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# **Manufacturing of durable furniture for rural households in South Africa using glass reinforced polymers**

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## **ABSTRACT**

*A number of South African rural households experience problems with roof leakage and flooding during rainy seasons and it results in the damage to their furniture. In most cases, the furniture is manufactured out of wood and these materials are not designed to withstand exposure of water for prolonged duration of time, their exposure limit is especially low that they can withstand enough water for cleaning. This paper aims to provide ordinary South Africans with durable, water resistant and aesthetically appealing furniture by providing the technical shrewdness for manufacturing the furniture using glass reinforced polymer (GRP) material. The employment of the recommendations from this paper will not only provide a solution to the green environment by saving the trees but also provide the personalized shapes and designs at economical costs, quicker as well as the creation of job opportunities for communities thus adding to the country's gross domestic product.*

**Keywords:** GRP furniture manufacturing, composite moulding, green environment.

**Paper category:** Knowledge and technology transfer

## **INTRODUCTION**

South Africa experiences heavy and severe seasonal rainfalls; despite the climate change, the impact of these rainfalls is still significant. The intensity of the rainfall events over the past 10 year period increased by over 10 mm (Mason, Waylen, Mimmack, Rajaratnam & Harrison, 1999). According to Kruger and Nxumalo (2017) the precipitation tends to increase extremely over some parts of the country with the increase in annual frequency of very heavy rainfalls. The continuous wet days in the country is

mostly in summer season for most part of the country with the exception to the south-western Cape. For the south-western Cape has the longest wet days, and to make matters worse they occur during the winter season where days are shorter than nights, the sun is further away from the surface of the earth and there is fog in the mornings.

The furniture used in most South African households is manufactured from wood and sheet steel, the furniture manufactured out of wood is preferred due to its aesthetic appearance, durability, low density, low thermal expansion and strength whereas the steel one is preferred due to the strength to weight properties (Broman, 2001; Hyvönen, Piltonen & Niinimäki, 2005; Wang, Chen & Chang, 2005)

The wonderful properties offered by the wooden furniture mainly depend on the maintenance and use of such furniture, particularly during wet conditions (Stark, Matuana & Clemons, 2004). The organic nature of wooden furniture makes it susceptible to organic decay; the decay is formed when a fungus is formed at a certain moisture and oxygen conditions for a certain period of time. The deterioration on the other hand is due to the combination of biological and physical process where the fungus causes decay or discoloration (Hyvönen, Piltonen & Niinimäki, 2005; Schultz, Nicholas & Preston, 2007; Stark, Matuana & Clemons, 2004).

In wood there may be water in the form of free water, bound water and water vapor (Hyvönen, Piltonen & Niinimäki, 2005; Kozłowska & Kozłowski, 2012). Free water fills the lumen by absorption using capillary action; the water does not bond to the wood hence it is referred to as free water. Bound water is attracted by hydroxyls to the cell wall and bound through monomolecular adsorption or polymolecular adsorption. In monomolecular adsorption the bond is stronger than polymolecular one and it is also difficult to separate the water from the hydroxyl group. Water vapor resides in the cavities of the cell wall and the lumina (Hyvönen, Piltonen & Niinimäki, 2005).

According to Hyvönen, Piltonen and Niinimäki (2005) the failure of wooden furniture due to water first starts with the adsorption of water, leading to the increase in volume proportional to the adsorbed water causing the swelling. Swelling increases until the cell wall is saturated with water, the increased saturation leads to a point where the water remains free water and no further swelling will occur. The moisture gradient between the surface and interior of the furniture causes stress resulting into surface warping, twisting and cracking. Above moisture saturation level fungi causes serious damage to the furniture, however this saturation level is not reached by water vapor but can be by exposure to liquid water.

The wood however can be preserved using the principle of toxicity and also by managing the fungi by controlling the temperature and removing the oxygen supply, the latter is however highly impractical (Schultz, Nicholas & Preston, 2007; Wang, Chen & Chang, 2005). The more practical way to manage the moisture content is via surface coatings that are achieved by applying water repellents and dimensional stabilizers to the surface. Common surface coatings used are varnish, lacquer or paint which are effective if there are no scratches, openings and imperfections on them. Absorption of water can be reduced by rendering the wood hydrophobic; this is very effective on the furniture that is used outdoors. The liquid water can only penetrate the hydrophobic layer unless the external pressure is greater than the capillary pressure. Typical water repellents are waxes, oils, resins (natural & synthetic), fungicides, insecticides and solvents. Water also gives rise to dimensional changes in the wood, to preserve the wood for biological durability, concentrations are vital in treatments. The developed preservatives can achieve a 50 year service life in the furniture; the typical example is in the wood used as railway sleepers. (Hyvönen, Piltonen & Niinimäki, 2005).

