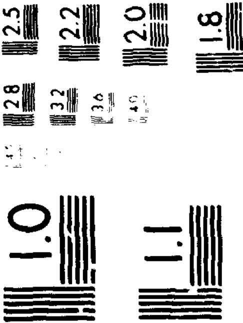


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Interregional Seminar on Cement Technology
Beijing, China, 9-24 October 1980

REPORT

Based on the work of Paul F. Janssens and Gjerløf Roed

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Explanatory notes

A comma (,) is used to distinguish thousands and millions.

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INTRODUCTION

The Interregional Seminar on Cement Technology was held in China from 9 to 24 October 1980. It was organized jointly by the United Nations Industrial Development Organization (UNIDO) and the Ministry for Building Materials of China.

The Seminar was organized to review and evaluate technologies developed under the influence of various factors ranging from a general desire for environmental protection and efficient use of natural resources to an awareness of the need for energy conservation. The latter was emphasized as a response to increasing oil prices and in order to preserve energy resources for coming generations.

Part one. Report of the Seminar

I. ORGANIZATION OF THE SEMINAR

The Seminar was attended by 30 participants and observers representing approximately half of the world population. The agenda covered developments in cement technology and the steps taken to meet current demand for cement, taking into account such matters as pollution controls, efficient use of natural resources and energy conservation. Technical and country papers were presented by participants from Burma, China, Denmark, Ethiopia, France, Germany, Federal Republic of, India, Libya, Malaysia, Nepal, Somalia, Thailand, Turkey and Zambia.

C.E. Rydeng, UNIDO, was Director of the Seminar. Xu Yongqing and Xu Jingyi, Ministry for Building Materials of China, were Co-Directors of the Seminar.

The participants visited five cement factories in Shandong and Changzhou Provinces.

II. FINDINGS

The first paper presented to the Seminar described the development of the cement industry in China, where rotary kiln technology for medium- and large-scale cement plants has co-existed with shaft kiln technology for small-scale cement plants. Various technical details of shaft kiln technology were then described. In particular, the black-meal and the semi-black meal processes were discussed together with equipment and process parameters.

Technical details regarding the nodulizing technique and the discharge technique were discussed on several occasions. A material-blocking discharge system developed in China was discussed and earned much appreciation for its simplicity.

Chinese and European shaft kilns were compared. Both were regarded as highly appro ate technology for covering local and relatively small cement demand in areas without easy access to cement supplies but with access to suitable raw materials, including coal.

Plants should preferably be built near the raw material supplies and away from towns, so as to reduce pollution in populated areas and make savings on transport costs. A shaft kiln plant should produce at least 60,000 t/a, and would be most economical with two or three shaft kilns operating together at capacities of 120,000 t/a or 180,000 t/a. For capacities above 200,000 t/a the rotary kiln technique should be preferred. Investment costs for rotary kiln plants above 200,000 t/a are equal to or less than investment costs for shaft kiln plants of equal size. The widespread application of the rotary kiln technique as a means of making economic use of fuel oil, natural gas and coal was emphasized, together with the recognized trend towards reduced dependence on fuel oil.

The heat economy of rotary kilns and fuel-efficient techniques in the use of good- and inferior-quality coal were discussed. The precalciner technique offers good possibilities for using low calorific coal with high ash content without impairing the Portland clinker sintered in the rotary kiln, provided sufficiently good fuel to complete the clinkerization process is applied.

In connection with large-scale rotary plants, a rational process design from quarry to kiln is essential. Good design and layout would help to minimize variations in the kiln feed.

The advantages of preblending and technical details regarding raw meal preparation with roller mills and ball mills were reviewed and discussed. Computer help to operators of large kilns was considered in connection with the use of automatic and semi-automatic systems. It was proposed that the semi-automatic system could help the operator to achieve continuous kiln operation without eliminating the need for his experience and initiative.

The conversion of wet process cement plants was discussed. The economic feasibility of such a change would be increased if it coincided with an expansion of the factory. Conversions should be carefully examined in techno-economic feasibility studies in order to avoid drastic changes in factory operations.

The fundamental diffusion processes governing the formation of clinker minerals in Portland clinker were dealt with in a paper on applied research in process control. Methods of directly evaluating the soundness of the clinker through the microscopic study of polished clinker sections were explained, and reasons for anomalies determined.

The importance of pozzolanic materials as admixtures to cement was emphasized on several occasions as a means of conserving energy and protecting the environment against the piling-up of waste, such as fly ash and metallurgical slags, near power plants, steel works etc. Developments in France suggest that extensive quantities of industrial tailings could be applied in the production of good cement and also in road construction.

Environmental protection, pollution control and the development of appropriate international standards were discussed. Pollution control equipment should from the outset be installed as part of the factory because retroactive modifications are usually very expensive.

The need for safety awareness was also mentioned, and it was noted that the physical working environment requires continuous attention in order to reduce the risk of factory accidents. A good record in this respect was reported by at least one of the factories visited in China.

Part two. Summaries of papers presented and discussions

Background information for seminar on cement technology in China

Fang Run

The history of the Chinese cement industry from its beginnings in 1949 to the present is reviewed. Current annual production has reached 75 million t, 35% of which is manufactured in large- and medium-size cement plants and 65% in mini-vertical-shaft-kiln plants. Different varieties of cement are manufactured in relative amounts of approximately 50% ordinary Portland cement, 40% slag cement and 10% pozzolanic, rapid-hardening, oil-well, low-heat, white and other cements. Raw materials and fuels and the utilization of various industrial wastes are discussed, and attention is drawn to specific problems facing the Chinese cement industry today.

