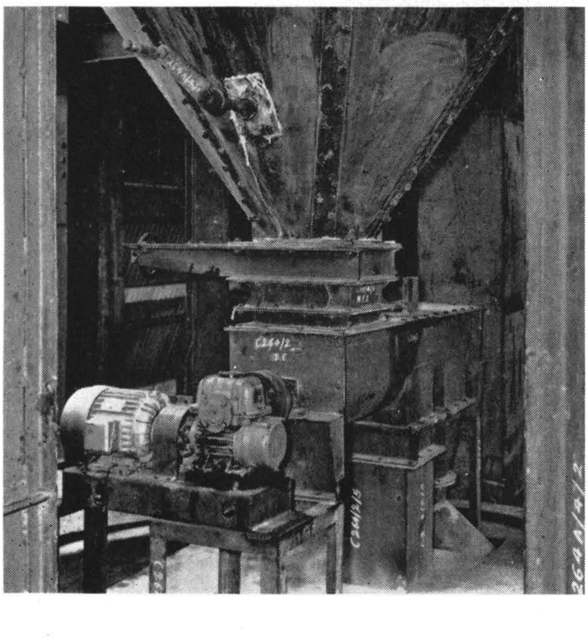


Fig. 3. Discharge from blending silos

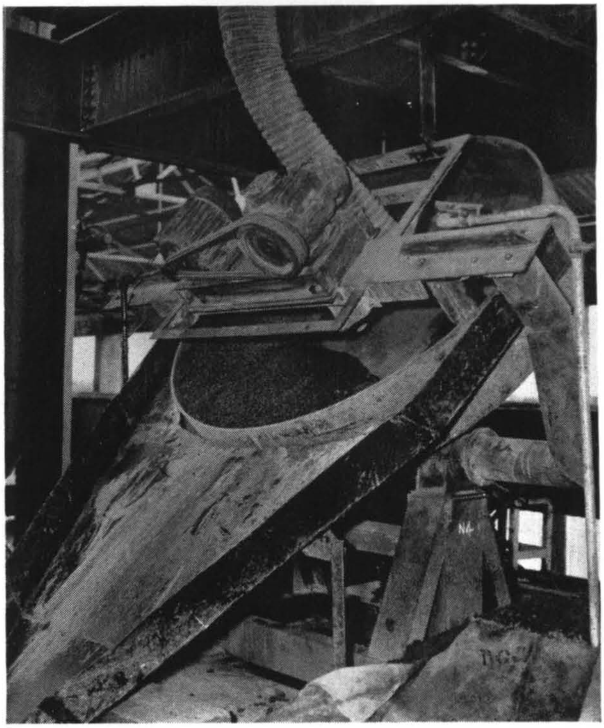


Fig. 4. Noduliser

blending is effected by a re-circulation process achieved through a special system of screw-conveyors and elevators. The carbonate content of the raw meal is checked at regular intervals to ensure that uniformity of blending is achieved. The corrected raw meal is then discharged by means of a screw-conveyor into a steel storage silo located directly below the blending silo.

Nodulising

The raw meal, in the form of dry powder, has now to be made into nodules of ½-in. diameter before being fed into the kiln. This is carried out in a dish noduliser of 5-ft. 2-in. diameter (*Fig.* 4), where a controlled quantity of raw meal and water is continuously added into the rotating dish to form nodules of uniform pea-size. A vibratory feeder (*Fig.* 5) controls the raw-meal feed to the noduliser. The noduliser is driven by a 7·5-h.p. motor, and is provided with an automatic scraper to prevent moist raw meal from sticking to the bottom and sides. There is also provision to change the angle of inclination of the dish as well as the height of the dish wall. Thus, by making suitable adjustments, nodules of any desired size can be produced.