GRP material use and manufacturing is said to increase steadily since the introduction of this material during the 2<sup>nd</sup> world war (Abramovich, 2018; Bar, Alagirusamy & Das, 2018; Cooper & Turvey, 1995; Kaw, 2005; Patil & Ingale, 2018; Rafiee, 2013; Turvey & Zhang, 2006; Zou, Reid, Li & Soden, 2002). The growth is due to amongst others factors costs, weight, corrosion resistance, low friction factors, chemical resistance, excellent fatigue and impact resistance as well as damage tolerance (Avcı, Şahin & Tarakçıoğlu, 2007; Chandra, Singh & Gupta, 1999; Cooper & Turvey, 1995; Farshad & Necola, 2004a, 2004b; Hogg, 1983; Hogg, Hull & Legg, 1981; Jones, 1989; Kawada & Srivastava, 2001; Khalili, Mittal & Kalibar, 2005; Knox, Cowling & Hashim, 2000; Melot, 2018; Noble, Harris & Owen, 1983; Prakash, Srivastava & Gupta, 1987; Price & Hull, 1987; Rafiee, 2013; Salibi, 2001; Stokke, 1988; Turvey & Zhang, 2006; Vallittu & Sevelius, 2000; Yang & He, 2016).

## **METHODOLOGY**

There are a number of ways to manufacture furniture using glass-fiber reinforced polymer (GRP) materials, the main purpose is not to deviate from the strength, appearance and appeal to the user's eye (Broman, 2001). To achieve the two, the price and the weight should be kept at a minimal level, this paper considers the manufacturing

of the furniture using GRP material. The simplest methodology is to create a mold that will help achieve the required shape, in this work this is achieved by manufacturing three layers i.e. inner layer, outer layer and middle layer.

The inner layer is manufactured to have the strength to contain and withstand the contents of the furniture; in most cases the product in contact with the furniture has the certain level of moisture content. It is because of this reason that the inner layer needs to be manufactured in order to protect the furniture from the moisture, chemical attack and the electrical conduction.

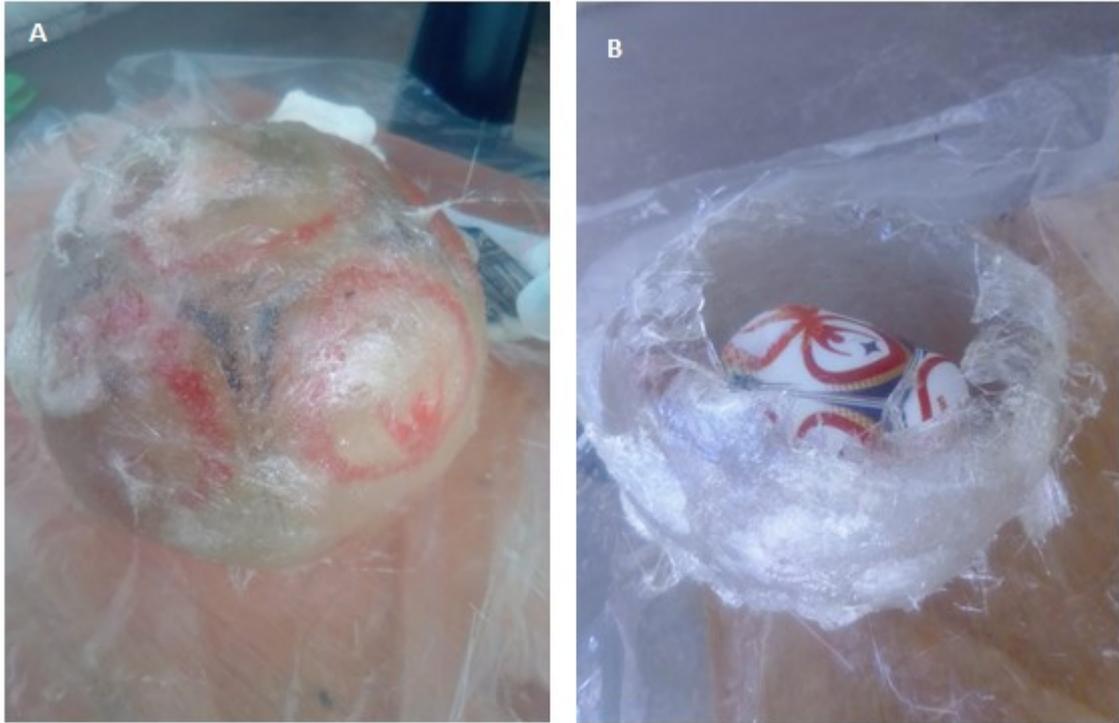
The middle layer is the critical layer because it is the layer that is to be used to give the furniture its shape, has low weight and strength and can be used as a mold. Figure 1 (A-F) below shows the polystyrene foam in different forms, properties and quality. All as indicated below come in different colors, and can be shaped as seen below as in B and F. B and D are the most economical as they are available in portable spray bottles at a low cost. Their advantage is that the user can only use what is close to the required amount and thus eliminating the material losses. C and E are available as part of the packaging for furniture and fragile materials that are transported, the advantage of these is that they can be recycled to lower the costs and improve the environment. The most important use

of these is to create the required shape before the resin material cures; as such, the foam is crafted into the required shape as seen in B and F.



