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Matlab Analysis of Flexural Strength and Modulus of Hybrid Nano Polyester Composite

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Abstract

The effect of hybrid nano rice husk (RH) and calcium carbonate ($CaCO_3$) on the flexural strength and flexural modulus of polyestercomposites. Polyester composites were prepared at different weight per cent of the rice husk/ calcium carbonate nano particle sizes- 65g of Unfilled polyester (S1) 0/100 (S2),10/90 (S3),20/80 (S4), 30/70 (S5), 40/60 (S6), 50/50 (S7), 60/40 (S8), 70/30 (S9), 80/20 (S10) 90/10 (S11) and 100/0 (S12).The unfilled polyester which was used as reference , polyester/calcium carbonate composite, polyester/rice husk and the hybrid nano composites were prepared from the above formulation by casting. The flexural strength and modulus of polyester, rice husk/polyester composite, calcium carbonate/ polyester composite and hybrid nano composites were determined. The results obtained were analysed using the robust MATLAB modelling environment. It was observed that weight of 0/100 of calcium carbonate composite gave the highest flexural strength and flexural modulus but decreased as the weight percentage of calcium carbonate reduced. The least value of flexural strength and modulus were recorded at unfilled polyester or neat polyester.

Keywords: C*alcium carbonate, flexural modulus, flexural strength, Matlab modelling, nano composite, polyester, rice husk.*

1.0 Introduction

Combination of organic and inorganic fillers has been developed over past decades to prepare organic/inorganic hybrid composites. These composites possess unique properties those of composite systems but with improved physical, mechanical and thermal properties. The material properties of physically mixed components depend on the polymer matrix, the uniformity of particle dispersion and other factors. (Bondeson & Oksma, 2007).

The new hybrid materials exhibit a controllable combination of the characteristics of both organic and inorganic fillers. The smallness of the formed particles normally of nanometre size is such that those hybrid materials are also called nano composites (Chin-Lung *et a*l., 2013). A Nano composite is a multiphase material derived from the combination of two or more components, including a matrix (continuous phase) and a discontinuous nano-dimensional phase with at least one nano sized dimension (that is, with less than 100 nm). The nano-dimensional phase can be divided into three categories according to the number of nano sized dimensions. Nano spheres or nanopacticles have the three dimensions in the nano scale. Both nano whiskers (nano rods) and nano tubes have two nano metric dimensions. The difference is that nano tubes are hollow while nano whiskers are solid. Finally, nano sheets or nano platelets have only one nano- sized dimension (Alexander & Dubois, 2000).

Most nano-sized phases have a structural role acting as reinforcements to improve mechanical properties of the matrix (usually a polymer), since the matrix transfers the tension to the nano reinforcement through the interface. Nano reinforcements are useful for biopolymers, because of their poor performance when compared to conventional petroleum- based polymers (Alemdar & Sain, 2009).

Polymer Nano composites usually have much better polymer/ filler interactions than conventional composites (Luduena *et al*., 2007). A uniform dispersion of Nano fillers into a polymer matrix results in a very large matrix/filler interfacial area, which restricts the mechanical mobility of the matrix and improves its mechanical, thermal (especially glass transition temperature-T_g) and barrier properties.

The ratio of the largest to the smallest dimension of filler is an important property known as aspect ratio. Fillers with higher aspect ratios have higher specific surface area, providing better reinforcing effects (Azizi Samir *et al*., 2005) and (Dalmas et al, 2007). In addition to the effects of the nano reinforcements themselves, an interphase region of decreased mobility surrounding each nano filler results in a perorating interphase network in the composites which plays an important role in improving the nano composite properties(Paul et al. 2009). For a constant filler content, a reduction in particle size increases the number of filler Particles, bringing them closer to one another; thus, the interface layers from adjacent particles overlap, altering the bulk properties more significantly (Jordan *et al*., 2005) The aim of this work is to determine the effect of Nano filler particle sizes (rice husk and calcium carbonate) and hybridization of the two fillers on the flexural strength and flexural modulus of polyester composites using MATLAB modelling Analysis .

