

# Comparison of Cashew Nut Shell Liquid (CNS) Resin with Polyester Resin in Composite Development

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**ABSTRACT:** Natural resins can compete effectively with the synthetic ones in composite development. In this research, cashew nuts were picked and processed for the extraction of the resin content. The resin (natural resin) so obtained was mixed with cobalt amine (accelerator), methyl ethyl ketone peroxide (catalyst) to develop two sets of composite specimens – specimens without fibres and specimens reinforced with glass fibres. This method of sample specimen development was repeated with polyester (synthetic) resin. Compressive and tensile strength tests conducted proved that composites developed with cashew nut shell liquid (CNSL) resin were comparable to those developed with polyester resin. In the results, CNSL has an ultimate compressive strength of 55MPa compared to that of polyester resin with an ultimate strength of 68MPa. The result of tensile strength proved cashew nut shell liquid resin (with ultimate strength of 44MPa) to be better than polyester resin with 39MPa as ultimate tensile strength. This means that natural resins could be a better substitute for the synthetic ones when the required quantities of fibers (reinforcements) and fillers are used in the fibre-reinforced plastic composite developments.

**KEYWORDS:** CNSL resins, polyester resins, composite development, strength tests

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## I. INTRODUCTION

The need to use natural materials in composite development is necessary as it will save cost in importing synthetic ones and at the same time be a source of revenue generation. Before now, little research made on natural resins only centered on their production and curing characterization instead of their mechanical properties. Major research works in composite development have been focused on the use of synthetic resins. Different kinds of resins are the epoxide, polyester, vinyl ester and phenol formaldehyde resins. Polyester resins, for example, are low molecular weight resins containing C = C unit in the chain to allow cross-linking by the free radical polymerization of vinyl monomers such as styrene (Dyson, 2007). A general-purpose polyester resin is made from propylene glycol and a mixture of di-functional acids. Unsaturated polyester resins are used as the basis of fibre reinforced plastics while glass fibres are the most usual reinforcing materials (Vermar, 2009).

In the course of composite development, the resin (matrix) binds the fibres together, holding them aligned in the important stress directions. Loads applied to the composite are then transferred into the fibres, which constitute the principal load-bearing component, through the matrix, enabling the composite to withstand compression, flexural and shear forces as well as tensile loads (Wood, 2008). The capacity of composites reinforced with fibres to support loads of any kind is exclusively dependent on the presence of the matrix as the load transfer medium, and the efficiency of this transfer is directly related to the quality of the fibre/matrix bond

(Enetanya, 2000). The matrix isolates the fibres so that they can act as separate entities.

The matrix protects the reinforcing filament from mechanical damage (e.g. abrasion) and from environmental attack. Since most resins which are used as matrices for fibres permit diffusion of water, this function is often not adequately fulfilled in many reinforced plastic materials, and the environmental damage that results is aggravated by the presence of stress (Hollaway, 1990). Though the quality of its grip on the fibres manifested most directly in the interfacial bond strength, the matrix can be an important means of increasing the toughness of the composite (Segeet *al*, 2000). It also enable load on a composite to be transmitted from one fibre to another. Generally, composite materials are made up of reinforcement, embedded in a matrix which holds them to form the desired shape while the reinforcements improve the overall mechanical properties of the matrix. When designed properly, the newly combined material exhibits better strength than would each individual (Richardson, 2007).

Most reinforcing fibres are solids which are brittle; their strength is therefore highly variable. When such materials are used in the form of an aggregate fine fibre, not only are the fibres stronger than the monolithic (structural) form of the same solid, but also there is the additional benefit that the fibre aggregate does not fail completely (Nick and Mark, 2004). The fibre bundle strength is also less variable than that of a monolithic rod of equivalent load-bearing ability. These advantages of the fibre aggregate can only be realized if the matrix separates the fibres from each other so that cracks are unable to pass unimpeded through sequences of fibres in

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contact. A ductile matrix provides a means of slowing down or stopping cracks that might have originated at broken fibers while, a brittle matrix depends upon the fibres to impede crack propagation (Zhang *et al.*, 2010). The glass fibres are usually blended with an unsaturated monomer, such as styrene. Subsequently, on mixing in an initiator, an addition polymerization occurs between the styrene and the polyester, giving a hard and rigid molecular network. Benzoyl peroxide is generally used as an initiator and curing will occur rapidly at elevated temperature, up to 100°C (Powell, 2006). When certain amino compounds are present with benzoyl peroxide, the curing process will take place at ordinary temperatures and the application of heat is not necessary. It is customary to mix the initiator thoroughly into the polyester resin immediately before use, and then make up a resin/fibre laminate. The final properties will depend, not only on the nature of the resin, but also on the type and form of reinforcing fibres used (Rahman and Khan, 2007).

