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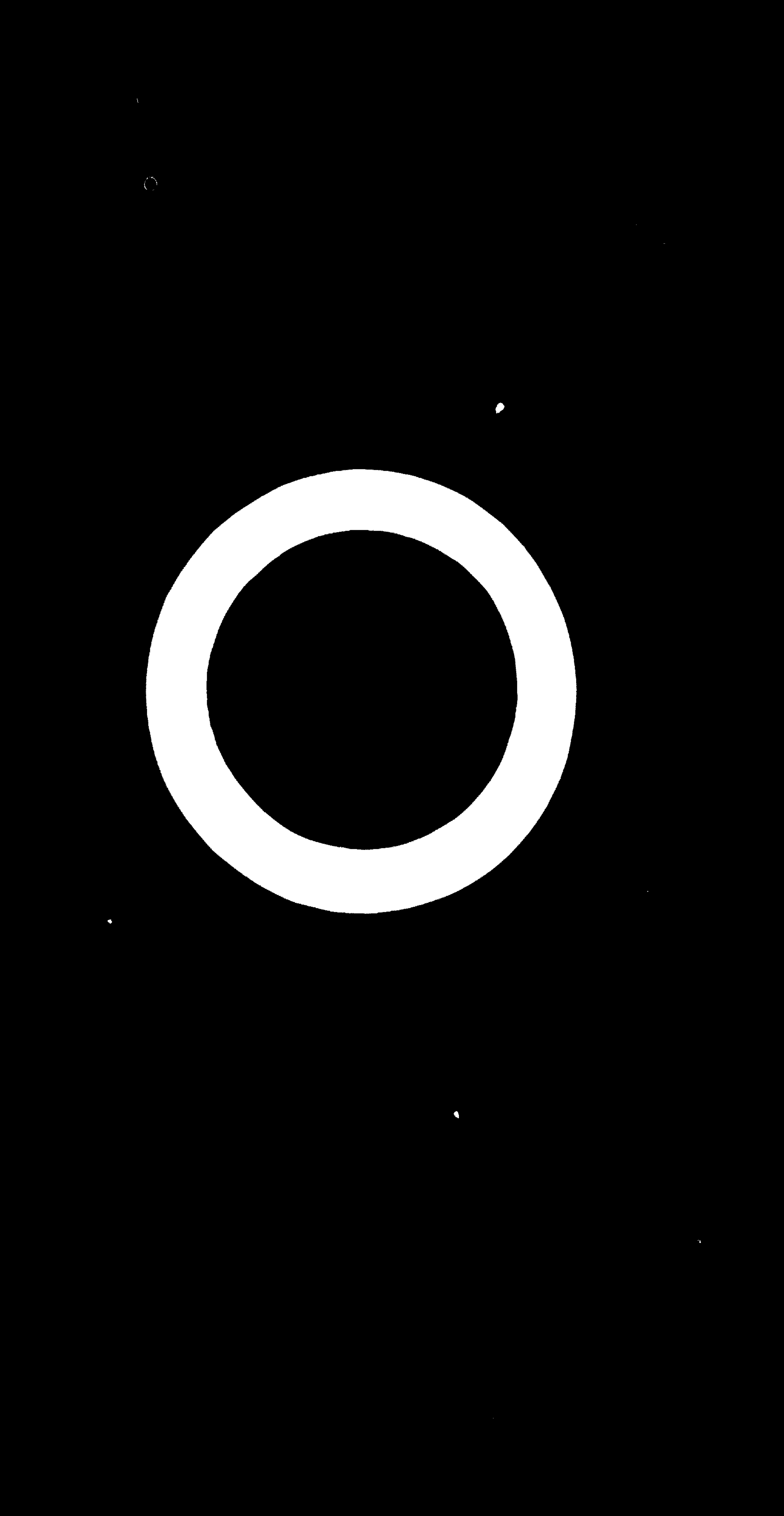
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

FIBRO-CEMENT COMPOSITES

UNITED NATIONS



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

FIBRO-CEMENT COMPOSITES

Report and proceedings
of Expert Working Group Meeting
Vienna, 20-24 October 1969

I. REPORT OF THE MEETING

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Contents

Explanatory notes

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

1 micron (µm) = 0.0000001 m

cm = centimetre

kg = kilogram

kVA = kilovolt ampere

m = metre

Preface

1. The Expert Working Group Meeting on Fibro-Cement Composites was held at UNIDO Headquarters, Vienna from 20-24 October 1969.

2. The object of the meeting was to review the design, specifications, production technology and application of fibro-cement building materials in roofing, insulation and wall materials. Eleven papers were presented. (A list of the documents prepared for the meeting is attached to the report as annex 3.)

3. The discussion, which is reviewed below, covered the following agenda items:

Conventional asbestos cement products;

Materials based on plastic and glass fibres;

Some aspects of the manufacture and use of fibrous building materials in developing countries;

Substitution of asbestos by mineral fibres in asbestos cement products;

Full substitution of asbestos and cement-polysand materials.

The report contains basic information about fibro-cement composites, a summary of the discussion, and the conclusions and recommendations adopted by the participants. Annex 1 contains summaries of the papers presented.

4. The meeting was attended by participants and observers from Austria, Czechoslovakia, Denmark, the Federal Republic of Germany, Hungary, India, Kuwait, Lebanon, Syria, the Union of Soviet Socialist Republics, the United Kingdom and the United States. Also represented were the Food and Agriculture Organization of the United Nations (FAO), the United Nations Economic Commission for Asia and the Far East (ECAFE), the International Atomic Energy Agency (IAEA) and the International Asbestos-Cement Review. (The participants are listed in annex 2.)

5. Mr. R. Singh, Director of the National Building Organization, Regional Housing Centre for ECAFE, India, was elected as Chairman and Mr. A. E. Chittenden, Chief Experimental Officer of the Tropical Products Institute, the United Kingdom, as Vice-Chairman.

Mr. O. Berger, Head of Research and Development Laboratory, H and H Industri A/S, Denmark, acted as Rapporteur. Mr. W. A. Caldwell and Mr. S. A. Boldyrev, Industrial Technology Division of UNIDO, served as Director and Technical Secretary respectively.

6. The Eternit-Werke Ludwig Hatschek pipe factory in Biedermannsdorf was visited by participants in the meeting. The visit is discussed in annex 4.

Introduction

7. Fibro-cement materials represent a large group of building materials used in construction for roofing, finishing, insulating and asbestos-cement pipes. Recently developed fibrous composites are based on fibres other than asbestos and on binders other than cement. In many developing countries there is a lack of asbestos especially of high grades as well as a lack of cement. The use of asbestos substitutes for the production of fibrous building materials should lead to an increase in the utilization of local raw materials and wastes and to savings in foreign exchange.

8. Fibro-cement composites contain a binder and a fibrous material. The binder can be an inorganic cementing material such as gypsum or Portland cement or an organic resin such as starch or phenolic resin. Both inorganic and organic fibrous materials can be used. If the volume of the binder is the predominant part of the composite material, the binder is called the matrix in which the fibres are embedded.

9. Inorganic building materials normally have high compressive strength. However, their poor resistance to tensile and impact forces rarely permits the effective utilization of this high compressive strength in structural applications. The mechanical properties of inorganic fibres under certain conditions correspond to those of crystallised solids. These materials are valuable in composites because there is no creep or plastic flow. Unlike metals they have no yield point; fracture occurs before deformations become permanent and the fibres are always in tension when they fail. Therefore it is possible to obtain strong composites by embedding rigid fibres in a comparatively weak matrix.