2.0 Materials and Methods

2.1 Materials

General purpose unsaturated polyester resin, and commercial grade methyl ethyl ketone peroxide (Catalyst), poly (vinyl alcohol), gel coat, cobalt naphthanate solution (accelerator) used were bought from Centre for Composite Research and Development, JuNeng Nigeria Limited, Nsukka. Rice husk was obtained from a rice mill in Adani, Enugu State, Nigeria and 11 nm particle size of calcium carbonate was obtained from Micromat Limited, Lagos state, Nigeria .

2.2 Preparation of Hybrid Nano Composites (Calcium Carbonate/Rice Husk Filled Polyester)

The rice husk was sun dried and carbonized at a temperature of 880 ^oC in absence of oxygen using an electric resistance furnace and it was sieved to obtain 11nm particle size at Bio Co. Ltd Seoul, Korea. Prior to the composites preparation, the mould surface was cleaned with acetone and coated with a mould releasing agent. Then, 67 g of general purpose grade unsaturated polyester resin was mixed with one weight percent of methyl ethyl ketone peroxide, two weight per cent of naphthanate for 5 minutes. Different weight percent of nano rice husk /calcium carbonate; 0/100 (S2), 10/90 (S3), 20/80 (S4), 30/70 (S5), 40/60 (S6), 50/50 (S7), 60/40 (S8), 70/30 (S9), 80/20 (S10), 90/10 (S11) and 100/0 (S12) were added to the mixture .They were homogenized and processed by casting to obtain rice husk , calcium carbonate and hybrid nano composites as shown in Table 1 . The Different hybridnano composites were prepared from the following formulations as shown on the Table 2.

Table 2.1: Formulation of Hybrid RH and $CaCO_3$ Nano Particle Sizes

SPECIMENS	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Weight (%)	67g	0	10	20	30	40	50	60	70	80	90	100
	Pure	RH	RH	RH	RH	RH	RH	RH	RH	RH	RH	RH
	UPR	100	90	80	70	60	50	40	30	20	10	0
		$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$

2.3 Testing

The flexural tests were performed according to ASTM D 790 using Universal Testing Machine at a constant rate of 2 mm/min. Test specimens were cut to 200 mm length, 20 mm width and 3 mm depth .The support span was 160 mm. The flexural strength and flexural modulus were calculated using the following equations. (Navaneethakrishnan *et al.*, 2015).

$$\text{Flexural Strength} = 3PL/2bh^2 \quad (1)$$

$$\text{Flexural Modulus} = mL^2/4bh^4 \quad (2)$$

where P = maximum load applied on test specimen (N)

L = support span (mm)

b = width of specimen tested (mm)

d = thickness of specimen tested (mm)

m = slope of tangent to the initial strength line portion of load deflection curve (N/mm)

3.0 Results and Discussion

The results obtained from unsaturated polyester composite, hybrid nano composites, calcium and rice husk composites are illustrated in the form of a combined chart which displayed the values of the flexural strength and modulus as bar chart and scatter plots respectively on parallel axes against the force values (Figure 1 to 12). Figure 1 shows the result obtained from regression modelling of the flexural strength and modulus (MPa) of the unfilled unsaturated polyester (S1). Figure 2 shows the result obtained from regression modelling of the flexural strength and modulus of 100 % nano calcium carbonate (0/100 %) filled polyester (S2). Figure 3 shows the results obtained from regression modelling of the flexural strength and modulus of 10 % nano rice husk and 90 % of nano calcium carbonate (S3). Figure 4 shows the results obtained from regression modelling of the flexural strength of 20 % nano rice husk and 80 % of nano calcium carbonate (S4). The results obtained from regression modelling of the flexural strength and modulus of 30 % nano rice husk and 70 % of nano calcium carbonate (S5) is shown in figure 5. Figures 6 to 11 shows the results obtained from regression modelling of the flexural strengths and modulus of 40 % nano rice husk and 60

% of nano calcium carbonate (S6), 50 % nano rice husk and 50% nanocalcium carbonate (S7), 60 % nano rice husk and 40 % nano calcium carbonate (S8), 70 % nano rice husk and 30 % nanocalcium carbonate (S9), 80 % nano rice husk and 20 % nano calcium carbonate (S10), 90 % nano rice husk and 10 % nanocalcium carbonate (S11). 100 % nano rice husk (100/0 %) (S12).

