OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

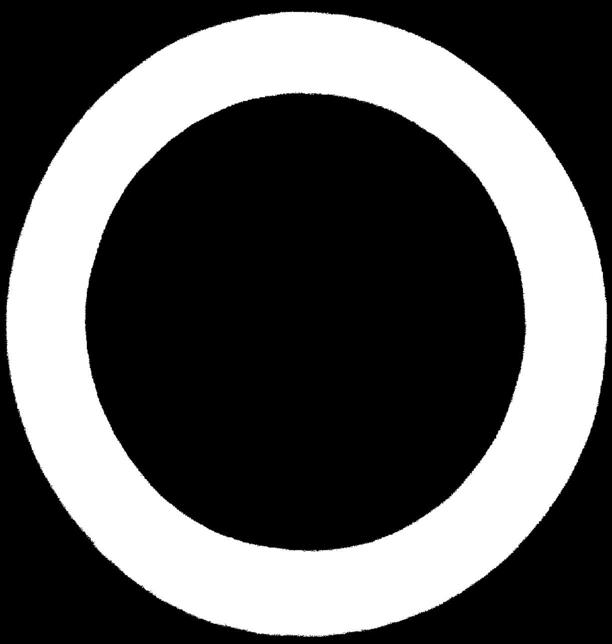
Please contact publications@unido.org for further information concerning UNIDO publications.

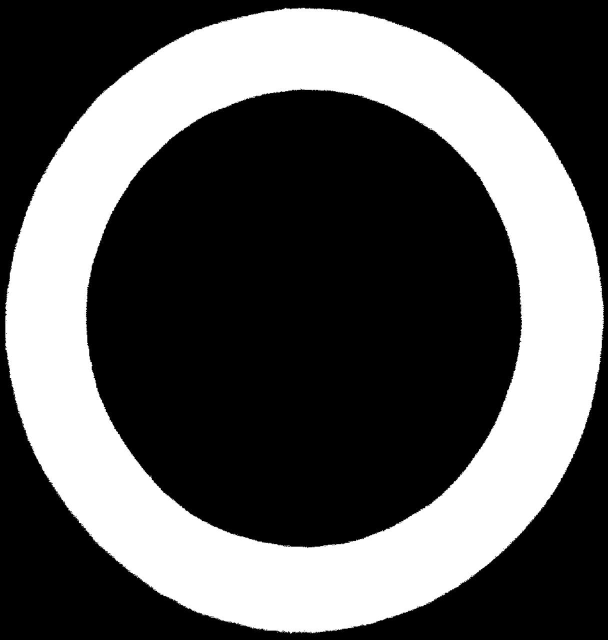
For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

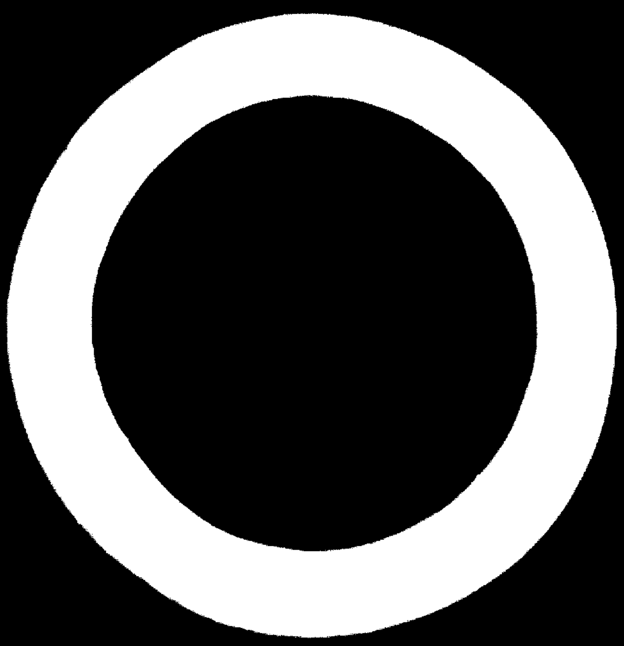
THE MANUFACTURE AND UTILIZATION OF PORTLAND CEMENT

UNITED NATIONS





THE MANUFACTURE AND UTILIZATION OF PORTLAND CEMENT



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

THE MANUFACTURE AND UTILIZATION OF PORTLAND CEMENT

Report of the Interregional Seminar held at Holte, Denmark, 7–20 May 1972

including a summary of lectures presented to the Seminar

UNITED NATIONS
New York, 1972

ID/97
(ID/WG.125/8/Rev.1)

UNITED NATIONS PUBLICATION
Sales No.: E.72.II.B.32
Price: $US 1.00 (or equivalent in other currencies)

CONTENTS

Explanatory notes

Reference to tons indicates metric tons and to dollars ($) United States dollars.

The following abbreviations have been used in this publication:

ASTM American Society for Testing Materials

ISO International Organization for Standardization

UNDP United Nations Development Programme

Introduction

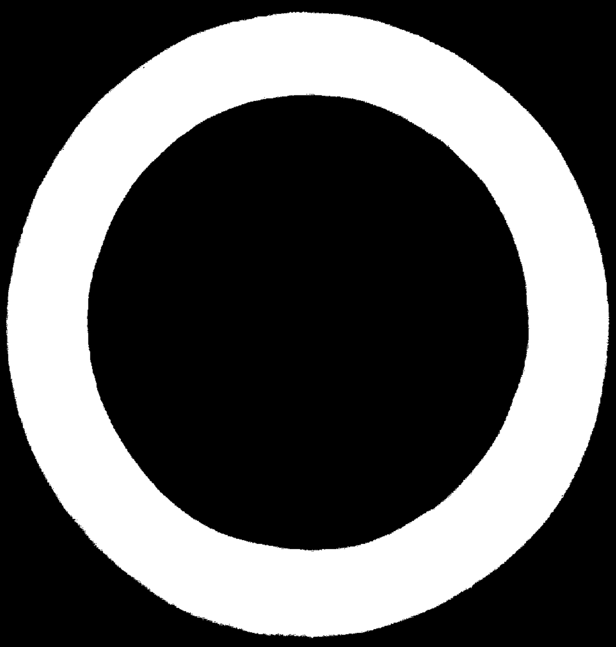
The Interregional Seminar on the Manufacture and Utilization of Portland Cement[1] was held at Holte, Denmark, from 7 to 20 May 1972. It was organized jointly by the United Nations Industrial Development Organization (UNIDO) and the Danish International Development Agency (DANIDA).

The Seminar provided a forum for the exchange of technical information on the cement and concrete industries. It explored the uses of cement as an industrial product and as the basic material for other industries. During a parallel activity, meetings were arranged between representatives of industrial and consulting firms and the participants in the Seminar. The Seminar was attended by 25 participants and observers from countries in Africa, Asia, Latin America and the Middle East as well as 30 representatives of industrial firms. In addition to lectures, country papers were presented by participants from Argentina, Bolivia, Brazil, Egypt, India, Indonesia, Iraq, Libya, Mauritius, Mexico, Peru, Saudi Arabia, Sudan, the Syrian Arab Republic, Tunisia, Uganda, the Union of Soviet Socialist Republics, the United Republic of Tanzania and Zaire.