Polyester laminates are produced to meet a number of specific requirements and separate grades are available for general purposes, heat resistance, chemical resistance, water resistance and for good impact resistance. Epoxide resins are a group of resins that are finding a growing use in engineering. They are more expensive than the polyester resins. The uncured resin consists of polymer molecules with a highly reactive epoxy group at both ends of each chain. Epoxide materials are generally used with reinforcing fibres, such as glass fibres, to produce hard and strong structural materials.

The use of carbon fibre to reinforce epoxide resin is a fairly recent development. Carbon reinforced epoxy resins are extremely strong materials with a very high value of Young's Modulus, compared with other plastic materials, and they are finding applications in the aerospace field as compressor blades in gas turbine engines, wing leading edges and flaps and rocket motor cases (John, 2002). Another property of the epoxide materials is that they adhere to virtually all materials. Consequently, they find a use as high-strength adhesives, particularly in the aerospace industries. Other applications of epoxides are for the encapsulation of miniature electronic components and for road surfacing. The extreme resistance to wear of these materials makes them suitable for use at busy road junctions. The high cost of the material is offset by the greatly reduced need for repair operations and the consequent disruptive effect on traffic.

Gel-coat resin is a thin coating of unfilled resin. In addition to masking the reinforcement, the gel-coat improves the resistance to weathering and corrosive attack of the composite (Wang *et al.*, 2005). It is a resin rich formulation containing pigments. The gel-coat is formulated to impart surface hardness, abrasion resistance and carry any pigment since it is not reinforced; it has to be applied in a relatively thin layer. It is often possible to design the structure of a laminate to achieve flame retardant gel-coat. During gel-coat application, the material is allowed to reach an optimum temperature (between 25 to 30°C). They are produced with basic characteristics such as adequate coverage with good wetting properties, quick gelling and good adhesion to the main laminate.

Natural resins are secretion from plants, appearing on the external surface of a plant after a cut (Mwaikambo and Anseli, 2001). The resins form protective coatings over the plant cut, preventing the entrance of pathogenic micro-organisms and also excessive loss of sap from the cut. Chemically, natural resins differ from one another in detail, but they all contain carbon, hydrogen and oxygen (John 2002). An example of a natural resin is the cashew nut shell liquid (CNSL).

Cashew nut shell liquid is a very sticky secretion (gum) from cashew nuts which is similar to gum Arabic. It can be used as a substitute for liquid glue for paper in pharmaceutical and cosmetic industries (Mwaikambo and Anseli, 2001). Cashew gum (like polyester resin) is a complex polysaccharide of high molecular mass and if properly processed, will exhibit the same bonding characteristics as the synthetic resins (Njoku *et al.*, 2012). The aim of this article therefore, is to establish the relevance of a natural resin (in terms of mechanical properties) in composite development.

## II. MATERIALS AND METHOD

### A. Cashew resin sourcing, extraction and modification

The cashew nuts used for this project were sourced commercially from a cashew plantation in Lokpanta in Umuochi L.G.A of Abia State. The first processing operation was the cleaning since the nuts were collected from the ground. At the simplest level, the nuts were sieved by hand using a three-quarter inch (20 mm) mesh sieve. The cleaned nuts were then conditioned in preparation for removal of the shell.

The cleaned nuts were placed in a large open drum, and water was added. The nuts were allowed to stand for ten minutes prior to draining off the water through a hole in the base of the drum. The dampened nuts were then allowed to absorb the adhering water. This soaking (conditioning) operation was repeated up to three or four times until a moisture content of nine percent (being the optimum moisture content suitable for the processing of cashew nut) was attained (Njoku *et al.*, 2012). This value of nine percent moisture content was determined by obtaining the weight difference of the nuts before and after the soaking (conditioning) operation. All nuts conditioned in this way were further processed in the same batch and the vat was completely emptied prior to the further addition of nuts to ensure that the moisture content is not exceeded.