10. The classical fibro-cement composite material is asbestos cement in various forms. To establish this industry, developing countries face not only major capital expenditures for production equipment but also the very difficult raw materials situation in which the deposits of high-grade asbestos are limited to a few areas such as Australia, Canada, South Africa, United States and

USSR. Consequently, other countries must meet their import requirements at the expense of foreign exchange.

11. Table 1 below shows that the world asbestos consumption has more than doubled during the last fifteen years. The market prices are increasing with the added demand. In the future the price of high-grade asbestos may be beyond the means of many developing countries. At present the known deposits of all varieties of asbestos are estimated to be 150 million tons. If the trend in asbestos consumption continues, these known deposits may be exhausted by the turn of the century. Therefore, the use of lower grades of asbestos and the development of substitutes become increasingly urgent.

Table 1

Main world producers of asbestos fibres and powder a/

	Thousand metric tons		
	1953	1960	1968
Total world production	1,430.0	2,240.0	3,470.0
Australia	4.9	14.2	0.8
Brazil	1.2	98.4	345.4
Canada	826.6	1,014.7	1,447.9
China (mainland) b/	...	80.0	150.0
Cyprus	14.5	21.2	19.3
Finland	10.9	9.6	...
India	0.7	1.7	9.1
Italy	20.4	54.9	103.4
Japan	4.1	15.5	22.3
South Africa c/	36.0	159.5	236.3
Southern Rhodesia	79.6	121.5	160.0 b/d/
Swaziland	27.3	29.1	38.5
USSR b/	280.0	540.0	800.0
United States e/	49.4	41.0	109.5
Yugoslavia c/	3.7	5.4	10.4

Source: United Nations Statistical Yearbook 1969.

a/ Excluding the Democratic People's Republic of Korea, Ethiopia and Romania.

b/ Source: United States Bureau of Mines.

c/ Excluding asbestos powder.

d/ 1966 production.

e/ Asbestos sold or used by producers.

12. The term asbestos refers to a number of crystallized silicate minerals that can easily be separated into fibres. The two major minerals are chrysotile and amphibole. The most important variety is chrysotile, which is a fibrous form derived from serpentine. The most remarkable properties of chrysotile asbestos are high tensile strength, extremely small fibre diameters (0.02 µm) and the large surface area which makes possible the strong bond between the fibre surface and the cement matrix in asbestos cement products. These properties are not matched by any other asbestos mineral or by artificial fibres. About 93 per cent of the total world production is chrysotile asbestos.

13. The amphibole group accounts for the remaining 7 per cent of the total production. It is based on the mineral hornblende. The two most important varieties are Amosite from the asbestos mines of South Africa and the alkali containing crocidolite which because of its colour is also known as blue asbestos. Amosite and crocidolite account for 5.4 per cent of total world production. These fibres are generally hard and brittle with fibre diameters one order of magnitude larger than chrysotile diameters. Amphibole fibres have a lower tensile strength than chrysotile fibres. Absorption by amphibole fibres is not as good as by chrysotile due to the smaller surface area and different chemical composition. The chemical stability and infusibility of these fibres are excellent. Therefore, Amosite is widely used in the manufacture of wet-felted high-temperature insulations.

14. The remaining 1.6 per cent of the world production is low-grade amphibole asbestos. One of the objectives of the meeting was to collect the available technological know-how by which low-grade asbestos can be utilized more extensively.

Standard asbestos cement process

15. Asbestos cement is the oldest fibro-cement composite and is the most commonly used fibro-cement composite. In its manufacture, the two basic raw materials of asbestos and cement are slurried in water and transferred to a filtering device where the water is

removed. The de-watered sheet is then compressed to remove additional water. After this operation the product is stored for 24 to 48 hours to set the cement. Final strength is developed after additional storage for 1 to 2 months. Some manufacturers reduce this storage time by raising the ambient temperature. The way in which the asbestos fibres are felted in the presence of cement and the ease with which the excess water can be removed are of great importance in the process as well as for the properties of the end-product.

16. Specifications for the cement used in the asbestos cement process must satisfy both the properties of the finished product and the requirements of the manufacturing process. In order to maintain a high filtration rate and satisfactory production rates, it is essential to avoid the formation of colloidal particles which reduce the filtration rate. The setting of the cement should be delayed until filtration and moulding are completed. In order to meet these requirements the cement should contain a high percentage of tricalcium silicate (C_3S) and a low percentage of tricalcium aluminate (C_3A). The cement should also be of reasonable fineness; the clinker should preferably be processed by closed circuit grinding. Care must be taken that the gypsum added is in the form of dihydrate rather than the hemihydrate.

17. According to USSR standards Portland cement for use in asbestos cement manufacture should meet the following specifications:

Free CaO	maximum 1 per cent
MgO	maximum 5 per cent
C_3S	minimum 50 per cent
C_3A	maximum 8 per cent
SO_3	1.5 to 3.5 per cent
Initial set time	1.5 hr
Final set time	12 hr maximum
Grain size	maximum of 7 per cent by weight in grains exceeding 70 µm diameter

18. In asbestos cement manufacture the fibrous part plays a triple role:

(a) By attracting the cement grains, it forms a strong bond between fibre and matrix;

(b) It forms a felted matrix which should have proper draining properties for high production rates;

(c) It must maintain its strength when exposed to alkaline cement paste and to the subsequent curing process.

For a given cement, (a) and (b) are largely determined by the nature and specific surface of the asbestos fibres.

19. The mechanical strength of asbestos cement products depends to a large extent on the ratio ℓ/d, where ℓ is the length of the fibre and d the diameter of the fibre strands. Short fibres require additional shredding to reduce d if the strength is to be maintained.

20. Another important parameter is the ratio of asbestos and cement which to a great extent depends on the quality and type of asbestos used. The optimum ratio must be determined for each type of asbestos. Up to a certain maximum ratio the strength of asbestos cement products increases with an increase of the fibre content. Beyond this maximum ratio, additional asbestos not only increases the cost but also lowers the bulk density and increases the water absorption. Normally, from 11 to 16 parts of asbestos by weight are used for 100 parts of cement depending on the raw materials and type of product to be manufactured.

Conclusions

21. The following conclusions are based on the information presented in the papers and the subsequent discussion.

22. The partial replacement in high-grade asbestos in the conventional cement asbestos process by low-grade asbestos can be achieved by changing certain process parameters or by additional pressing of the moulded sheets. The performance of the resulting product is not seriously impaired.

23. Low-grade amphibole asbestos requires a special treatment as a result of which the fibre bundles can be opened without breakage. Treatment with carbon dioxide or a surfactant was proposed.

24. Equipment is available to process low-grade chrysotile. The fibre bundles are opened without mechanical damage to the individual fibres.

25. The degree of replacement of high-grade asbestos by lower grades depends on the type of asbestos available and on the required properties of the finished product. The latter is a function of the final application of the product. The use of low-grade asbestos in the production of pressure pipes is not recommended.

26. Semi-production runs have indicated that 10 to 20 per cent of the asbestos content can be substituted by basalt wool or the so-called A-type mineral fibre without a decrease in strength properties.

27. Substitution of asbestos by cellulose pulp fibres has been successful in a number of countries. This possibility should be considered when lower binding strength and higher water absorption are not important. Under severe climatic conditions these materials should be protected by surface coatings or by impregnation.

28. The complete replacement of asbestos by pulped and whole vegetable fibres such as bamboo produces building materials which have properties that deviate from those of standard asbestos cement products. Their suitability and duration are dependent upon climatic conditions. Therefore an evaluation in these terms will be required for each country or region.

29. About 40 per cent of the Portland cement in asbestos cement products can be replaced by finely ground silica sand in combination with an autoclave treatment at high temperatures and pressures. There is a slight decrease in impact strength but the volumetric stability is improved.