During the discussion following the presentation of the paper additional information about the cement industry in China was given. Small cement plants are established mainly in areas having cement supply problems but with sufficient access to raw materials and fuel, even when the latter must be transported for some distance. Large factories are sited near important raw material deposits and close to the market or to transportation facilities connecting the factory efficiently to the market.

For cement plants with an output smaller than 200,000 t/a the shaft kiln technology is usually applied. Investment costs for new cement plants in China amount to about 100 yuan per t of cement produced annually in shaft kiln plants and about 200 yuan in large rotary kiln cement plants.

The burning process of cement shaft kilns in China

Huang Jinyang, Wong Xiangming and Wong Yiguang

The paper outlines the production technology of shaft kiln cement works in China. Various aspects are considered, including burning technology, kiln ventilation, the reduction of the free lime content of the clinker, the height-diameter ratio of the kiln and large-diameter kilns. China has successfully developed and applied shaft kiln technologies such as the differential heat burning process and the black-meal process. It is possible to maintain regular operations in China using short and wide kilns with a suitable height-diameter ratio. Such kilns, with dimensions of 3.6 m in diameter and 10 m in height, have been in steady production for over a year.

With regard to the differential heat burning process, in the ensuing discussion it was noted that the amount of coal in the feed for the peripheral zone (1,100 kcal per kg of clinker) seemed to be too high, possibly because of excessive ventilation in the peripheral zone and excessive heat loss from the kiln shell. It was also suggested that in order to keep CO losses low, the fineness of the coal should not be too high. Moreover, height-diameter ratios of less than 3.3 were thought to result in poor cooling of clinker.

Discharge and sealing technique for cement shaft kilns

Yang Dahua

The paper describes a new and simple clinker discharge system with an air-locking system for vertical shaft kilns, known as the material blocking discharger, and compares its operation with traditional discharge systems. It involves locking the air by means of a clinker-filled discharger tube. The major advantages of the material blocking discharger are its structural simplicity, small steel requirement, low weight and cost, easy maintenance, slight air leakage and convenience in dedusting. Suggestions for further improvements and automation of the discharger are also outlined.

It was generally agreed that the material blocking discharge system developed in China might be of great interest to many developing countries applying the vertical shaft kiln technique. The simplicity, reliability and effectiveness of the system, together with the very low installation cost, makes it a very appropriate technology for transfer to vertical shaft kiln installations outside China.

Methods of evaluation and prospects of utilization of waste and brown coal as fuel and raw materials in the cement industry

Qin Zhigang, Jiang Zhigan and Wong Yiguing

The paper deals with the possible use of waste and brown coal as raw material and fuel in the Chinese cement industry. Years of industrial applications have produced results that should make possible a broadening of the scope of building material resources, saving high-quality coal, limiting pollution and improving protection of the environment. The division of waste into three categories according to its Al_2O_3 content is suggested and research findings relating to Portland and special cements are presented.

The successful firing of brown coal with heat values of 2,000 kcal/kg partly or completely to replace high-quality coal is discussed. The production of cement clinker with a consumption of 800-900 kcal/kg in shaft kilns in regions like southern China, which lacks high-quality coal, has made possible the rapid development of mini-cement-plants. The principle of using waste to replace clay and save fuel is similar. A reappraisal of shaft kilns therefore seems appropriate because of their low energy consumption and reasonable resource requirements.

In the discussion it was pointed out that no nodulizing problems had been observed in small plants (7,000-10,000 t/a) where the materials had been used. Larger vertical shaft kiln plants (60,000 t/a) may be more sensitive to the quality of nodules. However, no additive chemical binder has been used so far to facilitate nodulization.

Heat economy of cement rotary kilns

Zhu Zupei

Theoretically, 400-430 kcal of heat are required to produce 1 kg of cement clinker. In practice, however, 750-1,800 kcal per kg of clinker may be consumed in cement rotary kilns because heat losses are unavoidable in kiln operations. The main sources of heat loss are as follows: heat required for evaporation of water; exit gas, cooler ventilation air, clinker etc.; and radiation loss from the kiln shell.

The following measures can be taken to reduce kiln heat losses:

(a) Decreasing the amount and temperature of exit gas in order to reduce exit gas loss;

(b) Increasing the specific kiln output or using insulating bricks to reduce radiation loss;

(c) Decreasing the water content of slurry for the wet kiln to reduce the heat required for evaporation;

(d) Utilizing the cooler vent air to dry raw coal, or reducing cooling air so as to limit cooler vent loss. However, since a reduction in the amount of cooling air will increase both the exit temperature of clinker and clinker loss, a suitable compromise between them must be found.

In addition to the above-mentioned measures, an improvement in the burnability of raw meal and a decrease in the clinker heat requirement will also reduce total heat consumption.

Various problems arise in connection with the different heating systems of cement rotary kilns. In the combustion process, the problem is to ensure that the heat is effectively released from the fuel. In the heat transfer process, the prompt and efficient transfer of released heat to material must be considered. During the burning of material in the thermochemical process, the reactions must be made to occur rapidly.

With regard to the combustion process, a correct amount of air supplied for combustion is necessary to reduce the exit gas loss. The combustion air supply must be neither too big nor too small. A certain O_2 content in kiln exit gas is necessary to secure a complete combustion of fuel in the kiln. It is advisable to accelerate the combustion rate as much as possible in the kiln operation, without damaging the kiln lining. The result would be an increase in the flame temperature favourable to both clinker quality and kiln output. To accelerate the combustion rate would also shorten the flame length, and thus save combustion space and lower the exit gas temperature. The kiln operator would then be able to raise output further without increasing heat consumption. A long high-temperature burning zone could therefore be established with high-quality output and low fuel consumption.

