OCCASION

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

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

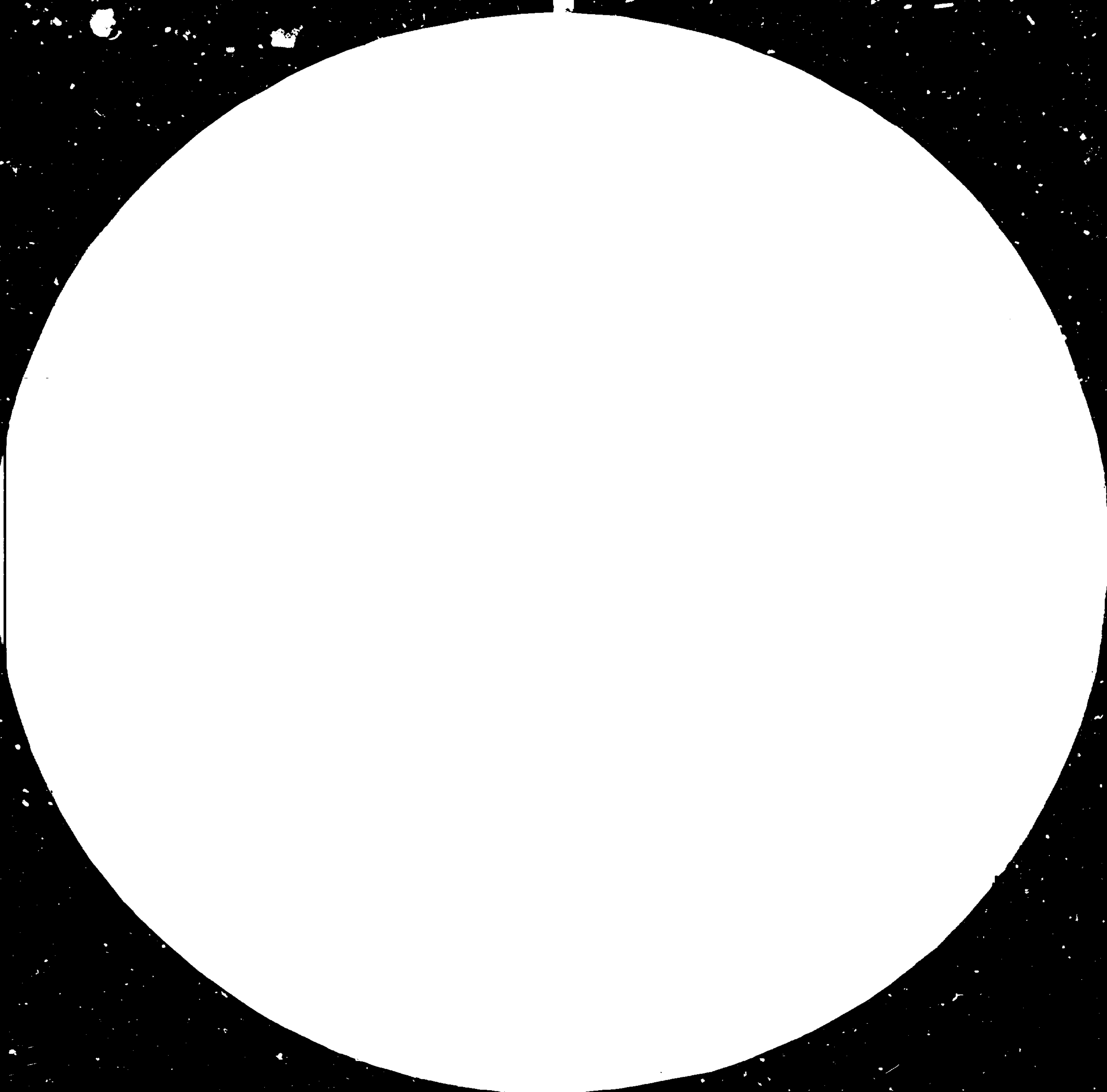
Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

