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Training Course on

Materials Design and Production Processes for Low-cost Housing

26-29 November, 2002

Bangalore, India

Jointly organised by

Building Materials and Technology Promotion Council

Ministry of Urban Development & Poverty Alleviation, Government of India, New Delhi

International Centre for Advancement of Manufacturing Technology

Bangalore, India

International Centre for Science and High Technology

Trieste, Italy

CONTENTS

BUILDING MATERIALS AND TECHNOLOGY PROMOTION COUNCIL (BMTPC)

The Building Materials and Technology Promotion Council (BMTPC) is an inter-ministerial autonomous body functioning under the aegis of the Ministry of Urban Employment and Poverty Alleviation, Government of India. The Council is primarily engaged in development and promotion of cost effective building materials and construction technologies in housing and buildings sector. It aims at strengthening continuing interaction with industry, financial institutions, construction organizations, R&D, standardization institutions and NGO's, nationally and internationally. The focus areas of BMTPC, inter alia, include the promotion of environment friendly and energy efficient building materials based on agro-industrial wastes and locally available resources.

INTERNATIONAL CENTRE FOR ADVANCEMENT OF MANUFACTURING TECHNOLOGY (ICAMT)

ICAMT is an international Centre established by United Nations Industrial Development Organisation (UNIDO) in Bangalore (India) in co-operation with the Government of India with a view to enhance manufacturing capabilities and competitiveness of industries in developing countries.

Its mission is to bridge the technology divide by promoting technology as the means to industrial competitiveness in developing countries.

ICAMT is implementing National programmes for development of selected sectors (toy, stone, machine tools & lock) in India. The centre has also taken initative to promote Indian technologies for manufacturing of alternative building materials based on agro-industrial waste in the developing countries.

BACKGROUND OF THE TRAINING COURSE

Fast changing demographic and migratory trends in most developing countries are exerting pressure on domestic construction industry for improving efficiency, productivity and delivery systems to meet the housing needs particularly for citizens in low income segments. The materials industry in most of the countries in African, Asian and Latin American regions is under tremendous pressure due to wide spread scarcity and rising costs of traditional materials. Severe shortages of materials are also impacting the deliverable costs of housing which makes it unaffordable for a large section of population belonging to the low income strata.

The other common characteristic feature of the building materials industry in most developing countries is continuing use of high energy consuming manufacturing technologies and the adverse impact on environment due to high consumption of natural raw material resources in manufacturing of traditional materials like cement, steel, timber, aluminium, etc.

In view of the above, one strong option is to promote use of innovative composite materials based on local resources from forestry, agriculture, natural fibres, plant materials and locally available agro-industrial wastes. Such alternative materials can be manufactured either by using the natural fibres as reinforcement in a binder such as cement or polymer or by using industrial wastes like fly ash, phosphgypsum and slags & sludges etc. It has been noted that increased industrial production of composite materials (consisting of particulate, fibre reinforced or laminar composites) not only helps in meeting the needs of housing sector but on the other hand greatly help in environmental protection and employment generation.

Research and development efforts of past 3 to 4 decades in several countries, specially in India, have led to the development of various scientific and engineering aspects of composite materials from local resources. Such efforts have reasonably demonstrated and established that many of these materials can effectively substitute traditional materials like cement, steel and wood. However, these technologies both in the design of composite materials and manufacturing processes have not been adopted on commercial scale except in few countries. In India, the research and development have helped in developing a large variety of composites in all three categories and many of these are being commercially manufactured. It has also been seen that enhancing the commercial production of composite building materials can answer three problems confronting the most developing countries that of

(i) creating sustainable livelihoods,
(ii) preserving the environment, and
(iii) meeting the demand of affordable building materials for housing.

In the above background, the efforts are being made by national governments and international agencies for development and promotion of composite building materials based on renewable raw material resources either from agro-forestry or from industrial by-products and wastes. It is in this context, the present Training Course was organised for motivating the scientists, engineers, industry representatives and decision makers in the government to realise that production and use of composite materials is one of the most appropriate options to meet the demand of affordable building materials required for achieving the national goal of housing in respective countries.

Recognising that the building industry is strategically linked to improving the standard of living in the developing countries and the fast emerging technological innovations can help in improving efficiency and productivity of the building materials industry, the International Centre for Science and High Technology (ICS) proposed to organise a Training Course on "Materials Design and Production Processes for Low Cost Housing" in cooperation with Building Materials and Technology Promotion Council (BMTPC) and International Centre for Advancement of Manufacturing Technology (ICAMT). The Training Course was organised from 25 - 29 November, 2002 at Bangalore, India. In order to assist the countries in South-East Asian region the Training Course was particularly structured to meet the needs of building materials industry in the countries of this region. The Course, therefore, attracted the participants from Indonesia, Vietnam, Nepal, Bhutan, Bangladesh, Sri Lanka and India.

PARTICIPANTS

The Training Course was attended by 10 participants from Indonesia, Vietnam, Bhutan, Nepal, Bangladesh, Sri Lanka and 12 participants from India. The participants from India included 9 from outside Bangalore and 3 from Bangalore.

Most of the participants were from Research Institutes, Academic Institutions, Housing and Building Agencies, Ministries of respective countries including representatives both from private and government sectors. Large number of officers from different ministries in India, responsible for actual adoption of cost-effective technologies in government construction had also attended the course as observers in different Sessions and participated in the Panel Discussion held on the last day.

The list of participants is appended in Annexure-4.

LECTURERS

Besides, 1 resource person Dr. P.V. Kandachar nominated by ICS, BMTPC had invited seven highly knowledgeable speakers of international repute from R&D Institutions, industry and funding agencies. Lecturers covered a wide range of topics such as raw materials selection, characterization of materials, type of composites and the actual fabrication of natural fibre composite in lab as well as factory conditions. Technical advantage of natural fibre composites over the other composite materials already in use has also been discussed in detail. Most of the lecturers were provided with extra time for interactive session with the participants in order to understand the possibilities of mutual cooperation and technology transfer of various natural fibre based technologies in the participating countries.

Speaker / Resource Person	Title of Presentation
Dr. Mohan Rai Deputy Director (Retd.) CBRI, Roorkee	Characterisation of Raw Materials for Design of Composite Building Materials
Dr. R. Gopalan Director & CEO, RV-TIFAC	Manufacturing methods for Eco-friendly, cost-effective GRP Building Products
Dr. Soumitra Biswas Advisor – Advanced Composite Programme, TIFAC	Composite Technology Development and Commercialisation – Some Successful Case Studies
Mr. Tommy Mathew Director, Natura Fibre Tech Pvt. Ltd.	Development & Production of Wood Substitute using Agro Wastes
Dr. P.V.Kandhchar Professor Delf University of Technology	Overview and advances on Science, Technology and Application of Composite Materials based on Natural Resources
Dr. K. G. Satyanarayana Deputy Director, RRL, Thiruvananthapuram	Natural Fibre Composites, Issues and Perspectives
Dr. N. G. Nair Former Professor & Head Composites Technology Centre, IIT, Chennai	Composite Materials Design & Manufacturing for Building Applications
Mr. A. K. Bansal Director, IPIRTI	Lignocellulosic as a Sustainable Source for Building Material
Mr. T.N.Gupta, Executive Director, BMTPC	Need for composite building materials and strengthening of technology transfer promoting technology transfer in the area of composite between India and developing countries in African and Latin American regions. Role and achievements of BMTPC in strengthening Technology sharing between India and other Developing Countries in the area of Composite Materials for Low-Cost Housing.

DETAILED DAILY SUMMARY OF THE TRAINING COURSE

Day – 1: Monday – 25 November

The Training Course was inaugurated on the morning of 25th November and the inaugural address was delivered by an eminent scientist Dr. B. R. Somashekar from National Aeronautical Laboratory, Bangalore and currently the Advisor to National Composites Mission, Government of India.

The participants were welcomed by Mr. Vasantha Kumar, Advisor, ICAMT. After the Lighting of the Lamp by Chief Guest, introduction to ICAMT/ICS activities was given by Mr. Vinod Yadav, ICAMT. Introduction of the Training Programme and activities of BMTPC were presented by Mr. T.N.Gupta, Executive Director, BMTPC.

The first Technical Session started with the introduction of the participants and the presentation of Prof. Kandhachar on overview and advances on science and technology of composite materials based on natural resources. In his presentation the following aspects were covered in detail:

- Availability of natural fibres
- Properties of natural and synthetic fibres
- Comparison of cellulosic fibres with glass for mechanical design
- Composites
- Surface treatment of fibres
- Manufacturing technologies
- Product design and estimation of properties

Activities of BMTPC relating to development of composite building materials and promoting technology transfer between India and developing countries in African and Latin American regions were presented by Mr. T.N.Gupta, Executive Director, BMTPC.

Audio Visual Presentation of ICS and activities and programmes of ICAMT were presented by Mr. Vasantha Kumar, Advisor, ICAMT.

Thereafter the Exhibition organized by BMTPC in the same venue was inaugurated. Throughout the duration of the Course i.e. from 25 to 29 November, the Exhibition was kept open. The display showcased the developments that have taken place in India in the field of development, commercial production and field application of composites. International ongoing programmes focussing on transfer of Indian technologies and expertise to other countries in African, Latin American and Caribbean regions were also included in the display.

Day – 2: Tuesday – 26 November

The second day started with the presentation by Dr. N. G. Nair on overview and advances on science and technology of Composite Materials Design & Manufacturing for Building Applications. The lecture covered following aspects of composite materials:

- Basic design requirements
- Composite materials for building applications
- Material selection and material structure design
- Selection of fibres
- Matrix materials
- Mechanical properties of natural fibre composites

Some Successful Case Studies on Composite Technology Development and Commercialisation in India were presented by Dr. Soumitra Biswas. The lecture covered different aspects of industry – academia partnership, natural fibre composites, jute composite and their potential applications.

Dr.R.Gopalan presented the Manufacturing Methods for Eco-friendly, cost-effective Glass Reinforced Polymer (GRP) Composite Products. During his lecture he emphasized upon the composite materials offering exciting advantages over known structural materials, in terms of stiffness-to-weight and strength-to-weight ratios, high resistance to abrasion, dimensional stability amenability to desired and engineered into any desired shape and size, resistance to chemical and atmospheric corrosion, lower tooling costs, simplification of manufacture by parts integration, etc.

Day – 3: Wednesday – 27 November

Field visit to RV-TIFAC Composite Design Centre was organized in the morning session.

Field Visit RV-TIFAC

Dr. R. Gopalan, Director of CEO, RV-TIFAC composite design centre explained the various steps for the production of Glass Fibre Reinforced Composites.

Different production methods such as hand-lay-up technique, spray-up, vacuum bag, compression moulding, resin transfer moulding, filament winding pultrusion etc. were explained. Low temperature compression moulding and high temperature compression. moulding of various glass fibre products were displayed. A systematic way for the production of GRP-PUF sandwich composite technology was demonstrated to the participants. Advantage of semi mechanised and fully mechanised production process was explained. Different aspect of core material and wooden reinforcement for the development of door and window frame have been demonstrated and explained.

The lab set up for the testing of various doors and window frames as per IS: 4020-1994 was also shown to the participants. Various dimensional and engineering property measurement methods where explained to the visitors.

Afternoon session started with the lecture by Dr. K. G. Satyanarayana. The lecture was on Natural Fibre Composites, Issues and Perspectives. In his lecture, he covered different aspects of natural fibres:

- Composites
- Natural fibres, source, extraction, structure, property, cost etc.
- Natural fibre composites, their current status, fabrication techniques, properties, products development, cost comparison, problems and solutions and selection criteria

The Session concluded with the presentation of Prof. Kandhachar on overview and advances on science and technology of composite materials based on natural resources with special reference to auto-mobile and agriculture industry.

A field visit to Natura Fibre Tech Pvt. Ltd.was organized to explain all the participants the different production processes of coir & jute fibre composites.

Day – 4: Thursday – 28 November

The forth day started with the presentation by Dr.Mohan Rai on Characterization of Raw Materials for Design of Composite Building Materials. The lecture covered different characterization parameters on following aspects:

- Characterization of fibres
- Variability in chemical and physical properties of natural fibres
- Mechanical and chemical properties of natural fibres

- Types of composite materials
- Essential properties of fibre and matrix
- Natural organic fibres in cement matrix
- Steel fibre, and glass fibre reinforced cement concrete
- Properties of fibre reinforced concrete composites

Mr. A. K. Bansal made the presentation on Lignocellulosic as a Sustainable Source for Building Material. During his lecture he covered various aspects of bamboo based building materials in India including research, training, standardization related to panel products from wood, bamboo & other renewable fibres including forest/agro residues.

Mr. Tommy Mathew made a presentation on Development & Production of Wood Substitute using Agro Wastes. Use of coconut and jute fibres in manufacturing of composite materials and its processing. Application of coir fibre for the production of materials such as acoustic & false roof panels, door panels, partitions, corrugated roof sheets etc. were covered in the lecture.

A field visit to Indian Plywood Industries Research & Training Institute (IPIRTI) was organized.

Day – 5: Friday – 29 November

In the first Session, Country Reports were presented by all foreign participants and three Indian participants (Annex-7). Later, a panel discussion was organised with the participation of representatives from technology developers, industry (engaged in production and marketing of composite materials), end-users (construction organisations) and one HRD expert. The panel discussion was coordinated by Prof. Kandachar. The panel discussions was concluded with presentation of recommendations and outcome as formulated jointly by Mr. T.N.Gupta and Prof. Kandachar from the interaction with the participants from various countries, resource persons and country reports as discussed in the open house. These recommendations comprised issues (recommendations) which deserve to be addressed through short term and medium term strategies in the framework of south-south cooperation policy of UNIDO.

After the panel discussion, the valedictory address was delivered by Prof. Dattaguru, Chairman of Aerospace Engineering Department of Indian Institute of Science, Bangalore.

Panel Discussion - 29 November 2002

On the final day, a panel discussion was organised with the participation of representatives from technology developers, industry (engaged in production and transfer of technology marketing of composite materials, end-users like construction industry and one HRD expert. The following experts participated in the panel discussion:

1. Prof. P.V. Kandachar, Co-ordinator
2. Mr. T. N. Gupta
3. Prof. B. Dattaguru
4. Dr. R. Gopalan
5. Mr. N.Sivasailam
6. Mr. Emdadul Huq
7. Dr. C.S.Vishnukant Chattpalli
8. Mr. S.Vasantha Kumar
9. Mr. Tommy Mathew

The panelists made detailed presentations about the aspects of composite materials as related to their own fields. These were followed by a presentation of conclusions and recommendations by Prof. Kandachar. The recommendations were proposed, discussed and finalized in consultation with the resource persons, panelists and the participants.

FIELD VISITS

Visit to RV-TIFAC Composite Design Centre - 27th November 2002

The visit was useful as the participants were explained in details about the coir fibre mat technology as well as the manufacturing processes of the coir, jute and other natural fibre based composite materials. The visit was of particular interest as the Glass Reinforced Polymers (GRP) composite material is fast emerging new class of materials. During the visit production methods of GRP composites such as hand-lay-up technique, spray-up, vacuum bag, compression moulding, resin transfer moulding, filament winding pultrusion were covered.

Field Visit to Natura Fibre Tech Pvt. Ltd. - 27th November 2002

Use of coconut fibre in manufacturing of composite materials and its processing were explained in detail to participants. The meet the increasing demand for wood based panel products there is a great need to identify substitutes for wood based products. Jute and coir are agro fibres grown in the rural areas. Products of these fibres are sustainable and renewable. Application of coir fibre for the production of materials such as acoustic & false roof panels, door panels, partitions, corrugated roof sheets etc. were shown to the participants.

Visit to Indian Plywood Industries Research & Training Institute (IPIRTI) - 28th November 2002

During the visit various technologies of the bamboo based composites were explained in detailed. Considering the need for developing alternate eco-friendly, energy efficient and cost effective roofing sheets, Building Materials & Technology Promotion Council (BMTPC) and Indian Plywood Industries Research & Training Institute (IPIRTI) jointly have developed a technology for manufacturing Bamboo Mat Corrugated Sheets (BMCSs). BMCS produced at pilot scale facility established at the IPIRTI used in several demonstration buildings was explained. The sheets have been found to be resistant to water, fire, decay, termites, insects, etc. They are light but strong and possess high resilience and offer better thermal comforts. The participants were also informed that these Bamboo Mat corrugated sheets are being commercially manufactured.

EVALUATION OF THE TRAINING COURSE

Information on bio-degradable plastic, use of different natural fibres in the making of composite materials and visit to RV-TIFAC composite design center and IPRITI, Bangalore where on the spot manufacture of composite materials was demonstrated has generated interest among the participants to start similar type of research work in their respective countries. Most of the participants showed their keen interest in the various lectures and interacted with the resource persons in order to improve their knowledge about the natural fibre composite materials. This activity helped in establishing a link between the South East Asian countries for future collaboration between the countries in the region.

Comments about the Training Course by participants

Nepal

- All the lectures conducted in this training course are equally useful, because the topics chosen for this training are basically for low cost and substitute building materials in the field of building construction which the developing country like Nepal is demanding. Among all the lectures, composite material design and manufacturers for building applications seemed more useful.

- In my opinion, such type of training course should be regularly conducted in every year, because it deals a lot of knowledge about the new building materials to reduce the cost of the building construction.

- Of course, the topics / tools that we studied during the training course could be used by the industries in my country. We have quite a lot of bamboo available in my country. The technique of using bamboo to produce door panels, roofing sheets etc. can be used to substitute wood.

- Nepal is a mountainous country. So ICS can help to develop the building materials to improve the stone. Also we have quite a lot of bamboo and jute. ICS can help us to improve jute and bamboo production building materials.

- Of course, this training program course is very much benefited to us, because Nepal is a developing country and need low cost of the building materials. So, we can introduce the substitute building materials to reduce the cost.

Vietnam

- The training course opens a lot change for collaboration in research and in producing technology for Asia and developing countries. However, the problems for developing countries is finance. If there can be some programme which will support by UNIDO for above purposes.

- I found very useful with demonstration and lecture on composite material using natural fibre. Coconut, banana, bamboo during training course. I recognised some good direction for my future research.

- I would like to organise some collaboration with India on the other hand, I have persuaded examples in India.

Bhutan

- I think, I can make use of the training course in my country but at present we don't have any plants and so I think it will take some time to come up.

- I would like if this sort of training course to be used in our country where we have so many natural resources available.

- This training course has benefited me a lot. Our country requires lots of houses for the people, so now, I know how to make use of the locally available materials.

- I will disseminate the information that I have acquired during this course by sharing all those brochure which I am taking with me from here and also by your website.

Bangladesh

- Few manufacturer in Bangladesh is manufacturing. FRP using Glass Fibre, but more with natural fibres. Bamboo, banana plant, jute etc. are grown abduntly in Bangladesh. Existing FRP producing plants can be modified or new plants can be set up for producing FRP with natural fibres. Only technologies transfer is necessary in this regard.

- The course provided an opportunity to share the experiences with other participants, which widened scope for R&D in the specific are of the programme.

- The information gathered during the course can be use for making aware. The possible entrepreneurs of the new technologies available for implementation.

Indonesia

- The information and knowledge gathered in the course can be for the benefit of coir and bamboo composites industries which are the most possible to be developed in my country. Since, both kind of fibre resources are plenty in my country, however, it have not use optimally.

- In addition, this knowledge can also be used for other indigenous fibres are considered to be used for composite materials design as well.

- The course provided the platform to establish regional working group on composite materials based on natural resources.

- To conduct collaborative research programme among participating countries.

Sri Lanka

- Factory visit was most important part of the training course.
- Yes, now we can improve the building material industries in our country.
- This training programme is most useful to us and it is very successful training programme.

ACHIEVEMENTS OF THE TRAINING COURSE

The Training Course proved to be a very useful event as felt by most of the participants from other countries. Many participants were not aware of the potential of composite materials particularly for applications in construction and building industry. Their participation in the Course and free interaction with knowledgeable Resource Persons encouraged them not only to know more about the composite material, production technologies but motivated them to take initiative on developing science and engineering of composite materials in their respective countries. Some of them felt that R&D organisations in their countries should undertake projects for developing composite materials based on their local resources in collaboration with institutions in India and Netherlands. The biggest achievement of the Training Course reflects in the fact that most of the participants realised that composite materials based on natural fibres, plant materials and other agro-industrial wastes can be developed and utilised effectively as substitute to traditional materials like cement concrete, corrugated iron sheets, hard wood panels and doors shutters.

Researchers, scientists, technocrats and bureaucrats who attended the Course and interacted with the participants all realised that there is a need for taking policy initiatives to encourage further R&D and industrial development for promoting composite building materials in their countries. The other important outcome of the Course was the expression of the visiting participants from other countries to collaborate with Indian R&D institutions and industrial enterprises for development and promotion of such materials and manufacturing technologies.

RECOMMENDATIONS

1. Design a region (South East Asia) specific database structure of technological, economical and ecological properties of local resources (natural materials, natural fibers, natural resins, composites based on such materials, etc). For this purpose a form has been developed, and have been distributed to all the participants of the training course.

2. All the involved countries are recommended to complete this database with actual data and keep updating.

3. The Building Materials Technology Promotion Council of India (BMTPC) is prepared to co-ordinate, to collect the data, and to make the collected data available on their homepage.

4. Inventarise the country-specific and region specific needs, which are likely to be met with such local resources. Involve end users in this phase. This step is essential for designing and building housings suitable for local people.

5. Define region/country specific opportunities for such local resources.

6. List the Universities, R&D Institutions and local enterprises interested/involved with such materials as well as products from such materials.

7. Design, develop and demonstrate products in such materials to meet local requirements, by involving the end users, Universities, R&D Institutions and local enterprises. Affordability, durability and reliability should be the essential criteria in all decisions.

8. Provide assistance to acquire the scientific and technological facilities to conduct R&D and some basic technological work. For this purpose two lists of equipment have been prepared, and have been distributed to all the participants of the training course.

9. During the process of R&D and technology demonstration, develop country specific test and evaluation methodologies, standardization of such methods, in case the current international standards do not meet the requirements of local needs.

10. Transfer knowledge to local enterprises as well as to Universities and R&D Institutions, both in the country where such knowledge is developed and in other countries of the region as well.

11. Provide hands on training courses to practicing engineers, technicians and scientists.

12. Educate the students at all levels about the science, technology and applications of local materials, to increase their awareness as well as to promote the use of indigenous local materials.

13. Teamwork is essential to reach the desired goals, as this field is complex and involves contribution of several specialists. Co-ordination of these is also required. Stimulate teamwork and co-ordination.

14. India has made considerable progress in science & technology of local materials, including technology demonstrations. India should take lead in helping and supporting other nations in the region.

15. The initiative of interregional co-operative effort (within the framework of the Government of India and UNIDO's ongoing programme) aimed at sharing of knowledge, experience and skills needs to be actively promoted.

16. Such training courses as conducted at Bangalore should be repeated frequently. Include the knowledge and experiences of other resource persons from other countries and from previous training courses when organizing future training courses.

17. To achieve the desired goals long term commitment of all the involved, including policy makers, is essential. Organize regularly such events on low cost housing which policy makers of governmental organizations can/will also attend.

18. Regular evaluation of all initiatives and corrections by the involved parties are also recommended.

19. It is strongly recommended that concrete follow-up actions are taken based on these Bangalore recommendations.

FOLLOW UP ACTIONS

From the nineteen recommendations as mentioned above, it will be seen that the action to follow up of the Training Course should be undertaken by UNIDO. The recommendations need to be translated into action areas which lie in the domain of national governments of the participating countries. The recommendations are addressed to policy makers, R&D institutions, industrial enterprises, practicing professionals. It is, therefore, desirable that ICS/UNIDO should analyse each recommendation and take up further action in consultation with the governments of the countries whose participants attended the Training Course so that it is possible to catalyze policy initiatives and technical cooperation programmes amongst the developing countries of the region. It is also required that a regional programme on investment promotion and technology transfer in the area of composite building materials for cost effective housing should be developed by ICS/UNIDO with the objectives of strengthening the institutional framework, industrial base of materials sector as well as advancement of technology in the developing countries of South-East Asian region.

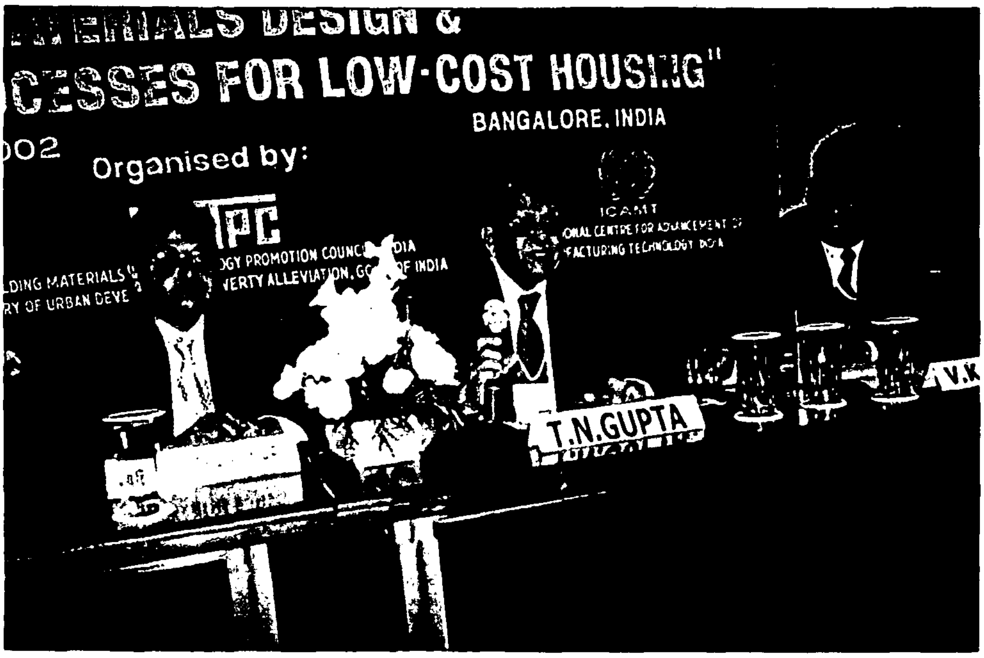
COMMENTS AND CONCLUSIONS

There is a need to evolve an appropriate policy for organizing such Training Programmes. As the coordinating organization, BMTPC was unable to satisfy all those prospective participants from different countries who were keen to participate in this Course but could not attend due to shortage of financial support. Because of financial constraints it was not possible to satisfy all those who desired to attend. It will be desirable to allocate realistic budget in future, if such Training Courses are to become real instruments for South-South Cooperation and technology dissemination and transfer amongst developing countries. The financial support provided by ICS and ICAMT (UNIDO) was too meagre for organizing the Training Course of international level as it was not possible to attract a good cross-section of participants from R&D, academic institutions, Governmental representatives responsible for decision making and industrial enterprises.

All the participants, towards the end, felt that the theme of the Course was very important from the points of view of the housing situation obtaining in their respective countries, but they felt that atleast one representative at the Policy-making level should have been there. Presence of such a representative from each country would have helped in creating appreciation at highest policy making level for taking nationally relevant initiatives to take full advantage of the technologies that are available for strengthening their housing programmes and upgrading the status of building materials industry.

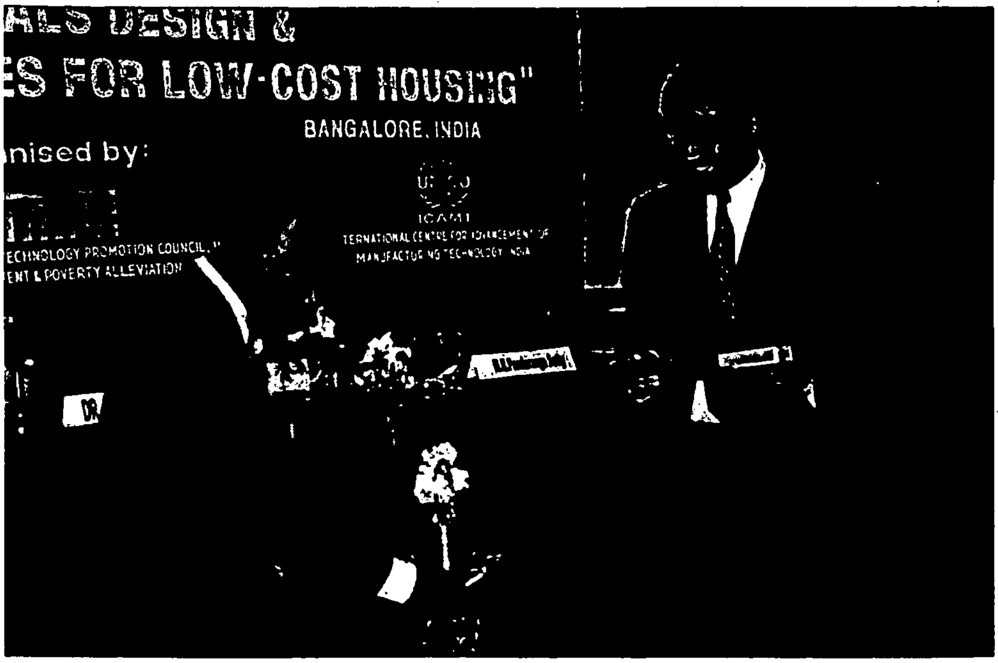
Annexure – 1
Photographic Presentation

Address by Dr. M.K.Panduranga Setty/Inaugural Session

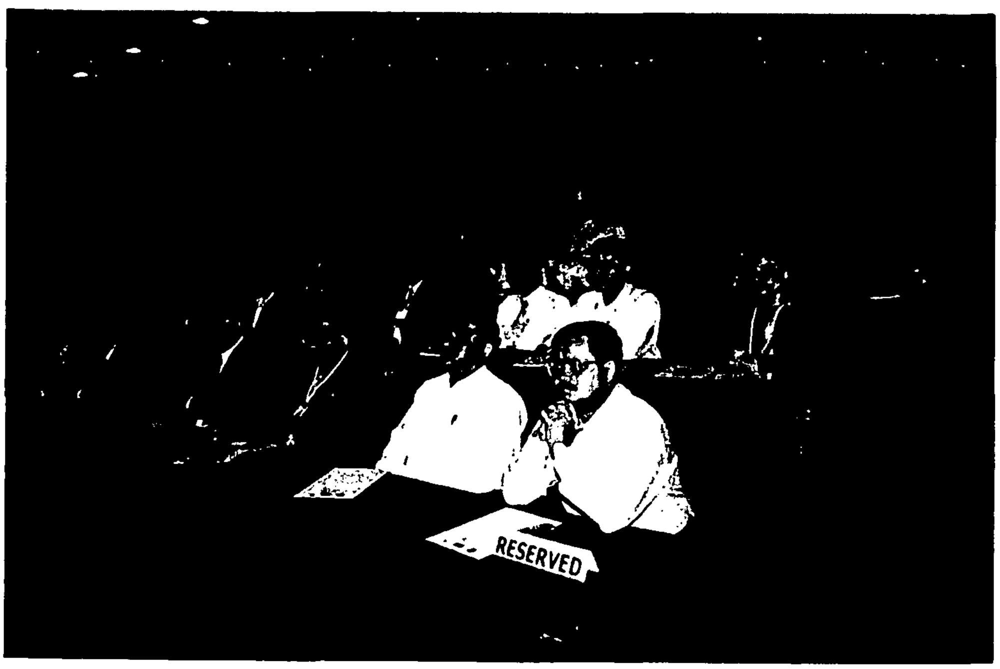


Opening remarks by Mr. T.N. Gupta/Inaugural Session

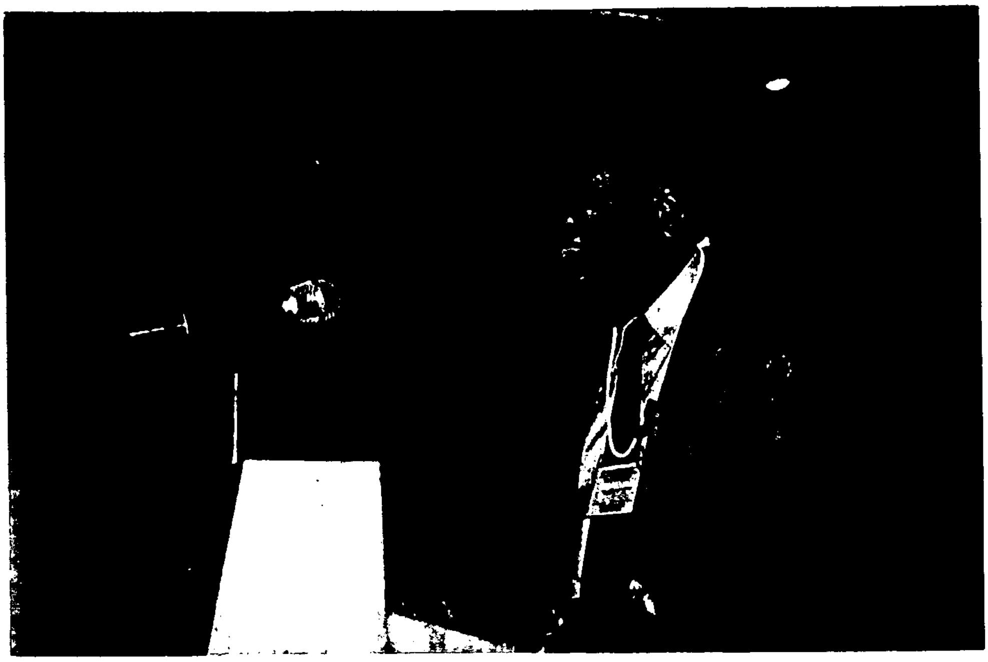
Lighting of lamp by Mr. T.N. Gupta & Mr. Vinod Yadav



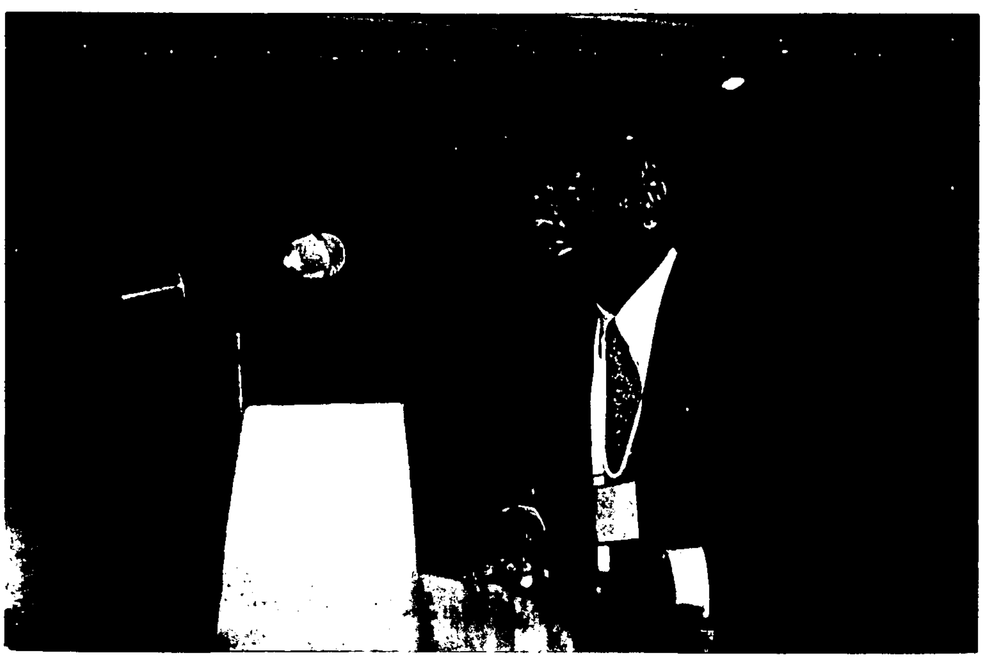
Lighting of lamp by Dr. M.K.Panduranga Setty



Participants in Inaugural Session

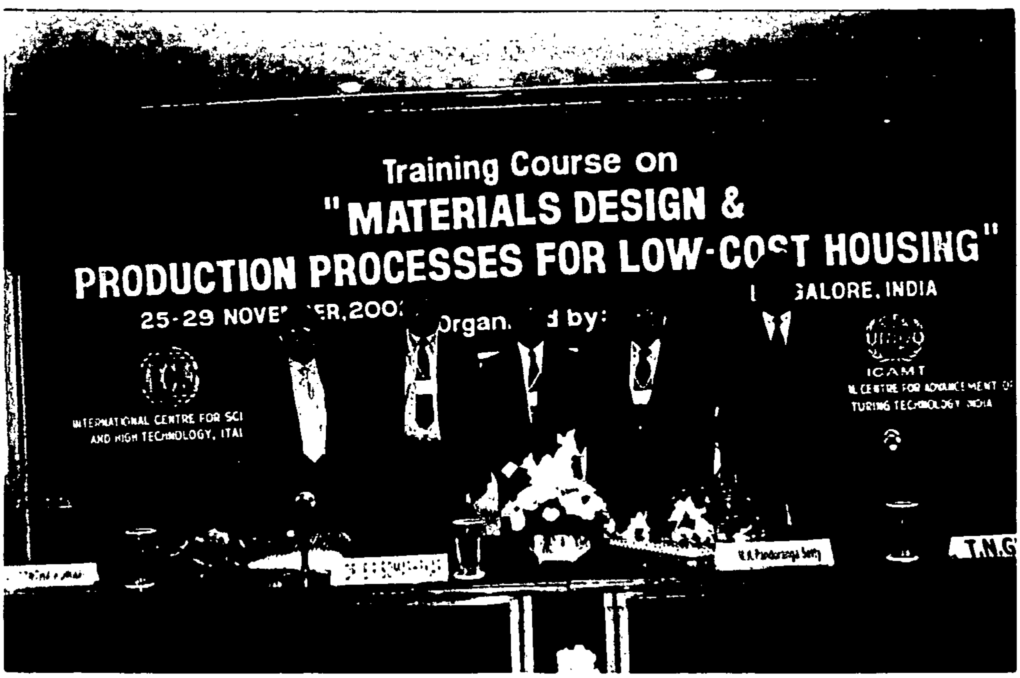


Inaugural lecture by Dr. D.R. Somashekar

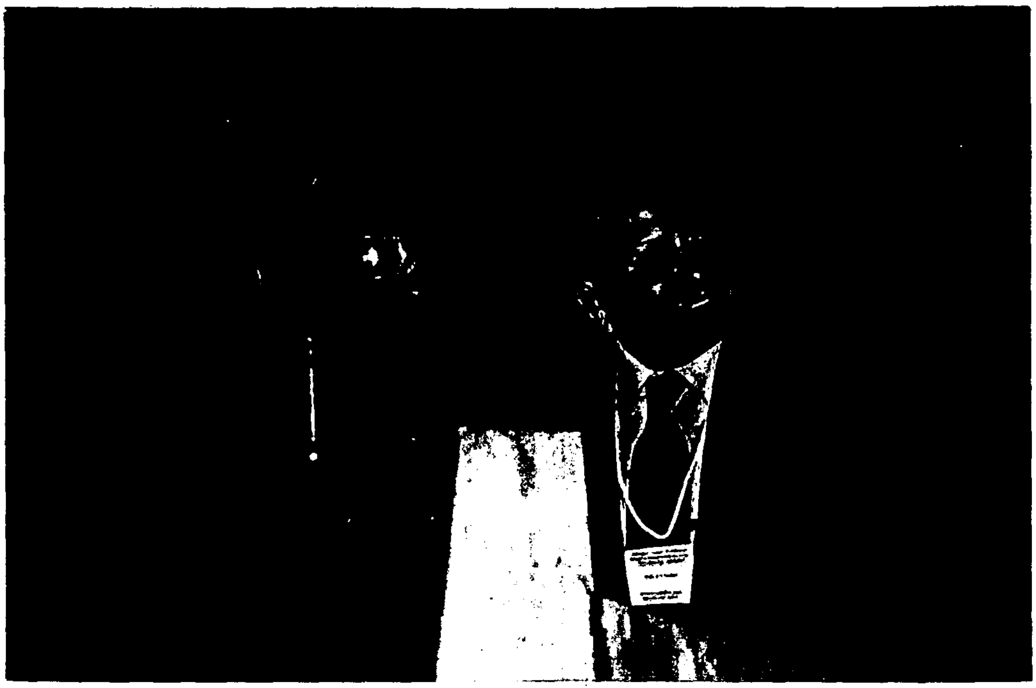


Inaugural lecture by Dr. M.K.Panduranga Setty

Presentation by Mr. Vasantha Kumar

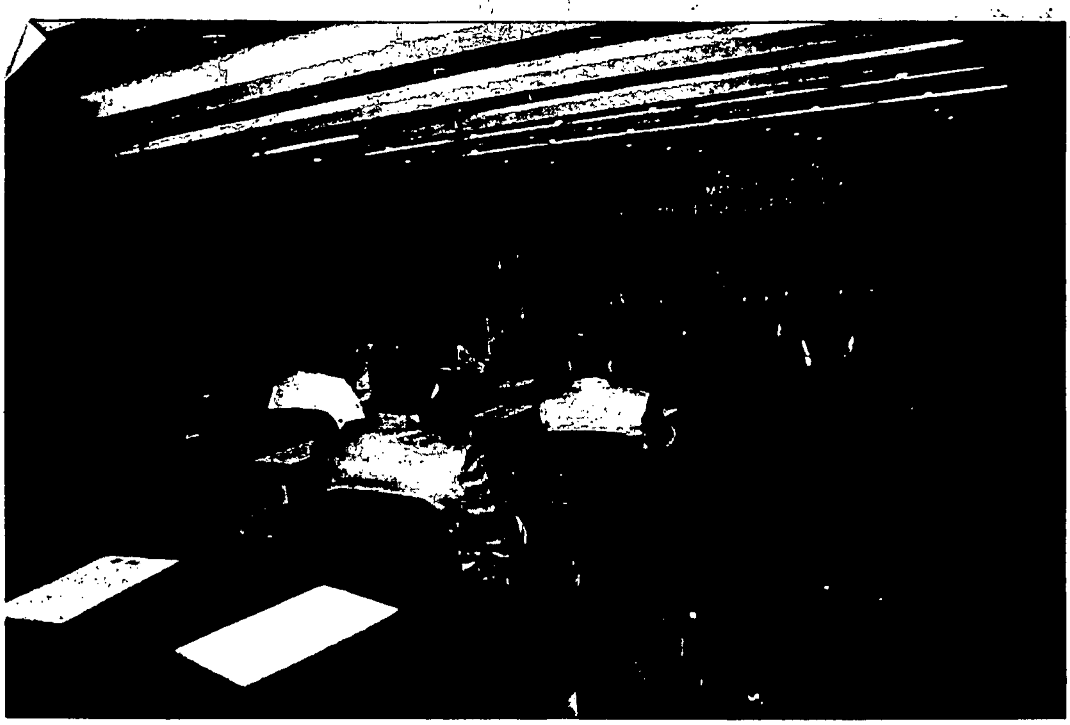


Dignitaries at dias in Inaugural Session

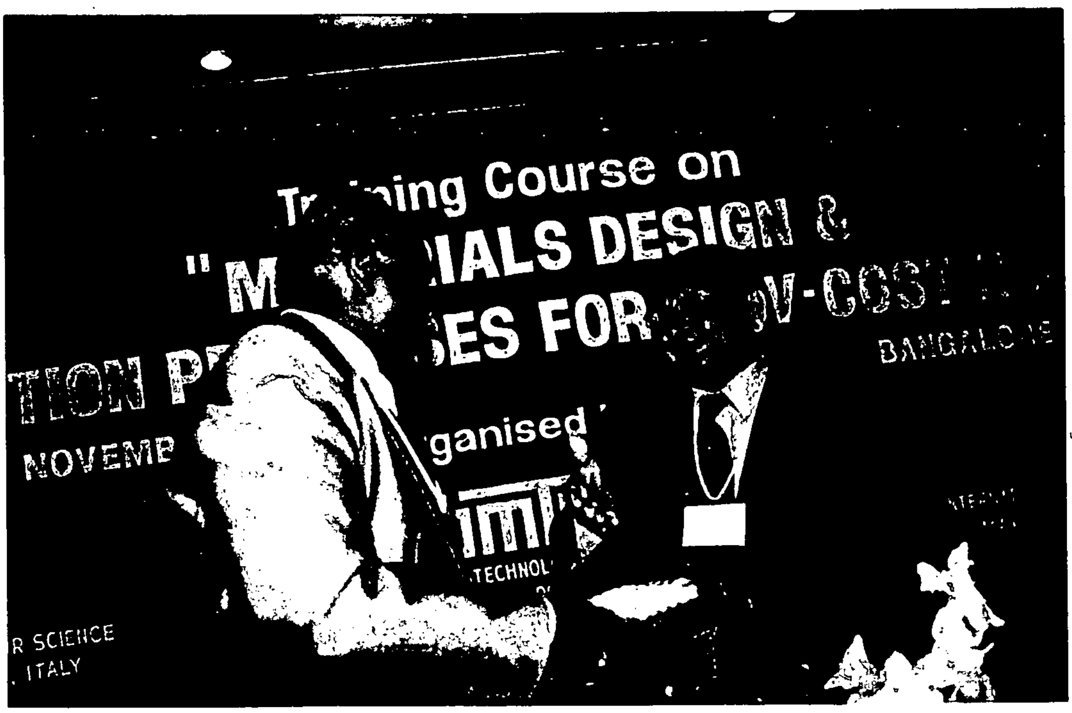


Introduction to programme by Mr. T.N. Gupta

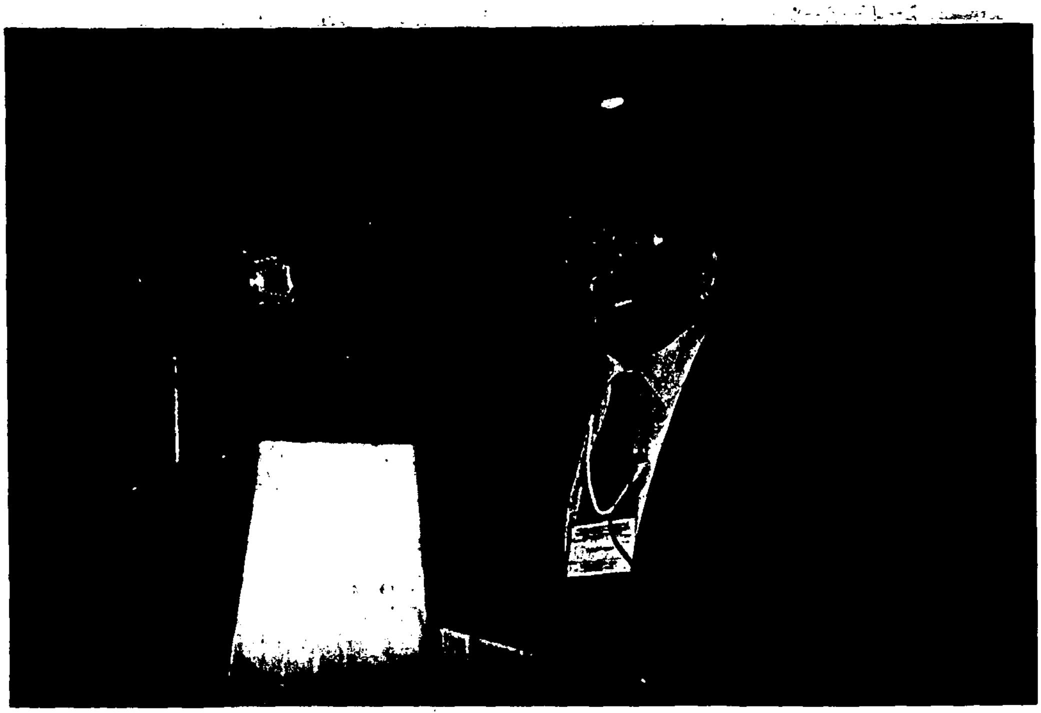
Lecture by Mr. Prabhu Kandachar



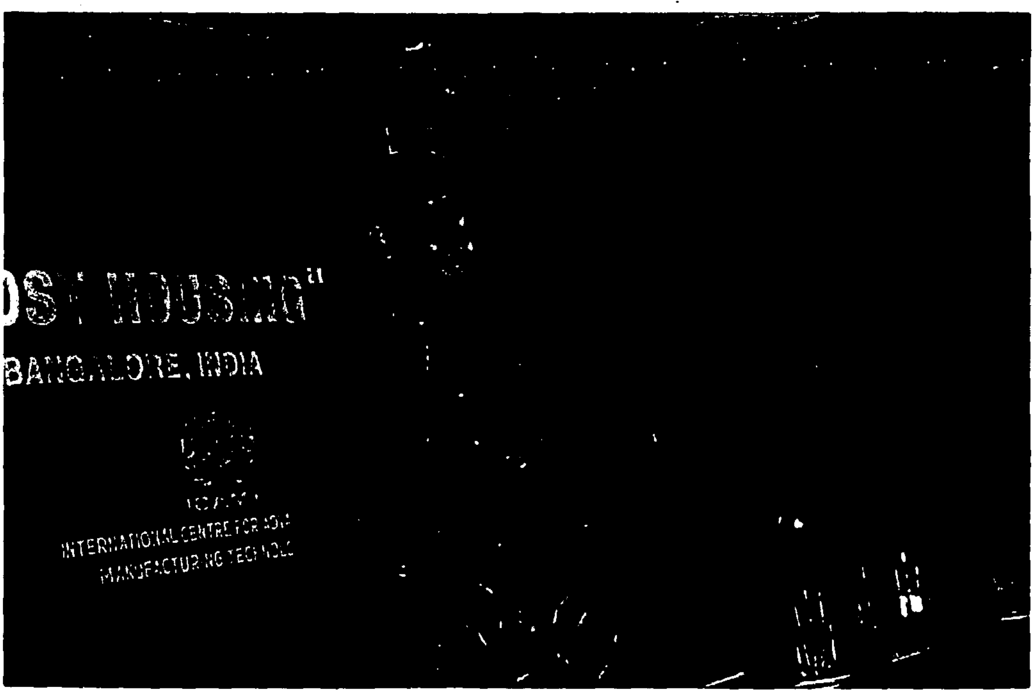
Introduction of ICAMT/ICS by Mr. Vinod Yadav



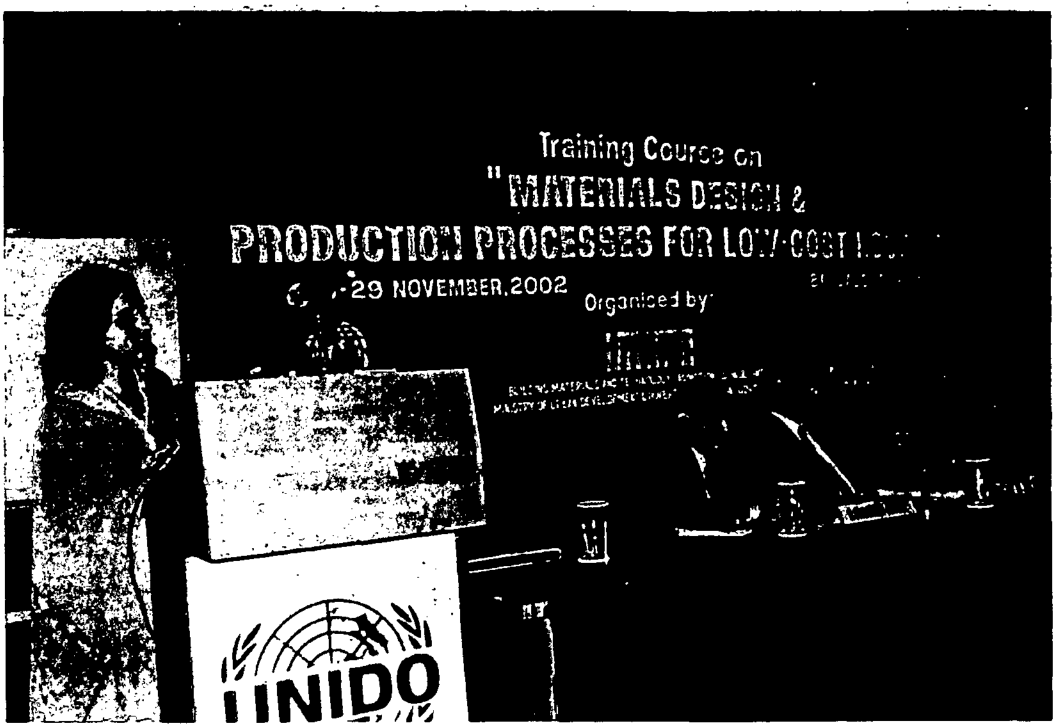
Souvenir Presentation to Dr. B.R. Somashekar