S. A. Koch-Petersen, DANIDA, was director of the Seminar. H. C. Alsted Nielsen, DANIDA, C. Rydeng, Industrial Technology Division, UNIDO, and Q. Tran-Le, Industrial Policies and Programming Division, UNIDO, were Co-Directors of the Seminar.

The participants visited a cement factory, an asbestos cement plant, a ready-mixed concrete plant, prefabrication industries and producers of aggregates and basic materials.

[1]The Seminar was a further development of the Interregional Seminar on the Cement Industry held in Denmark, from 2 to 16 May 1964 (see ST/TAO/SER.C/71).



Part one

REPORT OF THE SEMINAR

SUMMARY OF THE DISCUSSION

Development and planning

The economic and social importance of well established cement and cement-based industries was recognized. However, the establishment of these industries is a difficult phase in industrial development: governments should give special priority and support to these capital-intensive industries.

Although the profitability of cement plants compared with other industries often appears to be low, cement is one of the basic building materials in the industrialization process. Therefore, governments should encourage and support appropriate growth in cement and cement-based industries. Furthermore, new cement projects generate employment through the diverse uses of cement. However, since the return on capital investments is limited, a carefully prepared feasibility study is a prerequisite to the planning of new cement plants and expansion of existing facilities. Only well-prepared and carefully evaluated estimates of the expected profitability will be favourably considered by prospective investors. A general guideline for a healthy return on the invested capital is that not only should it provide the necessary amortization of the fixed assets but also appropriate dividends to shareholders and the accumulation of reserves for future investments.

Important factors in the optimal location of a cement plant are the market to be served and the raw-materials supply. The transport costs in relation to this location must be calculated in the feasibility study.

A cement plant should be established with an annual minimum capacity of 150,000 tons. In some cases, political considerations might justify the establishment of a plant with other economic and technical parameters. The capital cost for a new cement plant is $50 to $75 per ton annual capacity. The installation of equipment to eliminate environmental pollution increases the annual capital cost requirements to $85 per ton annual capacity.

The establishment of complete cement plants could be preceded by installation of clinker grinding plants to justify the larger investments or by the use of imported cement. However, the imported cement should be sold and distributed in accordance with valid standard specifications.

After the decision has been made to establish a cement industry in a new area, skilled personnel must be recruited. During the construction period, technicians and skilled workers must be selected. The key personnel, such as burners and foremen, must be trained in advance so that they may be familiar with their duties when the factory starts production. Moreover, all new factories usually require a team of specialists to assist and control operations during the commissioning period. The value of the equipment in cement plants often justifies the permanent presence of a production specialist from the supplier to ensure correct and efficient plant operation.

To satisfy the gradually increasing demand for cement, it is advisable to expand an existing plant by installing a new unit of at least the same capacity as the first unit. During the period prior to the operation of the new facilities, the increased demand could be satisfied by importing sufficient clinker to use the maximum capacity of the existing plant.

The choice of the manufacturing process depends on the raw materials. The dry process will generally be preferred, unless special conditions justify the use of the wet or a semi-dry process. Important considerations are the actual content of impurities and moisture. The wet process may be favoured when there is a high content of alkalis, chlorides and sulphates; the semi-dry method may be used under special conditions after beneficiation of the raw materials by wet methods.

Concrete and aggregates

Aggregates are needed for the production of concrete. Natural aggregates are obtained directly from geological deposits or by the crushing of rock. In both cases, a careful grading of the aggregates is required to ensure concrete of good quality. Cube-shaped particles in crushed aggregates are made by using cone-crushers. However, proper operation of the crushers is vital. When evaluating new aggregate supplies, the chemical stability of the raw materials should be determined; alkali reactive aggregates require special attention.

Certain types of aggregates will cause alkali aggregate expansions in concrete when exposed to wet conditions. Although the very basic mechanisms are not well understood, the main types of active aggregates are amorphous SiO_2, flint and basic volcanic rock (high content of glass).

Aggregate reactions can be avoided by using stone materials that do not contain active alkalis or cement with a low alkali content. The negative effects of these reactions could be minimized by making good dense concrete or by intergrinding of pozzolana and Portland clinker. The presence of dangerous aggregate might be detected by one of the well-defined ASTM methods [either the fast chemical method (ASTM C289 64) or the expansion test (ASTM C227 67)].

Calcium chloride causes corrosion in the steel used for reinforcement. Therefore, the following limits are suggested in the use of reinforced concrete: 1.5 per cent $CaCl_2$ calculated on cement basis with plain reinforcement and 0.5 per cent with prestressed reinforcement. For unreinforced concrete, the limit is 2.5 per cent.

Sulphate-containing aggregates are common in certain countries. In Iraq, for example, a maximum limit of 0.25 per cent of SO_3 in aggregate is used. A final statement could not be made on this question as very little literature on this subject is available. Furthermore, various countries have different limits for SO_3 that are probably related to the composition of the sulphates in the aggregates ($CaSO_4$, $MgSO_4$ and $BaSO_4$).

Special cements are necessary in certain cases, but they should be avoided as far as possible. Danish experience has shown that harbour structures previously made with cement mixtures containing diatomaceous earth may be constructed from ordinary grey Portland cement provided the right concrete quality is made.

A general discussion was held on recommended methods for mix design. The well-known British Road Note No. 4 gives very good guidelines and is valid for the initial approach. Large stones are generally not used in concrete in Europe. However, they can be used provided that the surfaces are clean and there is no direct contact between the stones.

Curing at elevated temperatures is a well-established procedure but the ultimate strength may be reduced as much as 20 per cent. Furthermore, proper attention should be paid to the time-temperature relation during the curing process.

The concrete made by the Romans in 300 A.D. has a compressive strength of about 160 kg/cm^2. Today's concretes are somewhat better in regard to compressive strength, but a major breakthrough can be foreseen with the marketing of advanced compacting methods. It is expected that the compressive strength can be increased to 1,200 kg/cm^2.

Tall buildings have been erected in the United States of America using concrete made with so-called "heavy" expanded shale. Danish manufacturers have also developed heavy expanded clay aggregates for this purpose. Other medium-density artificial aggregates are expanded steel slags and sintered fly ash.

Further research is necessary on making good concrete with industrial waste water. Sea-water may be employed for concrete mixing but it may be a wise precaution to substitute ordinary Portland cement with sea-water or sulphate-resistant cement in order to avoid sulphate expansions in the finished concrete.

The use of cement could be promoted by the establishment of small-scale concrete industries producing concrete pipes, blocks and pavement slabs. Many types of machines are available for the industrialization of these industries.

The establishment of an advisory service for cement users should be considered. Customers should be advised independently of the cement manufacturers' sales interest.