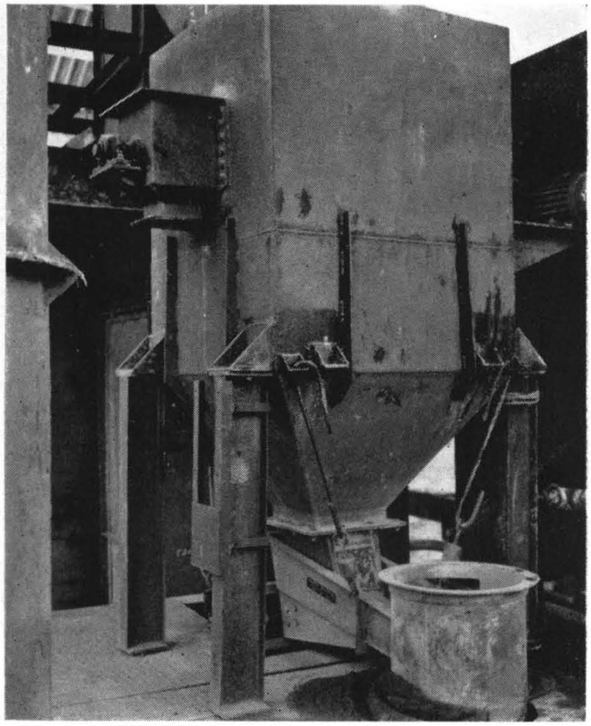


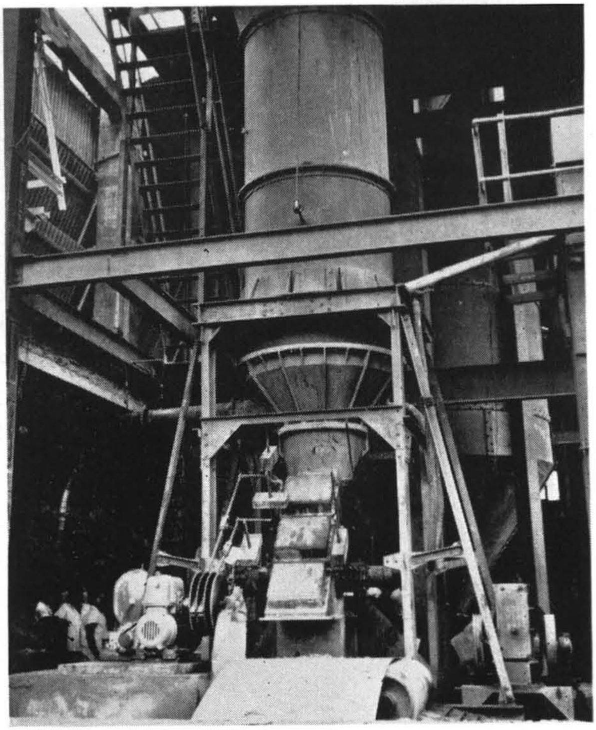
Fig. 5. Vibratory feeder controlling raw-meal feed to noduliser

The Shaft-kiln

The shaft-kiln is provided with a rotary feeding chute at the top (*Fig.* 6) and nodules, falling by gravity from the noduliser to the feeder, are distributed uniformly over the fire-bed by the feeder. Inspection doors are provided in the conical upper part of the kiln for the operator to observe the fire-bed while he stands on the operating platform.

A Roots blower (shown in the course of installation in *Fig.* 7), driven by a 50-h.p. motor and capable of delivering a supply of 2,400 cu. ft. of air at 2 lb. per sq. in., provides the air required for the kiln. The air enters at the bottom of the kiln, proceeds upwards in counter-current fashion to the flow of the clinker, and cools the clinker while becoming preheated before entering the burning zone in the top part of the kiln. The well-burnt clinker is drawn out of the kiln by means of a rotary grate (*Fig.* 8) and is discharged through a set of automatic discharge gates which prevent the escape of the air while allowing the outward flow of the clinker. The kiln is thus fully automatic in operation and the feeding, burning and discharging of the clinker is done under controlled conditions thus ensuring clinker of good quality.

Fig. 6.
Shaft-kiln



Instrumentation

A common instrument panel is located on the operator's platform in the kiln building. The panel indicates the volume and pressure of the air supplied by the blower, and the draught pressure in the kiln chimney. The temperature obtained inside the kiln and in the flue gas are given by four thermo-couples, fixed at appropriate levels, and a temperature recorder in the panel records the temperature continuously.

Transporting and Grinding Clinker

The clinker produced from the kiln is fed into a jaw-crusher, driven by a 7·5-h.p. motor, where the larger lumps are broken down to less than 2 in. and are then transferred by an elevator to the clinker storage part of the storage hall. The same grab-crane that handles the raw materials is also used for the clinker.

The clinker and gypsum, when required for grinding, are removed from the hall and are fed into two steel silos from which they are discharged at a constant rate by two rotary table-feeders into the cement mill. The table-feeders are capable of fine adjustment in order to control the proportion of the feed to the mill.

The mill is 20 ft. long and 5 ft. in diameter, and is driven by a 130-h.p. motor.

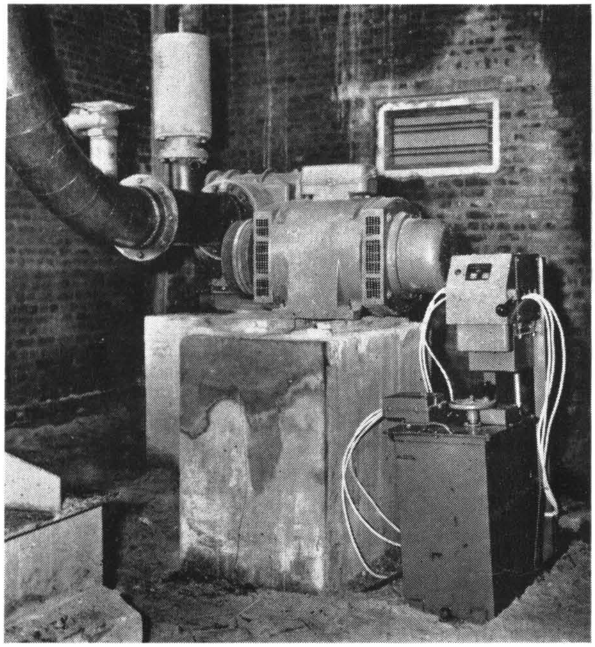


Fig. 7. Blower (during erection)