In the heat transfer process, the type of heat transfer in the high-temperature (sintering and calcining) zones of the kiln is different from that in the low-temperature (preheating and drying) zones. Since heat transfer in high-temperature zones mainly depends upon radiation, a higher gas temperature will promote the heat transfer. The rotating speed, angle and charge of a kiln also influence the process. Heat transfer in low-temperature zones can be promoted only by increasing the contact surface between gas and material.

The effect of the fineness of raw meal and the influence of the liquid phase on clinker formation are discussed in connection with the thermochemical process. Information is also given concerning mineralizers and additives for slurry, lime and blast furnace slag as raw materials, black slurry and the coating of kiln linings in cement plants in China.

The contradiction between kiln output and heat consumption is not an antagonistic one. Increased output does not necessarily mean increased heat consumption. There is a point which represents the most economical output for every kiln. Below that point, kiln output can be raised without increasing heat consumption. A kiln with an output below that point is considered to possess a potential production capacity. In order to tap that potential, a concept called "three bigs and one fast" was suggested by the cement industry of China in 1958. The paper reviews that proposal and concludes that the basic requirement for improving the heat economy of the rotary cement kiln is to harmonize the relation between the heat release capacity and the heat transfer capacity of the kiln.

In the ensuring discussion it was noted that water cooling seems to lower the inner surface temperature of the lining and make possible a more rigid attachment of the coating to the lining bricks. The lifetime of the lining in the burning zone achieved in China is about six months. The problems arising from the use of slags in the raw mix, which is done in only a few plants, were also mentioned. A far greater amount of slag is used as admixtures to clinker.

Technique and economy for the use of lignite in cement rotary kilns

Study by a team of Chinese experts

The paper describes a successful attempt to use lignite as a fuel in manufacturing ordinary Portland cement at the Kay Yuan Cement Plant, Yunnan Province. The test programme was conducted in a wet-process kiln measuring 3.3 m, 3 m and 3.3 m in diameter and 118 m in length. The results seem to demonstrate the feasibility of burning high-quality cement clinker with inferior lignite as a fuel so as to expand the available energy resources. Lignite has a high moisture content and low calorific value (2,000-3,000 kcal/kg). When burned in the wet-process kiln, the flame length became longer, the combustion temperature decreased, the heating power of the kiln declined, the heat consumption of clinker increased and the kiln output dropped by about 15%. As countermeasures, the burnability was adjusted accordingly, the rate of primary air increased, and adequate thermal conditions and operation methods were worked out. At the same time, the capacity of the drying equipment and grinding system for raw coal had to be increased.

Experience at the Kay Yuan Cement Plant during the past ten years has shown that although the kiln output is rather low, the quality of the cement clinker is good. The plant provides a good example of the results that may be achieved through the efficient utilization of an abundant local energy resource.

It was pointed out in the discussion that when lignite is burned, as in heat production, the remaining fly ash sometimes possesses hydraulic properties and can be added to the clinker in the cement mill for making blended cement.

Precalcination with coal

Huang Nabyue and Xu Bingde

The paper deals with a number of different factors and technical conditions that should be taken into account when selecting among different technical solutions for coal-based precalciners. Various common types of coal-fired precalciners are discussed. It is noted that not only soft coal, but also low-grade coal and refuse can be used as fuel. The combustion process of pulverized coal should be decided according to the actual conditions.

The following recommendations are made concerning operating conditions: the excess air efficiency of exit gas should be controlled at about 1.25; the fineness of coal should be below 15% residue on an 88 mm sieve; the required retention time of coal in the precalciner should be 1.5-2.0 sec; the gas velocity in the furnace should be 5-8 m/sec; the furnace temperature should be 850°-900°C; and a multiparameter adjusting system should be used for automatic control of the furnace temperature. A suitable calcination rate of the feed would be 85-90%.

In the discussion the view was expressed that neither the particle size nor the coal quality was of much importance in coal-fined precalciners. Only the duration seemed important for burning out the coal completely. It was pointed out that in the one coal-fired precalciner plant in operation in China, the alkali content of the raw mix is about 1%, the chloride content between 0.002% and 0.005%, and the sulphur content below the normally accepted value. The increase in production after installation of the described precalciner system was approximately 100%.

Utilization of coal in cement manufacture

Villy Egesø

On the basis of various studies carried out on coal samples in cement plant laboratories, a number of coal properties of great importance to coal firing are discussed. Variations and optimal ranges of different coal properties are given in graphs showing the relationship between calorific value and volatile matter, calorific value and ash and moisture content etc. Fundamental aspects of the drying and grinding of coal are mentioned, and advantages and disadvantages of different mill types such as ball mills and vertical mills are briefly discussed. Four layout possibilities for coal grinding plants, involving direct and indirect firing, and central and inert grinding, are described.

The application of modern instrumentation and automation in coal grinding plants, an example of which is the system known as Folaphone, is also considered. The system referred to uses an electrical ear that is able to measure the vibrations in the mill tube from the grinding media. The intensity of the vibrations is inversely proportional to the quantity of coal in the mill. The electrical signal from the Folaphone can therefore be used for automatic regulation of the feed to the mill. The technique of coal-firing of rotary cement kilns is introduced, general information on coal combustion under various conditions given, and the optimum ranges of control parameters indicated for the diffusion flame characteristic of the rotary kiln burner. A bright luminous flame should be avoided because of its poor heat transmission properties. The major part of the radiation from the flame to the kiln material is emitted in the invisible infra-red range and only about 1% as visible light.

The proper dosing of coal in different firing processes is mentioned, and various types of combined firing methods involving coal and gas or coal and fuel oil are described. Safety regulations adopted for pulverized coal installations in various European countries and in the United States of America are reviewed.