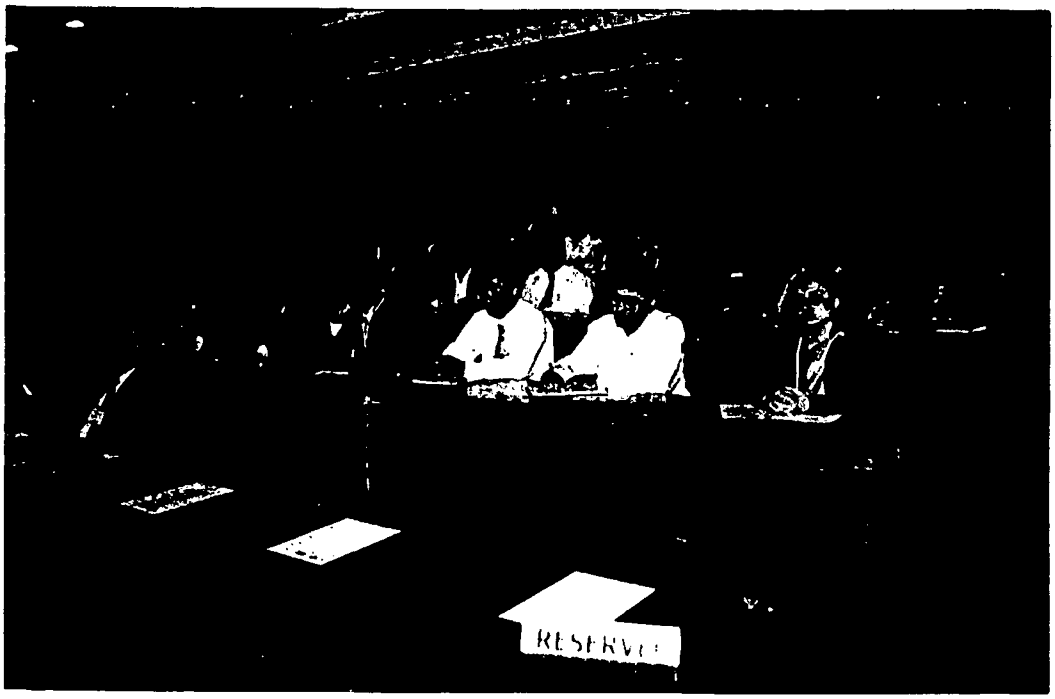
BMTPC presentation by Mr. T.N. Gupta



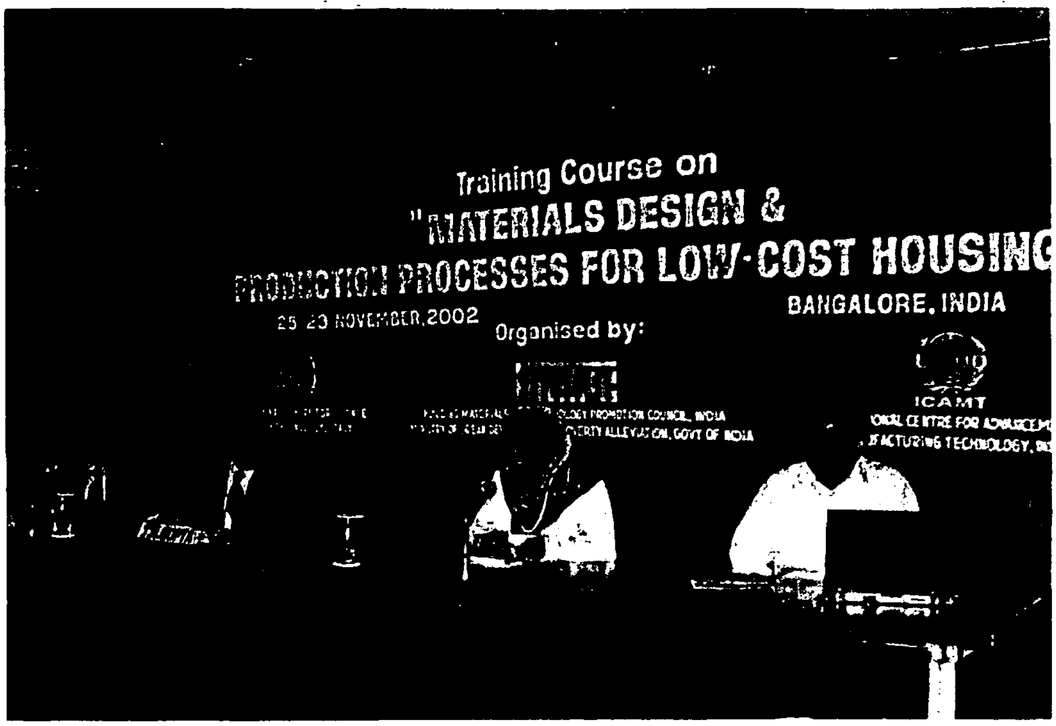
Lecture by Dr. Soumitra Biswas



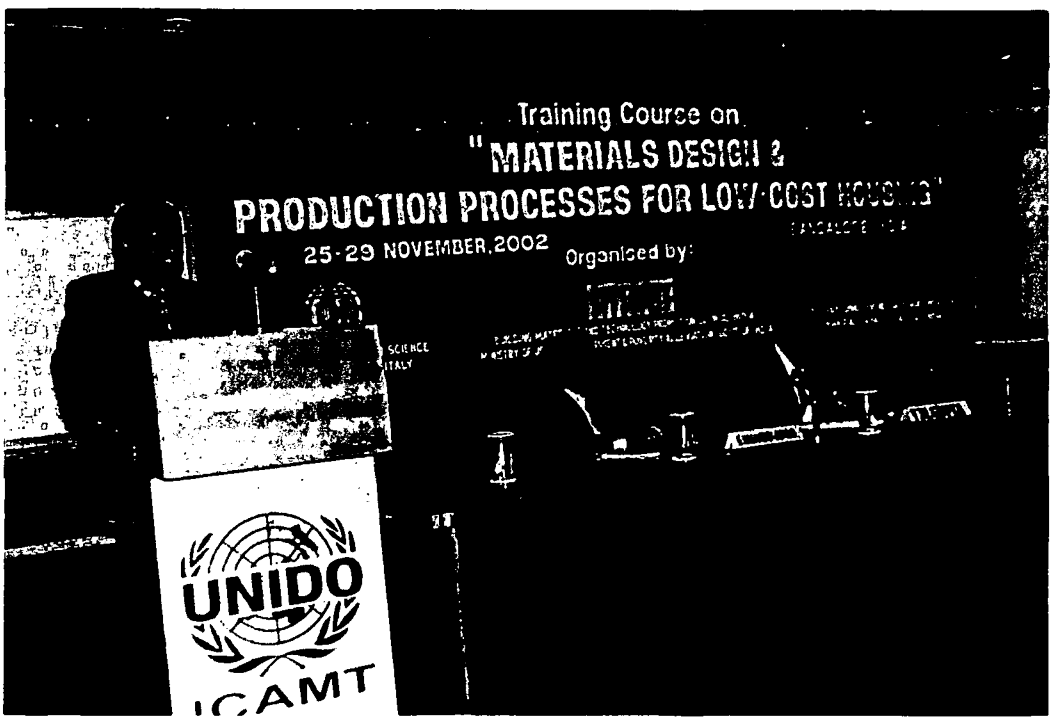
Introduction by Dr. Hina Tarannum, India



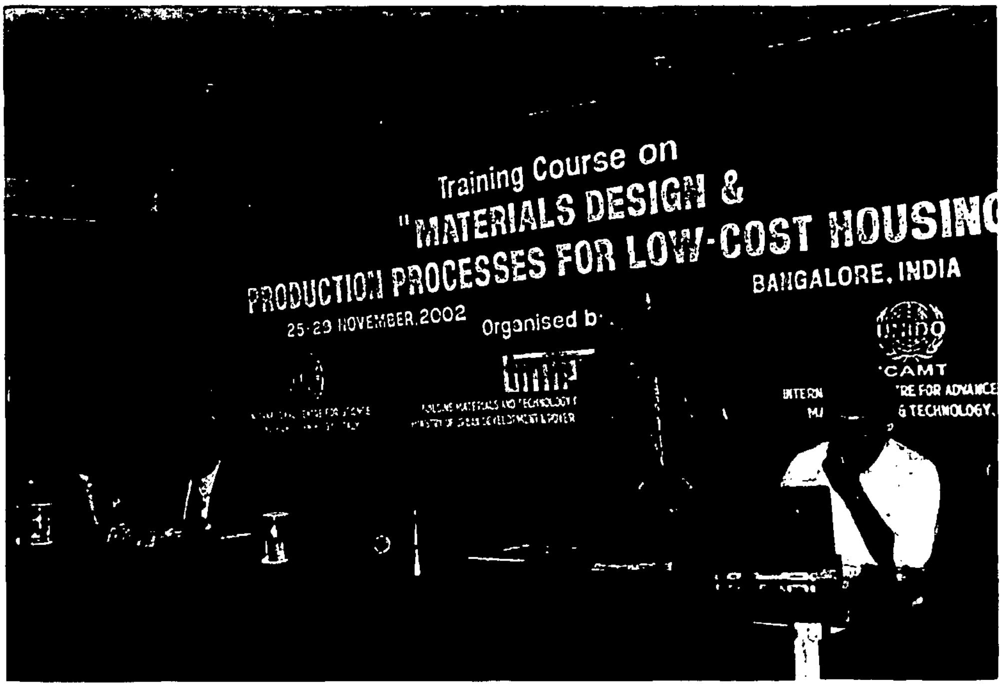
Participants in Inaugural Session



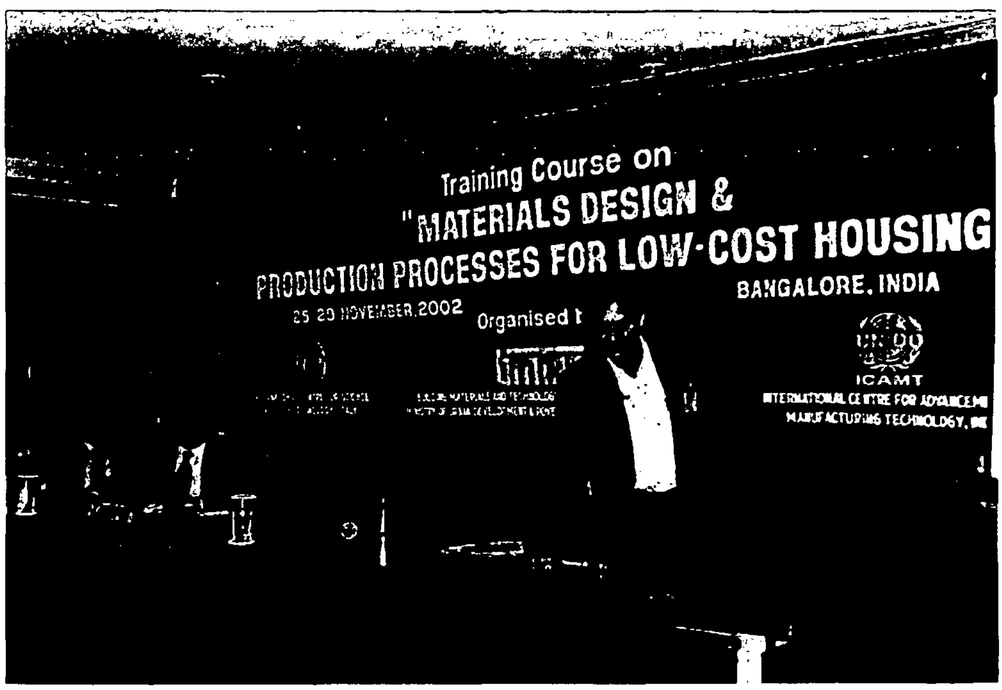
Presentation by Dr. Wiwik S. Subowo, Indonesia



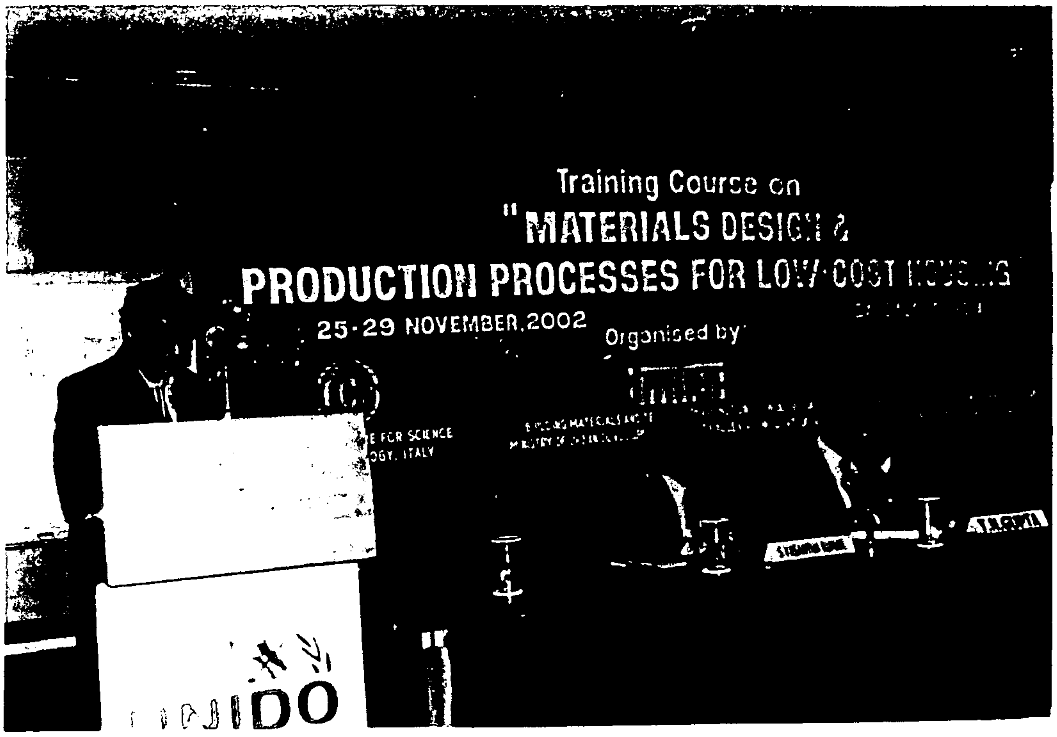
Presentation by Dil Chhetri Ranjan, Bhutan



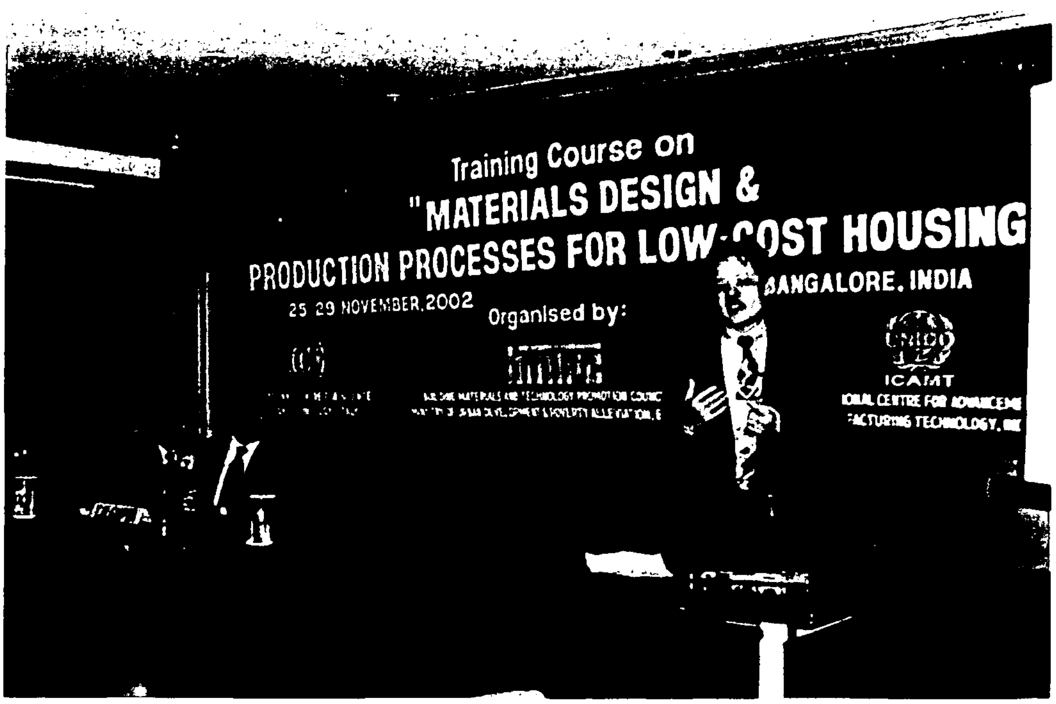
Presentation by Mr. Mani Ratna Tuladhar, Nepal



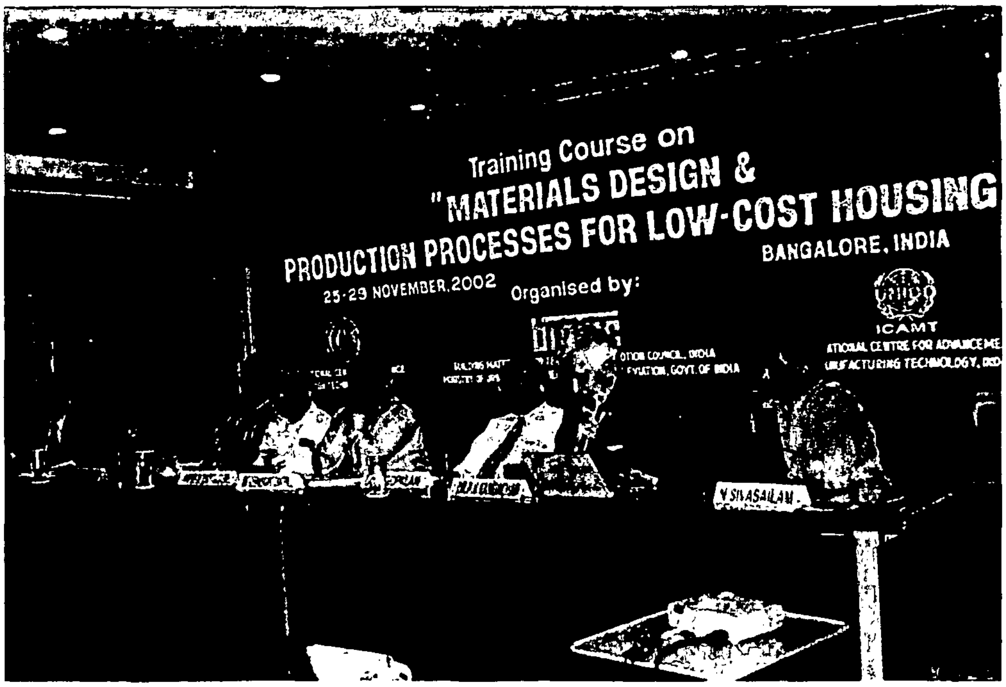
Presentation by Er. Thakur Raj Pant, Nepal



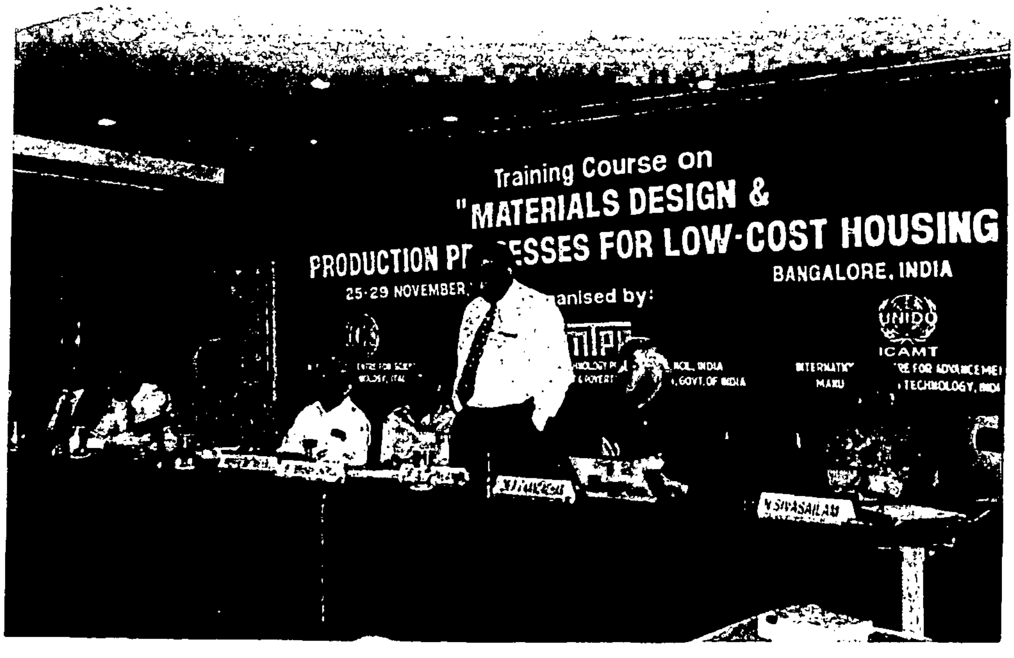
Presentation by Mr.K.T.D.S. Wickremaratne, Sri Lanka



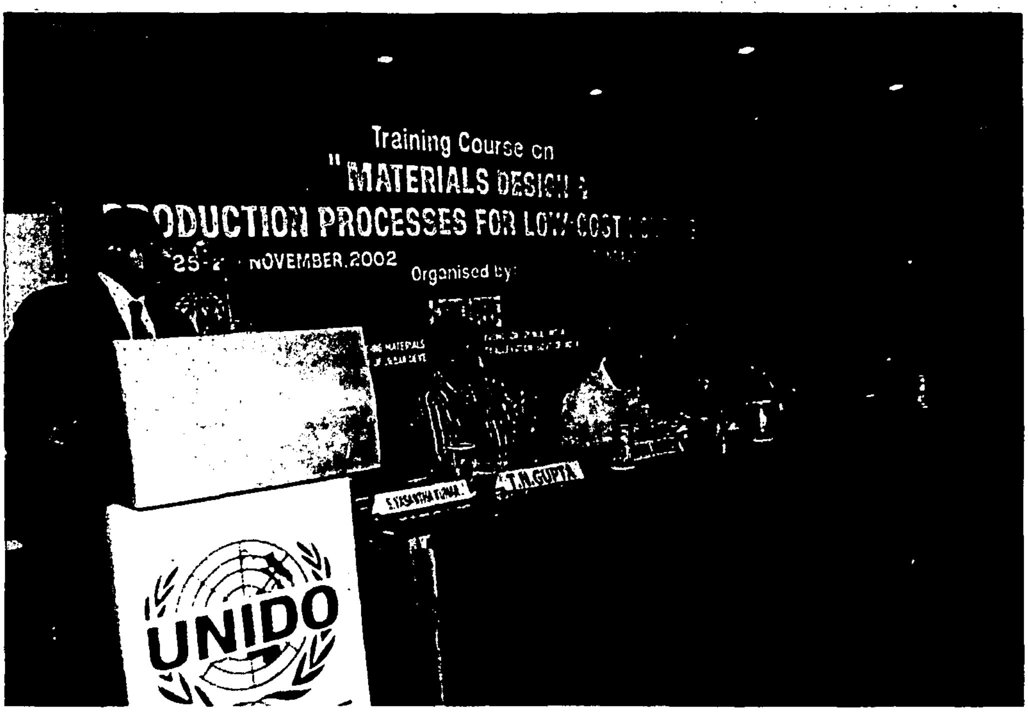
Presentation by Mr. Dau Duc Hai, Vietnam



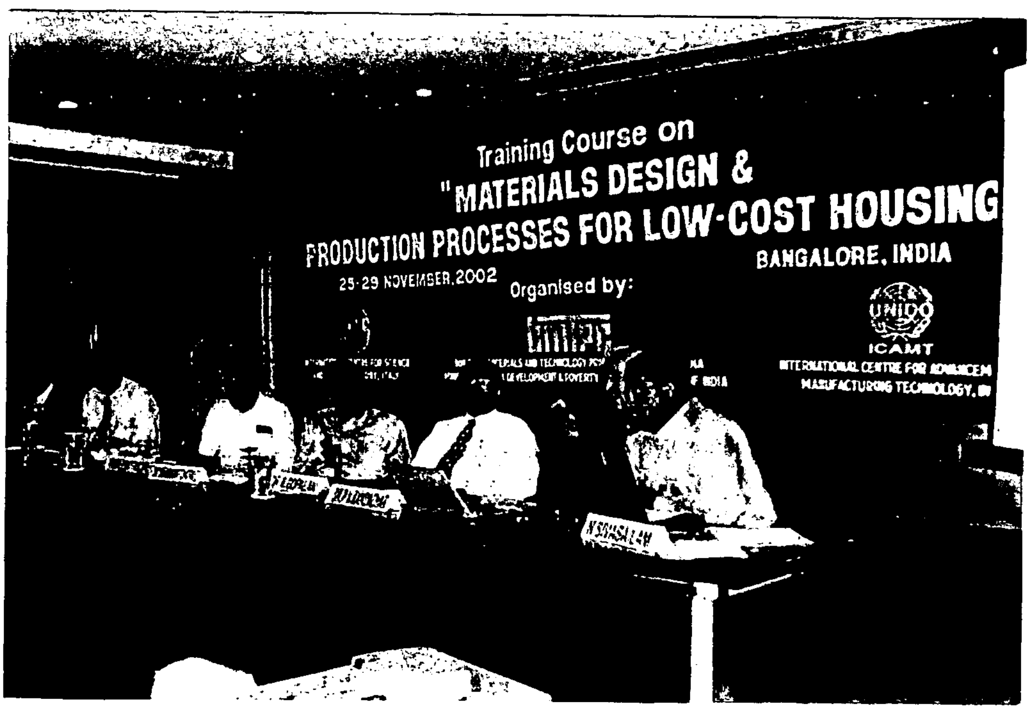
Prof. Prabhu Kandachar in panel discussion



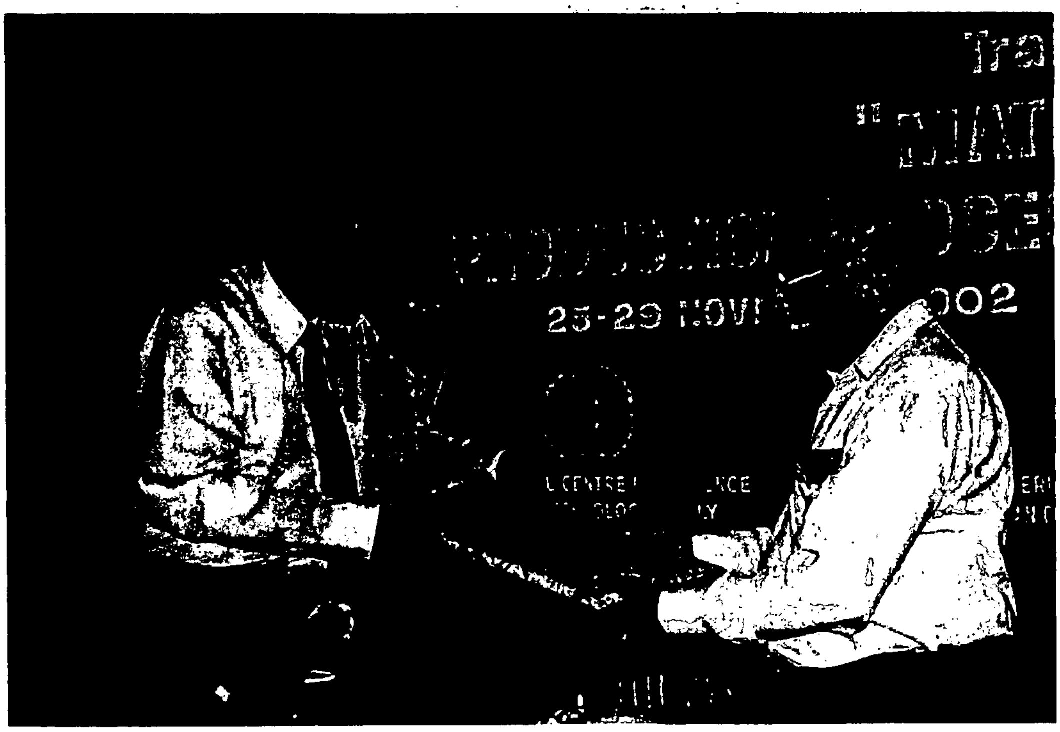
Dr. R. Gopalan during panel discussion



Mr. T.N. Gupta summarising the Training Course

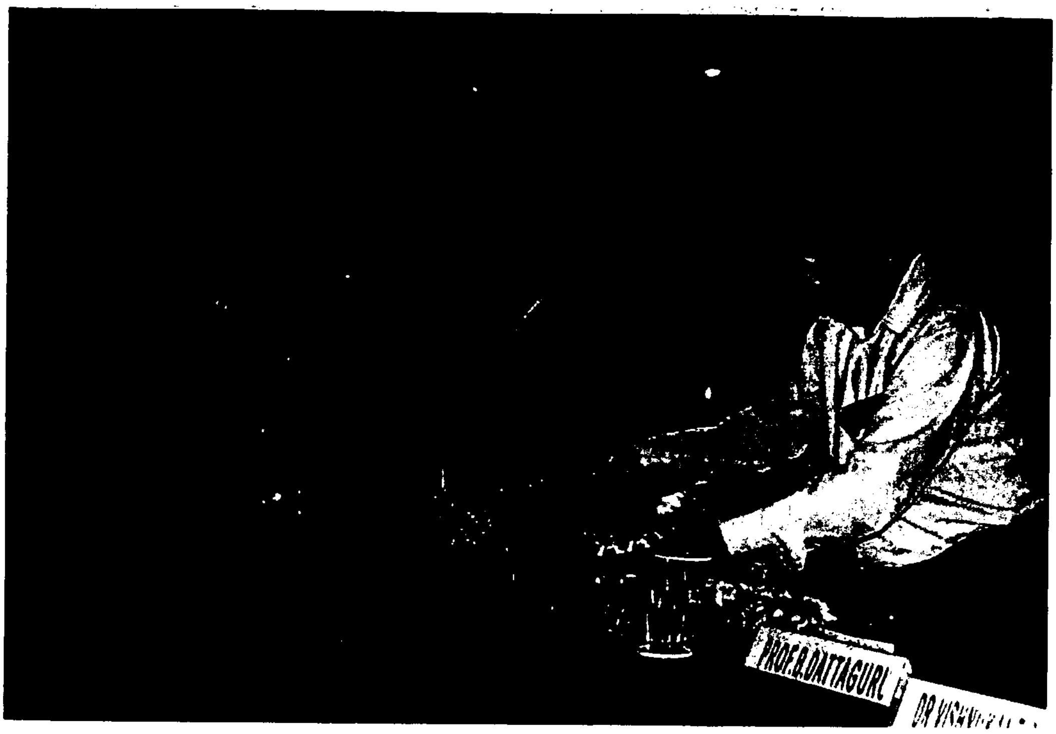


Presentation and discussion by Mr. N. Sivasailam in panel discussion

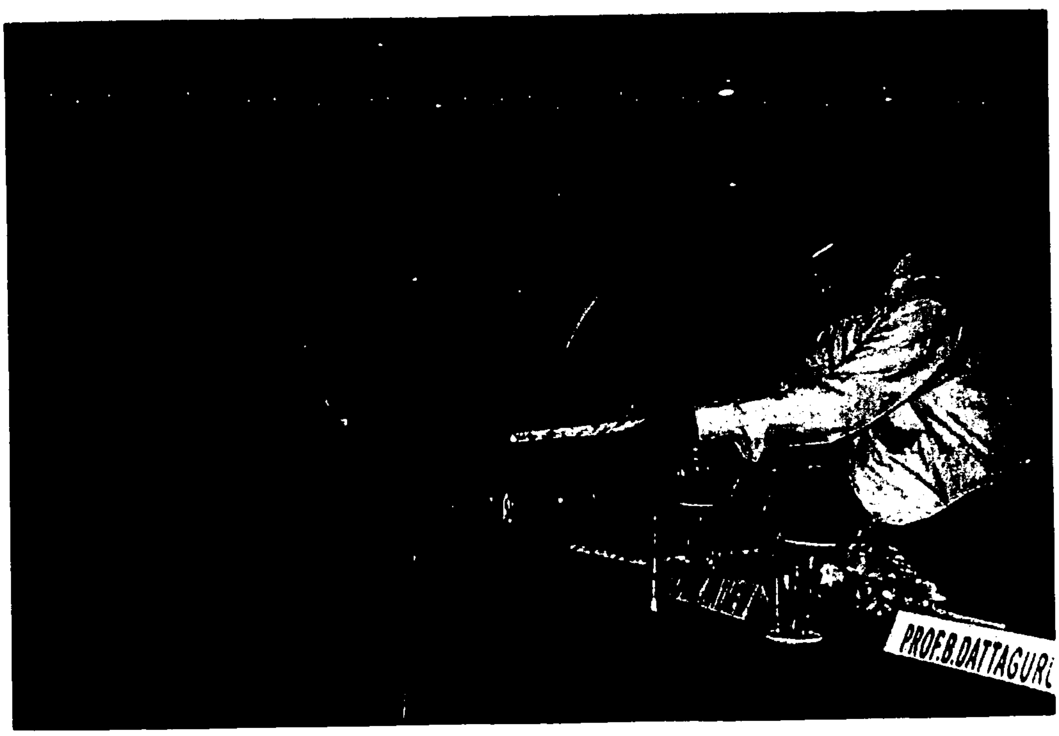


Presentation of Certificates to Mr. M.Mahbub-ul-Alam by Prof. B. Dattaguru

Certificate presentation to Mr. M.B.M.N.B. Gawarammana, Sri Lanka



Certificate presentation to Mr. Dau Duc Hai, Vietnam



Certificate presentation to Dil Chhetri Ranjan, Bhutan

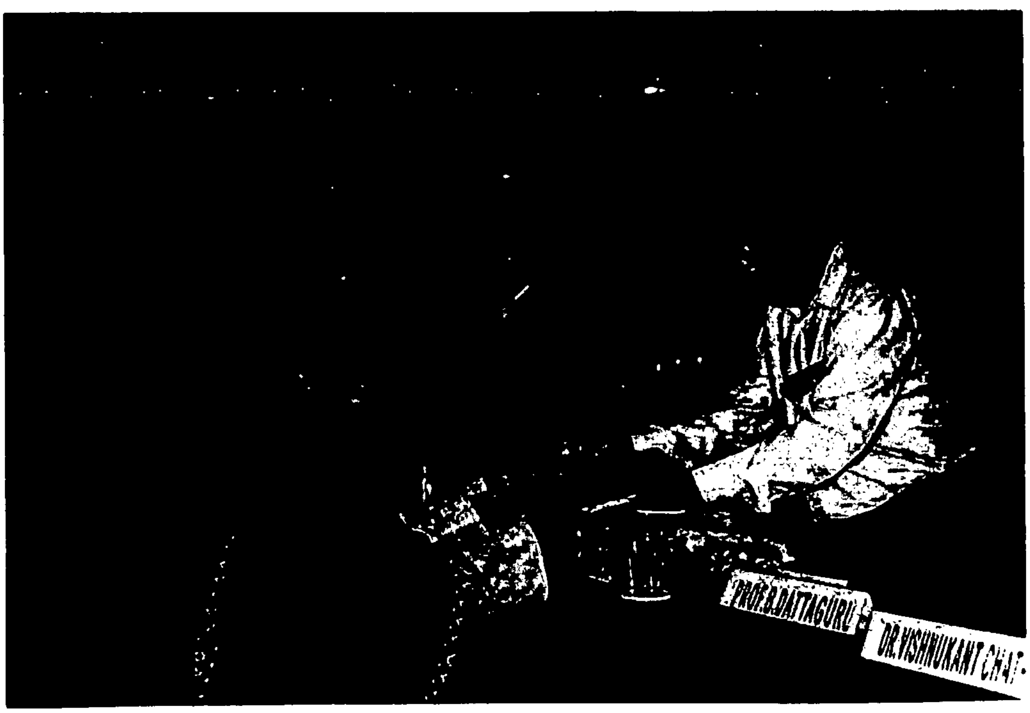
Certificate Presentation to Dr. Wiwik S. Subowo, Indonesia

Certificate presentation to Dr. Amit Rai, India

Certificate presentation to Prof. M.Nagaraja, India

Certificate presentation to Dr. Hina Tarannum, India

Certificate presentation to Dr. C. Pavithran, India

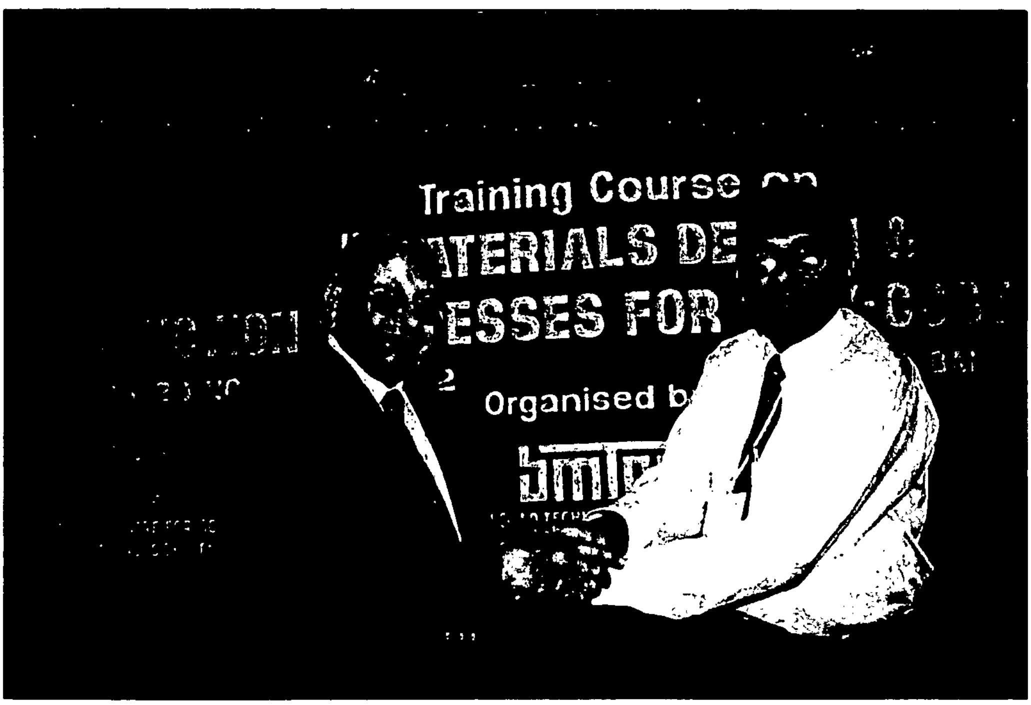


Certificate presentation to Ms. Farida Sultana, India

Souvenir presentation to Mr. Sivasailam

Thanks to Dr. Vishnukant Chatpalli by Mr. T.N.Gupta

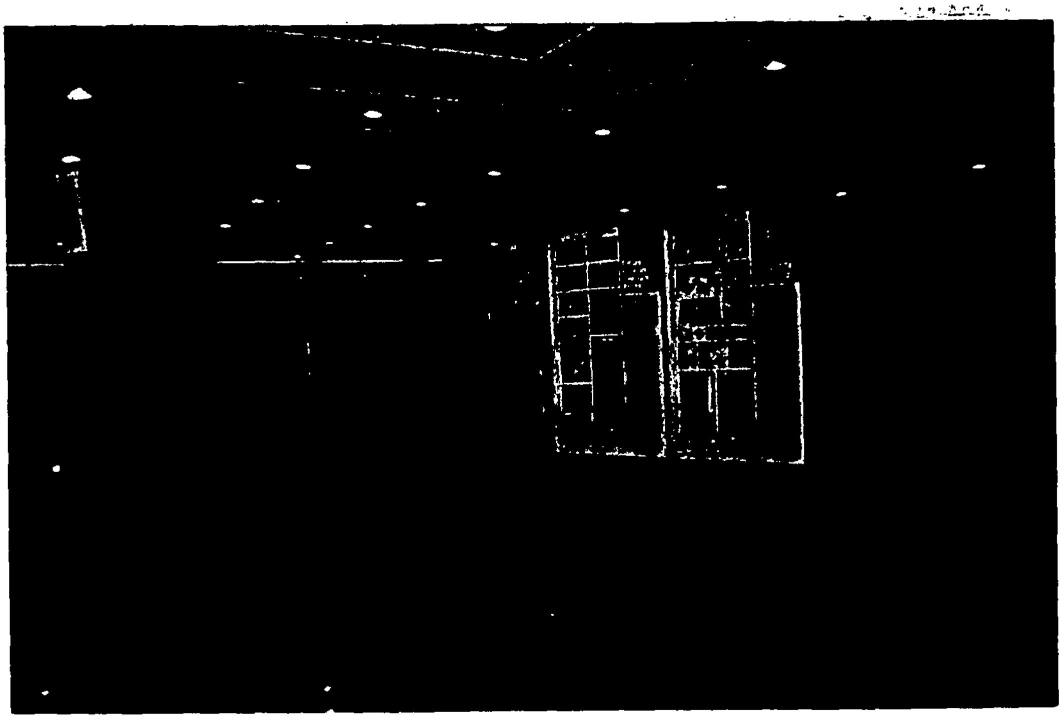
Thanks to Prof. B. Dattaguru by Mr. T.N. Gupta



Thanks to Mr. T.N.Gupta by Mr. Alam on behalf of all the participants

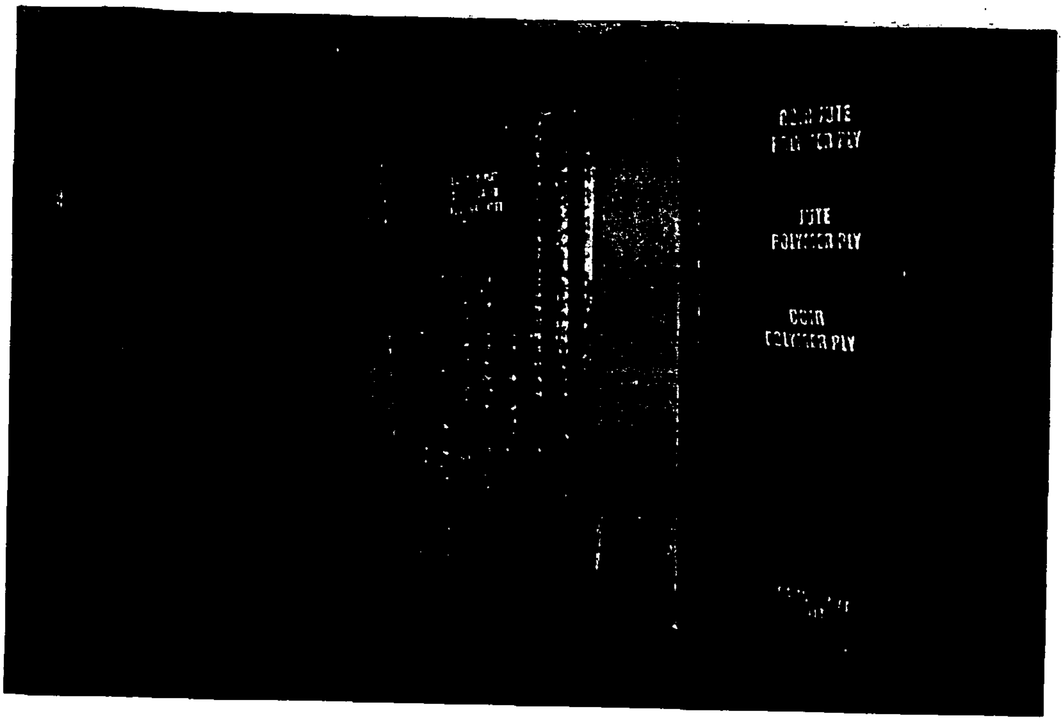
Distinguished guests during exhibition

Mr. T.N. Gupta explaining various technologies to Prof. B. Dattaguru

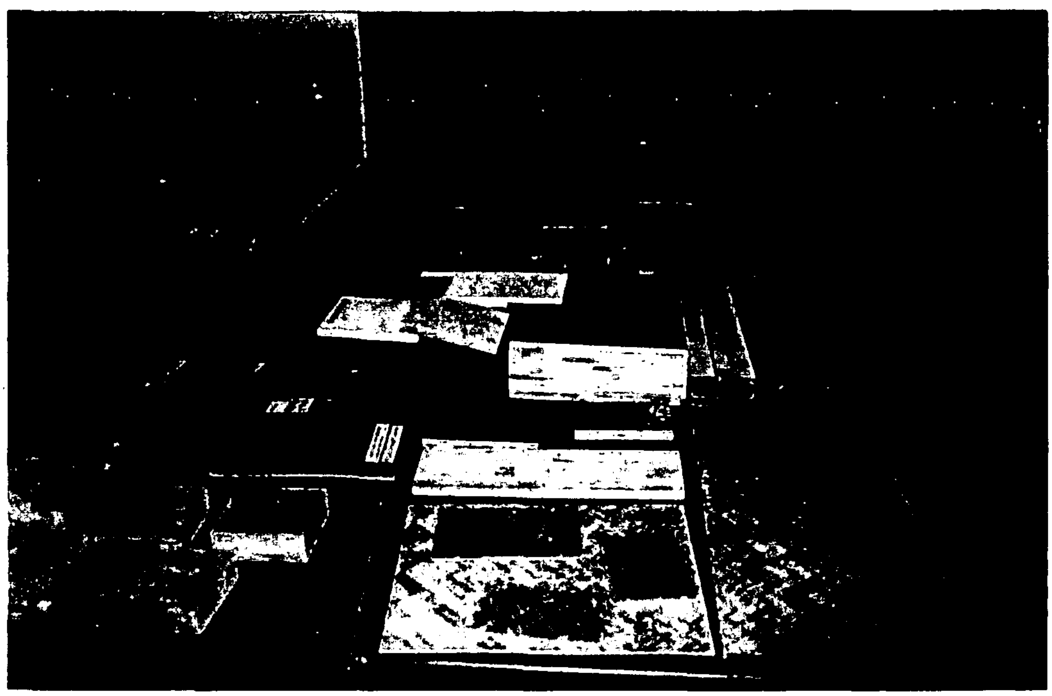


Exhibition organised by BMTPC

Doors developed by BMTPC displayed in Exhibition

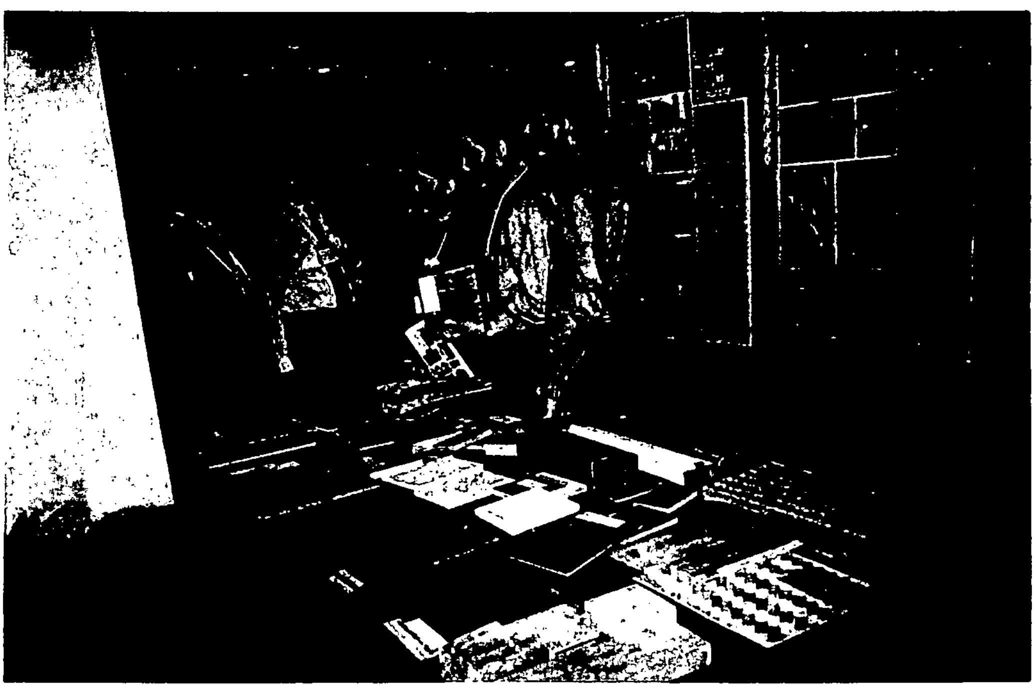


Natural fibre products developed by BMTPC

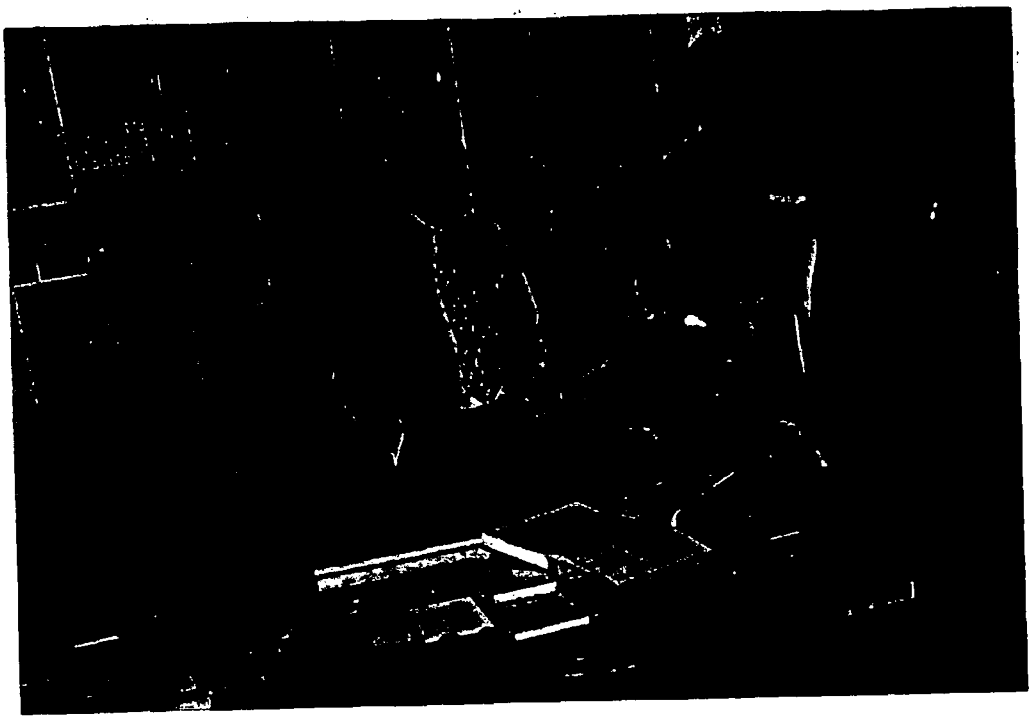


Various products developed by BMTPC

Mr. T.N. Gupta explaining various product to wife of Hon'ble Urban Development Minister, Govt. of India



Mr. T.N. Gupta with foreign participants in Exhibition



Mr. T.N. Gupta explaining about BMTPC publication

Foreign participants at BMTPC Exhibition

Annexure – 2
Aide Memoire

International Centre for Science and High Technology

in cooperation with

Building Materials & Technology Promotion Council

and

International Centre for Advancement of Manufacturing Technology

organise a

Training Course

on

"Materials Design and Production Processes for Low-cost Housing"

25-29 November 2002
Bangalore, India

AIDE-MEMOIRE (eff. 17/07/02)

BACKGROUND

In every country the building industry is a fundamental and strategic sector linked to improving the standard of living. The building industry depends highly on technological innovation as a constant driving force. Technological innovation creates added value, it improves the product, and cuts the costs, thus allowing for a greater distribution of the product on the market and an extension in the distribution range.

For a long time man has been using natural fibre composites in house construction in the form of fibre-reinforced soil blocks, thatches and walling panels. But people do get attracted towards burnt-clay bricks and cement concrete, and consider fibre-composites as sub-standard materials. Natural-fibre based composites have great potential as alternative and cost effective building materials. There is vast scope for self-help and self-reliance in building materials if the inherent potentials of fibre-composites are properly exploited.

The natural fibres being of lower density than of glass, carbon, Kevlar fibres etc. a natural fibre reinforced product will always be thicker than one reinforced with the same mass of glass fibre but both will have comparable specific strength properties. Hence in all load application oriented products the design-developments can adequately take care of the required stiffness, without increasing costs. All these greatly depend on the interaction between structural function and design of materials. It is an integrated approach, which has been successful that new in new technologies applications.

The recommended products are usually composites for roofing tiles & sheets, panels for door shutters/partitions/ceilings and load bearing bricks and blocks.
The successful example may include the following:

- Rice husk-phenolic resin particle board
- Cotton fibres-P VC-phenolic resin products for door and window frames, shutters, panels
- Glass-fibre and coir fibre-HDPE products for water tanks, door frames, shutters
- Coir fibre or sisal fibre-cement composites for corrugated roofing sheet/tiles and door panels
- Sisal-coir-gypsum plaster composites for ceiling and partition.
- Jute fibre-polyester composite for walling, partitions, shutters etc.

JUSTIFICATION

Modern concepts of material science are based on the understanding of the structure-property relationships of materials. Several advanced composite materials, now being produced are light weight but structurally very strong, fracture resistant and highly impermeable. They are being produced using polymer as well as cement matrix, with both manmade and natural fibres. Many types of composites, using jute, sisal, coir, bagasse, mixed with steel and glass fibres, have been used in the manufacture of door and window shutters and frames, panelling and partitioning systems. The concepts of composites have been extended to the amorphous-crystalline phases of materials for the development of glass-ceramics and refractories of outstanding structural properties and long durability.

Especially in developing countries there is an urgent need to be better acquainted with new techniques on composites and new materials for low cost housing design and their production processes.

Having a mind that UNIDO/ICS New Materials subprogramme is to streamline materials science and engineering into applied research in order to assist developing countries, within this subprogramme, building materials design and improvement ranks highest in the priority list as they link raw and recycled materials exploitation within the building industry processes. Further to this goal, the UNIDO/ICS New Materials subprogramme focuses on the development of technologies for the realization of lightweight building components based on renewable natural resins and fibres, blended into bio-composite materials.