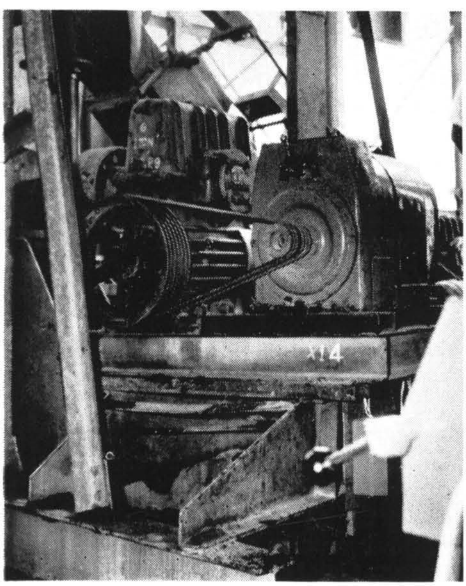


Fig. 8. Motor driving rotary grate

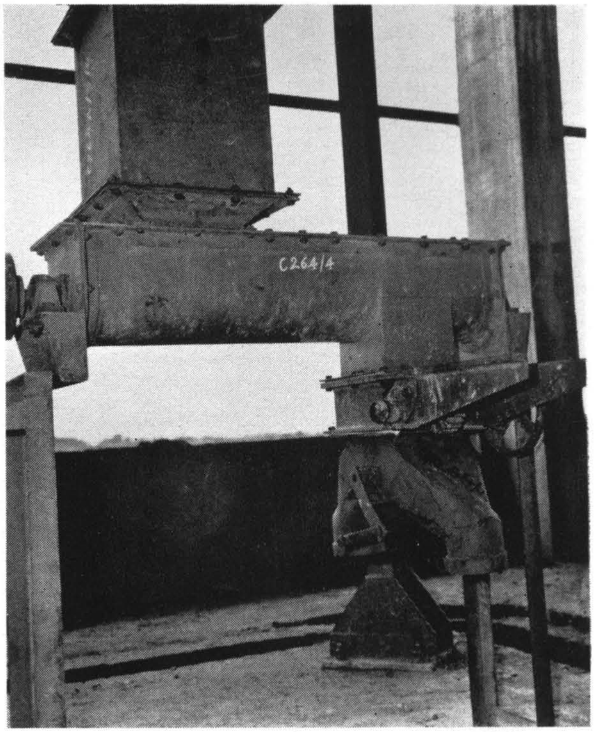


Fig. 9. Screw-conveyor drawing cement from silo and feeding to bags

It operates on open circuit. The ground cement is delivered into the boot of an elevator which discharges it into a steel cement silo of 60-tons capacity and of 11-ft. 6-in. diameter.

Bagging and Dispatch

A simple and reliable system is used for bagging. The cement is drawn from the cement silo and is fed directly into the bags. Otherwise the operation is manual. The equipment allows two operators to fill the bags and weigh them alternately. The 30 tons of cement produced in one day by the plant can be bagged by two men in one shift. The equipment for drawing cement from the silos and filling bags is shown in *Fig.* 9.

The bags of cement are loaded into 5-ton wagons which run directly into the cement-mill building to a position very near to the bagging department. The loading of the vehicles is done by hand.

The complete shaft-kiln plant was designed and built by the Government of Madras, all the machinery being fabricated in Indian workshops. The author designed the shaft kiln and auxiliary plant which was fabricated under his direction, and he was also responsible for the layout and the material-handling system. The building and civil engineering works were carried out by the Government of Madras with the assistance of local contractors.

Research in Sweden.

A DETAILED survey of past and present activities relating to research on cement undertaken in Sweden is given in recent publications by the Swedish Cement & Concrete Research Institute of the Royal Institute of Technology.

In the first (1) of the three publications reviewed in the following, a history of cement research, in which reference is made to Swedish contributions and to the activities of the Institute, and the present conditions of physico-chemical research are outlined. An account is given of various alternatives for projects or assignments in the physical and chemical sections of a cement research institute, such as advanced testing, examination of damages, development of new materials, and basic research on the nature of hydraulic binding and the relationship between physico-chemical structure and mechanical properties of hydrogels. With specific reference to the last of these several subjects, the present conditions of research work with respect to questions on materials and methods are described.

Portland cements of ordinary types are mixtures of several mineral constituents. It is difficult to follow the hydration reactions of each separate component and to distinguish the various products of hydration, even when the most modern and selective methods of structure-analysis are used. There has, therefore, been a tendency to employ methods of crystal and colloid chemistry in studies of pure components or chemically well-defined systems, whereas studies of the deformation and failure of hydraulic materials have mostly been made using standard cement, often in combination with sand and gravel in cement mortar or concrete. Not many attempts have been made to correlate the two sets of data. Standard experimental equipment for studies of microstructure, such as electron microscopy and X-ray diffractometry, have now reached such a degree of reliability, power of resolution, and accuracy, that they can be used to advantage for comparing and characterising various types of hydraulic materials with respect to their microstructural properties. However, in order to be able to elucidate these problems, it is also necessary to use purified and standardised materials in the samples investigated.

In the general case, a hydrogel consists of aggregates of very small, badly crystallised or colloidal particles of various shapes. The cohesion in the mass is caused by the development of contact interfaces between particles in contiguous aggregates. Most of the bonds are probably hydrogen bonds, either developed between hydroxyl groups in adjacent surfaces of hydrated particles, or transmitted through complete interlamellar layers of water molecules. A hydrogel is usually prepared by mixing anhydrous material with water in certain proportions. In order to study the relationship between microstructural and mechanical properties of the gel itself, it is important to use pure, stable gels as materials of investigation. Thus the phases initially present, anhydrous material as well as water-filled capillary pores, should be eliminated as completely as possible.