A related paper by T. Enkegaard, entitled "Conservation of energy in cement manfuacture fuel and power consumption", was also summarized. The organizing committee considered that paper to be a useful background document for the discussions on energy conservation.

In the discussion it was mentioned that coal of lower calorific value than 4,000 kcal/kg would be of interest for cement production in only a few cases. Low-grade coals causing temperature problems may require supplementary firing with fuel oil.

For practical reasons coal is usually ground to the same fineness both for the precalciner and the kiln. The dedusting of coal grinding facilities could be made with electrostatic filters, the modern versions of which are efficient and safe. The temperature is kept under control and the design of the modern filter nearly eliminates the risk of fire caused by the ignition of settled coal dust inside the filter.

Economical aspects of Loesche vertical kiln for compact cement plants of small capacity

H. Klatt

The historical development of the vertical shaft kiln technique is described and the need for such a technique in small-scale cement plants discussed in the light of the industrialization levels and availability of resources in different parts of the world. Small vertical shaft kiln plants based on new process technology with improved homogenization and nodulizing techniques may still be economically feasible, if certain basic requirements are met. A location far from larger industrial centres in a remote area with poorly developed transportation facilities and with a limited local demand for cement favours the installation of compact vertical shaft kiln plants.

Experience has shown that the smallest reasonable production unit for cement is a plant producing 60,000 t/a. Plants with a capacity of 90,000-120,000 t/a are very likely to be economically sound, and plants up to, but not above, 200,000 t/a could still be regarded as compact vertical shaft kiln plants.

Operating conditions in vertical shaft kiln plants are dealt with. The black-meal process of intergrinding the fuel, developed in the Federal Republic of Germany during the 1950s, seems to have important advantages compared with earlier techniques, especially with regard to clinker homogeneity. General figures for installation and operating costs and average values of heat and power consumption are presented, together with energy loss estimates.

If market requirements are restricted to small-scale consumption, the installation of a compact vertical shaft kiln plant seems feasible. The advantages of such plants are low investment, operating and maintenance costs, substantial savings in space and a high degree of reliability owing to the durability of refractory bricks. Given current energy constraints, the use of low-cost coal would be an additional advantage of vertical shaft kiln plants.

In Europe, as was noted in the discussion, the use of shaft kiln installations has been declining in favour of large cement plants with the smallest possible labour force, because wages are high and constant high demand for cement easily justifies the establishment and maintenance of large units.

Most developing countries have a different profile in the economy and use of cement, and shaft kiln plants represent a valid solution for demand below 200,000 t/a if the raw materials available are suitable for the shaft kiln process.

The efficiency of the shaft kiln has been considerably improved over the last 25 years, and cement produced from a shaft kiln plant can meet the same specifications as normal Portland cement from rotary kiln plants. The improvements in technique over the past 25 years have resulted in homogenization by means of preblending, uniform kiln feed without excess moisture (nodulizing pans), efficient kiln ventilation (Roots blowers), good fuel economy (exact proportioning of fuel and raw mix combined with efficient insulation of kiln), minimum air leakages (efficiently sealed discharge gate), continuous operation (kiln design and efficient discharge grate) and generally robust equipment with dust-free enclosures for motors, gears and bearings.

Cost of new cement plants and conversions

Oliver Jensen

The paper briefly outlines the aspects of installing new dry-process cement plants, focussing on comparable costs of plants of various outputs. It further deals in general terms with the conversion of plants from wet to dry process and comments on the replacement and modernizing of old plants

The complexity and the magnitude of the parameters make it difficult to present general guidelines on the problems dealt with. Sound advice can only be given in the context of thoroughly prepared projects taking into account individual conditions.

It was stated during the discussion that conversion of a wet process plant into a dry process plant depends on the local situation. Although the kiln capacity can easily be increased, other limiting factors can make the whole enterprise uneconomic. The best results have been obtained when a major plant expansion and a conversion from wet to dry process is made at the same time.

An intermediate solution may be to maintain the wet process and let the finished slurry pass a filter press to reduce the moisture content in the kiln feed. In addition to the filter press installation, changes in the chain system of the kiln will also be required.

Atmospheric pollution in cement plants

Jean-Claude Hillenmeyer

The development of pollution controls in the cement industry since 1950 is described. To illustrate the increasing international concern about pollution control during the years 1950-1978, representative figures are given for dust emission from the European and the North American cement industry. It appears from the data that the quantity of dust emitted has dropped significantly from 3% to 0.1% of annual production during the period mentioned.

The emission of dust and sulphuric compounds from a 1-million ton cement plant is compared with the emission of the same component from a city with a population of 1 million. A remarkably lower emission is noticed from the cement plant, especially for the sulphuric compounds.

Pollution control regulations in force in Eastern Europe, Western Europe, North America and other countries are breifly reviewed, and observations are made on pollution control in developing countries.

In the discussion it was noted that efficient pollution control has been shown possible through the use of electrostatic precipitators. However, the internationally recommended pollution limits appear to be at present too strict and expensive to enforce in many developing countries.

History of pozzolanic fly ash use in France

Jean-Paul Meric

Pozzolanic fly ash has been used in France since 1952 in the manufacture of various cements. Some types of standard cements may contain up to 35% of pozzolanic materials and some special binders are made of a mixture of fly ash and slag. The use of pozzolanic materials not only meets economic requirements but also improves the general properties of cement and concrete. Fly ash also finds many other outlets in road construction.

Fly ash has many uses related to cement production, as was noted in the discussion. It can be used as a component in the raw mix or as a pozzolanic additive to the finished cement. Limitations in the use of fly ash depend on the quality of the fly ash and how long it needs to be transported. Low initial strength and coal impurities are the main limiting factors.