With this in mind, UNIDO/ICS and Building Materials & Technology Promotion Council (BMTPC) with the UNIDO International Centre for Advancement of Manufacturing Technology (ICAMT) will organize an International Training Course on "Materials Design and Production Processes for Low-cost Housing" that will be held in Bangalore, India from 25-29 November 2002.

This training course will summarize the triennial subprogramme on low-cost housing materials and set further goals. It will primarily concentrate on a South-to-South co-operation scheme by supporting the participation of researchers and decision makers of India and South East Asia, with a limited but very high-ranking participation of lecturers from internationally renowned institutions.

OBJECTIVES

- To present the state of the art of the latest innovation technologies in the materials design sector and discuss the main aspects concerning the production cycle and the standardization demands;
- To disseminate up-to-date information, knowledge and experience on design, production, testing and application of composite materials based on natural renewable resources;

- To promote and encourage the realization of networks and cooperation schemes between countries of the region, for the adoption of appropriate and affordable technologies on low-cost housing, and international centres for the advancement of materials science and technology.

OUTPUTS

- Skill and awareness of about 30 technologists, from both R&D institutions and enterprises in order to update their knowledge on the production and potential application of building materials based on secondary and renewable resources upgraded.
- Contacts, in a South-to-South type of approach, within enterprises and standardization institutes operating in the sector of innovative materials and to establish a network of counterparts in developing countries who are informed on the ICS strategy and activities generated.
- Project proposals that may be implemented by national and international agencies, for the industrial use of environmentally friendly natural materials by facilitating the technology transfer of new materials design and production, while fostering South-to-South co-operation identified.

PROFILE OF PARTICIPANTS

There will be approximately 30 young experts from industrial R&D institutions, researchers and technologists of the industrial building materials sector. Preference will be given to participants from India and South East Asia. A number of senior level decision-makers will be encouraged to participate. Selected participants should have a degree in the field of material design and/or material production processes or have several years of practical experience. Participants will be required to present a short report of the state-of-the art of the building materials production industry in their country of origin and/or company where they are employed.

The course is also open to self-paying participants from developing countries interested in attending and no registration fee will be charged.

PROFILE OF RESOURCE PEOPLE

The resource persons that will be lecturing at the training course will come from renowned International institutions. The resource persons will be invited to deliver key lectures on the main topics of the programme, namely: materials selection and design in theory and practice, valorization of natural fibres either specific or agriculture and forestry by-products of potential use in the biomaterials composites design and production.

The resource persons will be required to provide a soft copy of their lecture notes by 10th November 2002.

DOCUMENTATION

The basic documentation for the Training Course will consist of the following.

- Aide-Memoire of the training course and agenda.
- ICS publications on "Development of Natural Polymers and Composites in East Africa";
- ICS proceedings on "Material Selection and Design for Low-Cost housing in Developing Countries" collected in previous meetings on this specific topic.
- BMTPC publications on materials.
- List of participants and lecturers attending the training course.
- Lecture notes.

LANGUAGE

All lectures and their related documentation will be in English.

PROGRAMME – STRUCTURE AND CALENDAR

Monday – 25 November
09.30 – 10.00 Registration
10.00 – 10.30 Presentation of ICS-UNIDO programme and policy
10.30 – 11.00 Pause
11.00 – 11.30 Presentation of local ICAMT activities and projects.
11.30 – 12.30 Presentation of BMTPC activities
12.30 – 14.00 Pause
14.00 – 16.00 Lectures on bio-composites science and technology.
16.00 – 17.00 Open session and discussions.

Tuesday – 26 November
09.00 –10.30 Lecture on composite materials based on natural fibres – part I.
10.30 – 11.00 Pause
11.00 – 12.30 Lecture on composite materials based on natural fibres – part II.
12.30 – 14.00 Pause
14.00 – 16.00 Lectures on products applications other than the in building industry.
16.00 – 17.00 Open session and discussions.

Wednesday – 27 November
09.00 – 10.30 Lecture on composite materials based on natural fibres – part I.
10.30 – 11.00 Pause
11.00 – 12.30 Lecture on composite materials based on natural fibres – part II.
12.30 – 14.00 Pause
14.00 – 16.00 Lectures on products development other than building industry.
16.00 – 17.00 Open session and discussions.

Thursday – 28 November
09.00 - 17.00 Open session-day: green composites and bamboo in the architectural design.
Contributions from participants and local institutions representatives.

Friday – 29 November
Panel discussions and recommendations
Project proposals presentation
Field visit

VENUE AND DATES

The training course will be held from the 25-29 November 2002 at ICAMT premises in Bangalore. The address is:
International Centre for Advancement of Manufacturing Technology
CMTI campus, Tumkur Road
Bangalore 560 022, India
Tel: 91-80-3478109/ 10
Fax: 91-80-3475450
Web site: www.icamt.org

FINANCIAL/ADMINISTRATIVE ARRANGEMENTS FOR ICS/ICAMT FINANCED PARTICIPANTS AND LECTURERS

For the participants and lecturers that are invited by ICS/BMTPC to attend the training course, round-trip air/train economy transportation from the airport/station of departure will be arranged and prepaid tickets issued where necessary according to UNIDO standards (i.e. the most direct and economical route). Room will be provided upon arrival in Hotel at Bangalore for which detailed information will be provided to the selected participants. The Breakfast will be provided by the hotel free of cost. Lunch from 25-29 November will be provided at the venue of the training course. All the other meals will be taken care by the participants themselves. All the participants will be provided US $ 30 per day (equivalent INR) as pocket allowance to cover the meal charges/ miscellaneous expenses. No other expenditure will be reimbursed.

The participants and lecturers will be required to bear the costs of all expenses in their home country incidental to travel abroad, including expenditure for passport, visa, and any other miscellaneous items as well as internal travel to and from the airport/station of departure in their home-country.

The organization will not be responsible for any of the following costs that may be incurred by the participant or lecturer while attending the training course:

- compensation for salary or related allowances during the period of the course;
- any cost incurred with respect to insurance, medical bills and hospitalization fees;
- compensation in the event of death, disability or illness;
- loss or damage to personal property of participants while attending the course.

VISA ARRANGEMENTS

To enable the participants to apply for visa, BMTPC will issue an invitation letter to all the overseas participants /faculty. Participants are requested to contact Indian Embassy / consulates in their home country for Visa.

AIRPORT

All the overseas participants/faculty are requested to send their arrival schedule at the following e-mail address / fax number. ICAMT will arrange meeting at the airport.
E-mail: d.ballani@icamt.org or bmtpc@del2.vsnl.net.in
Fax Nos.: +91-11-4647082 or +91-11-3010145

Contact Persons

ICS Scientific Responsible

Prof. Sergio Meriani
AREA Science Park
Building L2
Padriciano 99
34012 Trieste - Italy
Tel.: +39-040-9228126
Fax: +39-040-9228122
Email: vivian.zaccaria@ics.trieste.it

Organizational responsible at ICAMT

Mr. Deepak Ballani
National Expert
International Centre for Advancement of Manufacturing Technology (ICAMT)
c/o CMTI, Tumkur Road
Bangalore 560 022, India
Tel: +91-11-4647083
Fax: +91-11-4647082
E-mail: d.ballani@icamt.org

Organizational responsible at BMTPC

Mr. T.N. Gupta
Executive Director
Building Materials & Technology Promotion Council (BMTPC)
Ministry of Urban Development & Poverty Alleviation
'G' Wing, Nirman Bhawan
New Delhi, India
Phone: +91-11-3019367
Fax: +91-11-3010145
E-mail: bmtpc@del2.vsnl.net.in

ICS Secretariat Contact Person

Ms. Vivian Zaccaria
New Materials Secretariat
ICS-UNIDO
AREA Science Park
Building L2
Padriciano 99
34012 Trieste
Italy
Tel.: +39-040-9228126
Fax: +39-040-9228122
Email: vivian.zaccaria@ics.trieste.it

Annexure – 3
Programme of Event

International Centre for Science and High Technology

in cooperation with

Building Materials & Technology Promotion Council

and

International Centre for Advancement of Manufacturing Technology

ICAMT

organise a

Training Course

on

"Materials Design and Production Processes for Low-cost Housing"

25-29 November 2002
Bangalore, India

PROGRAMME

PROGRAMME – STRUCTURE AND CALENDAR

Day – 1: Monday – 25 November

09.30 – 10.00	Registration
10.00 – 11.00	INAUGURAL SESSION Welcome – Mr. Vasantha Kumar, ICAMT Lighting of the Lamp by Chief Guest Introduction to ICAMT/ICS Activities – Mr. Vinod Yadav, ICAMT Introduction of the Training Programme & Activities of BMTPC – Mr. T.N.Gupta, BMTPC Inaugural Address by Dr.B.R.Somashekar Vote of Thanks by Mr. B. Anil Kumar, BMTPC
11.00 – 11.15	*Tea Break*
	<u>TECHNICAL SESSION</u>
11.15 – 13.15	Overview and advances on science and technology of composite materials based on natural resources (Part I) By Prabhu Kandachar, Delft University of Technology, The Netherlands
13.15 – 14.00	*Lunch*
14.00 – 15.00	Introduction and Presentation by Participants
15.00 – 16.30	BMTPC Presentation by Mr. T.N.Gupta, Executive Director, BMTPC
16.30 – 17.00	Audio Visual Presentation of ICS and ICAMT Programmes by Mr. Vasantha Kumar, Advisor, ICAMT
17.00 – 17.30	Visit to Exhibition

Day – 2: Tuesday – 26 November

09.00 – 11.00	Overview and advances on science and technology of Composite Materials Design & Manufacturing for Building Applications By Dr. N. G. Nair, Retd. Prof. IIT, Chennai, NGN Composite Chennai
11.30 – 11.45	*Tea Break*
11.45 – 13.15	Composite Technology Development and Commercialisation – Some Successful Case Studies By Dr. Soumitra Biswas, Advisor – Advanced Composite Programme, TIFAC
13.15 – 14.00	*Lunch*
14.00 – 16.00	Manufacturing Methods for Eco-friendly, cost-effective GRP Building Products By Dr. R. Gopalan, Director & CEO, RV-TIFAC Composite Design Centre
16.00 – 17.00	Open session and discussion

Day – 3: Wednesday – 27 November

09.00 – 13.00	Visit to RV-TIFAC Composite Design Centre
13.00 – 14.00	*Lunch*
14.00 – 15.30	Natural Fibre Composites, Issues and Perspectives By Dr. K. G. Satyanarayana, Deputy Director, RRL, Thiruvananthapuram
15.30 – 16.30	Overview and advances on science and technology of composite materials based on natural resources (Part I) By Prabhu Kandachar, Delft University of Technology, The Netherlands
16.30 – 17.30	Field Visit to Natura Fibre Tech Pvt. Ltd.

Day – 4: Thursday – 28 November

09.00 – 10.30	Characterisation of Raw Materials for Design of Composite Building Materials By Dr. Mohan Rai, Deputy Director (Retd.), CBRI, Roorkee
10.30 – 11.00	*Tea Break*
11.00 – 13.00	Lignocellulosic as a Sustainable Source for Building Material By Mr. A. K. Bansal, Director, IPIRTI
13.00 – 14.00	Lunch
14.00 – 15.00	Development & Production of Wood Substitute using Agro Wastes By Mr. Tommy Mathew, Director, Natura Fibre Tech Pvt. Ltd.
15.00 – 17.00	Field Visit to Indian Plywood Industries Research & Training Institute (IPIRTI)

Day – 5: Friday – 29 November

Panel discussion and recommendations
Presentations on Project Proposals
Lunch at ICAMT
Presentations on country report
Valedictory Session

Annexure – 4
List of Participants

TRAINING COURSE ON MATERIALS DESIGN AND PRODUCTION PROCESSES FOR LOW COST HOUSING AT BANGALORE : 25-29 NOVEMBER 2002

LIST OF PARTICIPANTS FROM FOREIGN COUNTRIES

Sr.No.	Name	Organisation/Address	Tel.No./Fax/E-mail
1	Dr. Wiwik S. Subowo, APU.	Senior Principal Researcher on New Material Physics Division Research Centre for Physics, Indonesian Institute of Sciences Jl. Cisitu 21/154 D City : Bandung, 40135, **INDONESIA.**	Tel.No. 62-22-2503052 Telefax. 62-22-2503050 E-mail: p3ftlipi@bdg.certrin.net.id
2	Mr. Dau Duc Hai	Chemical Engineering Dep., Institute of Chemistry, National Center for Sciences & Technologies, (Vien Hoa Hoc, TTKHTN&CNQG) Hoang Quoc Viet, Nghia Do Tu Liem - Hanoi, **VIETNAM**	Tel. No. 84-4-7560742 Telefax: 84-4-8361283 E-mail: dauduchai@yahoo.com
3	Mr. Manathunge Bandara Mudiyanselage Nandasuri Bandara Gawarammana	Industrial Development Board of Ceylon - Provincial Office Yatinuwara Veediya, Kandy **SRI LANKA.**	Tel.No. 94-8-201696 E-mail: dynamicp@sltnet.lk
4.	Mr. Kekul Thotuwage Don Shelton Wickremaratne	Chief Engineer Department of Buildings Kurunegala **SRI LANKA**	Tel: +94-37-22437 E-mail: ktdsw@sltnet.lk / CEKurub@sltnet.lk
5	Mr. Mani Ratna Tuladhar	Senior Divisional Engineer Deptt. of Urban Development & Building Construction Ministry of Physical Planning & Works Babarmahal, Kathmandu **NEPAL**	Tel.No.: +977-1-262365 Fax: +977-1-262439 E-mail: dudbc@most.gov.np
6	Er.Thakur Raj Pant	Department of Local Infrastructure Development and Agriculture Roads	Tel.No.: +977-1-521021 Fax: +977-1-531850

Sr.No.	Name	Organisation/Address	Tel.No./Fax/E-mail
		Ministry of Local Development Jawalkhel, Lalitpur **NEPAL**	E-mail: dg@dolidar.wlink.com.np / Pthakurr@hotmail.com
7	Mr. Dil Chhetri Ranjan	Housing Division Dept. of Urban Development & Housing P.B.No. 129, Thimphu **BHUTAN**	Tel: +975-2-323147 Fax: +975-2-324358
8	Ms. Kiba Choden	Housing Division Dept. of Urban Development & Housing P.B.No. 129, Thimphu **BHUTAN**	Tel: +975-2-323099 Fax: +975-2-323147
9	Mr. Emdadul Huq	Addl.Chief Engineer (P&SP) Public Works Department Purta Bhaban, Segunbagicha, Dhaka **BANGLADESH**	Tel: +880-2-9550507 Fax: +880-2-9562913 E-mail: aceemdad@aitlbd.net
10	Mr. M.Mahbub-ul-Alam	Sub-Division Engineer Dhaka Sub Division-3 National Housing Authority Mohammedpur, Dhaka **BANGLADESH**	Tel: +880-2-911 1363 Fax: +880-2-956 2618 E-mail: mams_01us@hotmail.com

TRAINING COURSE ON MATERIALS DESIGN AND PRODUCTION PROCESSES FOR LOW COST HOUSING AT BANGALORE : 25-29 NOVEMBER 2002

LIST OF PARTICIPANTS FROM INDIA

Sr.No.	Name	Organisation/Address	Tel.No./Fax/E-mail
1	Mr. A.Fida Hussain	M/s. Raja Brick & Tile Industries, Rajanagar, Oorukere, Tumkur -572106 INDIA.	Tel. No. 91-816 211020 Telefax 91-816-211633 E-mail fida@vsnl.com
2	Mr. Abdul Jaleel KK	M/s Kap (I) Tiles, Peramangalam, Thrissur-680545 Kerala, INDIA	Tel. No.91-487-307393, 307593 Fax No. 91-487-308993 E-mail jaleel@vsnl.com
3	Mr. Govindan Madathil Gopinath	M/s Common wealth Trust (India) Ltd. Calicut - 673631 INDIA	Tel .No. 0091-495-402225 Telefax 0091-495-405828 E-mail: comtrust@sancharnet.in
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5	Mr.Rewashankar Ahirwar	Regional Research Laboratory, (CSIR) Hoshangabad Road, Near Habibganj Naka, Bhopal (MP) INDIA.	Tel.No.91-755-587244, 587809, 587615 Telefax : 91-755-587042,488323 E-mail: rsa_rrlbpl@yahoo.co.in
6	Dr. C. Pavithran	Dy.Director Regional Research Laboratory Thiruvanthapuram INDIA	Tel: 0471-490324/515220
		Central Glass & Ceramic Research Institute	Tel: 033-4733469, 4733476-77

Sr.No.	Name	Organisation/Address	Tel.No./Fax/E-mail
7	Dr. Swapan Kr. Das	196, Raja SC Mullick Road Kolkata - 700 032 (W.B.)	Fax: 033-4730957 E-mail: samirref@hotmail.com
8	Prof. M.Nagaraja	Chairman CHETANA - A Society for Rural & Urban Development 47, Sidheshawara Park, Vidyanagar Hubli-580031	Mob: 098452-20412 Fax: 0836-374985
9	Dr. Hina Tarannum	OBM Division Central Building Research Institute Roorkee - 247 667	Tel: 01332-82481 Fax: 01332-72272, 72543 E-mail: hinacbri@yahoo.co.in
10	Ms. Farida Sultana	Admn.Manager, Centre for Symbiosis of Tech., Environment & Management (STEM) 35, 17th Main, VI block, Koramangala Bangalore-560 095	Tel: 080-5522664, Fax: 080-5537664 E-mail: stemb@vsnl.com
11	Mr. S.P. Shashishekar	Civil Engineer, Centre for Symbiosis of Tech., Environment & Management (STEM) 35, 17th Main, VI block, Koramangala Bangalore-560 095	Tel: 080-5522664, Fax: 080-5537664 E-mail: stemb@vsnl.com
12	Mr. Dwarakanath Gudi	Project Engineer, Tool Design, NAL, Airport Road, Bangalore - 17	Tel: 080-5051894 E-mail: dwarakanathag@yahoo.com

Annexure – 5
List of Resource Persons

TRAINING COURSE ON MATERIALS DESIGN AND PRODUCTION PROCESSES FOR LOW COST HOUSING
AT BANGALORE : 25-29 NOVEMBER 2002

LIST OF RESOURCE PERSONS

Sr.No.	Name	Organisation/Address	Tel.No./Fax/E-mail
1	Dr.Soumitra Biswas	Advisor - Advanced Composite Programme TIFAC, Department of Science and Technology Government of India New Delhi	Tel: 686 3816 Fax: 6961158, 6863816
2	Dr. Mohan Rai	Former Dy.Director & Head -Building Materials Central Building Research Institute (CBRI) Roorkee	Tel: 01332 - 73632
3	Dr. K.G.Satyanarayana	Deputy Director Regional Research Laboratory Thiruvananthapuram	Tel: 0471-490674, 490811 Fax: 0471-491712, 490186 E-mail: root@csrrltrd.ren.nic.in
4	Dr. N.G.Nair	Former Professor and Head - Composites Technology Centre Indian Institute of Technology Chennai	Tel: 044-4464225 Telefax: 044-4466305
5	Dr.R.Gopalan	Director & CEO RV-TIFAC Composite Design Centre Bangalore	Tel: 8601513, 8602145 (O), Fax: 080-860 1512
6	Mr. Tommy Mathew	Director Natura Fibre Tech Pvt. Ltd. Bangalore	Tel: 080-2245090 Fax: 080-224 4077 E-mail: natura@blr.vsnl.net.in
7	Mr. Arun K.Bansal	Director Indian Plywood Industries Research and Training Institute Ministry of Environment and Forests Bangalore	Tel: 080-8395970 Fax: 080-8396361
8	Dr. Prabhu V. Kandachar	Associate Professor Faculty of Industrial Design Engineering Delft University of Technology Landbergstraat 15 2628 CE DELFT The Netherlands	Tel: +31.15.278.5769 Fax: +31.15.278.1839 E-mail: p.v.kandachar@io.tudelft.nl

Annexure – 6
Detailed Presentations from Resource Persons

Annexure 6

CONTENTS

bmtpc

Building Materials and Technology Promotion Council

An Inter-ministerial and Multi-disciplinary Organization
under the aegis of

Ministry of Urban Development

Government of India

bmtpc

Building Materials and Technology Promotion Council

An Inter-ministerial and Multi-disciplinary Organization under the aegis of

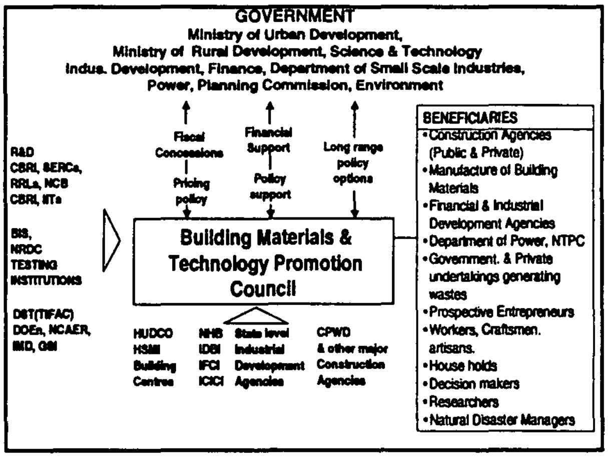
Ministry of Urban Development
Government of India

Mission Statement

Develop and operationalise a comprehensive and integrated approach for technology development, transfer and investment promotion to encourage application of environment-friendly & energy-efficient innovative materials, manufacturing technologies and disaster resistant construction practices for housing and buildings in urban and rural areas.

Objectives

- To promote development, production, standardisation and large-scale application of cost-effective innovative building materials and construction technologies in housing and building sector.
- To promote manufacturing of new waste-based building materials and components through technical support, facilitating fiscal concessions and encouraging entrepreneurs to set up production units in different urban and rural regions.
- To develop and promote methodologies and technologies for natural disaster mitigation, vulnerability & risk reduction and retrofitting/ reconstruction of buildings and disaster resistant planning of human settlements
- To provide support to professionals, construction agencies and entrepreneurs in selection, evaluation, upscaling, design engineering, skill-upgradation, and marketing for technology transfer from lab to land in the area of building materials and construction.



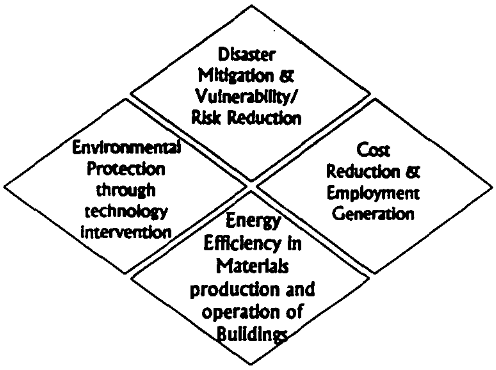
Thrust Areas

i) Economy and efficiency in construction projects
ii) Utilisation of flyash and other industrial and agricultural wastes
iii) Identification of appropriate technologies and their wide scale dissemination
iv) Standardisation, validation and certification
v) Promoting production units of new building materials
vi) Promoting disaster resistant technology

Areas of Strength

- Standardisation, validation/certification
- BMTPC as a repository of information
- Interface organisation for strengthening of technology base of housing & building sector
- Technology development, transfer and promotion
- Mobilisation of Policy support and fiscal incentives
- Disaster mitigation through vulnerability & risk reduction in buildings and human settlements
- Promoting Indian technologies, machineries and know-how in other developing countries

bmtpc



Usefulness of BMTPC's Services

Working Specifications formulated on 22 Innovative and Cost-effective Materials and Techniques

BUILDING MATERIALS		BIS CODE
BM01	Specifications for Calcium Silicate Bricks	IS:4139-1989
BM02	Specifications for Fly ash-Lime Bricks	IS:12894-1990
BM03	Specifications for Clay-Fly ash Bricks	IS:13757-1993
BM04	Specifications for Clay Flooring Tiles	IS:1478-1992
BM05	Specifications for Burnt Clay Flat Terracing Tiles	IS:2690-1993
BM06	Specifications for Fibrous Gypsum Plaster Boards	IS:8273-1984

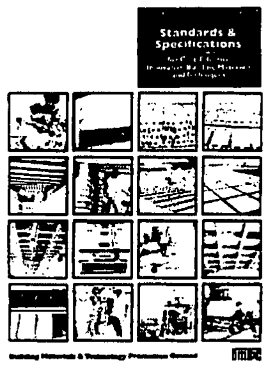
BUILDING COMPONENTS		
BC01	Specifications for Precast Solid Cement Concrete Blocks	IS:2185-1979 (Part I)
BC02	Specifications for Precast Concrete Stone Masonry Blocks	IS:14213-1994
BC03	Specifications for Hollow & Solid Light Weight Concrete Masonry Units	IS:2185-1983 (Part II)
BC04	Specifications for Precast Reinforced Concrete Door and Window Frames	IS:6523-1983
BC05	Specifications for Ferrocement Door Shutters	-
BC06	Specifications for Precast Ferrocement Water Tanks	IS:13356-1992
BC07	Specifications for Precast Concrete Manhole Covers & Frames	IS:12592-1988 (Part I) IS:12592-1991 (Part II)

Working Specifications ....contd.

CONSTRUCTION TECHNIQUES		BIS CODE
CT01	Specifications for Precast Channel Unit for Flooring/Roofing	IS :14201-1994 IS:14215 –1994
CT02	Specifications for Precast Reinforced Concrete Plank Flooring/Roofing	IS:13990-1994 IS:13994-1994
CT03	Specifications for Thin R.C. Ribbed Slab for Floors and Roofs	-
CT04	Specifications for Construction of Floors and Roofs using Precast Concrete Waffle Units	IS:10505-1983
CT05	Specifications for Prefabricated Reinforced Concrete L Pans for Roofs	IS:14241-1994 IS:14242-1995
CT06	Specifications for Precast Doubly-Curved Shell Units for Construction of Floors and Roofs	IS:6332-1984
CT07	Specifications for Precast Reinforced/Prestressed Concrete Ribbed or Cored Slab Units for Floors & Roofs	IS:10297-1982
CT08	Specifications for Reinforced Brick and Reinforced Brick Concrete Slabs for Floors and Roofs	IS:10440-1983
CT09	Specifications for Prefabricated Brick Panel for Floors/ Roofs IS:14143-1994	IS:14142-1994

Note: With the efforts of the Council all these items have been inducted in the CPWD schedule of specifications of CPWD, and housing agencies in Orissa, Tamil Nadu, Kerala and Andhra Pradesh.

Selection and Validation of Technology for Standardisation, Upscaling & commercialisation, wider field application



LIST OF MANUFACTURING UNITS PRODUCING WASTE BASED BUILDING MATERIALS & COMPONENTS ESTABLISHED

(As a result of Fiscal incentives given by Govt. of India and Council's promotional efforts)

S.No.	Waste Material	No. of Manufacturing units producing waste based building products
1	Fly ash	359
2	Blast Furnace Slag	12
3	Phosphogypsum	5
4	Red Mud door shutters/panel products	7
5	Paper waste	5
6	Rice Husk	3
7	Pulp, Straw & paper	2
8	Bagasse	6
9	Saw mill waste	8
10	Cotton Plant scantling, Eucalyptus & other plantation timbers	9
11	Bamboo Mat Corrugated sheets manufacturing unit	1
12	Jute	5
13	Coir/ wood wool	4
14	Sisal Fibre	3
15	Pine needle fibre	1
16	Rubber wood	2

Note: The above mentioned units are in operation in different States such as, West Bengal, Tamil Nadu, Gujarat, Andhra Pradesh, Maharashtra, Karnataka, Uttar Pradesh, Haryana, Delhi, Pondicherry Bihar,Madhya Pradesh, Orissa.

Investment Attracted in manufacturing of alternative building material/machines industry through awareness creation and promotional efforts of BMTPC

(Rs. in Crores)

Flyash based products	40
Waste & plantation based timber	100
GRP Composites	169
Machines	8
Total	317

Indicative savings in Cement, Fuel, Top Soil, Timber due to use of new technologies promoted by BMTPC during past 5 to 6 years

Saving in Consumption of Cement

	Quantity of Cement (Tonnes)	Cost of Cement (Rs. in millions)
Cellular Light Weight Concrete Blocks	38079	110.0
Ready Mixed Concrete	18000	52.0
Flyash Concrete Blocks	1906	5.5
Ferrocement Roofing Channels	1242	3.5
Grand Total	59227	171.00

Saving in Consumption of Fuel *by Replacing with Cement Concrete Blocks, MCR Tiles, Flyash-Lime-Gypsum bricks, Sand-lime/Flyash-Sand- Lime bricks, and Compressed Earth Blocks*

	Quantity of Fuel (Tonnes)	Cost of Fuel (Rs. in millions)
Cement Concrete Blocks in Place of Burnt Clay Bricks	50767	101.5
MCR Tiles in place of country clay tiles	21200	42.0
Flyash-Lime-Gypsum bricks	165375	331.0
Sand-Lime/ Flyash-Sand-Lime bricks	48080	96.0
Compressed Earth Blocks	88830	178.0
Grand Total (in coal equivalent)	374252	748.5

Indicative savings in Cement, Fuel, Top Soil, Timber due to use of new technologies promoted by BMTPC during past 5 to 6 years

Saving in Consuption of Top Soil *by Replacing with Cement Concrete Blocks and MCR Tiles, Flyash-Lime-Gypsum bricks and Sand-lime/Flyash-Sand Lime bricks*

Cement Concrete Blocks in Place of Burnt Clay Bricks	0.81 million cu.mt. or 42 hectare of land mass
MCR Tiles in place of country clay tiles	0.28 million cu.mt. or 14 hectare of land mass
Flyash-Lime-Gypsum bricks	2.57 million cu.mt. or 142 hectare of land mass
Sand-Lime/ Flyash-Sand-Lime bricks	2.52 million cu.mt. or 138 hectare of land mass
Grand Total	6.18 million cu.mt. or 336 hectares of land mass

Saving in Timber *by Replacing with Cement Concrete Chaukhats, various wood substitutes*

Quantity of Timber saved	21917 cu.mt.
Cost of Timber saved	Rs.403 millions
Quantity of Timber saved in CPWD Works	22266 cu.mt.
Cost of Timber saved in CPWD Works	Rs.611 millions
Grand total of timber and cost saved	44183 cu.mt and Rs. 1014 millions

Technology Development

- Red Mud/Flyash Polymer fibre door shutters
- Eco-friendly rubberwood flush door shutter
- Eco friendly solid core poplar wood flush door shutters
- Laminated splint lumber panel doors and door frames from rubber wood
- Veneer laminated lumber panel door and doors frame from poplar wood
- EPS-RMP Composite Door Shutter
- Bamboo mat corrugated roofing sheets
- Paint based on Flyash and other wastes
- Glass Ceramic products for Floor Tiles using wastes (three types) from Aluminium industry
- Light weight M-wood Door Shutter
- Building Materials from Marble industry waste
- Cementitious Binder from Acetylene plant waste
- Rigid PVC - Foam Board and Sheet

Technology Development...contd.

- Interlocking block mortarless masonry.
- Ferrocement roofing and walling components.
- Development of coir cement rafters.
- Development of Water-Reducing Agent from Coal Tar Industry.
- Development of Activated Puzzolana/Silica Fume from rice husk.
- Development of Anti-corrosive Paint utilising the industrial wastes.
- Production of bricks using mine tailings from Khetri Copper Mines.
- Development of ceramic tiles using wastes from aluminium plants
- Polymer bonded composite door shutters and panel materials using coconut fibre, jute.
- Glass fibre reinforced polymer based door shutters and wall panels.
- Panel for doors using banana sheath bonded with polymer resin.
- Development of improved design of metallic moulds for fabrication of door shutter and frame using GRP composites.

Technologies licensed to entrepreneurs for commercial production

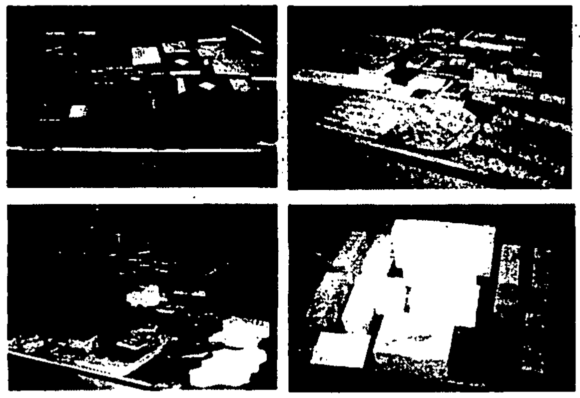
- Red Mud/Flyash Polymer fibre door shutters
- Eco-friendly rubberwood flush door shutter
- Eco friendly solid core poplar wood flush door shutters
- Glass Fibre reinforced Polymer based doors and door frames
- Development of process for production of reactive silica from rice husk (negotiations going on)
- Metallic mould for fabrication of doors and door frames using GRP/Coir composites
- Cost-effective rafters for rural house construction
- Bamboo Mat Corrugated Sheets - a plant to manufacture these sheets has been recently set up in Meghalaya.
- Ferrocement Components for varied applications
- Interlocking Block Mortarless Masonry

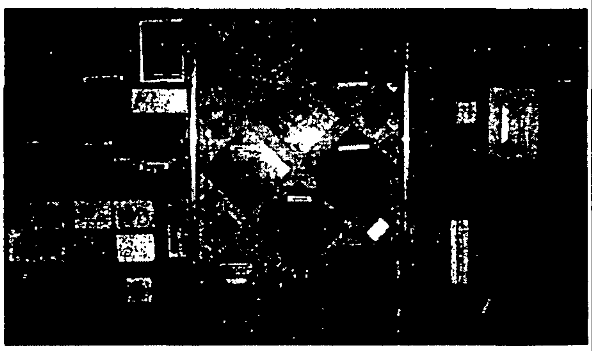
Policy Support Created

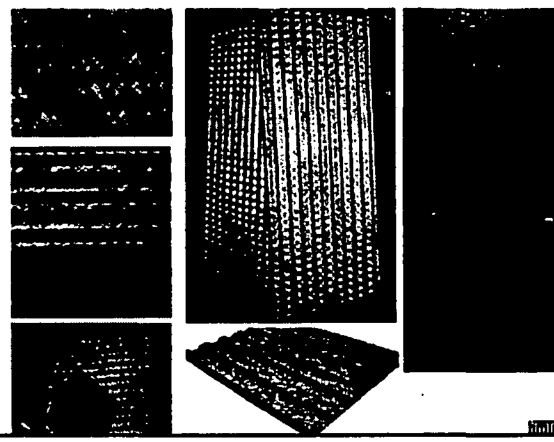
- Continuous interaction with the Ministries/Departments (Science & Technology, CSIR, Rural Development, Power, MNES, Environment & Forests, Industry) have resulted in facilitating several new policy instruments to promote wide scale diffusion of new technologies.
- Ban on the use of forest wood in the construction works resulted in development of a large variety of wood substitutes.
- The Council has been responsible for getting various fiscal incentives to attract more investment in the manufacturing sector of alternative building materials and components.
- The building materials manufacturing sector today stands as a part of the national productive sector and the institutional finance is accessible to the entrepreneurs.

Help to Building Materials Industry

- Modernisation for higher productivity
- Introducing environment friendly and energy efficient manufacturing practices and technologies
- Promoting waste based material technologies for making
  - Wood substitutes for door shutters and panels
  - Bricks, blocks and other walling materials
  - Cost effective roofing options such as ferrocement and prefab technologies
- Supporting the enterprises through tecno-ecnomic feasibility studies
- Facilitating fiscal incentives for promoting more investment
- Creating policy supports at national and state level for adoption of new technologies
- Developing and promoting use of simple machines and equipment for establishment of production units in different regions with low investment levels.







Machines Developed

Following machines and equipment have been developed by the Council and fabrication and manufacturing of these machines have been licensed to private entrepreneurs. These machines have become very popular as they are inexpensive and production enterprises can be established with low level of investment.

More than 900 machines of different types have already been procured by private entrepreneurs and Building Centres for production of components.

These machines have also become very popular in other developing situations like East African region and Trinidad & Tobago where Council have given live demonstration and helped in establishing Demonstration-cum-Production Centres.

1. Solid/hollow Concrete Block Making Machine (Egg. Laying Type)
2. Solid/hollow Concrete Block Making Machine (Standing Type)
3. Precast Concrete Door/window Frames Making Machine
4. Ferrocement Roofing Channels Making Machine
5. Micro Concrete Roofing Tile Making Machine
6. Concrete Block Making Machine (Sakar)
7. Compressed Earth Block Making Machine (Mardini)
8. Compressed Earth Block Making Machine (Balram)
9. C-brick Machine
10. Alternate Station Hydraulic Brick Making Machine
11. Stone/coal Dis-integrator (Crusher)
12. Bar and Pipe Cutting Machine
13. Bi Directional Vibro Press
14. Ferrocement Wall Panel Making Machine
15. Precast RCC Plank Making Machine
16. Precast RCC Joist Making Machine
17. Solid & Hollow Concrete Block Making Machine (Handheld Type)
18. Precast L-panel Making Machine
19. Combination Machine

Bi-Directional Vibro Press

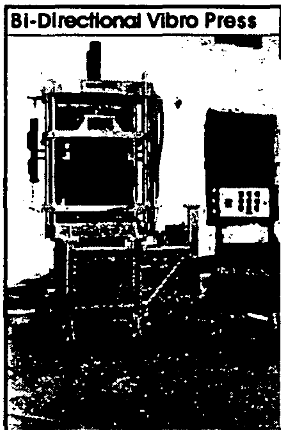
Model - AS 1818

Use: For production of concrete bricks/solid or hollow blocks, flyash concrete bricks/solid or hollow blocks and paving blocks/tiles of different shapes.

Specifications

• Production capacity Per day in 8 hours shift	: 5000 bricks or 1000 solid/hollow concrete blocks or 2500 paving blocks/tiles
• Size of machine	: 2500x2000x2300 mm
• Weight of machine	: 3500 kgs
• Size of brick/block/paver	
Brick	: 230x115x75mm
Solid block	: 300x200x150 mm
Hollow block	: 400x200x150 mm
Paver	: Any standard size & shape
• No. of bricks/blocks/pavers per cycle	
Bricks	: 6 nos.
Solid/hollow blocks	: 2 nos.
Paving blocks	: 4 nos.
• Manpower	: Skilled – 1, Unskilled – 4
• Energy Transmission	: 15 tons of vibro-hydraulic pressure
• Energy source	: Electrical, 3 phase ,440 volts
• Power requirement	: 7 HP
• Compressive strength	: 80 - 150 kg/cm2

Bi-Directional Vibro Press



Model - AS 189

Use: For production of concrete bricks/solid or hollow blocks, flyash concrete bricks/solid or hollow blocks and paving blocks/tiles of different shapes.

Specifications

• Production capacity Per day in 8 hours shift	: 3000 bricks or 400 solid/hollow concrete blocks or 800 paving tiles/blocks
• Size of machine	: 1470x1370x2300 mm
• Weight of machine	: 2000 kgs
• Size of brick/block/paver	
Brick	: 230 x 115 x 75 mm
Solid block	: 300x200x150 mm
Hollow block	: 400x200x150 mm
Paver	: Any standard size & shape
• No. of bricks/blocks/pavers per cycle	
Bricks	: 4 nos.
Solid/Hollow blocks	: 1 no
Paving blocks	: 2 nos.
• Manpower	: Skilled – 1, Unskilled – 3
• Type	: Light duty machine
• Energy Transmission	: 10 tons of vibro hydraulic pressure
• Energy source	: Electrical, 3 phase, 440 volts
• Power requirement	: 3 HP
• Compressive strength	: 80 - 150 kg/cm2

RCC Plank Casting Machine (Rotating Type)

Model - CP - 2

Use: For production of Precast RCC Planks for roofing which are used as alternative to RCC Slabs

Specifications

• Production capacity Per day in 8 hours shift	: 80 - 100 RCC Planks
• Size of Machine	: 1800x1850x1000 mm
• Weight of Machine	: 1250 kgs.
• Size of Plank	: 1500 x 300 x 30-60mm thickness
• No. of Plank Per cycle	: 1 No.
• Type	: Rotating type Medium duty machine
• Manpower	: Skilled – 1, Unskilled – 5
• Energy Transmission	: High amplitude vibrations
• Energy source	: Electrical, 3 phase, 440 volts
• Power requirement	: 2 HP
• Compaction by	: Vibration technique
• Compression strength	: 150 kg/cm2
• Others	: No casting platform is required
	: Can be designed/fabricated for different sizes of final products.

Combination Machine

Model - LP - 2

Use: For production of Ferrocement C-section, lintels and shelves which replaces similar elements made of steel and timber.

Specifications

• Production capacity Per day in 8 hours shift	: Depends on type and combination of moulds used
• Size of Machine	: 1600x1400x750 mm
• Weight of Machine	: 650 kgs.
• Size	
C-Section	: 2750 x 150 x 100 mm
Lintel	: 1200 x 200 x 200 mm
Shelf	: 900 x 355 x 38 mm or any other size
• Cross Section Size	
C-Section	: 150 x 100 mm
Lintel	: 200 x 200 mm
Shelf	: 355 x 38 mm or any other size
• Type	: Portable
• Manpower	: Skilled – 1, Unskilled – 3
• Energy transmission	: High amplitude vibrations
• Energy source	: Electrical, 3 phase, 440 volts
• Power requirement	: 2 HP
• Compaction by	: Vibration technique
• Compression strength	: 150 kg/cm2
• Others	: Can be designed/fabricated for different sizes of final products.

Compressed Earth Block Machine(Balram)

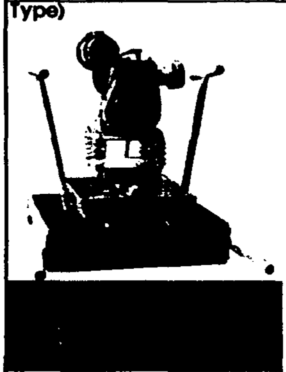
Model - MB-1

Use : For production of compressed soil blocks for walls to make strong and durable buildings

Specifications

• Production capacity Per day in 8 hours shift	: 1000-1500 blocks of Type-A or 500-750 blocks per day of Type-B
• Size of machine	: 1500x600x1200 mm
• Weight of machine	: 180 kgs.
• Size of block	
Type- A	: 230 x 109 x76 mm
Type-B	: 230 x 230 x 76 mm
• No. of blocks per cycle	
Type-A	: 2 Nos.
Type-B	: 1 No.
• Energy Transmission	: Lever with cam & toggle mechanism
	: Develops 10 tons of force during compaction.
• Manpower	: Skilled – 1, Unskilled – 5
• Type	: Portable
• Energy Source	: Manual
• Compaction by	: By pressure
• Compressive strength	: 20-30 kg/cm2
• Stabilisation of soil by	: 5-10% cement by weight of mix

Solid/Hollow Concrete Block Machine (Handheld Type)



Model - SVC-1

Use: For production of solid/hollow concrete blocks which are used as an alternative to brick

Specifications

- Production capacity Per day in 8 hours shift : 250-300 concrete blocks
- Size of Machine : 600x750x600mm
- Weight of Machine : 100 kgs.
- Size of Block
  Solid : 300x200x150 mm
  Hollow : 400x200x200mm
- No. of blocks per cycle
  Solid block : 6 Nos.
  Hollow block : 4 Nos.
- Type : Portable
- Manpower : Skilled – 1, Unskilled – 1
- Energy transmission : High amplitude vibration
- Energy Source : Petrol / Diesel
- Power requirement : 2 HP, Petrol/Diesel Engine
- Compaction by : Vibration technique
- Compressive strength : 60-80 Kg /cm2
- Others : Produces concrete blocks of any size depending on the size of mould.
  : Does not require electricity as it is petrol/diesel driven

C-Brick Machine

Model - SL-1

Use: For production of bricks/blocks/tiles from sand-lime, flyash-sand-lime, flyash-sand-cement and cement-sand-aggregates.

Specifications

- Production Capacity Per day in 8 hours shift : 3000 bricks
- Size of machine : 900x600x1600mm
- Weight of machine : 500 kgs.
- Size of brick/block/tile
  Brick : 225x107x70mm
  Tile : 225x107x40mm
  Block : 225x107x 150mm
- No. of bricks Per cycle : 4 Nos.
- Manpower : Skilled – 1, Unskilled – 4
- Type : Portable
- Energy Transmission : High amplitude vibrations
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 2 HP
- Compaction by : Vibro Compaction
- Compressive strength : 50-120 kg/cm2

Solid/Hollow Concrete Block Machine

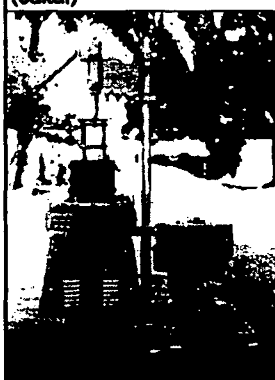
Model - CB-2

Use: For production of solid and hollow concrete blocks, concrete bricks for walling where space constraints are there.

Specifications

- Production Capacity Per day in 8 hours shift : 500 solid/hollow concrete blocks or 1500 bricks
- Size of machine : 900x900x1800 mm
- Weight of machine : 500 kgs
- Size of block/brick
  Solid block : 300x200x150mm
  Hollow block : 400x200x200mm
  Brick : 190x90x90mm
- No. of block/bricks per cycle
  Blocks : 2 nos.
  Bricks : 6 nos.
- Type : Portable, standing type
- Manpower : Skilled – 1, Unskilled – 4
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 3 HP
- Compaction by : Pressure vibration
- Strength of bricks/blocks : 70-100 kg/cm2

Concrete Block Machine (Sakar)



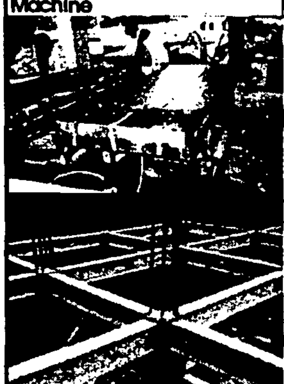
Model - CB-3

Use : For production of all types of Concrete Blocks including Solid and Hollow blocks of different shapes and sizes.

Specifications

- Production Capacity Per day in 8 hours shift : 1000 blocks
- Size of machine : 1270x915x1650 mm
- Weight of Machine : 500 kgs.
- Size of block
  Block : 300x200x150mm or any other sizes.
- No. of Block Per cycle : 1 No.
- Type : Portable machine
- Manpower : Skilled – 2, Unskilled – 6
- Energy Source : Electrical, 3 phase, 440 volts
- Power Requirement : 1 HP
- Compaction by : Pressure-vibration technique
- Strength of blocks : 60-70 kg/cm2
- Options : Replacement of Moulds are available for Stone masonry blocks, Flooring tiles, Sand lime bricks, Pavement blocks etc.

Ferrocement C-Beam Machine



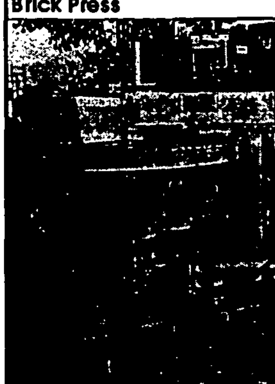
Model - FB-1

Use: For production of C-section beams (Rafter) of all sizes up to a span of 3600 mm

Specifications

- Production capacity Per day in 8 hours shift : 3 - 4 C-beams dependig upon the size
- Size of machine : 750 x 1200 x 3800 mm
- Weight of machine : 650 kgs
- Size of C-Beam : 150 x 100 x 3650 mm or 300 x 150 x 3650 mm
- Cross section size : 25 mm thickness
- No. of C-Beam per cycle
  150 x 100 mm : 4 Nos.
  300 x 150 mm : 3 Nos
- Type : Portable
- Manpower : Skilled – 1, Unskilled – 3
- Energy transmission : High amplitude vibrations
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 2HP
- Compaction by : Vibration technique
- Compressive strength : 250 kg / cm2
- Others : Can be designed/fabricated for different sizes of final products.

Alternate Station Hydraulic Brick Press



Model - AS-4/2

Use: For production of clay/clay flyash/flyash sand lime/clay cement bricks

Specifications

- Production capacity Per day in 8 hours shift : 10000 bricks per day
- Size of machine : 3900x1570x2100 mm
- Weight of machine : 7000 kgs
- Size of brick : 230x108x75 mm
- No. of bricks per cycle : 2 nos
- Type : Heavy duty machine
- Manpower : Skilled – 1, Unskilled – 3
- Energy Transmission : Hydraulic compression
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 20 HP
- Compaction by : Develops 100 tons of force during compaction
- Options : a)Auto indexing
  : b)Hydraulic toggle indexing
- Compressive strength : 60-200 kg/cm2 or more
- Others : Bricks produced are of accurate dimensions and have excellent surface finish.

Compressed Earth Block Machine (Hydraform)

Model - M-5

Use: For production of Interlocking type compressed earth blocks and flyash-lime-gypsum blocks

Specifications

- Production capacity Per day in 8 hours shift : 1200 blocks
- Size of machine : 2300 x 1800 x 1700 mm
- Weight of machine : 1000 kgs.
- Size of blocks
  - Interlocking block : 50-240 x 220 x 115mm
  - Conduit block : 50-240 x 220 x 115mm
  - Pavement block : 220 x 115mm x 75 mm
  - Plain block : 50-240 x 220 x 115mm
- No. of blocks Per cycle : 1 No.
- Energy Transmission : Hydraulic Pressure
- Energy source : Diesel or Electrical, 3 phase, 440v
- Power requirement : 13.3 hp diesel engine
- Manpower : Skilled – 1, Unskilled – 7
- Type : Road worthy tow frame
- Compressive strength of Blocks
  - Compressed Earth blocks : 50 - 100 kg/cm2
  - Flyash-lime-gypsum : 100 - 250 kg/cm2

RCC Joist Casting Machine (Egg laying Type)

Model - CJ-2

Use: For production of Precast R.C.C joists which are used as an alternative to timber and steel joists

Specifications

- Production capacity Per day in 8 hours shift : 80 - 100 RCC joists
- Size of machine : 1200 x 1500 x 4600 mm
- Weight of machine : 700 kgs
- Size of RCC joist : 150 x 150 x 3600 mm
- No. of joist Per cycle : 1 No.
- Type : Egg laying type
- Manpower : Skilled – 1, Unskilled – 3
- Energy Transmission : High amplitude vibrations
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 2 HP
- Compaction by : Vibration technique
- Compressive strength : 150 kg/cm2
- Others : Joists of different sizes can be casted by changing the mould

Solid/Hollow Concrete Block Machine (Egg laying

Model - CB-1

Use: For production of all types of Concrete Blocks including Solid and Hollow blocks of different shapes and sizes.

Specifications

- Production Capacity Per day in 8 hours shift : 1000 blocks
- Size of machine : 1500x1500x1500mm
- Weight of Machine : 1000 kgs.
- Size of Blocks
  - Solid Block : 300x200x150mm
  - Hollow Block : 400x200x200 mm
- No. of Blocks per cycle
  - Solid block : 6 Nos.
  - Hollow block : 4 nos.
- Manpower : Skilled – 1, Unskilled – 4
- Type : Portable, Egg laying type
- Energy Source : Electrical, 3 Phase, 440 volts
- Power Requirement : 6 HP
- Compaction by : Pressure-vibration technique
- Strength of blocks : 70-100 kg/cm2
- Options : Replacement of Moulds are available for Stone masonry blocks, and large size aggregate blocks.

Precast concrete Door/ Window Frame Machine

Model - CC-1

Use: For production of concrete door/window frames as a substitute to timber.

Specifications

- Production Capacity Per day in 8 hours shift : 4 Door or 5 window frames
- Size of machine : 2400x1200x750mm
- Weight of Machine : 500 kgs.
- Size of Door/Window Frame
  - Door : 2100x1035mm or
  - Window : 1130x1035 mm or any other pre-determined size.
  - Cross-section size : 100mmx60mm
- Type : Portable
- Manpower : Skilled – 1, Unskilled – 3
- Energy Source : Electrical, 3 phase, 440 volts
- Power requirement : 2 HP
- Compaction by : High amplitude vibrations**
- Compressive Strength : 250 Kg /cm2
- Others : Both Single Rebate and double rebate frames can be manufactured.
  : In built provision for hinges, locks, tower bolts etc.
  : Can be designed/fabricated for different sizes of final products.

Precast RCC Joist Machine

Model - CJ-1

Use: For production of Precast R.C.C joists which are used as an alternative to timber and steel joists

Specifications

- Production capacity Per day in 8 hours shift : 4 RCC joists
- Size of machine : 4550x1600x750 mm
- Weight of machine : 550 kgs
- Size of joist
  - Joist : 4168 x 100 x 125 mm or 4168 x 150 x 150 mm or any other sizes
- Cross section size : 100 x 125 mm or 150 x 150 mm
- No. of Joists per cycle : 4 Nos.
- Type : Portable
- Manpower : Skilled – 1, Unskilled – 3
- Energy transmission : High amplitude vibrations
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 2 HP
- Compressive strength : 150 kg/cm2
- Others : Production capacity can be increased by replacing the moulds
  : Can be designed/fabricated for different sizes of final products.

Compressed Earth Block Machine (Mardini)

Model - MB-2

Use: For production of stabilised mud blocks, fine concrete blocks and steam cured blocks for walls.

Specifications

- Production capacity Per day in 8 hours shift : 500-600 blocks
- Size of machine : 1300x500x500 mm
- Weight of machine : 140 kgs.
- Size of block
  - Block : 230x190x100 mm or 305x143x100 mm
- No. of block per cycle : 1 No.
- Energy Transmission : Lever with cam and toggle mechanism
  : Develops 12 tons of force during compaction.
- Manpower : Skilled – 1, Unskilled – 5
- Type : Portable
- Energy Source : Manual
- Compaction by : Pressure
- Compressive strength : 30-40 kg/cm2
- Stabilisation of soil by : 5-7% cement

Ferrocement Roofing Channel Machine

Model - FCR-1

Use: For production of Ferrocement Roofing Channels upto 6.1 mtr. span for roof and intermediate floors construction.