30. Ground silica sand or inert fillers can replace a portion of the Portland cement in asbestos cement products without subsequent autoclave curing. However, this method is restricted to products in which strength is not an essential factor.

31. Profiles and other design features concerning the geometry of sheet products can be optimized with regard to load-bearing capacity. Thereby, it has been possible to reduce the thickness of the sheets by 10 per cent, which requires smaller quantities of both cement and asbestos.

32. The Hatschek machine is the most applicable equipment for over-all performance due to its versatility. In addition to the standard processing equipment, an extrusion process and a dry moulding process are now available. The applicability of these new processes in developing countries requires further evaluation before definite recommendations can be made.

33. Completely new products have been designed which can replace asbestos cement products. Wet-felted sheets of vegetable fibres with mineral fillers and binders and with bituminous impregnation are applied as inexpensive roofing sheets.

34. Components of gypsum plaster with 5 to 10 per cent reinforcement by glass fibres are useful for indoor applications.

35. The conventional process to manufacture wood-wool slabs is of interest to countries with fast-growing timber. Current development work might broaden the raw materials base of this process for a wider application.

36. Various aspects of the production and application of mineral wool were presented. The production of this material in developing countries is possible if the necessary raw materials of natural stone or industrial waste products are available. Mineral wool products are used for thermal and acoustic insulation.

37. Specially treated glass fibres for concrete reinforcement may become available in the future.

38. A newly developed process produces building materials from sand, and industrial and agricultural wastes with unsaturated polyester resin binders. It can be carried out in small-scale units and does not require skilled labour.

39. Research in the plastics industry and its establishment in the developing countries will facilitate the use of plastic materials as binders for mineral and glass fibres, for surface coatings and for rigid insulating foams.

Recommendations

40. In the course of its discussions, the Expert Group set out certain recommendations for action that might be taken by the developing countries, or by UNIDO in combination with experts from industrialized countries to promote and assist in the establishment and operation of asbestos cement plants. The recommendations may be summarized as follows:

A. Developing countries:

1. Encourage the replacement of high-grade chrysotile by lower grade and less expensive amphibole asbestos;
2. Commission geological surveys to locate new deposits of chrysotile asbestos;
3. Increase the use of cellulose fibres of industrial and agricultural wastes in the production of building materials;
4. Encourage thermal insulation in structures to reduce the fuel consumption which might be an important factor in the national economy;
5. Promote the erection of mineral wool plants;
6. Encourage glass fibre manufacture if capital and economic conditions are favourable for an established glass industry;

B. Industrialized countries:

1. Provide technical assistance and advice related to all stages of the establishment and operation of asbestos cement plants;
2. Prepare background data sheets on the asbestos cement process and on asbestos cement products to aid in the selection of the most suitable plant size and type for any given country.

C. UNIDO in co-operation with the United Nations Centre for Housing, Building and Planning and other United Nations and international organizations and agencies:

1. Collect detailed data sheets on processes, production equipment and properties for the following products: mineral wool, wood-wool slabs, glass fibre products and vegetable fibre boards to aid developing countries and field experts to assess the raw materials situation, the various aspects of financing and the suitability of the building materials in a given country;
2. Encourage or sponsor research on the available test methods for the evaluation of low-grade asbestos with regard to suitability in the asbestos cement process until a satisfactory set of test methods and international grading specifications have been developed;
3. In co-operation with FAO, promote the development of new processes by which cellulose fibres in combination with an appropriate binder can be converted into suitable building materials;
4. Promote the establishment of a pilot plant to evaluate glass and organic fibre reinforced gypsum products in a developing country;
5. Emphasize the design of plants of moderate size and simple methods;
6. Collect the available data on the application of the building materials discussed at this meeting in low-cost housing;
7. Assist in establishing realistic quality specifications for fibrous building materials based on the functional concept rather than a direct adoption of standards from developed countries;
8. Support the geological surveys by the governments of developing countries;
9. Promote basic and applied research in the development of completely new fibrous and other organic and inorganic building materials for the replacement of asbestos cement products for roofing, cladding, insulation and wall materials.

Summary of the discussion

41. Experts from both developing and industrialized countries took part in discussions to define the needs of developing countries and the types and qualities of building materials they require. Three main stages of development were identified:

(a) In the first stage village industries prevail. The simple materials are manufactured with a minimum of technological equipment and know-how. (A number of publications about this kind of industry is available.)

(b) In the second stage, the development of small-scale industry is necessary. Assistance of commercial interests from developed countries may not be available. The technical know-how must be modified to the needs of the developing country. Markets are limited. Therefore small, simple plants will be established. At this stage the assistance of UNIDO and other United Nations organizations is most urgently needed for the greatest contribution towards improved living conditions in a number of countries.

(c) The third stage envisages the development of larger industries. Technology from developed countries can be applied without major modification although local economic conditions and customs should be considered. At this stage UNIDO's advice will still be an essential part of the evaluation process in the form of feasibility and pilot studies, and assistance in securing proper financing. However, commercial interests will be available to provide technology and to facilitate plant construction, initiation and possibly operation of the production facility.

42. Many developing countries are in the second stage of development (b) although special conditions, such as the availability of certain raw materials and skills, may place a country in the third stage of development. The choice of products which can be introduced depends on the stage of development; substitutes for asbestos cement and mineral wool will initially be of greatest interest to countries in the second stage of development. Simple asbestos cement products with or without the addition of substitutes could be introduced later.

43. The quality of building materials to be produced and marketed in developing countries must be considered in terms of the final use of the product. A functional definition of product

quality is the ability of a product to fulfil a certain function for the lifetime of the material; for example, quality does not mean extremely high strength properties which are never fully utilized and which have been obtained from expensive raw materials with increased production costs. In setting quality standards and specifications the local living habits and climatic conditions must be considered; in the tropics the frost resistance of a building material is not important but resistance to fungi may be very essential. In evaluating the suitability of building materials in tropical countries particular emphasis must be placed on properties such as resistance against weathering and stability under microbiological attack. In organic materials, toxicity may be another factor.

44. Even in industrialised countries the functional approach to quality is new and difficult. However, it will provide more meaningful standards in the long run. Ultimately, each country or region will make its own decisions.

45. It was also mentioned during the meeting that most markets require both low- and high-cost materials which can either be used locally or exported. In both cases, it is necessary to adopt quality standards to protect the customer. This is of particular importance for the market in most countries where demand frequently exceeds the supply of building materials.

46. Various national and international standards and testing methods can serve as a basis to establish quality standards. However, a direct and uncritical adoption of such standards can lead to conditions which discourage the development of new materials or which unnecessarily incre construction costs.

47. To assist developing countries in assessing their requirements of construction materials, there is an urgent need for statistical information about the nature of the current production of building materials. Forecasts of the future production should also be available.

Production processes

48. Asbestos cement products are the predominant fibro-cement building materials. They are available as roofing and flat sheets, siding, ducts and pipes. In asbestos cement a matrix of hardened Portland cement is reinforced with asbestos fibres.

49. A number of production processes are available for the manufacture of orthodox asbestos cement products. The Hatschek machine is generally used in the production of flat goods because it is versatile with regard to product choice. Despite certain limitations, the Magnani process is known for its simplicity and its ability to incorporate non-asbestos fibres. A dry moulding process and an extrusion method are new developments which may provide future opportunities in terms of smaller and more versatile plants for markets of limited size.

50. Raw material requirements were discussed in detail. The supply of high-grade asbestos fibres is limited; prices are high and deposits are found in a few areas. Most developing countries must import their asbestos requirements. Although lower grades of asbestos are less expensive and more generally available, their use in asbestos cement products has been limited. Certain grades with brittle, short fibres have been considered useless.