Applied research in process control

G. Roed

The paper presents the results of a comparative investigation of seven different cement factories, all of them medium- to large-scale rotary kiln plants. The work included physical tests and chemical analysis of cements, microscopic investigations of clinker samples and fineness analysis of raw mixes. The research programme was primarily intended to be a training programme for the scientific staff at a local laboratory, and a brief introduction to the application of equilibrium phase diagrams in cement research is given.

The usefulness of a recently published theoretical burnability model for cement raw mixes is demonstrated by the correspondence between calculated and experimental results. The burnability model used is based on the philosophy of a diffusion-controlled clinker reaction. The extreme importance of the raw mix fineness and homogeneity to burnability and clinker quality is emphasized.

Although the work described was carried out on materials and products from rotary kiln plants, the results and conclusions are also relevant to other processes, such as the vertical shaft kiln process. That is because the controlling mass transport mechanism in the clinker reaction is the diffusion process, whereas the mechanical mixing effect in the rotary kiln plays a minor role in the completion of the clinker reaction.

It emerged from the discussion that the equipment needed for a microscopic examination at present costs less than $30,000, and that the methods developed make it possible to check the suitability of the raw mix and its burnability, including the formation of the necessary clinker minerals and their possible decomposition with slow or quick cooling. The author had never found traces of decomposed alite, and the cooling speed of clinker minerals once formed in an industrial kiln cannot be proven to have any importance for the cement quality.

Kiln control

Villy Egesø

Two examples of kiln control sytems are discussed, namely a manual-automatic and a semi-automatic system. Reasons are given for the failure of attempts in recent years to develop fully computerized kiln control systems. The manual-automatic control system is based on a manual adjustment of set values of selected external conditions important for the kiln operation, such as the quality and quantity of raw meal feed, fuel supply and the amount of gas draught in the kiln system. The defined conditions are then maintained by automatic control loops. The manual adjustment of set values is based on information on kiln operation, including observations of the clinker charge in the cooling zone, kiln torgue clinker quality, free lime content, litre weight etc. The installation of continuous analysers of the NO_x content of the exhaust gas, primarily used for pollution control, has also appeared to be a useful parameter in kiln control.

A further development in automatic kiln control systems presented in the paper is the semi-automatic system known as fuzzy-control, based on an automatic adjustment of set values according to a series of typical preselected states in which the kiln could be encountered.

As was noted in the discussion, the application of sophisticated process control equipment requires special measures for its maintenance and accurate functioning. If such conditions cannot be created with a good margin of security, the plant should be operated by conventional means, including sampling and analysis.

Pollution control in shaft kiln factories

P. F. Janssens

The paper deals with dust and noise pollution in vertical shaft kiln plants. Figures for dust emission from larger-scale plants during the period 1950-1975 are listed for comparison with relevant values for vertical shaft kiln plants. Pollution sources are analysed and possible methods of reducing or eliminating them proposed. Since the most commonly used dedusting equipment is well known, the paper concentrates on more specific pollution control problems and equipment.

The dedusting of exhaust gas from shaft kilns was discussed and it was concluded that both bag filters and electrostatic filters could be applied.

Structure and nature of pozzolanas and their application in the cement industry in China

Fang Derui and Tong Sanduo

General properties such as chemical composition and the physical and mineralogical characteristics of a variety of Chinese pozzolanas are discussed, and the methods of evaluating the quality of pozzolanas for application in cement industry reviewed. Hardened pozzolanic cement samples were studied with respect to chemical, physical and physico-chemical properties. In spite of the relatively low activity of Chinese pozzolanas, they are widely used for pozzolanic cement production. They make an important contribution to energy conservation efforts and improve certain characteristics of cement products. Abundant resources of natural zeolites have recently been found in China. They possess high pozzolanic activity, and seem to be a promising resource for future applications in the cement industry.

In the discussion it was noted that the behaviour of the pozzolanas was not affected by the type of cement used. Although the two constituents are normally ground together, by grinding clinker and pozzolanas individually, the early strength of pozzolanic cement can be considerably increased with a corresponding increase in power consumption.

Additional technical information

Various other matters dealt with in the discussions are outlined below.

Type of plant used

The use of vertical as opposed to rotary kilns is usually considered for a maximum cement production of 200 t/d.

Wet or dry process

When converting from the wet to the dry process, it must be remembered that the former process requires less electrical power than the latter. Fuel cost reductions may therefore be partially offset by the power cost increase. It should also be noted that the alcaline content of the raw materials and the related problem of cyclone blocking should be thoroughly studied before conversion from the wet to the dry process.

Simple conversion can be done without much loss in production because the main parts of a two-stage preheater can be built with the wet kiln in operation. Only a one-month break in production will be needed to complete the change. A simple conversion may result in a production increase of up to 20% and calorific consumption corresponding to 950-1,100 kcal per kg of clinker.

Choice of cooler

The choice between planetary or grate coolers is not easy. The mechanical difficulties encountered with the big planetary coolers have been solved and their insulation has been improved. The final temperature of the clinker is therefore as low as in the case of grate coolers.

Grate coolers use excess air that must be dedusted and applied to the drying of raw material or the coal used for firing the kiln.

Parameters of verticle kilns

Suitable ratio of diameter to height: 1: 3.6

Suitable air pressure for each 1 m in height of the kiln: 200 mm water gauge

Suitable air quantity: 1 m^3/min for 1 t/d

Surface porosity of good nodules: 30%

Normal output: 50 t/d per m^2 of the sintering zone area

Capacity of nodulizer: diameter x 1.75 = capacity in t/h

Roller mill parameters for coal grinding of raw materials in an air-swept mill

As the density of coal is small (1.4) compared with the density of limestone shale or clay (2.6), the coal will pass quickly through the mill and not be ground very fine. The coal fineness will be 25-30% above 88 microns, while the raw materials will be 10% above 88 microns. Coal of that fineness is quite suitable for firing a vertical kiln.