Ready-mixed concrete

The simplest concrete product is ready-mixed concrete. It is delivered either from a central mixing plant or by in-transit-mixing lorries. Ready-mixed concrete can be delivered at distances up to 175 miles from central mixing plants under moderate temperature conditions. It can be transported in hot weather provided that the in-transit method is used, so that the mixing water is added at the correct time. Furthermore, retarders can be added.

A one-plant operation might be set up, but at the risk of severe damage being imposed upon major construction jobs, such as bridges, in the case of breakdown at the mixing plant. The contractor always bears the legal responsibility in case of failure in a structure.

The minimum plant size that is economically feasible has an annual output of 10,000 to 15,000 m^3. The minimum order for ready-mixed concrete in Denmark is 0.25 m^3. However, the profitability is nil in both cases.

Asbestos cement

Asbestos-cement plants work in close connexion with cement manufacturers. When establishing a new asbestos-cement plant in countries with no previous experience in asbestos-cement production, due consideration should be paid to the selection of profiles for corrugated sheets. Asbestos-cement plants may be started with simple one-cylinder Hatschek machines.

Chrysotile and amphibole asbestos have different characteristics. However, chrysotile fibres are widely available, while the supply of amphibole fibres is limited. Amphibole fibres are generally used to accelerate the speed of filtration of asbestos-cement slurry. Local conditions always determine the quantity of these fibres to be added to the mixture. Although cellulose fibres are not covered by international standards, they are widely used in the United Kingdom as well as in India.

Asbestosis might be counteracted by keeping the asbestos fibres away from the working area in the factories. Efficient dust removal is required as a health measure.

Pipes

Water and sewage pipes are vital for densely populated urban areas. Pressure pipes can be made of asbestos cement and of reinforced concrete. Drainage lines can be made of concrete and asbestos cement. Concrete pipes provide the cheapest pipes. Although several types of joints are available, preference should be given to easily controlled flexible joints. Pipes can be manufactured by quite simple manual operations or by completely automatic machines. Concrete pipes can be used in areas where plastic pipes cannot be used because of attack by termites.

Industrialized building systems

Developing countries might experience difficulties in finding industries with the necessary capital for the development of industrialized building systems. The cement industry should consider investments in this development since it very often has access to capital. However, this has not been the case in Scandinavia, although the cement industry in Sweden has recently purchased firms in the building industry. In Denmark, consulting engineers as well as the co-operative building societies have played a very important role in the development and establishment of industrialized building systems.

Co-operation between architects, builders and consulting engineers has in Denmark led to the wide use of supporting cross walls. The facades are kept free and flexible for different designs.

Promotion of industrial projects

The meeting to promote industrial projects consisted of discussions between participants in the Seminar and representatives of industrial firms; 80 appointments were scheduled. Information was given about a Norwegian-designed housing scheme in Abidjan, Ivory Coast, and about the use of laterite as a building material.

Country monographs

Each of the participants described the development and structure of the cement-based industries in his country. Although the development in each country is unique, several common factors emerged from the discussion. Inadequate infrastructure poses problems for the transport of raw materials and for the distribution of end-products. The lack of qualified technical personnel, knowledgeable consumers and modern marketing techniques are common conditions.

CONCLUSIONS

The following conclusions are based on the information presented in country monographs, lectures and the discussions.

The cement industry is one of the basic industries in the industrialization process. After it has been established, the consumption of cement increases gradually. Therefore, continuous preparatory efforts must be devoted to technical and economic feasibility studies, technical planning and worker training programmes.

Since large quantities of raw materials are consumed by the cement and cement-based industries, production-oriented surveys of raw materials must be planned and executed. The raw-material reserves must be known quantitatively and qualitatively so that potential production problems can be avoided. Future demands must be met by the rational and well planned exploitation of these resources.

The bulk nature of cement and concrete products and their relatively low price emphasize the need for well-organized transport facilities. The expansion of the present infrastructure is desirable as well as the adoption of a rational distribution network.

The establishment of a good market for cement should be based on a uniform quality of ordinary Portland cement. Special requirements should be met by the production of other cements such as rapid-hardening, low-heat and sulphate-resistant cements. Parallel to the capital-intensive nature of the cement industry are the labour-intensive activities of the construction industry that are based on the use of cement.

The magnitude of the capital investments and the low dividends are handicaps to the establishment of new cement factories, especially in developing countries. The establishment of cement-consuming industries should be encouraged through government planning and financial schemes. A good example would be an extensive building programme that requires a specific production of ready-mixed concrete, building blocks and elements, asbestos-cement sheets, concrete pipes and pavement slabs.

RECOMMENDATIONS

The Seminar approved recommendations for action by the developing countries, by UNIDO and by industrialized countries. The recommendations are summarized as follows:

A. Developing countries

(1) The cement industry should

(a) Institute and maintain adequate production control with appropriate consideration of quarrying, mixing, processing and proper handling of the end-product;

(b) Implement preventive maintenance procedures and determine the availability of suitable quantities of spare parts;

(c) Form regional groups of technical personnel to discuss experiences and common problems;

(d) Send engineers to UNIDO headquarters to discuss industrialization projects and specific technical difficulties;

(e) Select potential candidates for government nomination as participants in the UNIDO fellowship programme.

(2) The governments should

(a) Evaluate the development requirements of the Portland cement and cement-based industries;

(b) Define the national needs for technical assistance in consultation with the cement industry and submit these requirements to UNIDO.

B. UNIDO should

(1) Continue to channel technical documentation to engineers and decision makers in developing countries;

(2) Follow up the present Seminar by organizing several regional in-plant training seminars for engineers from cement and cement-based industries in developing countries;

(3) Provide comprehensive assistance for the realization of both short- and long-range technical development programmes by making available on request UNIDO experts and associate experts;

(4) Initiate a strengthening of UNIDO technical activities by recruiting experienced engineers to work as direct links between UNIDO headquarters and the developing countries and by instituting and maintaining for cement and concrete industries a system of interregional advisers to assist the developing countries in solving their problems on the spot and in elaborating their further assistance requirements in construction and building materials industries.

