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D00458

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.44
29 September 1969

ORIGINAL: ENGLISH

Expert [illegible] Meeting [illegible]
[illegible] - [illegible] [illegible]

Vienna, [illegible] - 24 October 1969

# FIBROUS BUILDING MATERIALS PRODUCED FROM INDUSTRIAL WASTES[1]

by

Rabinder Singh
Director, National Buildings Organization and
United Nations Regional Housing Centre for the ECAFE Region
New Delhi, India

1/ This paper was prepared by Mr. Singh in his capacity as consultant to UNIDO and the views expressed are not necessarily those of the organization. The document has been reproduced without formal editing.

id. 69-4932

United Nations Industrial Development Organization

Distr.
LIMITED
ID/WG. 41/? SUMMARY
29 September 1969
ORIGINAL: ENGLISH

Expert Working Group Meeting on
Fibro-cement Composites
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## SUMMARY

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### INTRODUCTION

Large volumes of industrial and agricultural wastes are available in many developed and developing countries. Extensive research and development work on the economic utilization of these wastes has engaged the attention of scientists and technologists. The economic utilization of some of the wastes in the construction industry has achieved a good measure of success.

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id. 69-4923

Fibrous wastes, both from industrial and agricultural sectors, are often disposed of by incineration or used as a cheap source of fuel. Sources of such fibrous waste materials include coconut husk, bagasse, sugar cane-tops, jute stalk and wood waste. Other fibrous materials which could be termed as wastes are scrap paper, cotton wastes, rags, rice husk and certain species of low grade bamboo not put to any profitable use at present. Coconut husk has been investigated and found suitable for the manufacture of particle boards having superior properties and low cost of production. Insulation and hardboard manufactured from bagasse and sugar cane tops are widely used in the building industry. Boards from jute stalk are being commercially produced and used in India.

Amphibole asbestos is used very little at present in the manufacture of building products. The availability of this low grade asbestos fibre and its profitable utilization in the manufacture of asbestos cement products has been engaging the attention of countries which have resources of amphibole asbestos, but are in short supply of chrysotile. Extensive research and investigation has been undertaken in many countries to develop methods of its utilization in the production of asbestos cement products. In part I of this paper, a review of the work done in laboratory and industry on the use of amphibole asbestos as a replacement to the chrysotile variety is presented. A fair amount of success has been achieved in this direction which perhaps require extensive industrial trials before adoption by the industry.

The use of bamboo pulp as a substitute source of fibrous material for use in asbestos cement products has also been investigated upon in several countries. In India, some measure of success has been achieved in this direction and commercial trial production of bamboo pulp cement sheets is envisaged in the near future. In part II of this paper the results of work done on bamboo pulp cement roofing sheets in laboratory and trial productions in industry are described. Though roofing sheets with bamboo pulp have been produced in laboratory and on pilot plant scale in the industry, their satisfactory performance in the field has yet to be evaluated.

In part III, manufacture of corrugated asphaltic sheets utilizing bitumen (asphalt), a waste product from petroleum refineries and paper felt manufactured from waste paper and rags, is described. This roofing material is used extensively for low cost and temporary construction in many developing countries of Latin America and the Carribean Islands. However, their manufacture and use in the developing countries of Asia, Far East and Africa is yet to be established. This roofing material has good scope for acceptance in place of the conventional thatch or grass roofing in the developing areas of the world.

It may be stated that very meagre published information is available on research, development and use of these materials. Most of the information presented, has been gleaned by the author through discussions with scientists and technologists engaged in research in industry or study of the manufacture and use of these fibrous building materials.

## SUMMARY OF PART I.

Asbestos cement building products constitute an important group of building materials and almost all industrially advanced countries and many developing countries have established indigenous industries for their manufacture.

Asbestos minerals fall into two broad classes, viz. Chrysotile and amphibole. Fibres of chrysotile possess high tensile strength and the available natural resources have been adequately exploited. Varieties of asbestos in the amphibole group on the other hand display varying characteristics due to their varying compositions. This fact may perhaps be responsible for their poor exploitation; the world production of amphibole is only 7% of the total asbestos production. Many countries like India are still importing chrysotile although they have known reserves of amphiboles. As a result attention has been focused on the utilisation of amphiboles for manufacture of building products. A good amount of development work is being carried out on the subject in South Africa, Australia, Italy and West Germany. It has been possible to use some proportions of selected quantities of tremolite and anthophyllite along with chrysotile in the manufacture of pipes of and building boards and such other applications in which impact strength is not a criterion to be fulfilled.

During the last decade in India, systematic research has been directed towards the utilisation of tremolite. It has been concluded that fairly large proportions of chrysotile could be substituted by tremolite in building products. In building boards and pipes, even 10% substitution of amphibole is considered permissible if strength is not a primary

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consideration.

Four processes have been developed in India for utilisation of amphibole asbestos. The main principles underlying these are:-

i. treating the minerals with a surface active agent to achieve the requisite 'opening up' of the fibres;

ii. Curing the products in air tight and humid atmosphere of carbon dioxide;

iii. Blending of selected varieties of indigenous and imported amphiboles;

iv. Judicious selection of amphibole asbestos based on certain specific properties of the fibre.

A scientific gradation of amphibole asbestos according to the physical, chemical and mechanical properties has not been evolved due to lack of data. Such a grading is an essential pre-requisite for selecting mineral of the right grade in the manufacture of asbestos cement products.

Test methods for grading chrysotile are already specified in respective standards of different countries and it may be possible to adopt them for amphibole with modifications. The Indian Standards Institution has taken up work for evolving standard test methods for gradation of amphibole asbestos.

## SUMMARY OF PART II

Pulp cement boards made from fibrious materials like wood pulp, straw, reeds and hemp seeds have been manufactured and used in U.S.S.R. and Japan. Investigations have been carried out in India on the use of bamboo pulp for the manufacture of pulp cement building boards and roofing sheets.

Results of laboratory experiments with boards prepared from bamboo pulp and commercial trial production are discussed in this paper.

Tests carried out on specimens prepared with bamboo pulp and portland cement revealed that it is practicable to manufacture (i) Plain building boards (ii) Flat sheets and (iii) Corrugated roofing sheets. The strength of these materials are also comparable with strength values as specified for asbestos cement products.

Roofing sheets made of this material were subjected to further tests as they are required to withstand more severe conditions in practice. The tests were aimed to evaluate their performance with regard to transverse breaking load, water absorption, weathering properties, resistance to microbe action and fire resistance. The bamboo-pulp-cement sheets were found satisfactory for adoption in construction considering the behaviour under the tests.

Based on Indian experience, the cost of production of sheets in a plant with a 50 tonne/day capacity, involving a capital expenditure of $ 277000, has been worked out to be $ 0.46 per sq.m.

## SUMMARY OF PART III

Corrugated asphaltic roofing sheets are a good substitute for asbestos-cement, aluminium and galvanised iron sheets in developing countries because of their lower cost and suitability to tropical and semi-tropical climates. They could be advantageously used for industrial structures, temporary buildings and low cost and rural houses. They are widely used in several Latin American countries.

Asphaltic roofing sheets consist primarily of a 'board' or 'paper felt' impregnated with an asphaltic medium and protected by a surfacing material. The 'board' is manufactured from waste materials like scrap paper, bagasse, jute waste, coconut fibre, rejected asbestos fibres and rags, which are generally available. The materials may be used singly or in various combinations which would impart the desired properties to the board. The impregnation medium used is usually a standard grade paving asphalt. For surface protection of the boards, mineral granule, aluminium foil or aluminium paint are used. Plastic emulsion paints may also be used for giving a pleasing coloured finish but they increase the cost.

The process of manufacture consists in reducing the basic raw material, waste paper, rags and other cellular fibres to a wet pulp of the required fineness successively in coarse and fine hammer mills and forming the pulp into sheets, in felt or board forming machines.

sun or in drying oven
rimmed. The dried boards
ts, cured for a short
brief description of the
is given in this paper.
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and tear. They are completely
sheets. Unlike galvanized
not corrode or are damaged
ree with asbestos-cement
not attacked by fungi or vermin.
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India with an annual
is approximately [illegible] 21,000
ed out to 34 cents/sq.m.

# CONTENTS

# INTRODUCTION

1. Large volumes of industrial and agricultural wastes are available in all developed and developing countries. Extensive research and development work on the economic utilisation of these wastes has engaged the attention of scientists and technologists. The economic utilisation of some of the wastes in the construction industry has achieved a good measure of success.

2. Fibrous wastes, both from industrial and agricultural sectors, are often disposed of by incineration or used as [illegible] source of fuel. Sources of such fibrous waste materials include coconut husk, bagasse, sugar cane-tops, jute stalk and wood waste. Other fibrous materials which could be termed as wastes are scrap paper, cotton wastes, rags, rice husk and certain species of low grade bamboo not put to any profitable use at present. Coconut husk has been investigated and found suitable for the manufacture of particle boards having superior properties and low cost of production. Insulation and hardboard manufactured from bagasse and sugar cane tops are widely used in the building industry. Boards from jute stalk are being commercially produced and used in India.

3. Amphibole asbestos is used very little at present in the manufacture of building products. The availability

of this low grade asbestos fibre and its profitable utilisation in the manufacture of asbestos cement products has been engaging the attention of countries which have resources of amphibole asbestos, but are in short supply of chrysotile. Extensive research and investigation has been undertaken in our country to develop methods of its utilisation in the production of asbestos cement products. In part I of this paper, a review of the work done in laboratory and industry on the use of amphibole asbestos as a replacement to the serpentine variety is presented. A fair amount of success has been achieved in this direction which perhaps requires extensive industrial trials before adoption by the industry.

4. The use of bamboo pulp as a substitute source of fibrous material for use in asbestos cement products has also been investigated upon in several countries. In India, some measure of success has been achieved in this direction and commercial trial production of bamboo pulp cement sheets are envisaged in the near future. In part II of this paper the results of work done on bamboo pulp cement roofing sheets in laboratory and trial productions in industry are described. Though roofing sheets with bamboo pulp have been produced in laboratory and on pilot plant scale in the industry, their satisfactory performance in the field has yet to be evaluated.

5. In part III, manufacture of corrugated asphaltic sheets utilising bitumen (asphalt), a waste product from

petroleum residues and paper felt manufactured from waste paper and rags, or wood fibres. This roofing material is used extensively for temporary and permanent construction in many developing countries of South America and the [illegible]. However, their manufacture and use in the developing countries of Asia, Far East and Africa [illegible] encouraged. This roofing material [illegible] in place of the conventional thatch or grass roofing in the developing areas of the world.

6. It may be stated that very meagre published information is available on research, development and use of these materials. Most of the information presented, has been gleaned by the author through discussions with scientists and technologists engaged in research in industry or [illegible] the manufacture and use of these fibrous building materials.

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[illegible] considerati[illegible].

[illegible] principles [illegible]:-

i. Treating the minerals with a surface active agent to achieve the requisite [illegible];

ii. [illegible] of carbon dioxide;

iii. [illegible] of [illegible];

iv. [illegible] properties of [illegible].

[illegible]

[illegible] growth.

[illegible] modified in [illegible] different countries [illegible]. [illegible] Indian [illegible] has taken [illegible] question of [illegible].

INTRODUCTION

1.1 Asbestos cement products constitute an important group of building materials universally employed in construction industry. Almost all the industrially developed countries have long established indigenous industries to manufacture these products. In the last decade many developing countries, including those which have indigenous cement production, have also installed plants to manufacture asbestos cement products. Amongst the countries in the ESCAP region, nine have such [illegible].

1.2 Asbestos group of minerals is sub-divided into two broad classes, viz. "chrysotile" and "amphibole". The chrysotile variety is more important commercially than amphibole due to the fact that the former possess high tensile strength. The amphibole group of minerals includes amosite, crocidolite, tremolite and anthophyllite. Of these, the first two are much stronger than the other two, and as such have found application in the manufacture of asbestos cement products. The fibres of tremolite and anthophyllite are weak and brittle and therefore use of these minerals in asbestos cement products industry where strength property is an important criterion, has been very limited.

1.3 Production of asbestos has been reported from 33 countries. Chrysotile variety constitutes roughly 93% of the world production, whereas amosite and crocidolite variety of amphibole account for only 5.4%

of the world production; the balance is made up of tremolite and anthophyllite. The bulk of chrysotile production is from Canada, USSR, Rhodesia, Swaziland and Republic of South Africa. Some of the other important asbestos producing countries are United States, China and United Arab Republic; Finland, Yugoslavia and Italy produce tremolite variety whereas amosite and crocidolite have been mainly mined in South Africa. The latest figures available for the production of asbestos in various countries are given in Table [illegible]. The world production of asbestos during 1966 was estimated around 3.[illegible] million tonnes. Canada and USSR continued to be the world's leading producers of asbestos during 1966. Recently, existence of large deposits of high grade chrysotile variety of asbestos has been reported from Indonesia. It is expected that in the very near future these deposits would be commercially exploited and Indonesia would become one of the major producers of this variety of asbestos.

GENERAL FEATURES OF ASBESTOS MINERALS

2.0 Chrysotile

2.1 Chrysotile is a hydrous magnesium silicate identified by the formula 3 MgO.2 $SiO_2$. $2H_2O$ with 13% water of crystallisation. Minor quantities of iron, nickel, manganese or aluminium may replace part of magnesium resulting in some modification of the physical properties of the fibre. Presence of impurities also influences the characteristics of the mineral, but in general chrysotile is more uniform in character than

TABLE I: WORLD PRODUCTION OF ASBESTOS

(Thousand tonnes)

| Country | 1953 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966* |
|---|---|---|---|---|---|---|---|---|---|---|
| WORLD [1] | 1140 | 1310 | 1510 | 1600 | 1730 | 1760 | 1850 | 2020 | [illegible] | [illegible] |
| Argentina | 0.0 | 0.3 | 0.3 | 0.3 | 0.3 | [3] 0.2 | [3] 0.2 | [3] 0.5 | [3] 0.2 | [3] 0.2 |
| Australia | 4.9 | 14.1 | 15.3 | 14.2 | 15.2 | 16.7 | 12.1 | 12.4 | 10.5 | 12.9 |
| Austria | - | - | - | 0.1 | 0.5 | 0.5 | 0.6 | - | - | - |
| Bolivia [2] | 0.7 | - | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Botswana | 0.5 | 0.1 | 1.3 | 1.2 | 1.7 | 2.2 | 2.1 | 2.0 | 0.8 | - |
| Brazil | 1.2 | 3.5 | 84.3 | 98.4 | 115.3 | 87.7 | 132.5 | 176.9 | 153.0 | [illegible] |
| Bulgaria | 0.9 | 1.0 | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.7 | 1.5 |
| Canada | 826.6 | 833.4 | 952.9 | 1014.7 | 1054.8 | 1103.0 | 1157.1 | 1282.1 | [illegible] | [illegible] |
| China (Taiwan) | - | - | 0.1 | 0.4 | 0.1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 |
| Cyprus | 14.5 | 15.0 | 12.1 | 21.9 | 14.7 | 20.8 | 15.1 | 12.6 | 18.0 | [illegible] |
| Finland | 10.9 | 7.2 | 8.7 | 9.6 | 9.4 | 9.9 | 9.3 | 10.6 | [illegible] | [illegible] |
| France | 9.3 | 19.6 | 21.0 | 25.5 | 27.9 | 25.4 | 23.7 | 53.0 | 6.4 | - |
| India | 0.7 | 1.2 | 1.4 | 1.7 | 1.5 | 1.7 | 2.8 | 2.4 | 4.5 | [illegible] |
| Italy | 20.4 | 32.6 | 47.4 | 54.9 | 50.7 | 55.0 | 57.5 | [illegible] | 71.6 | [illegible] |
| Japan | 4.1 | 10.1 | 13.4 | 15.5 | 17.1 | 14.0 | 16.5 | [illegible] | 14.0 | [illegible] |
| Kenya | [illegible] | [illegible] | - | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|
| Korea, Rep. of | - | 0.0 | 0.1 | 0.2 | 0.3 | 1.2 | 1.9 | 1.[illegible] | 1.[illegible] | [illegible] |
| Mozambique | - | 0.2 | 0.1 | 0.0 | 0.1 | 0.3 | - | - | - | - |
| New Zealand | - | 0.4 | 0.6 | 0.3 | 0.3 | 0.4 | 0.4 | - | - | - |
| Philippines | - | - | 0.1 | 0.0 | 0.1 | 0.9 | 0.4 | 0.5 | - | 0.5 |
| Portugal | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | - | 0.0 | - | [2] 0.0 | [2] [illegible] |
| Rhodesia, Southern | 73.6 | 115.3 | 108.6 | 121.5 | 145.6 | 139.1 | 120.1 | [illegible] | [illegible] | [2] [illegible] |
| South Africa | 56.0 | 150.3 | 165.6 | 153.5 | 174.3 | 200.8 | 198.6 | [illegible] | [illegible] | 250.[illegible] |
| Swaziland | 27.8 | 22.9 | 28.5 | 29.1 | [2] 27.9 | [2] 29.8 | [2] 30.[illegible] | [2] [illegible] | [2] 27.[illegible] | [2] [illegible] |
| Turkey | - | 0.[illegible] | 0.4 | 0.9 | 1.8 | 0.9 | 0.[illegible] | 1.[illegible] | [illegible] | [illegible] |
| USSR *[3] | (250) | (430.0) | (400.0) | (540.0) | (600.0) | (640.0) | ([illegible].0) | ([illegible].0) | ([illegible].0) | [illegible] |
| U.A.R. | 0.2 | 0.4 | 0.5 | 0.4 | 0.2 | 0.6 | 0.[illegible] | 1.6 | [illegible] | [2] [illegible] |
| United States[4] | 42.4 | 39.9 | 41.2 | 41.0 | 47.2 | 48.3 | [illegible] | 91.7 | [illegible] | [illegible] |
| Venezuela | 0.2 | 2.2 | 1.6 | 3.3 | 0.6 | - | - | - | - | [illegible] |
| Yugoslavia[5] | 3.7 | 4.4 | 4.2 | 5.4 | 6.1 | 6.7 | 8.[illegible] | 8.4 | [illegible] | [illegible] |

Note: The figures refer to non-fabricated asbestos fibres and asbestos powder.