Specifications

- Production Capacity Per day in 8 hours shift : 5 Channels by replacing moulds
- Size of Machine : 1150 x 1500 x 6600 mm
- Weight of machine : 1000 kgs.
- Shape of channels : Segment of a circle
- Section Size : 645x340x25 mm
- Length : Span Up to 6.1 mts. can be casted.
- Manpower : Skilled – 2, Unskilled – 4
- Type : Heavy duty
- Compaction by : Vibration technique
- Energy Soruce : Electric, 3 phase, 440 volts
- Power requirement : 4 HP
- Compressive Strength : 150 kg/cm2
- Others : Chicken mesh and welded mesh are used as reinforcement of channels
  : Can be designed/fabricated for spans upto 6.1 mt.

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Stone/Coal Dis-Integrator

Model - AS-1714

Use: For crushing of stone/boulders/coal at site.

Specifications

- Production capacity Per day in 8 hours shift : (a) Coal - 400 cft
  (b) Stone 200 - 320 cft
- Size of machine : 1650 x 1040 x 1600 mm
- Weight of machine : 100 kgs. approx
- Type : Portable, mobile
- Crushing Size : 6 mm to 25 mm
- Energy Transmission : Through jaw plates made of water quenched maganese steel (toggle clapping)
- Manpower : Skilled – 1, Unskilled – 1
- Type of coal/stone : Medium hardness stone or all types of coal
- Energy source : Electric, 3 phase, 440 volts
- Power requirement : 7.5HP
- Others : Suitable for manufacturers of concrete bricks & blocks, road contractors and brick field operators.

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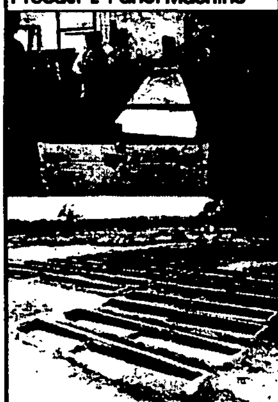
Precast L-Panel Machine



Model - LP-1

Use: For production of L-panels which are used as an alternative to R.C.C slabs.

Specifications

- Production capacity Per day in 8 hours shift : 2 L panels per mould
- Size of machine : 4200x800x750 mm
- Weight of machine : 750 kgs.
- Type : Portable
- Size of L-panels
  L - Panel : 4000x380x120x30 mm thickness
- Cross-section size : 30 mm
- No. of L-Panels per cycle : 2 Nos.
- Manpower : Skilled – 1, Unskilled – 3
- Energy source : Electrical, 3 phase, 440 volts
- Energy Tranmission : High amplitude vibrations
- Power requirement : 2 HP
- Compaction by : Vibration technique
- Compressive strength : 150 kg/cm2
- Others : Production capacity can be increased by replacing moulds
  : Can be designed/fabricated for different sizes of final products.

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Terrazo/Chequered Tile Machine

Model - ASH-40

Use: For production of Terrazo and Chequered tiles for flooring and walling.

Specifications

- Production capacity Per day in 8 hours shift : 400 - 500 tiles
- Size of machine : 900 x 600 x 1200 mm
- Weight of machine : 300 kgs
- Size of Tiles
  Terrazo tile : 225 x 225 x 25 mm thickness
  Chequered tile : 250 x 250 x 25 mm thickness
- No. of Tiles per cycle : 1 No.
- Type : Light duty machine, most suitable for site works
- Manpower : Skilled – 2, Unskilled – 2
- Energy transmission : Hand operated hydraulic compression
- Energy source : Manual
- Compaction by : Hydraulic pressure
- Compressive strength : 200 kg / cm2
- Others : Can be designed/fabricated for different sizes of final products.
  : Can also be used for production of kerb stones, interlocking pavement by changing the moulds.

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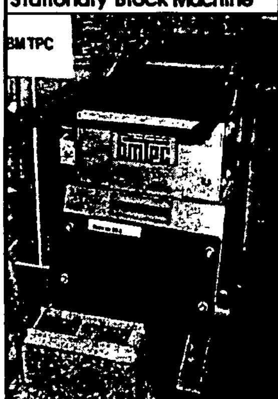
Stationary Block Machine



Model - ASH-168

Use: For production of solid/hollow concrete blocks for walling.

Specifications

- Production capacity Per day in 8 hours shift : 200 blocks
- Size of machine : 900 x 600 x 1200 mm
- Weight of machine : 300 kgs
- Size of Blocks
  Solid block : 300 x 200 x 150 mm with side block
  Hollow block : 400 x 200 x 150 mm
- No. of Blocks per cycle : 1 No.
- Type : Light duty machine, most suitable for site works
- Manpower : Skilled – 1, Unskilled – 3
- Energy transmission : High amplitude vibrations
- Energy source : Electrical, 3 phase, 440 volts or Diesel
- Power requirement : 1HP
- Compaction by : Vibration technique
- Compressive strength : 40-60 kg / cm2
- Others : Can be designed/fabricated for different sizes of final products.

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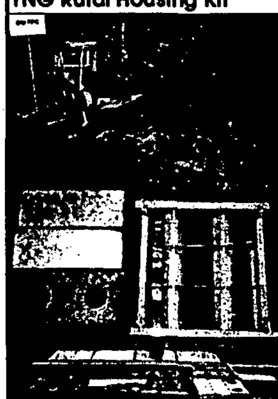
TNG Rural Housing Kit



Model - AS-1

Use: For production of building components for a complete house using local materials

Specifications

- Production capacity : Building components for single storey house of 220 sq.ft. can be constructed with in 6 days (excluding curing time)
- Size of Building Components
  Hollow blocks : 400 x 200 x 150 mm
  Solid blocks : 400 x 200 x 150 mm
  Corner blocks : L-shape, (600+400)x 225 x 150 mm
  Arch bricks : 175-200 x 200 x 300 mm
  Rafter for roof : 75 x 150 x 2100-4200 mm
  Roofing slab : 600 x 600 x 45 mm thickness
  Flooring tile : 200 x 200 x 45 mm thickness
  Roofing tile : 200 x 200 x 25 mm thickness
  Staircase treads : 230 x 800 x 45 mm thickness
  Staircase risers : 200 x 800 x 50 mm thickness
  Concrete window : 300 x 375 mm
  Concrete door frame : 900 x 2000 mm
  Water tank : 300 litres capacity
- Manpower : Skilled – 1, Unskilled – 5
- Energy transmission : Manually operated needle vibrator
- Others : Building components are manufactured using steel moulds.

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Multipurpose Stone Processing Machine

Use: Versatile stone drilling, cutting and polishing machine for semi-precious stone furniture and decorative items for rural and cottage industries.

Model - SP-1

Specifications

- Production capacity Per day in 8 hours shift : Depend upon the type of stone to be processed
- Size of machine : 900 x 600 x 900 mm
- Weight of machine : 100 kgs
- Energy source : Electrical, single or 3 phase, 220 volts or 440 volts
- Power requirement : 2 HP for single phase, 1 HP for three phase
- The motor of the machine is provided with variable RPM which can be used for different purposes as follows:

RPM	Purpose
450	: Leather polish and grinding
1000	: Drilling of hole 1.5" to 3" f
2000	: Cutting blade of 14" and drilling upto 0.5" to 0.5 f
4000	: Cutting blade of 8" & 6" f and drilling upto 0.5" f

- Manpower : Skilled – 2
- Others : Both ends of the machine can be used for various operations

Bi-Directional Vibro Press

Use: For production of concrete bricks/solid or hollow blocks, flyash concrete bricks/solid or hollow blocks and paving blocks/tiles of different shapes.

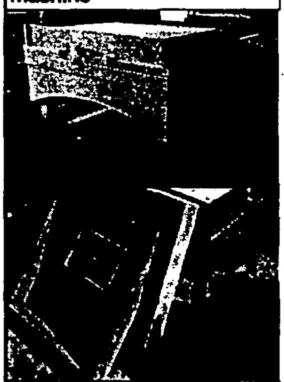
Model - AS-1824

Specifications

- Production capacity Per day in 8 hours shift : 7000 bricks or 2000 solid/hollow blocks or 5000 paving blocks/tiles
- Size of machine : 7000x3000x3000 mm
- Weight of machine : 5500 kgs
- Size of brick/block/paver
  - Brick : 230x115x75 mm
  - Solid block : 300x200x150 mm
  - Hollow block : 400x200x150 mm
  - Paver : Any standard size & shape
- No. of bricks/blocks/pavers per cycle
  - Bricks : 10 nos.
  - Solid/hollow blocks : 4 nos
  - Paving blocks : 8 nos.
- Manpower : Skilled – 1, Unskilled – 5
- Type : Heavy duty, automatic machine
- Energy Transmission : 20 tons of vibro-hydraulic pressure
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 12 HP
- Compressive strength : 80 - 150 kg/cm2

Ferrocement Wall Panel Machine

Use: For production of ferrocement panels which are used as an alternative to brick infill walls.



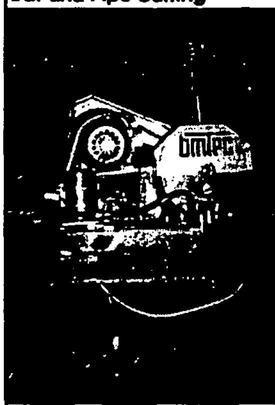
Model - WP-1

Specifications

- Production Capacity Per day in 8 hours shift : 4 walling units by replacing mould
- Size of machine : Depend upon the size of walling units to be manufactured
- Weight of machine : 600 - 800 kgs.
- Size of wall panel : 1200 x 900 x 150 mm or 1200 x 1200 x 150 mm or any other standard sizes
- Cross section size : 25 mm thickness
- Manpower : Skilled – 1, Unskilled – 3
- Type : Portable
- Energy source : Electrical, 3 phase, 440 volts.
- Power requirement : 2HP
- Compaction by : Vibration technique
- Compressive strength : 150 kg/sq.cm
- Others : Capacity can be increased by replacing the moulds.
  : Can be designed/fabricated for different sizes of final products

Bar and Pipe Cutting

Use: For cutting of bars and pipes to suit the requirement.



Model - AS-12

Specifications

- Production capacity : 1 mm to 25 mm bar. Steel pipe upto 80 mm dia
- Per day in 8 hours shift
  - 8 mm cut : 30 pcs/minute
  - 12 mm cut : 25 pcs/minute
  - 25 mm cut : 2 pcs/minute
  - 1" cut : 10 pcs/minute
  - 2" cut : 5 pcs/minute
  - 3" cut : 1 pcs/minute (depending upon feeding speed)
- Size of machine : 910x580x1000mm
- Weight of machine : Approx. 90 kgs
- Manpower : Skilled – 1, Unskilled – 1
- Energy Transmission : Hand stick operated cutting with auto coolant circulation
- Energy source : Electrical, 3 phase, 440 volts
- Power requirement : 2.5 HP
- Drives : 2 HP 4 pole Induction Motor, 1500 RPM to provide pulley ratio 1:3.5 for final RPM of cutter 4500
- Cutting tool : Parting wheel of 8" to 12". 2 to 4 mm thick, 1" holding hole
- Water pump : 1/4 HP, 4 pole, 4 LPM

Micro Concrete Roofing Tile Machine

Use: For production of Micro Concrete Roofing tiles for any type of Roof construction.

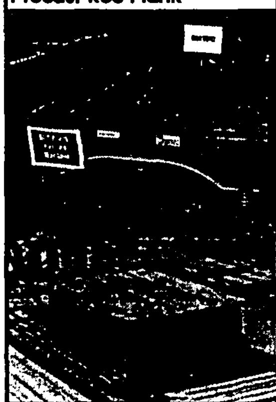
Model - MCR-1

Specifications

- Production capacity Per day in 8 hours shift : 200 Tiles
- Size of Machine : 1000x540x500 mm.
- Weight of Machine : 35 kgs.
- Weight of Mould : 525 gms.
- Moulds : High impact polystyrene plastic vacuum formed moulds.
- Size of tile
  - Tile : 488x240x8 mm
- Weight of Tile : 2.25 kg.
- Manpower : Skilled – 1, Unskilled – 2
- Compaction by : Vibration
- Energy Sorуce : Electric, 1 phase, 220 volts
- Power requirement : 0.25 HP
- Load bearing capacity : 80 Kgs.
- Others : Ridge tiles can also be manufactured.
  : Pan type and Roman type of MCR tiles can be manufactured

Precast Rcc Plank

Use: For production of Precast RCC roofing planks which are used as an alternative to RCC slabs.

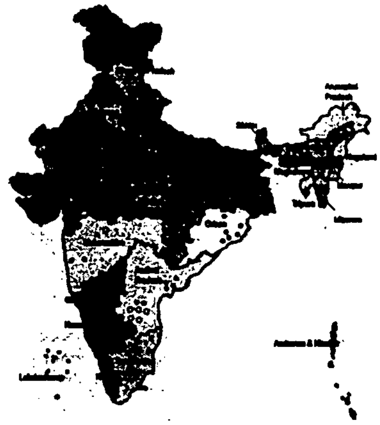


Model - CP-1

Specifications

- Production capacity Per day in 8 hours shift : 5 roofing planks
- Size of machine : 1600x1600x750 mm
- Weight of machine : 500 kgs
- Size of Plank
  - Plank : 1500 x 300 x 30-60mm or any other size
- No. of planks per cycle : 5 Nos.
- Manpower : Skilled – 1, Unskilled – 3
- Type : Portable
- Energy transmission : High amplitude vibrations
- Energy source : Electric, 3 phase, 440 volts
- Power requirement : 2 HP
- Compaction by : Vibration technique
- Compressive strength : 150 kg/cm2
- Others : Production capacity can be increased by replacing the moulds
  : Less maintenance
  : Can be designed/fabricated for different sizes of final products.

Promotion of Innovative Technologies and Machines through Production Centres and Demonstration Units being operationalised by BMTPC



Demonstration-cum-Production Units

Encouraged by BMTPC to Manufacture Cost Effective Building Components

Over **100** locations

Building Centre Movement in India

- A national network of Building Centres has been set-up by HUDCO, Ministry of Urban Development & Poverty Alleviation
- BMTPC provides appropriate technological backup and helps in building up their production capacity
- Nearly 550 such Building Centres are operational all over India

EMPLOYMENT GENERATION WITH FULL SET OF MACHINES IN A DAY

S. No	Name of Machine	Use	Production Capacity per day	Skilled Labour	Un-Skilled Labur
1	Alternate Station Hydraulic brick Machine	For production of stabilised soil bricks, flyash bricks	10000 Nos.	3	11
2	Bi-directional Vibro Press	For production of cement concrete bricks, blocks and pavers	7000 Nos.	2	14
3	Coal/Stone Disintegrator	For crushing of large size stone boulders and coal	Coal: 400 cft Stone:250 cft	1	5
4	Bar & Pipe cutting Machine	For cutting of bars and pipes		1	2
5	Precast concrete Door Frame making Machine	For making concrete door frames	4 Nos.	4	6
6	Precast concrete Window Frame making Machine	For making concrete window frames	5 Nos.	4	6

EMPLOYMENT GENERATION (contd...)

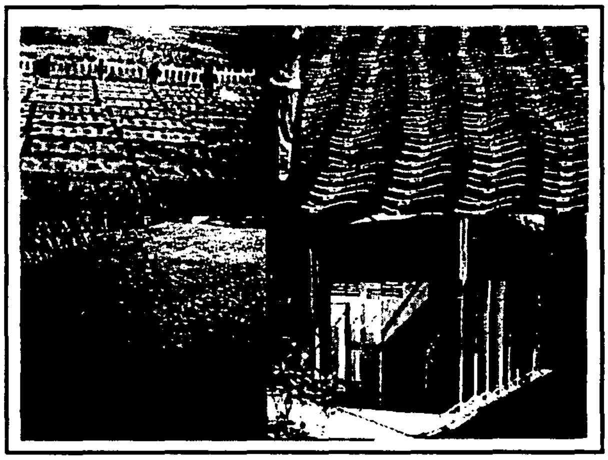
S. No	Name of Machine	Use	Production Capacity per day	Skilled Labour	Un-Skilled Labur
7	Ferrocement Rafter Machine	For making ferrocement rafter for roofing	6 Nos.	4	6
8	Ferrocement Purline Machine	For making ferrocement purline for roofing	18 Nos.	4	6
9	Precast concrete Lintel & Shelves making machine	For making concrete lintel & shelves	5 Nos.	3	6
10	RCC Plank casting machine	For making RCC plank	7 Nos	4	6
11	RCC Joist casting machine	For making RCC joist	4 Nos.	4	6
12	L-Panel making machine	For making l-panels for roof	2 Nos.	4	6
13	Ferrocement roofing channel making machine	For making ferrocement roofing channel	1 No.	4	6

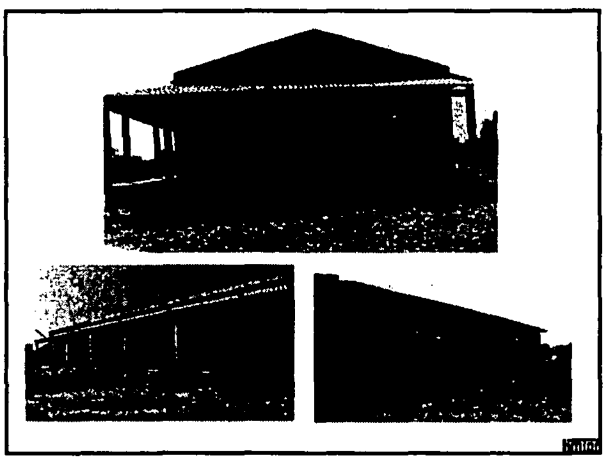
EMPLOYMENT GENERATION (contd...)

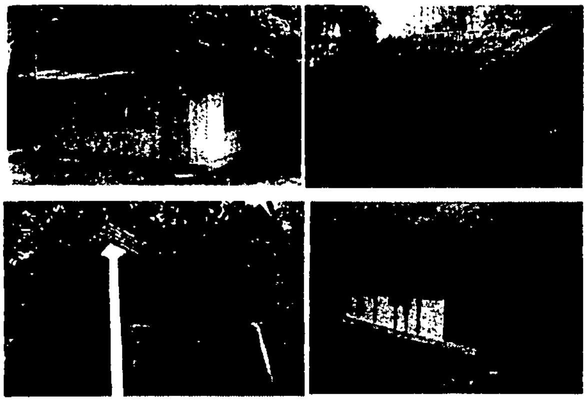
S. No	Name of Machine	Use	Production Capacity per day	Skilled Labour	Un-Skilled Labur
14	Ferrocement wall panel making machine	For making ferrocement wall panels	1 No.	4	6
15	Ferrocement door shutter making machine	For making ferrocement door shutters	1 Nos.	4	6
16	Solid/Hollow concrete block making machine (standing type)	For making solid/hollow concrete blocks	500 Nos.	2	6
17	Solid/Hollow concrete block making machine (egg laying type)	For making solid/hollow concrete blocks	1000 Nos.	2	6
18	Solid/Hollow concrete block making machine (surface petrol vibrator)	For making solid/hollow concrete blocks	250 Nos.	2	6
19	MCR tile making machine	For making micro concrete roofing tiles	200 Nos.	2	8

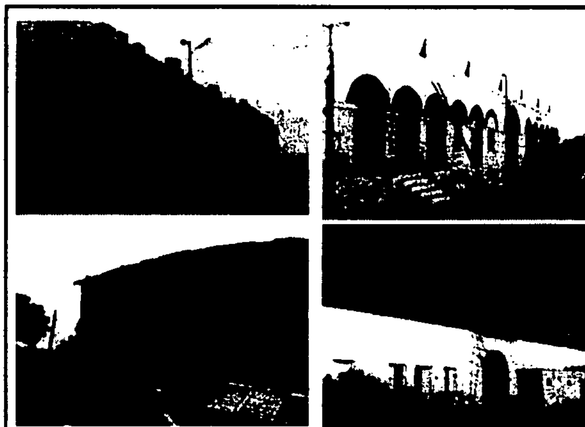
EMPLOYMENT GENERATION (contd...)

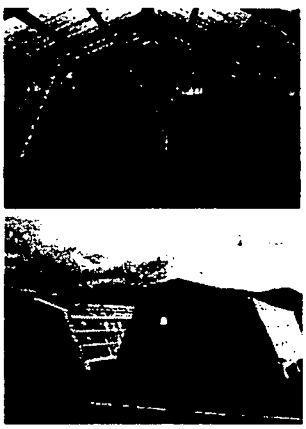
S. No	Name of Machine	Use	Production Capacity per day	Skilled Labour	Un-Skilled Labur
20	Sand cement brick making machine	For making sand cement bricks	3000 Nos.	2	6
21	C-brick making machine	For making sand cement bricks	3000 Nos.	2	6
22	Compressed earth block making machine (Balram)	For making stabilised soil blocks	1000 Nos.	1	6
23	Compressed earth block making machine (Mardini)	For making stabilised soil blocks	500 Nos.	1	6
24	Solid/Hollow concrete block making machine (SAKAR)	For making solid/hollow concrete blocks	1000 Nos.	2	6
			TOTAL	65	151

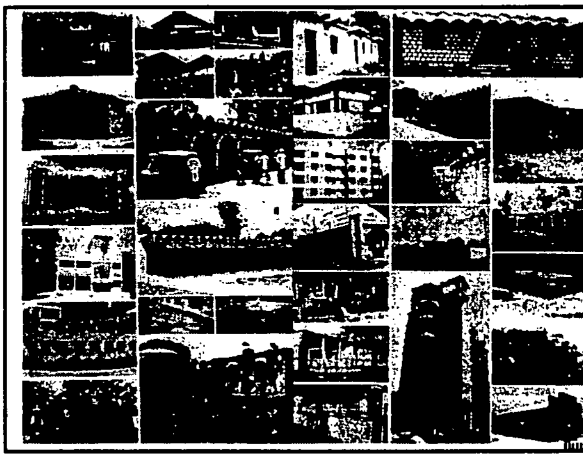












Disaster Mitigation and Management

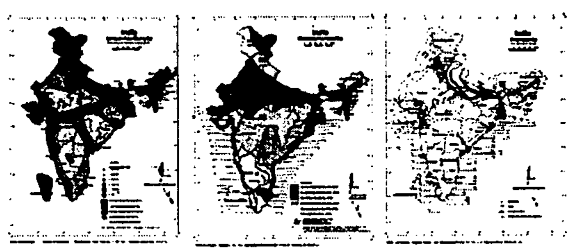
Vulnerability Atlas of India

• **Hazard Maps** • **Risk Tables**

- The Atlas aims to provide information base to support risk and emergency decision-making in disaster reduction.
- Atlas is intended for government institutions, administrative bodies, businesses, public organizations, educational institutions and individuals.
- It can also be used to develop disaster reducing measures and to plan preparedness and emergency activities.

The BMTPC project on Vulnerability Atlas and Knowledge Packing for non-engineered buildings was adjudged on 4th position out of 39 IDNDR Demonstration Projects reviewed by an International Jury.

Vulnerability Atlas of India



56% of land vulnerable to Earthquakes

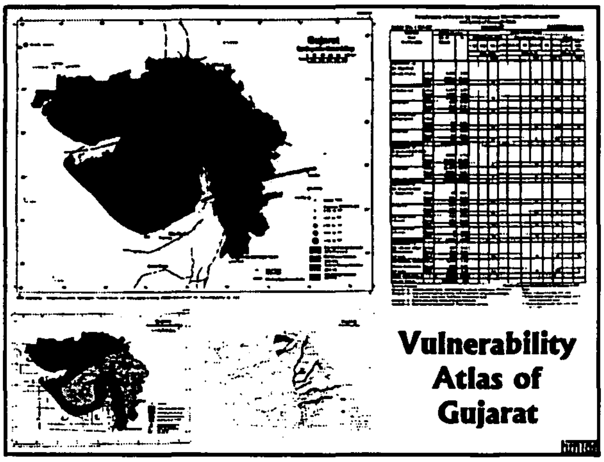
Biggest quakes in: Andamans, Kachchh, Himachal, Kashmir,N.Bihar and the North East

8% of land vulnerable to Cyclones

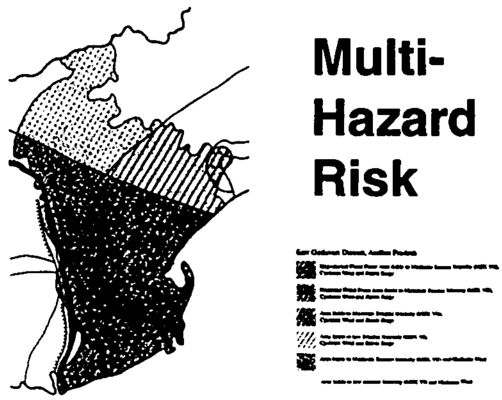
In 21 cyclones in Bay of Bengal (India + Bangladesh) 1.25 million lives have been lost

5% of land vulnerable to Floods

Lakhs of hectares of crops are damaged every year



Vulnerability Atlas of Gujarat



Multi-Hazard Risk

Districts prone to Multi-Hazard Risks

States	No. of Districts	States	No. of Districts
• Andhra Pradesh	12	• Orissa	5
• Assam	22	• Punjab	12
• Bihar	25	• Uttar Pradesh	50
• Goa	2	• West Bengal	16
• Gujarat	17	**Union Territories**	
• Haryana	8	• Delhi	1
• Kerala	13	• Pondicherry	1
		• Diu	1
• Maharashtra	13	Total Districts	190

India-UNIDO Programme

Investment and Technology Promotion and Transfer for Manufacturing of Construction Materials for Housing

ICAMT

India-UNIDO Co-operation

BACKGROUND

- Environmental problems due to huge quantities of agro-industrial wastes
- Development of technology for recycling
- Rising energy demand
- Need to promote technology with high potential for employment

India-UNIDO Programme focuses on:

- Environmental Protection
- Energy Efficiency in Manufacturing Processes
- Sustainable development of small and medium enterprises
- Modernization of Manufacturing Process of Materials
- Technology Sharing & Capacity Building
- South South Cooperation

Technology for Alternative Materials for Housing

- ➢ **E**nergy Efficient
- ➢ **E**nvironment Friendly
- ➢ **E**mployment Generating

Industrial & Agricultural Waste

ITEM	SOURCE	Qty Available	Application as Building Material in M.T./Yr.
Flyash	Thermal Power Stations	65.00	Portland pozzolana cement, bricks, lime pozzolana mixture, lightweight, aggregate cellular concrete.
Blast Furnace Slag	Steel Plants	7.41	Production of Portland blast furnace slag cement cement, super sulphate cement as an aggregate in concrete, as substitute for sand, lightweight concrete.
Cinder	Thermal Power Stations and Railways	3.00	Manufacture of lime cinder mortar, production of concrete building blocks, production of bricks from black cotton soil.
Coal Washery Waste	Coal Mines	3.00	Manufacture of bricks, tiles, lightweight aggregates, fuel substitute in the burning of bricks.
Copper Mine Tailing	Copper Mines	0.55	For manufacture of stabilised and high strength bricks, cellular concrete and masonry cement.
Copper Plant Waste	Copper plants	0.164	For making bricks/blocks.
Gypsum Mine Waste	Gypsum Mines	1.50	Gypsum building plaster, ready made plaster with lime.

Industrial & Agricultural Waste

ITEM	SOURCE	Qty Available	Application as Building Material in M.T./Yr.
Iron Tailing	Iron Ore Mines	11.25	For making stabilised and burnt clay building bricks, high strength bricks.
Kiln Dust	Cement Plants	2.00	In the cement industry, as a hydraulic binder.
Lime Stone Waste	Lime Stone Quarry	50.00	For production of masonry cement and activated lime pozzolana mixture.
Lime Sludge	Sugar, Paper, Fertilizer, Calcium Carbide acetylene industries	4.80	For the manufacture of portland cement, masonry cement, sand lime bricks, building lime pozzolana mixture.
Paper Waste	Paper, City garbage	–	For the manufacture of pitch fibre pipes, asphaltic corrugated roofing sheets.
Phospho-gypsum	Phosphoric Acid, Ammonium Phosphate, Hydro-fluoric Acid Industries	11.00	For making gypsum plaster, fibrous gypsum boards and blocks, cement clinkers, as a solid retarder and for making super sulphate cement.
Red mud	Aluminium Extraction Plant	4.00	For production of building bricks and tiles, lightweight structural blocks, roofing sheets and as an additive to concrete.

Industrial & Agricultural Waste

ITEM	SOURCE	Qty Available	Application as Building Material in M.T./Yr.
Waste Glass	Glass Plant	–	In the manufacture of mosaic and glazed tiles and light weight aggregate, brick making.
Waterworks Silts	Waterworks Settling Tanks	Huge Quantity	For manufacture of structural clay product, lightweight bloated clay aggregate, high strength bricks.
Zinc Tailings	Zinc Mines	–	For making cellular concrete, sand lime bricks, precast blocks, concrete flooring tiles.
Rice Husk	Rice Mills	18.00	As fuel, for manufacturing building materials and products for production of rice husk binder, fibrous building panels, bricks.
Bagasse	Sugar Industries	5.25	For manufacture of insulation boards, wall panels, etc.
Banana Leaves/ Stalks	Banana plants	0.20	In the manufacture of building boards, fire resistance and fibre board.
Coconut Husk aggregate.	Coir Fibre Industry	0.06	In the manufacture of building boards, roofing sheets, insulation boards, building panels, as a lightweight
Groundnut Shell	Ground Nut Oil Mills	5.75	In the manufacture of building panels, building blocks for making chip boards, roofing sheets, particle boards.

Industrial & Agricultural Waste

ITEM	SOURCE	Qty Available	Application as Building Material in M.T./Yr.
Jute Stick	Jute industry	2.05	For making chip boards, roofing sheets.
Rice Reeds & Wheat Reeds	Agricultural Farms	–	Manufacture of roofing units and wall panel/boards.
Saw mill Waste	Saw mills & wood based panel industries	2.00	Manufacture of cement bonded wood chips, blocks, boards, fibre boards, particle boards, insulation boards
Sisal Fibres	Sisal Plantation	–	For plastering of walls and for making roofing sheets.
Cotton Stick	Cotton plantation.	10.05	Fibre boards, panel, door shutters.

SHARING INDIAN EXPERIENCE

THAILAND - 1995


BMTPC displayed technologies for building materials from recycled industrial and agro wastes and initiatives in production of small building components

ISTANBUL (TURKEY) - 1996

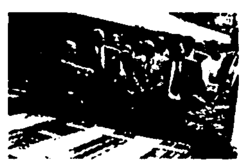
The display covered programmes, activities and achievements in the areas of Cost Effective Housing, Housing Finance Practices, Urban Development Programmes, City Development and Urban Design, Non-conventional Energy Sources, Small Enterprises, Building Materials and Innovative Technologies, Disaster Resistant Housing, Waste Based Materials, Plastics, Rural Housing Programmes, Sanitation Sector and National Drinking Water Mission etc.

ISTANBUL (TURKEY) - 1996


Noted amongst the key visitors of the India Pavilion was Dr. D Wally N' Dow, Secretary General of Habitat-II Conference, whose encouraging remarks were:

"A Wonderful Example of Improving Human Settlements for the Whole World. Congratulations!".

UGANDA - 1998

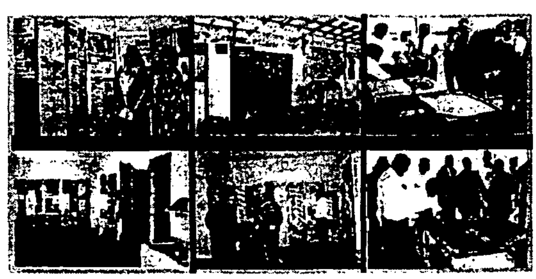



- Live demonstration of simple low-cost building components production
- Attendees included the business community associated with construction, manufacturing and supply of building materials, architects, builders, developers and representatives of NGOs.
- Entrepreneurs showed interest in importing Indian machinery to make simple building components, finished products like building hardware, flooring tiles and solar energy based appliances, and to set up production units for concrete based components.

TRINIDAD & TOBAGO - 1999

A MOU was signed in Port of Spain during the visit of the Hon'ble Prime Minister of India in February 1999.

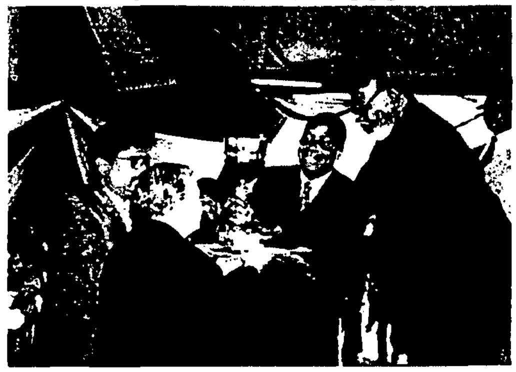
TRINIDAD & TOBAGO - 1999



This effort has finally led to the the formulation of a long term cooperation programme for sharing and transfer of technologies with Trinidad and Tobago.

TANZANIA - 2000

TANZANIA - 2000

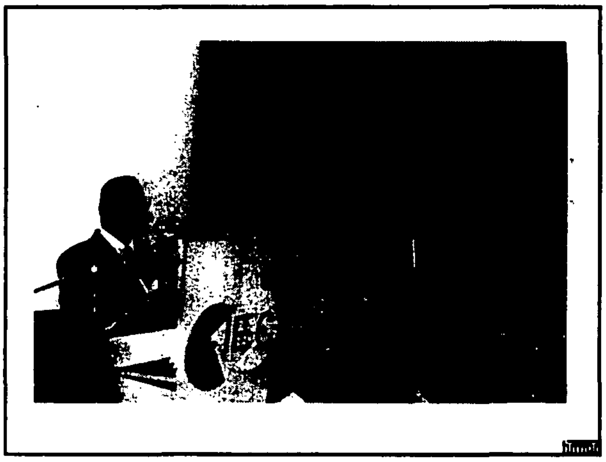


TANZANIA - 2000

TANZANIA - 2000

TANZANIA - 2000

Exhibition in Venezuela May 2002



Home Page of BMTPC

Sections on Home Page

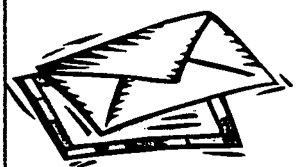
- Background
- Thrust Areas
- Objectives
- Special Events
- Machines developed by BMTPC
- Environment-friendly Materials and techniques
- Building Materials from recycled wastes
- Disaster Mitigation
- Performance Appraisal Certification Scheme
- News
- Publication
- Query
- Feedback

www.bmtpc.org
(Approx 10,000 Visitors per month)
Home page activated in 1999

Analysis of Queries received at BMTPC

E.Mail queries Analysis for Last 12 months

National ➡ 48 % International ➡ 52 %



African Countries	36 %
Latin America	16 %
Australia & Ex-USSR	14 %
Europe	10 %
USA	10 %
Gulf Countries	9 %
Asia	7 %

Analysis of Queries received at BMTPC

Nature of queries

Machinery Related	54 %
Seeking Trade/Technical Info.	18 %
Publications Related	10 %
Seeking general and Misc. Info.	12 %
Seeking Project Consultancy	4 %
Seeking Business Associations	2 %

Machine specific and Country/Region wise queries

India	25 %	Australia & Ex-USSR	7 %
African	32 %	Europe	5 %
USA	7 %	Asia	7 %
Latin America	15 %	Gulf	2 %

Demand generated for Transfer of Technical Know-how and Machineries developed and promoted by BMTPC

From: India and other countries...

No.	Name of the Country	No.	Name of the Country	No.	Name of the Country
1	Abu Dhabi	16	Kazakhstan	31	Surinam
2	Argentina	17	Libya	32	Syria
3	Austria	18	Malawi	33	Tahiti
4	Australia	19	Mongolia	34	Tanzania
5	Bahamas	20	Mexico	35	Thailand
6	Barbados	21	Mozambique	36	Trinidad & Tobago
7	Bhutan	22	Nairobi	37	Turkey
8	Canada	23	Namibia	38	UAE
9	Egypt	24	Nigeria	39	Uganda
10	Ethiopia	25	Norway	40	UK
11	Finland	26	Pakistan	41	USA
12	Germany	27	Panama	42	Venezuela
13	Ghana	28	Rwanda	43	Vietnam
14	Greece	29	Saint Lucia	44	Zambia
15	Indonesia	30	Saudi Arabia	45	Zimbabwe

Future Action Plan

- Long term project for identified countries in Africa under development
- Based on interest received, more programmes to be developed for South East Asian, Latin American and Caribbean region
- Donor agencies / Donor countries to be approached for funding

Thanks

ICAMT

INTERNATIONAL CENTRE FOR ADVANCEMENT OF MANUFACTURING TECHNOLOGY

S.VASANTHA KUMAR

November 25, 2002 Bangalore

ICAMT

INTERNATIONAL CENTRE FOR ADVANCEMENT OF MANUFACTURING TECHNOLOGY

S.VASANTHA KUMAR

November 25, 2002 Bangalore

ICAMT

Joint initiative of
Government of India & UNIDO

Established in October 1999

Core Objective

Emerge as focal point in a global network to enhance the manufacturing capability and competitiveness of industries in developing world.

Programme Focus

Awareness	❑Seminar ❑Expert Group Meeting ❑Technology Summit ❑Technology monitoring
Acquisition / dissemination of technology related information	❑Linkages with –Centres of excellence –R&D Organisations –Industry Associations –Industry Houses/groups –Universities ❑ Establishment of database ❑Linkage with existing databases

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Programme Focus

Technology Development	❑**Facilitate technology development** ❑**Develop product and process** ❑**Improve productivity** ❑**Enhance quality** ❑**Facilitate testing and bench marking** ❑**Apply IT to SME sector**
Technology Transfer	❑**Identification of technology gap** ❑**Technology sourcing** ❑**International technology transfer brokering** ❑**Expert advisory service** ❑**Business Networking** ❑**Sectoral projects** ❑**Linkage to Investment promotion**

Programme Focus

Enterprise development	❑Training ❑Seminar ❑Project conceptualisation and development
Market Development	❑International exhibitions ❑Organise ❑Facilitate participation ❑Business networking ❑Product development ❑Bridge missing links

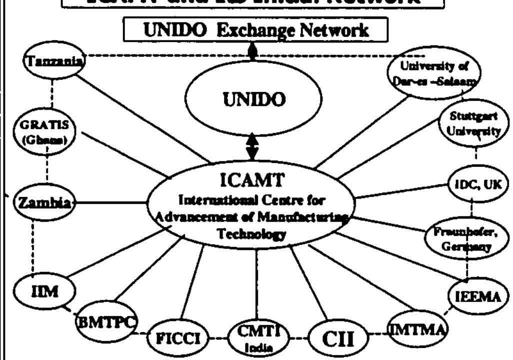
Programme Focus

Regional Co-operation	❑Setting up of focal points in developing countries ❑South-South, North-South business contacts ❑Technology Partnership programme ❑Exhibition/Seminar
Mobilisation of funds	❑Linkage with : ❑Multilateral/ bilateral funding institutions ❑Donor countries ❑Financial Institutions/Banks ❑Government Organisations ❑Development of market driven projects ❑Linkage with UNIDO ongoing projects

South – South Co-operation

- **International Co-operation for Technology transfer to Africa in the field of manufacturing of Alternative materials for low cost housing based on Agro and Industrial waste**
  - **International exhibitions at:**
    - **Bangalore (Dec'99)**
    - **Dar- Es –Saalam, Tanzania (July '00)**
    - **Ahemedabad (Nov '00)**
    - **Caracas , Venezuela May 2002**
  - **A Regional Programme is under development – identified countries in Asia , Africa and Latin America to be involved**

ICAMT and Its Initial Network



Competitive Edge

- **Application of IT in SMEs**
- **Development and Implementation of sectoral projects**
- **Strong Linkages with Private / Public Sector**
- **Manufacturing Technology - strong counterpart agency**

INITIATIVES IN FIRST YEAR

- International Co-operation for Technology Transfer – Building Material for Low Cost Housing
- Technology Development Projects for Indian SMEs
  - Toy industry
  - Machine Tool industry
  - Stone industry
  - Lock industry

THANK YOU

Overview and Advances on Science, Technology and Applications of Composite Materials based on Natural Resources

Prof Dr. P.V. Kandachar

TU Delft
Delft University of Technology

Materials Design and Production Processes for Low-cost Housing
25-29 November 2002, Bangalore, India
Organizers: UNIDO-ICAMT..UNIDO-ICS..BMTPC

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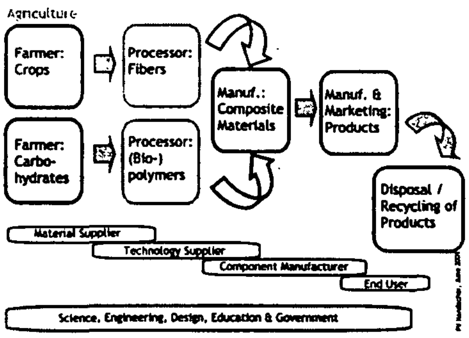
Characteristics

1. Recently re-discovered
2. Large gaps in scientific knowledge
3. Considerable interest in certain application areas
4. Scattered and proprietory knowledge base

Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

The Old and New Players



Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

Revived Interest

- Fossil fuel (petroleum) is a limited (and the synthetic polymers derived from oil), non-renewable resource (20-80 years)
- Can a renewable resource, such as agricultural produce, be an alternative? Bio-polymers? Polymers reinforced with agricultural fibres?
- Can they contribute to sustainable development?

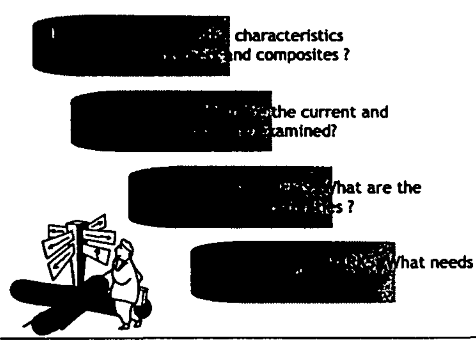
Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

Lecture Approach

- Technical rather than through consumer research and marketplace intelligence.
- Competition between fibres & composites.
- Properties (technological, economical, ecological) as the criteria for selection - Product Design & Development as Aim
- Broad overview - Eurocentric - Universal

Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

Lecture Structure



Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

Part 1

Materials and Processes

Classification

ORGANIC

Plant Based (Cellulose):

Seed fibres, Bast fibres, Hard fibres, Fruit fibres, Wood fibres

Animal based (Protein):

Wool, Hair, Silk

INORGANIC

Mineral Based:

Asbestos

Features of Natural Fibres

Kenaf

- Low cost, low density (value for money)
- High specific properties (*sisal ropes, jute bags)*
- Biodegradable, renewable
- Non-abrasive
- Ready availability

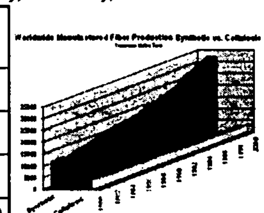
- Sensitive to moisture absorption
- Thermal degradability
- Variation in properties

Industrial Hemp

History

Have lost position due to increased dominance of synthetic fibres - on grounds of cost, quality, consistency, etc

Agave	8,000 years old, Tehuacan valley of Mexico
Woven palm leaf fabric	12,000 years old, Mexico
Yucca and Typha mats	11,000 years old, Nevada Cave
Woven Flax	8,000 years old, Switzerland
Cotton cloth	3,000 years ago, India
Hemp	2,000 B.C., China
Papyrus and flax	7,000 B.C., Egypt



Source: Botany Department, University of Wyoming

Fibersource.com

World Wide Availability (1990)

Fibre	Production, tonnes	% of total	Grown in
Cotton	18.645.000	71.80	China, USA, India, Pakistan, Uzbekistan
Jute	3.630.000	14.00	China, India, Bangladesh
Wool	2.100.000	8.10	
Flax	830.000	3.20	China, France, Romania, Belarus, Netherlands
Sisal	380.000	1.60	Mexico, Africa, South America
Hemp	220.000	0.09	Europe, China, Africa, Canada
Ramie	110.000	0.04	Southeast Asia, China, Japan, Southern Europe
Silk	75.000	0.04	

Production & Consumption in EU (2000)

Fibre (short fibres)	EU production, tonnes	EU consumption, %			
		Pulp	Apparel	Others	Export
Flax	60000 -70000	45	20	10	25
Hemp	25000 -30000	87	-	13	-

Source: Nova Institute, Germany, March 2000.

Application of Natural Fibres in Automobiles (Europe)

	1996	*1999*	*2000*
Germany	4,000	14,400	17,140
Rest of EU	300	6,900	11,160
total:	4,300	21,300	28,300

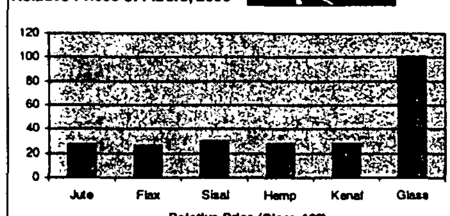
1999: 71% flax, 12% hemp, 7% kenaf, 6% jute and ½% sisal

Potential: 5 to 10 kg NF per car → 80,000 to 160,000 ton

Source: Novo Institute, Germany

Price of Fibres

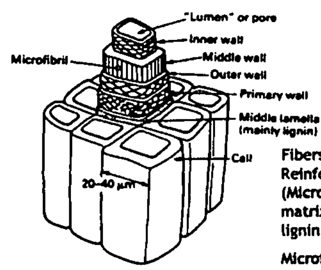
Coconut plant and coir fibre



Some Common (agro)Fibres

Common Name	*Scientific Name*	*Plant Family*
Stem (Bast) Fibers (Dicots)		
Flax	Linum usitatissimum	Linaceae (Flax)
Ramie	Boehmeria nivea	Urticaceae (Nettle)
Jute	Corchorus capsularis	Tiliaceae (Basswood)
Kenaf	Hibiscus cannabinus	Malvaceae (Mallow)
Indian Hemp	Cannabis sativa	Cannabaceae (Marijuana)
Leaf Fibers (Monocots)		
Sisal	Agave sisalana	Agavaceae (Agave)
Seed Fibers (Dicots and Monocots)		
Coir	Cocos nucifera	Arecaceae (Palm)

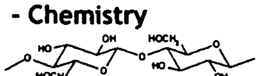
Fiber (Cellulose) - Structure



Fibers: Cellulose Fiber Reinforced Materials (Microfibrils in an amorphous matrix of Hemicellulose and lignin)

Microfibrils: Very rigid and stable; impart high tensile strength

Fiber (Cellulose) - Chemistry



- Cellulose: common material of plant cell walls (recognized by Anselm Payen in 1838)
- Occurs in almost pure form in cotton fiber(98%; flax is 80%)
- Occurs in combination with other materials, such as lignin and hemicelluloses, in wood, plant leaves and stalks, etc
- Long chain polymer (a polysaccharide), made up of repeating units of glucose
- Structural strength due to strong hydrogen bonding between the -OH groups; thus does not melt/dissolve in common solvents; difficult to convert short wood fiber to "artificial silk".

Fibre - Chemical Composition

Fibre	*Cellulose*	*Hemicellulose*	*Lignin*	*Pectin*	*Moisture*
Flax	68 - 85	10 -17	3 - 5	5 -10	10.0
Hemp	70 - 75	12 -15	10 -15	1	10.8
Jute	61 - 70		12 -19		12.6
Kenaf	31 - [illegible]	21.5	15 -19		

Responsible for Biodegradability, Thermal degradability, Moisture absorption

Responsible for Thermal stability, UV degradability

Together: Insulation (heat, sound & electrical) - High friction co-efficient - Combustibility - Meets flammability requirements of auto industry.

Fibre Quality (Properties) - Processing

- Geographical location of growth
- Test results of a single fibre or a bundle ?
- Location of fibre in the stem length
- Non-constant cross section
- Surface quality

RETTING, to separate bast fibers from the rest of the stalk, microbial process

DECORTICATION, to separate from the woody core, SCUTCHING (to remove particles), HACKLING (combing)

FIBRE QUALITY
- Scatter in properties
- Retting Process
- Decortication - 1 to 2% shive (poor mould surface)

Fiber - Physical Properties

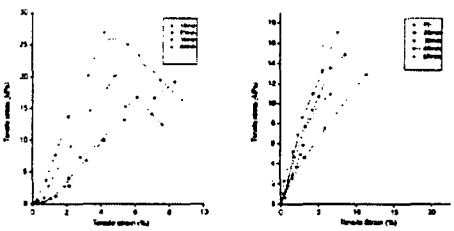
Fiber		Physical Properties	
Type	Form	Length Range, mm (average)	Dia. Range, mm (average)
Flax	Bundle	250 -1200	0.004-0.6 (0.02)
	Single	9-70 (33)	0.005 - 0.038
Hemp	Bundle	1000 - 4000	(0.025)
	Single	5 - 55 (25)	
Jute	Strands	1500 - 3600	0.01-0.025 (0.02)
	Single	2 - 5	

Choice between short fibres (for moulding compounds & injection moulding) and long ones (where anisotropy is desired)

Aspect ratios requirements (with man-made fibres) not stringent due to cell wall reactivity.

Stress Strain Behaviour - Fibre Length Effects

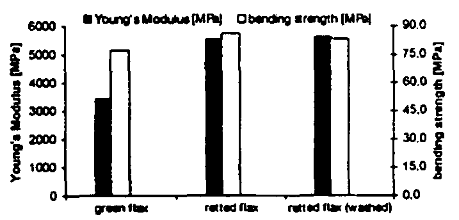
Better bonding with banana fibres because of reactive surface ?