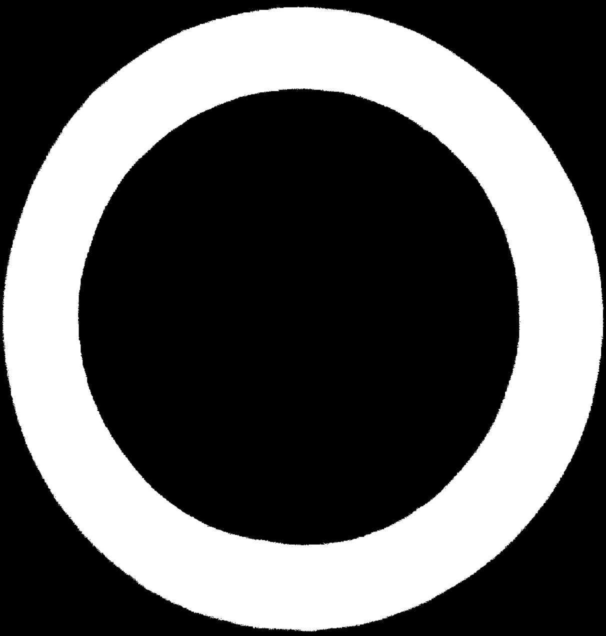
C. The industrialized countries should

(1) Increase the training opportunities for individual participants in the UNIDO fellowship programme;

(2) Continue to organize and host technical seminars and workshops, thereby facilitating a continuous transfer of know-how to developing countries;

(3) Endeavour to expand and revise the underlying philosophy for their financial co-operation in the establishment of cement and cement-based industries in the developing countries;

(4) Delegate a sufficient number of capable experts to train local personnel in all aspects of the operation of newly supplied plants.



Part two

SUMMARIES OF LECTURES PRESENTED

The development in cement and concrete industries

J. K. Rasmusen

The cement industry is often mentioned as a key industry, because it manufactures a product that is used extensively for all kinds of construction purposes. The importance of a cement industry, however, depends completely upon whether the necessary conditions for cement consumption exist. Thus cement production as such is rather a means than an end in itself for the fulfilment of a national or regional need. This geographic limitation is due to the low price and bulk nature of cement and aggregates that cause high transport costs. Until recently it was, therefore, impossible to market the finished products over long distances. However, this situation is undergoing change.

Cement consumption and development are reviewed through statistical information from Europe, United States and developing countries. It is shown that caution must be exercised in drawing conclusions from the situation in one country, because tradition, climatic conditions and a number of other factors influence the use of concrete and allied products in the local market for building materials.

Efforts in connexion with the development of cement quality, control and rationalization of the production indicate economies of scale. Therefore, cement industries should attempt to expand their markets by enlarging the geographical district served, by increasing the consumption in that district or by both means.

A potential geographical expansion is affected by factors such as general economic conditions, the extent of the raw-material resources and the strength of the competition. However, it is probably realistic to assume that the demand for large-scale production units and the economic risks involved accelerate structural changes based on a rationalized transport and distribution system. In view of the technical development in bulk transport of clinker and cement, the rational centralization of the production of cement could be a dynamic factor to increase the potential market.

Furthermore, the improved methods of bulk transport can be significant in areas where suitable raw materials are not easily accessible. Imported clinker could be the basis of cement production at clinker grinding installations near the centres of consumption.

A parallel step to increase the production is to increase the consumption of cement. The cement industry must be positively interested in any progress that the cement-consuming industries may enjoy; therefore, interests are parallel. In certain cases, economic and technical relations are established as well as management co-operation in the form of vertical integration.

The developments towards long-distance transport by large bulk carriers and the costly installation of equipment to eliminate environmental pollution could effect a translocation of part of the world production of cement. At any rate, a concentration of the structure of cement production is likely to occur.

Planning of new cement plants and expansions

H. Carlsen

Production of Portland cement is only economically feasible when the cement is manufactured in plants above a certain minimum size, which involves an initial capital investment of several million dollars. It is, therefore, essential that the decision to initiate a cement-plant project is based on careful investigations of the market, the raw materials and other technical and economical factors. Furthermore, it is important to have the project planned diligently because any major alteration of plans after the starting date is likely to be very costly and in many cases prohibitively so.

The purpose of a market survey is to ascertain that the demand for cement is sufficient to justify the construction of a new plant and to provide the basic data for determining the size of this plant. The survey should include detailed present and projected consumption figures as well as the production capacities of existing and expected future competing cement plants.

The success of a new cement plant project depends to a very large extent on the availability of adequate amounts of good quality limestone and aggregate materials. The quality criteria are a chemical composition within specified limits and suitable physical properties, for example, a low moisture content. The extent of the deposits should at least allow for operation of the works during the normal life of the equipment, which is often estimated to be about 25 years. As plant extensions are normally anticipated, the deposits should preferably be sufficient for at least a second unit which means that the normal minimum requirement is about 50 times the yearly consumption of the initial plant with one unit.

Geological investigations including bore hole sampling are normally required for the assessment of the deposits. The possibilities of upgrading low-quality raw materials or using artificial raw materials when the desired high carbonate limestone is not available are discussed.

As soon as it has been ascertained that the market and the raw materials are favourable for a new cement project, a preliminary feasibility study should be made to ascertain that the project deserves further consideration. It includes an over-all estimate of the initial capital requirements, the estimated costs of production, estimates of gross and net earnings, a preliminary financing programme and the calculated profitability. The different methods of expressing the return on invested capital, i.e. pay-back time, simple rate of return and internal (or induced) rate of return are discussed.

Once a cement plant has been built, it can only be moved at a cost which is normally prohibitively high. The choice of the plant location should therefore be made with due consideration to the future. The planning team should thus take existing development plans for the country or region into account.

In principle the ideal location of the plant may be determined by calculating the over-all costs of transportation of raw materials and cement for all suitable sites and then choose the one offering the lowest costs. However, a number of other factors, such as availability of electric power, water and manpower may influence the decision. Preferably, the site should be at a certain distance from cities or recreation areas to avoid complaints about dust or noise nuisance.

As the market for cement in most countries is increasing steadily, a new plant should be planned with some excess capacity thus covering the future demand for a few years ahead. However, the return on the additional capital for a larger plant is very small during the first years until the market has increased to match the plant capacity. The optimum plant size can be calculated from the market survey figures and the basic unit prices of cement, labour, fuel and power. As such calculations are based on assumed market volume and price development, it is recommended to check the effect of deviations from the basic estimates.

The nature of the raw materials is the main factor to be considered when deciding between the different dry, wet or semi-dry processes. The dry process is in most cases the most economical solution, but the wet process is advantageous in special cases, for example, when the natural moisture content of the raw materials is exceptionally high (above 15 to 20 per cent). A number of other processes, such as slurry filtration, spray drying, fluid bed operation and shaft kiln processes are discussed.

The plant equipment should be selected to suit the raw materials, the process and in some cases the site. If extensions in the near future are foreseen, provisions should be included in the layout for the second and possibly further units. These provisions will increase the cost of the first unit somewhat and are therefore not always justified.

A major extension requires the same preparatory planning as for a new plant. Furthermore, the choice of equipment should be made with due consideration to the existing plant, and the construction work should be planned to give a minimum of interference with the operation of the existing units. The cost of the second unit is normally considerably less than the cost of the first unit (barring the effect of price escalations). One of the reasons is that the storage capacity for raw materials, raw mix, clinker and cement often do not need to be increased as the operation of a two-unit plant requires relatively less buffer storage capacity.

After selection of the process, plant size and location, the total cost of the project can be estimated from quotations for the main equipment and estimates of costs of construction and erection. The financing plan should include a cash flow profile for the first five to ten years after the start of the project. The principles and examples of feasibility reports are discussed and typical figures for cost and construction time together with estimates of the cost of operation are provided for different types of cement plants.