51. Chemical and physical methods have been developed to open the fibre bundles of low-grade asbestos without fibre damage. Certain modifications of the asbestos cement process and additional pressing of the wet-felted sheets permit partial substitution of high-grade chrysotile asbestos by low-grade fibres.

52. Another possibility is the partial or complete replacement of asbestos fibres by artificial fibres. Attention has been focused in particular on inorganic fibrous materials of a vitreous nature such as glass and mineral wool. However, most glass and mineral fibres are not stable in the alkaline medium produced by the hydration products of Portland cement. The way in which this corrosion takes place is not entirely clear; a form of stress corrosion is suspect as the cause. At present a complete

replacement of asbestos by glass and mineral fibres is not possible without developing different types of building materials which in many essential points deviate from traditional asbestos cement products. It has been possible on a semi-production scale to replace 10 to 20 per cent of the asbestos by either basalt fibre or a so-called A-type mineral fibre without sacrificing strength or other performance properties in the finished product. It is hoped that these fibres can be generally recommended as a partial substitute for asbestos in the near future.

53. Cellulose vegetable fibres have also been proposed as a partial substitute for asbestos. However, there are disadvantages of lower frost resistance and higher water absorption which may require surface protection or treatment with plastic materials in regions with severe climatic conditions. In relatively iry areas this type of material may be completely satisfactory. The complete replacement of asbestos by vegetable fibres such as bamboo or other materials abundantly available in many developing countries will produce building materials which are essentially different from standard asbestos products. Therefore they must be evaluated on their own merits and not judged by the standards established for asbestos cement products.

54. Ground sand or inert fillers can be substituted for part of the Portland cement. In the standard asbestos cement process, the strength decreases relative to the quantity of sand used. In some uses, a decrease in strength can be tolerated; then the saving in the cost of raw materials is justified.

55. An autoclave process was described in which about 40 per cent of the Portland cement can be replaced by finely ground sand. After curing at elevated temperature and pressure, the matrix consists of calcium silicate hydrates of low basicity. Apart from a slight decrease in the impact strength, the mechanical properties do not deviate substantially from those of standard asbestos cement products. The volumetric stability is greatly improved.

56. The development of completely different building materials rather than substitution of the raw materials in the absestos cement process was discussed. Theoretical aspects of fibre reinforcement were presented. Continued research in this field should be encouraged to stimulate future developments.

57. A process was described to produce gypsum plaster reinforced with 5 to 10 per cent glass fibre. Gyspum plaster might be an acceptable alternative for asbestos cement or wood in countries without a cement industry or with gypsum deposits.

58. In another process vegetable fibres from jute and paper scraps can be wet-felted in combination with mineral binders and fillers. The felted sheets are then impregnated with asphalt. Roofing sheets of good durability have been manufactured by this process in a number of industrialized and developing countries. The traditional wood-wool slab process using locally available timber might also fulfil the immediate needs for building materials in many areas. Research and development of this process could ultimately facilitate not only small-scale plants but also provide a wider selection of locally available raw materials.

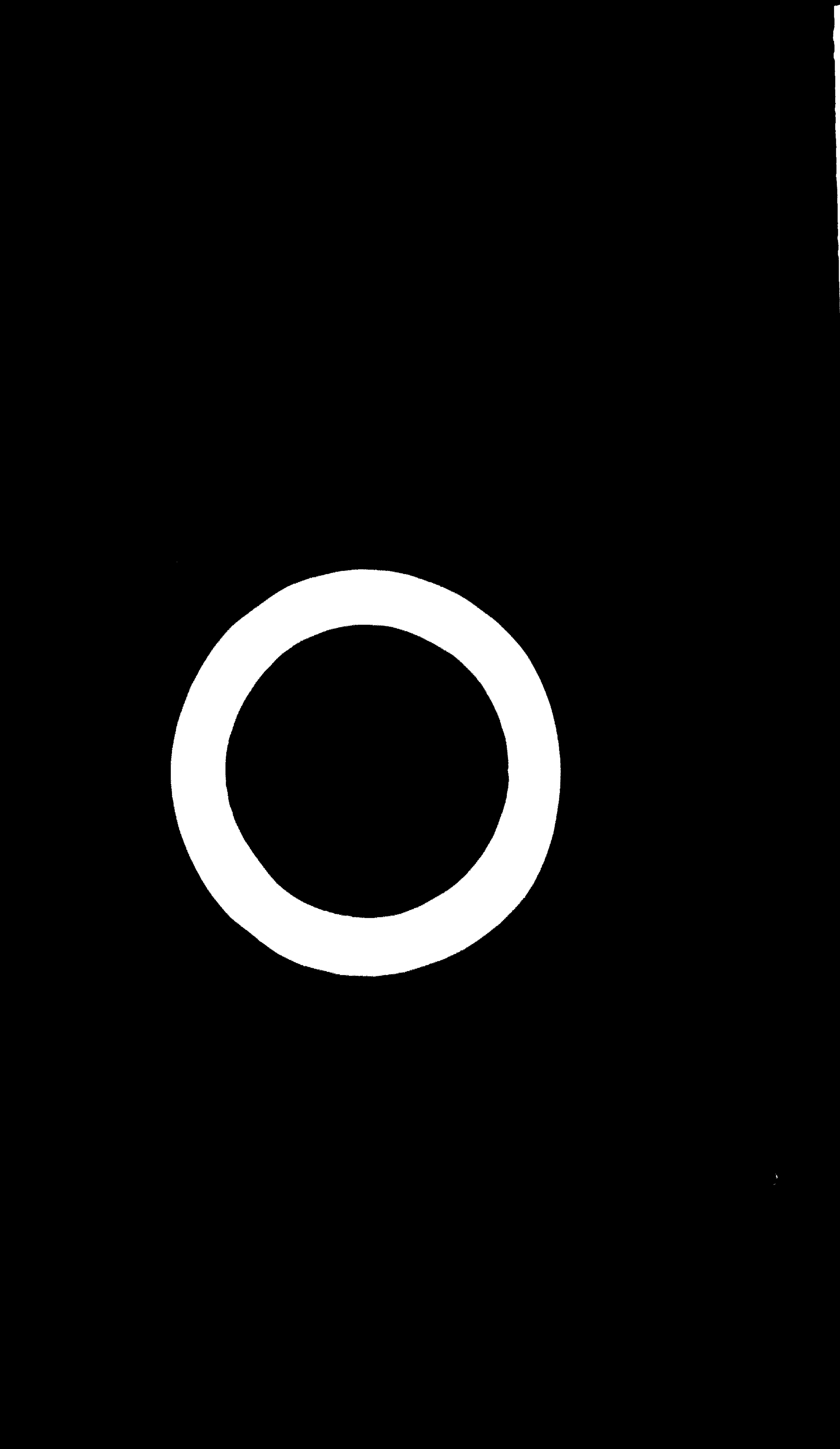
59. Dry and wet-felted mineral wool products differ essentially from asbestos cement and related materials in their properties and uses. Low-density products are useful for thermal insulation in homes and industrial buildings, while higher density materials are used in acoustic and high-temperature insulation in industrial equipment. Mineral wool boards surfaced or impregnated with asphalt are used as insulating roof decks.

60. A number of very versatile processes are available to developing countries which have the necessary raw materials of either natural stone of the proper chemical composition or slag from metallurgical smelting operations. In most cases a cupola in combination with a spinner is recommended. The binders in low-density insulation are mostly phenolic resins. Wet-felted mineral wool products have clay or starch binders.