Comparisons are made between ideal and actual cement-gels and are illustrated by the diagrams in *Fig.* 1 on page 26. In this illustration, diagrams A and B

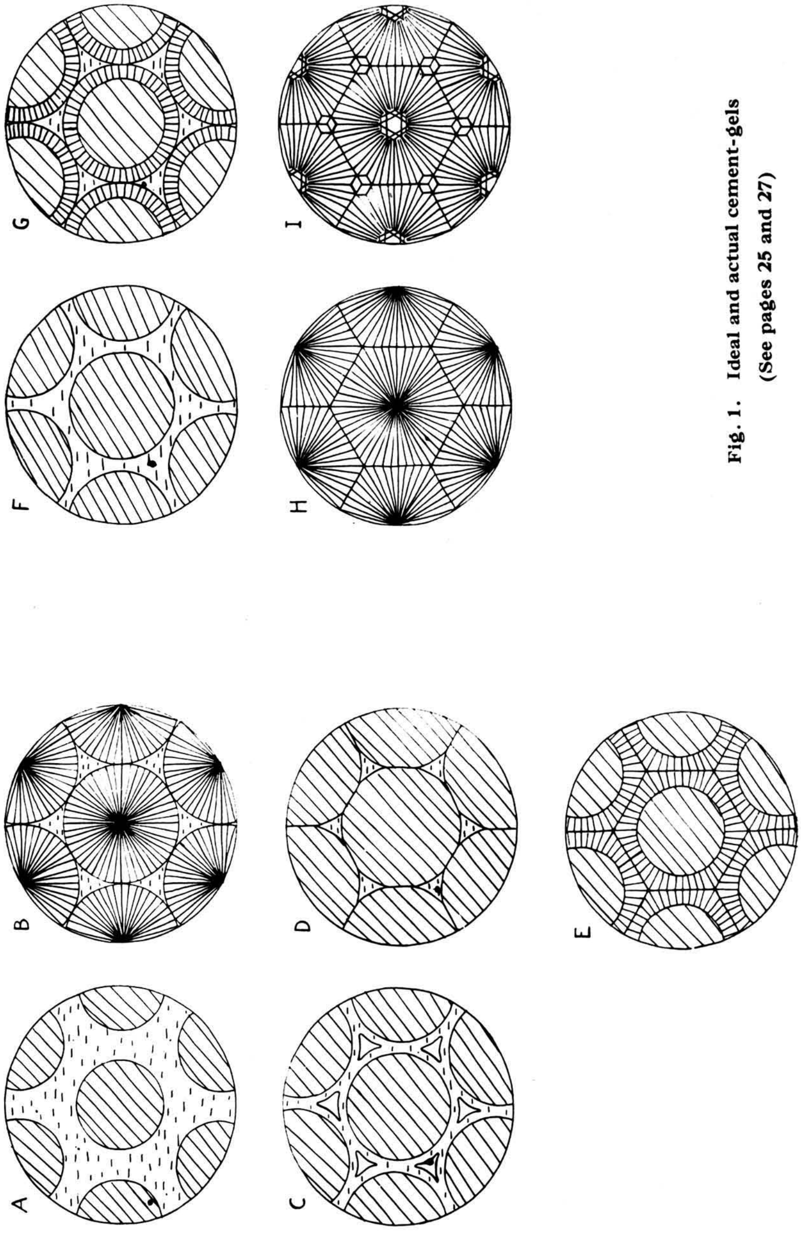


Fig. 1. Ideal and actual cement-gels
(See pages 25 and 27)

represent a cement paste of high water-to-solid ratio, before and after complete hydration respectively. Diagrams C, D and E relate to a paste of low water-to-solid ratio with entrained air; the first of these three diagrams represents the paste before hydration, the second after it has been vacuum-mixed or compacted, and the third after complete hydration. Diagrams F and G depict a paste of ideal water-to-cement ratio before hydration and during setting respectively. An ideal paste at complete hydration is shown in diagram H, while the diagram I represents a real paste of ideal water-to-solid ratio at completion of hydration.

Materials and Methods

In order to study the problems presented in the foregoing it is stated in the second publication ([2]) that it is necessary first to prepare a series of samples of suitable materials to be investigated, and secondly, to select and develop methods and devices for analysing and measuring the relevant properties of these materials. It is required that these materials should consist of fully-reacted homogeneous gel substances, implying that they should not contain residues of the basic materials, anhydrous compounds and water-filled capillary pores. On the other hand, it is not especially desirable to prepare materials which are closely related to Portland cement, but rather to have substances which are widely variable with respect to composition as well as microstructure.

Examples are given of reactions in the general system C-S-A-F-H, in which substances of the required type are likely to be the final product of reaction. The systems C-S-H and C-A-H are closely related to common cement systems and are therefore considered preferentially and in some detail, but possible reactions in systems containing ferrite, sulphate and carbonate are also included. A review is given of information extracted from available literature: relating to the probable course of reactions, the influence of the composition of the basic materials, temperature, and other factors on the rates and the final products of the hydration reactions, and the content of water necessary for obtaining fully-reacted dense homogeneous gel material. For many of these reactions the information available is very incomplete, and special studies are required to solve certain problems connected with the preparation of materials.