1. Excluding China (Mainland), Czechoslovakia, Ethiopia, North Korea, Romania and [illegible].
2. Exports.
3. Source: U.S. Bureau of Mines
4. Asbestos sold or used by producers.
5. Excluding asbestos powder.
6. Including vermiculite.

Source: U.N. Statistical Yearbook 196[illegible] amphiboles. Chrysotile fibres are of length 1/[illegible] mm and upwards and possess high tensile strength and good flexibility. These properties make chrysotile most useful for the manufacture of asbestos cement products.

2.2 Amphibole group of minerals.

The term 'amphibole' refers to a group of minerals which are generally silicates of magnesium, calcium, iron and other elements with 1 to 3 per cent of water of crystallization. The group is generally identified by the formula [illegible]. The variation of composition in amphiboles, which is a typical characteristic of this group of minerals, contributes to significant changes in physical and chemical properties. This characteristic necessitates strict controls to maintain uniform quality of the mineral for use in the manufacture of asbestos cement products.

2.2.1 Amosite: Amosite is a fibrous form of the monoclinic amphibole grunerite. It is an iron rich anthophyllite. Amosite finds application [illegible] in the manufacture of felted insulation material for high temperature service.

2.2.2 Crocidolite: Crocidolite, because of its blue colour, is also known as blue asbestos. It, however, becomes whitish when fiberised. The general chemical formula is 3 $Na_2O$ . 6 [illegible] . [illegible] . 16 $SiO_2$ . $H_2O$. Its important properties include high tensile strength comparable to chrysotile, harshness, acid resistance and resistance to effects of outdoor exposure.

2.2.3 **Anthophyllite:** It is a magnesium-iron-silicate represented [illegible] by the formula $(Mg,Fe)_7 Si_8O_{22} (OH)_2$. It is characterised [illegible] brittle fibres having [illegible] heat and acid resistance. [illegible] commercial importance [illegible] strength.

2.2.4 Tremolite: [illegible] amphibole mineral having a formula [illegible] MgO . [illegible] $SiO_2$ . $H_2O$. In this composition, calcium may be replaced by sodium, magnesium, iron or aluminium leading to variations in composition and properties. Tremolite consists of grey or white [illegible] fibres, [illegible] brittle. In tremolite, iron may substitute in part for magnesium and when [illegible] the mineral is called actinolite.

2.3 [illegible] the general properties of amphibole group of minerals. It is seen from the table that among the amphiboles, [illegible] and crocidolite have good [illegible] properties, [illegible] suitable for use in asbestos cement products, whereas the tremolite and anthophyllite, because of their poor strength properties, do not appear to be suitable for use in asbestos cement [illegible] at the present stage of development. Tremolite and anthophyllite, however, have better resistance properties to chemicals, heat, etc., which make them as [illegible] suitable for thermal insulation and linings, etc. But in these special applications the quantity of asbestos required is very

CHART [illegible] GENERAL PROPERTIES OF AMPHIBOLE GROUP OF MINERALS

| S.No. | Properties | Amosite | Crocidolite | Anthophyllite | Tremolite |
|---|---|---|---|---|---|
| | General Composition: $2CaO \cdot 5MgO \cdot 8SiO_2 \cdot H_2O$. | | | | |
| 1. | General Chemical composition formula | $(FeMg)_7Si_8O_{22}(OH)_2$ | $3NaO \cdot 6FeO \cdot 2Fe_2O_3 \cdot 16SiO_2 \cdot H_2O$ | $7MgO \cdot 8SiO_2 H_2O$ | $2CaO \cdot 5MgO\ 8SiO_2 \cdot H_2O$ |
| 2. | Colour | Grey to brownish grey, also clove brown | Lavender blue to dark blue | Brownish grey to Yellowish brown | Grey to pale white |
| 3. | Lustre | Vitreous to dull | Silky to dull | Vitreous or glassy | Silky |
| 4. | Hardness | 5.5 to 6 | 4 | 5.5 to 6 | 5.5 |
| 5. | Sp. gravity | 3.14 to 3.42 | 3.2 to 3.3 | 3.1 to 3.2 | 2.9 to 3.2 |
| 6. | Flexibility | Good | Fair to good | Both brittle and flexible | Generally brittle. Some may be flexible. |
| 7. | Length | 6.25 to 150 mm | Short to 75 mm | Generally short | Sometimes long. |
| 8. | Texture | Coarse and stiff hairline | Harsh or soft | Harsh or soft | Soft to harsh |
| 9. | Tensile Strength | Fairly good | Very good | Weak | Weak |
| 10. | Spinnability | Fair | Fair | Poor | Usually Poor |
| 11. | Resistance to acid | Good | Very good | Fair | Fair to good |
| 12. | Resistance to heat | Good | Poor (fuses) | Very good | Fair to good |
| 13. | Chemical composition % | | | | |
| | $SiO_2$ | 49-52 | 49-53 | 56-58 | 51-62 |
| | $MgO$ | 1-7 | 0-3 | 28-34 | 0-30 |
| | $FeO$ | 34-44 | 13-20 | 3-12 | 1.5 - 5.0 |
| | $Fe_2O_3$ | - | 17-20 | - | - |
| | $Al_2O_3$ | 0-9 | - | 0.5 - 1.5 | 1.0 - 4.0 |
| | $H_2O$ | 2-5 | 2.5 - 4.5 | 1.0 - 6.0 | 0.5 |
| | $CaO$ | - | - | - | [illegible] |
| | $Na_2O$ | - | 4 to 8.5 | - | [illegible] |
| | $CaO + Na_2O$ | 0.5 - 2.5 | - | - | - |

small, when compared to the requirements for asbestos cement products, where asbestos is required as a strong fibrous reinforcement.

REQUIREMENTS OF ASBESTOS IN INDIA

3.1 More than [illegible] requirement in India caters [illegible] industry, [illegible] use of mostly [illegible] varieties of asbestos imported from Rhodesia, [illegible]. The reserves of chrysotile variety in [illegible] are limited and [illegible] production from [illegible] is only [illegible] per annum. The import of [illegible] asbestos is approximately 24,000 tonnes per annum [illegible]. [illegible] use of asbestos fibres [illegible] of various asbestos cement products in India is given below:-

| | | |
|---|---|---|
| i. Roofing sheets | 19,000 | tonnes |
| ii. Flat sheets | 1,500 | " |
| iii. Building boards | 2,500 | " |
| iv. Pressure pipes | 1,000 | " |
| Total | 24,000 | " |

The demand for these products by the construction industry in India is estimated to increase substantially with the increase in construction activities during the Fourth Five Year Plan (1969-74). The total requirement of asbestos fibre is expected to increase to [illegible] tonnes per annum valued at Rs 1[illegible] by 197[illegible].

RESERVES OF ASBESTOS IN INDIA

4.1 India has modest reserves of chrysotile in Cuddapah District, Andhra Pradesh. However, presence of chrysotile has been reported in Rajasthan and Bihar.

A detailed survey [illegible] in Bihar to prove the quality and [illegible] of [illegible] and the feasibility of mining [illegible]. [illegible] chrysotile mined in Andhra [illegible] tensile strength, flexibility [illegible] the bulk of production is [illegible] asbestos textiles. India has [illegible] phyllite varieties [illegible] and amosite varieties [illegible].

[illegible] minerals in India is shown [illegible] estimated reserves of chrysotile and amphibole [illegible] in India.

The present production of asbestos in India is given in Table IV. [illegible] of amphibole asbestos is 873 [illegible] it is possible to increase it substantially should [illegible]

**SUITABILITY OF AMPHIBOLE ASBESTOS IN MANUFACTURE OF ASBESTOS CEMENT PRODUCTS**

5.1 [illegible] of amphibole [illegible] in the manufacture of asbestos [illegible] in many countries. In South Africa and Australia crocidolite has been used [illegible] products. Though crocidolite [illegible] due to its harsh texture, chrysotile is mixed with it for use in the manufacture of asbestos cement [illegible]. An advantage in the use of crocidolite [illegible] property of free and rapid filtration, [illegible] time, thus speeding [illegible] the manufacturing process.

5.2 Tremolite [illegible] anthophyllite, partly in blend with chrysotile, have been used to a limited extent in Italy,

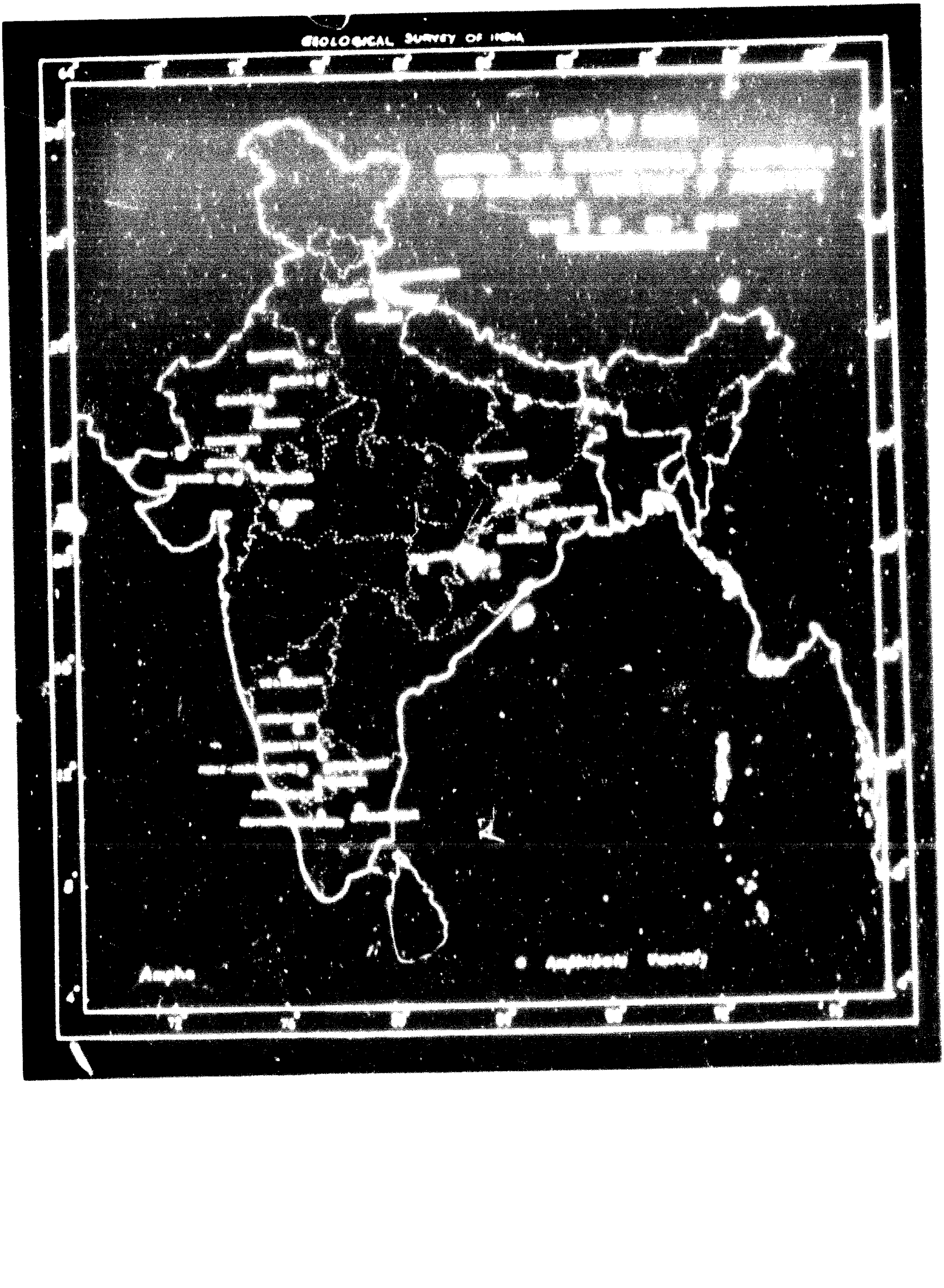
SURVEY OF INDIA

TABLE III: RESERVES OF ASBESTOS IN INDIA

| S.No. | State | Variety | [illegible] |
|---|---|---|---|
| 1 | Andhra Pradesh (Cuddapah) | Tremolite | [illegible] |
| 2 | Bihar (Dholadih, Dangasahi) | Tremolite | [illegible] |
| 3 | Mysore (Hassan) | Tremolite | [illegible] depth from the surface [illegible] estimated by the Department of Mines and Geology, Mysore. |
| 4 | Rajasthan (Bhilwara, Ajmer) | Tremolite | [illegible] asbestos fibre. |
| 5 | Orissa (Seraikela) | Tremolite | Not estimated |

TABLE IV: [illegible]

[illegible]

| Year | Total | Andhra Pradesh* | Bihar | Madhya Pradesh | Tamil Nadu | Mysore | Orissa | Rajasthan |
|---|---|---|---|---|---|---|---|---|
| 1960 | 1711 | 121 | 247 | 2 | - | [illegible] | - | [illegible] |
| 1961 | 1473 | 107 | 90 | 34 | 30 | [illegible] | 14 | [illegible] |
| 1962 | 1692 | 119 | 220 | 11 | - | - | [illegible] | [illegible] |
| 1963 | 2730 | 43 | 347 | 55 | - | [illegible] | 15 | 2138 |
| 1964 | 3376 | 64 | 417 | 66 | - | [illegible] | 4 | 2420 |
| 1965 | 4775 | 72 | 284 | 56 | - | [illegible] | 157 | [illegible] |
| 1966 | [illegible] | 331 | 320 | 50 | - | 509 | [illegible] | [illegible] |
| 1967 | [illegible] | 430 | 321 | 10 | - | [illegible] | [illegible] | [illegible] |
| 1968 | 9065 | 337 | [illegible] | 7 | - | [illegible] | [illegible] | [illegible] |

* The bulk of production of asbestos from Andhra Pradesh is of chrysotile variety

Source: Mineral Statistics of India, 1968. Indian Bureau of Mines, Nagpur, India

U.S.A. and West Germany in the manufacture of various asbestos cement products utilising both lamination and pressure techniques. The properties of chrysotile and amphibole fibres in a blend is dependent on the product to be manufactured and the strength properties of the two types of fibres. The addition of tremolite and anthophyllite to replace chrysotile would reduce significantly the strength of the resultant product. The improvements in preparation of raw material, careful selection, milling and changes in the manufacturing processes etc. could contribute to lessening of the reduction in strength. Such operations are costly, and therefore of interest only to those countries which lack in supplies of chrysotile and do not have crocidolite and amosite but may possess tremolite and anthophyllite. However, it is possible to use some proportions of selected qualities of tremolite and anthophyllite in the manufacture of building pipes and boards in the application of which high strength is not important as in the case of roofing sheets, pressure pipes, etc.

5.3 Factors which determine the choice of amphibole.

The following factors which determine the choice of amphibole fibres may be considered when replacement of chrysotile fibres by amphibole is desired:

5.3.1 Tensile Strength: The tensile strength of the fibres is the most important property guiding the selection of fibres for use in asbestos cement products. For normal use, the tensile strength of the fibre should be of the order of 350-420 kg/cm$^2$.

5.3.2 Fiberization: Amphiboles have poor fiberizability and are brittle. Fiberization improves uniform distribution of fibres in the asbestos cement mix. Increased cement absorption by amphibole fibres has practically no influence on the strength of asbestos cement products. For chrysotile fibres, the mechanism of cement absorption being different, increased cement absorption improves the strength of the products.

5.3.3 Chemical Composition: Chemical composition of fibres is the decisive factor in the choice of fibre for use in asbestos cement products. Ratio between the sum of the percentages of basic oxides to that of acidic oxides should be close to 1; it should not be less than 0.75.

5.3.4 Absorption of Cement: Cement is absorbed by fibres in two distinct ways: (i) by a surface chemical reaction, and (ii) by physical absorption. Major portion of cement retained by the chrysotile fibres is by chemical reaction. It is the chemically reacted portion of cement which influences the strength of asbestos cement products.

Major portion of cement absorbed by amphibole fibres is by physical absorption. Chemical reactivity of amphibole fibres towards cement is low. Fiberization of amphibole only helps to enhance the fraction of cement that is physically absorbed; the chemical reactivity of such fibres remains practically unchanged.

5.4 Choice of Portland Cement: When amphibole fibres are used in a large amount in asbestos cement products, the cement used should be rich in dicalcium-silicate and deficient in tricalcium aluminate.

5.5 <u>Absorption of Lime by Fibres:</u> Lime is liberated in asbestos cement during the setting of cement. Interaction between the liberated lime and chrysotile asbestos is well known. Mechanism of this interaction is a chemical reaction on the surface of the fibres. Chemical reactivity of chrysotile fibres towards such lime is much higher than that of amphibole fibres. Chrysotile fibres remove about 3 times more lime than the amphibole fibres from asbestos-cement systems under similar conditions.

The ratio between the strength obtained in asbestos cement products from chrysotile and amphibole fibres is nearly the same as their lime absorptive capacities.

Removal of lime by fibres influences the strength and larger the amount of lime removed, higher is the strength of asbestos-cement products. It is important to check the lime removed by the fibres in an asbestos cement system. The extent of removal should not be less than about 0.01[illegible] gm/gm of fibres from a system containing 10 gm of cement, in 100 cc of water, in 72 hrs at room temperature.

5.6 <u>Review of work done in India.</u>

5.6.1 Considerable research on the use of tremolite variety of amphibole asbestos in the manufacture of asbestos cement products has been carried out in the laboratories and in the industry in India. A review of work done in India is given below.