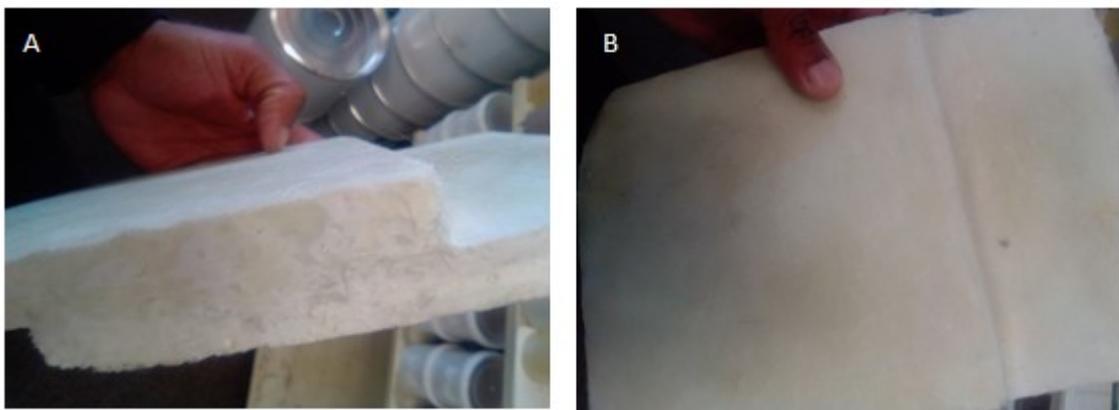
**Figure 1 Polystyrene**

The outer layer on the other hand is designed and manufactured to have an appealing look to the eye of the user as well as water resistance, durability, versatility strength and customized colors according to the user's requirements. This can be seen in Figure 3 below where a lap jointed material that contains three layers discussed in this work is used.



**Figure 2 Plastic ball as a mold**

The layers stated above do not necessarily have to be seen physically, a typical demonstration of this can be seen in Figure 2 where a plastic ball was used as a mold and as soon as the GRP material had cured its use was no longer relevant. In this particular instance, it became evident that the GRP material is strong enough to be used without the inner layer and the thickness of the material was not significant. It is common and assumed by most people that metals are stronger materials, but this assertion was proven otherwise by the introduction of GRP materials that are lighter in weight. In order to give the end user certainty about the strength of the product, the inner layer is added to increase the width of the furniture material as in Figure 3. The inner layer may well be considered in instances like during the manufacture of chair legs, etc.



**Figure 3 GRP Section**

Because this paper is not mainly addressing mass production of furniture, but rather focusing on customized furniture the middle layer is used as a mold. It is worth indicating that the industrial type molds that are suitable for mass production are expensive for ordinary individuals and startup businesses. Because of these costs, the ordinary African can use what is available and is on their disposal. The basic model is to use polystyrene foam or cardboard material, prepare it to the required shape. Apply the resin layer and then the reinforcement. The number of layers determine the thickness and depend on the required strength of the furniture, as in most materials the thicker the cross sectional area the stronger the material.

## **RESULTS AND DISCUSSION**

Manufacturing furniture using GRP has proven to be able to provide the benefits offered by metallic and wooden furniture combined. The material is durable, if one has to compare the metallic or wooden furniture with the same durability and weight GRP furniture will be the best option. The resin has high water resistance and will play a vital role in protecting the fiber from absorbing water because the water will cause the fiber to lose the durability in a long run. The aesthetic appeal of the GRP manufactured furniture will give the end user the feeling of fulfilment, as with the wooden furniture the owners still do their best to preserve using varnish and other similar solvents. With the GRP there will be no need to buy solvents to preserve, rather only a small amount of water is required to wipe the dirt on the furniture.

The costs associated with the manufacturing of the furniture are reasonably low with the minimal material loss because only the required amount can be used and the one that is not used can be reused. With the implementation of this, jobs will be created and thus help in building the economy of the country as well as contributing to the increase in the gross domestic production.

## **CONCLUSIONS**

Purchasing inferior quality furniture is far more expensive than buying expensive quality furniture. What is more fulfilling and satisfactory to any African is to manufacture the furniture that is appealing to their eyes, strong, inexpensive and water resistant with a very simplified manufacturing process. In addition to this the end user of the furniture also deserves the value for their money and to be rest assured that the quality of the product is suitable to their needs. These GRP furniture is the best solution to Africans to

make own furniture and will also help small and micro enterprise to grow and create employment the and thus contribute to gross domestic product of country and the continent. With the combination of both properties offered by the wood and steel that the GRP materials offer, the furniture that can be manufactured in this fashion can be the best option.

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