61. Plastio binders would be economically feasible when plastic materials are available in sufficient quantities and at reasonable prices. A process was described by which sand and waste materials can be combined with unsaturated polyesters to produce building units and pipes. Several plastic materials can be used to decorate the otherwise unattractive surfaces of asbestos cement products. The thermal insulation properties of asbestos cement can be improved by combination with either mineral wool or rigid plastic foams in sandwich constructions.

62. Standards of quality, size and raw materials were also discussed.

63. Several participants indicated that a number of countries may be willing to share their technical know-how. It was suggested that advances in process technology in the USSR may be of particular interest. Experience in India on the use of cellulose fibre could be of value to other countries. The successful low-cost housing schemes of Kuwait were also mentioned.



Annex 1

SUMMARIES OF PAPERS PRESENTED TO THE MEETING

Some aspects on the choice of asbestos-cement machinery, by K. Thiele, Denmark

Asbestos cement products are manufactured mainly in the form of sheets or pipes. This paper surveys a number of the available processes and recommends the equipment and plant size most suitable for developing countries.

The Hatschek machine is commonly used in the production of flat and corrugated sheeting materials. The asbestos cement sheet is formed on a sieve cylinder under application of a vacuum. The popularity of this process is due to its extreme versatility with regard to product choice. A moderate-size one-vat plant with an output of 30 to 40 tons/day of asbestos cement products can be gradually expanded into a sophisticated three-vat plant producing 130 tons/day; therefore this process is a natural choice for an initial asbestos cement plant. 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 dominate method in many countries for producing asbestos cement products.

During the discussion it was mentioned that in recent years a number of improvements on standard equipment has been made in the USSR. More powerful multi-stage presses permit the production of stronger material.

In the Magnani sheet machine, the prepared slurry is pumped to a moving distributor. The crude sheet is then calendered, cut and stacked. The dewatering process is performed by suction boxes under the felt. The process is remarkable for its simplicity and good-run factor; it is also suitable for non-asbestos fibres. The fibres are not oriented as in the Hatschek machine. Consequently, the strength of the products manufactured on this equipment is somewhat lower. Furthermore, the sheets are generally not suitable for hand moulding.

Cost and capacity data of asbestos cement machinery for these two processes are shown in table 1, below.

Table 1

Production capacity and capital cost of asbestos cement plants

	Capacity (tons/24 hr)	Investment excluding building, site and freight (dollars)	Power consumption (kVA/24 hr)
Production of sheets			
Hatschek machine			
one-vat machine	30-40	425,000	190
three-vat machine	130	1,100,000	
Magnani machine	160	800,000	275
Pipe plant			
Magnani method			
3-metre aggregate	9	100,000 a/	
4-metre aggregate	12		

a/ Installation in already existing plant.

Johns-Manville, United States, has developed an extrusion process which may become important in the manufacture of certain products. Another process developed by the same firm applies first a dry-moulding technique and then the quantity of water required for the hydration of cement. The surface veneer is applied by embossing rollers. The materials produced by this process are weaker than materials produced by wet-felting machines. The potential of this method lies in its ability to incorporate, at least in principle, any type of fibre. The extremely low consumption of water is another important factor in dry climates.

In the Magnani machine, the pipes are formed 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 a calendar for final compression. The pipes are cured for an initial period of 10 hours. The final curing requires 3 to 7 days.

An aggregate for manufacture of 3-metre pipes can be added to existing asbestos cement plants at a moderate cost. 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 much sophistication and experience. In addition, plant costs are about $1 million of which 85 per cent is the cost of mechanical and electrical equipment. The maintenance of this equipment may often be beyond the capabilities of locally available crews.

Autoclave method of production of sheets and pipes in the USSR, by V. Lapotnikov, USSR

Scientists of the USSR have developed a process in which 40 per cent of the Portland cement can be replaced by finely ground quartz sand. A combined grinding of Portland cement clinker with quartz sand of reasonable purity (86 per cent SiO_2 minimum) was found to be the most suitable process. The asbestos cement products are formed and then autoclaved in saturated steam according to an exact schedule. The autoclave pressure is 8 atm (175°C); the curing time at full pressure is 6 to 7 hours. Finely ground silica is able to fix the calcium hydroxide emitted during the hydration of Portland cement under formation of calcium silicate hydrates of low basicity which have excellent adhesion to the surface of asbestos fibres. Therefore, there is a reduction in the required quantity of Portland cement and a corresponding savings in raw material costs. In addition, the curing time for asbestos cement products can be reduced from 1 to 2 weeks to only 2 to 3 days.

The properties of autoclave-cured asbestos cement products are equal to or better than those of products made by the standard process except for a slight decrease in impact strength. Furthermore, the volumetric stability and resistance to corrosion are both improved. During a shortage of cement, sand and inert fillers have been used to replace part of the Portland cement. However, without autoclave curing, there is a decline in strength and performance properties.

Computations to optimize the shape, corrugation, profiles and other factors relating to the geometry of asbestos cement sheets for the best strength and load-carrying capacity indicate that the thickness can be reduced by as much as 10 per cent without a decrease in the over-all strength. There are corresponding savings in raw materials.

Completion and substitution of asbestos cement by plastic materials, by H. Schultheis, Federal Republic of Germany

Asbestos cement sheeting does not normally have an attractive surface structure and colour. Its heat insulation is also poor. A number of methods are described to cover asbestos cement sheets with polyester, polyurethane and epoxy coatings. The first two are the most commonly used resins, while the epoxies are generally considered to be too expensive despite their excellent properties. The approximate kilo prices are polyester resin, $0.35; polyurethane resin, $0.70 and epoxy resin, $1.20.

The poor insulation value of asbestos cement sheets can be improved by sandwich constructions of a core of plastic foam in combination with asbestos cement on both sides or with asbestos cement on one side and a variety of facings such as metal sheets, gypsum boards or foil on the other side. The light-weight prefabricated sheets prepared by this method can be used in curtain wall constructions and as partition walls. The types of foam which are of general interest in this connexion are polystyrene in boards or polyurethane which can be foamed in place. The economy of applying these materials depends to a large extent on the local raw materials situation; it must be evaluated in each individual case.

Glass fibre reinforcement of inorganic building materials, by A. J. Majumdar, UK

The poor stability of glass fibres in hardened Portland cement is generally recognized. The reasons for fibre corrosion are not yet entirely clear but some form of stress corrosion is thought to be responsible for the gradual decrease in the strength of glass fibre reinforced concrete. A glass fibre has not been developed which is stable in the alkaline medium of hardened Portland cement.

By replacing the Portland cement matrix with gypsum plaster, E-glass fibre reinforcement has been successfully achieved. A spray of plaster slurry and chopped glass fibre rovings up to 50 mm long is distributed over the surface of a perforated mould. The excess water required to spray the binder slurry is removed by the application of a vacuum or pressure. Therefore, the ratio of water to binder can be sufficiently small to produce a strong matrix. The glass fibre chopper is mounted on a spray gun to obtain a uniform distribution of the fibre in the binder matrix. This procedure avoids the difficulties experienced when an attempt is made to cast slurries containing larger quantities of chopped glass fibres. Composites containing up to 12 per cent glass fibre by weight have been prepared.

The physical properties of glass fibre reinforced gypsum composites are summarized in table 2. A practical advantage of these composites is the fact that a collapse under loading occurs gradually rather than suddenly. The stress-strain behaviour of these composites exhibits quasi-plastic properties which are similar to the properties of wood. The impact strength is similar to that of wood, but Young's modulus is about 50 per cent higher. The fire resistance of glass fibre reinforced gypsum is superior to that of ordinary plaster board.

Glass fibre reinforced gypsum composites can be used for the manufacture of panels, floor and ceiling units. Strength and fatigue tests indicate that these panels are suitable for use in buildings up to two storeys high. The manufacturing process is simple and the investment sufficiently small to be adapted to cottage industries.