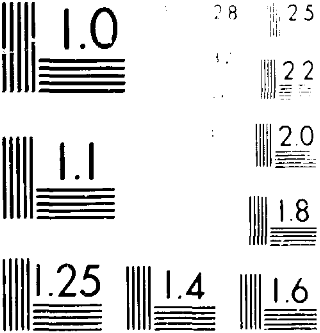
CONTACT

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

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

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




1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

12233

Distr.
LIMITED

ID/WG.375/38
4 February 1983

ENGLISH

United Nations Industrial Development Organization

Expert Group Meeting on Small-Scale Shipbuilding and Shiprepair Development for Latin American Countries

Havana, Cuba, 9-12 November 1982

GLASSFIBRE REINFORCED CEMENT USED IN THE BOATBUILDING.*

prepared by

Niels Ross**

* 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.

** Expert in boatbuilding

Glassfibre reinforced cement used in boatbuilding.

A material for boatbuilding has to fulfil, more or less, the following demands:

Watertight
Resistant to rot and marine borers
Corrosion resistant
Strong in relation to MOR - LOP - Impact
Fire resistant
Low weight
Low price for materials
Low labour costs
Easy to repair
Friendly to environments: (workshop and marine areas)

Wood, steel, aluminum, GRP, Ferrocement and other materials are used for shipbuilding. The ideal material in respect to all demands has not been found yet.

GRP was almost the ideal material 30 years ago, but after the oil prices were raised, it become very expensive. Furthermore, many countries have made rigorous rules for workshop ventilation and heating thereby further increasing expenses.

Ferrocement has been very popular the last years, but it needs a lot of labour and is therefore not competitive in countries with high labour costs. Also it is difficult to get a reasonable result that looks good.

It was a natural thought that cement could be reinforced with glass fibre, but the first test showed that the glass commonly used in GRP production was not resistant to alkalies in the cement. The glass production company Pilkington in England picked up the challenge and invented a new fibreglass; Cem Fill which was reasonably alkali resistant. This was 4-5 years ago and since then a new generation of fibres has been developed with even better characteristics.

In the beginning the material was not intended for boatbuilding (although a small test boat was built) but was used for large construction parts for buildings, large facade panels etc.

Before using the material in boatbuilding we had to know more about it and a group was founded consisting of an experienced cement company, Brandt Beton of Denmark, the classification company, Det norske Veritas, The Chalmers Technical school of Göteborg, Sweden. I joined the group as Naval Architect.

The glass company Pilkington, a material testing institute in Denmark and the Danish Government, represented by the foundation for industrial development in Denmark were also involved.

Basically the GRC-material is cement sand, about 1:1, about 27-30% water and 5-8% glassfiber. Some additives are needed to make the cement slurry easy to handle.

The 3 main properties are: The "LOP" = Limit of proportionality which in many respects can be compared to the crevice strength for ferrocement and the 0,2% strength for aluminum. The "MOR" = Modulus of rupture corresponds to breaking strength.

The "impact strength" was tested in different ways, but it was difficult to compare the different materials without using exactly the same testing machinery.

A typical load / deformation diagram is shown in FIG. I.

Compared with ferrocement it shows somewhat better characteristics at the beginning of the diagram but with an almost instant collapse after higher tension than MOR.

The material was also tested when artificially aged to 5-25 years as shown in FIG. II.

The collapse was even more distinct and happened at a little lower MOR.

We simulated a 10 year old boat hitting a rock. Although the impact was not very hard, it was followed by a total disintegration. Not a happy thought.

We thought of using other kind of fibres: Asbestos which has been used for many years in producing roof panels for houses, but for health reasons it is no longer allowed in our country.

A new fibre consisting of polypropyline has been developed to replace it. The strength figures are not very high for this material and we concluded that by using this material we would end up with boats much heavier than ferrocement. P.P. fibres are today widely used in cement where impact strength is important, for example in auto-fences.

The solution was to utilize the high impact strength in the polypropyline fibres together with the good ultimate strength of glassfibres. Not by mixing the fibres but by building a laminate with glassfibres on the sides and with polypropyline fibres in the centre.