As early as 19[illegible], the Department of Mines and Geology, Mysore, conducted experiments on the suitability [illegible] of amphibole asbestos for making asbestos cement products. The experiments revealed that locally available asbestos could be successfully used in the manufacture of asbestos cement sheets, if heavy pressure is used in their moulding. The application of external pressure, however, could be avoided by blending certain proportion of chrysotile with locally available amphibole.

During the last decade systematic research has been directed at the utilization of tremolite variety of amphibole since this material is available extensively in the country. As a result of research work carried out so far, it has been concluded that a fairly large proportion of chrysotile could be substituted by tremolite in the manufacture of asbestos cement products, especially in building boards and pipes. Where high strength is not of primary consideration, possibly cent per cent substitution by amphibole is permissible.

The principal processes developed in India are:-

**Process I.** Treatment of amphibole asbestos fibre with surface active reagent (sulphonated hydrocarbons) and application of pressure in moulding.

**Process II.** Curing of asbestos cement products using amphibole, in controlled humid atmosphere of carbon dioxide gas.

**Process III.** Blending of chrysotile and amphibole fibres so as to attain the specific characteristic desired in the final product.

**Process IV. Judicious selection of amphibole fibres based on specific properties and simultaneous fiberization and blending.**

ROCESS I.

5.6.2 It has been determined that the primary requisite in the utilisation of asbestos [illegible] is the degree of fiberization achieved in processing the mineral. The practice of mechanical crushing adopted in case of chrysotile for opening up of the fibres is not suited to crocidolite and anthophyllite, because of their friability, crushing reduces the fibres to powder [illegible]. Therefore, an alternative method of treatment with surface active reagent which opens up the fibres without appreciably reducing the fibre length has been developed in one of the laboratories [illegible] experimental manufacture of asbestos cement sheets and asbestos cement pipes using this process is described below.

(a) Manufacture of Asbestos Cement Sheets:

In this method a known weight of asbestos fibre is added to a solution [illegible] commercial surface active reagent and is kept under agitation for six hours by blowing air through it. The mixture is then filtered and washed free from the reagent. The treated fibres are put in water and specified amount of cement (asbestos cement in 1:[illegible] or 1:[illegible] ratio) is added to it. Sufficient water is added at this stage to make a 4% slurry which is kept under agitation for about [illegible] minutes by blowing air through it. The whole mass is filtered employing suction, to a water cement ratio of about [illegible]. The paste of asbestos and cement thus produced is subjected to a hydraulic pressure of [illegible] kg/cm² to squeeze out the water, ensuring a water cement ratio of [illegible] : [illegible]. The sheet as cast is [illegible] for a [illegible] [illegible] a [illegible] [illegible] room, and also immersed under water [illegible] [illegible] days for full curing. The transverse strength of the asbestos cement flat sheets of different composition, [illegible] [illegible] amphibole asbestos [illegible] from Saraikela and [illegible] and chrysotile from Cudappah fabricated with a pressure of [illegible] kg/cm² are given in Table V, and results [illegible] Saraikela amphibole and Rhodesian chrysotile, fabricated with a pressure of [illegible] kg/cm² have been given in Table VI. Further cost analysis of replacement of chrysotile with various percentages of amphibole [illegible] with two different proportions of fibres to cement, indicating the savings in the cost of production have been given in Tables VII and VIII.

It is evident from the results indicated in the tables that it is possible to manufacture the standard asbestos cement flat sheets with the furnish of 80% amphibole and 20% chrysotile (asbestos:cement = 1:5) or 90% amphibole and 10% chrysotile (asbestos:cement = 1: ), [illegible] or even 100% amphibole (asbestos:cement = 1:[illegible]). The results indicated that average transverse strength values of 59 kg, 51 kg and 44 kg. are comparable with the standard specifications for flat sheets.

It has been concluded that when the sheets with amphibole fibres alone or with blended chrysotile fibres are hydraulically pressed at 70 kg/cm² or more in order to increase the density comparable to the commercial

Table V

COMPARATIVE TRANSVERSE STRENGTH TESTS
ON ASBESTOS CEMENT FLAT SHEETS.
(FABRICATED UNDER PRESSURE OF [illegible] kg/cm²)

| Sl. No. | Composition: Sarsikeri amphibole | [illegible] amphibole | [illegible] amphibole | Average transverse strength in kg at the centre of span of [illegible] 254 [illegible] specimen) |
|---|---|---|---|---|
| 1. | 100% | - | - | 35 |
| 2. | 100% | - | - | 36 |
| 3. | 100% | - | - | 33 |
| 4. | 50% | 50% | - | 39 |
| 5. | 50% | 50% | - | 36 |
| 6. | 50% | 50% | - | 27 |
| 7. | 50% | 50% | - | 26 |
| 8. | 80% | 20% | - | 38 |
| 9. | 80% | 20% | - | 36 |
| 10. | 80% | 20% | - | 37 |
| 11. | 80% | 20% | - | 23.5 |
| 12. | - | 100% | - | 25 |
| 13. | - | 100% | - | 27 |
| 14. | - | - | 100% | 32 |

Note:
1. Size of sheets 254 x 254 x 6 mm
2. Asbestos cement ratio 1:5:7
3. Curing under water has been done for 28 days after removal from template [illegible]
4. The minimum requirement of transverse strength is 20 kg for 6.5 mm thick and 15 kg for 5 mm thick sheets as per IS: 2098 - 1964.

Table VI

RESULTS OF TRANSVERSE STRENGTH TESTS
ON ASBESTOS CEMENT FLAT SHEETS.
(PASSED [illegible] PRESSURE OF [illegible] kg/cm²)

| Sl. No. | Composition of [illegible] Amphibole | [illegible] Chrysotile | Average bending load in kg tested over a span of [illegible] cm (using [illegible]mm x [illegible]mm specimen) |
|---|---|---|---|
| 1. | 100 | - | 44 |
| 2. | 90 | 10 | 51 |
| 3. | 80 | 20 | 42 |
| 4. | 75 | 25 | 44 |
| 5. | 70 | 30 | 44.5 |
| 6. | 65 | 35 | 53 |
| 7. | 60 | 40 | 43 |
| 8. | 55 | 45 | 37 |

**Note:**

1. Size of sheets [illegible] x [illegible] x [illegible] mm
2. Asbestos cement ratio 1:[illegible]
3. Curing [illegible] water [illegible] after removal from template.
4. The minimum requirement of transverse strength for building boards is 20 kg for 6.5 mm thick sheets as per IS : 2098 - 1964.

# COST ANALYSIS OF ASBESTOS CEMENT FLAT SHEETS

Basis [illegible] production [illegible] 1000 tonnes
Ratio of fibre to cement [illegible]

| Details of sample | Cost of Chrysotile asbestos @ ฿ 175 | Cost of Amphibole asbestos @ ฿ [illegible] | Cost of Portland cement @ ฿ 14 | [illegible] cost of [illegible] per tonne | Total cost of [illegible] | Total cost of [illegible] |
|---|---|---|---|---|---|---|
| 100% chrysotile | [illegible] tonne x 175 = ฿ [illegible] | | 0.[illegible] tonne x 14 = ฿ [illegible] | ฿ [illegible] | ฿ [illegible] | ฿ 54.[illegible] |
| 50% chrysotile fibre + Amphibole fibre | .075 tonne x 175 = ฿ 13.[illegible] | .075 tonne x 66 = ฿ [illegible] | -do- | -do- | ฿ [illegible].00 | ฿ 33.[illegible] |
| 20% chrysotile fibre + 80% Amphibole fibre | .03 tonne x 175 = ฿ [illegible] | .12 tonne x 66 = ฿ 8.00 | -do- | -do- | ฿ 37.00 | ฿ 39.[illegible] |
| 100% Amphibole fibre | - | 0.15 tonne x [illegible] = ฿ 10.00 | -do- | -do- | ฿ 30.00 | ฿ 36,000 |

N.B: The breakage and rejections may be about 3 to 4%. It has been taken care in the above cost, hence no further increase in cost has to be shown.

Table VIII

## COST ANALYSIS OF ASBESTOS CEMENT FLAT SHEETS

Basis: Monthly production [illegible] tonne
Ratio of [illegible] = [illegible]

| Details of sample | Cost of Chrysotile asbestos @ ฿ 17[illegible] | Cost of Amphibole asbestos @ ฿ [illegible] | Cost of cement and [illegible] @ ฿ 14.[illegible] | Overhead cost of [illegible] per tonne | Total cost of production | Total monthly cost of production |
|---|---|---|---|---|---|---|
| [illegible] chrysotile fibre | 0.11 tonne x 173 = ฿ [illegible] | | [illegible] tonne x 14 = ฿ [illegible] | ฿ [illegible] | ฿ [illegible] | ฿ 47,400 |
| [illegible] chrysotile fibre + [illegible] Amphibole fibre | [illegible] tonne x 173 = ฿ [illegible] | [illegible] tonne x [illegible] = ฿ [illegible] | -do- | -do- | ฿ [illegible] | ฿ 39,720 |
| [illegible] chrysotile fibre + 60% Amphibole fibre | [illegible] tonne x 173 = ฿ 4.[illegible] | [illegible] tonne x [illegible] = ฿ [illegible] | -do- | -do- | ฿ 30.30 | ฿ 36,360 |
| [illegible]% Amphibole fibre | -- | [illegible] tonne x 66 = ฿ 7.[illegible] | -do- | -do- | ฿ 27.76 | ฿ 33,312 |

N.B: The breakage and rejections may be about 3 to 4%. It has been taken care of in the above cost, hence no further increase in cost has to be shown.

products, strength exceeding the minimum requirements for asbestos cement products may be obtained. Therefore, the replacement of chrysotile by indigenous amphibole asbestos could have lowered the cost of production to an appreciable amount (see Tables VII & VIII).

The investigations were further extended using samples of amphibole varieties of asbestos from Saraikela, Dholedi and Sankasahi. The samples were treated in the same manner described earlier with the commercial surface active reagent. The same process of manufacture was also followed with the proportion of asbestos to cement as [illegible]:8. The transverse strength of asbestos cement flat sheets prepared with different compositions was tested. Test results are given in Table IX. The results show that it would be possible to manufacture standard asbestos cement flat sheets using 100% of amphibole asbestos either from Dholedi, Sankasahi or Saraikela. The average transverse strength value of flat sheets prepared from them are [illegible] kg, 4[illegible] kg and 4[illegible] kg. respectively, which is comparable with the specification for flat sheets. It is noted that with the increase in the quantity of chrysotile fibre in the blend, there is corresponding increase in the transverse strength value. Therefore, it is expected that with the incorporation of a small quantity of chrysotile fibre, corrugated sheets and other products which require a higher transverse strength value, may be manufactured by applying hydraulic pressure of about 70 kg/cm$^2$ or more for giving an initial shape by lamination method prior to pressing.

## TABLE III

TRANSVERSE STRENGTH TEST RESULTS OF ASBESTOS CEMENT SHEETS
(FRESH [illegible] kg/cm²)

| S.No. | Composition | | Average transverse strength kg/cm² | Composition | | Average transverse strength kg/cm² | Composition | | Average transverse strength kg/cm² |
|---|---|---|---|---|---|---|---|---|---|
| | [illegible] % | [illegible] | | [illegible] | [illegible] | | [illegible] | [illegible] | |
| 1 | 100 | - | 4[illegible] | 100 | - | 4[illegible] | 100 | - | 4[illegible] |
| 2 | 90 | 10 | 43 | 90 | 10 | 43 | 90 | 10 | 43 |
| 3 | 80 | 20 | 45 | 80 | 20 | 51 | 80 | 20 | 4[illegible] |
| 4 | 75 | 25 | 49 | 75 | 25 | 4[illegible] | 75 | 25 | 4[illegible] |
| 5 | 70 | 30 | 50 | 70 | 30 | [illegible] | 70 | 30 | 45 |
| 6 | 65 | 35 | 50 | 65 | 35 | 48 | 65 | 35 | 50 |
| 7 | 60 | 40 | 51 | 60 | 40 | 43 | 60 | 40 | 4[illegible].5 |
| 8 | 55 | 45 | 52 | 55 | 45 | 4[illegible] | 55 | 45 | 41 |
| 9 | 50 | 50 | 43 | 50 | 50 | 45 | 50 | 50 | 43 |
| 10 | - | 100 | 53 | - | 100 | - | - | 100 | 53 |

1. Asbestos cement ratio = 1:[illegible]
2. Curing time under water in days = 28
3. Thickness of the sheets = 6.25 mm
4. Average transverse strength in kg/cm² tested over a span of 228 mm (using 254 mm x 254 mm specimen)

(b) <u>Manufacture of Asbestos Cement Pipes</u>:

Experiments have also been conducted using amphibole fibre treated with surface active reagent for the manufacture of pipes and factory trials have been given to this process successfully. In this process, a known weight of amphibole fibre is added to a solution containing 0.2% of the commercial surface active reagent and the mixture is kept agitated mechanically for about an hour, in a mixer. The required amount of chrysotile fibre was added, at an intermediate stage of agitation. The measured quantity of portland cement (asbestos:cement 1:10 or asbestos:cement 1:8) is added to it along with extra water, to attain the required consistency and the mixture is kept under agitation for another 10-15 minutes. The pipes are formed from this slurry by a forming roller on a removable iron mandrel maintained at an optimum vacuum, the product being rolled on to the mandrel. As soon as the desired wall thickness of pipe is obtained, the mandrel is removed from the machine and another is put in its place. There is provision for calendering the pipes on the mandrel prior to removal. Two sets of building pipes of each composition having diameters 50 mm - 38 mm are made - one set calendered and the other uncalendered. The pressure applied to the pipes is obtained from the calender roller. The iron mandrel is then replaced by a wooden mandrel and the product is kept aside for initial setting for 2-3 hours. The pipes are then removed from the wooden mandrel and weathered for a day on supporting racks. They are then kept immersed under water for 7 days and finally in the open for 21 days for curing.

The bursting pressure of the asbestos cement pipes for different compositions are given in Table X.

The formation of the pipes was found to be easier while using the ratio of asbestos:cement 1:10.

The mixture containing asbestos and cement in the proportion of 1:10 were pressed into pipes only with a blend of 50% amphibole fibre and 50% chrysotile fibre. Though a pressure of [illegible] kg/cm² is generally applied during calendering in the normal process of manufacture using chrysotile fibre, it was found possible for calendering the blends applying a pressure of 21-25 kg/cm² and the product was found to satisfy standard specifications. For manufacture of pipes using 100% amphibole variety, however, a higher pressure to the extent of [illegible]-70 kg/cm² is required.

The ease of production of pipes with the existing machinery and the standard bursting pressure results of pipes obtained with the blend fibres 50% amphibole and 50% chrysotile (asbestos:cement 1:10) show that there is considerable potential for commercial exploitation. The results also indicate the possibilities of using the blend fibres (80% amphibole fibre 20% chrysotile fibre with asbestos:cement in the ratio 1:10) with the existing machinery and controlled calendering.

Since the pipes are manufactured at a low pressure (21-25 kg/cm²) in the existing plants, the somewhat low bursting pressure results obtained with pipes made at sufficiently low pressure and using 100% amphibole fibre needs greater attention for the development of suitable machinery for [illegible] pressure upto 70 kg/cm².

## TABLE - X

BURSTING PRESSURE RESULTS OF ASBESTOS CEMENT PIPES
(Factory Trials)
Maximum Pressure Applied; 300-400  21-28 kg./cm$^2$

| Size of the pipe | Composition | | Asbestos cement ratio | Bursting pressure in kg./cm$^2$ | | Std. bursting pressure in kg./cm$^2$ |
|---|---|---|---|---|---|---|
| | Amphibole % | Chrysotile % | | [illegible] | [illegible] | |
| 1.5 m x 6.9 cm | 100 | - | 1:10 | [illegible].4 | | 15.15 |
| 1.6 m x 6.9 cm | 100 | - | 1:15 | | 1) [illegible] 2) 7.7 3) 6.3 | 15.35 |
| 3.04 m x 5.08 cm | 80 | 20 | 1:10 | 1) 13.3 2) 14 3) 17.1 | | 21.00 |
| 3.04 m x 5.08 cm | 80 | 20 | 1:10 | | 1) 21.7 2) 22.67 3) 17.1 | " |
| " | 50 | 50 | 1:10 | 1) 26 2) 19.66 3) 21.80 | | " |
| " | 50 | 50 | 1;10 | | 1) [illegible].6 2) 25.81 3) 23.6 | " |
| " | 50 | 50 | 1:8 | 1) 7 2) 6.3 3) 9.5 | | " |
| " | 50 | 50 | 1:8 | | 1) 16.26 2) 20.30 3) [illegible] | " |

Tests are being continued to determine the density, porosity and acid resistance properties of asbestos cement pipes.

PROCESS II. 5.6.3 In this process upto 50% of the imported chrysotile is replaced by Indigenous amphibole and the asbestos cement products are made as in normal practice. The products are specially cured for 28 days in airtight rooms and in humid atmosphere of carbon-dioxide gas. Transverse strength results of small specimens with various compositions conducted in the laboratory are given in Table XI. This process was also given factory trials in the manufacture of pressure pipes, and the results are given in Table XII. It is evident from the results in Tables XI and XII that indigenous amphibole asbestos can replace chrysotile fibre upto 50% in the manufacture of building boards and pipes. It is also found that special curing improves the strength of all asbestos cement products made of chrysotile or amphibole fibres, or of mixtures of these in any proportion. The principal advantages of this process are that the products are manufactured without the application of pressure and changes in the existing method of manufacture.

PROCESS III. 5.6.4 In this process judicious selection of both [illegible] It has been found that by such selection it is possible to replace nearly 50% of the imported chrysotile by amphibole. The asbestos cement products are made by the normal process used in the industry. No special curing is necessary. This process has been commercially given factory trials for the manufacture of large sized corrugated sheets ([illegible] cm). The results of factory trials [illegible] are given in Table No. 5.6.[illegible]

**PROCESS IV.** This process involves partial replacement of [illegible] amphibole fibres [illegible] of each fibre. No special choice of chrysotile fibres appears to be necessary.