In most developing countries, glass fibre rovings will have to be imported. However, plaster of Paris can be produced locally in many countries with a relatively low investment compared to the investment for cement plants. The possible use of vegetable fibres in combination with gypsum is also mentioned.

Table 2

Mechanical strength properties of glass fibre reinforced gypsum with 0 and 7 per cent weight of fibre

	Plaster of Paris		α-Hemihydrate	
	0	7	0	7
Modulus of rupture (kg/cm^2)	85	268	133	352
Tensile strength (kg/cm^2)	42	127	56	155
Impact strength (kg/cm^2)	1	30	3	30
Compressive strength (kg/cm^2)	320	260	550	420
Density (kg/m^3)	1,500	1,600	1,800	1,950

Fycrete - glass fibre reinforce plastics to strengthen concrete structures, by S. A. Klink, Lebanon

A glass fibre reinforced concrete has been introduced under the name Fycrete. Fybrites are the specially treated glass fibres used in this product.

In the experiments reported, E-glass fibres have been used. Roving fibres are impregnated with a thermosetting resin in order to protect the fibres from attack by the alkaline components of Portland cement. In addition, the resin impregnation assures an even transfer of the stresses to the individual fibres in the filament. An impregnation of the fibres with a two-component epoxy resin fulfilled the dual purpose of fibre protection and stress distribution. After curing, the impregnated fibres are chopped to suitable length. The cost of Fybrites is about $2.20/kg.

When mixing the impregnated fibres with the concrete mixture, it is important to have the correct balance between the components of the mixture and the types of Fybrite. Strength properties of the concrete increase with an increased concentration of the Fybrites in the mass. In particular, the increase in tensile strength is very pronounced. Therefore, this type of glass fibre reinforced concrete could be applicable in most constructions where reinforced steel is presently used. This material will require additional testing to explore all of its properties. The long-range performance in actual construction and the experience gained from field tests are particularly important.

Fibrous building materials produced from industrial wastes, by R. Singh, India

Use of amphibole asbestos in the manufacture of asbestos cement products

A number of different methods of processing is reported by which it is possible to substitute part of the chrysotile asbestos with low-grade amphibole. An opening of the fibre bundles after treatment with surfactant solutions and application of high pressure (70 kg/cm^2) to the sheets after forming leads many times to suitable products even if 80 to 90 per cent of the chrysotile is replaced by amphibole. An opening of the fibre by means of conventional methods of shredding or crushing is generally not possible without grinding the material to a dust. Another method of processing low-grade asbestos is reported to be curing in moist CO_2 atmosphere for 28 days. In many cases suitable blends of chrysotile and amphibole produce good results. In particular, fibres of the crocidolite group have excellent wet-felting properties because of the coarse nature of this asbestos.

Cost savings are reported to be up to 40 per cent where local deposits of amphibole are available. However, in many cases substitutions can only be applied in products where high strength is not essential.

The most interesting and sound method from a technical standpoint is a sandwich method where the central layer of the asbestos cement sheet is made of low-grade asbestos while the outer layers which are exposed to compression and tensile forces are produced from higher grade fibre (neutral axis method). However, frequently the savings experienced by the use of lower grades of asbestos in the centre of the sheet is compensated by the need for higher grades for the surface layers.

Bamboo pulp cement building boards

Extensive work has been done in India on using readily available bamboo as a fibrous raw material for inexpensive building boards for the low-cost housing market. In this process bamboo chips are pulped after treatment with a 20 per cent sodium hydroxide solution under steam pressure for 5 hours. The slurry of pulp and cement is processed in asbestos cement machinery. A pulp content between 7.5 and 10 per cent was found suitable in many applications. The remaining 90 to 92.5 per cent was rapidly curing Portland cement. In addition to normal asbestos cement machinery, a hydraulic press capable of exerting a pressure of 25 kg/cm^2 is required.

Flat sheets and roofing material produced by this process are now undergoing field trials for the evaluation of volumetric stability and other performance characteristics. Laboratory tests indicate that this material could potentially replace asbestos cement in low-cost housing.

Corrugated asphalt roofing sheets

Intensive work, particularly in Latin America and India, has led to the development of wet-felted boards from a wide variety of waste fibres largely of vegetable nature. The boards are based on scrap paper, bagasse, jute waste, coconut fibre, rags, sawdust, straw, waste lumber, bamboo chips, cotton and wool rags or suitable combinations of these materials.

The selection of the fibre raw materials is of great importance; the use of cotton and wool has a tendency to soften the boards and to increase porosity while jute produces harder and denser products. Clay is added as a filler and for greater density. The subsequent impregnation of the boards is with a standard-grade paving asphalt. The surfacing material can be mineral granules, aluminium foil, aluminium paint or plastic paint. The most economic surfacing is aluminium paint although foil gives the highest heat reflection and best durability.

The fibrous raw materials are soaked in water and are pulped in a hammer mill. Additional equipment is needed to remove contaminations and to homogenize the pulp before it reaches the forming machine. The sheets are transferred to pallets for drying either in the air or in an oven. The sheets are trimmed and then corrugated. They are impregnated in an asphalt bath and surfaced with a dip coat of aluminium paint. .

The material can be used to replace asbestos cement sheets for roofing purposes in areas where maximum temperatures do not exceed 45°C. The thermal insulation properties are reportedly good. The material withstands transport over longer distances better than asbestos cement sheets because it is tougher. Production costs are approximately $0.34/m^2$ in India. Its cost and properties are compared in table 3 with those of other types of roof construction.

Table 3

Costs and properties of roofing materials in India

	Approximate cost/m² (dollars)	Expected service life (years)	Weight/10 m² (kg)
Corrugated galvanized sheeting	12.50	30	55
Corrugated asbestos cement sheets	10.00	20	158
Single clay tiles on wooden battens	6.20	15-20	634 including batten
Corrugated asphalt roofing sheets	3.30	12-15	59

Proposed research and development programme at the Tropical Products Institute in wood-wool slab manufacture in developing countries, by A. E. Chittenden, UK

This paper emphasizes methods to produce wood-wool slabs in developing countries using local raw materials to the largest possible extent. The development of agriculture oan be oonnected with industrial production of building materials in developing oountries.

The basio raw materials of the process are timber and binders. In most cases, Portland cement is used as a binder although experiments are in progress at the Tropical Products Institute to develop other types of binders as an alternative for countries without a looal cement industry. However, Portland cement is the usual binder.

The process is based on the availability of cheap, fast-growing timber of suitable quality. Work is now in progress to catalogue the wood species which have suitable physical structure and chemical composition.

The initial step is the machining of timber into wood-wool. Particular emphasis is placed upon using timber which cannot be used for other purposes. The wood strands are soaked in mineralizing fluid which also contains the Portland cement. The treated wood-wool is moulded into slabs under slight pressure. After storage in the moulds from 8 to 24 hours, the slabs are kept in moist air to develop their final strength. The smallest units for the manufacture of wood-wool have an annual capacity of 300 tons. Plants for production of wood-wool slabs are available with capacities of 2,000 m^3 per annum and greater. The development of suitable plant sizes and simple equipment for small-scale manufacture of wood-wool slabs is another phase of the work at the Tropical Products Institute.

The chief applications of wood-wool slabs are in roof decks, partition walls and ceilings. The sound absorptive properties of wood-wool slabs are good; therefore, they are used in acoustic panels even for expensive types of construction.

Some conditions of asbestos substitution in asbestos cement products, by J. Talabér, Hungary

This paper presents a general discussion of the quality of raw materials for the standard asbestos cement process and reports a series of trial runs in which the ratio between short- and long-fibre asbestos was successfully increased. An increase in the rate of rotation of the filter produced an orientation of the fibres and an increase in the strength. This effect is similar to the result obtained by the use of higher grade asbestos fibres.