There are three main groups of methods for studying the relevant properties of the gel materials. First, it is necessary to have certain methods in which the data obtained can serve as criteria of the degree of reaction and of the homogeneity of the final gel product. These properties can be determined by quantitative mineral analysis, using X-ray diffraction methods, and by measurements of capillary porosity, using some kind of gravimetric determination of water adsorbed in pores of different sizes. The second group of methods concerns the examination of the phase composition, the crystal chemistry, and the microstructural morphology of the gel materials. These data can be studied by combining the results obtained by electron microscopy, electron diffraction, and X-ray diffraction. In addition, certain procedures involving chemical extraction analysis can be used to study the fixation and complex formation of certain structural elements and

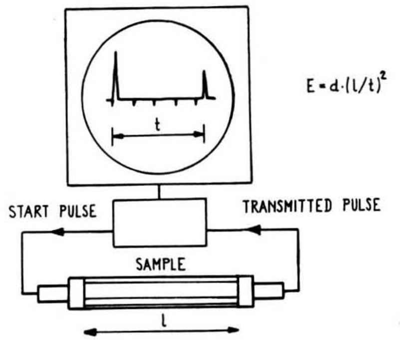


Fig. 2.

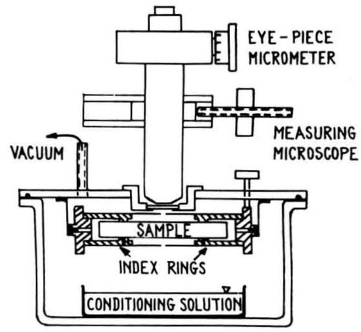


Fig. 4.

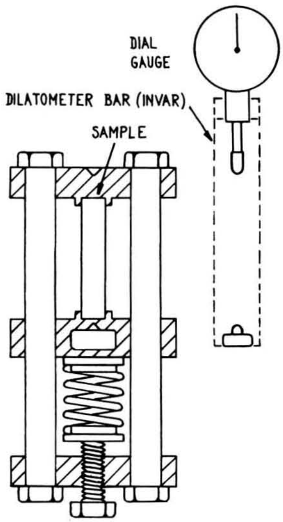


Fig. 3.

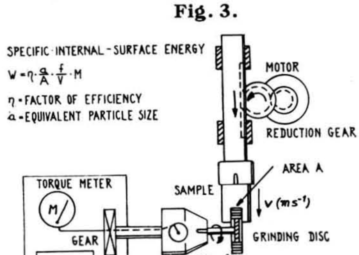


Fig. 5.

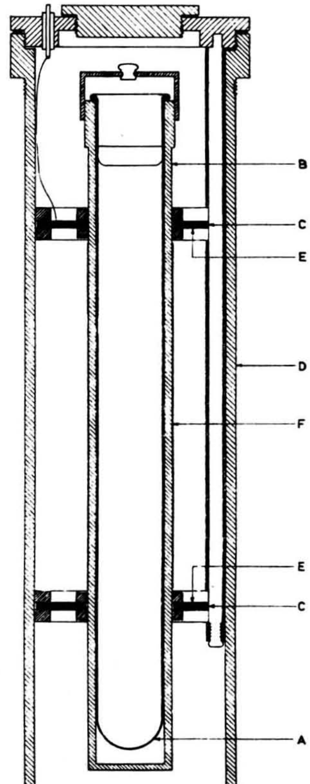
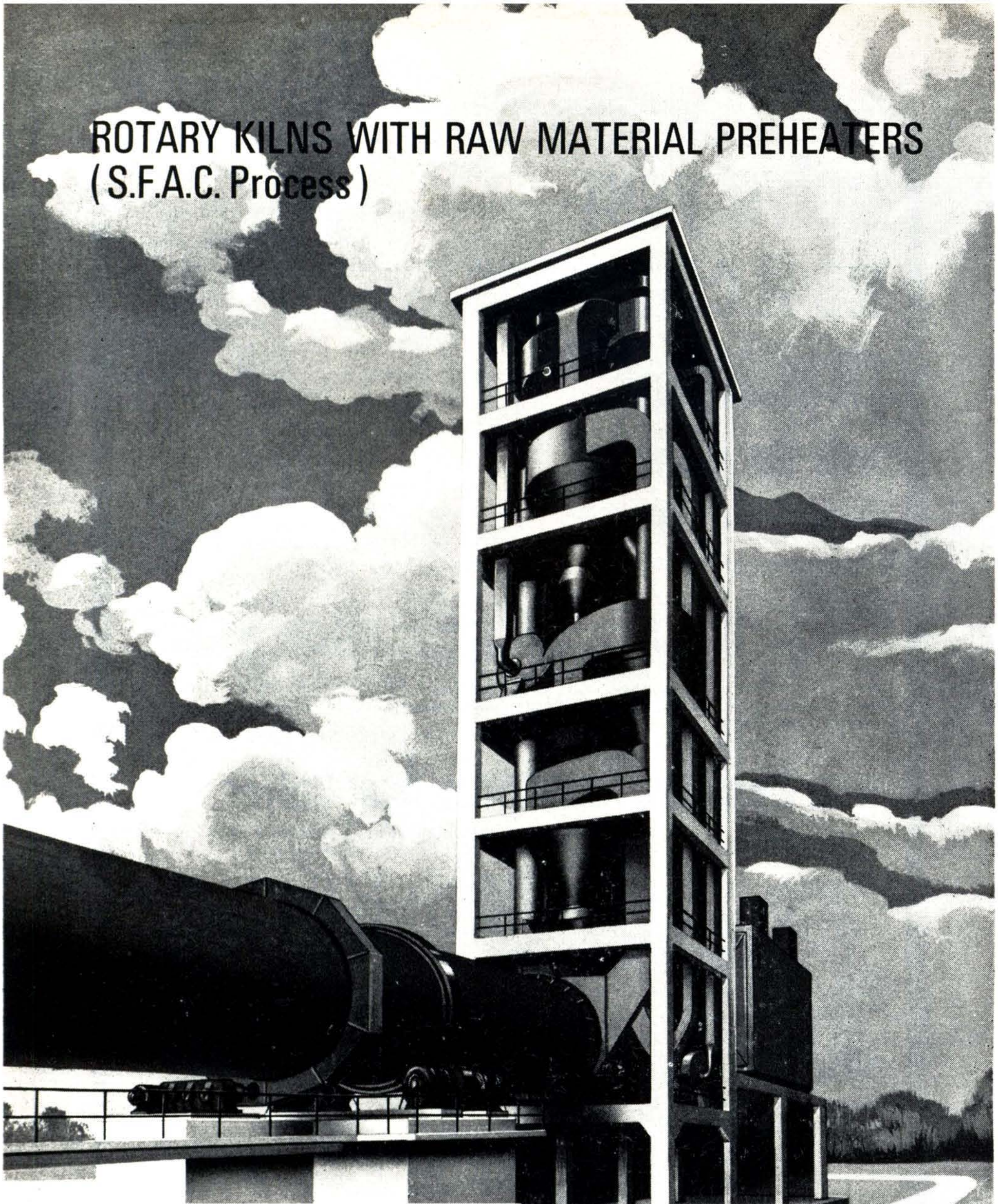