Requisite quantities of washed and processed amphiboles and chrysotiles are mixed by hand. The mixture thus obtained is subjected to a special method of simultaneous fiberisation and [illegible]. In the laboratory experiments were done with [illegible] sheets. These were cured by immersing in water for [illegible] days.

Preliminary results show that upto 25% replacement of imported chrysotile by amphiboles in the test sheets is possible with adequate strength. The quantum of replacement, however, can be ascertained using the actual commercial production of sheets, and commercially [illegible] further, it may be possible to increase replacement of imported chrysotiles in sheets. The experimental work on this process is still in progress.

Advantages of this method are that ordinary commercial methods can be used and no special curing or application of pressure is required.

## TABLE [illegible]

TRANSVERSE STRENGTH OF 250 mm x 250 mm SHEETS

| Asbestos cement No. | Sheet No. | Amphibole gm | Cement gm | Days of curing | Breaking load in kg for [illegible] mm thickness: Cured immersed in water | Breaking load in kg for [illegible] mm thickness: Cured in special atmosphere |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | 1 | [illegible] | [illegible] | [illegible] | [illegible] | |
| | 2 | 80 | 640 | 28 | [illegible] | |
| | 3 | 80 | 640 | [illegible] | 24.50 | |
| | 4 | 80 | 640 | 28 | 24.50 | |
| | 5 | 80 | 640 | 28 | 24.50 | |
| | 6 | 75 | 600 | 28 | | 37.20 |
| | 7 | [illegible] | 600 | 28 | | 34.0 |
| | 8 | 75 | 600 | 28 | | 34.0 |
| | 9 | 75 | 600 | 28 | | 34.0 |
| | 10 | 75 | 600 | 28 | | 32.65 |
| | 11 | 75 | 600 | 28 | | 34.47 |
| | 12 | 75 | 600 | [illegible] | | 34.47 |
| | 13 | 75 | 600 | [illegible] | | [illegible] |
| | 14 | 75 | 600 | [illegible] | | 32.65 |
| | 15 | 75 | 600 | 28 | | 31.75 |
| | 16 | 80 | 640 | [illegible] | | 31.75 |
| | 17 | 80 | 640 | [illegible] | | 23.56 |
| | 18 | Amphibole [illegible] 75 Chrysotile 7.5 + [illegible] | 600 | 28 | 46 | |
| | 19 | -do- | 660 | 28 | 56 | |
| | 20 | -do- | 660 | 28 | 56 | |
| | 21 | -do- | 660 | 28 | | 33.56 |
| | 22 | -do- | 660 | [illegible] | | [illegible] |
| | 23 | -do- | 660 | [illegible] | | 34.47 |

TABLE [illegible] Contd.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 24 | Amphibole 'A'<br>Chrysotile | [illegible]<br>8 | [illegible] | [illegible] | | 31.[illegible] |
| 25 | -do- | | 704 | [illegible] | | 35.[illegible] |
| 26 | -do- | | 704 | [illegible] | | 33.11 |
| 27 | -do- | | 704 | [illegible] | | [illegible] |
| 28 | -do- | | 704 | 28 | | 34.[illegible] |
| 1 | | 75 | 600 | 18 | 26.30 | |
| 2 | | 75 | 600 | 18 | 27.66 | |
| 3 | | 75 | 600 | 18 | [illegible].48 | |
| 4 | | [illegible] | [illegible] | 21 | | [illegible] |
| 5 | | [illegible] | [illegible] | [illegible] | | [illegible] |
| 6 | | [illegible] | [illegible] | [illegible] | | [illegible] |
| 7 | Amphibole 'B'<br>Chrysotile | 71.[illegible]<br>3.8 | 600 | 20 | | [illegible] |
| 8 | -do- | | 600 | [illegible] | | [illegible] |
| 9 | -do- | | [illegible] | [illegible] | | [illegible] |
| 10 | Amphibole '[illegible]'<br>Chrysotile | 67.5<br>7.5 | 600 | 20 | | [illegible] |
| 11 | -do- | | 600 | [illegible] | | [illegible] |
| 12 | -do- | | 600 | [illegible] | | [illegible] |
| 13 | Amphibole '[illegible]'<br>Chrysotile | [illegible].4<br>11.4 | 600 | 20 | | [illegible] |
| 14 | -do- | | 600 | [illegible] | | [illegible] |
| 15 | -do- | | 600 | [illegible] | | [illegible] |
| 16 | Amphibole 'C' | 75 | 600 | 21 | | [illegible] |
| 17 | -do- | | 600 | 21 | | [illegible] |
| 18 | -do- | | 600 | 21 | | [illegible] |
| 19 | Amphibole '[illegible]'<br>Chrysotile | 75<br>7.5 | 600 | 21 | | [illegible] |
| 20 | -do- | | 600 | [illegible] | | [illegible] |
| 21 | -do- | | 600 | 21 | | [illegible] |

Locality of asbestos:

A = Mysore   B= Rajasthan   C = Chamoli (U.P.)

## TABLE XII

**RESULTS OF [illegible]RSTING PRESSURE TEST ON A[illegible]STOS CEMENT PIPES USING A[illegible] OF [illegible] AND [illegible] FIBRES.**

| Dia. of pipes mm | Proportion of percentage [illegible] C[illegible]otile | [illegible]-bole. | No. | [illegible] | [illegible] pressure kg/cm² | [illegible] | Special coring bursting pressure kg/cm² |
|---|---|---|---|---|---|---|---|
| 0 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 9.[illegible] | [illegible] |
| | | | 2 | 9.[illegible] | 11.[illegible] | [illegible] | 14.00 |
| | | | [illegible] | [illegible] | 14.[illegible] | 9.[illegible] | 14.7 |
| [illegible] | 50 | [illegible]0 | 1 | 9.[illegible] | [illegible].7 | [illegible] | [illegible] |
| | | | 2 | [illegible] | 1[illegible] | [illegible] | 17.[illegible] |
| | | | 3 | [illegible] | [illegible] | [illegible].0 | 1[illegible] |
| " | 40 | 60 | | 9.0 | 7.00 | 9.0 | 1[illegible].2 |
| | | | | 9.[illegible] | 14.00 | 9.[illegible] | 19.5 |
| " | 30 | 70 | | [illegible].0 | 14.00 | 6.[illegible] | 7.70 |
| | | | | 9.[illegible] | 1[illegible].00 | [illegible] | 1[illegible] |
| " | 60 | 40 | 1 | 7.0 | 14.00 | [illegible] | [illegible].00 |
| | | | 2 | 7.[illegible] | 1[illegible].9 | 6.5 | 21.70 |
| | | | 3 | 7.[illegible] | [illegible] | [illegible] | [illegible].40 |
| " | 50 | 50 | 1 | 6.5 | 1[illegible].9 | [illegible].0 | 2[illegible].40 |
| | | | 2 | 7.[illegible] | 27.5 | 6.5 | [illegible].50 |
| " | 40 | 60 | 1 | 7.[illegible] | [illegible] | 7.0 | 18.2 |
| | | | | | [illegible].00 | 7.0 | 19.[illegible] |
| | | | | | | 7.[illegible] | [illegible].00 |
| " | 30 | 70 | 1 | 6.5 | [illegible].40 | 7.0 | 1[illegible].40 |
| | | | 2 | 7.0 | 1[illegible] | 7.0 | [illegible]1.70 |
| | | | 3 | 7.[illegible] | [illegible].00 | 7.[illegible] | 17.5 |

# TABLE XIII

RESULTS OF [illegible] A [illegible] CORRUGATED SHEETS (6 mm thick) WITH [illegible] PERCENTAGE OF AMPHIBOLES AND [illegible]

([illegible] load [illegible])

| Sl. No. | 100 per cent chrysotile | [illegible] chrysotile and [illegible] selected amphibole | [illegible] chrysotile and [illegible] selected amphibole | [illegible] chrysotile and [illegible] selected amphibole |
|---|---|---|---|---|
| 1. | [illegible] | [illegible] | [illegible] | [illegible] |
| 2. | [illegible] | [illegible] | [illegible] | [illegible] |
| 3. | 721.1 | 573.1 | [illegible] | [illegible] |
| 4. | 615.[illegible] | 492.[illegible]* | 479.4* | 599.4 |
| 5. | 707.[illegible] | 70[illegible].[illegible] | 526.1 | [illegible] |
| 6. | 605.0 | 692.9 | 529.0 | 536.8* |
| 7. | 766.8 | 596.4 | [illegible] | 509.7 |
| 8. | 724.4 | 59[illegible].2 | 644.2 | 520.1 |
| 9. | 764,5 | 569.4 | 580.0 | - |
| 10. | 669.5 | 711.7 | 615.[illegible] | - |
| Average. | 685.4 (100%) | 606.6 (88.5%) | 598.[illegible] (87.3%) | 577.4 (84.2%) |

The minimum requirement for breaking load is 544 kg.

* Specimens which have failed in the test.

**GRADATION OF AMPHIBOLE ASBESTOS FOR USE IN ASBESTOS CEMENT PRODUCTS**

6.0 While it has been possible to grade the chrysotile asbestos into several grades based on their properties, it has not been possible to formulate a suitable scientific gradation of amphibole asbestos so far, for use in asbestos cement products, mainly because sufficient test results of the properties of amphibole are not available. It would, therefore, appear to be necessary to deduce from the data available the tentative requirements which the amphiboles should conform to for satisfactory use. Such a gradation would not only help the manufacturers to get the right grade of amphibole asbestos for proper blending with different grades of chrysotile, but also may guide the geologist to locate suitable grades of amphibole asbestos for commercial exploitation.

6.1 The following properties are considered important for grading amphibole asbestos:

i. Tensile strength.

ii. Strength index value.

iii. Fineness [illegible].

iv. Chemical analysis.

v. Water and lime absorption.

vi. Acid and alkali resistance.

6.1.1 For grading chrysotile asbestos, standard methods of tests already exist in the respective standards of different countries. It may be possible to adopt these standard procedures with some modifications for amphibole asbestos. In India, work on formulation of standard methods of test for the above properties has been entrusted to the Indian Standards Institution and work so far accomplished is reported below:

6.1.4 Tensile Strength: Studies so far indicate that the tensile strength of different varieties of tremolite fibre is of the order of [illegible] kg/cm² as against 7140 kg/cm² for chrysotile fibre. The tensile strength is evidently an important criterion for obtaining the desired strength levels in asbestos cement products. Standard test for determining the tensile strength of chrysotile fibre has been accepted as an ISI standard test method for the amphibole asbestos also. This test method is under scrutiny for adoption in case of amphibole asbestos in a few laboratories in India at present.

6.1.5 Strength Unit: Strength Unit Value is another important test which helps to assess the suitability of chrysotile and amphibole asbestos fibres for use in asbestos cement products. Data from strength unit tests carried out with different amphibole fibres and different grades of chrysotile fibres are given below:-

| Sl. No. | [illegible] | Total strength unit value |
|---|---|---|
| 1. | Anthophyllite | [illegible] |
| 2. | Tremolite | [illegible] |
| 3. | Group [illegible] Chrysotiles | [illegible] |
| 4. | Group [illegible] Chrysotiles | [illegible] |
| 5. | Group [illegible] | [illegible] |
| 6. | Group [illegible] | [illegible] |

manufacturers [illegible] along with other [illegible] of [illegible] observed [illegible] different values [illegible] standard [illegible] also, [illegible] investigations [illegible] for determining the strain [illegible] value.

[illegible] used for elongation [illegible] analysis imported in [illegible] Adhesive [illegible], could [illegible] modification [illegible] properties and [illegible] flower [illegible] compatible fillers.

[illegible] be [illegible] surface [illegible] already [illegible] very

## TABLE XIV

Chemical analysis and other physical properties of samples of Indian asbestos

| Property | AMPHIBOLE (Tremolite) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | CHRYSOTILE 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Saraikella (Bihar) | Chaibasa R (Bihar) | Chaibasa S (Bihar) | Rajasthan | Bhilwara (Rajasthan) | Hasan Dt. (Mysore) | Mysore | Narda area | Bichuburu Chaibasa (Bihar) | Unmarked |
| Colour | White to light brown | White to greenish | Greenish to reddish | Greenish | Greenish to white | Reddish | Light grey | Golden yellow | Light yellow | Greenish grey |
| Habit | Long sticks | Massive to flaky | Massive fibrous aggregates | Flakes & sticks | Long flakes and sticks | Fibrous aggregates | Long flakes & sticks | Veins 19.05-3.175mm | Veins 3.175mm streaks | Veins 12.7-6.35 |
| Maximum fibre length | 180mm | 25mm | 150mm | 100mm | 100mm | 150mm | 75mm | - | - | - |
| Length (Ave) | Long | Short | Long | Medium | Medium | Medium | Long | Short | Short | 12.7-6.35 |
| Fineness | Fine | Medium | Coarse | Medium | Fine | Coarse | Coarse | Fine | Fine | Fine |
| Texture | Silky | Soft | Rough | Rough | Smooth | Rough | Coarse | Silky | Silky | Smooth |
| Flexibility | Flexible | Brittle | Brittle | Brittle | Brittle | Brittle | Brittle | Flexible | - | Flexible |
| Quebec Classification Screen test | (9.44-0.16-1.92-4.48) | (0-0.16-5.76-10.08) | (0.8-1.2-4.4-9.6) | (0-0-08-4.24-11.68) | (0.08-0.32-7.2-8.4) | (4.8-1.6-4.64-4.96) | (0.8-1.44-5.76-8.0) | (0-1.04-3.44-11.52) | - | (7.64-2.[illegible]-3.52-2.[illegible]) |
| Group | Group I | Group 6 | Group 5 | Group 7 | Group 5 | Group 3 | Group 5 | Group 6 | - | Group 5 |
| Chemical Analysis* | | | | | | | | | | |
| $SiO_2$ | 52.24 | 55.08 | 54.05 | 54.06 | 52.13 | 54.38 | 51.30 | 38.02 | 39.62 | 38.82 |
| $Al_2O_3$ | 1.78 | 0.79 | trace | trace | 1.25 | trace | trace | 3.92 | 1.89 | 1.98 |
| MgO | 21.69 | 25.34 | 27.24 | 30.73 | 31.78 | 30.11 | 29.80 | 37.98 | 37.56 | 38.16 |
| FeO | - | - | - | - | - | - | - | 4.08 | 5.47 | 5.02 |
| Total Fe as $Fe_2O_3$ | 7.7 | 5.57 | 12.55 | 10.79 | 7.41 | 11.2 | 11.61 | - | - | - |
| CaO | 11.53 | 10.57 | 1.49 | 1.68 | 2.27 | 2.40 | 2.08 | 0.31 | " | " |
| Loss on ignition | 4.34 | 3.79 | 4.59 | 2.61 | 4.35 | 2.11 | 3.11 | 15.80 | 16.05 | 15.17 |

* Alkalies and [illegible]

much on the fiberization property indicated by the wet volume or the specific surface reading. The standard wet volume test method applicable in the case of chrysotile asbestos is being investigated for adoption in case of amphibole asbestos.

6.1.6 Cement & Lime absorption: There is no standard method for finding out the cement absorption, but the Haydens' method shows promise of being accepted as a standard method for this purpose. Standard methods for assessing the cement and lime absorption are being formulated by the Indian Standards Institution. Average absorptive capacity of cement by asbestos fibres as determined by Haydens' method is [illegible] times for chrysotile fibres, and [illegible] times for tremolite, mass for mass. The lime absorption for chrysotile has been determined to be [illegible] gm./gm. while for tremolite it is [illegible] gm./gm.

6.1.7 Acid & Alkali Resistance: It is generally known that the acid and alkali resistance of the amphibole fibre is much higher than that of chrysotile fibre. This test can be carried out specifically in cases where resistance against any particular acid or alkali is required in the asbestos cement products.

6.2 Reliable data of the properties of amphibole fibres at present is not available for arriving at scientific grading with a view to using them in asbestos cement products. In most of the factory trials as also in laboratory studies undertaken with amphiboles from different sources, efforts have not been made to obtain the properties of the asbestos fibres by standard test methods, [illegible] of performance of asbestos [illegible] the properties [illegible] on the other cannot be [illegible] the present state of development, the grading [illegible] may be more [illegible] of chrysotile [illegible] because [illegible] in the [illegible] of the same [illegible] from a particular source.

It is, therefore, considered necessary to collect data on [illegible] been used successfully as partial replacement of chrysotile fibres in asbestos cement products so that a basis is established for evolving a tentative grading of amphibole asbestos which may be further modified when more data are available. Unless a scientific [illegible] amphibole asbestos is evolved, it may not be possible for the manufacturers to use it with confidence in asbestos cement products. It is, therefore, felt that in countries which are deficient in chrysotile asbestos but have large resources of weaker amphiboles namely crocidolite and amosite, studies may be undertaken to evolve a scientific system of gradation.