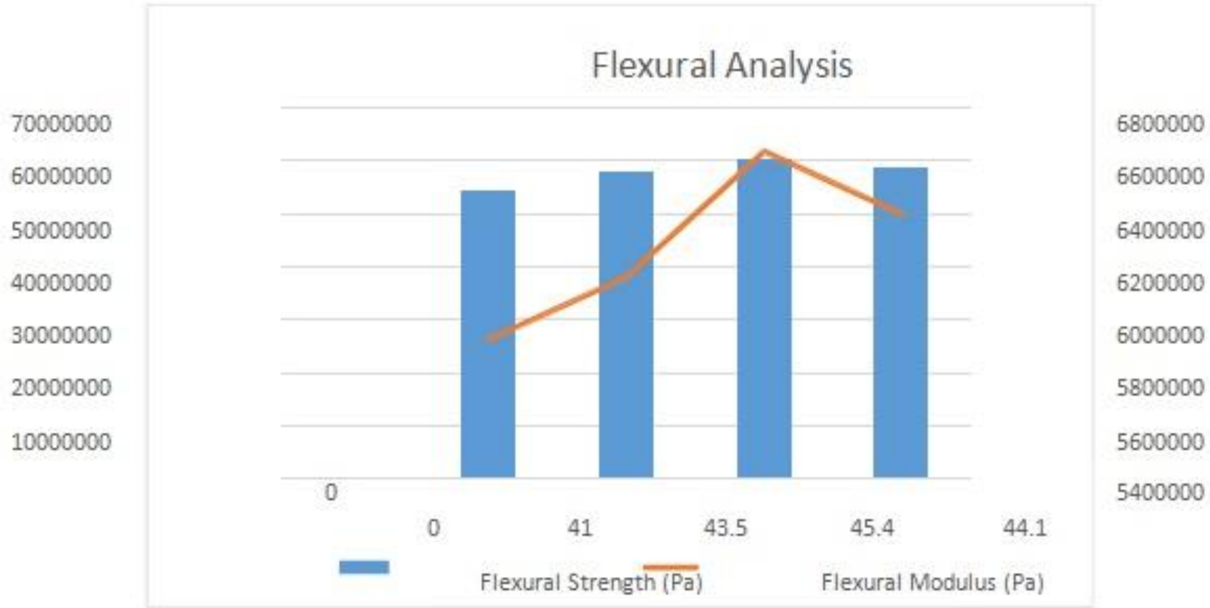

Figure 1. Regression modelling of S1 flexural strength and modulus

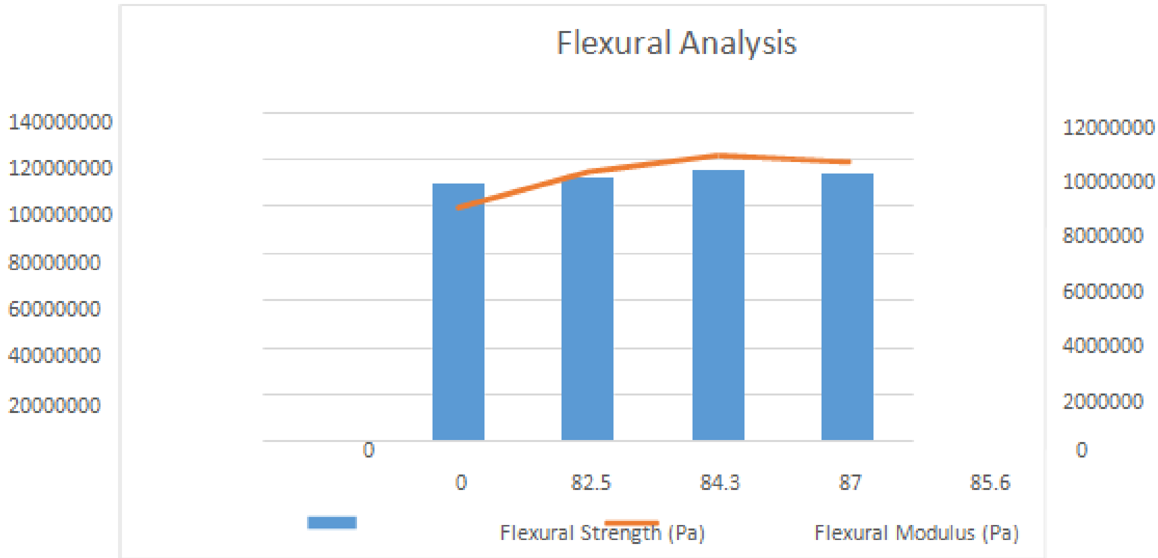