However, excessive use of short-fibre asbestos will always result in a product of lower strength and bulk density and higher water absorption than standard asbestos cement products. The degree of replacement of long-fibre asbestos with lower grades must be determined in each individual case on the basis of plant trials and economic considerations to attain the correct balance between cost and the required properties.

For a number of years there has been research on the following artificial fibres as a substitute or replacement for asbestos: organic fibres, glass fibres, slag and basalt wool, and zirconia stabilized fibres. The published results have been contradictory. The inherent drawback of all these fibres is a much lower specific surface than asbestos and poor stability in the alkaline medium of Portland cement paste. The extent alkali stability can be improved by the addition of zirconia to the fibre is the subject of current research. No known artificial fibre has suitable long-range stability in combination with Portland cement.

Experiments carried out by the author indicate that basalt wool with its somewhat larger fibre diameter, greater stiffness and strength is the most suitable substitute at present. The wet-felting characteristics of this type of wool and the drainage characteristics are very favourable. A replacement of 10 to 20 per cent of the asbestos with basalt wool seems to be possible without a loss in strength. These conclusions are based on major production runs.

Fibrous substitution of asbestos, by L. Mach, CSSR

The author reports the development of a so-called A-type mineral fibre which can be used as a substitute for 15 to 20 per cent of the asbestos in asbestos cement products. Pending patent applications preclude detailed information concerning the chemical composition of these fibres. The fibre can be produced by conventional mineral wool processes and raw materials. A few minor modifications of the production equipment are necessary to introduce an additive to the melt. Some form of cleaning equipment must be installed to separate the fibres from non-fibrous particles. The current price for this fibre is $200 to $250/ton. The increased cost is caused by the additive and the cleaning of the fibre.

Further research is required if a greater substitution of asbestos by mineral fibre is desirable because certain physical properties of the asbestos cement products will deteriorate with an increasing degree of substitution. The surface of the product must then be protected by suitable coatings in cold climates.

Mineral wool and its products, production and use, by I. A. Eremin, USSR (presented by M. Sukharev)

The author presents a comprehensive treatment of the technological aspects of mineral wool production and application. The raw materials for the manufacture of mineral wool are generally natural siliceous and carbonaceous rocks such as basalt, granite and silica gravel. In many cases they are combined with slags and other industrial waste products from smelting operations.

It is most common to melt the raw materials in a cupola although glass furnaces or electric furnaces are occasionally used if the raw materials are not available in granular form. A spinner is the most common and most economical unit for fiberization from the standpoint of over-all performance. In certain cases steam or air jets supply the energy for fiberization. Occasionally, a combination of the two methods is used.

Binders are applied on the surface of the fibres for dry-felted products. Urea- and phenol-formaldehyde resins are popular binders due to their low cost and because they can be prepared with relative ease by the mineral wool manufacturers. The binder is applied by spray atomization or infrequently by bath impregnation. Other forms of binders are bituminous emulsions. Dry-felted products are generally restricted to densities below 160 kg/m^3.

In wet-felted mineral wool products such as filters which are manufactured on certain types of paper making machinery, clay and starch binders are used. Their densities are about 300 kg/m^3.

Mineral wool products can also be classified by their rigidity. Loose wool and stitched blankets are used for thermal insulation in industrial installations. Flexible, semi-rigid and rigid felts with and without facings are used in home insulation and industrial applications. Rigid-block type insulation is frequently used in high-temperature applications. Certain rigid felts are also used for acoustic insulations. Roof decks have been made by impregnating rigid felts with asphalt. The paper contains extensive statistical data and the practical details of the application of mineral wool in home and industrial insulations.

Polysand building materials, their production and application, by K. A. Benedikter, Austria

Polysand building materials are based on sand and certain waste products in combination with quicklime, hydrate lime or organic polymers as binders. They can be produced with or without reinforcement by asbestos fibres; cement is also substituted.

The combination sand and lime was developed originally from the technology applied in the manufacture of steam-cured calcium silicate products. The process is economical in cases where a good grade of lime, but no Portland cement, is available.

Unsaturated polyesters are the recommended organic binders for the best process economy in comparison with asbestos cement. Building materials of a sand-resin nature in the form of roofing, siding, blocks and pipes can be manufactured on simple machinery by unskilled labour. These materials are being introduced under the name Polysand.

Annex 2

LIST OF PARTICIPANTS

AUSTRIA

K. BENEDIKTER
Consultant
Patentanstalt für neue Baustoffe, Liechtenstein
Burggasse 24
Vienna 1070

CZECHOSLOVAKIA

L. MACH
Head of Technological Group
Research Institute of Building Materials in Brno
Ostrava 2
Výstavní 30

DENMARK

O. BERGER
Head of Research and Development Laboratory
H and H Industri A/S
Lundtoftevej 1
Copenhagen

K. THIELE
Production Manager
Dansk Eternit-Fabrik A/S
Sohngårdsholmsvej
Aalborg

GERMANY, FEDERAL REPUBLIC OF

H. SCHULTHEIS
Leader of Group "Chemical Materials in Building"
Farbenfabriken Bayer AG
Anwendungstechnische Abteilung
509 Leverkusen

HUNGARY

J. TALABÉR
Director, Central Research and Design Institute of the Silicate Industry
Ministry of Building and Works
Budapest X
Bihari U. 6

LEBANON

S. KLINK
Member of the Faculty
Faculty of Engineering and Architecture
American University of Beirut
Beirut

UNION OF SOVIET SOCIALIST REPUBLICS

Y. LAPOTNIKOV
Deputy Chief, Main Directorate of the Asbestos Cement Industry
Ministry of Building Materials Industries
2/3, The Square of Nogin
Moscow

M. SUKHAREV
Deputy Director, Institute of Teploproect
7 Kominterna Street
Moscow

UNITED KINGDOM

A. CHITTENDEN
Chief Experimental Officer
Tropical Products Institute
Ministry of Overseas Development
Culham, Abingdon, Berkshire

A. MAJUMDAR
Senior Principal Scientific Officer
Ministry of Public Building and Works
Building Research Station
Garston, Watford WD27JR

Observers

A. ALASSAD	Director, Cement Factory P.O. Box 309 Damascus Syria
A. AUST	Aust and Schüttler Graf-Adolf-Strasse 81 D-4 Düsseldorf Federal Republic of Germany
S. BAR-SHLOMO	International Asbestos-Cement Review CH-8867 Niederurnen Switzerland
J. BUDIERI	General Manager Kuwait Asbestos Industries Co. P.O. Box 3314 Kuwait

E. DÜBELL
(Alternate: H. KRENN)

Federal Ministry of Construction
and Technology
Stubenring 1
Vienna 1010
Austria

H. FUCIK

Tivoligasse 41
Vienna 1120
Austria

R. JAHN

Consultant
Patentanstalt für neue Baustoffe,
Liechtenstein
Hügelgasse 6
Vienna 1130
Austria

G. JANSSENEGG

Eternit-Werke Ludwig Hatschek
Maria Theresienstrasse 15
Vienna 1090
Austria

P. NISCHER

Betontechnische Abteilung
Forschungsinstitut des Vereins der
Österreichischen Zementfabrikanten
Reisnerstrasse 53
Vienna 1030
Austria

S. SPEIL

Director, Corporate, Mining and
Pipe Divisions
Johns-Manville Research Center
P.O. Box 159
Manville, New Jersey
United States

A. TALLENTIRE

Product/Project Manager
Fibreglass Limited
St. Helens, Lancashire
United Kingdom

F. TAMÁS

Senior Chief Scientific Officer
Central Research and Design
Institute for the Silicate
Industry
Budapest X
Bihari U. 6
Hungary