**[illegible]UTRAL AXIS METHOD**

[illegible] has been [illegible] [illegible] application involves [illegible] the [illegible] An alternative [illegible] construction, [illegible] or Neutral axis method. The [illegible] of three layers or mats, the [illegible] amphibole asbestos, sandwiched between [illegible] layers of [illegible] chrysotile asbestos, [illegible] amphibole asbestos [illegible] quality of the [illegible] level. With this process, it has been [illegible] that up to [illegible] per cent of amphibole asbestos can be used, depending upon the design adopted and the [illegible] fibres. Using Indian amphibole asbestos, the following composite for the manufacture of corrugated sheets has been arrived:

Thickness of sheet [illegible] mm
Superior [illegible] layer 'A' [illegible] mm
[illegible] layer [illegible] [illegible] mm
Inferior [illegible] layer [illegible] [illegible] mm
[illegible]

Layer [illegible] is made of cement [illegible] 100
amphibole asbestos [illegible]

External layers [illegible] are made of cement = 100
asbestos class 4 [illegible] 12
(imported)

Asbestos class 4 can be - [illegible], [illegible]
[illegible] or [illegible]
or other similar qualities

A practical proposal [illegible] a plant with a minimum economic capacity of [illegible] tonnes of sheets/day, by adoption of the above [illegible] method has been investigated

The boards are dried in ov[illegible]
under controlled conditions and tr[illegible]
are impregnated in [illegible] asphaltic ba[illegible]
[illegible] and finally dispatched. A b[illegible]
machinery employed in the process [illegible]

The performance of the fi[illegible]
to a great extent depends on the [illegible]
will be controlled by the proper m[illegible]
for the manufacture of boards, sele[illegible]
of impregnating medium, selection of [illegible]
selecting finishing paint and [illegible]
to maintain correct conditions of [illegible]

Corrugated asphaltic shee[illegible]
properties which are useful in cer[illegible]
and possess excellent [illegible]
water proof, flexible and non-cond[illegible]
iron sheets, asphaltic sheets do [illegible]
in transit as is generally the ca[illegible]
sheets. These sheets are also no[illegible]

The capital cost of esta[illegible]
asphaltic roofing sheet plant in [illegible]
production of one million sq.ft. [illegible]
and the cost of production worked[illegible]

2 OF 2

DO

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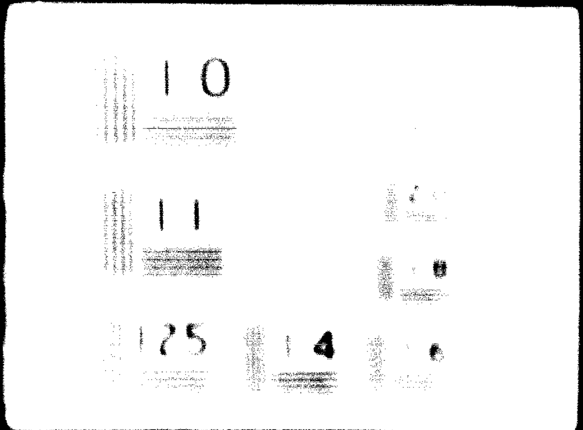

Hence tests up to 500°C were considered to be reasonable.

The following trends were observed from the test results:-

(i) up to 250°C there is no fall in unit bending stress values for both pulp-cement and asbestos cement sheets;

(ii) between 250°C and 500°C the decline in unit bending stress value was 0.54 kg./sq.cm./C° for pulp-cement sheet and 0.43 kg./sq.cm./C° for asbestos-cement sheet;

(iii) it appears that the behaviour of cement at high temperatures is a significant contributory factor for the behaviour of a cement product as compared to the behaviour of a fibrous ingredient.

**FULL-SCALE PRODUCTION TRIALS AND PROCESS UTILISATION**

6. Production trials have been successfully carried out at the asbestos-cement factories; with suitable adjustments in the asbestos-cement machinery, pulp-cement sheets could be easily moulded either manually or mechanically to corrugated or semi-corrugated sheet form. The only difference in the production techniques for pulp-cement and asbestos-cement processes is that for a pulp-cement process a hydraulic press capable of exerting a pressure of about 25 kg./sq.cm. is necessary.

**COST OF PRODUCTION OF PULP-CEMENT SHEETS.**

7. According to the present level of information based on experiments, asbestos can be substituted by pulp in the manufacture of asbestos-cement building boards and roofing sheets. An estimate of cost of

provide a cheap substitute for thatch roofing since the cost of light asphaltic sheets is generally comparable the cost of thatch roofing when annual maintenance cost is also taken into account. In addition, corrugated asphaltic sheets have wide application in industrial buildings, temporary houses and construction in hilly areas where transportation is difficult. It is well known that asbestos cement sheets suffer considerable breakage when transported over long distances by road. Also galvanized iron sheets, even of good quality, are apt to rust particularly when they are nailed to the supporting structure in conditions of high rain fall and humidity. With these factors in mind, the demand envisaged for corrugated asphaltic roofing sheets, specially in developing countries located in tropical and semi-tropical areas, is considered to be large to justify establishment of such plants, where asphalt and waste paper are available.

1.2 These roofing materials are already widely used in Mexico, Brazil, Argentina and other Latin American countries. They are produced and used to some extent in France and Belgium. An asphaltic roofing material is also manufactured and used for temporary structures in Denmark and other Scandinavian countries.

RAW MATERIALS

2.0 Corrugated asphaltic roofing sheets consist essentially of a 'felt' or 'board' which is impregnated with a suitable asphaltic medium and protected by a surfacing material. The principle materials required for the manu-

e) application of a stable and heat reflecting finishing paint.

6.1 The strength of the board is controlled primarily by the following:-

i. The length of the fibres in the felt. This is predetermined by:

a) the length of the fibres, as they exist in the rags,

b) the extent to which the fibres have been broken, shortened, or [illegible] in the beaters.

ii. The extent to which the rags or paper stock have undergone mastication. (Old rags or papers which have been allowed to rot before being converted into felt will produce a weaker sheet than new rags or paper).

iii. The skill displayed in running the sheet on the felt machine.

6.2 It is, therefore, obvious that training of operators and selection of waste material are important for quality control. For selection of the correct blend of impregnating asphaltic medium, the services of [illegible] consultants and machinery suppliers should be freely drawn upon. Experiment on various available grades of asphalt and coaltar pitch could also be useful in arriving at correct medium.

6.3 After careful investigation of various paints available for finishing the roofing, based on considerations of appearance, durability and capacity to reflect heat, tinted aluminium paint is considered to be most suitable. This can be applied by conventional dip painting methods. The comparative heat reflectance values for different types

ii. Rationalisation of thickness, pitch of corrugation and other dimensions of asbestos cement corrugated sheets. This could lead to saving of [illegible] fibre [illegible].

5. The manufacture of asbestos cement products on pilot scale using [illegible] in the various processes developed [illegible] laboratory and field performance tests, [illegible] it has been observed that products [illegible] have in a few cases developed cracks while in use [illegible] construction. Factors which are responsible for this phenomenon need identification and [illegible] before manufacture of asbestos cement [illegible] amphibole asbestos and their application in building industry is advocated.

6. Though the resources of amphibole asbestos reserves in India have to be fully assessed and the research so far done has to be exploited commercially, it must be stated from the available information that they hold out a promising future as an indigenous source of asbestos raw material for the Indian asbestos cement industry.

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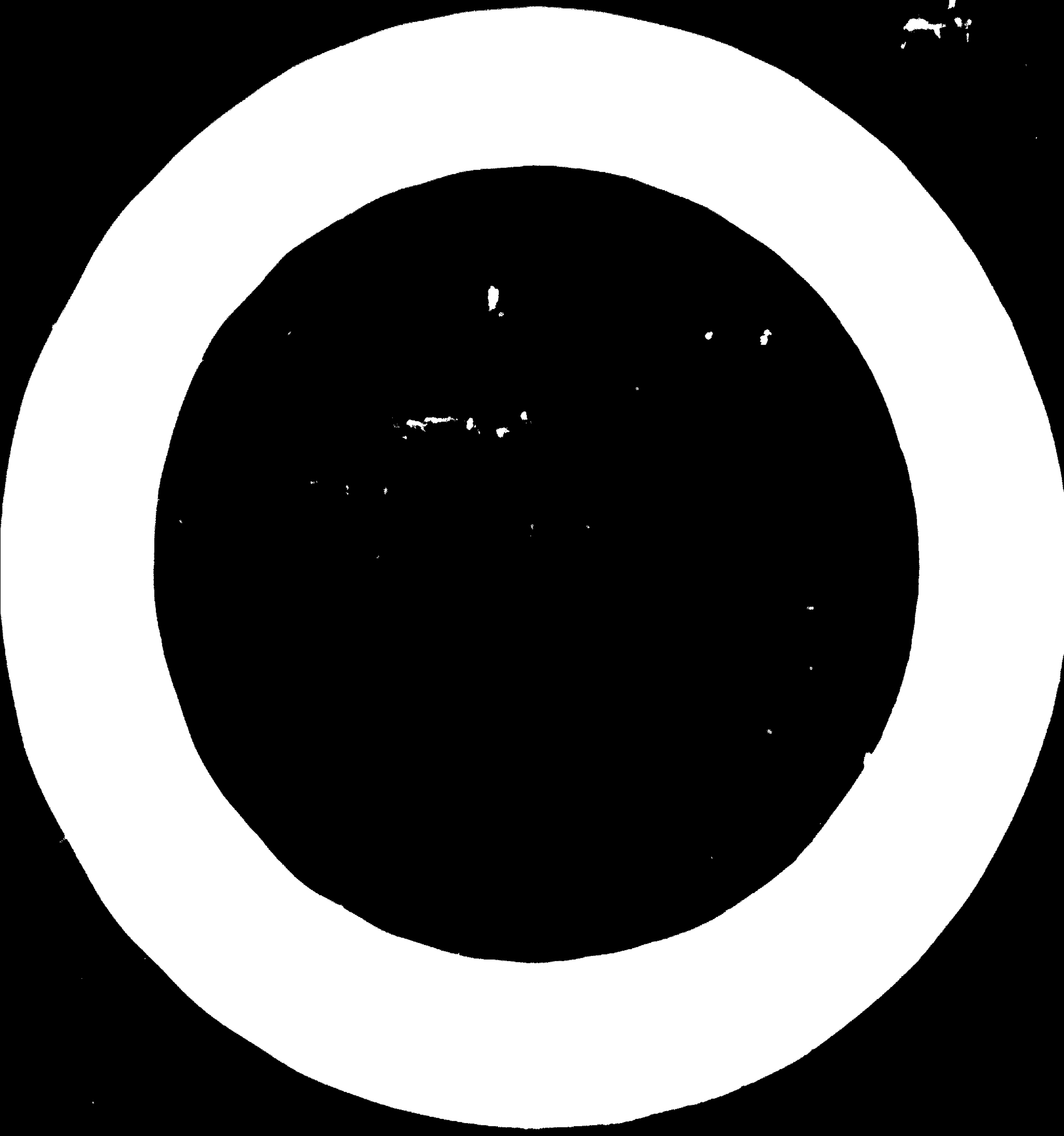
   (2) Shri [illegible] Biswas, Development Officer, Directorate General of Technical Development, New Delhi.

   (3) Shri A.K. Chatterjee, Scientist, Central Building Research Institute, Roorkee.



PART II

# BAMBOO PULP CEMENT BUILDING BOARDS AND ROOFING SHEETS

## SUMMARY

Pulp cement sheets made from fibrous materials like wood pulp, straw, cotton and hemp seeds have been manufactured and used in U.S.S.R. and Japan. Investigations have been carried out in India on the use of bamboo pulp for the manufacture of pulp cement building boards and roofing sheets.

Results of laboratory experiments with boards prepared from bamboo pulp and commercial trial production are discussed in this paper.

Tests carried out on specimens prepared with bamboo pulp and portland cement revealed that it is practicable to manufacture (i) Plain building boards (ii) Flat sheets and (iii) Corrugated roofing sheets. The strength of these materials are also comparable with strength values as specified for asbestos cement products.

Roofing sheets made of this material were subjected to further tests as they are required to withstand more severe conditions in practice. The tests were aimed to evaluate their performance with regard to transverse breaking load, water absorption, weathering properties, resistance to microbe action and fire resistance. The bamboo-pulp-cement sheets were found satisfactory for adoption in construction considering the behaviour under the tests.

Based on Indian experience, the cost of production of sheets in a plant with a 50 tonne/day capacity,

involving a capital expenditure of $ 277000, has been worked out to be $ 0.40 per sq.m.

**INTRODUCTION**

1.0 The use of wood pulp, straw, reeds or hemp seeds as reinforcement in the manufacture of structural light weight concrete panels is reported to have been developed in the U.S.S.R. and Japan. Pulp has proven to be a suitable fibrous material in place of asbestos fibre used in asbestos cement products.

1.1 In the process developed in the U.S.S.R., for making panels, the waste lumber is first passed through a machine that turns it into a pulp. The pulp is then wetted, mixed with cement, and placed in false work encased in a metal sheet. The sheets act as electrodes for passage of a direct current through the wet mix. The poles are changed periodically. The hydration process is then accelerated and a [illegible] m x 3 m x [illegible] m panel can be produced in 40 minutes. The panels comprising the walls and floors of the building are joined together with clamps. The door and window frames are set in the panels during moulding. Apart from being light in weight, buildings made of these panels (known as " Arbolite") are claimed to be economical in cost and provide excellent insulation against heat and sound.

1.2 The use of pulp cement boards in Japan is confined only to interiors. Details of the process adopted in Japan are not readily available.

1.3 In India research work was undertaken to develop an indigenous material which could substitute imported

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

asbestos fibre. It is realised that no substitute material can [illegible] identical [illegible] to asbestos. Therefore, [illegible] of the investigation [illegible] to find out the next best alternative [illegible] the requirements of roofing materials and satisfying economic conditions.

Various types of fibrous materials like hessian, cane, bagasse, [illegible], [illegible] pulp, etc., were experimented upon. The preliminary investigation revealed that bamboo pulp [illegible] better promise than the rest of the materials. As such further investigations were carried [illegible] the possibility of manufacturing building [illegible] roofing materials from bamboo pulp and cement. The results of these investigations in laboratory and [illegible] trials [illegible] given in the following paragraphs.

**MATERIALS** 2.0 The [illegible] bamboo pulp and cement.

2.1 <u>Bamboo</u> Pulp.

Bamboo pulp [illegible] obtained by digesting kako bamboo (*Dendrocalamus hamiltonii*) chips under a steam pressure of 8 to 10 kg. [illegible] 40 per cent alkali [illegible] bamboo chips ratio of [illegible], and [illegible] the [illegible] unbleached pulp, after washing with water, [illegible]. These pulp fibres were, on an average, [illegible] mm. long and 0.03 mm. in diameter. The tensile strength of these fibres could not be determined.

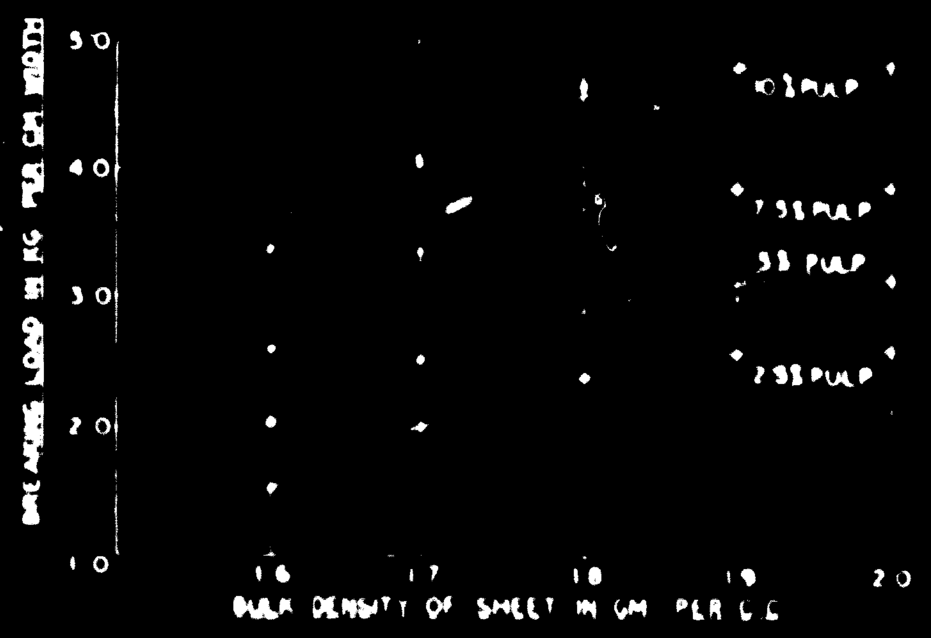



FIG 1 RELATIONSHIP BETWEEN BULK DENSITY OF PULP CEMENT SHEET AND BREAKING LOAD FOR DIFFERENT PULP CONTENTS

RESULT OF EXPERIMENTAL WORK

2.2 Portland Cement:

[illegible] satisfied the requirements of the Indian [illegible] Specification No. 269-1958 for ordinary, rapid hardening [illegible] Portland Cement.

3.0 [illegible] pulp [illegible], adjusted to a suitable [illegible], were mixed in different proportions and the slurry thus formed was poured into moulds and pressed in a [illegible] press [illegible] bulk densities to form sheets of [illegible] cm. x [illegible] cm. size. It was observed that the bulk density [illegible] the sheet as well as the pulp content in the sheet was increased with increasing pressure intensities. Typical observed values of pressure intensity for sheet formation are given in Table I.

TABLE-I

| Bulk density in gm/cc | Pressure Intensity in kg/sq.cm. at pulp content. | | | |
|---|---|---|---|---|
| | [illegible] | [illegible] | [illegible].5% | 10% |
| 1.6 | 5 | 10 | [illegible] | 29 |
| 1.7 | [illegible] | [illegible] | [illegible]3 | [illegible]4 |
| 1.8 | 1[illegible] | [illegible]1 | 29 | 39 |
| 1.9 | 15 | [illegible] | [illegible]2 | 47 |
| 2.0 | [illegible]0 | 3[illegible] | 41 | 52 |

3.1 After 28 days' curing, the sheets were tested for transverse breaking load according to the Indian Standard Specification No. [illegible] for asbestos-cement flat sheets. The test results showing relationship between bulk density of pulp-cement mix and breaking load strength for the test sheets for different pulp contents are plotted in Fig. I. It can be seen that;

(i) the strength values increase with the amount of pulp content in the mix, and

(ii) the strength values for any pulp content increase with the bulk density of pulp-cement sheet upto a value of about 1.8 gm/c.c. beyond which the increase in strength does not remain proportional to the increase in density.

Hence, for economic reasons, it is not desirable to increase the bulk density beyond 1.8 gm./c.c.

**APPLICATION OF TEST RESULTS**

4.0 Test results were applied to plain building boards, flat sheets and corrugated roofing sheets. The values obtained were compared with the standards laid down for asbestos cement sheets.