Fibre (left: Banana, right: Glass) reinforced Phenolics

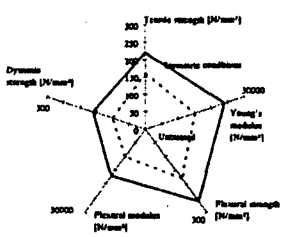
Source: Joseph, et.al, Comp. Science & Tech, 2002

Influence of Surface Treatment – Flax Fibre Bio-composite



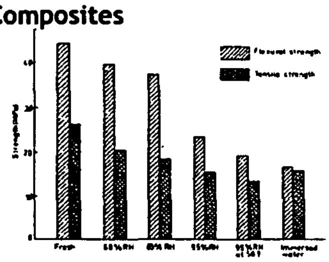
Retting: Controlled decay in the field, cementing substances decayed by microbes. Washing removes dust, pectin, etc; Source: Riedel, DLR

Influence of Surface Treatment - Jute (40%) Epoxy Composite



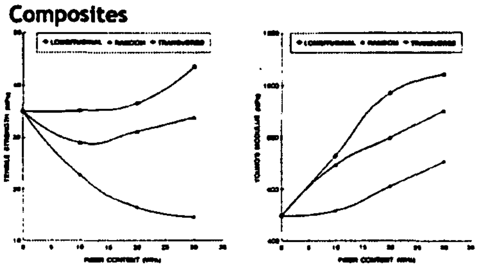
Treated with 26 wt% NaOH, 20 min, at 20°C; Source: J. Gassan, Composite Science & Technology, July 1999

Effect of Moisture on Jute-Phenolic Composites



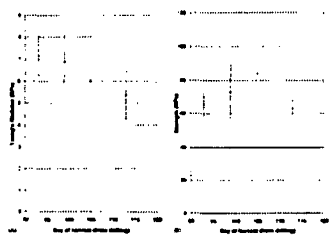
Source:B.Singh, Composite Science & Technology, March 2000

Effect of Fibre Orientation in Sisal-PP Composites



Source: P.V.Joseph, Composite Science & Technology, August 1999

Influence of Harvest Date - Hemp/Epoxy

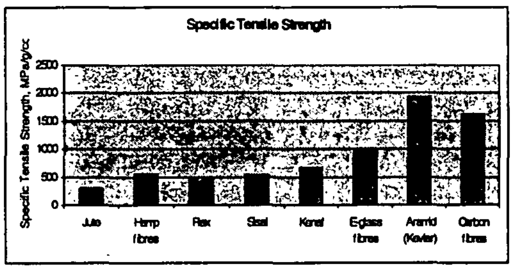


Hemp-epoxy composites tested in tension. (A) Young's modulus. (B) Strength. Fibre was unretted and pinned. (Ref: Hepworth, et al, Composites A, November 2000)

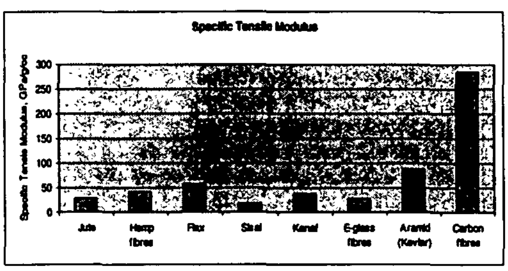
Fibres - Mechanical Properties

Properties	E-glass	flax	hemp	jute	ramie	coir	sisal	abaca	cotton
density g/cm^3	2.55	1.54	1.48	1.46	1.5	1.25	1.33	1.5	1.51
tens. strength (10E^6 N/m^2)	2400	800-1500	550-900	400-800	500	220	600-700	980	400
E-modulus (GPa) specific (E/dens.)	73 29	40-70 26 - 46	70 47	10-30 7 -21	44 29	6 5	38 29		12 8
elongation at failure (%)	3	1.2 - 1.6	1.6	1.8	2	15 - 25	2 - 3		3 - 10
moisture absorpt. (%)	-	7	8	12	12 -17	10	11		8 - 25
price / kg ($), raw (mat/fabric)	1,3 (1,7 / 3,8)	0,5–1,5 (2 / 4)	0,6–1,8 (2 / 4)	0,35 1,5 / 0,9– 2	1,5–2,5	0,25–0,5	0,6–0,7	1,5–2,5	1,5 – 2,2

Properties of Natural & Synthetic Fibres (1)



Properties of Natural & Synthetic Fibres (2)

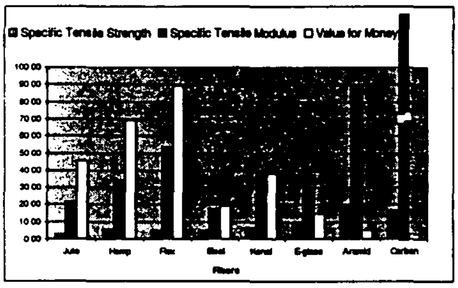


Fibres - Comparison with Glass Fibres

- \+ low specific weight
- \+ low price
- \+ renewable resource
- \+ low impact on environment (energy / CO_2)
- \+ better working conditions
- \+ low abrasive processing
- \+ combustibility
- \+ thermal & acoustic insulation

- \- lower impact strength
- \- variable quality
- \- moisture absorption (durability / swell)
- \- limited thermal stability
- \- smell

Selection of Fibres for Composite Fabrication



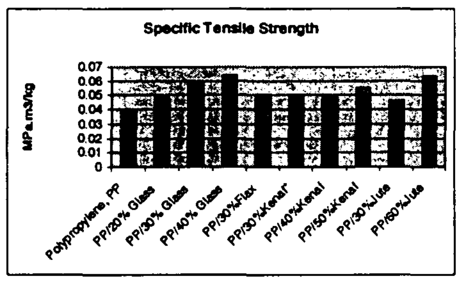
Properties of Synthetic & Biopolymers

Type	Water Absorption, %	Tensile Strength, MPa	Tensile Modulus, MPa	Density, kg/m³	Failure Strain, %	Price Euro/kg
Synthetic Polymers						
Polypropylene (PP)	0.01-0.1	24-38	1500-1800	900-946	87	0.67-1.23
PVC (hard)	0.07-3	34-60	2500-3000	1350-1500	40	0.79
Polycarbonate (PC)	0.15-0.46	53-75	2000-2600	1160-1200	80-96	1.9-3.75
Polystyrene (PS)	0.08-0.09	26-44	2000-3000	1000-1500	40-60	0.73-0.78
Biopolymers						
Polyhydroxybutyrate (PHB Biopol)	0.1-13	18-45	350-3800	1250	4-970	6-12
Polycaprolactone (PCL, Mater-Bi)	15-20	25-30	2100-2500	1350	2-6	1.8-3
Polylactic acid (PLA)	1.5-2	21-55	350-2800	1250-1260	1.5-280	2.7-3.6
Cellulose	1.5-2.3	24-76	1600-1800	1220-1320	5-55	2.5-3.5

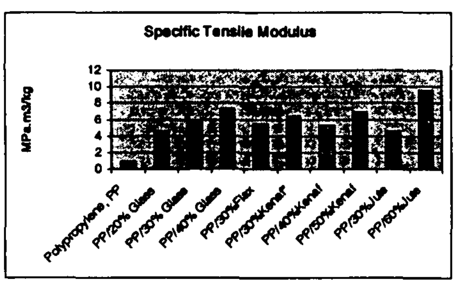
Selection of Matrix Materials for Composites

Property	Synthetic Polymer	Bio-polymer
Low Density	PP, HDPE, LDPE	PHB, PLA
Processing Temp.	PP, HDPE, LDPE	PLA
Tensile Strength	PAI, PA-66	PLA
Elastic Modulus	PAI, PET	PLA, PHB
Flexural Modulus	PAI, PEEK	PHB, PLA
Impact Strength	HDPE, PA-66	PLA
Moisture Absorption	PP, PET	PHB
Cost	PP	PLA

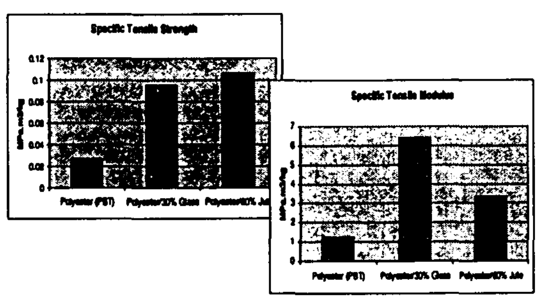
Properties of Composites (1)



Properties of Composites (2)



Properties of Composites (3)



Properties of Composites (SMC) -1

Property	Glass (20%)	Glass (40%)	Flax 1 (21%)	Flax 2 (21%)
E-modulus (GPa)	8.5	10.5	7	11
Tensile strength (MPa)	95	130	40	80
Flexural Modulus (GPa)	10	13.5	7	13
Flexural strength (MPa)	125	240	83	144
Impact strength (KJ/m²)	50	85	11	22

Weight percents
Flax 1: 6.25 mm long fibres; Flax 2: 25 mm long fibres

Properties of Composites (SMC) -2

Property	With Glass Fibre	With Flax Fibre
E-modulus (GPa)	8 - 11	7 - 12
Tensile strength (MPa)	35 - 75	40 - 80
Flexural Modulus (GPa)	7 - 11	7 - 12
Flexural strength (MPa)	70 - 160	83 - 144
Impact strength (KJ/m²)	40 - 70	3 - 7

Based on several literature data
Ref: B. van Voorn et.al, Composites, 2001, p.1271-1279

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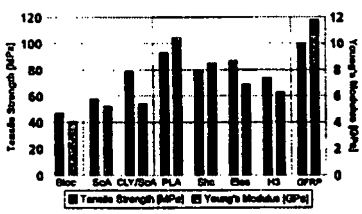
Properties of Biocomposites



30% non-woven reinforcement, natural fibres in various biopolymers; GFRP: Glassfibre Reinforced Plastic (Source: Riedel, Germany)

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Unresolved Issues & Challenges

Variability | Impact | Moisture

Micromechanical Modelling

Quality Control

R & D on products of Natural Fibre Composites?

Optimise surface treatment?

Understanding (Modelling)

Managed decay?

- Universite de Bretagne (Baley) model to estimate the elastic modulus of natural fibre (Flax) -*Composites, 2002*
- TUDelft model for estimation of the elastic modulus of a composite when elastic modulus of fibres is known, and vice versa-*Denmark 2002*

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Part 2

Current Applications

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Applications in Buildings

Product	Reinforcement	Matrix
Structures (beams, laminated veneer lumber, etc)	Wood boards& veneer, bamboo, bast fibres	Urea, melamine, phenol isocyanate, etc
Panels (plywoods, particle boards, MDF, insulation, etc)	Wood veneer, bamboo, flax, hemp, jute, paper, straw, etc	Urea, melamine, phenol isocyanate, protein:casein, soybeans based
Packaging	Wood, wood wool, bamboo, paper including wastes	Starch, silicates, urea resins, polyvinyl alcohol, lignin

Source: R. Kozlowski, Inst. of Natural Fibres, Poland,1998

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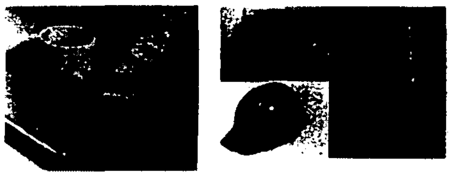
Applications - General



Source: Riedel, DLR - Institut fur Struktuurmechanik, 1999

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Applications in Automotives

NafpurTec by Hennecke and Bayer Corp., Germany
(other techniques: Interwet, LFI-PUR)

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Natural Fibers in Mercedes A-200

Interiors:
Upholstery of Doors, Pillars and Floor, Rear Shelf, etc.

- Low Cost & Weight
- Acoustic Insulation
- No Abrasive Wear
- No Skin Irritation
- Combustibility
- Ecological Advantage

Mercedes A - 200

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Natural Fibres in Automotive Interiors

Material	Manufacturing Technology	Applications
Flax, Sisal, Hemp (50-65%)-PU	**Impregnation & moulding**	**Instrument panels, door panels, seat upholsteries (Mercedes Benz S Class, BMW 5, 7 and 8 Series, Renault Clio, Opel Zafira, etc)**
Flax, Sisal, Hemp, Jute (40-50%)-Phenol or Polyester	**Impregnation & moulding, extrusion**	
Flax, Sisal, Hemp (45-55%)-PP	**Compression Moulding**	
Flax, Hemp, Kenaf (20-40%)-PP	**Injection Moulding, Extrusion**	

Meet most requirements, except: ***Quality consistency (from batch to batch) - lack of accepted quality standard ***Odour & fogging ***Impact (unpredictable) ***Recycling issues

Courtesy: Johnson Interiors, Germany

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Part 3

New Application in Horticulture

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New Application: Biodegradable Pots for Plant

Material: China Grass (Miscanthus sinensis gigantheus) reinforced with proprietory, natural thermoplastic, CO_2 neutral, 100% compostible

Product: Hot Moulding Process

Manufacturer: NAPAC, Ch.

Estimated Number of Pots in NL (2000): 1850 Million (29.500 tonnes of plastic) Exported: 1450 Million

Cost: 4 x expensive, with labour & recycling savings, approximately 4% cheaper.

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Hot Pressing of (Natural Fibre)Composites

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Flower shop, UK

Source: NAPAC

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Gardening Center, Holland & UK

Source: NAPAC

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Mass production & use

Production rates: 4 big pots or 6 small pots per cycle of 10 to 12 seconds. *Source: NAPAC*

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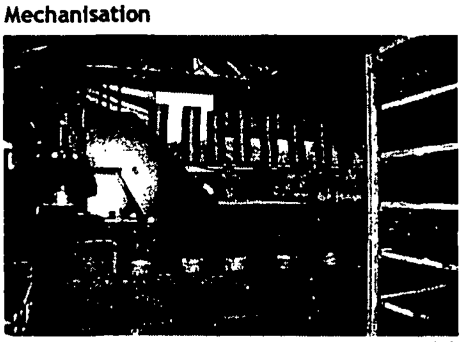
Mechanisation



Source: NAPAC

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Decay process

***Resin decays underground within 24 months.
***German standard DIN-54900 for industrial composting environment. *Source: NAPAC*

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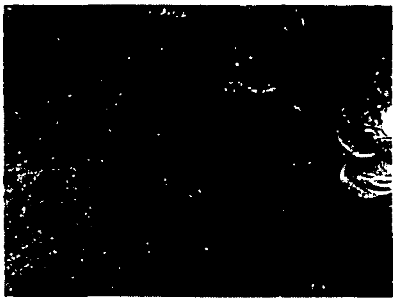
Roots penetrating through



Source: NAPAC

Part 4

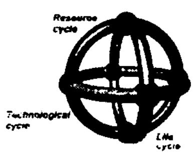
Designing a Car

Delft University Activities

TU Delft

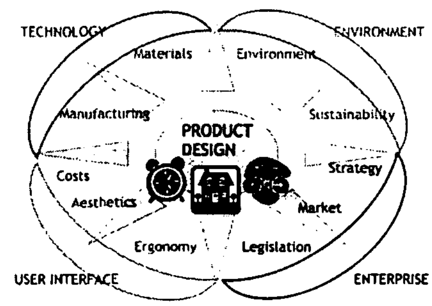
Delft University of Technology

Sustainable Development

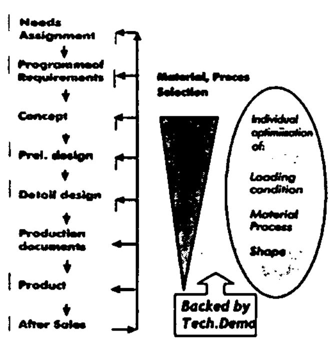


Transport Sector:
Resource Intensive
Energy Intensive

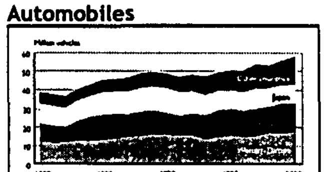
Factors Influencing Product Design



Design Process & Materials Selection



World Production and Consumption of Automobiles



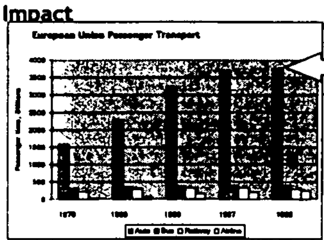
World Population:

More than 400 Million

World Production:
1.27 Cars/Second
2.4 Humans/Second

Source: UNEP publicatin on International Automotive Industry, 2002

Transport Sector - Resource Intensity & Env. Impact



Japan: 60%
EU: 80%
USA: 90%

27% total energy consumption, 33% CO_2 Emission of USA

Av. US Vehicle Weight Increase by 21%

Av. US Occupancy Decrease by 16%

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Transport Sector - Resource Intensity & Env. Impact

Transport related emissions as % of total : CO_2:16%, CO:70%, NO_x:61%, SO_2: 16%, VOC: 43% (in Netherlands,1990)

Third (16% of the total) largest energy consumer (after industry and housing) in Europe

Total Material Use in Europe

9% Transport ⇨ Passenger Cars 63%

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Government Initiatives: EU End-of-Life-Vehicle Directive

5.4 Producer/Importer pays
7.2 Recycling quotas, implemented in 2 stages

2006	Reuse + Recycling ≥ 80%	E+D ≤ 20%
	Reuse + Recovery ≥ 85%	D ≤ 15%
2015	Reuse + Recycling ≥ 85%	E+D≤15%
	Reuse + Recovery ≥ 95%	D ≤ 5%

LEGEND: *E : Energy recovery; D : Disposal or Treatment*
Recovery = Recycling + Energy recovery (E)

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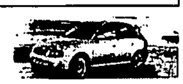
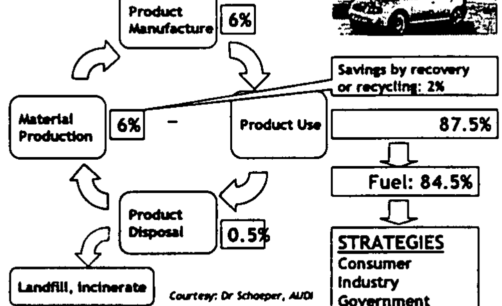
PRODUCT LIFE CYCLE
Energy Consumption

Audi A3, 200000 km on road





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Possible Approaches

CONSUMER
- *Reduce Automobile Use*
- *Shared Transport (Train, Bus, Carpool)*
- *Teleworking*

INDUSTRY
- *Reduce Automobile Weight* ⇨ Dutch≡v●
- *Downsize*
- *Alternate energy sources, engines*

Reduction in
- Resource Intensity
- Environmental Impact

GOVERNMENT
- *Legislation*
- *Taxation*
- *Speedlimit*

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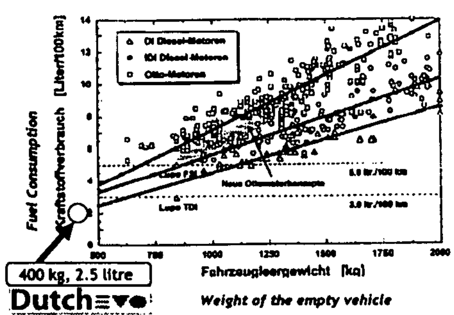
Setting Targets for Weight Reduction



Source: DLR Report STB 24, June 2001

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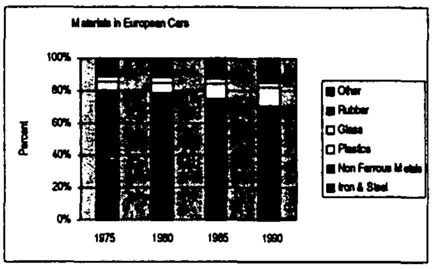
Materials in European Cars, 1975-1990 (Plastics: ca. 10% in 1990)



Source: Samel, Mat.Tech. & Adv. Perf. Mat,2001

Natural Fibers in DaimlerChrysler Cars & Commercial Vehicles

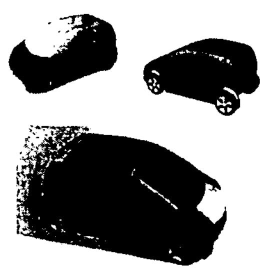
Raw Material	Used in components
Flax, Sisal, Hemp	Door trims & rear shelves (Polymer + 75% Fiber)
Reprocessed Cotton	Trunk paneling, roof lining, carpeting, silencing compounds, seat back lining, rear shelves
Sisal, repr. cotton	Rear shelves (sisal/cotton:75% + polymer:25%)
Coconut fibre /nat. rubber mixture	Seat cushions, seat backs, headrests and sun visors
Wood fibres	Reinforcement of dashboard panels, rear shelves, door trims
Laminated wood	Trunk floor panel
Wood veneer	Decorative strips, panels

Delft University Experimental Car

Design Concepts

Objectives

- •Petrol consumption 1l : 40km
- •Lightweight car(400 kg)
- •Environment friendly
- •Renewable materials
- •Design for recycling
- •Passenger appeal & comfort
- •Affordable price



Info: http://www.dioc16.tudelft.nl/dioc-intro/intro_main.html

DutchEVO Preliminary Specifications

4 Occupants + luggage - Product life-span 200000 km or 15 years - Front 20 kW engine - Front suspension: MacPherson - Rear: Trailing Arm Suspension - Three doors - European legislation & standards.

Mass: 400 kg Full payload: 352 kg 100.000 units/year

Consumer price: 12.000 Euro Max speed: 130 kph

Max. acceleration 0-100:25 sec. Fuel consumption: 2.5l/100km

Range: 400 (+100)km

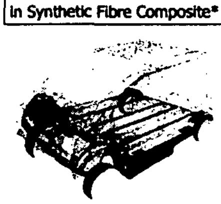
Height: Exterior: 1570 mm; Interior: 1150mm

Exterior length: : 3300; Exterior width: 1550 mm

Which Components?

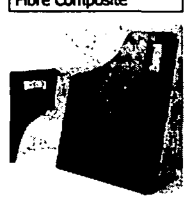
Exterior Component ???

Fully Integrated Bottom Platform in Synthetic Fibre Composite*

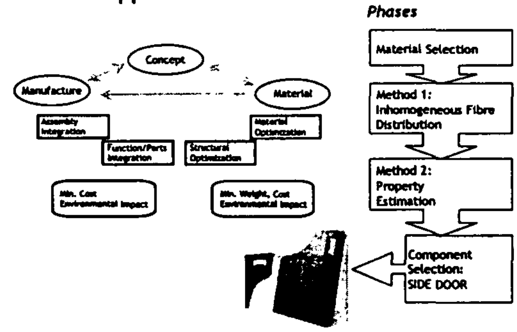


*Paper Study

Side Door in Natural Fibre Composite



Research Approach



MATERIAL SELECTION - Rough Choices & Competition

Material (Experience)	Strength	Density	Price	Manufc-tura-bility	Part Integra-tion	Environ-mental Impact	Weight Reduction Potential
Steels (++)	++	--	++	++	--	++	-
Aluminium (+)	+	-	-	-	--	-	+
Magnesium (-)	+	+	--	-	--	-	+
Plastics (+)	-	++	+	++	++	--	+
Biopolymer (--)	-	+	-	++	?	++	?
Synth. FC (-)	++	++	--	--	++	--	++
Natural FC (-)	+	++	+	?	?	++	?

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MATERIAL SELECTION - Energy Considerations

Material	Virgin, No Recycling	100%Recycling
Ferrous Metals	40	30
Plastics (average)	90	45
Aluminum	220	40
Rubber	70	-
Glass	30	15
Aramid (Kevlar)	25	?
Carbon Fibre	130	?
Plant Fibre	4	?

Energy Required to Produce Vehicle Materials, GJ per tonne (1000 kg)

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BARRIERS FOR MECHANICAL DESIGN - Developing Tool to Estimate Properties

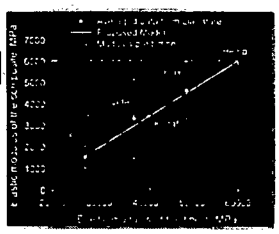
Modified Rule of Mixtures:

$$E_c = \alpha\left[V_f E_f + (1 - V_f)E_m\right] + \beta\left[\frac{1}{V_f/E_f + (1 - V_f)/E_m}\right]$$

α accounts for fibre orientation, length, stress concentration at ends

β accounts for fibre-matrix interface wettability

Basis: Hirsh's Model



Prediction of elastic modulus for PP+40% Hemp and Kenaf reinforced composite material.

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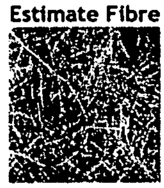
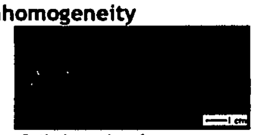
Barriers for Mech Design - Developing Tool to Estimate Fibre Mat Inhomogeneity



Flax



Optical scanning of non-woven fibre, followed by digital image analysis

Relating brightness variation with properties

⇩

Input to numerical modelling

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Part 5

Low Cost Housing

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Sustainable Development

- Definition of sustainable development in the Brundtland report from 1987.
- *"Meeting the needs of the present generation without compromising the ability of future generations to meet their own needs" (Personal note: Our wants have no limit. Sustainability defines limits)*

But:

- Human demand for ecosystem goods and services is growing dramatically
- We have made, and are making, changes to ecosystems of unprecedented magnitude

Wise choices are needed

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Housing Needs & Problem Statement 1

1/3rd of population in developing countries either homeless or without decent shelter (1990). One-half of urban population (2 billion in 2000) in slums/squatter settlements

One of the principle constraints (and need): affordable housing materials (UN Comm. on Human Settlements, 1993), continuous supply.

Risk of intensifying environmental stress when these needs are met - Challenge to meet the demands without squandering scarce (non-renewable) resources.

No single solution for a sustainable settlement

Housing Needs & Problem Statement 2

BUILDINGS:
Account for 1/4th of the world's wood harvest
2/5ths of its material and energy usage
1/6ths of its fresh water usage. (World Watch Institute)

POPULATION GROWTH compels us to multiply the total number of buildings on the planet over the next generation.

ASSIGNMENT: Find ways to provide safe and decent shelter for all without ravishing the global ecosystem.

Possible Applications for Natural Fibre Composites in Buildings

- Interior Walls - Partitioning, Surface paneling
- Roof - False ceiling
- Doors & doorframes
- Furniture, Cupboards, Wardrobes
- Tables, Chairs, Beds

Part 6

Synthesis & Summary

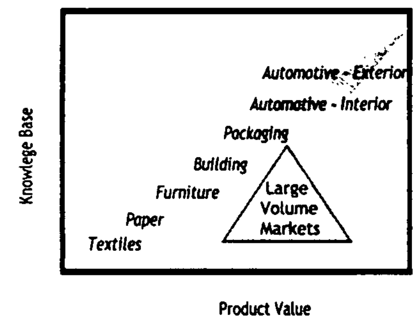
Synthesis (1)

Discipline	Aspect	Comment
Economy	Availability	In several parts of the world
	Price	Attractive
Legislature	R & D Support	EU is supporting
	Farm subsidy	EU does, but under criticism
	Recycling Directive	Debatable policy
Ecology	Life Cycle Analysis	Limited studies
	Waste & recycling	Limited studies

Synthesis (2)

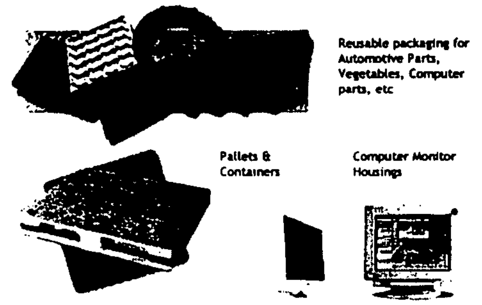
Discipline	Aspect	Comment
Technology	Mat. Quality	Varying
	Mat. Science	Growing body of knowledge
	Fab. Tech.	Under continuous development
	Engineering Properties	Available, but scattered and often proprietory
	Database	Hardly any
	Product demos	Few
	Design rules	Hardly any

Traditional & Future Applications



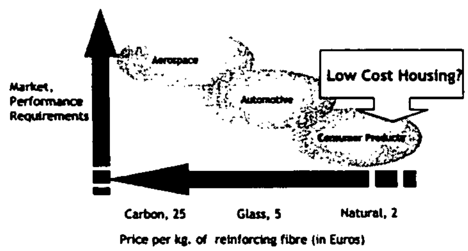
Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

New Opportunities ?



Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

Fibre Price & Application Domain



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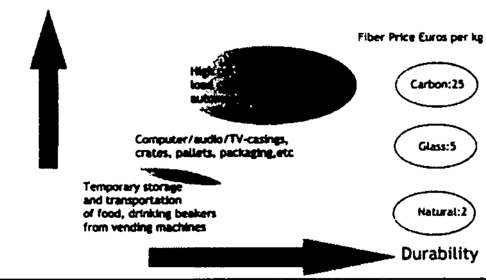
Reliability, Durability & Price



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Design and Co-ordination Needs

- DESIGN: Need for extensive, reliable and easily accessible data, similar to those available for synthetic fibre composites. Database. Standards. Demonstration of product development.
- MANUFACTURE: Semi-finished products
- CO-ORDINATION: Interaction between Science, Design & Manufacture, & Policy Makers

Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

Conclusions

Some agricultural fibers are capable of challenging glass fiber, when used as composite reinforcements.

They have already shown potential in automotive & building applications.

Wide spread use awaits addressing challenges in research, design, manufacture, ecology and legislation.

Overview on Natural Fibre Composites - *Prabhu Kandachar*- 25-29 Nov 2002, Bangalore, India

Acknowledgements

International Centre for Science and High Technology

The International Centre for Advancement of Manufacturing Technology (ICAMT)

Building Materials & Technology Promotion Council

...and all others

Composite

Technology Development & Commercialization

- Successful Case-Studies

Soumitra Biswas

Adviser
Advanced Composites Programme

TIFAC

Technology Information, Forecasting & Assessment Council
Department of Science & Technology
New Delhi

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Composite

Technology Development & Commercialization

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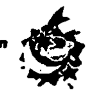
Technology Innovation Chain



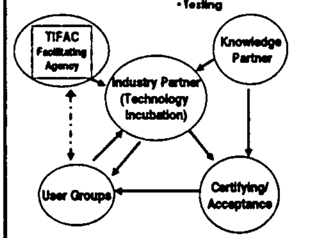
Basic & Applied Research	→	Design, Prototype/ Pilot Scale	→	Manufacturing & Market Development
University/ R&D Labs		Grey Area (Govt. Intervention)		Industry

Advanced Composites Programme

Technology Incubation - Proven Dynamics

- Networking
- Market Intervention
- Awareness Promotion
- Financial Support

- Design Support
- Raw Material Selection
- Fabrication Process
- Product Development
- Testing



- Design Approval
- Field Trials
- Development Orders

- Design & Product Approval

Advanced Composites Programme

Industry – Academia Partnership

Industry	Academia/National Labs
• Technological capability building • Guided technology absorption for reduced concept to commercialization cycle • Financially attractive technology & design support compared to international sources for world-class products • Credibility among users • Immediate improvement in bottom line	• Knowledge shaped into usable products • Expertise scaled up into large volume production • Exposure to industrial operations & user needs for developing marketable products • Attractive consultancy compensation; repeated for technology replication

...A Win-Win Concept

Natural Fibre Composites

Synthetic Fibre Composites

- *Well established world-over for a wide gamut of applications*

Natural Fibre Composites

- *Applications in crude form known from early days of civilization*
- *Scientific knowledge imparted value-added application niches*

Jute Composites

Jute & Glass Fibres

Property	E-glass	Jute
Specific Gravity	2.5	1.3
Tensile Strength (MN/m^2)	3400	442
Young's Modulus(MN/m^2)	72	55.5
Specific Strength (MN/m^2)	1360	340
Specific Modulus (GN/m^2)	28.8	42.7
Modulus/Cost (MN/m^2/£/T)	68.6	171.3
Specific Strength /Cost (MN/m^2/£/T)	1.3	1.05
Specific Modulus/Cost (MN/m^2/£/T)	27.4	131.8

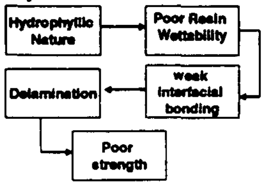
Jute Fibre :

- *Low cost renewable fibre with low embedded energy*
- *Ideal for low load bearing applications*

Jute Composites

Modification of Jute Fibre

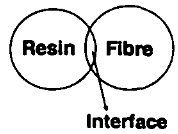
Why ?



Solutions

- Chemical treatment (Titanates, silanes, TDI, Sebacoyl chloride)
- Polymeric coating (PF, RF, polyesteramide polyol...)
- Graft-copolymertzation (vinyl monomers-AN, MMA, VA)

Natural Fibre Composites



Matrices :

- Phenolics
- Polyester
- Epoxy...

Maximum fibre/resin ratio :

- 60/40 for Polyester/epoxy
- 85/15 for Phenolics

Natural Fibre Composites

Salient Features

- Attractive natural wood look
- Waterproof with minimum surface absorption
- Strong & rigid
- Termite proof
- Good nail/screw holding strength
- Cost effective

Natural Fibre Composites

Potential Applications

- **Building & Construction**
  panels, false ceiling, roofing sheets, partition boards, insulating boards, doors & window, wardrobe...
- **Automobile & Railway Coaches**
  trims, body panels, seat & backrest, interior lining...
- **Storage Devices**
  grain storage silos, pallets, crates, boxes...

Advanced Composites Programme

Jute-Coir Composite Boards
[Natura Fibretech Pvt. Ltd., Bangalore]

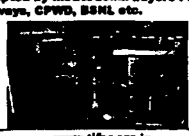
- Coirply (jute + coir + rubber wood waste) as Plywood substitute
- Jute-Coir boards as MDF substitute

Features

- Oriented jute face veneer for wood look
- Water & termite resistance
- Flame retardance
- Excellent nail/screw holding strength

Status

- Slowly penetrating consumer market
- Accepted by institutional buyers : Indian Railways, CPWD, BSNL etc.



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Advanced Composites Programme

Properties of Jute-Coir Composite Boards (Tested as per IS-12406) - 6 mm thick

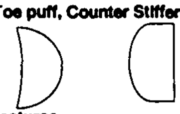
Tests	Observed Values	Specified Values as per IS:12406
Cross Breaking Strength (Kgs/Cm^2)		
a) before boiling	391	275 (min.)
b) after 8 hrs. boiling	270	150 (min.)
Bulk Density (Kgs/Cm^3)	739	500-900
Moisture Content	5.90	5 - 15
Max. Water Absorption (%)		
a) after 2 hrs. soaking	5.1	9
b) after 24 hrs. soaking	9.2	18

Advanced Composites Programme

Jute Composites as Footwear Components
[APL Polyfab Pvt. Ltd. & IJIRA - Kolkata]

Woven & raised jute-cotton fabric impregnated with PS/acrylic/nitrile, EVA

Product Range
- Toe puff, Counter Stiffener & Insoles



Features
- Cheaper replacement of leather & lining material
- Stiffness & better shape retention
- New application avenue of jute composites

Natural Fibre Thermoplastic Composites

PP & PE waste with agro-waste (jute/sawdust/rice husk)

Natural Fibre Micronising → Compounding with PP/PE → Granulation → Injection / Extrusion

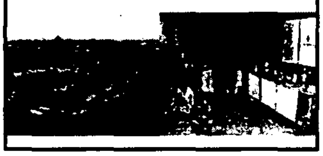
Injection → bobbin, spool, shells, fuse box

Extrusion → crates, pallets, trays, boxes

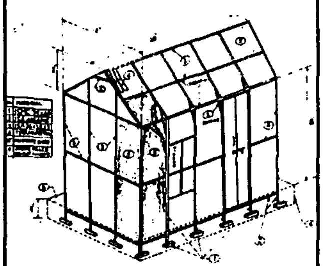
Features
- Cheaper wood substitute
- Corrosion resistance
- Recycling & waste utilization

Gujarat Earthquake Composites in Rehabilitation

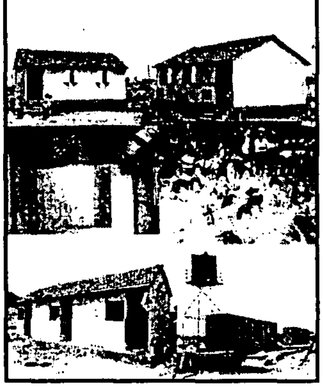
- *392 shelters (20'x12') made of jute-coir composite & bamboo mat veneered rice husk boards supported on steel structure*
- *128 FRP toilet units for community use*
- *25 school blocks(24'x20')*
- *15 shops (12'x8') & one Post Office*
- *250 composite artificial limbs fitted at Mehsana & Bhuj*



Gujarat Earthquake Composites in Rehabilitation



Gujarat Earthquake Composites in Rehabilitation



Bamboo Applications

Bamboo Composite Laminates
(Emmbee Forest Products, Manabari & University of Calcutta)

Features
- ✓ Excellent value-addition
- ✓ Wood/Timber substitute
- ✓ Innovative resin system
- ✓ Termite & borer proof
- ✓ Domestic & International market potential

Applications
- Reconstituted wood for furniture, door & window frames, rails & styles, furniture
- Panels for partitions, wardrobes, cabinets, wall cladding
- Industrial & Domestic Flooring...

Excellent export potential

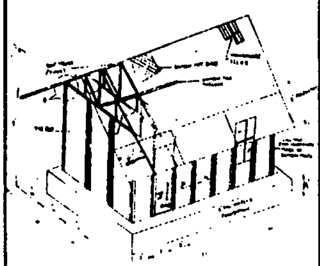
Bamboo Applications

Bamboo Composite Laminates – Flow Chart & QC

QC	Process
QC1 : Select Species	Raw Bamboo ⇩ Silvers/Slats ⇩ / Veneers ⇩
QC2 : Measurement of Thickness & Size	Machining to Uniform Thickness & Edge Straightness ⇩
QC3: Use of Natural Non-toxic Repellent	Starch Removal & Chemical Impregnation ⇩
QC4: Moisture Content	Reduction of Moisture by Gradual Drying ⇩
	Laying of Silvers/Slats ⇩
QC5: Uniform Spreading of Resin	Resin Application ⇩
QC6: Hot Press Temp. & Pressure	Hot Pressing ⇩
QC7: Dimensional Tolerances & Appearance	Formation of Composites ⇩
QC8: Quality of Sanding, Dimensions & Tolerances	Surface Sanding & Finishing ⇩
	Surface Coating & Curing ⇩
QC9: Stamping & Marking	Stamping & Packing

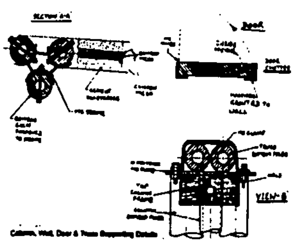
Bamboo Applications

Bamboo Shelter



Bamboo Applications

Structural Details



Advanced Composites Programme

FRP Gear-Case for Railway Locomotives
(Permali Wallace Ltd., Bhopal & RRL, Bhopal)

Features

- Reduced dead weight on locomotives
- Longer life cycle
- No damage on ballast hits & leakage of lubricants
- Easy maintainability

Status

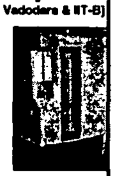
- FRP gear-cases for diesel & electric locomotives developed successfully
- FRP gear-cases inducted by Indian Railways
- W

Advanced Composites Programme

FRP Modular Toilets for Railway Coaches
[Hindustan Fibre Glass Works, Vadodara & IIT-B]

Features

- Aesthetically elegant
- Corrosion resistant
- Light weight
- Longer life
- Easy maintainability



Status

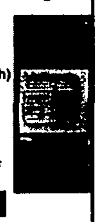
- Four toilets in Mumbai Rajdhani already covered over 2 lakhs Kms.
- 150 toilets fitted to Jan Shatabdi Express

Fast Technology Replication

Advanced Composites Programme

FRP Main & Sliding Doors for Passenger & EMU coaches

- ✓ No corrosion
- ✓ Reduced maintenance
- ✓ Weight saving (100 Kgs./coach)
- ✓ Crash worthiness
- ✓ Ready-to-fit condition
- ✓ Could be painted
- ✓ Successfully field tested
- ✓ 80 FRP doors procured by ICF



Advanced Composites Programme

Below-knee Endoskeleton type Composite Artificial Limb

(Mohana Orthotics & Prosthetics Centre-Chennai & MIT-Chennai)

Features

- Light-weight
- Improved aesthetics
- Near normal gait
- Helps in walking, cycling, climbing

Status

- Fitted to over 700 patients
- Exported to Sri Lanka
- Composite limb costs 8% of imported one

Bagged National R&D Award 2001

Advanced Composites Programme

Energy Efficient Axial Flow FRP Fans

[Parag Fans & Cooling Systems Ltd., Dewas & IIT-B]

- Improved aerodynamic & structural design of impellers
- Fans for *cooling towers (10000 mm dia.), textile mill humidification (1200 mm dia.), mine ventilation (2000 mm dia.), radiator cooling for diesel locomotives (1680 mm dia.) & air heat exchanger (4267 mm dia.)*

Features

- Higher efficiency with appreciable energy savings @ 10 - 30%
- Improved life of mechanical drive system
- Early pay back on replacement : 2 - 6 months

Status

- Successfully performance tested
- Orders received from Railways, Coal Mines, Reliance Industries & others

Advanced Composites Programme

New Projects

- Complete *Interiors for passenger coach*
  Coach to be designed with side-wall panels, partitions, flooring, ceiling, berth modules, etc
  Improving the aesthetics and ergonomics towards improved passenger comfort
- *Sky Bus coach* for Konkan Railway
  Lightweight suspended sky buses running on overhead rails housed in concrete box
- Interiors of *driver's cabin for diesel locomotive*
  An ergonomic improvement of driver's cabin interiors for diesel loco along with allied aesthetics
  New design of the cabin to address appropriate interiors, operational comfort & improved visibility for drivers, heat & sound insulation...

Thank You!

---

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NATURAL FIBER POLYMER COMPOSITES- RETROSPECT AND PROSPECT

Dr. K.G. Satyanarayana

Regional Research Laboratory (CSIR)

Thiruvanathapuram – 695 019

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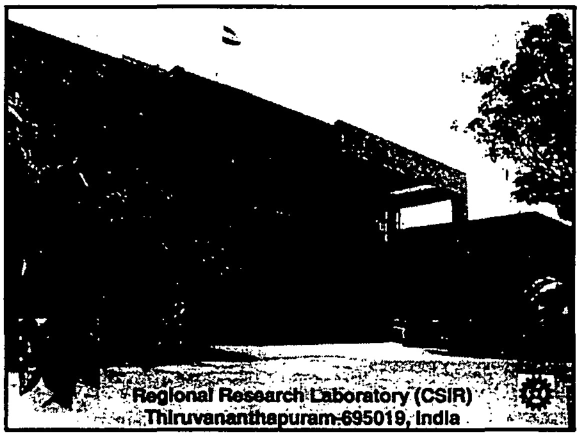


OUTLINE

- Introduction
- Composites
- Natural fibres, Source, Extraction, Structure Properties, cost etc.
- Natural Fibre Composites
  - Current Status
  - Fabrication techniques
  - Properties
  - Products Development
  - Cost Comparison
  - Problems and Solutions
- Choice criteria
- Conclusions

INTRODUCTION

- Building Industry- Fundamental and strategic Sector and sets the basis for economic development.
- Choice of materials for shelter is determined by what is locally available, appropriate and affordable.
- Building materials contribute about 60-70% of the cost of construction based on conventional and traditional building materials, energy intensive and cost is likely to move upwards.
- The demand for housing and buildings is increasing with concurrent material requirement.
- Added environmental concerns→ look at new avenues /alternates to meet the demands of high performance, quality and cost as well as generate employment

INTRODUCTION

- Issue and Possibilities
  - Growing needs of materials with property mixes cannot be met by monolithic materials.
  - Multi objective optimization in material design and selection may be a a solution for this.
  - Composite materials fulfil the above need, which may use abundantly available renewable resources such as plant fibres, agro and industrial wastes ('new resources' for new materials development) → leading to a strategy for their bulk utilization with appropriate processes to develop new materials.

- Much needed basis for innovations in composites is provided by the knowledge and advances available for the S&T understanding of traditional materials in terms of their processing and microstructures.
- Development of composite materials based on natural fibers, their properties and potential applications including building industry, existing problems and possible solutions will be discussed

LIGHT WEIGHT

- A DRIVING FORCE FOR VARIOUS APPLICATIONS
- LIGHT WEIGHT STRUCTURES
- BY MATERIALS [Strength & Stiffness/ Density]
- BY SHAPE [solid plates/stiffened plates]
- By PROCESSING [Riveting/Bonding]

ASPECTS OF LIGHT WEIGHT STRUCTURES

- **STRUCTURAL REQUIREMENTS FOR MATERIALS**
- **Production aspects [Reproducibility/ Sustainability]**
- **Functional aspects [Efficiency/Comfort/ Reliability]**
- **Technical requirements [Properties/Repairing/ Energy Consumption]**
- **Economical aspects [Production/Operating]**

COST ASPECT

- Low Cost—Not Low Value or low Quality but affordable.
- Life Cycle Assessment—Good Quality Product, may be with higher cost than similar material but resulting in savings in long term/ lasts longer & does not require frequent and expensive maintenance.

–Sergio Meriani

Composite Materials

- **structured combinations of continuous and discrete phases in which**
- **the stronger and stiffer discrete phase (reinforcement) is held**
- **in the weaker and softer continuous phase (the matrix) by interfacial bonding**

Composite Properties Influenced by Fibres

- **Rigidity (Modulus of elasticity): Rule of Mixture gives maximum gain – often unrealistic**
- **Tensile Longitudinal Strength**
- **Initiation of fracture of fibres**

Composite Properties Determined by the Matrix

- **Transverse mechanical properties**
- **Interlaminar shear strength**
- **Compressive strength**
- **Plasticisation of the matrix**

Composite Properties Determined By The Matrix

- Service temp
- Fire and corrosion resistance
- Tool design and fabrication process

Properties Controlled by Interface/bonding

- Fracture energy/Fracture toughness
- Interlaminar fracture energy also depends on the fabric type for the same V_f.

- Motivation
- Current trends
- Why the rapid growth?
- Research Issues
  - Compatibility, Strength, Modulus, Creep, Moisture, Cost. Durability, Recycling Needs

Motivation

- **Composites – Forest Products**
- **Natural Fiber's appeal:**
  - Renewable and available in most countries
  - Lightweight and hence high specific properties
  - Non-toxic/ No Hazards
  - Cost
  - Biodegradable
  - Moderate strength and modulus
  - High aspect ratio

Drawbacks

- **Poor Compatibility with matrices**
- **Non-uniform and wide variation in properties**
- **Lower strength and modulus compared to synthetic fibres**
- **High moisture absorption.**

Current Trends

- Rapid growth
- 13 % compounded last 10 years
- Currently 400 million lbs annually
- Growth projections to 2005:
- Building products 60 % per year
- Automotive products 50 % per year

[Ref.: Eckert, Kline & Co].

Building Products

- Current
  - 75 % of market
  - Decking, Trim, Fencing, Window/door profiles
- Soon
  - Shutters, siding, shingles
- Most applications have modest structural requirements

"Synthetic Hardwood" SHW Technologies Inc, Guelph, Ontario

- Process:
  - 70 % PP/30 % Wood Flour Ram Extrusion Cold Drawing
  - Oriented PP and High Void Content (40 %)
- Properties

Properties	Flex Str, psi	Flex Mod, psi
– PP	7,000	270,000
– Wood	14,000	1,300,000
– "SH"	20,000	1,100,000

Automotive Applications

- Less developed (about 8 % of market)
- Primary
  - Trim panels - Spare tire covers - Seatbacks
- Secondary
  - Instrument panels - Glove boxes
  - Headliners - Sun visors
- Exceed 100 million lbs of fibers in 2005

Lower Costs Sought

Fiber	Price, cents/lb	Specific Gravity	Price, $/ m³
Glass	85	2.6	4,850
Wood	12	1.6	420
Flax	18	1.5	600
PP matrix	33	0.9	650

- High Moisture Adsorption (> 10%)
  - (2-3 % after compounded)
- Must dry to compound
- Can use vacuum venting in extrusion
- Increases cost
- Interferes with fiber/matrix coupling
- Causes swelling
- Lowers strength and modulus
- Increases creep

Short Fibers Dominate

Advantages	Disadvantages
•Lower cost •Easier processing •Extrusion •compounding with intensive mixing •Extruded products •Conventional injection molding •Complex shapes	•Lower properties, particularly • Strength • Impact • Hard to orient

Long Fiber Systems

- Harder to make prepreg
- Mat composites not better than injection molded composites in tensile strength
  - Flax/PP comparison by Peijs at Eindhoven
- Long fiber pellets slightly better that short fiber pellets
  - Impact strength benefits most (> 200%)
- Why don't long fibers perform better?

CURRENT STATUS

POLYMER-NATURAL FIBER COMPOSITES

- Use of natural fibers/plant fibers with clay/polymer is an old concept [eg: clay bricks reinforced with rice straw],
- Renewed and greater interest in recent times in using these fibers for reinforcing plastics to develop composite materials.
- Reasons:
- Mostly driven by need-cum-resource base[abundant availability of a number of renewable resources which are under utilized and or amenable for value addition].
- Quest for new materials which support global sustainability.
- Diversification of uses to new areas, addressing to global environmental and stable economy through agro-industry, etc.
- Need includes exploitation of potential light weight of fibers, biocompatibility, eco-friendliness, reduction in energy consumption, etc.

POLYMER-NATURAL FIBER COMPOSITES *(Contd)*

- Also, they possess low density (1000-1200 kgm^{-3} compared to 2500 kgm^{-3} of glass fiber), better noise and heat insulation properties, not posing health or environmental hazards unlike man made fibers, their biodegradability.
- Processed by general polymer/composite processing techniques. Thermo forming is also developed for short wood fiber composites. Technique depends on the type, dimensions, quality requirement, etc. of the end product.
- Mechanical properties available
- Cost: 5 Gallon buckets made of HDPE- 40% sisal composite even with existing mold design produced by injection moulding process costs US $ 1.50 compared to US $ 1.65 for the same bucket made of matrix.
- Applications:

  During the World War II, cotton-polymer composite was used by the military for radar air-craft.

  Electrical insulations and semi-structural applications with thermoset matrix.

Comparison of Composites for Choice Criteria for Developing Countries

Criteria	NFIC	GFRP
Raw material production (fibers/Matrix)	X	X
Reinforcement in required form	Y	X
Flexibility of technology	X	X
Technology is proven	O	X
Skilled labor requirement	Y	Y
Quality control of raw material/product	O	Y
Satisfy local need	X	X
Improve quality of life	X	X
Use of local raw material	X	X
Provide employment	X	X
Solve sp problems	X	X

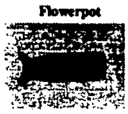
X – Criterion fulfilled
Y – Criterion partially fulfilled
O – no definite answer
NFIC – Natural Fiber Incorporated Composites
GFRP – Glass Fiber Reinforced Composites

APPLICATIONS OF PNFC

- *Automobile interiors*
- *Shipping pallets*
- *Construction products* → tiles
- *Office products*
- *Furniture*
- *Storage containers* →*buckets, crates*
- *Window and picture frames*
- *Food service trays*
- *Handles* → roller handle
- *Fan housings and blades*
- *Toys*
- *Flower pots*


Flowerpot


Fan housing


Handle

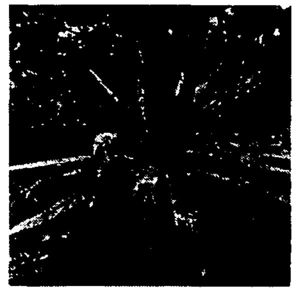

Toys

NATURAL FIBERS

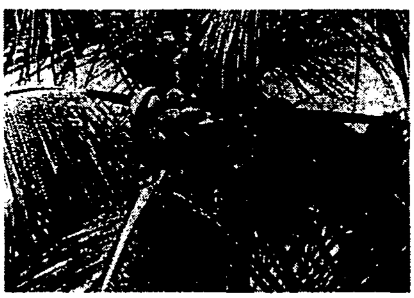
- FIBRES, THEIR ORIGIN, EXTRACTION, STRUCTURE AND PROPERTIES
  - Natural fibers (Vegetable or Lignocellulosic) are classified into three categories depending on the part from which they are extracted:
    - Bast fibers (Jute, Mesta, banana)
    - Leaf fibers (sisal, Pineapple)
    - Fruit fibers (coir and arecanut)

BANANA PLANT

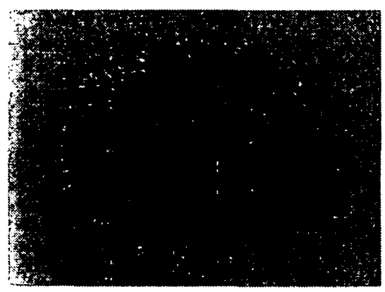
SISAL PLANT



COCONUT TREE



PALMYARA TREE



EXTRACTION METHODS, AMOUNT AND LENGTHS OF VARIOUS NATURAL FIBERS

Fiber	Method	Amount	Length (mm)
Banana	Manual/raspador	1.5 wt% of stem	300-900
Coir	Retting/mechanical	8% of nut (This weighs 1.1 Kg)	75-150
Jute	Retting and beating/chemical	3-4% of stem	1500
Mesta	Retting and beating/chemical	"	--
Palmyrah	By hand (by beating)	0.5 Kg per stalk	300-600
Pineapple	By hand/decorticator	2.5-3.5 wt% of green leaves	900-1500
Ramie	Decorticator	2.5-3.5 wt% of bark	900-120
Sisal	Manual (beating)/microbial/retting/decorticator	3-4% of green leaves	900-1200
Sunhemp		2-4% of green stalk	--

ANNUAL PRODUCTION OF NATURAL FIBRES AND SOURCES

Fibre source	World Production 10^3 tonnes	Origin
Abaca	70	Leaf
Bamboo	10,000	Stem
Banana	200	Stem
Broom	Abundant	Stem
Coir	100	Fruit
Cotton Lint	18,500	Stem
Elephant Grass	Abunbant	Stem
Flax	810	Stem
Hemp	215	Stem
Jute	2,500	Stem
Kenaf	770	Stem
Linseed	Abundant	Fruit
Nettles	Abundant	Stem

Fibre source	World Production 10^3 tonnes	Origin
Oil Palm Fruit	Abundant	Fruit
Palmirah	Abundant	Stem
Ramie	100	Stem
Roselli	250	Stem
Rice Husk	Abundant	Fruit/grain
Rice Straw	Abundant	Stem
Sisal	380	Leaf
Sun Hemp	70	Stem
Wheat Straw	Abundant	Stem
Wood	1,750,000	Stem

PHYSICAL AND MECHANICAL PROPERTIES OF NATURAL FIBERS

Fiber	Initial modulus (GN/m^2)	Ultimate tensile strength (MN/m^2)	% Elongation at break	Flexural modulus (MN/m^2)
Bamboo	20	--	--	--
Banana	7-20	54-754	10-3.5	2.0-5.0
Sisal	9-22	568-640	3-7	12.5-17.5
Pineapple leaf	34.5-82.5	413-1627	0.8-1	0.2-0.40
Jute	18	226	1.3	0.3-0.5
Ramie	--	870	3-4	0.08-0.12
Mesta	--	--	1-2	0.35-0.65
Sunhemp	--	760	2-4	12.5-17.5
Palmyrah	4.4-6.1	180-215	7.0-15.0	--
Talipot	9.3-13.3	143-263	2.7-5	--
Coir	4-6	105-175	17-47	15-20
Cotton	1.1	200-400	6-7	0.03-0.10

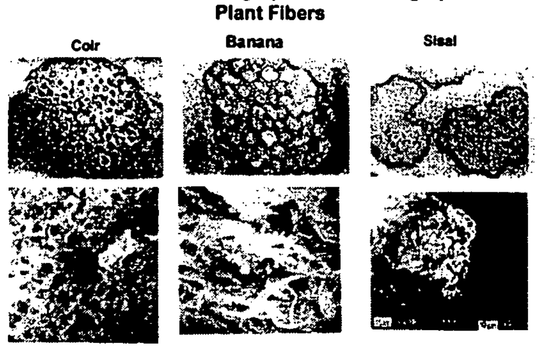
CHEMICAL COMPOSITION AND MOISTURE ABSORPTION OF SOME NATURAL FIBRES

Fibre	Cellulose %	Hemi-cellulose %	Lignin %	Moisture regain at 65% R.H	Transverse swelling in water %
Banana	60-65	6-8	5-10	10-15	18-20
Coir	43	<1	45	10-12	6-15
Cotton Lint	90	6	-	7	20-22
Flax	70-72	14	4-5	7	20-25
Jute	61-63	13	5-13	12.5	20-22
Mesta	60	15	10	13	20-22
Palmirah	40-50	15	42-45	10-12	–
Pine Apple Leaf	80	-	12	10-13	18-20
Ramie	80-85	3-4	0.5	5-6	12-15
Sisal	60-67	10-15	8-12	10-12	18-20
Straw	40	28	18	-	-
Sun Hemp	70-78	18-19	4-5	10-11	18-20
Wood	45-60	23	27	-	-

SPECIFIC STRENGTH, COST AND ENERGY CONTENTS OF SYNTHETIC AND NATURAL FIBRES

Fibre	Sp.gr.	Specific tensile strength (GPa)	Specific tensile modulus (GPa)	Cost (US$/tonne)	Energy content GJ/tonne
Plant Fibre	0.6-1.2	1.60-2.95	10-130	200-1000	4
Glass	2.6	1.35	30	1,200-1,800	30
Kevlar	1.4	2.71	90	7,500	25
Carbon	1.8	1.71	130	12,500	130

Cross Sectional Micrographs and Fractographs of Plant Fibers



Natural fiber reinforced polymer composites

- **Can be used to replace virgin, recycled, mineral or glass filled polymers in most applications to *reduce cost, enhance appearance and improve performance***
- **Fibers:** Coir, Jute, Kenaf, flax, agave, sisal,
- Sunhemp, rice and wheat straw. Dust from processing fiber
- **Polymers:**Polyester, Epoxy, Phenolics, Polypropylene, polyethylene, polystyrene

NFPC SYSTEM PREPARED BY VARIOUS PROCESSING TECHNIQUES

Composite systems	Technique
Cotton-polymer	Press molding
Coir-Polyester	Hand lay-up / Press molding
Coir/glass-polyester	Hand lay-up
Banana-polyester	Press molding
Banana-cotton fabric-polyester	Press molding/hand lay-up
Sisal-polyester	Hand lay-up
Pineapple-polyester	Press molding/hand lay-up
Jut-polyester	"
Jute-epoxy	"
Jute-glass-polyester	" / filament
Bagasse-polyester	"
Straw-polyester	"

Mechanical properties of selected plant fiber-polyester Composites

Fiber (wt %)	TS (MPa)	YM (GPa)	FS (MPa)	FM (GPa)
Continuous-				
Unidirectional	129	8.5	192	7.5
Sisal(40)	121	8.0	–	–
Banana(30)	45	4	56	4
Coir(30)				–
Short(20mmL)-Random	34.5	1.9	86.4	–
Sisal(25)	43.5	2.3	92	–
Banana(25)	14.0	1.4	31.2	–
Coir(25)	28 -36	3.3	50 -64	–
Banana-Cotton (woven Fabric)				

TS- Tensile strength, YM- Young's modulus, F.S – Flexural strength, FM – Flexural modulus, WOF – Work of fracture (Charpy test), * 0.5 Vf,

Impact performance of selected plant fiber-polyester Composites

Fiber	Fiber Properties		Composite Properties	
	Toughness* (MNm^{-2})	Spiral angle	Fiber pull-out length (mm)	WOF (KJ/m^2)
Banana	816	12	1.9	51.6
Pineapple	970	15	2.2	79.5
Sisal	1250	20	3.5	98.7
Coir	3200	45	1.1	43.5

* calculated from area under stress-strain curve

POLY COIR

- POLYCOIR – a new thermoset mouldable natural fibre polymer composite. A substitute for wood-based products. Being renewable fibre, its everlasting scope.
- FEATURES
- Wood-like appearance
- Mouldable to various shapes for decorative appearance and appropriate end use
- Physical & Mechanical properties judiciously
- Variable to substitute various types & grades of wood-based products.