Portland cement, manufacture, properties and use

T. Enkegaard

Data are presented about the consumption of Portland cement and other types of cement. The mechanism of shrinkage and creep of cement is discussed with suggestions as how to avoid them and to formulate expanding, prestressed cement.

The correlation between the raw materials and the type of process used for the manufacture of cement and the properties of the finished Portland cement are explained. A short review is then given of the manufacture of cement from a chemical point of view that stresses the importance of homogenization, burning process, cement grinding and cement storage. The modern equipment for operating cement plants by means of analogue or computer control is mentioned.

A summary of some of the more important world cement standards is given. The RILEM Cembureau testing methods have been adopted by the International Organization for Standardization (ISO). The suitability of the various cement standards as a measure of their quality in the final product, concrete, is discussed. Since Portland cement is to a large extent a product with part of its performance quite closely related to the raw materials provided, the limits in the international specifications should not be too narrow as to unduly restrict some manufacturers or the use of some large, locally important, raw-material deposits.

Products and industries based on Portland cement

G. Idorn

Considering the enormous global demand for housing and civil engineering development, it is now important for cement and concrete research to be directed towards innovation. New industrial processes and product development are pressing research problems.

A high proportion of the basic research is public and academic. It is only remotely related to application in cement and concrete manufacture. There is much less research on cement manufacture than on other modern, mass-production industries. Since the concrete industry is in an incipient phase of industrialization in most parts of the world, the advance of basic research should be reinforced and used in more intensive research and development programmes.

Rationalization rather than qualitative innovation has been the dominant feature in the development of the cement and concrete industries for the following reasons:

Mechanization of excavation and transport of raw materials;

Increase of kiln sizes from 500 tons to 4,000 tons/day;

Rationalization of kiln operation;

Introduction of bulk transport.

The introduction during the 1940s of the theory and experimental technique of physical chemistry in concrete research replaced the traditional testing methods in many respects. Although more meaningful and deeper knowledge of the nature of cement paste and concrete has been attained, there has resulted insignificant innovation of concrete manufacturing methods or markedly improved characteristics of concrete products such as workability, strength and durability.

The precast concrete industry, for instance, is still largely based upon conventional concrete technology. The savings and capacity increase have been attained by mechanization and rationalization. Even acceleration of the hardening for instance by steam curing has been introduced quite empirically. The research has been used sporadically in this development of adjustments of materials and manufacturing specifications. Thus, the development of the precast industry is a result of developments in the machine industry and the ingenuity of design and construction engineers.

Current research on concrete employs new techniques and methods. Important future research projects will include the following areas: aggregates and water supply, mixing and placing of concrete, and the structural formation and hardening of concrete.

AGGREGATES AND WATER SUPPLY

Selected high-quality aggregates will be demanded for special concrete of high density and strength. Resources of conventional aggregates are being depleted in some regions and must be replaced by crushed rock types of varying qualities, artificial aggregates and poor-quality gravel. Industrial waste water and sea-water will have to be made acceptable as mixing water in regions where fresh water supplies for domestic purposes tend to be threatened.

MIXING AND PLACING OF CONCRETE

The automation and "flow" of manufacturing processes will concentrate on the following processes: mixing, transport, placing, compaction, demoulding and registration and control.

STRUCTURE FORMATION AND HARDENING OF CONCRETE

Savings in labour costs and innovation of concrete properties as a structural material point towards the use of accelerated hydration by steam, electricity and hot water curing, chemical accelerators and microstructure reinforcement (monomer/polymer).

Concrete technology

P. Nepper Christensen

Portland cement concrete is a two-phase material. It consists of the aggregate, which is usually a non-active system of discrete particles, and the binding agent, which is the cement paste that fills the voids between the aggregate particles and ties them together to form a hard durable material. The aggregate is approximately 75 per cent of the total volume of the concrete and the binder paste only 25 per cent. Therefore, both the type and quality of the aggregate and the properties of the cement paste have significant effects on the quality and the properties of the concrete.

The type and characteristics of the aggregate material affect the following factors:

Water requirement of the fresh concrete;

Strength and weight level of the concrete;

Physical and chemical durability of the concrete.

The characteristics of the aggregate particles which are of major importance in this connexion are:

Particle-size distribution;

Weight and porosity of the particles;

Mineralogical composition.

The cement paste binder is formed by the chemical reaction of Portland cement and water. During this process, a solid material with increasing strength and density is formed. The cement paste starts to set one to three hours after mixing. The setting period lasts usually four to six hours; this stage is followed by the hardening stage that lasts from weeks to years.

The ratio between the weight of the water and the weight of the cement in the mix, the so-called water-cement ratio, is the factor most responsible for the strength level of the paste after final hardening and for the permeability or watertightness of the paste. The type and quality of the cement mainly influence the velocity of strength increase and the chemical resistance of the hardened paste. A number of chemical admixtures can be added to the paste in order to influence the setting and hardening, the workability of the fresh mix and the resistance to chemical attack.

Cement, water, fine and coarse aggregates and possibly one or two admixtures are weighed and added to the mixer in the predetermined proportions. The consistency of the fresh mix should be carefully controlled and adapted to the compaction equipment available. The fresh mix is transported to the mould either on the building site or at the factory. Pumping may be used. After placing in the mould, the mix is carefully compacted by means of vibration; various types of compaction equipment may be used.

After placing and compaction, the concrete must be protected against drying and rapid temperature changes. An artificial increase of the curing temperature, e.g. by means of steam, is sometimes used especially at pre-cast concrete factories to accelerate the setting and hardening processes. This leads to quicker removal and re-use of the form. The future trends in concrete design and quality are discussed.

Natural and artificial aggregate materials for concrete production

P. Christensen

Ordinary concrete consists of a mixture of cement, aggregate and water in which the volume of the aggregate is the largest. In Denmark, the following types of aggregates are used: aggregates from land deposits, sea-dredged aggregates, crushed bedrock (granite) and artificial aggregates, e.g. expanded clay and potassium fly ash.

Until a few years ago, the aggregate was considered an inactive, cheap filler in concrete. It is now well known that proper choice of aggregate can give certain advantages. In fresh concrete, the shape of the grains and the grading of the aggregate have a certain influence on the water requirement and the workability of the concrete.

In hardened concrete, the strength is mainly a function of the water-cement ratio since natural aggregates in general are considerably stronger than the mortars. When artificial aggregates are used, this is not always the case. The drying shrinkage is influenced by the grading of aggregates since only the binder phase shrinks. The durability of the concrete is ascertained by the choice of aggregates that do not react chemically with the minerals in the cement.

The Danish standards for aggregates are currently being revised. The present standards give certain limits to the content of dirt, silt, clay, calcite and organic impurities. Specifications for the grading are not given, although certain suggestions are recommended.