The typical load/deformation diagram is shown in FIG. III.

The improvement to the former tests is that this laminate can absorbe a much higher amount of work without total collapse.

The testpieces used for making diagrams that could compare GRC and ferrocement were about 20mm in thickness as this is almost the smallest you can make in ferrocement according to the norske Veritas construction rules.

In practice you can make GRC as thin as 5mm.
(See the picture of the dinghy total weight 33 kg). That means it can be used in secondary dements as bulkheads-ceiling etc. and save weight

Practical boatbuilding of GRC:

No production has been started yet, but several small boats have been build as test boats. Moulds are now ready for production of a 38' sailboat.

GRC has also been used for other purposes for some years, e.g. facade-elements, garden - fountains etc.

Det norske Veritas is now ready to approve a design for a boat in GRC, but construction rules have not been finished. The loads on hull, decks, houses, tanks etc can be calculated from the rules for ferrocement or GRP or even steel and the dimensions will then have to be calculated in every case. As a general rule the heavy loaded elements, Bottom shell, etc. will have nearly the same dimensions as those in ferrocement, while the elements with less tension, houses, fish hold ceiling etc. can be constructed much lighter.

It is practical to produce the boat in large elements: Hull - deck - houses etc. and put them together the same way as for GRP parts.

Equipment in workshop:
Shop has to be of reasonable standard, no temperature below freezing, but otherwise no special demands with regard to temperature or ventilation.

For preparing the cement slurry you need a fine meshed strainer; an accurate scale for weighing sand and cement and water; a mixer; a few simple instruments for control of the matrix.

A special pump and nozzle have been developed for spraying the cement slurry and mixing it with the glass. The glass is delivered in endless rolls. In the spraying head there is a rotating knife that cuts the glass into about 2" pieces (length can be adjusted).

Using airpressure the cement/glass mix is sprayed into the mould, about 5mm in one spray. Then the mix is compressed by rolling with the same kind of rollers used in GRP production.

The spraying of a new layer can be done immediately. The process is very fast, a man can spray about 2000 kg a day, maybe more. I believe that even a large boat can be sprayed in one operation.

The mould is very similar to moulds for GRP with not too small slip angles. The mould can, as an advantage, be build-of GRC.

The quality of the surface need not be up to same standard as the surface for GRP moulds.

Small elements can be released from mould in a day, but elements as large as a ship have to cure in the mould for a week.

Total curing time is about 14 days, depending on type of cement used and temperature. During curing time the moisture must be kept near to 100% (as for ferrocement). Accelerated curing by steam is possible.

Stiffening of hull, deck or bulkheads can be made by stringers of foam covered by GRC (similar to stringers in GRP).

Elements with very heavy loads; engine-bearers, foundations for gallows, etc. can be reinforced by steel.

Elements of GRC; for example, deck and hull, can be connected by use of apoxycement (Epoxy and sand) and/or bolted together.

Training of workers :

There are no major difficulties involved in the GRC process, but I would not recommend starting this process without a thorough knowledge of the process. Even small mistakes in the matrix or the glass content can reduce the properties drastically.

Taking into account the expenses involved is producing the plug and mould, and purchase of mixer and pumping equipment you will find that GRC boatbuilding is not for the smallest boatyards, but more suitable for middle sized yards.

It is possible that a small yard which is used to build ferrocement boats, could increase the production by taking up GRC boatbuilding. The Danish group will, if necessary, assist in setting up a production.

Cost:

The greatest incitement for developing the GRC for boatbuilding was the price. The sand and cement are among the cheapest building materials available and although the glassfibre is quite expensive it only amounts to 5-8% of the laminate (by weight).

In Denmark the prices for materials plus labour overhead covering machines and workshop, but expenses for plugs and mould not included are:

GRP:	5$ pr. kg.
Aluminum:	10$ pr. kg.
GRC:	0.5 - 1$ pr. kg.

In Denmark ferrocement boats are not produced commercially, therefore no price is showr here.

For further information concerning boatbuilding of GRC, please contact the Danish Ministry of Foreign Affairs, or the Danish Embassy in your country.