Fig. 6.

Research in Sweden
(See pages 27, 29 and 30)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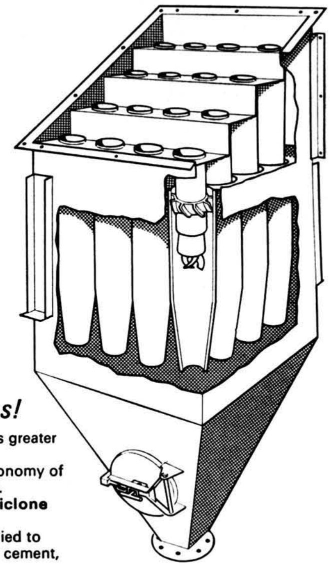

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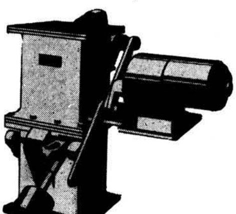

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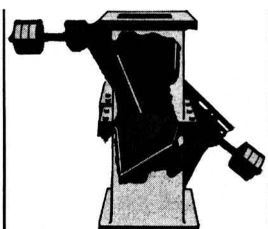

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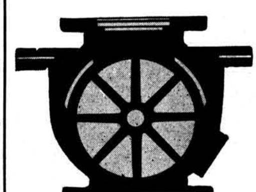

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measurements of dielectric data can give certain information on the fixation of water in the gel structures.

A third group of data concerns the mechanical properties of the materials. The dynamic modulus of elasticity, corresponding to a certain pulse velocity, is a measure of the content and distribution of elastically deformable bonds between the material particles. The deformation under sustained load (creep) reflects the inelastic rheological properties of the material, that is mainly the character of the mechanism of breaking and recombining of the bonds in the zones of internal contact. A different type of material displacement is the change of volume caused by changes in the hygrothermal conditions. The cohesive properties of gel can be expressed in different ways. One characteristic quantity is the tensile strength, as expressed for example by the data obtained in a so-called diametral-compression test. Other measures of the specific internal cohesion energy can be obtained by determining the resistance against fine subdivision or the microhardness.

Suitable methods of measurement of these various mechanical properties are briefly described and discussed, and the apparatus required are illustrated. For example, *Fig.* 2 shows diagramatically the apparatus used for determining the dynamic modulus of elasticity E or pulse velocity. The diagram in *Fig.* 3 represents the apparatus for measuring creep, while that in *Fig.* 4 illustrates a suggested principle for an apparatus for the measurement of hygrothermal volumetric changes. The diagram (*Fig.* 5) shows a device for the measurement of the specific internal-cohesion energy.

Heat of Hydration

A specific problem, namely, the study of the heat of hydration of Portland cement by means of a conduction calorimeter is treated in considerable detail in the third publication([3]). One of the calorimeters used is shown in *Fig.* 6.

The investigations described were made on neat pastes of a standard Portland cement and distilled water stored under sealed conditions. Where the cement pastes were pre-hydrated at one temperature and then the temperature suddenly altered to the temperature at which the rate of heat of hydration measurements were made, the following conclusions were reached.