4.1 Plain Building Boards:

Test specimens of plain building boards prepared with 2.5% pulp content and compacted to a bulk density of 1.6 gm/c.c. were tested in accordance with the Indian Standards Specification; a breaking load value of 1.3 kg/cm width was obtained. The Indian Standard Specification for asbestos cement building boards (IS:2098-1964) specifies a minimum breaking load of 20 kg. for a span of 22.5 cm over a specimen width of 25 cm or an equivalent of 0.8 kg./cm width. It was, therefore, observed that the actual test values obtained provide a factor of safety of about 1.6 in relation to the standard. This figure is above the normal factor of safety of 1.25 considered necessary for the transition of the process from the laboratory scale to the manufacturing scale.

The pressure required for producing the boards with a 2.5% pulp content and 1.6 gm/c.c. pulp density was of the order of 3 - 5 Kg./sq.cm. which is quite nominal in a manufacturing process.

4.2 Flat Sheets:

A reference to Figure 1 shows that a pulp cement mix with 7.5% pulp, compacted to 1.7 gm./c.c. density or with 10.0% pulp compacted to 1.6 gm./c.c. will satisfy the requirements of strength laid down for asbestos cement flat sheets. The Indian Standards Specification for asbestos cement flat sheets (IS:2096-1966) specifies a minimum breaking load of 2.4 Kg./cm. width for a span of 25 cm. and thickness of 6 mm.* Assuming a factor of safety of 1.25 for transfer of laboratory results to production scale, the laboratory value should be 3 kg./cm. width. It is, therefore, concluded that a pulp cement mix with 7.5% pulp compacted to 1.7 gm/c.c. density or with 10.0% pulp compacted to 1.6 gm/c.c. density, is suitable for practical application. The intensity of pressure to achieve the desired density will be of the order of 25 Kg./sq.cm.

4.3 Corrugated Roofing Sheets:

It is not possible to work out a co-relation between the strength values of plain and corrugated

---

* The ISO recommends a breaking load of 2.5 kg./cm. width for a 25 cm. span.
(ISO/R-396-1964(E) para [illegible].5.2).

sheets as the corrugated sheets give a much higher value of section modulus on account of the corrugations. However, it is a recognised [illegible] that if a certain material gives adequate strength in the flat sheet form, the same material will certainly fulfil the strength required of the sheet in its corrugated form. In factories manufacturing asbestos-cement products, corrugated sheets are checked for quality by testing cut [illegible] cm. x [illegible] cm. size flat specimens and testing them for breaking load at 28 days. The value usually is of the order of 1.7 - [illegible] kg./cm. width. Specimens 25 cm. x 25 cm. size cut from the flat portion of commercial semi-corrugated sheets have been observed to give a maximum value of the order of 2.9 kg/cm. width. The excess value may be ascribed to the age effect on cement.

The Indian Standard Specification for unreinforced corrugated and semi-corrugated asbestos cement sheets (IS: 459-19[illegible]) specifies a minimum breaking load of 5.1 kg/cm width for the load span of 100 cm. for the full width of [illegible] cm for a [illegible] mm thick sheet.@

Allowing a factor of safety of [illegible] over 2.2 kg/cm width, the laboratory specimen should give a 28 day strength value of [illegible] kg/cm. width. By referring to figure 1 it can be seen that a pulp cement mix with 5.0%

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@ The ISO recommends an average breaking load of [illegible].2 kg/cm width for a test span of [illegible] cm for the full width for corrugated [illegible] sheets [illegible].
(ISO/R [illegible]) & [illegible].

pulp compacted to 1.8 gm./c.c. density or a mix with 7.5% pulp compacted to 1.7 gm./c.c. density or a mix with 10.0% pulp compacted to 1.6 gm./c.c. density should be reasonable for adoption. In all these cases the pressure intensity in hydraulic press will be about 25 kg./sq.cm. It is preferable to adopt a mix with a lesser proportion of pulp content, viz. 5%.

TESTS ON PULP-CEMENT ROOFING SHEETS

5.0 The requirements of strength, durability etc., for roofing sheets are more severe than those for building boards on account of differences in loading and exposure conditions. Hence a detailed testing has been carried out for roofing sheets prepared with 10% pulp and compacted to 1.6 gm/c.c. density.

5.1 Transverse breaking load test:

For pulp-sheets of 25 cm x 25 cm x 6 mm, the transverse breaking load value was on the average 4.6 kg/cm. width. This was much above the desired value of 3.0 kg/cm. width for roofing sheets.

5.2 Water absorption test:

The per cent water-absorption test is carried out by immersing the pulp-cement sheets in water at 27°C ± 2°C for a period of 18 hours. The observed per cent water-absorption value for pulp cement sheets was 19.2% as against the maximum of 28.0% specified for asbestos cement sheets.

5.3 Resistance to acidified water test:

Pulp-cement sheet samples were placed for 24 hours in 5 per cent acetic acid solution at 27°C ± 2°C. The concentration of acetic acid before and after immersion of the specimen was determined by titration against a 0.5 N solution of sodium hydroxide. The amount of acetic acid used per sq. cm. of area of the specimen was calculated from the fall in concentration of acetic acid. The resistance value for pulp-cement sheets was 0.105 gm./sq.cm. as against the maximum value of 0.115 gm./sq.cm. specified for asbestos cement sheets.

The results of water absorption and resistance to acidified water tests indicate that pulp-cement sheets are comparable with regard to these two properties to asbestos-cement sheets. It can be also seen that pulp-cement sheets in exposed condition would offer sufficient resistance to weak acids formed by corrosive gases in the atmosphere.

5.4 <u>Weatherometer Test:</u>

Samples of plain pulp cement sheets were tested for 200 hours in a weatherometer. These samples were exposed to ultra-violet [illegible] in the weatherometer chamber at a temperature of 58°C and humidity of 80 - 85 per cent and were occasionally sprayed with water through the shower fitted in the chamber. It was found that there was no change in the strength properties of the samples after exposure for an equivalent of 250 days, and that there was no shrinkage or swelling of samples. These results indicate that the pulp-cement sheets are resistent to the effects of heat, humidity and light.

5.5 <u>Test for resistance to microbial attack:</u>

As the pulp fibres are of organic origin, they are likely to deteriorate from microbe attack. It was however, felt that when fibres are coated with a cement paste, the deterioration may not be of a significant degree. In order to verify this, samples of pulp-cement sheets were buried in the open ground at a depth of 30 cm from ground level for a period of 2 years. It was found that there was no reduction in the strength of the sheets. Similar results were obtained for sheets exposed to atmospheric conditions for the same period.

5.6 Resistance to fire heat:

Samples of 2[illegible] cm. x [illegible] cm. size were cut out from pulp-cement sheets fabricated in the laboratory and also, for comparison purposes, from commercially available asbestos-cement sheets. These were placed in an electric furnace for a duration of 4 hours at temperatures of 125°C and [illegible]°C. After each exposure, a sheet sample was tested for the bending stress as per IS:2096-1966 for asbestos-cement sheets. Both pulp-cement and asbestos-cement sheets contain about 90 per cent ordinary Portland Cement. It is obvious that the behaviour of cement at high temperature would affect to a great extent the behaviour of a test sheet. Tests have shown that up to 300°C, there is practically no change in strength properties of a cement product, while at [illegible]°C, about [illegible]0 per cent of strength is lost.@

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@ Properties of Concrete by A.M.Neville pp 379-381.

The following are the approximate estimated costs of the above plant:

1. Capacity: 100 tonnes/day

2. Capital Cost:

| | | |
|---|---|---|
| (a) (i) Land Development | = | $. 10,000 |
| (ii) Factory Buildings | = | $ 70,000 |
| (iii) Ancillary Buildings (for office, laboratory staff and labour welfare) | = | $ 25,000 |
| Total | = | $ 105,000 |
| (b) (i) Plant & Machinery | | $ 400,000 |
| (ii) Laboratory & Testing Equipment | | $ 10,000 |
| (iii) Tools & Accessories | | $ 20,000 |
| Total | = | $ 430,000 |

(c) Working Capital

| | |
|---|---|
| Margin money at 25% of requirement for storing raw materials and one month stock of finished product | $ 21,200 |

3. Manufacturing Cost (economic capacity = 30,000 tonnes/annum)

| | |
|---|---|
| (i) Raw materials & Stores | $ 1,200,000 |
| (ii) Power, Water & Services | $ 40,000 |
| (iii) Direct Labour | $ 60,000 |
| (iv) Depreciation (5% on buildings and 10% on plant) | $ 45,250 |
| (v) Overheads, interest on capital insurance, etc. | $ 200,000 |
| (vi) Other expenditure | $ 54,750 |
| Total ex-factory cost | $ 1,600,000 |

Ex-factory cost per tonne $ 53.00 approx.

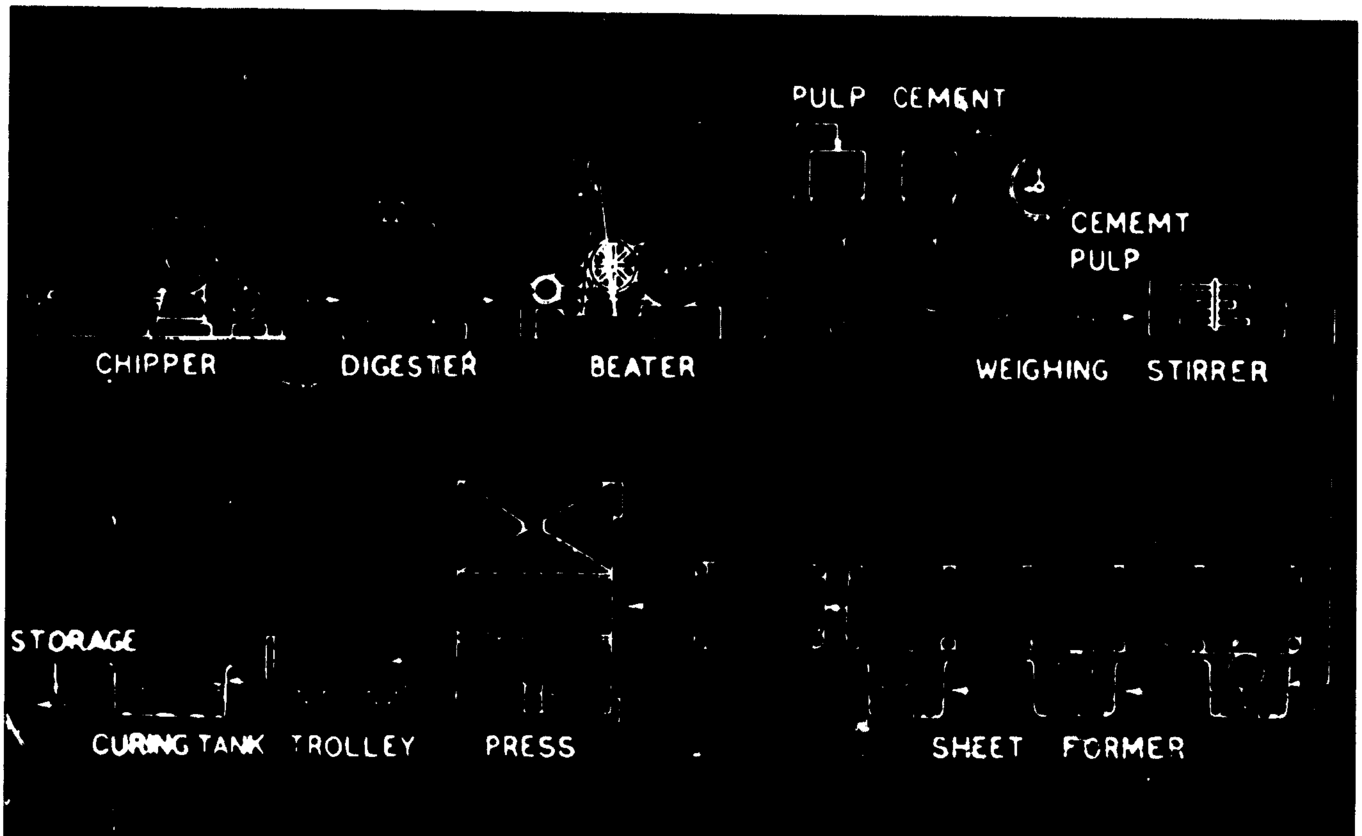


FIG 2. FLOW SHEET FOR PULP CEMENT ROOFING SHEET PROCESS.

production of pulp-cement sheets based on 50 tonne per day capacity plant involving a capital expenditure of $ 277000 is given in Appendix A. A flow-chart indicating different operations for the plant is shown in Fig. 2. The annual production is rated to be 9,00,000 sheets of 150 cm. x 105 cm. x 6 mm. size. The cost of production is worked out to be 46 cents per sq. metre which compares favourably with the market price for an asbestos-cement corrugated sheets in India.

## APPENDIX - A*

**CAPITAL COST AND COST OF PRODUCTION FOR A PLANT TO MANUFACTURE 12,000 TONS OF PULP-CEMENT SHEETS PER YEAR.**

.. .. ..

I. Land - 20,000 sq.m. @ 1.00/- sq.m. — $20,000

II. <u>Buildings & Civil Works</u>

| | | |
|---|---|---|
| i. | Pulp manufacturing unit, shed for pulp manufacture and shed for pulp storage | 750 sq.m. |
| ii. | Factory building | 2500 sq.m. |
| iii. | Office building | 500 sq.m. |
| iv. | Finished goods store | 1000 sq.m. |
| v. | Curing tank | 750 sq.m. |
| | | 5500 sq.m. |

@ $ 20.00 per sq.m. — $110,000

III. <u>Plant & Equipment</u>

a)
- i. Chipper with conveyor belt, motor starter, etc.
- ii. Screen (vibratory type) to suit above chipper - 1 No.
- iii. Conveyors-bucket type or pneumatic type.
- iv. Digester bin - 1 No.
- v. Spherical rotary digester - 1 No.
- vi. Blow pit.
- vii. Liquor preparation tank - 1 No.
- viii. Conveyor pumps for carrying digested chips and liquor.
- ix. Washing poacher - 1 No.
- x. Beaters Hollander type - 3 Nos.
- xi. Pumps for carrying pulp - 2 Nos.
- xii. Steam boiler - 1 No.

$70,000

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* Based on Indian experience.

## APPENDIX - A (continued)

**b) Sheet Manufacturing Unit**

i. Weighing Machines - 2 Nos.
ii. Stirrers - 2 Nos.
iii. Vats, felt and other accessories of sheeting machine - 1 No.
iv. Movable moulds - 1501 Nos.
v. Hydraulic Press - 1 No.
vi. Trolleys - 50 Nos.
vii. Laboratory equipment.

| | |
|---|---|
| | $ 77,000 |
| Total capital investment: | $ 277,000 |

## COST OF PRODUCTION

**I. Cost of production of pulp of 5 tonnes/day:**

| | |
|---|---|
| 1. Materials: | |
| i. Bamboo 12.5 tonnes @ $ 10.00/tonne | $ 125.00 |
| ii. Caustic Soda, power & fuel. | $ 450.00 |
| 2. Labour and Supervision. | $ 25.00 |
| 3. Depreciation: | |
| i. Machinery<br>ii. Buildings | $ 27.00 |
| Total: | $ 625.00 |

Cost of pulp per tonne: $ 125.00

**II. Cost of production of Sheets of 50 tonnes/day:**

| | |
|---|---|
| 1. Materials: | |
| i. Cement 50 tonnes at $ 27.00/tonne | $1350.00 |
| ii. Pulp 5 tonnes at $ 125.00/tonne | $ 625.00 |
| iii. Power, fuel. | $ 65.00 |
| 2. Labour and Supervision | $ 62.00 |
| 3. Depreciation: | |
| i. Machinery<br>ii. Buildings | $ 70.00 |
| Total: | $2172.00 |

III. Total daily production: 50 tonnes or 3000 sheets.

Total area of sheets (of size 150 cm x 105 cm x 0.6 cm) : 4725 sq.m.

Cost per sq. m. : $ 0.46

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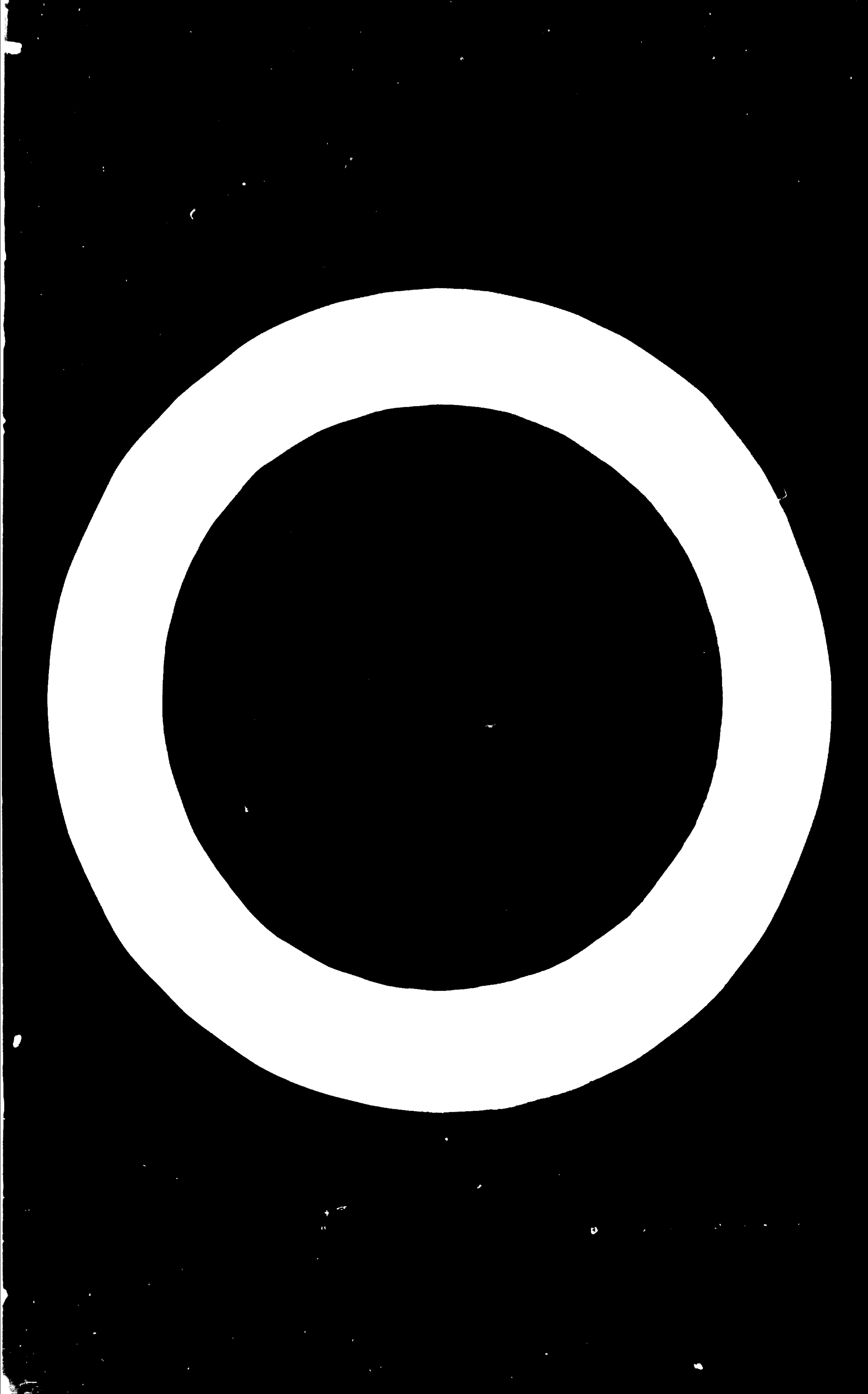


[illegible] III

## CORRUGATED ASPHALTIC ROOFING SHEETS

### S U M M A R Y

Corrugated asphaltic roofing sheets are a good substitute for asbestos-cement, aluminium and galvanized iron sheets in developing countries because of their lower cost and suitability to tropical and semi-tropical climates. They [illegible] used for industrial structures, temporary buildings and low cost and rural houses. They are widely used in several Latin American countries.