PROCESS STEPS

- Making needle-felt of coir fibre
- Resin impregnation and forming prepreg sheets
- Prepreg sizing and laying
- Hot pressing the prepreg into final shape
- Trimming and finishing

Physical input per ton of a typical product: (High density,BWR,FR grade)

- Coir fibre : 1 ton
- Resin : 0.25 ton
- Energy : 500 kwh

MAJOR EQUIPMENT AND ACCESSORIES:

- Needle felting machine
- Prepreg forming unit
- Hydraulic hot press
- Dies and Moulds
- Steam/Thermic fluid heater
- Resin manufacturing plant

PROPERTIES*

- Density (Kg/m3) - 500-1200
- Moisture Content (%) - 8-12
- Flexural Strength (Mpa) - 15-70
- Flexural modulus (Gpa) - 2-5
- Tensile Strength (Mpa) - 10-55
- Water resistance - CWR TO BWR
- Fire resistance - Retardant
- Termite resistance - Termite proof
- *The upper limit of the Isotropic properties corresponds to those of general purpose medium density compreg for general engineering purposes.

Flexural properties of POLYCOIR (density 1.0) in comparison with wood and plywood

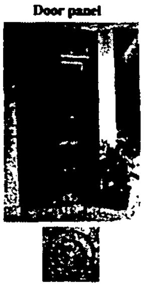
Material	Density g/cm³ Kgm³	Flexural Strength (MPa)		Moduls (GPa)	
		II	Ir	II	Ir
Solid timer (20 mm) (Douglas Fir)	500	2.2	80	0.80	12.7
Plywood (4.8 mm)	520	16	73	0.89	12.0
Polycoir(5mm)	1000	56	63	4.3	4.7

APPLICATIONS

- As Building Material (Acoustic & False roof panels, door panels,partitions,corrugated roof sheets,etc.)
- As furniture Components (Chair/Table tops,etc.)
- Others (Automotive interiors/instrument covers/machinery components)

POLYMER-NATURAL FIBER COMPOSITE [Poly-Coir]

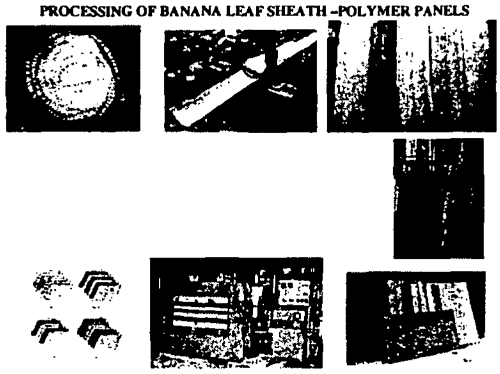
Door panel



Acoustic Boards

Chair

PROCESSING OF BANANA LEAF SHEATH -POLYMER PANELS



Properties of OSM laminates – Effect of wood-veneer facings(wvf) (type-III, 6mm, 20% resin, 0.7mm thick rubber-wood-veneer)

Properties	Unit	Without wvf	With wvf
Density	Kg/m^3	400-450	600-700
Tensile strength, ∥ (⊥)	MPa	28 (18)	42 (20)
Young's modulus, ∥ (⊥)	GPa	3.1 (2.4)	4.3 (2.4)
Flexural strength, ⊥ (∥)	MPa	29 (15)	45 (17)
Flexural modulus, ⊥ (∥)	GPa	2.7 (2.3)	6.2 (3.3)

Note: ∥ and ⊥ correspond to values measured parallel and perpendicular respectively to fibre orientation of the surface layer.

Table-7. Properties of banana leaf-sheath OSM laminate (BLOSM) and commercial panels

Properties	unit	BLOSM*	Plywood	MDF	Particle board
Density	Kg/m^3	600-700	400-700	750-850	700-800
Moisture content	Wt%	6-12	5-15	5-15	5-15
Tensile strength(∥)	MPa	33-42	35-55	7-8	4-4.5
Flexural strength(⊥)	MPa	38-45	28-48	25-28	12.5-15
Flexural modulus (⊥)	GPa	5.8-6.2	3.5-7.4	--	--

Note: ∥ and ⊥ correspond to values measured parallel and perpendicular respectively to fibre orientation of the surface layer. *BLOSM with 0.7mm thick wood veneer facings.

Recommended equipment required for Research, development and manufacture of natural fibre

- Fibre Extraction Equipment
- Fibre Sorting Equipment
- Low Load Fibre Strength Testing Equipment
- Fibre Pretreatment Unit
- Fibre Weaving of Knitting Equipment
- Filament Winding Equipment
- Hand Layup Composite Fabrication Equipment
- Polymer-Fibre Spray Unit for Spray Formed Composites
- Database on Properties of Fibres and Composites of Different Compositions-Carpet Plots
- Computers and Computer Aided Design Programs for Design of Composites

Composite Testing Equipemnt

- Optical Microscopes
- Scanning Microscopes
- Density Measurement Equipment
- Moisture Absorption Equipment
- Tensiometer or Instron or MTS Equipment for Measuring Strength, Modulus and Fracture Toughness
- Impact Energy Tester, Radiographic Equipment, IR Equipment
- Weatherability Test Chambers to Test Deterioration Due to Exposure to Elements of Weather
- Flammability Testing Equipment
- Dilatometer for Measurement of Co-efficient Expansion
- Simple Machining Equipment to Shape Composite Components

Injection Molding Cost Savings!!! (even with existing mold designs)

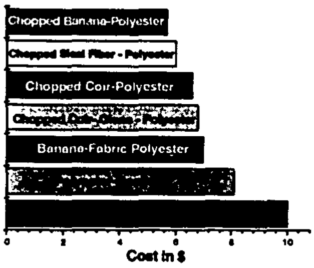
5 Gallon Bucket	HDPE	HDPE/40% Sisal
Part Weight(g)	900	1050
Resin Cost($/LB)	050	0.45
Resin Cost ($/part)	0.99	1.04
Cycle Time(seconds)	28	20
Molding Cost(@/hr)	85	85
Molding Cost($/part)	0.66	0.47
TOTAL PART COST($)	1.65	1.50

Fully-Coupled, Polypropylene(1)/Natural Fiber Composites

Fiber	Fiber(2) Loading (%)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Izod notched (J/m)	Izod unnotched(J/m)
Jute	50	73	8.5	100	7.5	40	210
Sisal	50	60	6.0	65	5.1	55	190
Wood(3)	50	39	5.5	68	5.3	23	90
none	0	32	1.7	41	1.4	24	620

Solvay Fortilne 1602, MI=12
Property values(except impact) are proportional to fiber loading
30 mesh pine

Comparative Cost of NFIC and GRFP and Polyester for the same dimension



POLYMER-NATURAL FIBER COMPOSITE PROBLEMS

- Criteria for selection of the plant fibers→ technical and chemical properties, performance and environmental aspects.
- The properties well documented but show a wide range of properties even for the same type of fibers →resulting in large scatter of properties for their composites.
- Criteria for justifying plant fiber polymer composites in various applications → cost effectiveness to satisfy specific requirements or substitution of existing products.
- PNFC can replace GRP products in developed countries.
- In developing countries or under developed countries, wood based materials are still cheaper than plant fiber composites on volume basis due to higher cost of raw materials. But as a wood substitute in these countries, it may be possible to use natural fiber composites only with appropriate design and fabrication of products to achieve material saving and over all economy. Otherwise, commercialization of these becomes difficult despite their attractive properties.

SOLUTIONS/SUGGESTIONS(Contd) Polymer Natural Fiber Composites

- Attempts to produce genetically engineered plant fibers to get consistent properties,
- Development of natural resins and their composites based on renewable resources with a stress on ecological aspects as well as replacement of wood/GRP in various applications for wider acceptance.
- Quality aspects should be defined properly whereby standardized quality specifications should become available. This is important since quality criteria depends on the envisaged application.
- For durability and dependability, more information on resistance to environment should be known.
- Also exchange of different raw materials (when properly processed) is reported possible so that dependence on one or two raw material by the user increases.

SOLUTIONS/SUGGESTIONS *(Contd)*

- Development of suitable surface treatments to plant fibers including insitu sizing, is required for better bonding, proper dispersion of fibers and dimensional stability. [For eg. Modification by mercerization and silane treated sisal fiber incorporated epoxy composites showed reduced moisture absorption and improved mechanical properties over composite containing untreated sisal fibers].
- Research needs -→Treatments for biodegradation, Reduction of swelling properties, Heat and Flame Resistance and Alkaline Resistance.
- Industrial production and availability of various plant fibers which have potential for use in development of composites for various applications. This includes systematic extrusion methods to get consistent quality fibers at favourable costs including in different types/shapes (non-woven/mats/prepegs, etc.) and statistical data on the availability of the fibers. This would bring the farmers a new source of income in future.
- Generation of a data bank on the technical properties including weathering aspects of these fibers and their different types such as non wovens, mat, etc. This would attract more user industries to find new applications.

SOLUTIONS/SUGGESTIONS *(Contd)*

- Development of surface treatments for these reinforcements for achieving better bonding with resin and durability in different environments.
- Development of fiber preform technology (prepreg) for optimum fiber orientation and component design.
- Development of cheaper resins including from plant origin which would be compatible with plant fibers and properties comparable with synthetic resins as well as taking care of environmental aspects.
- Development of appropriate designs and processing techniques for composite to meet customer satisfaction in respect of cost, performance and not the least appearance.
- Possibility of exporting these 'green/bio Composites' to Europe/USA and other countries where ecological and biodegradability have greater premiums.
- On the lines of European Commission, Establishment of a forum under the State or Central Government to look into various aspects mentioned above.

PROSPECTS/PERSPECTIVES POLYMER-NATURAL FIBER COMPOSITES

- Potential markets for natural fiber incorporated composite with polymer matrix include construction, machine building, sports, biomedical, automotive and aircraft sectors.
- For automotive application of plant fiber composites, attractive characteristics are light weight, noise reduction, reduced fiber brittleness and post moulding treatments, diminished tool wear, operator safe, better waste management but not the least is cost factor [with FRP 7% ashes remain after burning while no such problem exist with plant fibers].
- Banana leaf sheaths-PF panelling materials and bamboo-PF resin composites for roofing and as wood-substitutes have also been developed with thermo-plastics.
- Use of plant fibers in composites in USA, Japan and Canada; 20 major European Country Research Institutes active product development.
- Market-oriented study conducted on plant fibers has thrown light on exploration of potentials of various non-food fibers and their market, identification of gaps in the R&D needs and appropriate agencies such as industries, R&D institutes and universities.

PROSPECTS/PERSPECTIVES (Contd..)
POLYMER-NATURAL FIBER COMPOSITE

- Recent studies in Australia have shown that wood (flakes/ waste)-polyethylene composite with 50:50 ratio exhibited higher or equal stiffness, UV stability and heat deflection temperature as that of poly propylene (PP) fascias (bumper covers of automotive) thus indicating this composite may be suitable material for fascias and other auto body parts. In fact, flexural modulus of this composite is 2250 MPa and impact strength 5-6.3 J/mm.
- Cotton - phenolics/Jute-polypropylene/Sisal-PF foam are being used as interior trim parts (Roof lining, rear wall lining etc.) on cars produced by Mercedes in Brazil.
- Sisal / flax-epoxy composite as roof inner parts of luxury Sedan Car in Germany
- Technology developed with plant fiber incorporated composites in Germany is being introduced in North America.
- BASF, Germany produces flax or sisal fiber –polypropylene composites called "NMT" (natural fiber reinforced composites), which are 17% lighter than GRP without any sacrifice in warpage, an important factor for such applications.

PROSPECTS/PERSPECTIVES (Contd..)
POLYMER-NATURAL FIBER COMPOSITES

- Glass fiber suppliers such as Owens Corning are exploring a joint venture opportunities with natural fiber producers to broaden their supplies to automotive industries.
- Composites synthesized by Delaware Group in USA using the natural resins with glass fibers as well as flax and hemp fibers revealed E-glass fiber containing composites showed tensile strength of 400 MPa, Young's modulus 20 GPa and a fracture energy of 50 kg/mm which are comparable with those obtained in composites with synthetic resins such as vinyl ester and polyester.
- Composites, processed by RIM technique using plant fibers (flux, hemp, jute and banana) with appropriate sizing through surface modification, showed comparative tensile and flexural properties with those obtained using synthetic resins. In fact, flax fiber-soya resin composite exhibited better properties than flax- PP composites when evaluated for automotive applications.
- Recycled thermoplastics can be used with plant fibers to develop composites for building and construction applications as both structural and non structural components.

PROSPECTS/PERSPECTIVES(Contd..)
POLYMER-NATURAL FIBER COMPOSITES

- Acoustic and thermal insulation, dimensional stability, water resistance, microbial resistance and non flammability are essential for non-structural applications. For structural applications, mechanical property and weight are important factors. For example, specific flexural stiffness of polyester-straw (60 wt %) composite is found to be 2.5 times greater than that of the matrix and half that of soft wood and GRP. Work of fracture of this composite is half that of soft wood and hence could be a potential wood substitute in building applications.
- Another interesting collaborative programme is between Kafus Biocomposites, a wholly owned Kafus Environmental Industry and Visteon of Ford Motor Company, USA to jointly develop and produce natural fiber composites for auto industry with long term objective to become global leader in bio-composites field. Develop non-woven mats and panel products using kenaf and other natural fibers for door panels, seat backs, package trays, etc for Ford and other auto industries. Ford would evaluate and commercialize these natural fiber composite products in automotives.

PROSPECTS/PERSPECTIVES (Contd..)
POLYMER-NATURAL FIBER COMPOSITES

- Dallamer Chrysler's research department in Ulm in Germany has field tested flax-PP composite as car underbody cover which took off at 94 km/hr after submerging in the water tank. As an exterior, small trial with 200-300 components made of the same composite started in 1998-99 and it is estimated that 5000 components can be produced in 2 days with an out put efficiency of 20 seconds indicating uninterrupted production process to cut over time and cost. They have decided to use natural fiber based composite in all their future cars.
- US Federal and UK Civil Aviation Authorities (FAA/CAA) have decided to approve the use of natural fiber based composites in aerospace structures as interior components such as parcel shelves, headliners and interior trim panels.

PROSPECTS/PERSPECTIVES (Contd..)
POLYMER-NATURAL FIBER COMPOSITES

- Natural fibers and the data on their properties, processing techniques of their polymer composites available.
- A number of problems still exist for the wide spread applications of both MMC and PNFC.
- Need for further research to make them economically viable and acceptable particularly by developing and underdeveloped countries. This include, development of cheaper resins that are compatible with natural fibers and properties comparable with synthetic resins; development of reinforcements in required forms such as woven or non-woven mats are reasonably low cost, and development of appropriate designs and processing techniques for composite to meet the cost and performance.
- Appropriate knowledge transfer including training to adopt new products is called for between R&D personnel and user industries both in India and abroad.

CONCLUSIONS

- Natural fibers and the data on their properties, processing techniques of their polymer composites available.
- A number of problems still exist for the wide spread applications of PNFC.
- Need for further research to make them economically viable and acceptable particularly by developing and underdeveloped countries. This include, development of cheaper resins that are compatible with natural fibers and properties comparable with synthetic resins; development of reinforcements in required forms such as woven or non-woven mats at reasonably low cost, and development of appropriate designs and processing techniques for composite to meet the cost and performance.
- Appropriate knowledge transfer including training to adopt new products is called for between R&D personnel and user industries both in India and abroad.

Manfuacturing Methods for Eco-friendly Cost Effective GRP Composites Building Products

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1.0 Introduction

Glass Reinforced Polymers (GRP) and Composites, the fast emerging new class of materials, are making significant gains in a thousands of industrial applications, ranging from military and aerospace, (aircraft, rockets, missiles) to transportation (automobiles, highway bridge structures, passenger railway coaches), house and building construction (doors, door frames, window shutters, partition/wall panels, roof panels, water supply and sanitary fittings), energy sector (e.g. fuel cylinders of natural gas vehicles, blades of wind-powered turbines) and medical engineering (bio-medical implants) and sports and leisure industries (golf, skis, tennis rackets, etc.). It is reported that currently as many as 40,000 industrial products are being made out of composites the world over.

The Composite materials offer exciting advantages over known structural materials, in terms of stiffness-to-weight and strength-to-weight ratios, high resistance to abrasion, dimensional stability, amenability to be engineered into any desired shape and size, resistance to chemical and atmospheric corrosion, lower tooling costs, simplification of manufacture by parts integration, etc. The mechanical properties of composite materials is shown in Table–1. Material property compartion between composites and other materials is shown in Fig. 1. It is no wonder, therefore, that these structurally superiour composites are acclaimed as the wonder materials of the future, replacing the traditional materials like wood, metals, concrete etc.

The current composite production technology used for manufacturing products for industrial, and building & construction applicatons are based on the aerospace community's technology spin offs and combined experience with composite parts made with fiberglass fabric and unifirectional materials. This experience has been adapted to chopped strand glass fibres, which are the common form of fibres used for composite building products. The production of composite parts with thermosetting resins involves many steps depending on the nature of the product.

During the cure cycle, the glass fibres a soft, multi-layered mixture and resins in liquid form are transformed to a hard structural component. The resin changes from a liquid to a rubbery and eventually to a solid at the gel point. Beyond the gel point, there is little resin movement or flow; typically, the cure is 40 to 60 % completed, and the final shape and thickness of the composite are fixed.

In the curing process, several requirements such as void elimination, solvent removal, consolidation, fiber wet-out, resin removal, must be met simultaneously

Very different production methods are required for manufacture of composite parts with varing valume / functional requirements. Even though the use of composite materials can achieve part reductions up to 60 % over conventional metal assemblies, composite components often need to be trimmed to net size and/ or shape and attached to the final assembly. Machining, drilling, fastening and assembly requirements peculiar to composite structures also looked into.

2.0 Production Methods for GRP Composites

Glass Fiber-Reinforced composites can be produced by a variety of different methods such as; Hand-lay-up technique, Spray-up, Vacuum Bag, Compression Moulding, Resin Tranfer moulding, Filament winding Pultrusion etc. The schematic diagram of some of these production methods are shown in Fig.2.

Any one of these methods affects the properties of the part to be built with respect to dimensional precision, surface smoothness, trimming, machining and assembly procedures, quality and reproducibility, durability, reliability and safety, and production costs.

The production costs of composite part includes expenditures for manufacture of tools (molds), lay-up of fibers and matrix resins, processing of the matrix resins (cure), trimming and machining after curing, assembly of parts, surfare fininshing and quality control.

The choice of the most suitable production method for a given structural part depends on the performance requirements of the part, the characteristics of the selected materials, the available facilities (type, size, degree of automation).

3.0 Tooling Aspects

Glass Fiber-Reinforced resin systems in their virgin state are soft and pliable. Prior to their curing, the individual layers of a laminate must be laid up on tools whose surfaces correspond exactly to the shape of the part to be produced.

High-quality tools, therefore, are necessary prerequisites for all production methods. The selection of the tool materials and the construction of the tool depend on the curing temperature of the resin system, number of parts to be produced, desired surface quality.

Commonly used tool materials include wood, plaster of paris, metals, fiber reinforced composites, etc. The surface quality of the tool is of critical importance because the finished part will reflect all irregularities if any. The manufacture of most tools commences with a full-size master model of the part to be produced.
As a rule, the usually expensive master model cannot accept thermal or

mechanical loads and is retained as reference and control configuration for the tools made of reinforced polymer materials. The processes applied for building the tool are pouring of a layer of plaster of paris on the master model produces a reverse of the intended shape of the part (negative impression), pouring of another layer on the negative impression creates a positive impression, i. e., the desired contours of the part, on this true copy of the master model the reinforced plastics tool material is laid up and cured after application of a finishing coat to its surface, the tool is mated to a stable substructure, and structural parts laid up and cured on such tools have configurations identical to those of the master model except for possible shrinkage.

The manufacture of metallic tools is substantially more complicated as (a) in case of developable surfaces the tool contours are approximated by bending or rolling of sheet or plate material which is then adjustably attached to the substructure and (b) in case of non-developable surfaces additional machining and welding operations are necessary.

Filament-wound vessels with closed end sections require tools which either remain inside the vessel as liners, or are removed destructively after curing by melting, dissolving, or dismantling ("lost" tools). Depending on the relative coefficients of thermal expansion of the tool and the part to be produced, departures from the design configuration may occur because of dissimilar thermal deformations and must be guarded against. In increasing numbers, tools are manufactured from composite materials. Their advantages are lower weight, lower thermal strains, good repair and shorter manufacturing times.

4.0 Hand-Lay-Up Method

The hand-lay-up method is the oldest and simplest of all methods but is still popular because of minimal technical requirements. This particularly suited for small series of simple structural parts. Prior to the layup process, the tool surfaces must be coated with a release agent to facilitate the removal of the cured part from the tool. Usually, a gel coat is also required in order to provide smoothness and to improve the appearance of the outer surface of the part. After applying a coat of resin, the first layer of chopped strand mat or fabric reinforcement is then placed onto the tool. By means of rollers and stiff brushes, the resin is distributed uniformly to remove the bubbles. The process is repeated as often as necessary to reach the required thickness of the laminate. After placement of the last layer, the laminate can be cured with out further preparation either at room temperature or at moderately elevated temperature, in accordance with the characteristics of the resin.

The hand-layup method Is also referred to as the "wet-lay-up" method because the next layer is applied before the preceding one has hardened. With resins of standard viscosity and with common mats or fabrics as reinforcements, fiber volumes of no more than 30 - 40 % can be realized so that the use of high-performance fibers is hardly worthwhile.

4.1 Characteristics of the Hand Lay-up Method

- Tool materials : wood, plaster, metals,reinforced polymer, etc.
- Curing temperatures : 25 - 40^{0}C.
- Curing pressure : none required.

4.2 Advantages:

- Inexpensive tooling
- No constraints on tool contours
- Arbitrary stacking sequences.

4.3 Disadvantages:

- Labor-intensive process
- Part has only one smooth side
- Low temperature resistance of finished part
- Low strength and stiffness per unit thickness.

5.0 Vacuum-Bag Method

The Vacuum-bag method is a refinement of the hand- lay-up method. It does not require rolling and brushing operations after placement of each layer Instead, the uncured laminate is covered by an air-tight rubber membrane and the air under the membrane is evacuated. The vacuum action causes a more complete compaction and removal of air bubbles than is possible manually.

5.1 Characteristics of the Vacuum Bag Method

Tool materials : wood, metals, reinforced polymer, etc.
Curing temperature : 25 40^{0}C.
Curing pressure : 1 bar.

5.2 Advantages:

- Fairly smooth surfaces on both sides
- Relatively high and uniform fiber content
- Less labor-intensive process

5.3 Disadvantages:

- Frequent replacement of rubber membranes
- Need for vacuum equipment

6.0 Resin Injection Method

The resin injection method requires top and bottom tool halves whose shapes correspond to the desired thickness and configuration of the part to be produced. The tool halves must be sufficiently stable to preclude deformations affecting the geometry of the part. The insides of the tool are normally coated with both release agents and gel coats.

The reinforcing materials in the form of rovings, fabrics or mats are placed between the tool halves in a dry state. The tool halves are sealed along their common peripheries and have provisions for resin supply lines and removal lines for excess resin. The resin is injected by means of a vacuum, the speed of the injection being dependent on the degree of fiber compaction and on the viscosity of the resin. The most appropriate vacuum level must be reestablished for each new part.

The resin injection can be accelerated by external pressure on the resin in the supply vessel.

6.1 Characteristics of the Resin Injection Method

- Tool materials : metals, reinforced polymers.
- Curing temperature : 25 - 40 %.
- Curing pressure : 1 bar (optionally, additional pressure on resin supply line)

6.2 Advantages:

- both surfaces smooth
- no porosity
- long tool life

6.3 Disadvantages:

- expensive tooling
- high resin waste
- time-consuming process.

7.0 Pultrusion Method

The pultrusion technique is the reverse of the extrusion technique, i. e., the material is pulled rather than pushed through a die. It Is ideally suited for the production of straight lengths of solid or hollow cross-sections. Fiber rovings, weaves or mats are unwound from spools and gathered in sufficient quantity to provide the desired shape of the cross-section.

The mixing of the reinforcements with the resin is of prime importance and is usually accomplished by passing the rovings, mats or weaves over several rollers located within a resin bath. The thoroughly impreganted reinforcements are then pulled through contoured dies, cured and post-cured in adjacently located ovens and, after, cooling, cut into, appropriate lengths. The resulting parts have fiber volumes of up to 70 - 80 % and, therefore, excellent extensional and bending strength and stiffness.

A critical issue is the adequate protection of the exterior layers of the fiber

bundles against abrasion as they pass through.

7.1 Characteristics of the Pultrusion Method

- Die Material : Metal
- Die Pressure : 0.2 - 2.0 bar.
- Curing Temperature : 80 - 130^{0}C

7.2 Advantage:

- High production rates of continuous lengths
- Excellent and uniform mechanical properties
- Easy exchange of dies.

7.3 Disadvantage:

- High initial investment
- Special resins required
- Parts with constant cross-section only

8.0 Filament – Winding Method

The filament-winding method involves the placement of resin impregnated continuous ravings, bands or mats onto a rotating mandrel and their subsequent curing. For geometrical reasons, the method is restricted to structural parts with circular, elliptical, oval or polygonal cross-sections without re-entrant angles. As in all other Production methods, the shaping of the part to be produced requires the manufacture of a tool.

In case of open-ended parts, the tool is generally retrievable and may be used repeatedly; in parts closed at both ends, the tool must be designed, as a self-supporting liner which, after curing, forms an integral part of the structure, or as a 'lost" tool which, after curing, is destroyed in the process of removal

Various filament-winding techniques are in use, which operate on different principles. The majority of them can be reduced to lathe or planetary. In lathe-type facilities the tool is rotated with variable speed about a firm axis. The rovings are supplied from spools and placed onto the tool by means of a carriage, which moves parallel to the axis of rotation.

The angular orientation of the reinforcements depends on the direction of motion and the speed of the carriage. In planetary-type facilities the tool moves slowly about its longitudinal axis, while the carriage rotates at high speed around the tool in orbital planes. The winding angle of the reinforcements is determined by the inclination of the orbital plane relative to the tool.

The range of possible winding angles lies between 0^0 and 89^0 so that the reinforcements can be placed: (a) Axially, to provide bending and extensional strength, (b) Circumferentially, to resist burst pressures and to improve buckling stiffness and (c) cross-wise, to enhance torsional strength and stiffness.

Specific loading cases can be accommodated by proper combinations of winding angles which can be identified analytically. Glass, carbon and aramid rovings are commonly used as reinforcements in combination with polyester, epoxy, polyimide and other resin systems. Prior to their placement on the tool, the rovings or bands are, thoroughly wetted by passage through a resin bath. In the placement process, the rovings or bands are moderately stressed to obtain high fiber volumes. The quality of a filament-wound structure depends to a large extent on the precision of the fiber placement. Photograph of a filament wound pipe for water transportation developed at CDC is shown in Fig. 3.

Modem filament -winding facilities are almost exclusively operated numerical controlled or computer controlled.

8.1 Characteristics of the Filament-Winding Method

- Tool material : -steel, aluminum, reinforced polymers, low-melting metals for "lost" tools.
- Curing temperature : 25 - 120^{0}C
- Feed-speed of reinforcements: 1 5 meters /second.

8.2 Advantages:

- Flexibility of process parameters
- Low labor cost
- High quality of structural parts.

8.3 Disadvantages:

- High initial investment
- Need for skilled operating personnel
- Limitation on structural geometries.

9.0 Low Temperature Compression Molding

The production of structural parts by low temperature compression molding requires a top and a bottom tool half of sufficient stiffness to sustain considerable pressure loads. Both tool halves are treated with a release agent and generally also with a gel coat. A liberal amount of resin is then poured into the lower tool half followed by the placement of a prepared staple of weaves or mats. Closure of the tool under pressure causes the resin to penetrate the reinforcing -material. Air bubbles and excess resin are allowed to exit into cavities on the periphery of the tool halves. The Cutting edges built into the tool provide near-final dimensions of structural parts. The curing process takes place at room temperature or moderately elevated temperature.

9.1 Characteristics of low Temperature Compression Molding

- Tool material : wood, reinforced polymers.
- Curing temperature : 25 -70^{0}C.
- Curing pressure : 5 bars.

9.2 Advantages:

- Low tooling cost
- High fiber content and uniform quality
- Smooth part surfaces on both sides.

7.3 Disadvantage:

- Massive tools, limited to one configuration
- Potential separation problem of tool halves.

10.0 High Temperature Compression Molding

In the high temperature compression molding method the reinforcements are usually high-quality prepreg staples, which are cured in the presence of both temperature and pressure. Apart from the heat application, the method corresponds to the low temperature compression molding method. Both the lower and the upper half of the tool have hollow sections through which a hot medium can be circulated. The production process commences with the preheating of the tool halves and the insertion of the prepreg staple. Temperature and pressure are then applied simultaneously and monitored throughout the cure cycle. Depending on the properties of the prepregs the cure cycle may involve:

- High temperatures over short time intervals with high or low pressure intensities, or

- Moderate temperatures over longer time intervals with high or low-pressure intensities.

10.1 Characteristics of High Temperature Compression Molding

- Tool material : steel, aluminum.
- Curing temperature : 100 - 180^{0}C.
- Curing pressure : l - 40 bars.

10.2 Advantages:

- Suitable for mass production
- Uniform structural parts with excellent properties
- Minimal subsequent machining operations.

10.3 Disadvantages:

- High initial tooling cost

- Difficulties in case of configuration changes.

11.0 Operations After Curing

After removal from the tool, the cured laminates / components generally require some degree of machining as well as preparation for depending on the size, contour and thickness of the laminates and on the fiber material, standard procedures are available trimming purposes:

Circular saws with diamond-impregnated blades well suited for flat plates or straight rods of arbitrary thickness; cutting speeds of 3 cm/sec with water as a cooling and flushing agent are realizable even for thick sections. Band saws with hard metal or diamond-impregnated bands are used for curved cuts in flat or slightly curved panels; the quality of the cuts at intermediate cutting speeds is good; however, in case of laminates reinforced with aramid-fibers, thicknesses of 5 mm should not be exceeded. Structural parts with complex contours are finished by means of impregnated routers; with proper routing pressures and water cooling, high-quality cuts are possible.

Rough surfaces are usually smoothed by grinding operations. The drilling of holes can be accomplished with normal drilling, although the drill speed, drill pressure and the cutting angle of the drill bit must be chosen carefully to avoid damage to the laminate.

12.0 GRP – PUF Sandwich Composite Technology

Structural sandwich construction is one of the first forms of composite structure to have attained broad acceptance and usage for primary load bearing structures. Virtually all-commercial airliners and helicopters, and nearly all military air and space vehicles make extensive usage of sandwich construction. In addition to air and space vehicles, the sandwich construction is commonly used in the manufacture of products such as cargo parts in the transportation automobiles and recreation vehicles, residential constructional materials, interior partitions, doors, cabinets etc., using this technology several cost effective composite products are manufactured and developed for building and construction applications at RV-TIFAC CDC.

12.1 Advantages of a Sandwich Composite Structure

- Light weight with higher stiffness & strength
- Moisture resistant, fire retardant, Termite resistance,
- Maintenance free, functional superiority.
- Low tooling cost.
- Cost effective.

12.2 Sandwich Structure Concept

A sandwich structure consists of two thin, but high strength face sheets (Glass Fibre Polymer Composite for example) bonded by means of a liquid adhesive,

to a thick but lightweight core material (Polyurethane foam for example). Each component by itself is relatively weak and flexible however when combined together in a sandwich panel they produce a structure that is highly stiff, strong and yet lightweight. The core materials serve to stabilize the face sheets against buckling under edge vise compression, torsion, or bending loads and provides a rigid and highly efficient structure. Schematic diagram of a sandwich composite panel is shown in Fig. 4, and typical mechanical properties of sandwich core materials is given in Table-2.

13.0 Typical Fabrication Technique for GRP-PUF Sanwich Composite door shutter

Two GRP Composite face sheets are fabricated employing is or hand lay–up process as described earlier in this paper. The two most important characteristics of polyester resins viz., it can be cured without heat or pressure. The front and back GRP sheets for the door are fabricated separately. Wooden reinforcement in the form of frame and incerts are placed between the two sheets. Polyurethane foam is sandwiched between the sheets by in-situ foaming technique. Polishing / painting on the door is done to meet aesthetic requirements. Photographs of some of GRP-PUF Sandwich composite door shutters developed at RV-TIFAC CDC are shown in Fig. 5.

Brief Description of Fabrication Process:

- **Front and back sheets (GRP Skin)**
  - The cleaned and dried surface of the mould is applied with releasing agents.
  - Gelcoat mixed with pigment is uniformly applied and allowed to gel at room temperature.
  - One layer of chopped strand mat is laid over the gelcoat.
  - Resin is applied over the mat with the help of brush. Entrapped air is removed by brush dubbing.
  - Another layer is added to acquire the required thickness and strength
  - After curing, the sheet is released and trimmed to pre–defined size.
- **Core Material**

EPS, PVC, PUF foam cores of desired density and thickness shall be used for fabricating the door shutters

13.3 Wooden Reinforcement

Seasoned sal wood frame and reinforcements of required cross section shall be provided for fixing the metal fitting such as tower bolts, aldrops, etc.,

13.4 Structural Adhesive

An Adhesive compatible with the core material chosen shall be used for bonding the core material with the sal wood reinforcement and GRP skins

13.5 Process

The door shutters are fabricated using adhesive bonding techniques by applying high pressure using high tonnage hydraulic press. In the case of PU foam two component liquids (PUF) is handcast and poured between the sheets in order to sandwich them

13.6 Tests

The GRP skins should comply with IS Standards. The finished door shutter is subject to various test as per standards IS 4020. the door shutter shall successfully with stand all the tests.

13.7 Surface finishing - Polishing / Painting.

In order to remove PVA and releasing agent adhering to the door, it is washed with soap water. To prepare the surface for painting it is emeried with water emery. Air bubbles are removed from the surface carefully and the subsequent void developed is filled with resin putty and is applied on the surface to form the base for paint and allowed to dry. Using NC Putty scratches, pinholes on the surface are filled and excess putty is removed using putty blade. The filled areas are then rubbed with emery. Another coat of surfacer is applied and above step is repeated with 400 grade emery. Not more than 7 – 10 % of thinner is mixed with paint of requisite colour. The door is spray painted with spray gun uniformly.

13.8 Quality Standards

The products have to be tested according to IS: 4020 – 1994. It includes the following tests:

1. Dimensions & Defects of squareness
2. General flatness test
3. Local planeness test
4. Impact indentation test
5. Flexure test
6. Edge loading test
7. Shock resistance test
8. Buckling test
9. Misuse test
10. Slamming test
11. Screw holding test
12. Knife test
13. Glue adhesion test.
14. End immersion test.

13.9 Safety Measures

- It is recommended to prohibit smoking in work places
- The floor should be well – built. The cleaning of floors at various places is recommended by water mopping.
- A centralized waste collection system should be provided.
- Provision of exhaust fans in the work place.
- Usage of hand gloves & safety goggles recommended.
- Fire fighting devices should be provided in the work place.

Table –1 Typical Mechanical Properties of FRP Laminates[a]

Material	*Fibre volume fraction V_f*	*Specific gravity (SG)*	*Young's Modulus E(GPa)*	*Shear Modulus (GPa)*	*Tensile Strength σ_{ut} (MPa)*	*Compressive Strength (MPa)*	*Shear strength (MPa)*	*Specific young's modulus (E/SG)*	*Specific tensile strength (σ_{ut} / SG)*
E-glass polyester (CSM)	0.18	1.5	8	3	100	140	75	5-3	67
E-glass polyester (balanced WR)	0.34	1.7	15	3-5	250	210	100	8-8	147
E-glass polyester (unidirectional)	0.43	1.8	30	3-5	750	600		16-7	417
Carbon / epoxy (high-strength balanced fabric)	0.5	1.5	55	12	360	300	110	37	240
Carbon / epoxy (high-strength unidirectional)	0.62	1.6	140	15	1500	1300		87	937
Carbon / epoxy (high-modulus unidirectional)	0.62	1.7	300	20	700	650		176	412
Kevlar 49 / epoxy (unidirectional)	0.62	1.4	50	8	1600	230		36	1143
Steel (B-quality or Lloyds EH32)	-	7.8	207	80	325[b]	340[b]	190[b]	26.5	42
Aluminium (5083 alloy)	-	2.8	70	26	150[b]	150[b]	87[b]	25	54
Marine plywood (mahogany)	-	0.6	7	1.0	40	25	8	11.7	67

[a] Source: Chapter 2, Refs 29-32; Chapter 3, Ref. 30.
[b] 0.2% Proof yield strength.

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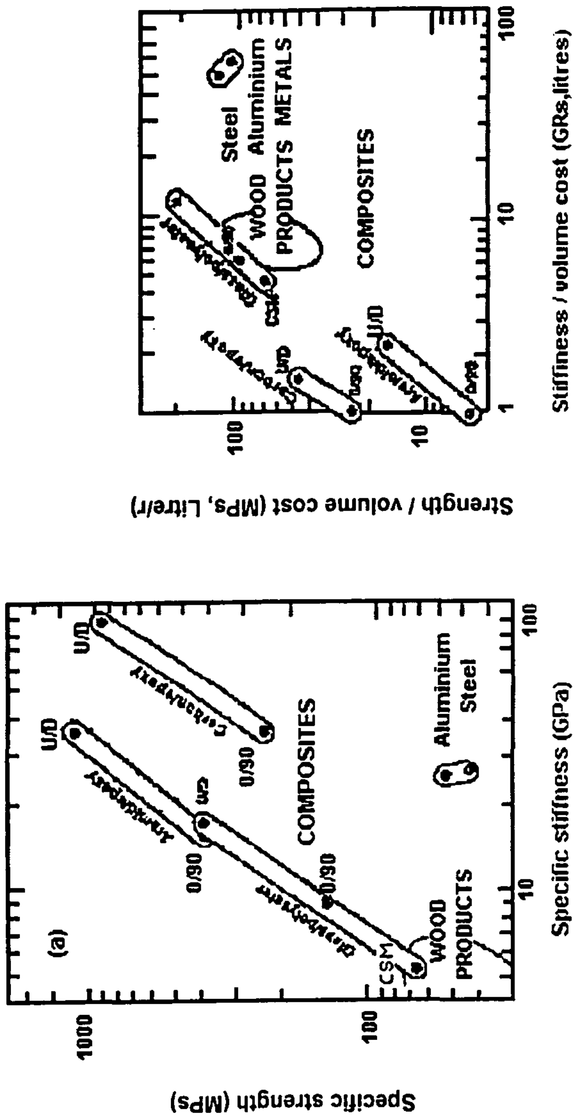

Fig. 1 Material Property (Strength and Stiffness) Comparisons between Composites and other Materials

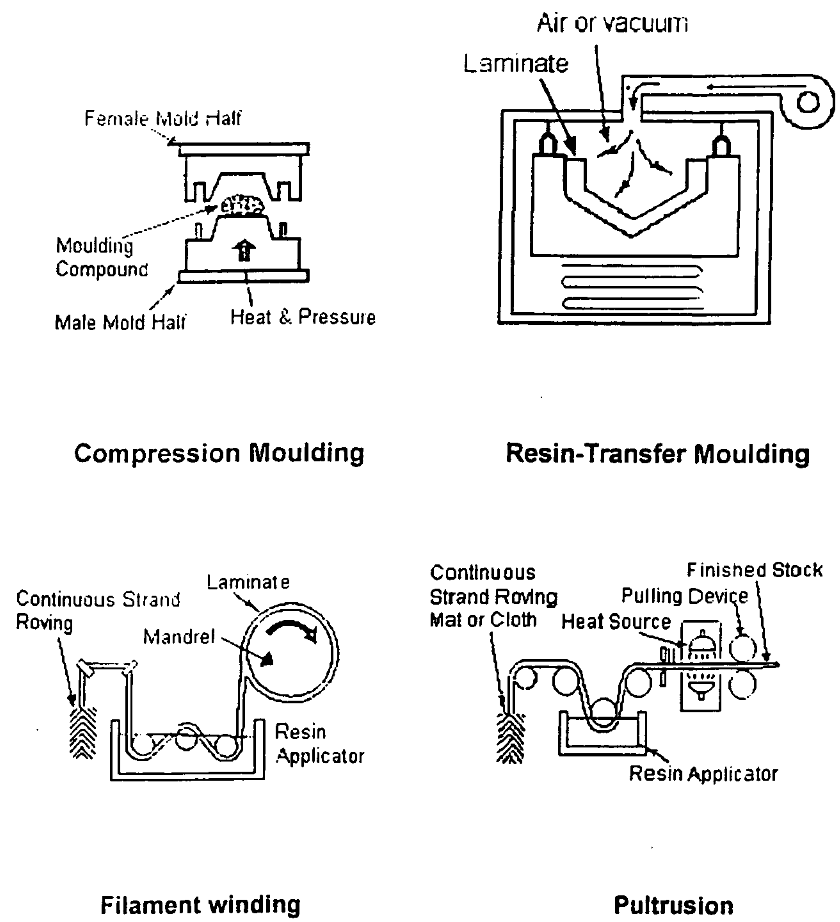

Fig. 2 Manufacturing Methods for Composites Products

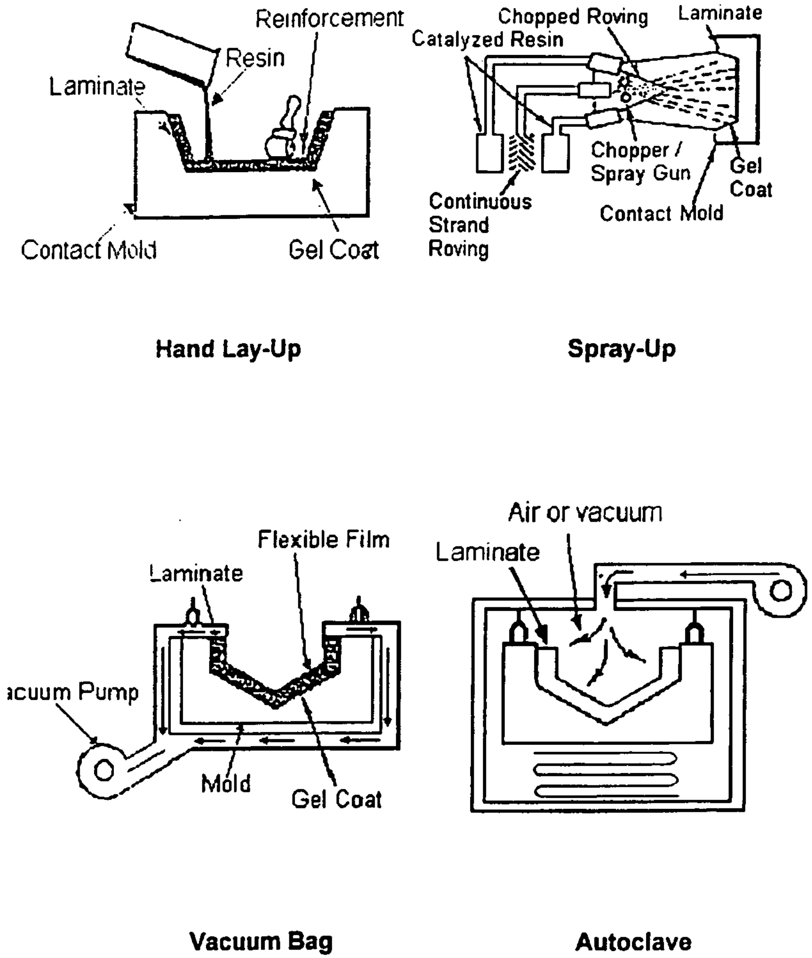

Fig. 2 Manufacturing Methods for Composites Products

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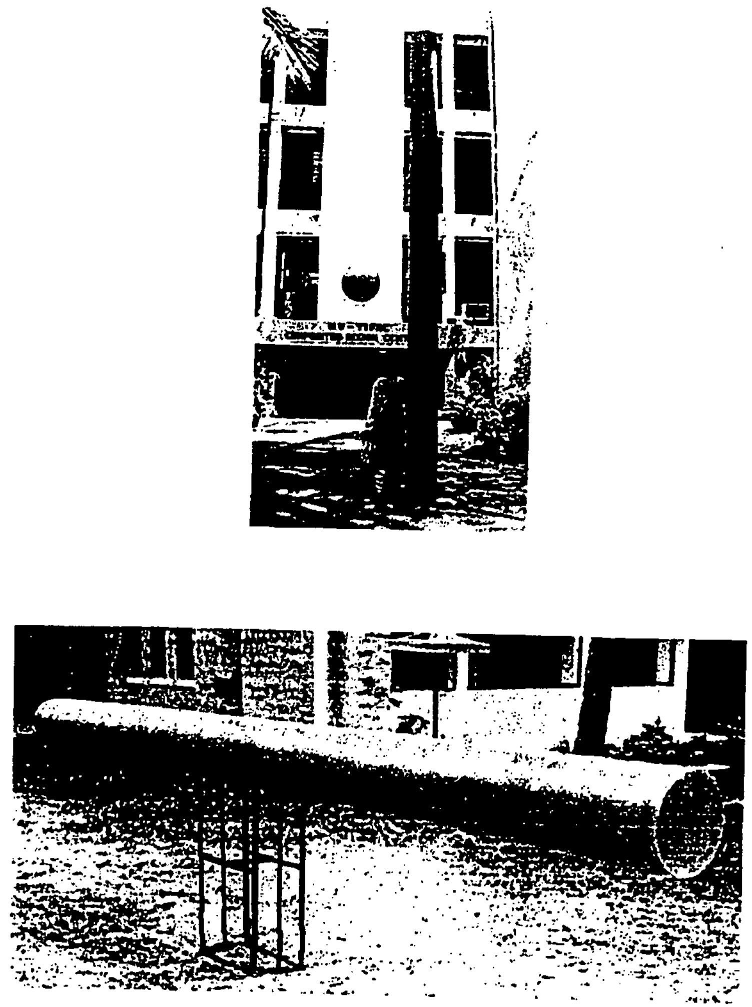

Fig. 3. Filament Wound Pipe for Water Supply

Sandwich Composites

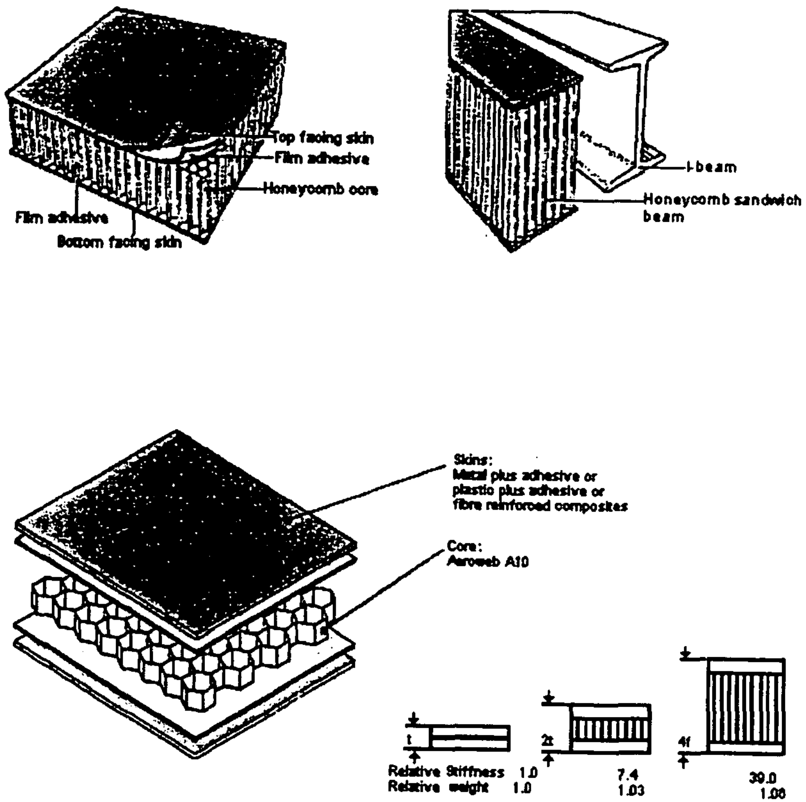

Fig. 4. Schematic Diagram of Sandwich Panel

Fig. 5. Some Important Designs of GRP/Composite Doors Developed at CDC

COMPOSITE MATERIAL DESIGN AND MANUFACTURE FOR BUILDING APPLICATIONS – AN OVER VIEW

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Former Head, Composites Technology
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1. INTRODUCTION

Building and civil infrastructure applications are the biggest markets for modern composites in the developed countries. Almost 44 % of composites made in Japan, 24 % in USA and above 19 % in Europe go to the building applications. India also uses 25 % of the composites production for this application, but this share is only a mere 14,000 Tonnes of material per annum. This consumption is very small considering the total building construction activities. The relatively high cost of fibrous composites and the lack of know-how for the design and manufacture of durable products at affordable cost are hindering the wide scale use. China with its 5,00,000 Tonnes per annum capacity is perhaps the one developing country which has a flourishing composites industry. The high cost of the material makes it necessary to resort to cost effective designs and manufacturing methods to reduce overall cost.

This lecture outlines the use of composites in buildings and explores the design and manufacturing methods that can be used for developing cost effective building applications using these modern composites.

2. BASIC DESIGN REQUIREMENTS

Every product or structure whether it is a building, bridge or furniture has to be designed fulfilling the following four basic requirements.

(i) **Function**: The product shall fulfil the functional needs for which it is made. The materials used in buildings shall be thermally insulating, moisture resistant, aesthetically appealing and preferably fire retardant.

(ii) **Safety**: The structure shall have adequate strength, rigidity and other mechanical properties to make it safe under various loads and environmental effects for the people to use it without any concern to safety.

(iii) **Reliability**: The product must give reliable service to the users without causing total or partial collapse.

(iv) **Cost effectiveness**: All the benefits and above-mentioned requirements must be achieved at affordable cost.

The design must take into account the expected life period of the product and the performance requirements must be ensured for the entire life period. Buildings depending up

on their importance are expected to have a life span of 30 years to 100 years. The life cycle cost, which is the total cost of a product given by the following formula, is taken as the cost criterion in design

Life cycle cost = Initial cost + Cost of operation + Cost of maintenance – Cost recovered at the end of life

Since composites have no resale value, the recoverable cost at the end of service life can be neglected. The initial cost consists of the cost of materials plus the cost of design, development and manufacture. The operational and maintenance cost are generally low in composites. The initial cost of composites is generally higher than that of concrete or steel, but the high initial cost can be offset by the low operational and maintenance cost. Cutting down of initial cost is possible in composites by the following five considerations. Attention must be given to these considerations during the design stage itself so that the high cost of materials can be offset by cost effective designs and manufacturing methods.

(i) Select the materials like fibres, matrices etc., which are technically suitable and cost-wise affordable.

(ii) Design the material structure taking the product configuration, loading and manufacturing method into account so that overall material consumption can be reduced.

(iii) Design the product configurations and their cross sectional geometry to give reduced stresses and increased rigidity.