FIG 1

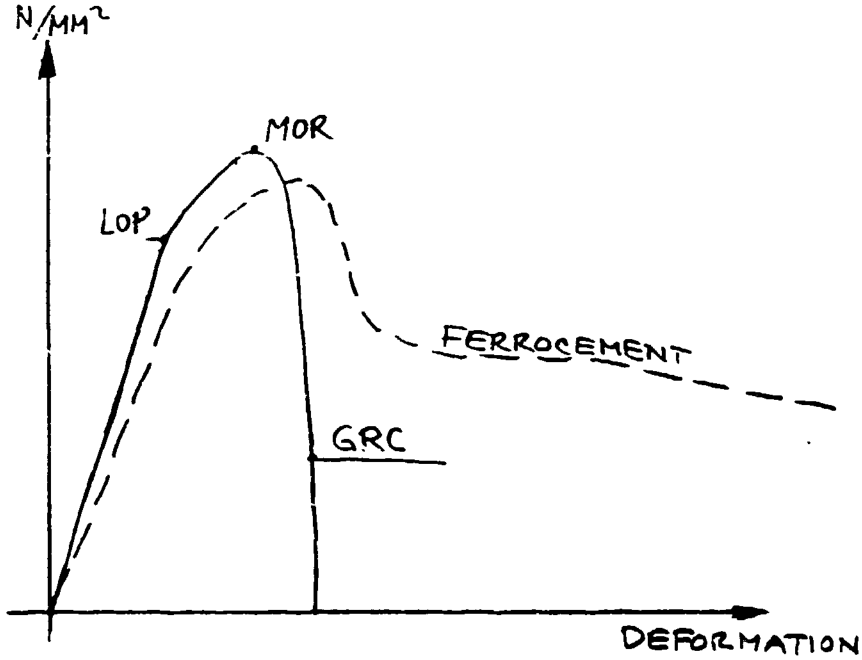


FIG. 2

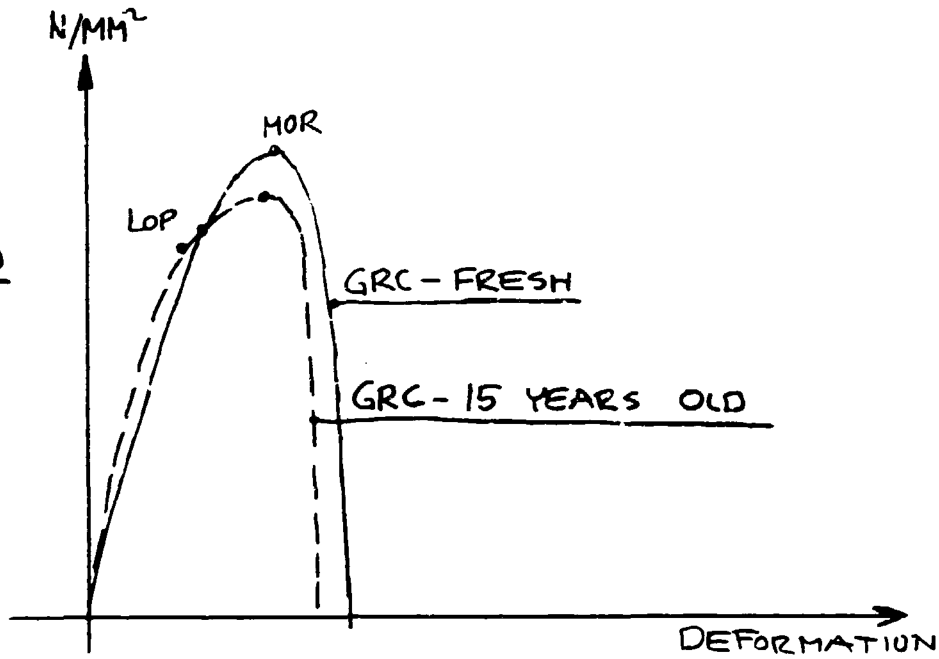


FIG. 3