### B. Extraction of Cashew Shell Nut Liquid (CSNL)

The Cold Solvent Extraction Method: The cashew nuts obtained were broken into two layers for the removal of the edible parts. The shells of the nuts were then poured into a vat containing a suitable volume of n-hexane and the whole arrangement allowed to stay for 24hrs. With the aid of glass wool in an extraction column the cashew resulting solution was heated in order to distil off the n-hexane, thereby leaving only the CNSL.

The Hot Solvent Extraction Method (Hot oil method): The hot solvent extraction method proceeded with the oil derived from the cold solvent method. The principle of this method is that at high temperature, oil containing substances give out

their oil constituents to the bulk, thereby increasing the volume of the bulk-the liquid constituent of the entire cashew nut shells in the bath (Mwaikambo and Anseli, 2001).

In the hot oil method, cashew nut shell liquid obtained from the cold solvent method was transferred into the aluminum container and the set-up heated to a temperature of 150°C. At this temperature, fresh cashew nuts were added into the container and the heating process continued until the system attained a temperature of 190°C which was enough to char the nuts. The charred nuts were then removed and another set of fresh ones charged into the container while the heating process continued. After about three sets, the CNSL obtained was poured out and the entire process was started all over again with small volume of cashew nut shell liquid left to avoid degradation.

**Modification of Cashew Nut Shell Liquid (CNSL) Conversion of CNSL into resin:** Cashew nut shell liquid is a unique natural source for unsaturated long-chain phenols. It is a cheap and renewable product of cashew nuts. It is useful as insecticide and fungicide.

A typical CNSL extracted contains anacardic acid (60-65%), cardol (15-20%) and traces of 2-methyl cardanol (Figure 2.3). The anacardic acid is thermally unstable and is decarboxylated during the extraction process by heating and then transformed into cardanol. Depending on the condition of the hot oil extraction process, the composition of the CNSL can change and reach a higher cardanol content of 90%. (Njoku *et al.*, 2001).

**Synthesis of CNSL Resin:** One mole of CNSL at 90% cardanol content was mixed with 2g of oxalic acid in a three-neck 500ml reactor equipped with stirrer and water cooled condenser. On purging the mixture with nitrogen for ten minutes, the set-up was heated to a temperature of 70°C; after which about 0.5mole of formaldehyde was slowly added. The formaldehyde was allowed to react with the set-up for about two hours, after which the set-up was heated again till all the containing water had evaporated. This is the conversion of 90% cardanol content of CNSL into resin.

### C. Fabrication of Specimens

The hand-lay-up method was employed in the production of specimens. A 3×80×300mm mould made of wood was provided. This was followed by the dusting of the mould and the brushing of polyvinyl alcohol solution (release agent) inside it. This was done in order to prevent the adhesion of the cured specimen to the mould. Then the resin was poured into the mould (with glass fibres already laid down) still it was filled to the brim. 1% by resin weight of methyl ethyl ketone peroxide was added as catalyst to cure the composite at elevated temperature. At room temperature, however, the composite cures if an accelerator (cobalt amine) is added to the catalyzed resin. As the specimen cured, it was de-moulded and set aside to cure. Curing occurred at room temperature within two hours after moulding. This happens when all the heat of reaction had been given off (exothermic reaction) – a situation initiated by the presence of catalyst. The specimen so formed was smoothed with a sand paper and subsequently cut into 3×20×300mm for testing (Figure 1). This method of

samples- development was the same for both synthetic and natural resins. It was also repeated with the resins reinforced with 30% by volume of glass fibres.