(iv) Adopt manufacturing methods that are cost wise competitive without affecting the product quality.

(v) Enforce quality control throughout manufacture to avoid material wastages, product rejection and costly repairs.

3. COMPOSITE MATERIALS FOR BUILDING APPLICATIONS

Composite material is created by combining more than one material in such a way that the resulting material is an entity of its own giving improved or pre-designed properties. The wood, concrete, bamboo and straw filled brick etc. used in building construction are traditional composites and they have established their supremacy in this field of applications for centuries. Compared to these, the modern composites made by fibre reinforcement of plastics, cement or gypsum are new generation composites. The history of these materials started only around 1938 when Owens Corning Fibreglass commercially produced glass fibre in USA. Since then, several advanced reinforcement fibres like carbon, aramid, polyethylene and ceramic fibres have been developed. They are being used for reinforcing polymers, metals and ceramics. There are well over 200 families of composites in use today with a world production of 5.5 million Tonnes per annum. Compared to other traditional materials like steel, aluminium or wood, this volume of production is very small. However, the development of advanced composites is adjudged as one of the top ten technological achievements of 20th century. Because of cost considerations, glass fibre reinforced plastics and natural fibre composites only have found acceptance in the building industry. They find applications in prefabricated houses, site offices and holyday homes, doors, windows, cladding and partition panels and roof systems.

Polymer matrix composites and composites made of reinforcing cement and gypsum by glass fibre or natural fibre are the composites being used in civil construction. Metal matrix and advanced ceramic matrix composites are too costly and too complex to be used in building components.

On a weight-to- weight basis, polymer matrix composites are much costlier than concrete or steel. If that is so, why these composites are to be used at all? In fact, it is this question that has been retarding the large-scale usage of composites in buildings. In spite of the high initial cost, there are several other features that make the material system cost effective.

(i) **Weight savings**: Polymer matrix composites are lighter than metals and concrete and hence PMC help to reduce overall weight of the product. Weight reduction is attractive in portable building construction, transportation of building components and in high-rise buildings. The self-weight of a building is the predominant factor in high-rise buildings with height exceeding six storeys. Composite cladding panels and partitions can help to bring down the cost in such high-rise buildings. Weight reduction is also important for buildings in earthquake prone areas.

(ii) **High productivity and mouldability**: Most of the manufacturing methods for PMC are faster than concrete floor construction with 28-day cure of cement. Complex shaped components and doubly curved shells can be moulded more easily than by using concrete or metals.

(iii) **Chemical resistance**: The resistance to corrosive chemicals, seawater, freshwater and moisture of polymer matrix composites is quite superior to that of metals or steel reinforced concrete and thus the durability is increased.

(iv) **Light transmission**: Translucent roofing sheets can be made of glass reinforced plastics.

(v) **Sound and Heat insulation**: FRP sandwich panels with polyurethane foam core not only give good strength and rigidity but also give good sound and heat insulation.

(vi) **FRP as Wood substitute**: Wood is getting scarce and costly. FRP laminate can be used in place of wood for doors, windows, partitions and furniture with better fire retardance, weather resistance and resistance to attack of rodents and termites

(vii) **Directional property**: Because of the use of fibre reinforcements composites can be made with fibres orienting in the direction in which load is acting and strength and rigidity are required. This makes the material more efficient.

4. MATERIAL SELECTION AND MATERIAL STRUCTURE DESIGN

Composites can be broadly divided into fibre-reinforced composites and Particulate filled composites. The former type uses fibres as reinforcements whereas small flakes or particles are used in the latter as fillers. Polymer concrete is a typical example of filled composites and they are used only for construction of walls, floors, sanitary wares and insulation blocks. It is

the fibre composites that find novel applications and only that group of composites is considered in this article

The choice of the fibres, matrices and other additives and the designing of the geometrical arrangement of fibres within the matrix for achieving optimum performance are important steps in the overall product design. Designing the material to suit to the product is an exclusive feature of composites, which is not done in designing with conventional materials where the material is selected and fitted into a designed structure.

4.1 Selection of Fibres

Glass fibres are the cheapest in the market amongst the advanced fibres and hence they are the most commonly used reinforcements in building applications. Since the aircraft grade carbon fibre is too expensive for civil engineering applications, an American company, Zoltek, has developed a cheaper civil engineering grade carbon fibre. Even this carbon fibre can find applications mostly in high-rise buildings, bridges and rehabilitation of damaged concrete structures. Table 1. shows the typical properties of manmade fibres used in building applications.

Table 1. Properties man made reinforcement fibres

Fibre Type	Specific Gravity	Young's Modulus E (Gpa)	Strength σ (Gpa)	Strain to failure (%)	Diameter (μm)	Highest useable Temp. (^{0}C)
E glass	2.5-2.6	69-72	1.7-3.5	3	5-25	350
S-glass	2.48	85	4.8	5.3	5-15	300
Carbon HM	1.96	517	1.86	0.38	8-4	600
Carbon HS	1.8	295	5.6	1.8	5.5	500
S_iO_2	2.2-2.5	75	5.9	1.5-1.8	1-3	1100
Nylon 66	1.2	<5	1	20	25	150
Polyester	1.38	<18	0.8	15	25	150

Natural fibres can be a cheaper alternative to glass fibre for making reinforced plastics. Table 2 shows the mechanical properties of some of the indigenously available natural fibres, and Table 3 gives the properties of reinforced plastics made of them. Prefabricated houses, boats and silos where made in IIT Madras during 1977-78 and it has proven the technical viability of using natural fibres for such applications. However, there are several limiting that have to be solved before natural fibres can be used as regular materials for making buildings and building components.

(i) All natural fibres are biodegradable and are prone to gradual reduction in strength due to the exposure to moisture and natural environment. Good protective coatings or treatments for the fibres have to be developed for increasing their resistance to environmental effects and moisture and for increasing the durability. The low cost construction should not be at the expense of the durability of the buildings.

(ii) The bonding of natural fibres with polymers like polyesters and epoxies have to be studied and standard materials and manufacturing procedures evolved.

(iii) The moduli of elasticity of natural fibres are mostly less than that of glass fibre and more or less same as that of plastics. Hence, the material structure has to be designed to increase the flexural rigidity by increasing the moment of inertia

4.2 Matrix Materials

Thermoset plastics like polyesters, phenolics, vinyl esters and epoxies are the matrices used for GRP fabrication. Among these, isophthalic polyester and phenolics are the cheapest durable resins and therefore they find applications in buildings. Thermoplastics like polypropylene, polyvinyl chloride and Nylon can be reinforced with glass and natural fibres. Because of the processing problems, they can however be made in smaller panels and they have to be joined together at the site. Ordinary cement and gypsum can also be used as matrix materials that can be reinforced with fibres.

Table 2. Mechanical properties of natural fibres in comparison to conventional reinforcement fibres

Fiber	Density (gm/cm^3)	Elongation (%)	Tensile strength (MPa)	Young's modulus (GPa)
Cotton	1.5 - 1.6	7.0 - 8.0	285 - 597	5.5 - 12.6
Jute	1.3	1.5 - 1.8	393 - 773	26.5
Flax	1.5	2.7 - 3.2	345 - 1035	27.6
Hemp	-	1.6	690	-
Ramie	-	3.6 - 3.8	400 - 938	61.9 - 128
Sisal	1.5	2.0 - 2.5	571 - 635	9.4 - 22.0
Coir	1.2	30.0	175	4.0 - 6.0
Viscose (cord)	-	11.4	593	11.0
Soft wood kraft	1.5	-	1000	40.0
E-glass	2.5	2.5	2000 - 3500	70.0
S-glass	2.5	2.8	4750	86.0
Aramide	1.4	3.3 - 3.7	3000 - 3150	63.0 - 67.0
Carbon	1.4	1.4 - 1.8	4000	230 - 240

4.3 Material Structure design

The effective properties of a composite material are dependent not only on the constituent fibres and matrices, but also on their proportion and the geometric arrangement of the fibres within the matrix. The fibre packing and orientation are defined with respect to the lay up within the structural cross section. Material composition is possible in fibrous composites in two distinct ways. (i) Multi-phase Composition and (ii) Multi-layered Composition

Table 3. Mechanical Properties of Natural Fibre Composites

Property	Polyester Resin	GRP (Polyester)	Cotton fabric reinforced polyester (11 wt%)	Banana fabric reinforced polymer (11 wt %)	Coir reinforced polyester (9 wt %)
Density (gm/cm^3)	1.3	1.5 - 1.9	1.4	1.215	1.16
Tensile strength (MN/m^2)	41.38	241.4-689	34.5-68.9	35.92	18.61
Flexural (MN/m^2)	89.69	344.8-862.1	62-124	50.6	38.15
Modulus of elasticity (GN/m^2)	2.06	6.9-41	2.76-4.14	3.33	4.045
Impact resistance (unnotched) Kgm/m^2	77.5	3116-8476	257.3-428.8	748.5	391

a. Multi phase Composition: In the multi-phase composition, the fibre phase is inserted into the matrix phase as shown in Fig. 1. No identifiable layer separation of fibres occurs as in this composition. The fibres can be short discontinuous fibres or long continuous fibres. The short fibres can be oriented randomly in a two-dimensional plane or in three-dimension. Random mat composites made of hand lay up process, compression moulded SMC and PMC and short-fibre filled thermoplastics are examples of short-fibre composites. Fibre lengths vary from 1 mm to 40 mm depending upon the manufacturing process.

Continuous fibre composites are made in four different ways.

(i) Continuous random mat
(ii) Uni-axially oriented fibre composites as in pultruded parts.
(iii) Bi-axially woven mat composites
(iv) Tri-axially woven, knitted or braided fibre composites

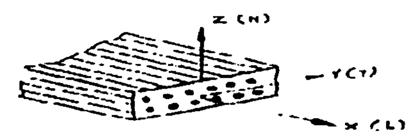


Fig. 1 Multi phase Composites

The latter two types of composites are generally called textile composites as the reinforcements are made by textile processing methods commonly adopted in clothing materials. Table 4 gives a list of the multi-phase composite structures created by various manufacturing methods and their characteristic features. The material designer has to select suitable structure from this list for the product being designed by them.

The mechanical properties of the multi-phase composites depend not only on the fibre content but also on the fibre length, fibre packing and fibre orientations. The modulus of elasticity of the composites in any one direction of fibre can be given as

$$E_{CL} = \eta_l \eta_p E_f V_f + E_m (1 - V_f)$$

Where V_f = fibre volume faction

η_l = a factor between 0 and 1 that accounts for fibre length effect. η_l is 1.0 for fibre length to diameter ratio > 100

E_f, E_m = modulus of elasticity of fibre and matrix respectively

The strengths of composites also depend on these parameters and values of η_l and η_p. However, the strength is dependent on several micro structural defects and hence the predictions by formulae is not as accurate as for elastic property predictions

The above model shows that the mechanical properties can be controlled and material efficiency increased by using longer fibres, orienting the fibres and by giving higher fibre contents. Products made either by pultrusion or by uniaxial fibre orientation can give the maximum efficiency. Product can be designed wherever possible by proper packing and orientation of fibres and by using pultruded sections.

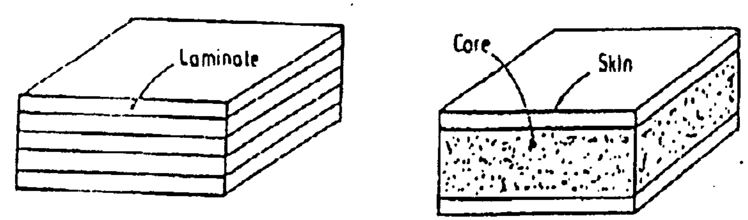
Table 4 Material structure created by manufacturing methods and their characteristic features or GRP Composites

Sl No.	Material structure	Manufacturing Methods	$*\eta_p$	Characteristic features
1	2D Random with chopped fibre mat or continuous fibre mat	Hand Lay up, RTM, VIM	0.33	Maximum fibre content 30 to 45 % by weight Depending upon the manufacturing method used. Gives 2D isotropic properties. Chemical and moisture resistance is good due to the high resin content.
2	2D Random in SMC	Compression moulding	0.33	Max. fibre content 20 to 30 % by weight, high filler loading. 2D isotropic properties. Not as strong as item 1
3	3D Random	Injection moulded reinforced thermoplastics	0.2	Fibre length 1 to 3 mm. Max. fibre content 40 %. Isotropic in 3D. Fibre improves rigidity and impact strength.
4	Uni-axial fibre composites	Pultrusion, Hand Lay up, RTM etc.	1.0	Max. fibre content 70 %. Fibre is continuous and straight. Gives very high mechanical properties in fibre direction. Relatively week in the transverse direction
5	2D Woven Mat	Hand Lay up, RTM, VIM and prepreg moulding	0.5	Max. fibre content 50 % . Orthotropic with equal property in perpendicular directions
6	Knitted, Braided and Stitched fibre mats	RTM, VIM and Hand Ly up	0.2	Fibre content less than 50%. Good shear strength and good tensile strength in 3rd direction. High strength and rigidity possible in 2D Plane

**Fibre packing efficiency factor varies from 0 to 1*

b. Multi layered Composition: Multi layered composition is done by bonding several layers or plies of materials held together by the binding matrix material or by adhesive layers. There are identifiable inter laminar surfaces, which are weaker than the material within the layer. Multi layered composites can be broadly divided into laminated composites and sandwich composites. In laminated composites, material structure is created by laying and bonding several layers of lamina or ply. Each ply can be of homogeneous material or of multi-phase composites. The lamination is generally done by bonding uni-axial fibre plies oriented in different directions or by packing woven roving mat and random mat alternatively. The properties in two directions can be controlled and designed by proper stacking and orientation of plies with report to the local coordinates of the structural elements.

Sandwich is a special case of laminated composition in which two skins of high strength and stiffness are kept apart by an inner core of lightweight and mechanically less strong. This process can reduce both weight and cost while achieving the required load carrying capacity. The skin is made of homogeneous or laminated composites and the core is of foam, balsa wood, honeycomb or corrugated profiles. Honeycomb cores used in aircrafts are too costly to be used in civil construction. Foam core has the added advantage that panels get good thermal and sound insulation properties. Fig. 2 shows the laminated and sandwich composite construction. The following design calculations can help to achieve economy in laminated and sandwich construction.



a. Laminate   b. Sandwich

Fig. 2 Multi layered Laminate and Sandwich composites

(i) The laminae or layers must be made with maximum fibre content possible. This can be achieved by proper fibre orientation

(ii) The laminae must be packed as far possible symmetrically and in balanced construction to avoid unwanted bending - stretching coupling.

(iii) Making a laminate of given thickness by large number of plies can also help to reduce bending - stretching coupling. However, since this can increase production cost, bulkier plies are used in civil construction.

(iv) Plies of high strength and rigidity must be placed at outer layers to increase bending strength.

(v) Panels under bending can be made of sandwich composite construction for increased rigidity without increasing weight.

5 COST EFFECTIVE STRUCTURAL FORMS

Although glass fibre reinforced plastics (GRP) are very strong compared to steel, their moduli of elasticity are much less than that of steel, iron or aluminium. Hence, GRP structures show more deflections than similar steel structures under same load. To compensate this, the thickness of composite laminates can be increased in such a way that their rigidities are matched. The high cost of FRP makes it very essential to use alternate structural forms for achieving economy rather than increasing the thickness. Good structural forms have to be selected and their design optimised. This requires considerable ingenuity, analysis, design and optimisation. The conventional solid beam or plate constructions are not economical particularly under bending or compressive loads. Some of the innovative product forms developed to reduce the use of materials are illustrated in Fig. 3 and are described as follows

a. **Stiffened panels**: Whenever, FRP has to be used as flat panels, stiffener ribs can be provided for increasing the flexural rigidity and load carrying capacity. The stiffeners can be of wood, steel or FRP itself.

b. **Sandwich panels**: Another way of increasing the rigidity and strength without adding to the weight is to use it in the form of sandwiches.

c. **Grid construction**: A grid is an integral construction of beam elements oriented in different directions in a plane so that when constructed, the grid can behave like a plate. Since the beams have larger depths than solid plates of same cross section, the moment of inertia is higher and correspondingly the rigidity increases. Since grid beams can be made with fibres in their axial direction, modulus of elasticity is also high. The grid beams may be oriented in two perpendicular directions (ortho grids) or in three directions at 0^0 to 60^0 and 120^0 (called iso-grids). The fibres can be uni-directionally oriented to give high modulus and high fibre content. Thus grid frame is an innovative design for improving rigidity without increasing weight.

   Grids can be covered with skins on either side to increase the rigidity further and / or to allow light transmission without letting in the rain

d. **Shell shaped constructions**: Shell shapes although difficult to manufacture can increase rigidity and strength. Spherical and cylindrical shells are used for water tanks. Modular types shells can be assembled to form a roof system. Geodesic dome made by assembling triangular panels along the geodesic lines is one such rigid structural system suitable for covering large areas.

e. **Folded plate construction**: Folded plate construction is a 3 dimensional assembly of fiat panels. The simplest form of this is a pyramidal shape. Folded plate construction method can be used in such a way that structural rigidity, aesthetics and controlled light transmission can be achieved in the product.

f. **Framed structures**: Two-dimensional and three-dimensional framed structures can be made out of pultruded sections. As described earlier, pultruded sections are structurally efficient and in a framed structure, the members can be efficient since they are in tension and compression.

g. **Inflated structures**: Plastic coated fabrics maintained under in-plane tension by hot air or compressed air can be used as inflated structures. They can cover large areas.

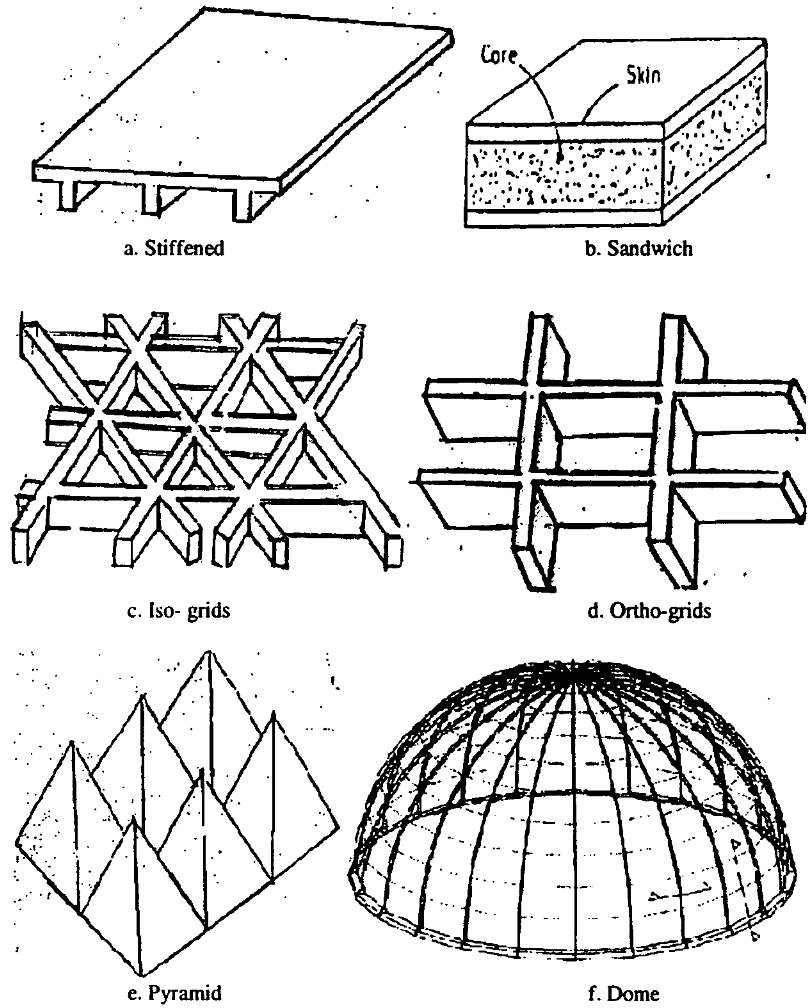


Fig. 3 Cost effective structural forms

6 COST EFFECTIVE MANUFACTURE PROCESSES

Table 6 gives a list of the manufacturing methods and the characteristic features. There are several important steps to be taken in the manufacturing process. FRP are made by moulding, filament winding or by pultrusion processes. Filament winding and pultrusions are special mechanised processes to make one dimensional pipes and structural sections respectively. Products are generally of high strength and stiffness. Pipes generally do not find applications in low cost housing, but they can be used as columns, piles and towers. Pultruded sections on the other hand have a variety of uses like grids, roof frames, doorframes, handrails, ladders etc. In terms of material efficiency, pultruded sections are very cost effective and are durable.

Table 6. Manufacturing process of Thermoset PMC suitable for building

Manufacturing method	Features
Hand Lay up	It is a labour intensive method, using relatively in expensive FRP moulds. One component can be made in 3 or 4 hours. Used for large size custom built building components
Spray up	In this process, the fibre and matrix materials are sprayed onto the mould using a spray up machine. Production is faster but curing can take 3 to 4 hours. Material consumption is more and hence component can be costlier than hand lay up components.
Resin transfer moulding (RTM)	The reinforcement is packed in a two-piece mould and resin is injected under pressure after closing the mould. Suitable for small to medium size components. Products can be made in 30 minutes, RTM machine is required.
Vacuum infusion moulding (VIM)	Process is similar to RTM but resin is sucked in under vacuum, instead of under pressure. Suitable for medium to large components by multiple point injection. One-piece mould with a bag can be used. Production time 30 minutes.
Hot compression moulding	This method is suitable for fast production. The moulding compound (SMC or DMC) is compacted within the two halves of the mould and the curing is done under heat. Production time 3 to 10 minutes depending upon the thickness.
Centrifugal casting	Cylindrical columns, posts and other objects with good out side finish can be made by this process. Raw materials are sprayed in a rotating drum and cured under centrifugal force. Production time 30 min. to 3 hrs. Ornamentals, axi-symmetric products like columns can be made.
Pultrusion	Structural profiles like angles, channels, pipes etc. can be made by pulling material through a die and curing by heating. These profiles can be used for roof trusses and frames, door frames, hand rails etc.
Sandwich moulding	Sandwich panels are made by using foam core or core mat by hand lay up or vacuum infusion.

Hand lay up, spray up, resin transfer moulding (RTM), vacuum infusion moulding (VIM), vacuum assisted RTM (VARTM) and compression moulding are moulding methods generally used in building construction. The initial investment is not as high as in filament winding or pultrusion. The hand lay up, which requires no machines except hand tools is labour intensive and is very much suitable for developing countries both for employment generation and for achieving cheaper fabrication costs. In India, a hand lay up product has

only about 10 to 20 % of its cost as the labour cost. The labour cost is about 40 % of the product cost in developed countries.

(i) There is a chemical reaction like polymerisation. Cross-linking involved in the processing. Care has to be taken to see that this chemical reaction is completed during processing.
(ii) The process selected shall have high productivity. Processes like SMC moulding and RTM take less time compared to hand lay up.
(iii) Modular type construction is advantageous because using one mould, several pieces can be made and used.
(iv) Prefabrication helps to make the products in factory conditions and consequently products of consistent quality can be made.

7 CONCLUSIONS

Modern composites have found their way into building and civil engineering applications in a large way. The total volume of consumption still forms only a small fraction of total materials, but the technological advantages are far more attractive. The use of natural fibre and resins made from agricultural products like corn and soyabean oils can help to reduce the prices. Cost reduction strategies have to be developed at al levels including material selection, product design and manufacturing. Cost reduction without cutting into durability and performance efficiency can certainly take composites into more and more applications.

CHARACTERISATION OF RAW MATERIALS FOR DESIGN OF COMPOSITE BUILDING MATERIALS

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1.0 Introduction

The determinates of materials in any civilization have been described as "possessing them, understanding them and use them judiciously". These three aspects closely represent the availability of materials, processing them to conform to the standards and specifications and then transforming them into applications based on sound engineering principles. Hence, the term characterisation, no doubt, encompasses the evolution of the chemical, physical and engineering properties but is essentially related to a particular application.

In the world of engineering materials, there are only three classifications (i) metals and alloys, (ii) ceramics (which includes lime, gypsum, brick, tiles, glass, refractories, cement and pozzolana) and (iii) polymers (which include wood, cellulosic fibres, biomass, rubber, bitumen, synthetic organic fibres, and various elastomers). Any combination of the above three groups of materials could safely be called composites or composite materials. The composite materials must consist of two or more substances, complimenting to overcome the weakness of one another and also mutually sharing their strong points. In addition, however, in modern concepts, all composites or composite materials essentially contain a fibre and a matrix, with or without any additives.

Among the earliest composite materials used for housing, the most widespread are the fibre reinforced mud constructions, split bamboo/reed and mud walls, and timber (a composite of cellulose fibre and lignin). They have been followed by nearly 12,000 years old history of discoveries of metals, alloys and cermaics (excluding cements which followed much later). In more recent past, synthetic polymers and polymeric fibres have demonstrated far superior engineering properties. On the other hand, parallel developments in non-polymer fibres, such as of carbon, glass, boron, basalt, silicon carbide and silicon nitride, have resulted into their uses in aircrafts, spaceships, machine tools and various high temperature resistant materials.

The use of man-made fibre reinforced composites (carbon, boron, SiC, Si_3N_4, Al-Li, ZrO_2 etc.) and the metal-metal, metal-ceramic, metal-ceramic-polymer composites) is not of much relevance to low cost housing, because of their high cost and certain other technical limitations. The choice for housing, therefore, has to be made among the fibres from steel, glass, natural organic fibres and some synthetic organic fibres, and among the matrices from cement, gypsum, synthetic polymers. In this paper, the wood fibre reinforced composites have not been covered as there are other papers on the subject for presentation.

2.0 Characterisation of fibres

Table 1 gives the physical properties of the metals and mineral fibres, natural organic fibres and synthetic organic fibres. These properties are closely related to three basic structural properties, (a) strength (measure of resistance to deformation), (b) stiffness (elastic modulus measure of stiffness or rigidity), and (c) toughness (measure of resistance to fracture or ability to tolerate defects). At first, the discussion will be restricted to those of natural organic fibres.

Table 1(a) : Physical and mechanical properties of natural organic fibres

Fibre	Length (mm)	Dia (mm)	Density (kg/m^3)	Young's modulus (GPa)	Tensile strength (MPa)	Elongation at break (%)
Bagasse	NA	0.2-0.4	1250	17	290	NA
Bamboo	NA	0.1-0.4	1500	27	575	3
Banana	NA	0.8-2.5	1350	1.4	95	5.9
Coir	50-350	0.1-0.4	1440	0.9	200	29
Flax	500	-	1540	100	1000	2.0
Jute	1800-3000	0.1-0.2	1500	32	350	1.7
Pineapple	NA	0.2-0.8	NA	14.5	400	NA
Sisal	NA	0.5-2.0	1450	100	1100	NA

Table 1(b) Physical and mechanical properties of metal and mineral fibres

Fibre	Length (mm)	Dia (mm)	Density (kg/m^3)	Young's modulus (GPa)	Tensile strength (MPa)	Elongation at break (%)
Glass C	NA	NA	2700	70	3100	4.5
Glass E	NA	NA	2900	72	3400	4.8
Steel	5-200	0.1-0.4	7860	207	700-2100	3.5
Boron	NA	NA	-	410	3800	2.8
SiC	NA	NA	-	430	240-2400	-
Si_3N_4	NA	NA	3250	410	3200	-

Table 1(c) : Physical and mechanical properties of polymeric fibres

Fibre	Length (mm)	Dia (mm)	Density (kg/m^3)	Young's modulus (GPa)	Tensile strength (MPa)	Elongation at break (%)
Polyethlene	-	0.1	900	-	400-600	-
Polypropylene	-	0.03	-	-	400-600	-
Polyester	-	1.4	1400	-	1000	-
Polyamide	-	-	-	-	400-650	-
Acrylic	-	-	-	-	850	-
Kevlar	-	1.5	1500	-	2800	-

2.1 Variability in chemical and physical properties of natural fibres

Although natural organic fibres are the most preferred, they show a large variation in their chemical composition, structure and dimensions. Many fibres are well known to the manufacturers of textiles, matting and ropes, and some of them are considered on the basis of their cellulose content, low microfibril angle and high aspect ratio (length/diameter). In fact, their suitability as reinforcing material in a synthetic polymer matrix is reported to be quite competitive with that of glass fibre. Hence, in spite of great variability in their physical properties, the present trend is to design various components for housing with natural organic fibre reinforced polymer composite materials.

2.2 Mechanical and chemical properties of organic fibres

Among many world wide standard specifications for determinging the physical and mechanical properties of the fibres, the following ASTM standards are used very extensively. Specific gravity (D792), water absorption (D570), tensile strength, elongation and modulus of elasticity (D638), compressive

strength (D695), flexural strength (D790), hardness (D785), impact test (D256), heat absorption (D648) and flamability (D635).

The standard specifications applicable for the determination of cellulose, hemicellulose, lignin, moisture swelling etc. in timber are equally applicable for natural organic fibres.

Table 2 gives the chemical properties of some natural organic fibres. Except for the coir fibre and wood almost all others show similar chemical compositions and moisture regain and transverse swelling in water characteristics.

Table 2 : Chemical properties of some natural organic fibres

Fibres	Cellulose (%)	Hemi cellulose (%)	Lignin (%)	Moisture regain at 65% RH	Transverse swelling in water (%)
Banana	60-45	6-8	5-10	10-15	15-20
Cotton lint	40	6	-	7-8	20-22
Coir	43	21	45	10-12	5-15
Flax	70-75	14	4-5	7	20-25
Jute	60-65	13	5-13	12.5	20-22
Sisal	60-65	10-15	8-12	10-12	18-20
Hemp	70-80	18-20	4-5	10-11	18-20
Wood	45-50	20-25	27	-	-

The high specific strength (tensile strength/density) and specific modulus (modulus of elasticity/density) along with high aspect ratio make the organic fibres very suitable reinforcing material in various synthetic polymer binders, yet the composites made even with a few combinations show widely variable properties because of the variations in the physical properties of the matrices shown in Table 3. The best combinations are available, not with natural organic fibres but with glass fibre reiforced polymer composites.

Table 3 : Physical properties of matrices

Material	Density $(kg/m^3)x10^3$	Compressive strength (MPa)	Tensile strength (MPa)	Modulus of elasticity (GPa)
P'cement	2.1-2.3	10-25	3.0	10-20
Gypsum plaster	1.2	10-12	2.2-2.9	-
Polyester resin	1.05-1.3	90-250	30-90	1.5-6.0
Epoxy resin	1.1-1.2	90-200	40-90	2.0-5.0
Styrene resin	1.1-1.2	70-150	20-70	2.0-5.0
Polyurethane resin	1.1-1.2	-	-	1.5-2.5
Phenolic resin	1.1-1.3	90-200	30-70	1.5-5.0

Polymers could be evaluated as per IS-8543:1978 method of testing of plastics (4 parts).

Many attempts have been made to standardise the design-developments for various components using organic fibre reinforced cement composites but the results reported are from moderate success to total failures, in many pilot plants and commercial productions. It is mainly because of wide variability in the properties of an organic fibre even grown in various locations within the same country.

Natural organic fibres, in general, possess the modulus of elasticity (E_f) lower than the modulus of elasticity of the matrix. Hence, the reinforcing effect could only be better as the E_f/E_m increases. This can be monitored only through the characterisation data of all natural organic fibres.

3.0 Types of composites materials

Composites can be classified into the following three types :

(a) **Particulate composites** : Distinct particles and/or fibres are embedded in a matrix, for example : RCC/Ferrocement or a metal fibre combined in metallic or non-metallic matrix e.g. Aluminium-aluminium oxide composite.

(b) **Fibre-reinforced composite** : The classic example is glass fibre reinforced plastics or jute fibre phenolic resin combinations.

(c) **Laminar composite** : In this type, fibres are stacked and bonded, placing them into various orientations and made as laminates. The common examples are plywoods and other lignocellulosic products using a synthetic resin or an inorganic binder. Sometimes, instead of one fibre a hybrid of fibres is incorporated giving it nonmenclature as hybrid-fibre-resin composite.

3.1 Essential properties of fibre and matrices

Properties of fibres

(a) High ultimate strength

(b) Variation in strength between individual fibres should be low

(c) Should be stable and retain their strength during processing

(d) The diameter and surface should be uniform and free from grease and dirt

(e) The aspect ratio (length/diameter) should be large.

Properties of matrix

(a) It should bond well with fibres

(b) Its should disperse the fibres and prevent cracks

(c) It should transfer the load to the fibres effectively

(d) It should have good compatibility with the fibres

3.2 Rule of mixtures

The properties of composites follow certain simple rules of mixtures. For example, density of a particulate composite is represented by $\rho_c = f_m \rho_m + f_p \rho_p$ in which ρ_c is the density of the composite, f_m and f_p are the volume fractions of the fibre and of the particles and ρ_m and ρ_p the densities of the two components. Other properties such as strength, modulus of elasticity and toughness can also be predicted with the simple rule of mixtures. Similarly, in a fibre-reinforced polymer composite $\rho_c = f_m \rho_m + f_f \rho_f$ wherein ρ_c is the density of the composite, f_m and f_f are the fractions of matrix and fibre and ρ_m and ρ_f are their densities. The modulus of elasticity is represented by : $\frac{1}{E_c} = \frac{f_m}{E_m} + \frac{f_f}{E_f}$ in which E_c is the modulus of elasticity of the composite f_m and f_f are the fraction of matrix and fibre and E_m and E_f are their modulus of elasticity. Some typical results of the composites properties are given in Table 4(a) and 4(b).

Table 4(a) : Bending strength of natural and glass fibre-rienforced composites

Fibre-matrix	Specific gravity	Bending strength (GPa)	Fibre volume fraction (%)
Wood fibre/phenolic	1.2	0.11	65
Woven jute/polyester	1.2	0.09	50
Felted jute/polyester	1.2	0.10	60
Cotton/epoxy	1.4	0.17	35
Kenaf/epoxy	1.2	0.42	70
Glass/epoxy	1.7	0.69	70

Table 4(b) : Physical properties of some vegetable/glass fibre reinforced polyester composites

Property	Glass fibre	Cotton fabric	Banana fabric	Coir fibre	Banana + cotton fabric
Density (kg/m^3)	1500-1900	1400	1215	1160	-
Tensile strength (MPa)	240-690	340-680	35.9	18.6	25.8
Flexural strength (MPa)	344-660	62-124	50.6	38.1	52.30
Modulus of elasticity (GN/m^2)	6.9-41	2.7 - 4.2	3.33	4.05	1.36
Impact resistance (kg/m^2)	3110-8400	250-430	748	390	-
Water absorption (%)	0.2-1.0	0.8	1.93	1.36	-

4.0 Natural organic fibres in cement matrix

The failures and success stories of organic fibres compatibility with the cement matrix are well known because of their unsatisfactory interaction. Almost all natural fibres in cement matrix show poor alkali resistance and low wettability resulting in unsatisfactory performance in natural weathering. The fibres become brittle, lose adhesion, show cracking and increase in water permeability. Many attempts have been made to overcome these difficulties including use of blended cements and/or modifications of the fibres with coatings with isopropyl tri-isostearoyal titanate and y-aminopropyl trimethyoxy silate to improve interfacial bond. Phenolformaldehyde coatings and hybrid fibres are other methods used for improvement.

5.0 Steel fibre, and glass fibre reinforced cement concrete

Among steel and glass fibre reinforced cement-concrete composites the following are gaining importance in the building and construction sector.

(i) Rollar compacted concrete, (ii) Very high strength concrete, (iii) Compact reinforced concrete, (iv) Slurry infiltered fibre reinforced concrete, (v) Macro defect free concrete (vi) Ferro cement and (vii) Glass fibre reinforced cemet concrete (also polypropylene fibre reinforced cement concrete).

The main characteristics of steel fibres are the following : Aspect ratio (*l*/d) 30-250, if length ranges from 6-75 mm; Round steel fibre, d = 0.25-0.75 mm; Rectangular cross section 0.25 mm thick. The glass fibres are of d = 0.005-0.015 mm but bonded to make into filaments of 0.01-1.5 mm diameter.

In most of the steel fibre reinforced cement concrete composites, there is improved mechanical bond, crack growth are the minimum and flexural strength and toughness are improved. Typical properties are given in Table 5 and the improvements in the physical and mechanical properties over plain cement concrete are shown in Table 6. A polymer added to cement, with steel fibre acting as reinforcement, the properties of the polymer concrete are given in Table 7.

Table 5 Typical proportion for steel fibre reinforced concrete

Cement	325 - 560 kg/m^3
Water to cement ratio	0.4 - 0.6
Fine aggregate/total aggregate	0.5 - 1.0
Maximum aggregate size	10 mm
Air content	6-9%
Fibre content	0.5 - 2.5 % by volume

Table 6 : Improvements in physical and mechanical properties in steel fibre reinforced concrete

Property	Fibre reinforced concrete	Advantages over plain concrete
Flexural strength (ultimate)	Upto 17.5 N/m^2	About 3 times higher
Compressive strength	Upto 90 N/m^2	Significant
Impact resistance	1367	Nearly 3 times higher
Fatigue endurance limit ratio	0.8 - 0.95	More than 70% higher
Abrasion resistance	2	Twice as resistant
Shear strength	Upto 5 MPa	Nearly 2 times higher

Table 7 : General and mechanical properties of polymer concrete (density 2000-2400 kg/m^3)

Monomer polymer	Polymer loading (% by wt.)	Strengh		
		Compressive (MPa)	Tensile (MPa)	Modulus of elasticity (GPa)
MMA	5.5-7.5	150	11	42
Styrene	4.5-6.0	100	8	44
Acrylonitrile	3.5-6.0	100	7	40
Vinylchloride	3.0-5.0	72	5	29
Polyester	10	117	13	32
Epoxy	10	95	12	30

In these recent developments in steel fibre reinforced concrete, one of the attempts is to reduce the cement content per m^3 of concrete by incorporating fly ash or ground granulated blast furnace slag or rice husk or condensed silica fume, with admixtures such as plasticizers and superplasticizers and other water reducing substances besides the methods used for laying, placement and compaction.

5.1 Properties of fibre reinforced concrete composites

The rheological properties of FRC depends on the size and type of fibres and on the method of production. The fibres usually have large surface area and therefore they have large water requirements, as well as tendency to interlock or ball. Glass fibre requires more water which gets absorbed in between the filaments. As a general rule, higher the fibre content lower is the workability.

Apart from the difficulties in workability, it is hard to compact fibre reinforced concrete, and therefore external vibration is required. So far, there are no standard test methods for determining structural properties of FRC although many tests have been proposed. For adequately compacted concrete, compressive strength is hardly affected but tensile strength increases, and also shear and flexural strength and toughness get improved. Polypropylene fibre increases the toughness but does not improve tensile strength, the mixture of polypropylene fibre and glass fibre proudces much better mechanical properties, such as abrasion, erosion, shock and fatigue resistance. Fibres also contibute to reduction of shrinkage by 20-30 per cent whereas SFRC shows adequate protection to steel fibres from corrosion.

Fixed form and slip form paving machines, pneumatic application, pumping and spraying of fibre reinforced concrete have also been done. SFRC has usually 1-4% fibre content.

Major applications of SFRC are in pavements, fibre shotcrete, overlays, airport runways, precast roofing, flooring, pipes, piles, manholes, bridge

decking, folded plates, shells, storage structures, ware houses, water front etc.

A typical composition for glass fibre reinforced cement is p'cement 38.9, sand 38.9, water 12.8, fibre 5, admixture 0.4 and polymer 4.0% by weight. GRC and GRCC applications in building are for form work system, frameless housing system, fencing, roofing elements, ducting and sandwich panel constructions.

6.0 Ferrocement

Ferrocement is also a class of steel fibre reinforced composite material which has already established its potential application in agriculture, industry and housing. Its thickness is not more than 25 mm. It uses a wide variety of reinforcement of wire-mesh. Sand to cement ratio of 1.5 to 2.5 by weight and water to cement ratio of 0.35 to 0.55 by weight is used. The wire meshes are made as woven or interlocking, welded steel, expanded metal lath or perforated steel. The ACI 549R-62 includes definition of ferrocement of non-metallic reinforcement also, i.e. including natural organic fibres and glass fibre assembled meshes.

The volume of reinforcement is 4 to 8 % in both directions i.e. between 300 - 600 kg/m^3. Fibres, in the form of short steel wires or other fibrous materials can also be added to the mortar mix to control cracking and increase the impact resistance. Compaction is achieved by beating the mortar with a flat pice of wood. Care is taken not to keep any reinforcement exposed, the minimum cover is 1.5 mm.

Major applications of ferrocement is in walls, roofing, partitioning, silos, bath tubs, water storage tanks, septic tanks, pipes, and in furniture such as cup boards, tables and many other precast elements.

7.0 Gypsum plaster-glass reinforced composites

Gypsym binder composites with glass fibre reinforcement or even with coir, jute or sisal fibre reinforcement are made with usual spraying or table moulding methods. A typical range of the properties of glass fibre reinforced gypsum plaster and that of gypsum-slag binder composites is given in Table 8. These boards are traditionally used for partitions and ceiling, door shutters, furniture etc.

Table 8 : Properties of glass fibre reinforced gypsum plaster and gypsum-slag-cement binder composites

Property	Gypsum plaster composite (E glass 4%)	Gypsum-slag-cement composite (E glass 4%)
Bulk density (kg/m³)	1.2	1.63
Consistency (%)	81	65
Flexural strength (MPa)		
3 days	4.97	12.17
7 days	4.98	13.21
28 days	4.96	22.00
Tensile strength (MPa)		
28 days	2.75	1.80
Impact strength (MPa)		
28 days	10.20	1.86
Thermal conductivity		
(Kcal/mh°C)	0.12	0.09

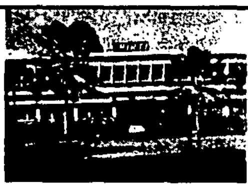
8.0 Concluding remarks

Composites have been known since ancient period of civilisation. There have been outstanding discoveries and innovations in the production of fibres and binders which resulted in the diversified processes, design and applications of composites. Synthetic organic fibres, glass, metal and ceramic fibres have greatly supplemented the natural wood and organic fibre based composite building materials. Characterisation data are in constant investigations, database on fibres and matrices are getting stored into the modern dissemination pipe lines. Following the reduction of expenditure in aerospace and defence programmes, there are inevitable diversions of resources earmarked for high profile composites to down the earth applications such as in housing and agriculture. It is quite realistic to believe that the next 20 years will find a major break through in the application of composites in construction and building sector.

Bamboo Development in India

Arun K. Bansal
DIRECTOR

Bamboo Development in India



Arun K. Bansal
DIRECTOR

Indian Plywood Industries Research & Training Institute

(AN AUTONOMOUS BODY OF the Ministry of Environment & Forests)

UNION MINISTER for Environment & Forests
PRESIDENT

↓

SECRETARY, E & F, GOI,
CHAIRMAN BOARD OF GOVERNORS

↓

DIRECTOR

↓

- Hqrs. & MAIN LAB, BANGALORE
- FIELD STATION, KOLKATA
- FS for NW Region (PROPOSED)

MANDATE

- RESEARCH
- TRAINING
- STANDARDIZATION

RELATED TO PANEL PRODUCTS FROM WOOD, BAMBOO & OTHER RENEWABLE FIBERS INCLUDING FOREST/AGRO RESIDUES.

VISION

IPIRTI'S VISION IS
CONSERVATION OF NATURAL FORESTS through
DEVELOPMENT AND ADOPTION of
EFFICIENT TECHNOLOGIES *for*
MANUFACTURING WOOD AND PANEL PRODUCTS *from*
RENEWABLE FIBERS,
Including PLANTATION TIMBERS AND BAMBOO
to meet the VITAL NEEDS OF DEVELOPING SOCIETY

BAMBOO - A WONDER GRASS

- ✓ *GROW 3 TIMES AS FAST & CAN BE HARVESTED 4 TIMES AS OFTEN AS EUCALYPTUS*
- ✓ *YIELDS 6 TIMES MORE CELLULOSE THAN FAST GROWING TREES*
- ✓ *FOUND EXTENSIVELY IN NATURAL FORESTS AND* is also suitable for afforestation of degraded lands
- ✓ *2.5 BILLION PEOPLE WORLDWIDE USE BAMBOO*
- ✓ *1.0 BILLION PEOPLE LIVE IN BAMBOO HOUSES*
- ✓ HAVE A VERY HIGH MOE 9000-10000 N/mm2 IS THUS IS VERY STRONG wt by wt stronger than steel
- ✓ BAMBOO IN PANEL/LAMINATE FROM IS A GOOD WOOD ALETRNATE

BAMBOO RESOURCES

WORLD DISTRIBUTION

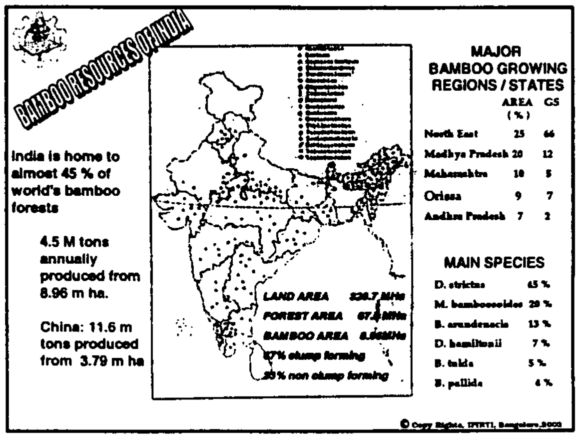
1250 KNOWN SPECIES
46° N to 47° S
80 % in S & SE Asia & China

BAMBOO BIOMASS
- 25% OF TOTAL IN TROPICS
- 20% OF TOTAL IN SUBTROPIC

Bamboo Resources - South Asia

Country	Species Diversity	Area/ Production	Main Uses
Bangladesh	9 genera. 33 spp. 17 spp cultivated	village groves	Housing. Transport. Agr. Implements. Small Irrigation. Fodder. Fuel
Bhutan	14 genera. 31 spp.		Housing. Bow & Arrow. Fencing. Baskets (storage/water container). Trays
India	24 genera.130 spp.	9.6 million ha 4.5 million tons Agro Forestry	Rural Housing. Handicrafts. Paper pulp. Food (shoot/pickle). Scaffolding. Agri/Horti/Sericulture. Fuel Several New Industrial Products
Mynamar	17 genera.100 spp.	.36 million tons	Toothpicks. Chopsticks. Paper/pulp. Food. Fodder. Fencing. Housing & Construction. Aesthetic Plantations
Nepal	11 genera. 33 spp.	3 million culms Agro Forestry	Rural Construction. Baskets. Scaffolding. Fodder (in late winters). Strip based brush dams (under evolution)
Pakistan	Nil. except ornamental		
Sri Lanka	10 spp.+ 20 exotics (7 cultivated)	.3 million culms	Housing and construction. Handicrafts

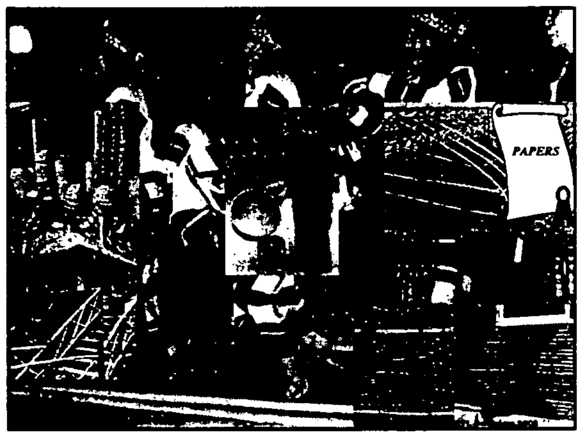
Source: Silviculture and Field Guide to Priority Bamboos fo Bangaladesh and South Asia by R.L. Banik, 2000

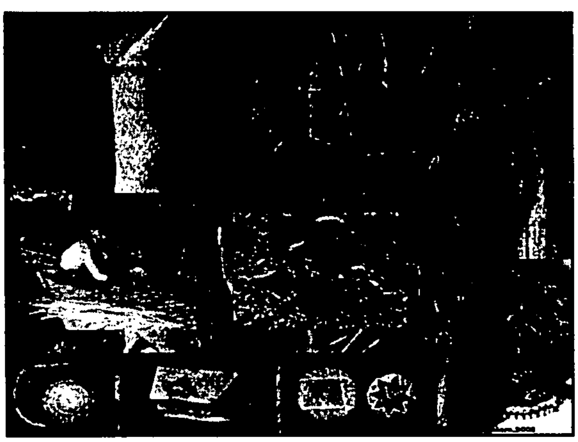


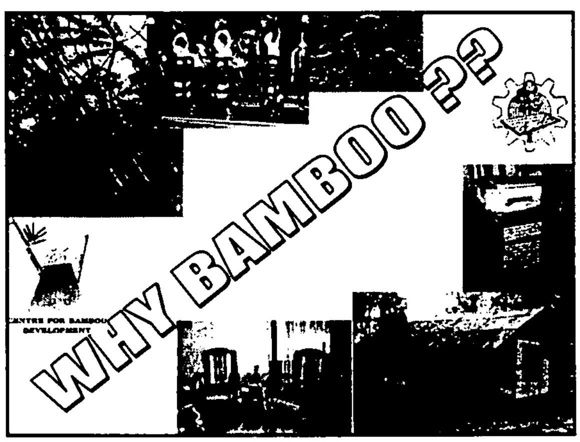
BAMBOO USE PATTERN - India

USE	%
PULP	35
HOUSING	20
NON RESIDENCIAL	5
RURAL Agr. etc	20
FUEL	8
PACKING/BASKET	5
TRANSPORT	2
FURNITURE	1
OTHERS	4

SOURCE:TIWARI, 1992 "A MONOGRAPH ON BAMBOO"







ANNUAL REQUIREMENT OF WOOD

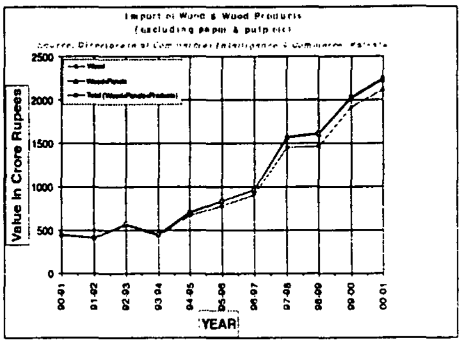
(excluding fuel wood)

Sector	Requirement 2000 (M cum)	Requirement 2005 (M cum)	Requirement 2011 (M cum)
Sawn Wood	47.00	50.00	54.00
Pulp Wood	23.60	28.50	35.00
Wood Composites	2.11	3.17	3.97
Total	73.01	81.67	92.93

APFSOS Working Paper No 10, FAO, 1998

Supply of Timber from Forests
(NFAP 2000 estimate)
12 million cum per annum

WOOD IMPORTS



Bamboo products

- STRUCTURAL APPLICATIONS
  - BUILDINGS
    - Earthquake-resistant, conventional housing and buildings
    - Two-floored bamboo-cement mortar composite rural houses
    - Scaffolding
    - Community buildings: Schools, community centre, hospitals and others, tourist resorts, convention centres
  - ROADS
    - Road grids, bridges, pathways
    - Landslide retaining walls
  - OTHER INFRASTRUCTURE
    - Small dams, water-tanks, biogas plants, telephone/electricity poles

Bamboo products

- NON-STRUCTURAL APPLICATIONS
  - Decorative plywood, various board products such as block board, strip board, roofing sheets, flooring
  - Furniture
  - lorry bodies & flooring, railway sleepers
  - Matchsticks, incense sticks, toothpicks, skewer sticks, blinds, etc
  - Fuelwood, charcoal, briquettes, activated carbon
  - Bamboo shoots, pickles, crisps, wine, vinegar, juice, beer
  - Schooling: pencils, rulers, blackboards
  - Handicrafts
  - Pulp and paper

Bamboo products

ENVIRONMENT & ECOLOGY

Bamboo is fastest growing plant

Bamboo stands release 35% more O_2 than equivalent stands of trees

Used for soil and riverbank erosion protection, wasteland and watershed management

BAMBOO BENEFITS

Economic

- Economically viable!
- Investments not of a high order
- Technologies available
- Revival/growth of wood industry
- Higher value addition with financial benefits to local people
  - Increased cash output from micro-enterprises will help local population through opportunities created for local populace as cultivators, processors, consolidators or logistic providers

BAMBOO BENEFITS

Social

- Preserves, enlarges and enriches traditional livelihoods from local resources
- New livelihood opportunities - imbibing skills of a higher order leading to better work ability in the local population
- Gender issues – involvement in primary processing gives women income for education, nutrition, etc.
  - Time flexibility helps women manage work
  - Nature of crop allows equitable contribution
- Builds consolidated markets based on co-operative principles
  - Ownership serves as incentive

BAMBOO BENEFITS

Environment

- Cultivation of bamboo is a more positive approach towards a cleaner environment
- Reduces pressure on forests
- Benefits:
  - Reduces landslides and erosion control
  - Contributes to wasteland development
  - Assists in watershed management
  - Protects forest regeneration and microenvironments
- Benefits are natural fallout of sector growth
  - No special effort required to improve the environment if bamboo used for development

Energy requirement of construction materials

Material (1)	Energy for production MJ / Kg (2)	Weight per volume Kg / m³ (3)	Energy for production Kg / m³ (4)	Stress when in use (5)	Energy per unit stress (4) / (5)
Concrete	0.8	2400	1920	8	240
Steel	30	7800	234000	160	1500
Wood	1.	600	600	7.5	80
Bamboo	0.5	600	300	10	30