Asphaltic roofing sheets consist primarily of a 'board' or 'paper felt' impregnated with an asphaltic medium and protected by a surfacing material. The 'board' is manufactured from waste materials like scrap paper, bagasse, jute waste, coconut fibre, rejected asbestos fibres and [illegible] generally available. The materials may be used singly or in various combinations which would impart the desired properties to the board. The impregnation medium used is usually a standard grade paving asphalt. For surface protection of the boards, mineral granules, aluminium foil or aluminium paint are used. Plastic emulsion paints may also be used for giving a pleasing coloured finish but they increase the cost.

The process of manufacture consists in reducing the basic raw material, waste paper, rags and other cellular fibres to a wet pulp of the required fineness successively in coarse and fine hammer mills and forming the pulp into sheets in felt or board forming machines.

The boards are dried in sun or in drying oven under controlled conditions and trimmed. The dried boards are impregnated in an asphaltic bath, cured for a short time and finally dip painted. A brief description of the machinery employed in the process is given in this paper.

The performance of the finished corrugated sheet to a great extent depends on the quality of the board which will be controlled by (i) proper selection of waste materials for the manufacture of boards, adoption of a correct blend of impregnating medium, application of a stable and heat reflecting finishing paint and (ii) regulating the process to maintain correct conditions of manufacture.

Corrugated asphaltic sheets have noteworthy properties which are useful in construction; they are light and possess excellent thermal insulation. They are completely waterproof, flexible and non-conducting. Unlike galvanized iron sheets, asphaltic sheets do not corrode or are damaged in transit as is generally the case with asbestos-cement sheets. These sheets are also not attacked by fungi or vermin.

The capital cost of establishing a corrugated asphaltic roofing sheet plant in India with an annual production of one million sq.m. is approximately $ 212000 and the cost of production worked out is 34 cents/sq.m.

# CORRUGATED ASPHALTIC ROOFING SHEETS

INTRODUCTION 1.0 The demand for efficient and low-cost building materials has increased enormously during the last decade in the developing countries of the world. "Roofing" represents one of the major items of construction and the commonly used materials like asbestos-cement sheets, aluminium sheets and galvanised iron sheets are not only costly but are in short supply. Moreover, most of the developing countries have to spend their precious foreign exchange to import asbestos fibre for manufacturing asbestos-cement sheets; aluminium and steel are also imported and are needed for priority uses. The following typical data presents the input requirements of raw materials for asbestos-cement and galvanized iron sheets in comparison with asphaltic corrugated roofing sheets:-

| Roofing Material | Area covered per ton in sq m. | Cost per sq.m. in US $ | Foreign exchange requirements as % of cost per ton |
|---|---|---|---|
| Asphaltic Roofing sheet | 300 sq.m. | 0.42 | Nil |
| Galvanized iron sheets | 150 sq.m. | 1.60 | 17 (for zinc for galvanizing only) |
| Asbestos cement sheets | 70 sq.m. | 1.40 | 33 (for asbestos fibre only) |

The need for substituting roofing materials like galvanized iron sheets and asbestos cement sheets, is therefore apparent and corrugated asphaltic roofing sheets can fill this need.

1.1 Asphaltic corrugated sheets are very well suited for low-cost and temporary housing. In rural areas they

The precise capital cost and the cost of production needs to be worked out for each location, considering local conditions and prices but the above details of inputs would be helpful in working out the costs in individual cases.

CONCLUSION

1. From the foregoing pages it will be observed that a fair amount of work has been undertaken on the use of Indian amphibole asbestos in the manufacture of asbestos cement products. The utility of any asbestos in the manufacture of asbestos cement products lies in two basic properties inherent in asbestos, viz., (i) tensile strength, and (ii) the cement absorption capacity. Research work so far carried out in India has indicated the possibility of utilizing amphibole asbestos which has comparatively poor tensile strength but at the same time has satisfactory cement retention capacity. By one set of experiments it has been concluded that fiberization of amphibole asbestos plays an important role in increasing the cement absorption capacity and that fiberization by usual mechanical method is not satisfactory. Instead the use of surface active reagent has been suggested. By another set of experiments application of pressure in moulding has been found necessary. However, the lamination technique as adopted in case of chrysotile has not been considered suitable for amphibole asbestos. Various experiments carried out have established the possibility of utilizing amphibole asbestos in whole or in part in blend with chrysotile. Curing of asbestos-cement products containing amphibole asbestos in humid atmosphere of carbon dioxide gas has shown promising results.

facture are briefly described in the following paragraphs:

2.1 'Felt' or 'Board'

2.1.1 Paper felt or board is mostly manufactured in the plant employing scrap paper, or what is usually termed as 'road pickings', with varying quantities of cotton rags and lint. In India, road pickings which are plentifully available at a cost of [illegible] per tonne delivered at the factory site, are most economical and easiest to process. They are obtainable in large quantities in and around big cities.

The specifications of cardboard required for the manufacture of asphaltic corrugated sheets are as below:-

i. Thickness: Maximum 3.2 mm
Minimum 2.66 mm
Average 2.93 mm

ii. Weight by area: 0.999 $gm/cm^2$

iii. Mullen Test: 10 $kg/cm^2$

iv. Freeness Test: 470/$cm^3$

2.1.2 Organic fibres and other materials which could be used in various combinations for manufacturing felt or board are:-

i. ground wood, saw dust;

ii. defibered wood;

iii. shredded bark of trees;

iv. straw;

v. baggasse;

vi. rags and jute waste;

vii. coconut fibres;

viii. bamboo;

ix. disintegrated leather fibres and animal hair;

x. asbestos fibres;

xi. slag wool, mineral wool and glass wool.

Addition of a certain amount of clay is advantageous as it lowers raw material cost and imparts greater stiffness.

2.1.3 Raw materials like waste cotton or wool rags, seams and cloth strippings from garments tend to soften the board and increase the porosity and absorption of the saturant. Jute waste tends to harden the board and makes it denser and less absorbent.

The stiffness of the board and complete impregnation are important characteristics to be sought for in the finished product. Various combinations of raw materials named above are used to ensure that the required characteristics are maintained in the manufactured felt or board.

2.2 Impregnating medium: The second basic raw material used in the manufacture of corrugated asphaltic roofing sheets is the asphaltic impregnating medium which is generally a paving asphalt of standard grade. This material is available in plenty in most of the developing countries, especially in those countries where petroleum refineries have been installed. In India, asphalt of the required grade as per specifications given below, delivered at site, is available at $ 60 per tonne:

| | |
|---|---|
| i. Density | 1.037 |
| ii. Flash point | 230°C |
| iii. Penetration index | 80-100 gm. in 5 sec. at 25°C |
| iv. Softening point | 45 - 53°C |
| v. Ductility at 25°C | Min. elongation 100 cm. |
| vi. Solubility in carbon di-sulphide | Min. 99.5% |
| vii. Percentage loss by evaporation | Max. 50 gm. in 5 hours at 163°C |

2.3 <u>Surfacing materials</u>: Mineral granule, aluminium foil as well as aluminium paint are used for surface protection of asphaltic corrugated sheets. Mineral granule could be manufactured or obtained in natural form in many colours and then they can be employed to give surfaces with pleasing shades. Aluminium foil is known to give better protection and is also more effective in reflecting the heat of the sun. However, it is a costly material and is not available from indigenous sources in most of the developing countries. Aluminium paint is a satisfactory substitute and is easy to apply. It imparts sufficient protection from weather as well as from the heat of the sun. Other paints, especially plastic emulsion paints, can be used for giving decorative coloured finish to the upper surface of the corrugated sheets. However, they increase the cost and are, therefore, not widely adopted. Aluminium paint which is the most satis-factory media used in India, is available at approximately 70 cents per litre; one litre of the paint could cover 18 sq.m. of surface.

2.4 The quantities of major raw materials required for the production of 100,000 sq.m. of corrugated sheets per annum are as follows:-

| | |
|---|---|
| i. Waste paper in the form of [illegible], or other fibrous materials | 7 tonne per day |
| ii. Asphaltic impregnating medium | 5 tonne per day |
| iii. Aluminium paint | 370 litres per day |
| iv. Fuel oil for heating | 1 tonne per day |
| v. Process water | 50000 litres per shift. |

MANUFACTURING PROCESS

3.0 The flow chart showing the sequence of operations is given in Appendix I. The layout of machinery is shown in Appendix II. The different sequences are arranged in such a manner that there is a continuous flow of materials from the raw materials yard to the finished product store.

3.1 The waste paper and other fibrous materials are received in truck loads and dumped in the open raw materials storage yard which is adjacent to the pulping section. The waste paper is transported by means of mechanical equipment and dropped into the soaking pit. An optimum quantity of water is added to soak the waste paper for a minimum of 24 hours. The soaked paper is then fed by belt conveyor or grab bucket to the feed hopper placed above the rough hammer mill. From the rough hammer mill the pulp flows by gravity into a tank at ground level from where it is lifted by means of a pump to an overhead tank. The pulp is discharged into one end of the tank and passes over baffles to the other end from where it is drawn out and fed into the hopper of the fine hammer mill. The pulp is reduced to the required fineness in this mill; then it flows into a ground level pit from where it is lifted to senders by means of a bucket wheel. It then passes over a series of baffles and then through a chute to the feeding tanks of the felt or board forming machines. The board when formed to the required thickness on the forming machine is stripped off and stacked on pallets. These pallets are moved by lift trucks to the open area where they are spread on the ground for sun drying. Alternatively, drying ovens with controlled humidity and temperature can also be employed for quick drying. However, drying of the boards in the sun is a cheaper and satisfactory method. The dry sheets are collected and transported to the impregnating shed where they are trimmed, wetted, corrugated and impregnated in an asphaltic bath maintained at a temperature of [illegible]°C. The trimmings of the board are sent back for repulping. After impregnation, the sheets are sprayed with cold oil to quickset the asphalt and prevent the sticking of sheets, and thereafter allowed to cure for a short [illegible], before transporting to the painting shed where they are dip-painted in aluminium paint. The painted sheets are hung vertically in racks till they are dry. The corrugated sheets are finally graded for quality and stored for despatch.

**DESCRIPTION OF PLANT AND EQUIPMENT**

4.0 The machinery for the manufacture of corrugated asphaltic sheets consists essentially of:-

i. Waste paper sorting machines.

ii. Soaking pit conveyor.

iii. Course Hammer Mill.

iv. Fine Hammer Mill.

v. Screen.

vi. [illegible]

vii. Corrugating equipment.

viii. Impregnating equipment.

4.1 Specifications of machinery and equipment used are given in Appendix III. The description and function of these machines are briefly mentioned below:-

Waste Paper [illegible] Machines: These machines are used to clean the waste paper free of metal pieces and other tramp material present in the waste supplies so that the pulping machinery is not damaged.

Soaking Pit Conveyor: It is a belt conveyor dipping at one end into the soaking pit with the discharge end located over the coarse hammer mill feed hopper.

Coarse Hammer Mill: The coarse hammer mill is used to break down the waste paper and other materials into a pulp by the [illegible] of a set of radially mounted stellated hammers. The hammers are welded to a sturdy central shaft and the assembly rotates within a heavy perforated [illegible]. When the waste paper forms a homogeneous slurry, it passes through the perforations and flows by gravity.

Fine Hammer Mill: The construction and operation of the fine hammer mill is similar to that of the rough hammer mill. By this second operation the pulp is completely homogenised and the fibres fully separated.

__Sander:__ The sander unit performs the dual function of washing the slurry of [illegible] as well as of regulation of the density of the pulp slurry. The sander consists of series of baffles and storage tanks so arranged that clean pulp of the required consistency comes out from the outlet end of the unit. This is very important as otherwise a uniform mat will not be formed on the forming machine.

__Forming Machine:__ The forming machine converts the pulp into the board of predetermined thickness. The operation of the machine is as follows:

Slurry of a controlled density is fed from the outlet end of the sander to the pulp pool at the beginning of the forming machine. The pulp is picked up from the pool by means of a forming roll. The forming roll consists of a large decanter drum covered by stainless steel mesh of different sizes. The pulp adheres to the outer surface of the mesh and the excess water is drawn into the drum from where it is pumped out.

An endless felt blanket passing at one end and pressing on to the mesh drum continuously picks up the pulp layer adhering to the mesh drum. At the other end of the felt blanket the pulp layer is again transferred on to a metal roll consisting of a steel drum with serrated surface. By regulating the number of turns of the steel drum, predetermined thickness of the board can be built upon the drum. The board is then quickly peeled off the drum without stopping it and the process continued.

<u>Corrugating equipment</u>: The corrugating equipment consists of a set of wetting drums to wet the surface of the sheet which is then impressed upon in sequence by a set of down [illegible] rollers heated by the gases from the asphalt boiler. In this manner the requisite number of corrugations are impressed on to the board. The hot rollers automatically [illegible] the board in the corrugated form.

<u>Impregnating equipment</u>: The impregnating equipment consists of an open asphalt pan in which the asphalt is melted out of the drums in which it is received. The molten asphalt then flows by gravity into the asphalt boiler and impregnating unit.

The asphalt is further heated and maintained at the requisite temperature by instrumentation.

The corrugated boards are stacked vertically in pallets and the assembly dipped into the molten asphalt by means of a jib crane.

STANDARDS

5.0 There do not exist any standards for corrugated asphaltic roofing sheets. In India, the Indian Standards Institution have taken up the subject recently. From the study of the available data on asphaltic roofing and other materials, a number of basic assumptions in regard to the raw materials, intermediate products and finished products have been deduced. These assumptions will help in formulating a complete set of standards for the roofing material. Finished product specifications tentatively adopted are given below:-

| | | |
|---|---|---|
| 1. | Size: | 1.2 m x 0.6 m; corrugation diameter 25 mm. |
| 2. | Thickness: | 5 mm to 6 mm nominal |
| 3. | Asphalt content: | approx. 40% by weight |
| 4. | Weight: | 2.5 kg to 3 kg/sheet |
| 5. | Estimated useful life: | 12 - 15 years. |
| 6. | Absorption of water by wt in 24 hours: | 5% in sample kept immersed in water for 24 hours. |
| 7. | Percolation of water: | After testing for 24 hours with 0.6 m head of water, no apparent moisture detected on the reverse face of the sheet. |
| 8. | Beam strength at breaking: | 50 kg on a 0.6 m span.<br>100 kg on a 0.3 m span. |
| 9. | Impact strength: | Should withstand 5 kg weight dropped on to the sheet from a height of 1.5 m. (The material may only tear but not shatter). |
| 10. | Durability of aluminium paint: | No visible deterioration of paint after repeated wetting and drying of sheet for 100 cycles at 28°C ± 2°C. |
| 11. | Fire protection: | Fire protection covered by Clause [illegible] National Board of U.S. Fire Underwriter, i.e. moderate protection against fire. |

**QUALITY CONTROL**

6.0 Control of quality of the finished product can be achieved by:

a) controlling the quality of the board;

b) using correctly blended impregnating asphaltic medium;

c) regulating the temperature of impregnation;

d) determining the correct corrugation form for maximum sheet rigidity;

2. The gradation of amphibole group of minerals is an essential prerequisite for their use in the asbestos cement industry. This is due to the fact that there is a considerable variation in the properties of amphibole even from the [illegible]. In the absence of suitable gradation, it becomes difficult for the manufacturers to choose the right variety for specific use. To this effect the Indian Standards Institution is engaged in evolving suitable gradation of amphibole group of minerals.

3. In India, up to 20% of [illegible] blended with chrysotile is reported to have been successfully used commercially in the manufacture of [illegible] boards and pipes with the existing machinery.

4. In addition to [illegible] on the suitability of amphibole [illegible] number of other measures that would help conserve the use of chrysotile are.