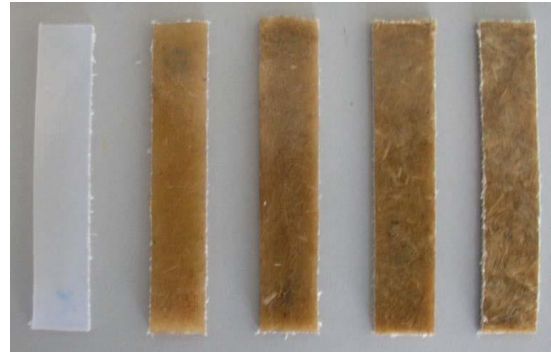
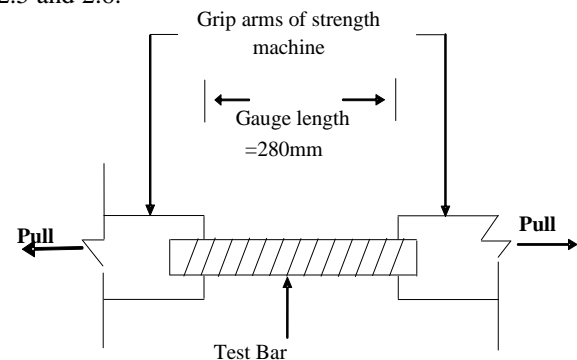


Figure 1: The sample specimens for strength test

### D. Tensile and compressive Tests

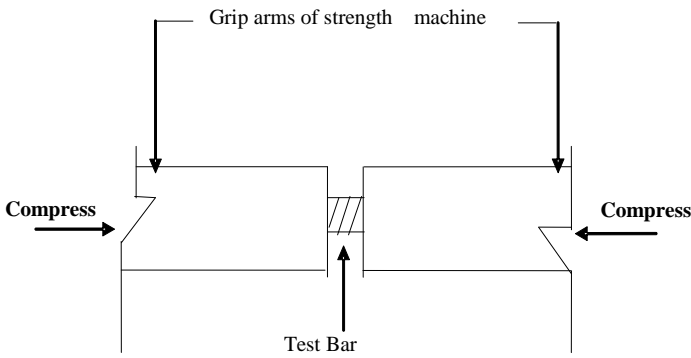
The Hounsfield Monsanto universal tensometer (ANISO-9001) was used for both the compressive and tensile tests in the strength of materials laboratory of Michael Okpara University of Agriculture Umudike, Abia State. The dimensions of the test specimens were 3×20×300mm for the tensile test and 3×20×20mm for the compressive test. The specimens so far developed were tested to failure in tension and compression. The failure mode of the specimens in tension occurred by breaking which is an indication of delamination (Figure 2.2a). On the other hand, the failure mode of the specimens in compression occurred by crushing at the limits of compression resistance (Figure 2.2b). Six identical test specimens were prepared and tested for each sample at ambient condition. Average data for the six specimens were then computed for each point of Figures 2.3, 2.4, 2.5 and 2.6.



(a) Tensile Test

## III. DISCUSSIONS

From Figures 2.3 and 2.4 it will be observed that, both the natural and the synthetic resins can withstand compressive and tensile strengths. The compressive strengths for both resins are higher than their tensile strengths because the composites contain no fibers as reinforcements to improve the tensile strengths. It should also be noticed that, the polyester resin has a higher compressive strength than the CNSL resin. However, reverse of this result is the case for their tensile strengths.



(b) Compressive Test

Figure 2: Strength Tests

Figures 2.3 and 2.5 are the same. This is because the inclusion of fibres in polymer matrices does not change the compressive strength of the resulting composite (Han *et al.*, 2006). In Figure 2.6, there is a remarkable increase in the tensile strengths of the composites developed from the two polymer matrices. This is because when fibre reinforced composite materials are subjected to tensile loading, the fibres absorb the major component of the load and this makes the fibres to be responsible for the tensile strength of any composite.