For a given total amount of heat of hydration, the rate of heat evolution is not a unique function of the temperature, but depends also upon the previous temperature-history of the paste. The hydration products formed at different temperatures vary in one respect or another as, for instance, in phase composition and morphology. The rate of heat of hydration is usually lowered when the paste is kept at a high temperature during the pre-hydration period, and vice versa. The longer the pre-hydration period, and the more the pre-hydration temperature deviates, the more pronounced is this effect.

The rate of heat of hydration for a paste pre-hydrated at a higher temperature can be so strongly influenced by the pre-hydration that the total heat of hydration after a time becomes lower when compared with a paste of the same age which has been kept all the time at the lower temperature at which the former paste has been kept during measurement. In the reverse case, with a lower pre-hydration temperature the pastes do not, in general, exhibit higher values for the total heat of hydration than pastes kept at the higher temperature all the time, but they do eventually attain the same values.

Due to the foregoing facts, no time-temperature function can be exactly valid for the heat of hydration of the pastes investigated. This follows also from the results of experiments carried out at constant temperature. Nevertheless, the time-temperature functions given by other investigators can be used for practical purposes in order to calculate approximately the heat of hydration developed at various temperatures within the temperature range studied, provided the heat of hydration developed at one temperature is known.

The total heat of hydration is found to be proportional to the amount of bound water, with a proportionality constant which is not essentially influenced either by temperature or the water-cement ratio. For high ages, there seems to be a tendency for the values to deviate from proportionality in a way that corresponds to less heat being released per gramme of the water bound.

The specific heat of the unhydrated cement is found to be 0·183 cal. per g.°C at 20 deg. C and its temperature coefficient about 4×10^{-4} cal. per g.°C². The specific heat of cement pastes hydrated at 20 deg. C. for about thirty days is approximately $0{\cdot}18 + 0{\cdot}42\, w_0$ cal. per g.°C. for water-cement ratios between 0·25 and 0·50. The specific heat of the paste decreases linearly with the total heat of hydration in the beginning but, for high degrees of hydration, the decrease seems to be faster.

For cement pastes hydrated at various temperatures in the range —2 deg. C. to 40 deg. C., for ages of from twenty-one to thirty-six days, the specific heats lie between 0·05 and 0·08 cal. per g.°C., below the corresponding values calculated for an unreacted cement-water mixture with the same water-cement ratio.

The relative water-vapour pressure in equilibrium with a cement paste having no water exchange with its surroundings is, after sixty days, still about 80 per cent. and 90 per cent. for pastes with water-cement ratios of 0·25 and 0·40 respectively.

It is stressed that the quantitative results obtained for cement pastes would not be valid for mortars or concretes made with the same cement, because the aggregates cause the course of the hydration processes to be modified.

Publications

1.—GRUDEMO, Å. " The Conditions of Cement Research." Part I: " Retrospect, Present State and Prospect." Reprint No. 37 (from " Nordisk Betong," September, 1965). Published (in Swedish) by the Swedish Cement & Concrete Institute. Price: 2 kroner.

2.—As Reference (1) above, except as follows: Part II: " Materials and Methods." Reprint No. 38 (from " Nordisk Betong," October, 1966).

3.—DANIELSSON, U. "Conduction Calorimeter Studies of the Heat of Hydration of a Portland Cement." Proceedings No. 38 (In English). Swedish Cement & Concrete Institute. Price: 15 kroner.

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The Cement Industry Abroad

India.—Mr. D. Sanjivayya, Union Minister for Industries, announced recently that the present annual productive capacity of the Indian cement industry was 12,000,000 tons but only about 11,000,000 tons were being produced, although by the end of the year (1966) it was expected production would increase by 2,000,000 tons. The Third Plan target of 13,000,000 tons had not been reached. In the Fourth Plan, the annual productive capacity of the cement industry would be doubled, making it 25,000,000 tons, but actual production might be only 20,000,000 tons. The country was self-sufficient in cement. It was the lack of railway wagons that delayed movement. The Minister stated that the Government was endeavouring to export cement. As the Fourth Plan progressed, construction work would increase and for this more cement would be needed.