Sea-dredged aggregates are taken from the coast or the sea bottom using specially equipped ships. In the harbour they are treated and graded before they are marketed.

Sand and gravel deposits are usually covered by overburden that is removed by excavators. The overburden is carried to a previously worked part of the quarry by lorries, dumpers or conveyor systems. The gravels are dug by various types of excavators. The internal transport from the face to the plant is by dumpers, lorries, trains or conveyor systems, often after pre-crushing or removal of large boulders.

In the aggregate plant, the materials are screened by passing through revolving grizzlies or vibration screens. Stones smaller than 60 mm are often washed either by sprinkling at the screen or in separate scrubbers. The waste water is purified in sedimentation tanks or in hydrocyclones; the sand is used as aggregate after dewatering. Materials larger than 60 mm are often crushed and returned to the main flow since the demand for smaller stones is larger than for large, uncrushed stones. In certain quarries, the big stones are sorted mechanically or by hand. The granite and flint are treated in crushing and screening plants and sold as aggregate, while the limestone is used for other purposes.

The quality control is by sieve analysis, sedimentation analysis, determination of organic impurities and determination of mineralogical composition. The sand and gravel are graded and then sold by volume or weight.

Ready-mixed concrete

S. Lund

The organization of Danish ready-mixed concrete plants and production, their delivery service and customers are outlined. The methods of central mixing and transport mixing are discussed with particular attention to the relative advantages and disadvantages of each method. Two types of factories are examined in detail with regard to the basic equipment, maintenance, initial costs and dependability. The advantages and disadvantages of several types of delivery vehicles are compared with respect to their performance and maintenance.

The ideal conditions for the production of good-quality concrete are explored. The control of raw materials and the control of the fresh and hardened concrete are considered as a part of the technical process.

The most important delivery problems are discussed. Suggestions are given for procedures to avoid some of these problems.

Concrete industries: Building blocks, building systems, pipes and miscellaneous products

J. Fuglsang

The concrete prefabricated-unit industry was originally a small-scale industry started in the backyard as a small establishment. However, today the industry in Denmark is being transformed from small-scale operations to modern mass production. The prefabricated concrete products industry must satisfy the varying demands for housing and industrial plants. The most important products made in Denmark are pipes, curbings, flags, building blocks, foundation poles, building elements, railway sleepers and poles for supporting telegraph or electrical power cables. The various types of machines for making these products are reviewed. The total volume of pre-cast concrete production in Denmark is more than $150 million.

A typical large Danish concrete products plant has a yearly turnover of $3 million. The consumption of Portland cement is to 60 t/day or 14,000 t/year. The annual output is 90,000 t of concrete, and the unit costs are approximately $70/m^3 of finished concrete product.

The raw materials used in Denmark are rapid-hardening Portland cement and gravel aggregate. A special Danish requirement is that a frost-resistant aggregate must be used for the surface of concrete elements, flags and curbings; therefore, the aggregate must not contain limestone. In addition to these traditional raw materials, white cement and other coloured cement are used to provide particular surface colours. An exposed aggregate finish is currently very much in demand. Additives are not used in the Danish industry with the exception of accelerators during the cold winter months.

The raw materials are measured by weight, mixed and then automatically transferred to the mould. The concrete is then compacted by vibration, the mould is removed, and the articles are cured in a chamber at 20°C. Some factories use steam curing while other factories use pre-heated raw materials to shorten the initial hardening period. Thus, it is possible to transfer the articles to an outdoor stock area after about 18 hours.

After a hardening period of varying duration depending on the season, the products are ready for distribution. The cost of transport is 8 to 10 per cent of the final price. In Denmark, the transport is within an area of a 100 km radius.

Asbestos cement

K. Thiele

Asbestos cement products are manufactured mainly as sheets or as pipes. A number of processes available for the manufacture of these products is surveyed. Recommendations are made concerning the process equipment and plant size which are most suitable for developing countries.

The Hatschek machine is common for the production of flat and corrugated sheeting material. The asbestos cement sheet is formed on a sieve cylinder under application of vacuum. The great popularity of the Hatschek process is based on its extreme versatility with regard to product choice. The fact that a moderate-size, one-vat plant with an output of 30 to 40 t/day can be expanded gradually into a sophisticated three-vat plant producing 130 t/day of asbestos cement products makes this process a natural choice for many countries where asbestos cement products have not been produced previously. The disadvantage of the Hatschek machine is its limitation to asbestos as the fibrous component. However, from the standpoint of the over-all performance, the Hatschek process will be the dominating method for producing asbestos cement products in many countries.

During the discussion, it was mentioned that in recent years a number of improvements on standard equipment have been made in the Union of Soviet Socialist Republics. More powerful multi-stage presses permit the production of higher strength material.

In the Magnani sheet machine, the asbestos cement slurry is distributed by means of a distribution pipe on an endless band moving over suction boxes in such a way that the ultimate thickness is built up gradually. Then the sheets are pressed between calendar rolls, cut and transferred to the curing chamber. The process is remarkable for its simplicity and good-run factor. Furthermore, it is suitable for non-asbestos fibres. Unlike the Hatschek machine, the fibres are not oriented. Consequently, the strength of the end-products is somewhat lower. Generally, the sheets are not very suitable for hand moulding.

A company in the United States of America has developed an extrusion process which may be important in the future for certain types of products. Another process developed by the same firm applies a dry-moulding technique followed by wetting with sufficient water for the hydration of cement. The surface finishing is applied by veneering with embossing rollers. The strength of the materials produced in this process is far smaller than the strength obtained on wet felting machines. The great potential future of this method lies in the ability to incorporate any type of fibre. The extremely low consumption of water is another factor of importance in dry climates.

Asbestos cement pipes are formed in the Magnani machine by depositing an asbestos cement layer from a slurry on a canvas-clad, hollow-steel mandrel under suction. The outer profile is formed by rotating rollers. The steel mandrel with the green pipes is then transferred to the calendar for final compression. The pipes are pre-cured for a period of 10 hours. The final curing takes from 3 to 7 days. An aggregate for the manufacture of 3-m pipes can be added to existing asbestos cement plants at moderate costs. In developing countries, it is recommended to restrict initial pipe production to either ducts or low-pressure pipes. The manufacture of high-pressure pipes requires a high degree of sophistication and experience.

Furthermore, plant costs are about $1 million, of which 35 per cent is for mechanical and electrical equipment. The maintenance of this equipment may often be beyond the capabilities of locally available crews.

Building systems

P. Snabe

The purpose of "system building" is to optimize the use of scarce resources, while maximizing the annual output of economically viable buildings. Specific building systems are normally geared to a particular basic material. The greater part of system building production in Europe is based on concrete because of its availability and low cost.

System building achieves its objectives through a radical reduction in skilled labour consumption relative to traditional methods and by a substantial acceleration of the entire production process. However, specific building systems developed to meet requirements of a particular country cannot be applied at random around the world. The Scandinavian building systems have been adopted in many countries, but they must be adapted in countries where the cost of labour is substantially lower than in Scandinavia or where nearly all basic equipment must be imported.