Source: Prof J. A. Janssen
Eindhoven University, the Netherlands

R&D Institutes in Bamboo Sector

- Resource Survey, Management & Preservation
  - ICFRE Institutes, FSI Dehradun, KFRI Peechi, SFRI Itanagar
- Processing Technology and Products– Industrial Products
  - IPIRTI, FRI Dehradun (an ICFRE Institute), NID Ahmedabad
- Processing Technology – Food products
  - CFTRI Mysore (CSIR)
- Products designs, processing technology & tools - Handicrafts
  - NID Ahmedabad, IPIRTI, IIT Mumbai, BCDI Agartala (DC Handicrafts)
- Housing & Construction
  - BMTPC, IPIRTI
- Facilitators/Entrepreneurship Development
  - CBTC, NMBA–DST

ENVIRONMENT & PEOPLE FRIENDLY TECHNOLOGIES

R&D WORKS at IPIRTI

BAMBOO MAT BASED

- BAMBOO MAT BOARD
- BAMBOO MAT VENEER COMPOISTE
- BAMBOO MAT CORRUGATED SHEETS

BAMBOO STRIP BASED

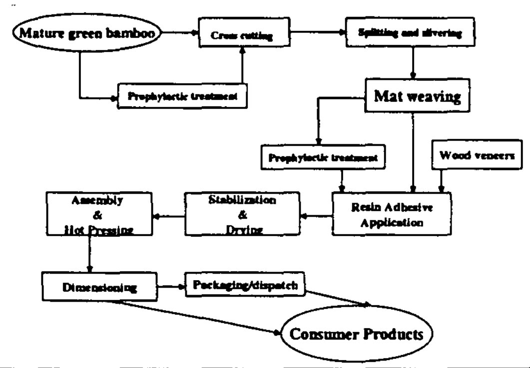
- ➢ BAMBOO-WOOD (LAMINATES) FROM INDIAN BAMBOOS
- ➢ DEVELOPMENT OF TRANSPORT VEHICLE FLOORING

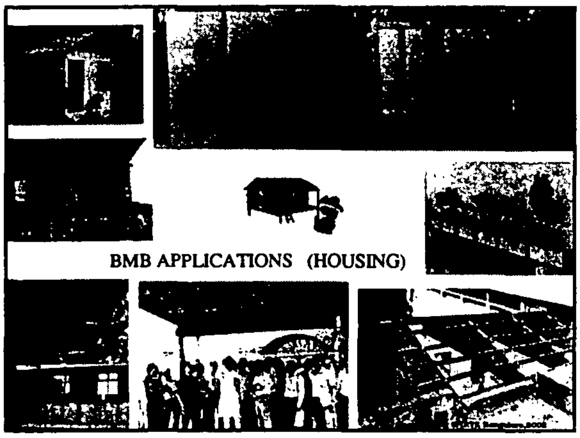
BAMBOO IN ROUND/SPLIT/COMPOSITE FROM
BAMBOO BASED HOUSING SYSTEM

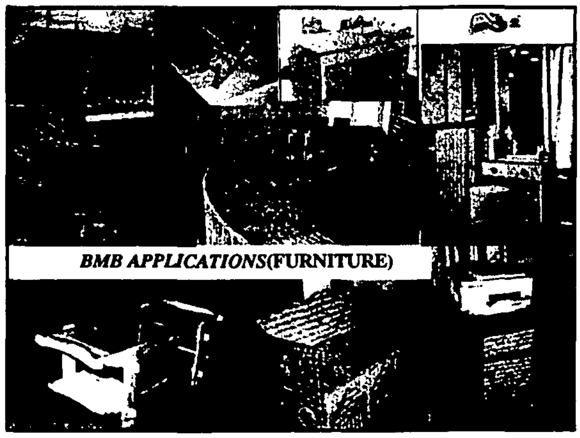
Bamboo Match Sticks

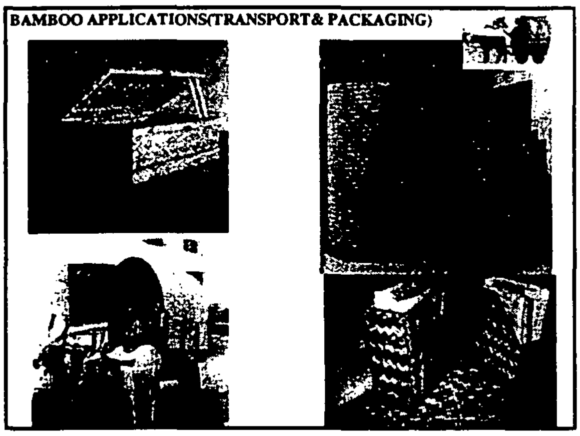
Bamboo Mat Based Composites

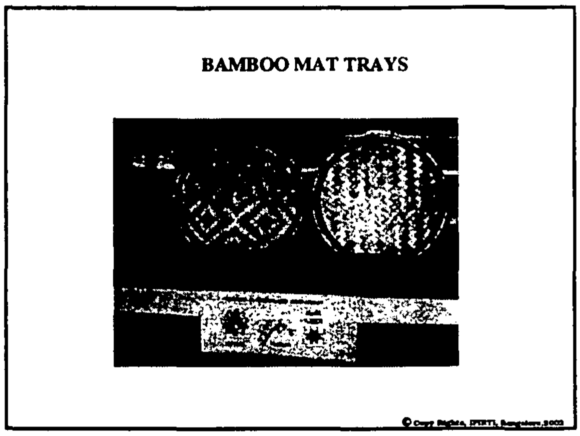
PROCESS FLOW CHART

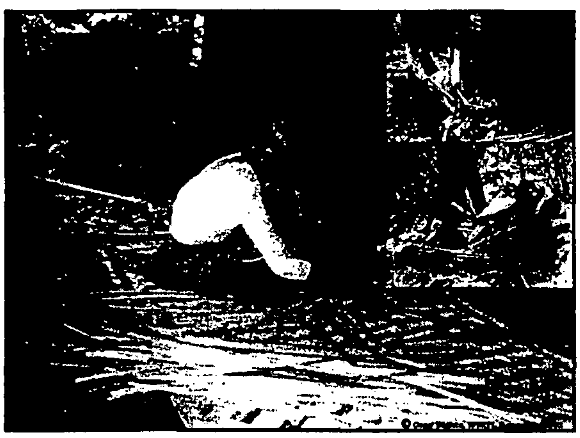


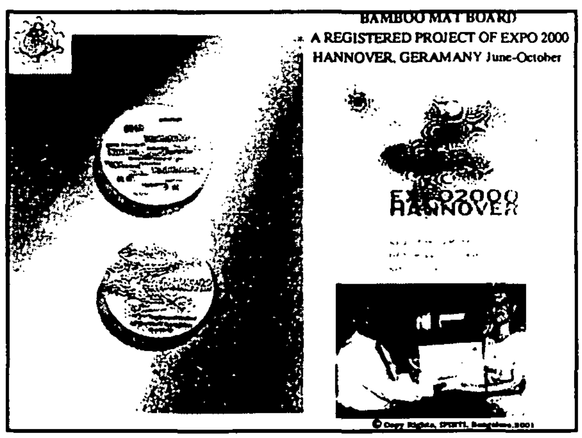

BMB APPLICATIONS (HOUSING)


BMB APPLICATIONS(FURNITURE)


BAMBOO APPLICATIONS(TRANSPORT& PACKAGING)

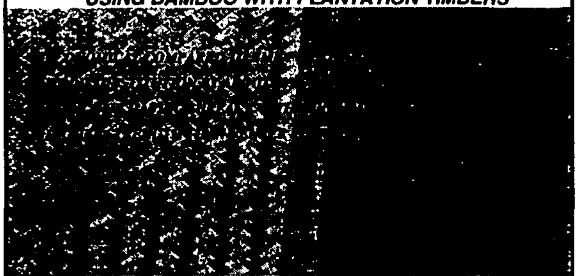

BAMBOO MAT TRAYS




BAMBOO MAT BOARD
A REGISTERED PROJECT OF EXPO 2000
HANNOVER, GERAMANY June-October

BAMB00 MAT VENEER COMPOSITES

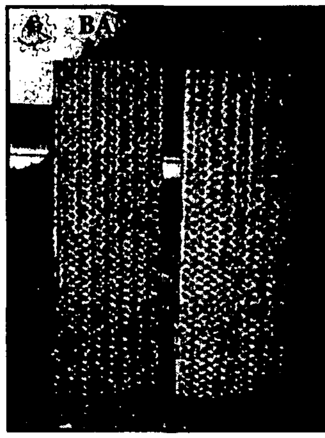
USING BAMBOO WITH PLANTATION TIMBERS



INDIAN STANDARD SPECIFICATION

IS: 14588 :1999 BMVC for general purpose

BA ... UGATED SHEET



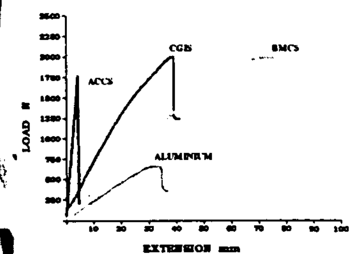
TECHNOLOGY DEVELOPED AT

IPIRTI

FUNDED BY BMTPC

MoEF, GOI

LOAD BEARING STRENGTH OF BMCS



Some Important Properties of BMCS

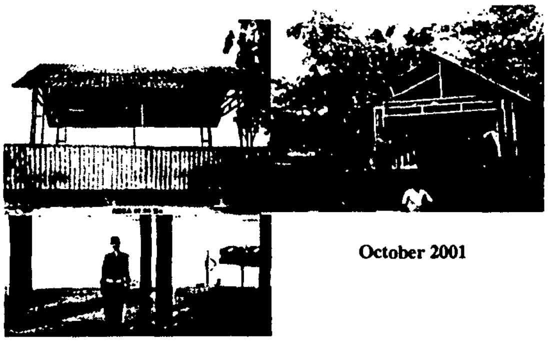
Size	:	1.05m X 1.8 m X 3.5 mm
Weight	:	6.5 – 7.90 kg/sheet (app. half that of ACCS)
Load Bearing Capacity	:	4.8 N/mm width
Deflection at Breaking Point	:	85 mm
Thermal Conductivity	:	0.1928 k cal/m °C (app. half that of ACCS)
Fire Resistance	:	Conforms to flammability test
Energy Requirement	:	Highly Energy Efficient

BMCS
at
TERRACE CAFÉ

DFID
NEW DELHI
October, 2000

Traffic Pedestal
(prototype)
Two installed at
Mathura Road
New Delhi (Nov. 2000)

Rain/Sun Shelter at Nandankanan biological park, Bhubaneswar, Orissa

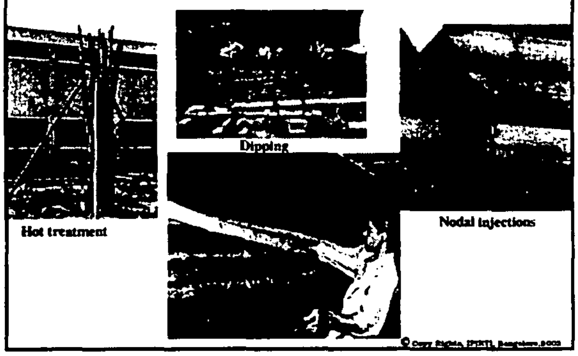


October 2001

BAMBOO BASED HOUSING SYSTEM

EVOLVED IN COLLABORATION WITH TRADA Tech., UK UNDER A PROJECT FUNDED BY DFID

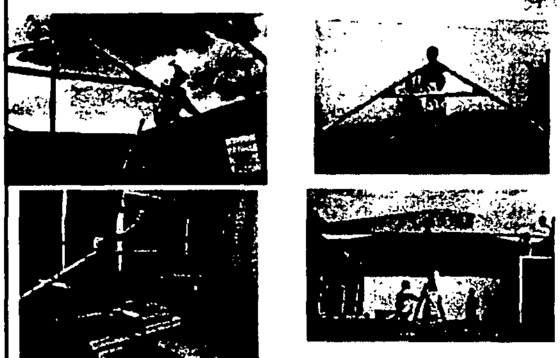
PRESERVATIVE TREATMENT OF BAMBOO

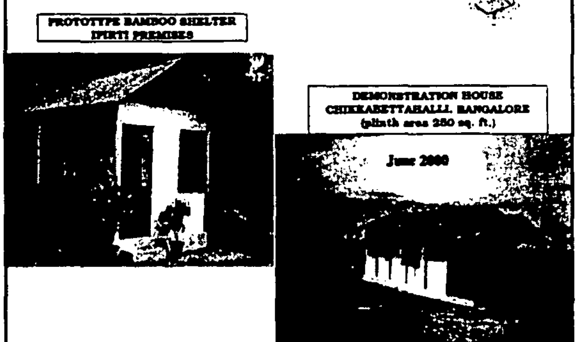


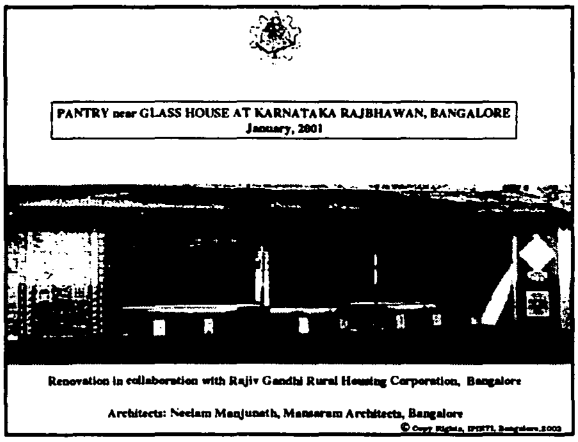
DEVELOPMENT of BAMBOO SHELTER

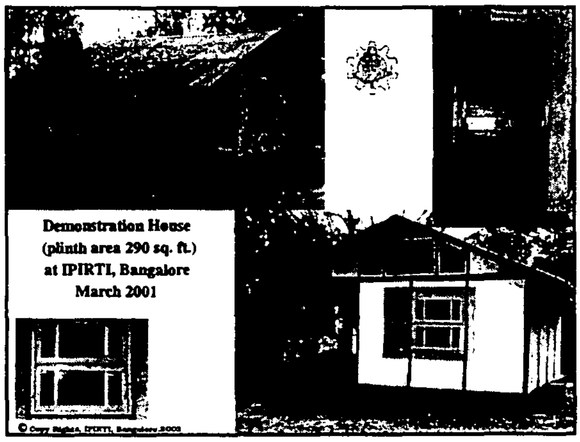
IPIRTI, Bangalore, INDIA / TRADA Technology UK

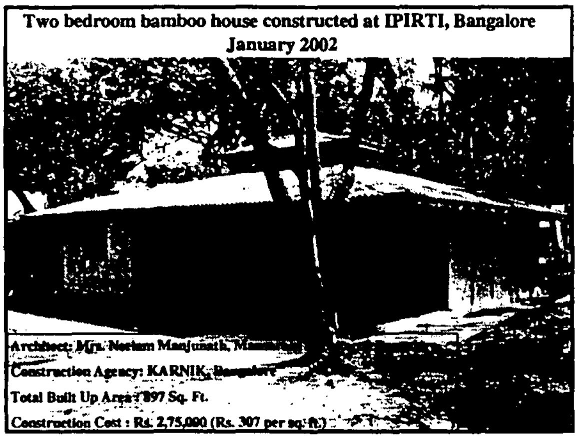
BAMBOO BASED TUSSES & BEAMS

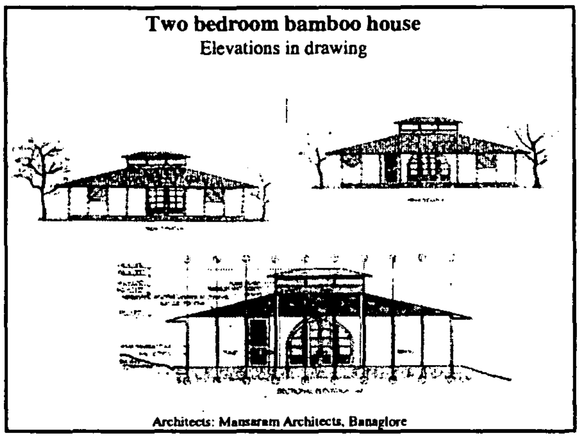


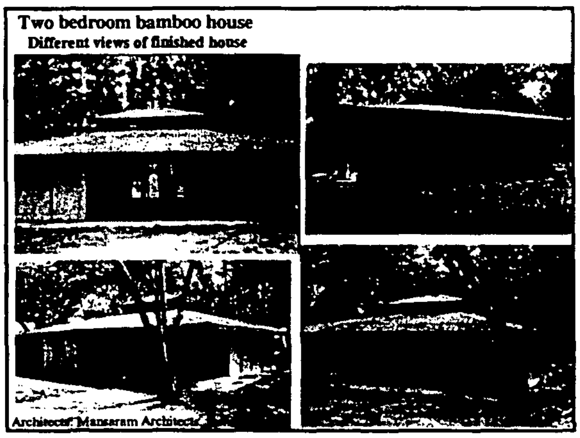


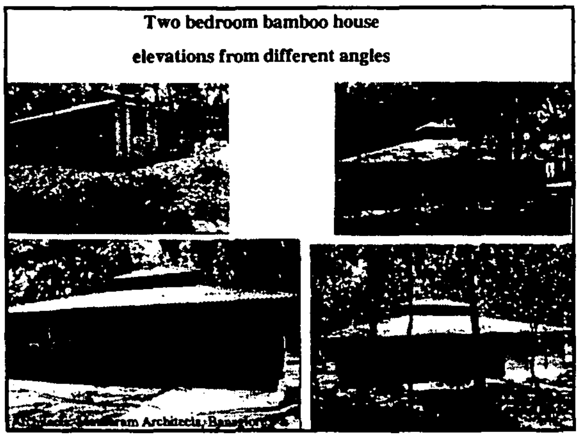

PANTRY near GLASS HOUSE AT KARNATAKA RAJBHAWAN, BANGALORE
January, 2001
Renovation in collaboration with Rajiv Gandhi Rural Housing Corporation, Bangalore
Architects: Neelam Manjunath, Mansaram Architects, Bangalore


Demonstration House
(plinth area 290 sq. ft.)
at IPIRTI, Bangalore
March 2001


Two bedroom bamboo house constructed at IPIRTI, Bangalore
January 2002
Total Built Up Area 897 Sq. Ft.
Construction Cost : Rs. 2,75,000 (Rs. 307 per sq. ft.)


Two bedroom bamboo house
Elevations in drawing
Architects: Mansaram Architects, Banaglore


Two bedroom bamboo house
Different views of finished house


Two bedroom bamboo house
elevations from different angles

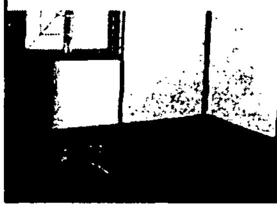
Two bed room bamboo house

Interior views

Architects: Mansaram Architects, Banaglore

Two bed room bamboo house

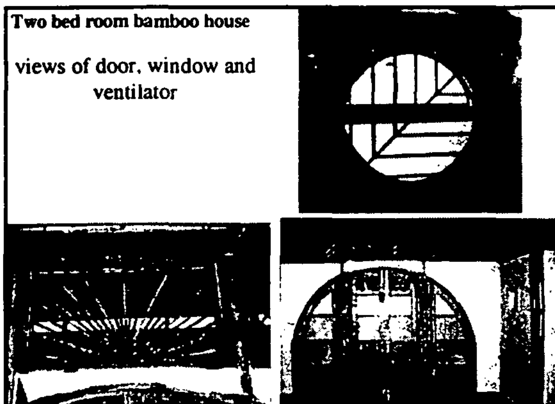
Finished floor



Architects: Mansaram Architects, Banaglore

Two bed room bamboo house

views of door, window and ventilator



Architects: Mansaram Architects, Banaglore

BAMBOO MATCH STICKS

TEHCHNOLOGY DEVELOPED
IN COLLABORATION WITH INBAR

SPECIES TRIED

BAMBUSA BAMBOOS

DENDROCALAMUS STRICTUS

STRENGTH CONFORMS TO IS 1140:1970

HEAD FIXING CONFORMS TO IS 2653:1993

NO AFTER GLOW

BURNING - CONTINUOUS TEMP ACHIEVED 300 °C

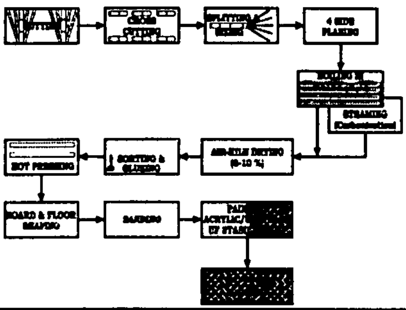
PATENT

Application 627/MAS-7-8-2000

BAMBOO LAMINATES

UNDER DEVELOPMENT at IPIRTI
under
MoEF FUNDED PROJECT

BAMBOO FLOOR BOARD/LAMINATES (BAMBOO WOOD) Process Flow Chart



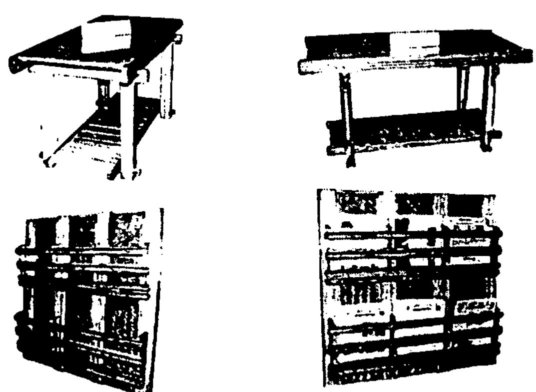
Mechanical Properties of bamboo wood made from Bambusa bambose

Bamboo Wood(laminate) R&D at IPIRTI

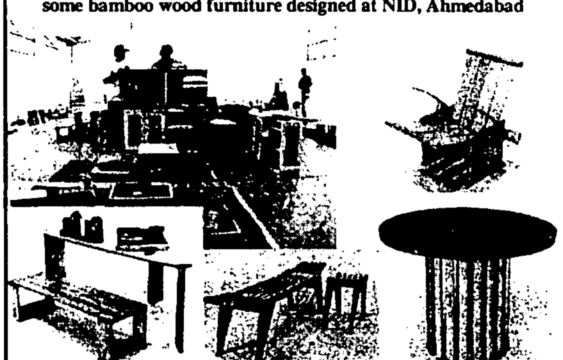
Property	Unit	Bamboo Wood (Vertical Laminate) (Bambusa bambose)[$]	Teak @ 12% Moisture Content
Density	Kg/m³	728 (44.3)	604
Modulus of Rupture Parallel Perpendicular	N/mm²	122.5 (22.83) 135.6 (17.62)	93.95
Modulus of Elasticity Parallel Perpendicular	N/mm²	12028 (1311) 15344 (1556)	11720
Block shear Strength	N/mm²	11.9 (2.18)	9.37 / 10.59 (9.98)
Compressive Strength	N/mm²	61.7 (4.7)	52.15
Screw withdrawal Strength 1.Face 2.Edge	N	4999 (370)* 2333 (4640)	3900 2881

[$] Average of ten samples. Figures in brackets are standard deviations

* Screw Head Broken



some bamboo wood furniture designed at NID, Ahmedabad



implications of bamboo technologies

Women Empowerment through Bamboo Mat Weaving

Socio-Economic study by Bangalore University,
Bamboo Mat Board Factory Angamally, Kerala (2000)
11565 registered mat weavers, 28 depots in 3 districts

Sex Composition of Respondents in a random sample from registered weavers from 17 depots

Particulars	Frequency	%
Female	143	77
Male	57	23

Occupation of the Respondents

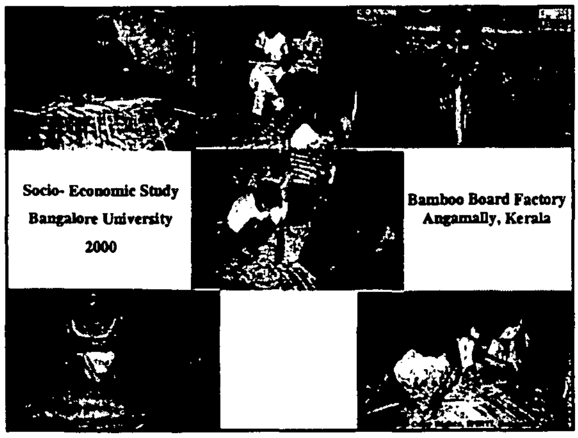
Particulars	Frequency	%
Mat Weaving	192	96
Basket Weaving	2	1
Agriculture	1	0.5
Business	1	0.5
Service	4	2

Mat Weavers Perception of Nature of Occupation

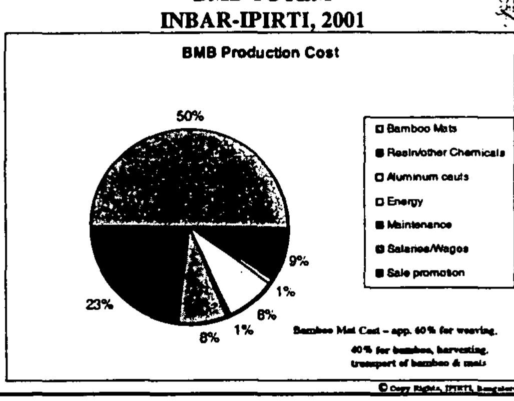
Occupation	Frequency	%
Traditional	163	81.5
Non-Traditional	36	18.0
No Idea	01	0.5

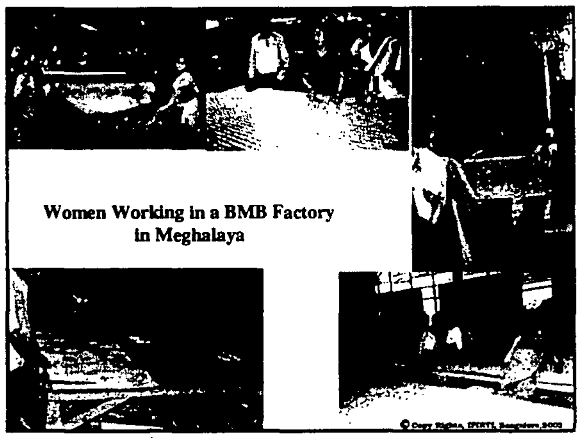
Motives for Engaging in Mat Weaving (multiple answers)

Category of Motives	Frequency	%
Support to Family	101	50.5
Additional Income	82	41.0
Bound by Tradition	17	8.5
Most Convenient	20	10.0
Use of Leisure time	03	1.5
Easy availability of work	08	4.0



BMB TOTEM
INBAR-IPIRTI, 2001





Bamboo can address three major national concerns

ECOLOGICAL SECURITY: through conservation of forests through timber substitution, efficient sequestration, alternate materials to non-biodegradable & high energy consuming materials like metals, and plastics

SUSTAINABLE FOOD SECURITY: through bamboo based agro - forestry system, maintenance of soil fertility of adjoining agricultural lands, and bamboo shoots

LIVELIHOOD SECURITY: through generation of employment in planting and primary processing for manufacturing mat based composites and other market driven bamboo products

IPIRTI publications related to bamboo technologies

1. Techno-Economic Feasibility of Bamboo Mat Board Manufacture (1992, priced)
2. A Techno-Economic Feasibility of BMB by AFC of India (1999, priced)
3. Pre Feasibility Profile for Bamboo Mat Corrugated Sheets (2001,priced)
4. Market Study for Bamboo Mat Corrugated Sheets in Bangalore (2001 – not published)
5. A Socio-economic impact study of BMB manufacturing in Kerala (2001 – not published)

6. National Workshop on Bamboo Mat Board – Proceedings (1993)
7. Plantation Timbers and Bamboo – Proc. National Seminar held at IPIRTI, Bangalore (1998,priced)
8. Affordable Housing using Bamboo and Bamboo Composites – Seminar Proceedings (2001

9. Manufacture of Bamboo Mat Board – a Manual (1999, priced)
10. Bamboo Composites : an Annotated Bibliography (1999, priced)
11. IPIRTI –News : Special Issue on Bamboo Mat Board (1999)
12. Status of Bamboo Housing Technology Developed at IPIRTI (2001)

13. Bamboo Mat Board Video (2000)
14. Bamboo Shelter (Video/ Video CD) (2001)
15. Technology/Product brochures
    Bamboo Mat Board, Bamboo Mat – Wood Veneer Composites, Bamboo Mat Trays, Bamboo Match Sticks, Bamboo Mat Corrugated Sheets, Affordable Bamboo Shelter

INDIAN SPECIFICATIONS FOR BAMBOO & BAMBOO PRODUCTS

- IS 14588 : 1999 - Specification for Bamboo Mat Veneer Composite for General Purposes
- IS 13958 : 1994 - Specification for Bamboo Mat Board for General Purposes
- IS 1902 : 1993 - Code of Practice for Preservation of Bamboo and Cane for non-structural purposes
- IS 10145 : 1982 - Specification for Bamboo Supports for Camouflaging Equipment
- IS 9096 : 1979 - Code of Practice for Preservation of Bamboo and Cane for Structural purposes
- IS 8242 :1976 - Method of Tests for Split Bamboo
- IS 8295 :1976 - Specification for Bamboo Chicks ; Part 1 Fine
  Specification for Bamboo Chicks ; Part 2 Coarse
- IS 7344 : 1974 - Specification for Bamboo Tent Pole
- IS 6874 : 1973 - Method of Tests for Round Bamboo

Evolving Bamboo Building Code

initiatives under way

Prerequisites for development of bamboo sector

- Awakening – to change the mind set – bamboo as poor man's material
- Enabling environment – policy –
  - use in public constructions,
  - movement restrictions on bamboo,
  - evolving standards and codes of practices
- Entrepreneurship promotion
  - new products
  - improved applications

egional planning for development of bamboo sector

Analysis of bamboo resource with special emphasis to species of bamboo and sustainable availability.
Enhancement of bamboo resources with people's participation.
Present use pattern and sectoral consumption, including study of artisan groups/local people's dependence on bamboo.
Opportunities for use of bamboo resources – screening of available technologies
- Bamboo mat based composites i.e. BMB, BMVC, BMCS
  - Bamboo Wood or Laminate
  - Reconstituted Bamboo Wood
  - Bamboo Based Housing
  - Bamboo shoots
  - Bamboo Match Sticks and other stick based products
  - Bamboo mat moulded items
- Impact of alternate industrial uses on local people s through involvement in various activities including growing, primary processing etc.
- Downstream processing for consumption within the state and exports (Market Potential)

Institutional arrangement and infrastructure - present scenario and future needs for growth of bamboo sector.

recent initiatives

- National Mission for Bamboo Applications housed at the Department of Science & Technology
- GOI intervention to the tune of Rs.1000-1200 million planned during the tenth five year plan
- Six Committees Constituted by Planning Commission to prepare action plans on various aspects for development of Bamboo Sector
- States

THANK YOU

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http://ipirti.com
http://bamboocomposites.com

Development & Production of Wood Substitute products using Agro Waste

Mr. Tommy Mathew
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Development & Production of wood substitute products using Agro Waste

INTRODUCTION

Coir fibre is an extract from the coconut husk, a waste material. The fibres extracted from the husk namely 'coir' are used for centuries, for house buildings, boat buildings, rope, carpets etc. These raw materials have proven the use and utilities for centuries. However developments in this sector were limited.

Jute fibres are extracted from the bark of the two cultivated species of the plant to obtain white and tossa jute by the combined of water and microorganism on the green plant in the retting process. Jute fibres are grown nine months of the year and are commercially exploited for various products from packaging, carpets, furnishing cloth etc., Jute as lignocelluloses fibre by definition more woody in its constituents. The high stiffness of reinforcing filler is one of the basic requirements of any composite material and jute fits in well.

The dry fibre constitutes about 7-9% by weight of the green plant. Whereas, the dry stem, commonly referred to as Jute stick, an agro-residue, constitutes about 15-20%. The fibre has a multi-cellular & multi-constituent structure having cellulose, ligin & hemi cellulose as major constituents.

Jute and coir are agro fibres grown in the rural areas. Products of these fibres are sustainable and renewable.

Using these indigenous, renewable and agro based raw materials; Coir Board (Govt. of India) from its research institute had developed a technology to produce Coirply. With the help of Technology Information Forecasting Assessment Council (TIFAC), Department of Science & Technology, United Nations Development Programme and World Bank has successfully commercialized this technology. This product has been test-marketed in the country and the response from the market shows that it has been well accepted as an alternative to plywood. For the last ten years Coirply has been accepted as an alternative to tropical timber products.

This is an innovative product that is set to replace solid products from timber and scarce forest resources in the market. Coirply is a board that uses renewable natural hard fibres such as Coir and Jute, impregnated with Phenolic resin and limited pretreated Plantation timber veneers.

THE NEED FOR AN ALTERNATIVE

Importance Of Tropical Forests

Tropical forests have a special role in the conservation of biodiversity. They are the home to 70 percent of the world's plants and animals – more than 13 million distinct species (Anon., 1996). The tropical forests contain 70 percent of the world's vascular plants, 30 per cent of all bird species, and 90 per cent of invertebrates. Many of the mammals are among the most famous icons of natural history – the great cats, the primates, and the ungulates of the East African woodlands. In tree species alone, tropical rain forests are extremely diverse, often having more than 200 species per hectare. Boreal forests, on the other hand, are biologically much simpler, with as few as one species per hectare for fire-regenerated stand like lodge pole pine in North America.

Forests influence the local and probably global climates. They moderate the diurnal range of air temperatures and maintain atmospheric humidity levels. Forests absorb atmospheric carbon and replenish the oxygen in the air we breathe. The conservation of forest resources in the watersheds that supply water for irrigation, sanitation, and human consumption is an important component of water supply strategies. When tropical watersheds have balanced land use, their forests absorb excessive rainfall that is gradually released later. Forests regulate stream flows by intercepting rainfall, absorbing the water into the underlying soil and gradually releasing it into the streams and rivers of its watershed. This minimizes both downstream flooding and drought conditions. Tree roots enhance soil porosity, reduce compaction, and facilitate infiltration. Trees act as windbreaks, reducing the force of desiccating, eroding winds at ground level.

A tropical tree, which is 90 years old, would achieve a height of 15 mtrs. with 0.5 mtrs.width and 0.5mtrs.depth gives about 3.75 cu.mtrs. of lumber. Timber recovery at 60% would yield about 2.25 cu.mtrs of planks and sheets. When converted into a finished product, there is a further wastage of 20 percent. Hence the total recovery would only be about 1.80 cu.mtrs.

On an average the current consumption of Tropical Rain Forest Timber can be looked upon as follows:

A team of carpenters would convert roughly about 50 sheets a day into finished product. Assuming one sheet is about 0.0518 cu.mtrs this would amount to about 1.44 trees. At this rate 500 carpenter teams in 23 states of India would convert about 49,68,000 trees per annum into finished product, which would be on an average 46,178 acres of tropical forest being cleared every year.

a) An average office of about 60 sq.mtrs requires about 3 cu.mtrs of logs or about 1.6 trees per office.

b) An average middle class household would require furniture of about 0.50 cu.mtrs of wood products, which will about 0.25 tree per house.

c) Architects and Interior Designers

An average architect or interior designer with an annual billing of about one crore would be using about 248 trees per annum. (Assuming cost of one cu.mtr is Rs.22388)

When calculated on an all India basis the consumption by about 20000 interior designers and architects would be about 54,60,000 trees per annum or clearing of 50753 acres of forest.

Indian Scenario

India is a timber deficit country and during 1993-94, the country imported wood and wooden items worth more than Rs. 500 million. India's estimated annual requirement of timber is around 40 million cum.m. For various industrial applications and current availability is estimated to be .25 million cum.m.

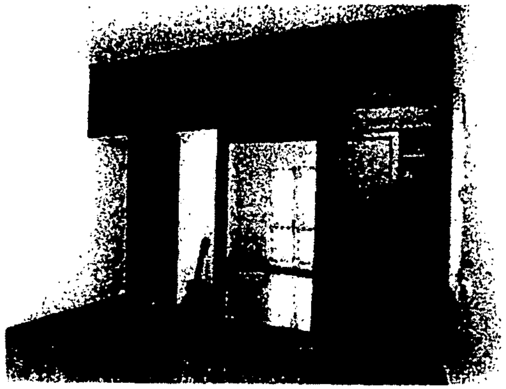
By Using Coirply

Corresponding to the above calculations one unit of coir ply with a production capacity of 40 cubic meters a day would be able to save about 22 trees per day. This would relate to 6,600 trees per year.

Assuming that one such tree requires 40 square meters, then that would be about 25 trees in one acre. With one such unit of coir ply we would be able to save about 264 acres of tropical forest every year.

In addition to the above, a coconut harvest is done once in 45 days. From 1000 coconuts it would be possible to extract 10 kgs. Based on the A.P.C.C. production of coconuts of 51,281 million nuts in 1994. That relates to a coir fibre production of 5 million tons of fibre yield. Even if 10% of this is utilized in the manufacture of coir ply that would correspond to half a million tones of coir utilization per year. In relation to the above, this would save about 8,80,000 tropical trees per year which corresponds to 8,800 acres of tropical forests per year.

To meet these increasing demand for Wood based panel products there is a great need to identify substitutes for wood based products, which is exactly where Coirply comes into the picture.



Coirply wardrobes

The major replacement for wood products in today's scenario is plastic, metals and a few other products. Given Coir's close resemblance to wood in its chemical composition and the availability of renewable fibre every 45-60 days, it would, in all practical aspects be a good replacement for tropical timber. This new innovative product can give us the entire range of wood products, by substituting wood with value added coir and rubber wood.

Coconut and Rubber are permanent tree crops causing less soil degradations than many other agricultural crops. Coconut and Rubber plantations have generally a positive impact on the environment. Agro forestry systems with coconut and rubber trees could be used for stabilization of degraded water catchments. When

Coir and rubber wood is sustainably produced from plantations, it substitutes saw logs and fuel wood otherwise exploited from natural forests. The economically available volume of rubber wood logs corresponds to an amount of native tropical timers which is annually harvested from an area of about 0.6 million ha Rubber wood production and utilization therefore can reduce the pressure on natural tropical forests and contribute to biodiversity conservation.

Poor rural areas need means for socially and environmentally sustainable development. Coconut and rubber plantation can be considered a production system, which is socially desirable and environmentally positive, particularly if agro forestry is applied. The social and environmental benefits of rubber plantations have clearly outweighed possible ecological problems. In particular we must also consider the socio economic conditions of the agro-based industry as an employment potential for millions of Rural Population.

<u>**Coirply Kitchen Cabinets**</u>

Presented by:
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Annexure – 7
Detailed Country Presentations

DETAILED COUNTRY PRESENTATIONS

Vietnam Building Industry

Geographical condition, wars and intellectual standards of people strongly affect on all industries in Vietnam including the building industry.

The development of Vietnam building industry can be divided into 3 main periods:

First period: Under French colonialism (before 1954)

Building industry had not been developed at all. The main building materials were wood, bamboo and species of bamboo. There was no cement production yet in Vietnam, but were only several small fabricating cooperatives producing bricks and roof tiles using backward technology. That's why there used to very few of buildings located mainly in the cities like Hanoi, Saigon (Ho Chi Minh City now), whereas in provinces, habitats were nearly all built/made from wood, bamboo and species of bamboo.

Second period: American war and embargo time after war (1954-1990)

There was only one cement production plant in Vietnam until 1980. Later, in order to meet the needs of people several small cement producing factories using blast furnace technology were built. However, those factories could not last long because of the high cost and low quality of their product.

Building materials at that period still mainly relied on wood and bamboo.

For the time to 1990, the main data of building industry has been recorded as followed:

- Cement production: 3 Million ton per year
- Brick: 2.5-3 Billion bricks
- Floor tile: under 8-10 Million m square – cement base
- Glass (pull technology): 5 Million m square per year
- Ceramic Floor tile : No
- Composite material: No

Third Period: From 1990- now

Peace time, open-door policy with ASEAN and other countries over the world. On the other hand, the domestic customer needs for building new, more and more decorated houses are strong driving force for speedy development of Vietnam building industry, in which technology displays important role for increasing production of building materials. With the increasing foreign investment, technology transferred and apparatus imported from abroad the view of building industry in Vietnam has changed dramatically, e.g.:

- Cement technology: from blast furnace turned into reverted furnace. With this change, the capacity of cement production has been increased from 3 to 18 million tons per year
- Capacity of brick: from 3 billion to 8.4 billion per year, from which 45% is produced by tunnel furnace
- Especially, ceramic floor tile: from nothing in the year before 1990 became 108 million M square produced by 35 plants distributed across the country in 2001.
- Building glass: changed from pull to floating technology, together with capacity of glass production increasing from 5 m square per year to 59 million m square per year in 1990 and 2001 respectively.
- Sanitary ceramic became one production of building industry in this period with 10 plants and 3.05 million items per year.

Instead of conclusion:

Though Vietnam building industry has grown very fast for the last decade, several questions still remain however, for today:

- Building material is still expensive for poor people especially who live in rural or mountain areas – nearly 30 % population are living in house built by non standards building material.
- The need of light and strong building materials for building houses in flood and far away areas.
- Lack of technology to use green building material
- Lack of technology to use secondary and agriculture by-products such as saw dust, rice husk and coconut shells and branches ...

Building Materials Production Industry In Bangladesh

Housing Scenario

There is a huge shortage of housing in Bangladesh. Of the available houses, many are not quality ones. People become homeless due to river erosion, floods etc. The number of homeless people in cities is more than that of the rural areas.

A. Rural Area Housing:

In rural areas, the houses are mostly kutcha or mud houses with a few semi-permanent type.

The components of rural houses are as follows:

a) Wall: Five inch brick masonry, Split bamboo thatch, CI Sheet, Jute stick, Mud block with rice husk, Goal leaf etc.
b) Roof: CI sheet, Clay tiles, Goal leaf, Straw etc.
c) Floor: Mud, Plastered brick soling, Cement concrete etc.
d) Door & Windows: Mostly wooden.

In northwestern districts of Bangladesh, the rural houses are mostly mud houses with straw or C.I sheet roofing. Even two storied mud houses can be seen in many places of those area. These mud houses remain cool in summer and warm in winter. Most of the rural houses are damaged either fully or partially when struck by natural calamities like cyclone, flood etc.

B. Urban Area:

In Urban areas of Bangladesh the houses are mostly of permanent nature either in the form of brick masonry or RCC frame structures. Among all the Urban areas of the country, housing problem in Dhaka City is the most acute. Out of 10 million city population of Dhaka, 2 million live in slums. The land price is extremely high and beyond the reach of common people. Developed land is also shrinking very rapidly for which surrounding wet land is systematically being filled by the private real Estate Developers posing a threat to the environment.

Because of high price of land, the obvious choice for housing in Dhaka City is multistoried flats. In some parts of the city high-rise building (15 to 20 story) are being built on both sides of narrow roads. This is causing a serious problem to the utility services resulting in rainwater stagnation, clogging of sewer line traffic congestion and fire fighting etc.

Common building materials used in Urban Housing:

Brick, cement, sand, stone chips, Lime, Glass, Wood, Aluminum Sections, Particle Board, Rebar, steel sections, Woodtex, sand cement solid bricks & hollow blocks, ferro-cement materials. The floor finish materials are machine made ordinary and homogenous, mosaic chips, tiles, marbles, granite etc.

The average cost per sft of building construction is approximately Taka 800 (US$ 14) in Dhaka City.

The building materials production industry in Bangladesh:

Brick: Brick is still by far the most common building material in Bangladesh. Except two machine made brick factory, bricks approximately 2500 million bricks are produced annually
in about 3000 coal/gas/wood fired kilns in the country. The brick burning kilns are causing serious environmental problem for which government is thinking for replacing bricks by sand-cement blocks.

Cement: The present installed capacities of modern cement factories in Bangladesh are double the demand of the country. Except one, all the factories are producing cement with imported clinker. One factory has started producing composite cement with Indian flyash.

Rebar: The country is self sufficient in producing reinforcing steel. But unfortunately, except two factories, all the factories are producing rebars from scrap.

Shingles/Stones: the country has abundant supply of these materials. Maddhapara hard rock mine is producing very high quality stones.

Glass and aluminum sections: Glass and aluminum sections used in building construction are mostly imported. Clear float glasses are produced locally but are not self-sufficient.

Sand cement hollow blocks: A state of the art factory in the private sector is producing sand -cement hollow blocks. But people are still reluctant to use it.

It has been found that 10% cost reduction is possible for high rise building by using sand -cement hollow blocks.

Particle Board: Two factories in the private sector are producing particleboards using jute sticks which are widely used in doors and partitions.

Woodtex: With saw dust and waste wood, woodtex are manufactured locally which are mainly used for door panels.

Ferro cement: It is used on small scale in water tanks.

Plastic Tanks: Various capacity good quality plastic water tanks are produced locally.

UPVC Pipes: One factory in the private sector is producing good quality UPVC water pipes, but fittings are imported.

Conclusion:
There is a wide scope for using alternative low cost building materials for houses in rural and urban areas in Bangladesh which should be explored for durable and affordable houses.

Composite Materials For Low Cost Housing In Indonesia

Housing is the basic need of human being, every house hold has to have a house. However, in the contrary the house is usually expensive, especially for the low income people. The government of Indonesia take effort to help the low income people to overcome the housing problem by credit system for housing through the State Saving Bank (KPR BTN). The KPR-BTN currently delivering about 60,000 low cost housing unit per year in urban Indonesia.

For the illustration, the need of low cost housing in Jakarta about 130,000 per year, about 30% fulfilled. However, still millions people have no reasonable housing. The problems are the low income, fast growing population, limited urban area, and housing materials are more and more expensive.

As we know that technological development is the most important aspect in the industrial development, therefore the government and research institutions should do more efforts to support the industries. Research institution should generate cooperative works in composite research, and build the effective link to industries in order to transfer new and higher technology.

The traditional composite materials have been used for centuries and still used up to now, such as bricks and tiles which is made of soil or clay reinforce by rice straw. At this moment fly ash, the waste of coal which is used as fuel in steam generator, is using as the raw material of panel. About 800,000 metric tons of fly ash is produced every year. "Arcon", is fiberized concrete panel production using fly ash as raw material. Particle board, is building material made of wood chips or other ligno-cellulosic materials bound by organic binder and one or more agent such as catalyst. Then pressed by hot press. The density can be adjusted to conform to the buyer's specification.

Composite materials development using indigenous natural fibers

Two things of using the natural fibers to develop new composite materials for low cost housing, the first step is to inventory the resources of indigenous natural fibers, which are potential to be made composite materials and the house components that suitable in using the composite materials. In Table 1 and Table 2 are listed the available fibers in Indonesia and house components made of composite materials respectively.

Optimization in the utilization of the available raw materials such as wood, rubber, and fibrous materials will be very important. Regarding wood for example, it has been estimated that annually there are more than 22 million cubic meters left as residues from logging, saw mill and plywood industries. The impregnation techniques is thought to be one of the prospective ways to improve the performance of low quality wood available in Indonesia; this can also be considered as the modification of natural composite materials. The development of composite material processing utilizing the natural or synthetic fiber or mixtures of these two as reinforcing materials and the suitable polymeric matrices will provide new opportunities to the application of the waste as prospective construction or housing materials.

Table 1. The available natural fibers in Indonesia (among others)

No.	Kind of fiber	Plantation potential (Ha)
1.	Bagasse	335.100 (1998)
2.	Rice straw	11.613.267 (1998)
3.	Bamboo	(no data)
4.	Kenaf	2.128 (1999-2000)
5.	Abaca / banana tree	142.800 (2000)
6.	Corn stalk	3.833.800 (1998)
7.	Palm oil bunch/trunk	2.500.000 (2000)
8.	Coconut coir	Plenty (no data)
9.	Pine apple leaf	44.906.138 trees (no data in Ha. Unit), (2000)
10.	Ramie	No data
11.	Sisal	No data
12.	Water Hyacinth	No data

Table 2. The house components made of composite materials

House components	Composite materials
Column	Wood composite
Panels	Wood fiber-cement
Roofing tiles	Rice husk-clay / soil
Window / door shutter	FRP / Wood composite
Partition	Wood / coir - gypsum
Ceiling	Coir / ramie / sisal - gypsum
Bricks	Rice straw/husk - clay / soil
Frame / profile	FRP
Pipes	RRP
Blocks	Sludge - cement / sand

Composite materials technology processing and design in industries generally are still poor and less competitive, since using low and medium technology. The added value of such industries mostly give low impact to the national economy.

The Role of Research Institution and Universities in Housing Composite Material Industrial development

Research institutions and universities as the center of science and technology development, must be concern to the needs of social life. Thus, they have to improve their capability in order to transfer the knowledge to support industrial development, whilst universities have to make effort to push the education to the science and technology suitable to develop composite materials needed.

The co-operation program on the development of science and technology capability in processing as well as characterisation of composite material, is one of the way that can be adopted to accelerate the improvement. The program would include the development of expertise and skill of research staff, to collect science and technological information, providing facilities to conduct research at the laboratory and to develop the pilot plant scale, and the introduction of the technology to the relevant industries.

The research institutions and universities in Indonesia which are interested on composite materials are listed on the Table 3.

Table 3. Research institutions and universities which are interested on the composite materials research

Research Institutions	Universities
Research and Development Centre for Applied Physics, Indonesian Institute of Sciences.	Bandung Institute of Technology: Chemical Dept; Mechanical Dept.
Research Institute of Human Settlement, Agency for Research and Development, Ministry of Public Works	Hasanudin University: Chemical Dept.
Institute for Research & Development Of Cellulose Industries	Airlangga University
Agency for the Assessment & Application of Technology	Lampung University

Conclusion

- The new composite materials using indigenous natural fiber is important to be developed in order to get strong and cheaper housing materials
- Research institutions have to concern to the needs of social life. To transfer new materials science and technology to the industries, in order to support industrial technology development
- International or regional co-operation program on science development in processing and design of composite materials is needed.

State-of-Art of Construction Materials For Low Income Houses In Bhutan

Rammed mud to walls

Introduction:

Rammed mud walls are extensively used in Bhutan : Specially in the rural areas. This is a traditional method of constructing houses which was practiced more than a millennium ago.

In this method of construction the superstructure of building is constructed by compressing or ramming earth using moisture and compacted to a point where it reaches highest state of compaction. The shutter plates are then removed and the walls are dried any cracks seen are cover by mud plaster mixed with binders like cement or lime.

Specification:

Selected dry earth is taken which is free from any organic matter, grits, or stone chips or bolder etc. Normally earth from same area is used for one particular construction. All clods of earth clods shall be broken or removed before laying.

The earth shall be laid in layers not exceeding 50 and then rammed with wooden or iron rammers. The density shall not be less than that achieved in the laboratory.

Disadvantages:

Rammed mud walls need thickness of 750mm to 1m for three storeyed buildings. As machine compaction is not feasible, human labour is required and the quantity of labour is high (intensive). Though there are no records of failure of structure, there appears to be risk during severe earth quacks. Still buildings upto double storeys are constructed with rammed mud walls in rural areas. But in urban areas people prefer, RCC and bricks for construction for neat finishing, durability and utility purposes.

Compressive strength, is not tested at site, but assumed to be about 2-25kg/cm^2.
Cost = 290/m^3.
Compare brick work= Nu.1600 – 2000/m^3 within mortar 1:4 to 1:6
Half brick = 290/m^2

Bamboo walling:

Popularly known as 'Ekra' walls, these walls are constructed by using split bamboo 25 x 6mm sizes which are slipped into the grooves of vertical timber members of specified sizes which are first fixed as frames in the proposed wall section. The split bamboo mat thus laid is then plastered from both side, about 20mm thick using cement mortars of ratios 1:4 to 1:6 and also mud mortar as per affordability : The green bamboos are preferred and reported to have lasted longer than the dry bamboos.

Cost per m^2 = 270 – 290/ m^2 with cement mortar plaster = 120 – 155/ m^2 with mud mortar plaster.

Mud block plain:

Plain mud blocks or unbaked bricks were and are still used in Bhutan extensively. These blocks are prepared from good selected granular soil mixed with water and cast in mould. They are in fact unbaked bricks.

These materials have no crushing strength and hence not used for load bearing structures but only as infill panels. In some cases, when required to be plastered, a thin type of mesh or chicken wire mesh is used on surface and to hold plaster. This makes the proposal a bit costly. But now these blocks are being constructed as stabilized mud blocks, using cement as binder.

These blocks have become very heady for construction single storey building or for good infill material for 2-4 storeyed building.

Compressive strength, is not tested at site, but assumed to be about 2-25kg/cm^2.
Cost = 290/m^3.
Compare brick work= Nu.1600 – 2000/m^3 within mortar 1:4 to 1:6
Half brick = 290/m^2

Building materials production industry in Nepal

Establishment of Building Material Research Laboratory Building

About 5 years before the department had established a project named "Building Materials and Govt. Building Research Project" to give continuity on material research works. The major functions of the project were to collect the data of construction technology used in various districts of Nepal and study of availability of local building materials all over the country. In the mean time some equipment for testing of building materials also had been purchased from HMG budget. The project aims to collect and research on local building material throughout Nepal.

National Building Material Research Center in Jhapa and it's Major Functions

Recently, our organization HMG, Department of Urban Development and Building Construction, established National Building Material Research Center in Jhapa district (Far Eastern of Nepal) for research and development of local building materials of Nepal.

The New Building Construction Material Factory in Nepal

1. **Harisiddhi Brick tile Factory:**

   Name of Products

   - Brick
   - Roofing Tile
   - Flooring Tile
   - Decorative

2. **Prefab Concrete Industries (P) Ltd.:**

   Name of Products
   - Pre-stressed Hollow Core Slab