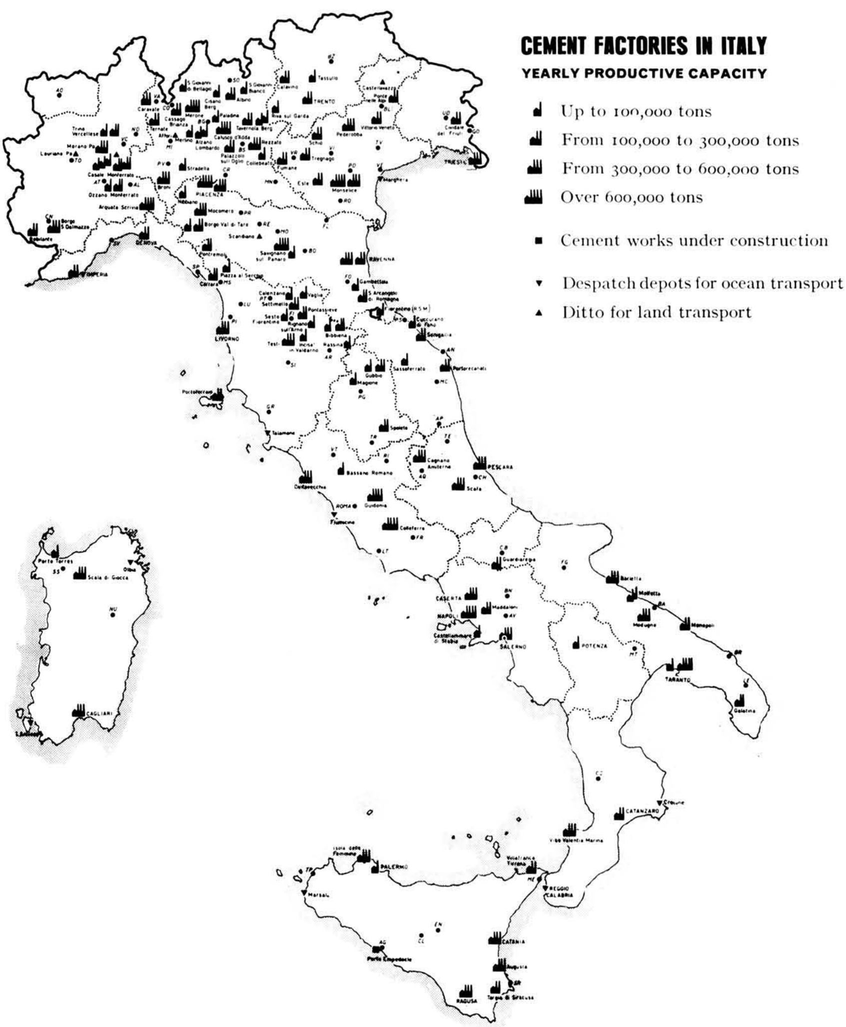
Brazil.—It is reported that the International Division of Allis-Chalmers has received an order valued at 3,300,000 dollars to make cement plant for installation in a works at Rio de Janeiro. The plant, which will embody the Allis-Chalmers " grate-kiln " system, is part of an expansion project being undertaken by Companhia de Cimento Portland Branco do Brasil, S.A. It will be installed adjacent to the existing plant in Iraja Industrial Park. The annual productive capacity of the works will be expanded from 36,000 tons to 231,000 tons when the new plant is in operation which is expected to be in 1968. The present conventional plant was supplied by Allis-Chalmers in 1952. The new plant will be the first " grate-kiln " system to be installed in South America. This system is claimed to have the advantages of pelletising with a special preheating method to produce cement of more uniform quality at lower cost and under cleaner conditions. The equipment to be supplied by Allis-Chalmers includes a pelletising pan of 15-ft. diameter, a 64-ft. travelling grate, a 160-ft. rotary kiln, a 70-ft. cooler and a 50-ft. rotary dryer, together with the motors, controls, electrical and allied machinery, and three 240-h.p. wheel-loaders for handling the increased quantity of materials. The raw materials, limestone and clay will come from reserves owned by the Branco Company.

France.—The annual production of cement in France was 22,255,000 tons in 1965, an increase in respect of 1964 of 4·4 per cent. Thus France is in the fifth position among cement-producing countries of the world, following directly the U.S.A., U.S.S.R., Japan and Germany.

Africa.—In the number of this journal of November 1966, it was stated that the new rotary kiln installed in the Lichtenburg (Transvaal) works will produce 250,000 tons of cement per annum and that this will almost double the productive capacity of the works; actually the increase will be about 50 per cent., since the present annual production is about 500,000 tons.

The annual cement production in the entire African continent is estimated at 11,000,000 tons. In 1965, the total number of cement works was sixty-nine, fourteen being in the Republic of South Africa. Egypt produces 2,500,000 tons per year and Morocco 1,000,000 tons.

Italy.—The data in the following and the map on page 32 are abstracted from a recent number of ACM (the magazine of the Asbestos Cement Industry).



The average decrease in the production of cement in Italy was 7·6 per cent. for the first six months of 1966 compared with the same period in 1964. The drop is mainly in the north where the decrease is 17 per cent., and where consumption has fallen to about 5,000,000 tons compared with 6,000,000 tons in 1964. Although production has decreased, the productive capacity of cement works has considerably increased due to modernisation of old works and the establishment of new works which was undertaken when the demand for cement was rising.

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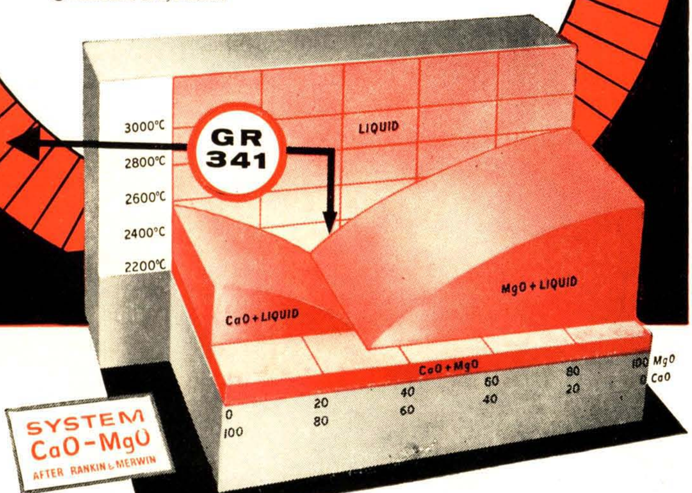

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