Figure 2. Regression modelling of S2 flexural strength and modulus

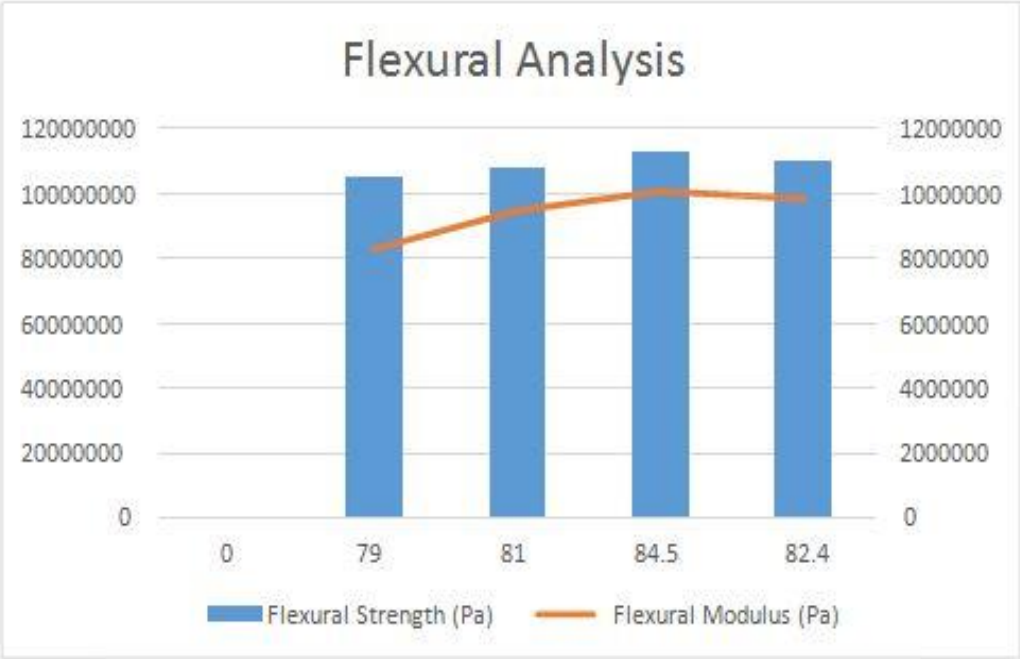

Figure 3. Regression modelling of S3 flexural strength and modulus

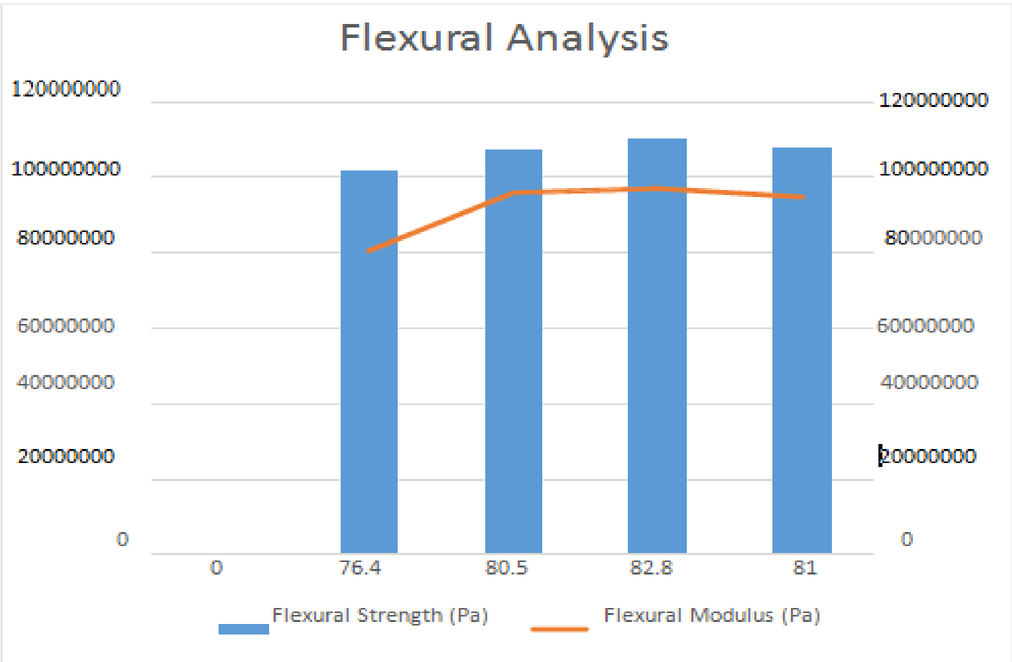