Power consumption is less for roller mills than for grinding ball mills, but the mechanical wear is greater. The retention time of materials is two minutes instead of 20-30 minutes in ball mills. That facilitates quick changes or corrections of the raw mix composition.

Cement technology

Experience from the last 30 years of development within the cement industry has shown that the rotary kiln technique is superior to the vertical shaft kiln technique in all respects, provided an annual production of over 200,000 t is justified. However, for smaller production capacities required by certain local conditions, the vertical shaft kiln technique may still be a relevant technological alternative for a number of developing countries.

The development of vertical shaft kiln technology in different parts of the world has led to the application of the black-meal process and the semi-black-meal process. The black-meal process seems to possess some advantages with respect to clinker quality and kiln control that justifies recommending it for vertical shaft kiln production. However, the difference between the two processes seems to be minor. A change from the semi-black-meal to the black-meal process involves modifications of the nodulizing operation and the air draft conditions of the kiln because of the significantly increased activity of the finely ground coal used in the black-meal process. As a result, a considerable amount of coal particles react with the CO_2, which is liberated from the limestone in the hot zone (Beaudoir reaction), thus producing an increased combustion rate.

Some developed countries have extensive experience in building and operating cement factories. Developing countries should therefore consider taking appropriate advantage of such experience until they reach a suitable level of development in the field of cement technology. It should however not be overlooked that some developing countries are fully capable of helping other developing countries. UNIDO is promoting such technical co-operation among developing countries.

Cement quality

With regard to cement and clinker quality and the subject of combustibility, there appears to exist a general assumption that the cooling rate of clinker from vertical shaft kilns under normal operating conditions puts certain limits on clinker quality. It is assumed that an increased level of free lime is unavoidable result of slow cooling because of the decomposition reaction of alite: $C_3S \rightarrow C_2S + CaO$. However, the reaction is seldom if ever observed in actual cement production, even under the special atmospheric conditions of reduction that normally exist in a vertical shaft kiln. Representative samples from a number of vertical shaft kiln plants in China have been examined microscopically, with special attention being paid to the appearance of C_3S and the free lime. In all cases the alite phase was unaffected by the cooling and no indication of decomposition reactions were observed. Furthermore, in all the samples investigated, the content of free lime could be identified as primary free lime originating from incompletely reacted coarse lime particles inhomogeneously distributed in the clinker matrix (see also the paper entitled "Applied research in process control", by G. Roeds).

Energy conservation

The conversion of plants from the wet to the dry process is an interesting, but not easy, solution. Capacity increases with a modified kiln will require expensive changes. The usual solution is to modify in combination with a plant extension. The modification will include conversion of the wet raw mills to cement mills and installation of a new raw materials department, with the raw mills, storage facilities, and means of transport required for the combined capacity of the modified kiln and the new kiln.

Annex I

CEMENT PRODUCTION IN CHINA AND DESCRIPTION OF THE PLANTS VISITED

Cement production in China

China is a very large country with a constantly increasing need for cement. A consumption of 94 million tonnes of cement is planned for 1985 and 150 million tonnes, according to conservative forecasts, in 2000. To meet such demand the cement industry must have a well-prepared programme of expansion, with special attention being given to the following points.

Plant location

All new plants should be close to the raw material deposits, which must be sufficient to cover up to 50 years of exploitation. New plants should be away from residental areas and easily accessible by road, water or rail.

Plant capacity

A detailed survey of available resources and future cement needs in each province of China must be carried out in order to assist in selecting building sites and technology for new factories.

Description of plants visited

Jinan

Dry process plant

Yearly production: 300,000 t of blast furnace slag cement (30% slag)

Raw materials: Limestone and coal located near the plant
Iron oxide and pyrite ashes

Crushers: Two steps, jaw and impact crushers

Raw materials

Drying: rotary dryers

Grinding: Ball mill, 2.2 m in diameter, 13 m in length, 43 t/h, open circuit, with addition of coal (semi-black process)

Fineness: 9%, 80 microns

Clinker burning section

Two vertical kilns, 2.9 m in diameter, 9 m in height

Production: 300 t/d for each kiln

Heat consumption: 960 kcal/kg

Nodulization: pan 2.8 m in diameter, 14% water

No dedusting: two precipitating chambers

Jaw crushers and cyclone dedusting

Coal grinding: two ball mills

Coal quality: moisture, 6%; ash, 23%; volatile matters, 10%; sulphur, 0.3%

Cement grinding section

Five mills, 1.83 m in diameter, 6.1 m in length, 7.5 t/h when open circuit
8.5 t/h when closed circuit

Fineness: 7%, 80 microns

External cooling of the shells with water

Power consumption: 99.4 kWh per t of cement

1,345 employees

Observations

The nodulization process could be improved by using a larger nodulizer pan (3.6 m in diameter instead of 2.8 m). The rotating speed should also be increased to 77% of the critical value. The recommended inclination is 22°-25°. That would make is possible to obtain nodules of much better size and mechanical strength. The air resistance of the kiln will decrease, and better cooling and a more regular sintering zone will be achieved.

In order to secure correct quantities of air for the kiln, the present turbines should be replaced by Roots blowers. Air pressure must be kept on the same value.