None the less these building systems embody and illustrate the following universal concepts in system building:

Economies of repetition;

Flexible application of standard components;

Flow line processes yield accurate dimensions;

Detailed planning and programming of production, erection and finishing.

The degree of automation must be adjusted to suit the local economy. The degree of rationalization should always be maximized.

Industrialization describes the adoption of increasing automation as well as the adoption of increasing rationalization. The essential prerequisites for successful industrialization in both senses are continuity of production and ease of repetition. The former is basically a political problem, and the latter is largely a design problem that requires a limit to the number of basic components and the number of variants of each basic component.

National implementation of the following measures is necessary to achieve the prerequisite conditions:

Adoption of uniform national building regulations;

General adoption of functional as opposed to material- or product-oriented technical standards and specifications;

Application of a standard system of dimensional co-ordination for all building projects;

A high degree of national uniformity of the shapes and sizes of basic components;

Long-term planning of the national housing programme as a basis for continuity of production.

The success of system building is then strongly dependent upon the effectiveness of the organizational formula at the project level. The key requirement of the organizational formula is the appointment of a single project co-ordinator with full authority and preferably complete independence from the design leaders (it is impossible to be an effective arbiter of oneself). The project co-ordinator can be an employee of the client organization, the contracting firm or of an independent firm specializing in building co-ordination (a type of firm that was pioneered in Scandinavia).

The Portland cement industry and its relationship to the building and construction industries

C. Bang-Petersen

The Portland cement industry ranks high on the list of desirable industries in a developing country. However, the establishment of a cement industry is not without risks and problems; some of these problems are related to the interdependence between the cement industry and the building and construction industries.

A study of the relations between these industries may therefore help to clarify and solve some of the problems of co-operation. The risks and uncertainties facing the new or young cement industry, in particular those highlighted in the planning of the production capacity, must be studied and evaluated with great care by the capital-intensive cement industry. Already at this stage, the building and construction industries have much help and experience to offer. Thus from the planning stages, the relationship between the two industries occupies a central position.

The Portland cement industry has the following characteristics:

Raw materials are available in most countries;

Large investments and low capital turnover;

Very pronounced economies of scale;

A multiplying economic effect in a country;

Cement ex works is a cheap product;

The distribution costs are high compared to production costs;

Cement is a raw material and not an end-product;

The performance of the cement industry is closely tied to the performance of the cement-consuming industries.

The following features are characteristic of the building and construction industries:

Present in all countries;

Major sector of the national economy;

Labour intensive;

Dependence on governmental policy;

Dependence on standard of living;

A very large potential consumer of cement.

The basic relationship between the cement industry and the building and construction industries is that of supplier and customer. The following factors contribute to the relationship:

Common product cement;

Properties of the cement;

Technology of concrete manufacture;

Competitive performance of concrete against other products;

Common educational and promotional activities;

Industrialization of house construction;

Industrialization of the building and construction industries;

Standardization of cement and concrete products;

Vertical, financial co-operation;

Vertical integration.

General policy guidelines to promote good relationships between the cement industry and the building sector are as follows:

Reliable supply of cement;

Fair price of cement;

Suitable quality of cement;

Advisory service available;

Technical service laboratory available;

Educational activities;

Promotional activities;

Documentation service;

Research and development on cement and concrete;

Technical assistance;

Financial aid;

Integration.

Annex

DESCRIPTION OF THE PLANTS VISITED

Nymølle Stenindustri aggregate plant, Hedehusene

The Nymølle Stenindustri is one of the 10 largest gravel pits in the world. For its total annual output of more than 2 million m^3 of aggregates and 3,000 tons of limestone for the manufacture of burnt lime in shaft kilns, 200 technicians and workers are employed.

The overburden is removed by using two 1.5 m^3 excavators. Lorries and a conveyor belt carry the overburden to previously excavated areas of the pit. The gravel is excavated and transported from the face to the plant by lorries, dumpers and dumping wagons.

The gravel is then screened at different levels into the common commercial products. Crushing is used at different levels to satisfy the requirements of the Danish market for small stones. At Nymølle, there are 15 crushers (both jaw crushers and cone crushers) at different levels in the process. To remove the undesired clay from the aggregates, there is a sluice on the screen.

The waste water is led to a sand tank, where the sand is sedimented and removed to be dewatered either at dewatering screens or in double screw washers. From the overflow of the sand tank, a certain amount of fines is concentrated in hydrocyclones. The water still containing a certain amount of fines is led to a basin for purification and is thereafter recirculated in the plant.

Clay and humic acids are removed by washing the sand. It is then stockpiled for dewatering.

To satisfy the frost-resistance requirements of the Danish standards for the content of porous limestone, the stones can be sorted by hand. The granite and limestone are removed at the same time.

Modulbeton, Ølstykke

Modulbeton is one of the two largest plants in Denmark that manufacture concrete elements. The Jespersen system is used primarily in the construction of blocks of flats.

The production requires concrete quality with a cement content of 280 kg/m^3. The daily consumption of cement is 100 tons.

Steam curing and hardening permit demoulding after only three hours with the use of rapid-hardening cement. The compressive strength after three hours is 150 kg/m^2 at 70°C to 80°C.

A motion picture showed a Canadian plant based on the Jespersen system. The annual production from this factory is 2,500 flats with an average size of 100 m^2. The total investment for this prefabrication plant was $2.8 million.

Larsen and Nielsen, Glostrup

The Larsen and Nielsen system of pre-cast concrete elements uses internal supporting walls with external cladding on the buildings. The system can be used for the erection of both multi-storey blocks and attached dwellings. After observing the production at the plant, the Brøndby Strand project was visited, where Larsen and Nielsen are delivering 2,800 flats during a period of four years. The Brøndby Strand project is based on modern ideas featuring, for example, particular areas only for pedestrians.

A motion picture showed the low-cost housing project in Kuala Lumpur, Malaysia, that was built under a Larsen and Nielsen licence. The total capital investment of $8 million provided for the erection of the factory and the production of 3,000 dwellings. The flats have an average area of 60 m^2; the calculated cost is $40/$m^2$. The construction period for the factory and the first 3,000 dwellings was 27 months.

The Kuala Lumpur project is a standardized system using only nine different building elements. The usual Larsen and Nielsen Nybo system uses 60 different elements, while the sophisticated Brøndby Strand system has 300 different units.

De Danske Betonfabrikker, Hedehusene

De Danske Betonfabrikker in Hedehusene is the most modern ready-mixed concrete plant in the greater Copenhagen area. A general introduction to the distribution of ready-mixed concrete included a survey of the various types of transport vehicles.

The plant has an annual capacity of 80,000 m^3 of ready-mixed concrete. The capacity can easily be trebled by the use of two additional concrete mixers. Vertical flow is used in the production. An analogue computer provides centralized control of the various concrete mixes.