Figure 4. Regression modelling of S4 flexural strength and modulus

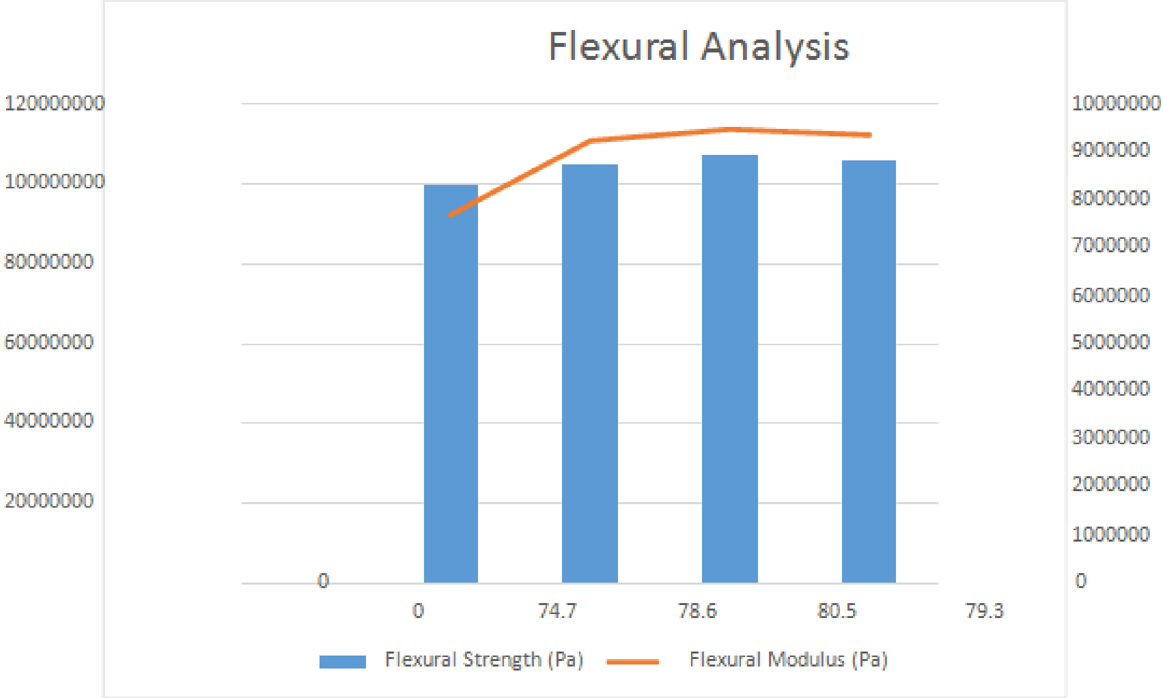

Figure 5. Regression modelling of S5 flexural strength and modulus

