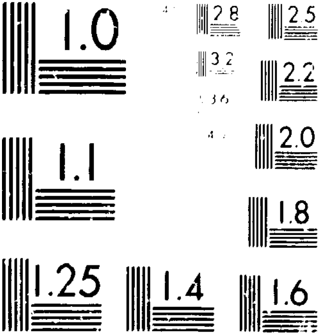
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



MICROCOPY RESOLUTION TEST CHART

11440

Distr.
LIMITED

ID/WG.368/10
19 April 1982

ENGLISH

United Nations Industrial Development Organization

Petrochemical and Polymer Consultation Week

Porto Alegre, Brazil, 17 - 21 May 1982

LOW ENERGY HOUSING WITH COMPOSITES*

by

Georges A.R. Patfoort**

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

** Professor in Material Science, Nationaal Instituut voor Bouwkunst en Stedebouw, Antwerp, Belgium.

V.82-24795

Synopsis :Since 1975 UNIDO planned an extensive program on low cost cost housing , using less raw materials with a low energy input and with the integration of local available materials . Results are presented using fiber composites systems in the building sites of Cyprus,Ecuador,Mexico,Upper-Volta and Uruguay .
Three main problems had to be solved :

- adapt high technology to local circumstances and eventually jungle conditions, non skilled labour and absence of local energy and water supply .
- Use the versatile properties of composites and make them able to work in combination with locally available materials .
- Solve a double design problem consisting of creating a structure using less material and energy and offering maximum living space.

The system uses basically an appropriate filament winding technology.

ENERGY SAVING

One is usually not aware that every raw material requires an input of energy for its extraction , seperation, purification, packaging , transport, stockage and marketing . Every consumer product is made from raw materials and each operation of manufacturing , publicity, selling, transport and even the maintenance and elimination , of the product entails a consumption of energy . The sum of the energy needed for each operation is the integrated energy input . To obtain the integrated energy input per time unit , one has to devide by the lifetime of the product. It is evident that energy saving can be realised in two ways : either by reducing the energy input or by increasing the life time .

It has been calculated that the integrated input for a normal motorcar is nearly 5-5 times the total equivalent quantity of petrol that the car will consume during the whole period of its use without even considering the social costs and the transport infrastructure . So , here is an indication of the kind of topics we have to focus our attention on , in an energy saving programme .

It becomes evident that each human activity and each consumer product uses up a lot of energy . Different events have given rise to alarm and have demonstrated that difficulties are imminent in the supply of energy . Authoritative opinions give warning that serious problems will arise before the end of the century and perhaps quite soon , if the political climate is unfavourable . We have to look out for energy saving methods as long we have not found a substitute for oil in the form of a source of renewable energy .
Unfortunately , the moment when majority of the inhabitants of the planet could taken part in Western welfare coincides with a period of shortage of energy and raw materials . The laws of the Western economic system appear to lack the flexibility to escape from the dilemma . We must look for a technological solution .

Since 1971 United Nations Industrial Development Organization - UNIDO - was looking for solutions . As a typical example of a product with high energy input , housing was considered . The construction of the 370,000,000 dwellings that have to be built for the next 10 years using traditional building methods would significate an ecological suicide . So , it was decided to develop a "low energy housing system " that could function as an example for lowering energy in other production systems.

COMPOSITE SYSTEMS

Composite materials are developed from components on the basic assumption that the properties of the whole are different from and represent more than the sum of the properties of the components . The composite has one more important property : the relations between the components are more important than their intrinsic properties in determining the nature of the whole . The composite acquires a certain degree of independence from its componets . A component having similar relations with the others , may act as a substitute for the original in spite of its being different .
An example may illustrate this : an insulating material is composed of a binder , for e.g. a polymeric matrix and air inclusions . The composite has insulating properties that cannot possibly be obtained from the separate components . Moreover , it is possible to substitute PS by PU or any other polymer foam in the matrix . In the same way it could be possible to replace the air by any other inert gas, without changing very much the insulating properties of the whole . We can apply the same reasoning to a fibre reinforced poliester .