In Denmark, central mixing plants are operated. However, in other countries with longer transport distances, in-transit mixing is common.

Aalborg Portland Cement Fabrik Rørdal, Aalborg

The Rørdal cement works is the largest cement works in Denmark. The annual capacity of 25 million tons is based on the large nearby deposits of chalk and clay. In addition to Portland cement, the production includes special cements (primarily white cement).

The operation of the new part of the works, i.e. slurry production, kilns, clinker store and cement mills, is supervised and controlled from a central control room. The control room is equipped with a digital-analogue-process control system.

Chalk and clay are processed in wash drums and wash mills, respectively, and ground together to a slurry. The principle of continuous homogenization is applied for the kiln slurry. Because of the high moisture content of the raw materials *in situ* (about 25 per cent) and because the raw materials lend themselves to wet processing at very low production costs, a wet process plant was chosen for the latest extension. The wet processing is so economical that it compares favourably with dry-process installations in spite of the higher fuel consumption of the wet-process kilns.

Nine kilns are in operation at the Rørdal works. For each of the new kilns it is possible to separate the dust precipitated in the electrostatic dust precipitators into a fraction rich in alkalis and a fraction suitable for return to the kiln. The fraction rich in alkalis is either washed with sea-water and pumped as slurry to an abandoned clay pit or sold as fertilizer. The other fraction is split into two streams; one is conveyed to the side intake for the kiln, the other is blown through a pipeline directly into the burning zone of the kiln. At one new kiln, the electrostatic dust precipitator has several additional outlets for dust rich in alkalis, which makes it possible to adjust the quantity of discarded dust and thereby keep the alkali circulation within acceptable limits.

The amount of return dust to the side intake and burning zone, respectively, is kept at a constant level by means of a special feeder arrangement. Fluctuations in the amount of return dust from the electrostatic dust precipitator is levelled out in a surge bin.

Each of the new kilns has a separate coal mill and coal meal hopper, from which coal is fed to the kiln by an enclosed feeder arrangement. The air used for drying in the coal mills is used as primary air in the respective kilns. In order to avoid disturbances of the kiln operation due to starting or stopping of the coal mills, they have been designed with variable speed motors for continuous operation. The production of coal meal is controlled automatically to keep the coal meal hopper full regardless of variations in the coal consumption of the kiln. Furthermore, the automatic control is designed to maintain a constant fineness of the coal meal.

The MINIPEBS Grinding System in which fine grinding takes place in open circuit using a primary and a secondary mill simplifies the grinding plant. It is advantageous from the point of view of installation, operation and costs.

Most of the cement is distributed and sold in bulk. Specially designed ships transport the cement to bulk cement depots around the country. From these depots, a fleet of company-owned bulk lorries deliver the cement to the customers.

Dansk Eternit Fabrik, Aalborg

The large asbestos-cement works is equipped with 11 lines for making sheets and one line for making pipes. Hatschek and Magnani machines are used for the production of asbestos-cement sheets. The merits of these machines may be compared as follows:

The daily production capacity of the Magnani machine is 200 tons or slightly higher than the capacity of the three-vat Hatschek machine.

The investment costs are higher for the large Hatschek machines than for the Magnani machines. The Hatschek machine is the more versatile since it can produce both flat and corrugated sheets as well as a wide range of other products.

The strength of asbestos-cement products from the Hatschek machine is slightly higher than that from the Magnani machine. However, this is outweighed by the better profile of the corrugated sheets from the Magnani machine that gives the sheets a good strength.

Since the imported asbestos is an expensive raw material, special consideration is given to its processing, which is accomplished by two modern rod mills. The average daily consumption of asbestos is from 80 to 100 tons.

The annual production capacity for asbestos-cement products is almost 300,000 tons. The consumption of asbestos cement in Denmark is 50 kg *per capita* compared to 16 kg *per capita* in the Federal Republic of Germany and 12 kg *per capita* in Sweden.

The production includes a variety of hand-moulded products, flat and corrugated sheets, shingles and high-pressure pipes. The corrugated roofing sheets are the most important products; they constitute 70 per cent of the total output. However, it is expected that the market share for roofing sheets will be slightly reduced, while new products are expected to gain in importance. A noteworthy characteristic of the production is the fairly high degree of standardization as compared to other countries.

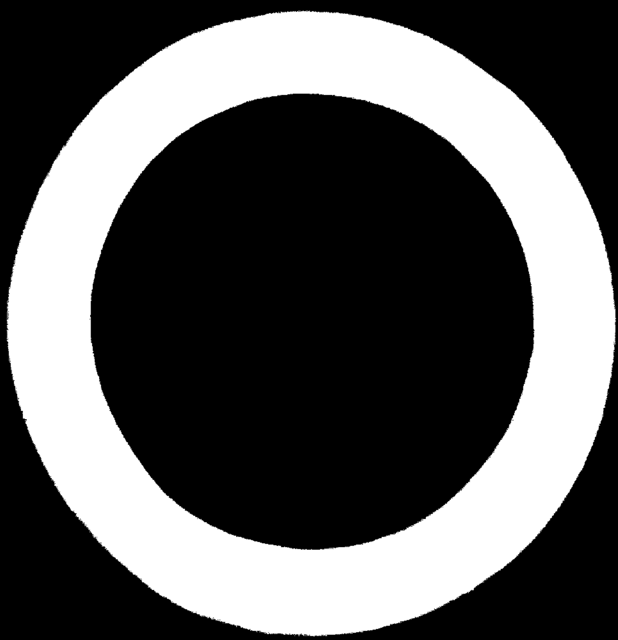
Pedershaab Maskinfabrik, Brønderslev

The Pedershaab Maskinfabrik produces the well-known VIHY pipe machines. After the production lines were seen, a demonstration was carried out in the concrete laboratory where new pipe machines are built and tested. A new model manufactures concrete pipes up to 60 cm inner diameter and 250 cm length. It is fully automatic; one pipe is produced in three minutes. The only worker required is a truck driver to remove the pipes from the machines. Other pipe machinery is manufactured that makes pipes with up to 200 cm inner diameter.

A less complicated machine manufactures pipes with a length of 125 cm and an inner diameter range from 10 cm to 40 cm. It is operated by one man and has a daily output of 250 to 300 pipes.

The concrete pipes can be assembled in various ways. The simplest joint is made with cement mortar; the best joint is made with synthetic rubber rings. The latter joint has the following important advantages: flexibility, the possibility to open it if desired, security from leakage, easy installation and easy control.

The cement used for production of concrete pipes is ordinary Portland cement during the summer and rapid-hardening cement in the winter. No curing is necessary in Denmark except for indoor storage during the first 24 hours. In countries with low humidity, special precautions may be necessary.



HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre librairie ou adressez-vous à: Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Printed in Austria

Price: $U.S. 1.00 (or equivalent in other currencies)

United Nations publication

72-4469 December 1972 3,500

Sales No.: E.72.II.B.32

ID/97

74.09.12