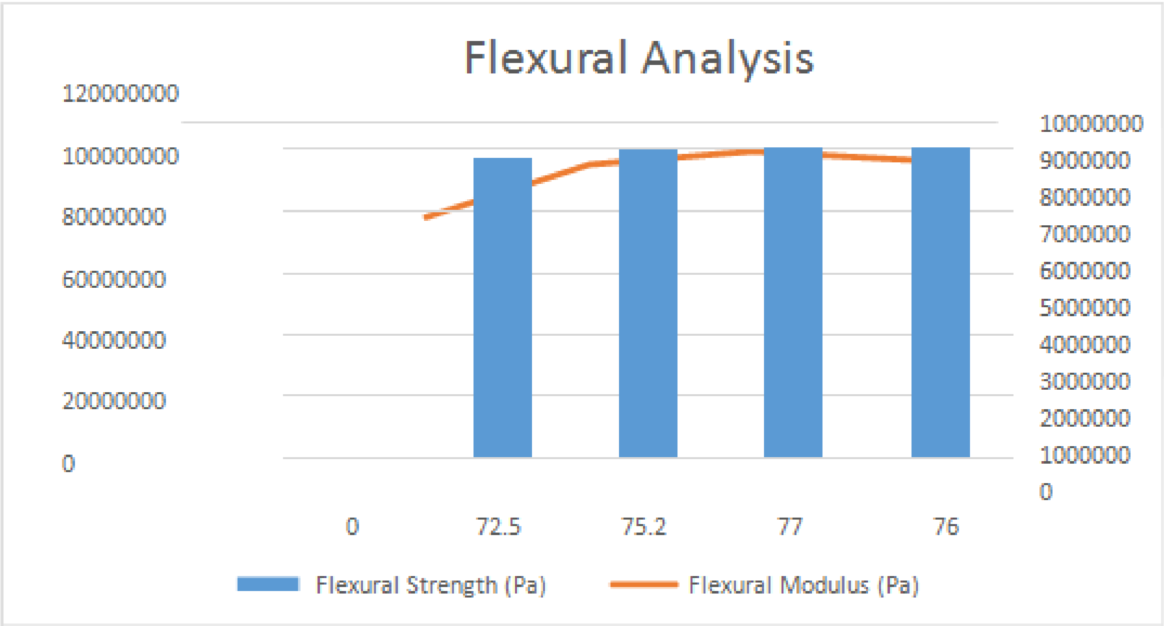

Figure 6. Regression modelling of S6 flexural strength and modulus

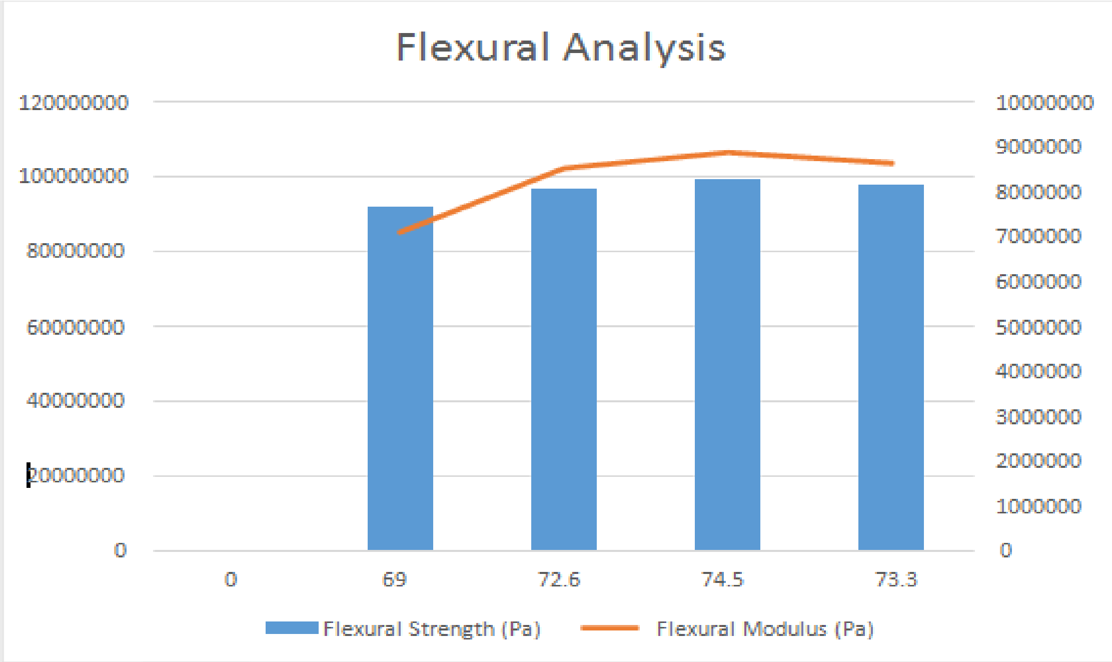