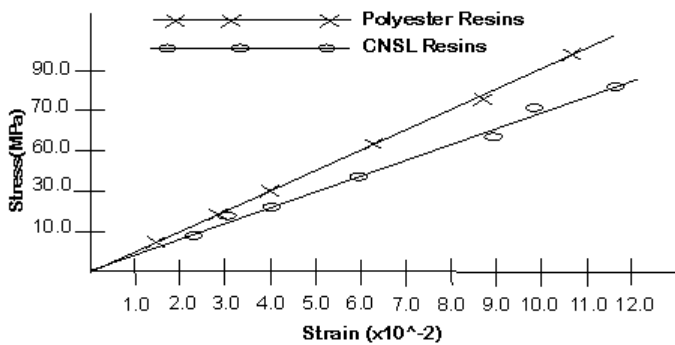


Figure 3: Graph of compressive stress against strain of unreinforced polyester and CNSL resins

IV. CONCLUSION

Fibres are essential components of composites since their presence enhances the tensile stress absorbing capacity of any composite. Cashew nut shell liquid resins have mechanical properties capable of making them compete effectively with the synthetic ones in composite development. This means that natural materials should be considered as close substitutes for synthetic ones. Research activities involving natural materials should therefore be encouraged.

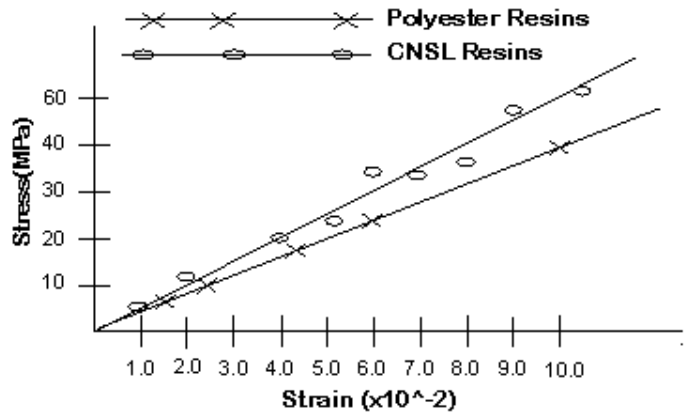


Figure 4: Graph of tensile stress against strain of unreinforced polyester and CNSL resins

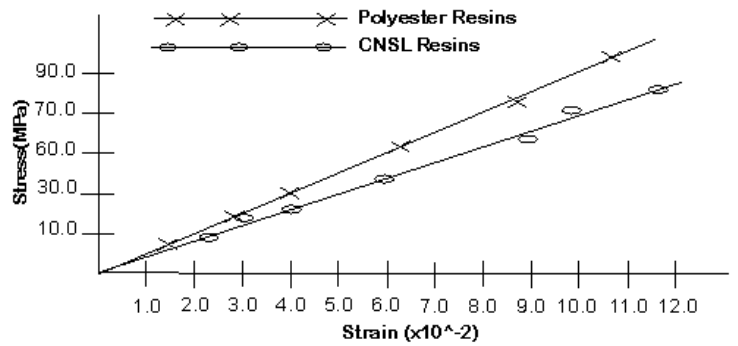


Figure 5: Graph of compressive stress against strain of polyester and CNSL resins reinforced with glass fibres

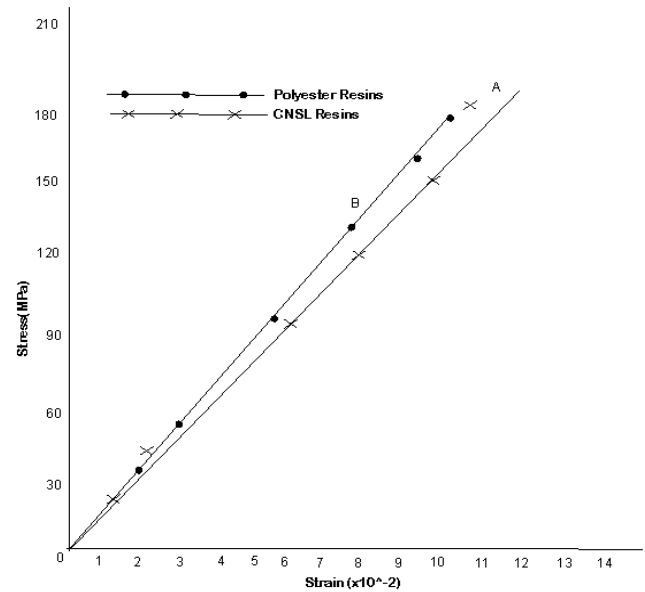


Figure 6: Graph of tensile stress against strain of polyester and CNSL resins reinforced with glass fibres

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