1. Adopting neutral axis method for the manufacture of asbestos cement sheets. The central laminate of which is made of weaker amphibole asbestos sandwiched between outer layers of chrysotile asbestos of higher strength than that used usually; with this process up to [illegible] % of cheaper amphibole asbestos can be used. It may, however, be pointed out that with the use of high grade chrysotile the advantages in the use of low cost amphibole may be neutralized.

of roofing are given below:-

| Type of Roofing | Percentage Heat reflected |
| --- | --- |
| Cement concrete roof | 10 - 15% |
| Aluminium sheet roofing | Above 80% |
| Galvanised iron sheet roofing | Above 30% |
| Asphaltic corrugated sheet roofing surfaced with aluminium foil | Over 80% |
| Asphaltic corrugated sheet roofing with aluminium paint | Over 40% |

**USE OF CORRUGATED ASPHALTIC SHEETS**

7.0 Asphaltic corrugated sheets are recommended to be used in temperatures not exceeding 44°C in the shade. However, recent experimental construction in India has proven that these sheets could be used for temporary structures at temperatures as high as 48°C in shade. Asphaltic corrugated sheets have excellent thermal insulation properties. The comparative thermal insulation values for different types of roofing are tabulated below:-

| Material | Insulation value |
| --- | --- |
| Aluminium sheet roofing | 0 |
| Corrugated asphaltic sheet roofing | 0.44 |
| Asphaltic shingle roofing | 0.15 |
| Reinforced cement concrete roofing 200 mm thick | 1.71 |
| Reinforced cement concrete roofing 100 mm thick | 0.71 |
| Asbestos-cement sheet roofing | 0.21 |

7.1 Corrugated asphaltic sheets are completely waterproof, flexible, non-conducting and are not attacked by fungi or vermin as in the case of thatch roofs. They are not susceptible to corrosion and leakage as may often happen in the case of galvanized iron sheets.

7.2 Fear is often expressed that these sheets may be a fire hazard. They do not support combustion, however, are prone to damage by excessive heat. Extensive tests have revealed that a flame playing on the under side of the sheet for as long as half an hour only scorched it. These roofing sheets are covered by the National Board of U.S. Fire Underwriters under Class [illegible], i.e. moderate protection against fire.

7.3 Since these sheets are expected to be used in tropical and sub-tropical climates where wind velocity is often high, wind tunnel tests were conducted on a model roofing. It was found that asphaltic roofing sheets would stand wind loads up to 192 km/hr. as compared to only 128 km/hr. for the asbestos-cement sheets.

7.4 The life expectancy of corrugated asphaltic sheets has not been confirmed, though it is stated that they are good even in adverse conditions of use for a period of 12 to 15 years. It has been observed in one construction in Brazil that sheets installed in a roof were in perfect condition even after 17 years.

7.5 Being light, the sheets require lighter structural support, thereby effecting reduction in cost of construction of the roofing. They are not brittle like asbestos-cement sheets and hence are not damaged when transported on rough roads for long distances. These could be nailed directly on the supporting structure even by unskilled labour and do not require any special fixing equipment.

7.6 The comparative cost of construction in India of roofing with corrugated asphaltic sheets as against other roofing materials is given below:

| S. No. | Type of roofing | Approx. cost of 10 sq.m. of roofing surface (initial cost) in $ | Service life expected (years) | Weight per 10 sq.m. | Remarks |
|---|---|---|---|---|---|
| 1. | Corrugated galvanized iron 22 SWG sheets & accessories | $ 12.50 | 30 | 55 kg & above depending on gauge of sheet | Should be protected against atmospheric corrosion by paint. Generally, for greater comfort a layer of wooden shingles is preferred over the roof. Small repairs may necessitate replacement of complete roof. Noisy in rain and hailstorm. |
| 2. | Corrugated asbestos cement sheets and accessories | $ 10.00 | 20 | 155 kg | Losses in transport and storage due to breakage, necessity of replacing whole sheets due to cracks, holes, etc. |
| 3. | Single clay tiles on wooden battons. | $ 1.20 | 15-20 | With batton 634 kg | Losses due to breakage in transport and by monkeys during service period. Gives room for rodents to live in and breed. |
| 4. | 76 mm thick fire-proofed palmyrah thatch roofing | $ 8.00 | 6-7 | 204 kg including frame | Damage in transit and weathering during service. Provides room for rodents & snakes to live in and breed. |
| 5. | Corrugated asphaltic sheet roofing aluminium paint surfaced. | $ 5.30 | 12-15 | 59 kg | Flexible, no loss in transport. Vermin proof. Good appearance, light in weight. |

COSTS

8.0 A plant to manufacture corrugated asphaltic roofing sheets can be of any capacity since the bulk of the production cost is made of raw materials. However, 1 million sq.m. capacity is rated to be most economical under conditions prevailing in India. Capital cost for a plant of this capacity would approximately be as follows:-

| | |
|---|---|
| i. Land, building and civil works | ฿ 46,500 |
| ii. Plant and machinery - | |
| a) Special purpose equipment | ฿ 96,000 |
| b) Electrical sub-station, water supply, etc. | ฿ 37,000 |
| c) Ancillary equipment such as soaking station, fork-lift trucks, drying racks, etc. | ฿ 13,000 |
| iii. Pre-operative expenses including interest during construction. | ฿ 6,500 |
| iv. Working capital | ฿ 13,000 |
| | ฿ 212,000 |

8.1 Cost of production: The cost of production of corrugated sheets, assuming the net saleable production to be 80% of 1 million sq.m. capacity, would be:

I. Raw Materials

| | |
|---|---|
| i. Blown asphalt 1200 tons @ ฿ 60/ton | ฿ 72,000 |
| ii. Paper scrap 1250 tons @ ฿ 27/ton | ฿ 34,000 |
| iii. Painting materials | ฿ 54,000 |
| iv. Sundry items | ฿ 850 |

II. Conversion Cost

| | |
|---|---|
| i. Labour & supervision including managerial and general office overheads. | ฿ 40,000 |
| ii. Power, fuel [illegible] | ฿ 21,000 |

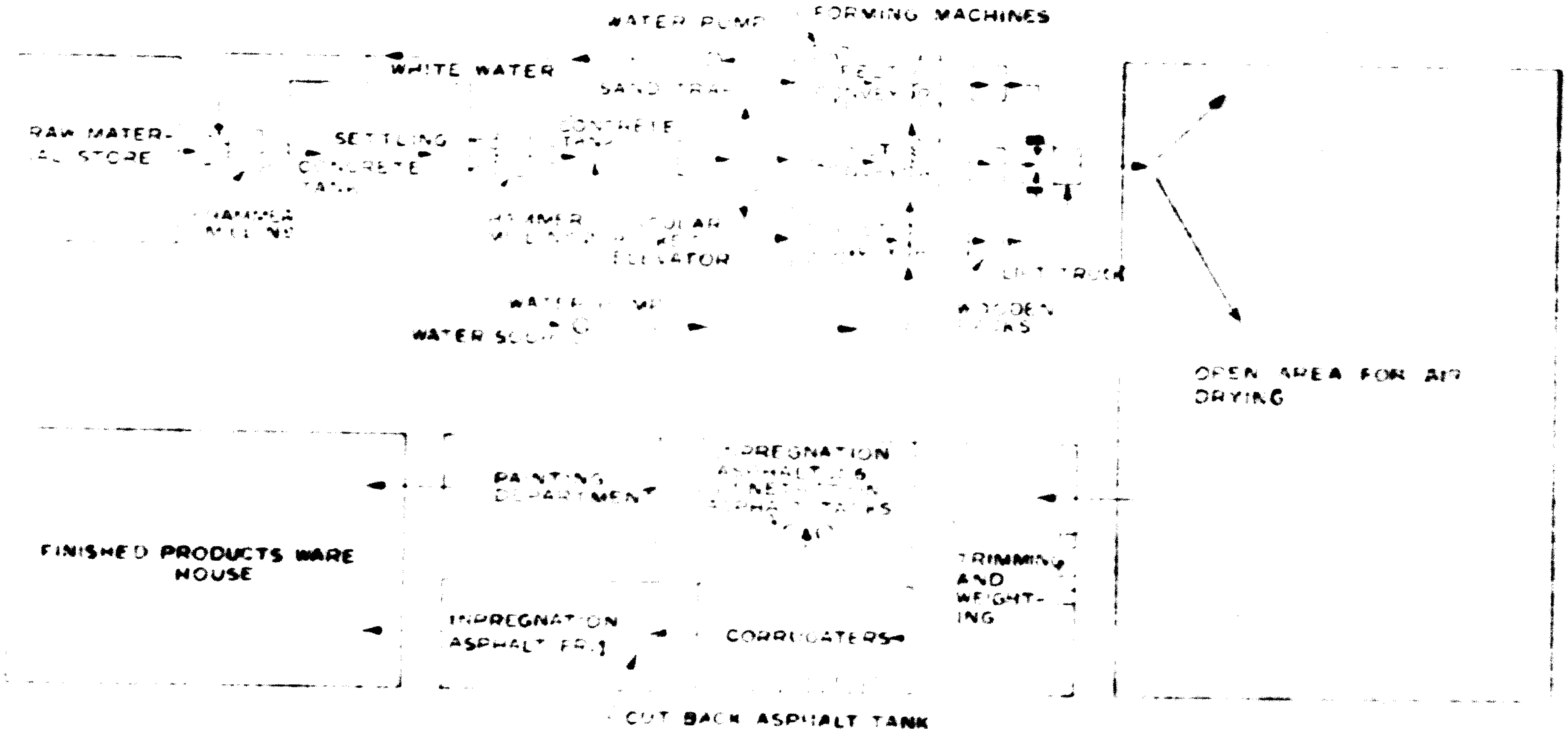
| | |
|---|---|
| iii. Maintenance materials and sundry expenses. | ฿ 16,000 |
| III. <u>Depreciation</u> | |
| i. Building @ 5% | ฿ 19,400 |
| ii. Plant & Machinery @ 10% | ฿ 12,000 |
| | ฿ 269,250 |

Taking 80% net saleable production, the cost of production per sq.m. $= \frac{27}{8}$

$= ฿\ 0.34$/sq.m.

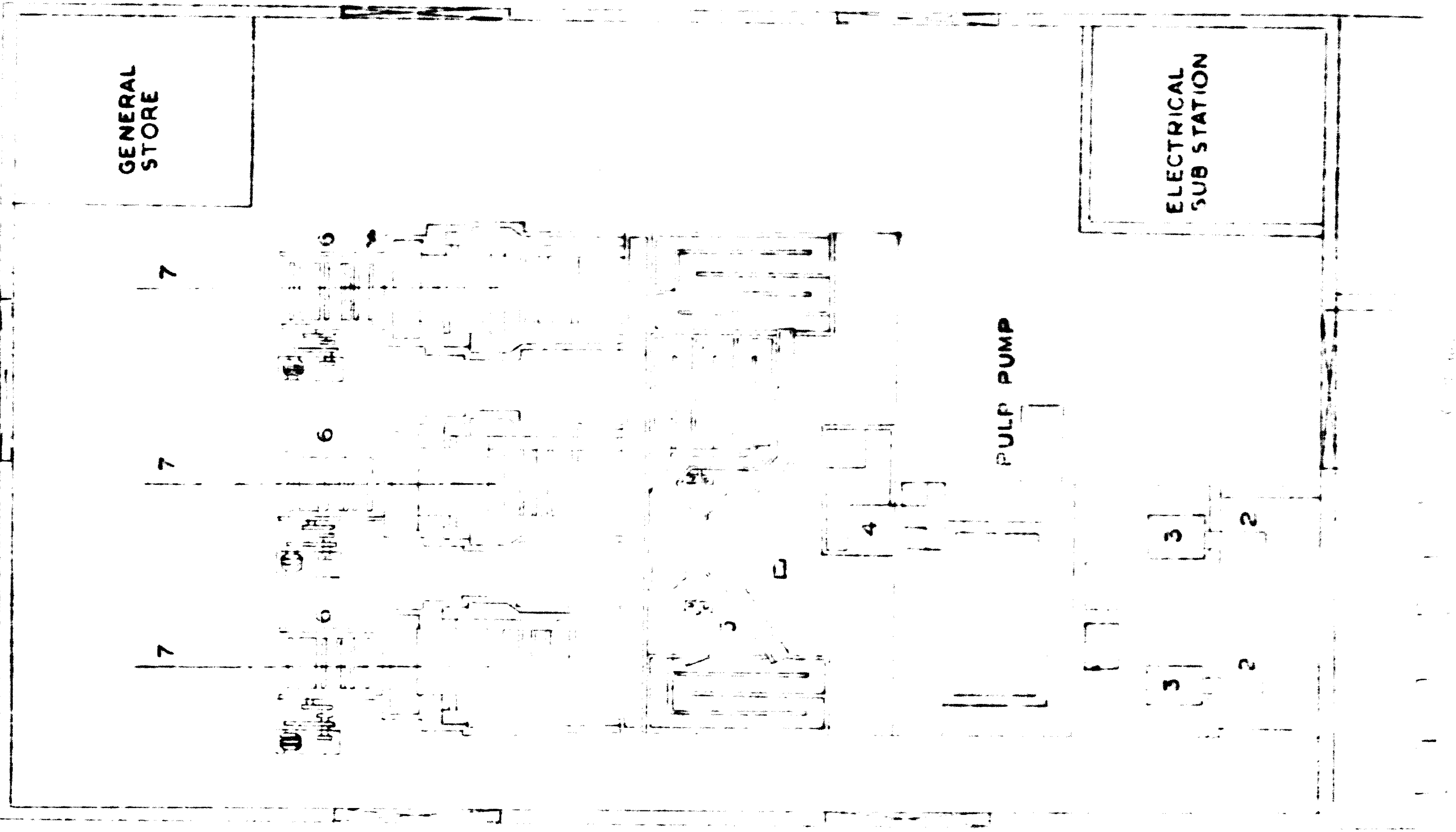
ASPHALTIC [illegible] ETS

FLOW CHART



... LTD. OF ...UGATED ROOFING SHEETS

LAY OUT OF MACHINERY



Appendix III

## Specifications of Machinery and Equipment

| S.No. | Description |
|---|---|
| 1. | Wastepaper [illegible] complete [illegible] 3 phase AC motor, starter, gear box, belts, base frame, etc. |
| 2. | Feeding conveyor [illegible] to convey paper mass from [illegible] to rough hammer mill feed hopper, complete with conveyor belt, [illegible], [illegible] H.P. 3 phase AC [illegible], [illegible] reduction gear box etc. |
| 3. | Rough hammer mill [illegible] totally enclosed, [illegible] construction [illegible] consisting of a specially designed outer shell and revolving rotor fitted with [illegible] fixed [illegible] the action of which the paper mass is pulped [illegible]. |
| 4. | Refiner hammer mill similar to rough hammer mill (item No. [illegible]) driven by 40 H.P. totally enclosed 3 phase AC motor complete [illegible], belts etc. to reduce the [illegible] mass to the final required grade of pulp. |
| 5. | Bucket wheel [illegible] driven by [illegible] H.P. 3 phase AC motor complete with starter and reduction gear-box consisting of 3m diameter bucket wheel duly reinforced, fitted with suitable elevator buckets and discharge chute for elevating pulp from the sediment pool to the sanders. |
| 6. | Cylinder mould forming machine suitable for forming boards of the required width for manufacture of 1.2 m x 0.6 m corrugated roofing sheets complete with all rollers, tensioning devices, forming rolls, endless treated felt, one spare belt, of robust construction to give trouble free service complete with [illegible] H.P. 3 phase AC motor, fly wheel reduction, belts, etc. |
| 7. | Mono-rail with 1 tonne chain blocks and trolley for handling pallets loaded with wet sheets from forming machine to storage area and also for machine maintenance and cleaning purposes. |
| | Hydraulic pallet trucks for handling pallets from storage area to external jib crane. |
| | Pallets 1.6 m x [illegible] of welded MS angle construction. |
| | Jib crane with 1 No. chain block and trolley for loading pallets on to drying truck. |

Appendix III--Contd.

| S.No. | Description |
| --- | --- |
| 8. | Specially designed wet sheet conveyor trucks with floating platform speed synchronised flat belt conveyor for transfer and piling of wet sheets on ground in drying area with operator platform belt-tensioning and powered by [illegible] H.P. tractor. |
| 9. | Cutting machine [illegible] and ground steel [illegible], complete with 2 H.P. 3 phase AC motor, starter, reduction gear-box, sprocket wheel & chain-drive, feed table, sheet-guide capable of cutting maximum width of 1.4 m. |
| 10. | Pallets [illegible] construction |
| | Hand trolleys with [illegible] baskets for storage and transport of dried sheets. |
| 11. | Wetting machine consisting of felt covered wetting roller, [illegible] complete with 1 H.P. 3 phase motor starter, reduction gear box chain-drive for [illegible] wetting of sheets. |
| 12. | Undulating equipment consisting of specially designed corrugating machine and heat-setting chamber complete with [illegible] controls, hot air-generator, blower and ducting to machine. |
| 13. | Asphalt impregnation equipment complete with bitumen melting, preheating and [illegible] equipment, mono-rails handling system, dipping baskets, burners, blowers, service oil tank, semi-rotary gear pump and multi-point pyrometer for temperature control. But not including refractory bricks, linings and connected civil works for construction of furnace chamber and also not including the air and furnace oil pipe-line connections, valves, etc. |
| 14. | Equipment for [illegible] of sheets consisting of mixing tank, dipping tank, stirrer, overhead, mono rail, chain block and trolley, 6 Nos. dipping baskets, 30 Nos. trolleys, trolley, truck, etc. |
| 15. | Other general [illegible] equipments consisting of trolleys with mesh cages. |
| 16. | Felt washing equipment & forming cylinder stand. |

## BIBLIOGRAPHY

No published literature is available on corrugated [asphaltic roofing] sheets. The work reported here has [been based on] author's study of the industry [established] in Brazil ([illegible]), Rio-de-Janeiro, [illegible], [illegible] Minas), and Denmark ([illegible], [illegible]), and M/s [Light] Roofings Ltd ([illegible]) [illegible], India, and [private] communications from John [illegible], Industrial Consultant, [illegible], Florida.

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