The raw materials used in construction have been limited to some restrictive classes : metals, ceramics, glasses and polymers . Composite materials allows to escape from the traditional dependency : materials ⟷ properties . The choice of materials in composite systems has increased their technological and intellectual potantialities hundred of times.

HOUSE CONSTRUCTION

From 1975 on , UNIDO planned a housing programme for developing countries using composite materials . The construction had to meet following requirements : low cost , minimum transport , locally constructed , low energy and material input, high construction speed , use of non skilled labour , integration of locally available materials .
Demonstration projects were carried out in Cyprus, Uruguay, Ecuador , Upper-Volta and Mexico , introducing each time new technical and architectural variables related with mechanical strength , sandwich construction , natural fibre reinforcement etc.

Considering the requirements , an appropriate and simplified system of filament winding came out as the adequate method to construct the insulated spaces of air needed for the building of dwellings . The wounded shells have been manufactured locally on a retractable rotational mould, supported by an ax, driven by hand by means of a cranck and a reduction device . The fibres pass in a resin bath , laterally moving allong the rotational mould, distributing the wet reinforcement on the mould. The resin bath is a wooden support with a through-away PE bag , containing the resin . The excess of resin is pressed out by adjustable rubber strips that permit at the same time to adjust tension on the fibers .

STRUCTURAL BEHAVIOUR

The structure is strenghtened at both ends by two flanges . They have a dual purpose . They are usefull in bolting endwalls r one module to another . Structurally they act as a diafragm rigidifying the cilindrical shape .
Beam action in the longitudinal direction is neglectable ,because the module does not span between the flanges but is resting and sustained over its whole lenght in a bed of sand or stones . In that sence strenght and rigidity is only required during transport .

On the contrary , the membrane action , typical in shell structures transmit loads axially . The strongest cross-sectional shape in this respect is a circle . The greater the deviation from the circle the lesser the structural strenght the better space requirements . The flanges act in this respect as streghtening elements . Quantity and design of the strenghtening elements is adaptable . On that way it was possible to obtain a fantastic increase in rigidity and to eliminate any sagging after removal from the mould
If desirable , it is possible to obtain even rectangular shapes, using of course more material to obtain the same strenght .

Beam action can also be observed in each segment of the curved shell. The stresses could be accomodated by sandwich construction , the strenght depending on the reinforced layers of the sandwich structure and its thickness determining the moment of inertia . The bond of the foam core to the two exterior layers , is the most critical factor affecting the strenght of the whole structure . Taking into account local circumstances such as nature and quality of the foam layer and the lack of equipment to maintain and control the quality of the adhesion, it was advisable not to rely upon the properties of the sandwich construction to obtain the necessary stiffness and strenght Reinforcing flanges and rips made it possible not to be dependent on the sandwich structure and allow to build single wall shells when insulating foam is not justified .

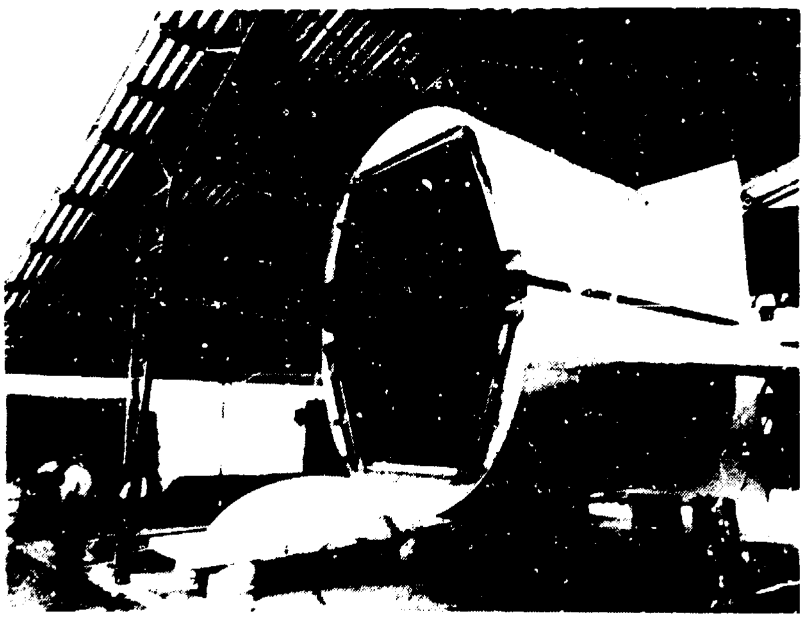


Fig.1 Low energy housing with composites building technologies and materials .Hand driven retractable mould and filamnt winding unit in Ecuador (South America)

Fig 2 Removal from miuld.This shell structure
is of 15 m2 habitability and its weight
is 250 kg .