J. WESSELY

Tivoligasse 41
Vienna 1120
Austria

Representatives of the UNIDO Secretariat

W. A. CALDWELL	Chief, Basic Chemicals, Pharmaceuticals and Building Materials Industries Section Industrial Technology Division
S. A. BOLDYREV	Industrial Development Officer Industrial Technology Division Technical Secretary - Expert Group Meeting

Representatives of other United Nations Organisations

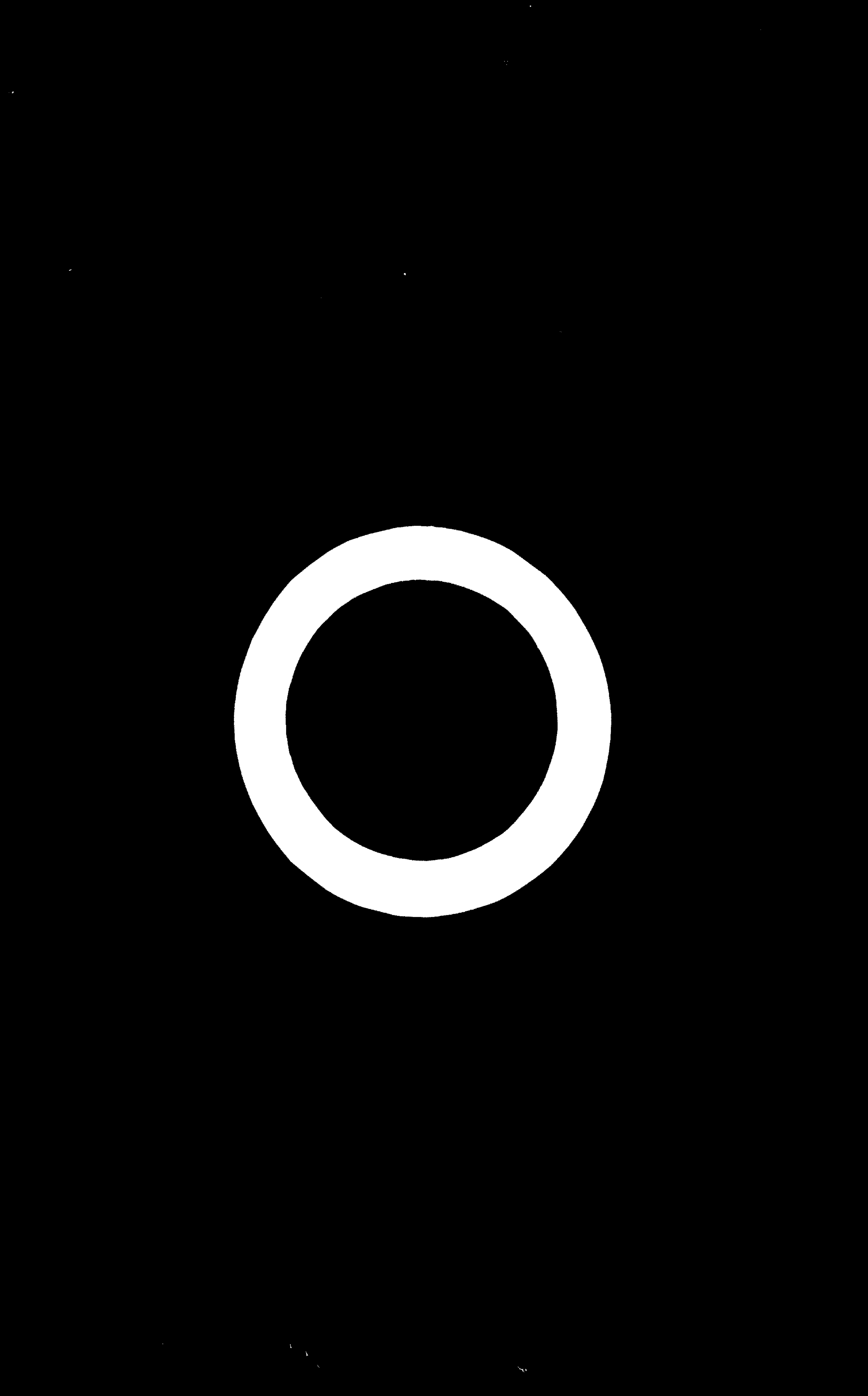
ECAFE	R. SINGH Director, National Building Organization Regional Housing Centre for ECAFE Niman Bhawan Maulana Azad Road New Delhi India
FAO	A. ATEN Liaison Officer (Industrial Activities) Inter-Agency Liaison Division (FAO) Via delle terme di Caracella Rome Italy
IAEA	H.-C. YUAN Division of Research and Laboratories, IAEA Kärntnerring Vienna 1010 Austria

Annex 3

LIST OF DOCUMENTS PREPARED FOR THE MEETING[1/]

ID/WG.44/1	Provisional Agenda
ID/WG.44/2 and Summary	Glass fibre reinforcement of inorganic building materials, by A. J. Majumdar
ID/WG.44/3 and Summary	Proposed research and development programme at the Tropical Products Institute in wood-wool slab manufacture in developing countries, by A. E. Chittenden
ID/WG.44/4 and Summary	Some conditions of asbestos substitution in asbestos cement products, by J. Talabér
ID/WG.44/5 and Summary	Autoclave method of production of asbestos cement sheets and pipes in the USSR, by V. I. Lapotnikov
ID/WG.44/6 Summary	Fycrete-glass fibres reinforce plastics to strengthen concrete structures, by S. A. Klink
ID/WG.44/7 and Summary	Completion and substitution of asbestos cement by plastic materials, by H. Schultheis
ID/WG.44/8 and Summary	Fibrous building materials produced from industrial wastes, by R. Singh
ID/WG.44/9 and Add.1 and Summary	Some aspects on the choice of asbestos cement machinery, by K. Thiele
ID/WG.44/10 and Summary	Polysand building materials, their production and application, by K. Benedikter
ID/WG.44/11 and Summary	Mineral asbestos substitutes, by L. Mach
ID/WG.44/12	Provisional list of participants
ID/WG.44/13	List of documents issued
ID/WG.44/14 and Summary	Mineral wool and its products, manufacture and use, by I. A. Eremin

1/ A limited number of copies are available upon request.



Annex [illegible]

[illegible] ETERNIT-[illegible]

The participants of the meeting visited the Eternit-Werke Ludwig Hatschek asbestos cement pipe factory in Biedermannsdorf. Asbestos cement under the name Eternit was invented by [illegible] in [illegible] and patented in [illegible], and the cradle of the industry is considered to be the Eternit plant in Vöcklabruck, which is still the largest asbestos cement production plant in Austria.

The plant located in Biedermannsdorf was erected within an eighteen-month period and began production at the end of [illegible]. It produces asbestos cement pipes at the annual production rate of 25,000 tons of asbestos pipes with diameters ranging from [illegible] mm to 1,600 mm. Of this production, 10 per cent is exported while the rest is utilized for fresh and waste-water projects in Austria. For example, the Vienna water works use 1,200 mm pipes in the city's sewerage system.

Austria has one of the highest <u>per capita</u> consumptions of asbestos cement sheet goods; 50 per cent of it is corrugated sheets, 35 per cent flat sheets and shingles, and 15 per cent decorative materials. Asbestos is imported from Canada, South Africa and the USSR. A six-month supply of asbestos is kept on stock at the pipe plant in Biedermannsdorf.

The participants observed the operation of a modern pipe machine and the further processing and testing of high pressure pipes at one of the most modern installations of its kind.

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