Since the bottle-neck of the plant is located in the raw materials grinding sections, it would be suitable to replace the present limestone and clay driers and the raw mill by a vertical roller mill. Such mill can handle limestone and clay up to 80 mm in size and with a moisture content of up to 8%. It will grind and dry limestone, clay, iron ore and coal together. Its capacity should be calculated to match the feed for the two kilns with a nominal capacity of 300 t/d.

It is probably unnecessary to cool the grinding mills by sprinkling water on the shell, considering their small size. For large cement mills internal water cooling should be considered.

Quingdao

Dry process plant

Production: 110,000 t/a of slag cement

Raw materials

Limestone has to be transported by railway from the quarry about 200 km away from the plant, thereby increasing production costs.

Raw materials grinding

Limestone, clay and the coal needed for combustion are ground in a ball mill (1.83 m in diameter, 6.1 m in length, 14.5 t/h, closed circuit) to a fineness of 4%, 80 microns.

A new grinding mill is under construction (2.2 m in diameter, 13 m in length, closed circuit, 40 t/h)

Clinker burning section

One vertical kiln: 2.5 m in diameter, 9.9 m in height

Production: 240 t/d

Heat consumption: 950 m kcal per kg of clinker

Dedusting: Electrostatic precipitator

Refractories (burning zone): 40% Al_2O_3

Roots blower: 12,000 m^3/h, 2,200 mm water gauge), oscillating grate with 4 water-cooled crushing rollers

A new kiln is under construction (3 m in diameter, 2 t/h and 9 m in height).

A very interesting automatic system for the continuous supply of water during the nodulization process is used.

Cement grinding section

Two ball mills: 1.83 m in diameter, 6.1 m in length, 2 chambers, closed circuit, 35 t/h, fineness of 4-6%, 80 microns

Cement composition: 61% clinker, 35% slag, 4% gypsum

Power consumption: 81 kWh/t

608 employees

Observations

As mentioned for the Jinan plant, the nodulization process could be improved by modifying the nodulizer.

The clinker is too hot at the discharging point of the kiln.

More air should be blown into the kiln in order to obtain better cooling, That would also help to avoid some reduction reaction in the clinker and improve the strength of the cement. The air quantity would presumably increase.

Jionan

Dry process plant

Production: 55,000 t/a of pozzolanic cement
The limestone is transported 30 km by truck and preblended with clay at the storage areas.

Raw materials grinding: mill 1.83 m in diameter, 6 m in length, 9 t/h
Fineness: 10%, 88 microns
Semi-black process

Clinker burning section
One vertical kiln: 2.5 mm in diameter, 10 m in height

Production: 200 t/d

Heat consumption: 900 kcal/kg

Three Roots blowers

Cement grinding
The clinker with 30% pozzolana is ground in 2 ball mills (1.5 m in diameter, 5.7 m in length, 4 t/h, open circuit)

Power: 81 kWh per ton of cement
Fineness: 5%, 80 microns

Work-force: 276 employees

Observations

Separate grinding of clinker and slag or pozzolanas may be considered in order to reduce power consumption and increase the quantity of slag in the blended cement. Separate grinding may necessitate additional equipment, for instance for mixing and homogenizing the blended cement.

Preblending of pozzolanas or slags should be considered in case of quality variations in the slag.

Special efforts such as the following must be made to update safety measures:

(a) Screen plates should be provided for the belt transmission instead of crates with very large spaces;

(b) Some electrical motor wiring needs to be protected;

(c) In many places protective fences are missing, for instance on a working platform situated 20 metres above ground level.

Changzhou

Dry process plant

Production: 100,000 t/a of slag cement (up to 40% slag)

Raw materials

Limestone is loaded on barges 60 km from the plant.

Clay is transported 30 km by barge.

Slag is transported 160 km.

Raw materials grinding: two grinding mills (1.83 m in diameter, 6.2 m in length)

Burning section: one rotary kiln in operation; one under construction; one vertical kiln

Rotary kilns: 2.2 m and 2.4 m in diameter and 40 m in length

Planetary cooler

Production: 5.5 t/h or 130 t/d

Heat consumption: 1,890 kcal per kg of clinker

The boiler located behind the kiln regains about 660 kcal, and as the slag is dried by mixing with the hot clinker, the final heat consumption is around 1,170 kcal per kg of clinker.

Primary air: 25-30%

Vertical kiln: 2 m in diameter, 8 m in height
Production: 130 t/d

The gases of the rotary kiln are dedusted partially in the boiler chamber, then in three cyclones, then in a big filter offering a surface of 2,000 m^2. The filter bags in fibreglass have a diameter of 250 mm and a height of 6.3 m. They work in two steps and collect 3 t/h of dust, which is sold as fertilizer, because it contains about 10% of potassium.

The boiler and the generator produce 55% of the electric power used in the plant (80 kW per ton of cement).

Capacity: 1,000 kW, 6,600 V, 50 Hz

Cement grinding

The clinker and the slag are ground in three mills.
(1.83 in diameter, 6.2 m in length; 1.83 m and 1.8 m in diameter, both 6 m in length)

Fineness: 4-5% above 80 microns for 500 kg/cm^2
and 5-7% above 80 microns for 400 kg/cm^2

Power consumption: 80 kWh per t of cement

Work-force: 665 employees

Observations

The sealing at the hot end of the rotary kiln must be improved in order to avoid big quantities of false air.

The external cooling of the burning zone is unsuitable for protecting the lining, because in case of interruption of the water cooling the coating ma ·ll off.

Th· nstruction of a retention ring at the end of the burning zone will help ·o obtain a better cooling of the hot clinker and a more regular distribution of the clinker into the tubes of the planetary cooler.