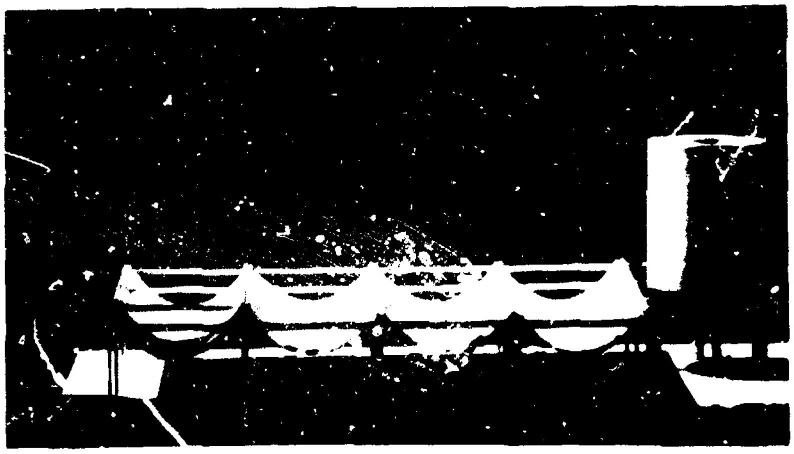


fig 3. Applixa.ions of semi rigid membranes in
housing, silos, covered spaces, parkings etc.

Fig4. Integration of local materials in housing units .

CONCLUSIONS

Practical results may be summarized as follows :

- a housing module can be built adjusting size, shape and proportions to any architectural design or environmental requirement
- closing panels & endualls without strenght demands can be adapted to available local materials and local architecture .
- machine and mould are of a simple design and of low investment.
- machine and mould are dismontable and transportable to differant building sites . This operation is cost, time and energy saving in comparison with transport of heavy prefabricated parts.
- No foundations are required . It is logical to consider the structure as a floating unit, and to put sheep ballast between floor and shell as in a ship ! So, no soil deterioration .
- this ballast is part of the thermal inertia of the module .
- the construction is easely adapted to any climatic condition.
- the construction is possible without water andenergy supply.
- the same technology is suitable to construct self supporting roofs, silos, reservoirs, containers, sewagework, large diameter pipes etc.
- the curved surface obtained most easely by filament winding is at the same time the form that uses least material an energy and offers the highest mechanical strenght and the largest living space . It is ergonomically best adapted to human beings and suited to adjust itself to human and social requirements. It is thermally attractive , because it offers a larger volums in relation with the surface exposed to the outside climate.
- it has been proved that unskilled people can handle the technology and build for themselves after a training period of no more than two months . Experiences have been performed in the open air, in windy regions and tropical climates and even with differences in temperature of 20°C in a few hours time .
- strenght experiments proves that self-supporting storeyed houses can be constructed .
- synthetic polymeric materials , in spite of the fact that they are oil derivates are energy saving when the integrated energy input is considered . Furthermore , present experiments gives the prove that composite technology opens a new way to change drastically the usual way of wasting energy and raw materials and to escape the dilemma between production and scarcity .
- only the structural shell necessitates high performance material . Sidewalls, partitions, ballast and even parts of the shell can follow the composite principle and accept the combination with renewable materials or rural, industrial and even urban wastes.
- Present results indicates :
  A weight input in relation to European construction 1/100
  in relation to local brick construction 1/50
  an energetic input in relation to Europe 1/20
  in relation to local construction 1/10
  Speed of construction including equipment of the house}
  120 m2 = 300/ men hours .
  Price : 1/2 of local low cost housing .
- There is good reason to believe that the energy input and the price can still be lowered substancially thanks to the new composite formulations .