Jiangnan

Wet process plant

Production: 550,000 t/a, 50% ordinary Portland, 50% slag cement (30-40% slag)

Raw materials: limestone and clay, both quarries located near the plant

One impact crusher

Grinding: three raw mills (two 2.22 m in diameter, 14 m in length, one 3 m in diameter, 12.1 m in length)

Slurry storage: large slurry blending tank, 2,800 m^3 capacity, 33% water

Fineness: 12%, 80 microns

Burning section: three rotary kilns
2.6 m and 3.05 m in diameter, 134 m in length, 17 t/h
2.6 m and 3.5 m in diameter, 134 m in length, 22 t/h
4.5 m in diameter, 134 m in length, 29 t/h

Coal composition: 1% moisture
30% volatile matters
2-25% ash
2-4% sulphur
Calorific value of 4,800 kcal/kg

Fineness: 15%, 80 microns

Kiln No. 1: planetary cooler
Kiln Nos. 2 and 3: shaking grate cooler
Kiln Nos. 1 and 2: electrostatic precipitator
Kiln No. 3: new electrostatic precipitator under construction, heat consumption of 1,400 kcal per kg of clinker

Cement grinding: two cement mills (2.4 m in diameter, 14 m in length, open circuit, and 3 m in diameter, 9 m in length, closed circuit)

Cement packing: paper bags of 50 kg, 4 or 6 plies, 12 spout rotating packing machine (100 t/h)

Cement delivery in bulk: 25% of production

Power consumption: 100 kWh/t (ordinary)
80 kWh/t (slag)

Work-force: more than 2,000 employees

Observations

By the addition of a small quantity of tension-active agents, the water content of the slurry may be reduced. In the case of the Jiangnan plant, some experiments should be carried out because each decrease of 3% of the water content will correspond to 75 kcal per kg of clinker.

An oxygen analyser is recommended to help in the exact operation of the kiln, especially when an electrostatic precipitator is used.

Continuous recording of all the main variables in operating the kiln will be useful for the correct operation of the kiln and for evaluating its performance.

The utilization of isolating refractory bricks between the shell of a rotary kiln and the usual refractory lining is not recommended. Several unsuccessful experiments have been made in Europe with extra insulation.

Analysis o   ment production at plants visited

Item	Chemical composition (percentage) and mechanical strength (kg/cm^2) Quingdao	Jionan		Changzhou	Jiangnan	
Material		Limestone	Clay	Limestone	Limestone	
Less on ignition		38.5	6	42.4	37 to 42	
SiO_2		8.2	68	1.2	3 to 10	
Al_2O_3		1	13	0.32	0.5 to 2	
Fe_2O_3			5	0.23	0.6 to 2.76	
CaO		50.14	2.4	54.2	48.8 to 53	
MgO		0.6	2.5	0.78	0.3 to 0.9	
Material	Raw meal	Raw meal		Raw meal	Slurry	
Loss on ignition	38	37.57		34.94	36.91	
SiO_2	12.25	12.95		13.57	11.6	
Al_2O_3	2.86	2.46		3.45	2.6	
Fe_2O_3	2.44	1.86		2.32	3.29	
CaO	41.77	42.72		42.02	44.8	
MgO	1.16	3.11		1.12	0.6	
Clinker						
Loss on ignition	0.53	0.54				
SiO_2	21.06	21.38		22.15	20.82	21.16
Al_2O_3	5.26	4.25		5.9	5.64	5.42
Fe_2O_3	4.36	3.76		4.01	5.6	5.4
CaO	65.43	65		64.85	66	66
MgO	1.89	3.41		1.77	0.93	0.94
Free lime	3.06	3.25		0.87	1.2	1.12
C_3S	52.42	55		46.17	59.56	60.66
C_2S	26.26	19.75		20.68	14.84	14.84
C_3A	6.55	4.88		8.82	5.48	4.89
C_4AF	13.25	11.43		12.28	16.95	15.51
Bending Strength (kg/cm^2)						
3 days				61	63.5	66.3
7 days		40 to 53		68	74.3	82.9
28 days		65 to 78			88.5	

(continued)

Item	Chemical composition (percentage) and mechanical strength (kg/cm^2)			
	Quingdao	**Jionan**	**Changzhou**	**Jiangnan**
	Compressive strength (kg/cm^2)			
3 days			277 to 329	315 342
7 days		190 to 255	390 to 449	445 508
28 days		350 to 447	585	687

Annex II

LIST OF DOCUMENTS

ID/wg.326/1	Methods of evaluation and prospects of utilization of waste and brown coal as fuel and raw materials in the cement industry
ID/WG.326/2	Structure and nature of pozzolanas and their application in the cement industry in China
ID/WG.326/3	The burning process of cement shaft kilns in China
ID/WG.326/4	Heat economy of cement rotary kilns
ID/WG.326/5	Background information for Seminar on Cement Technology
ID/WG.326/6	Discharge and sealing technique for cement shaft kilns
ID/WG.326/7	Precalcination with coal
ID/WG.326/8	Technique and economy for the use of lignite in cement rotary kilns
ID/WG.326/9	Conservation of energy in cement manufacture, fuel and power consumption
ID/WG.326/10	Economical aspects of Loesche vertical kiln for compact cement plants of small capacity
ID/WG.326/11	List of documents
ID/WG.326/12	Cost of new cement plants and conversions
ID/WG.326/13	Pollution control in shaft kiln factories
ID/WG.326/14	Utilization of coal in cement manufacture
ID/WG.326/15	Applied research in process control
ID/WG.326/16 + Corr.1	Atmospheric pollution in cement plants international point of view
ID/WG.326/17	History of pozzolanic fly ash use in France
ID/WG.326/18	Kiln control
ID/WG.326/19	LD steel slag-zeolite cement