Figure 7. Regression modelling of S7 flexural strength and modulus

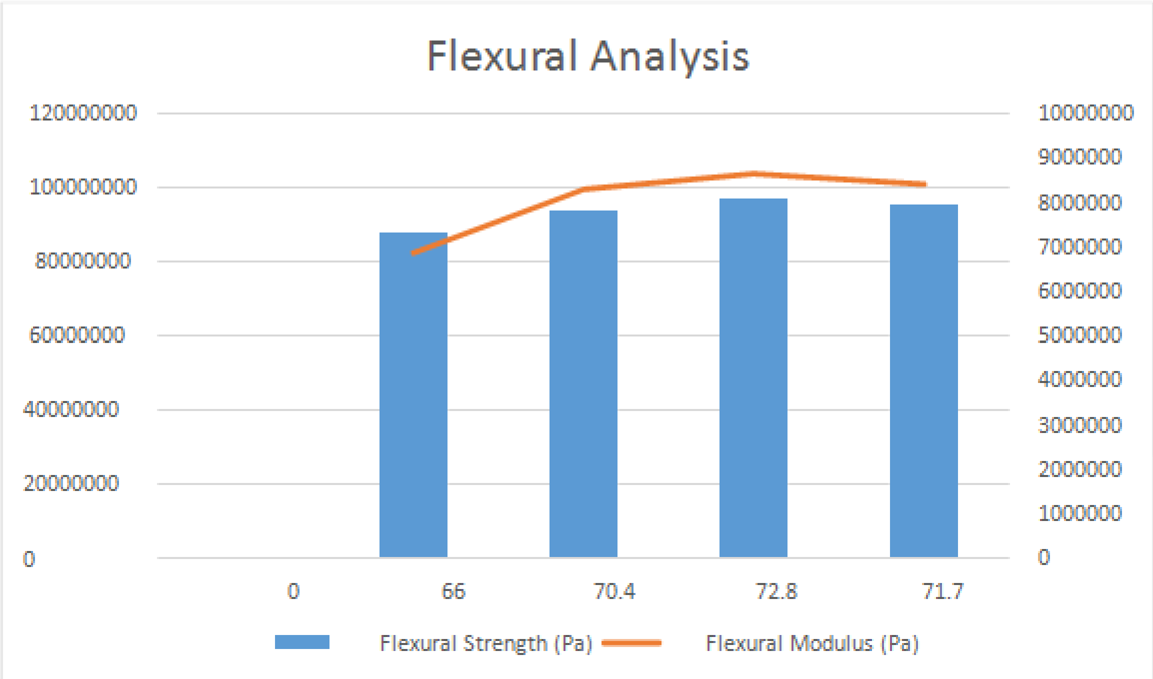

Figure 8. Regression modelling of S8 flexural strength and modulus

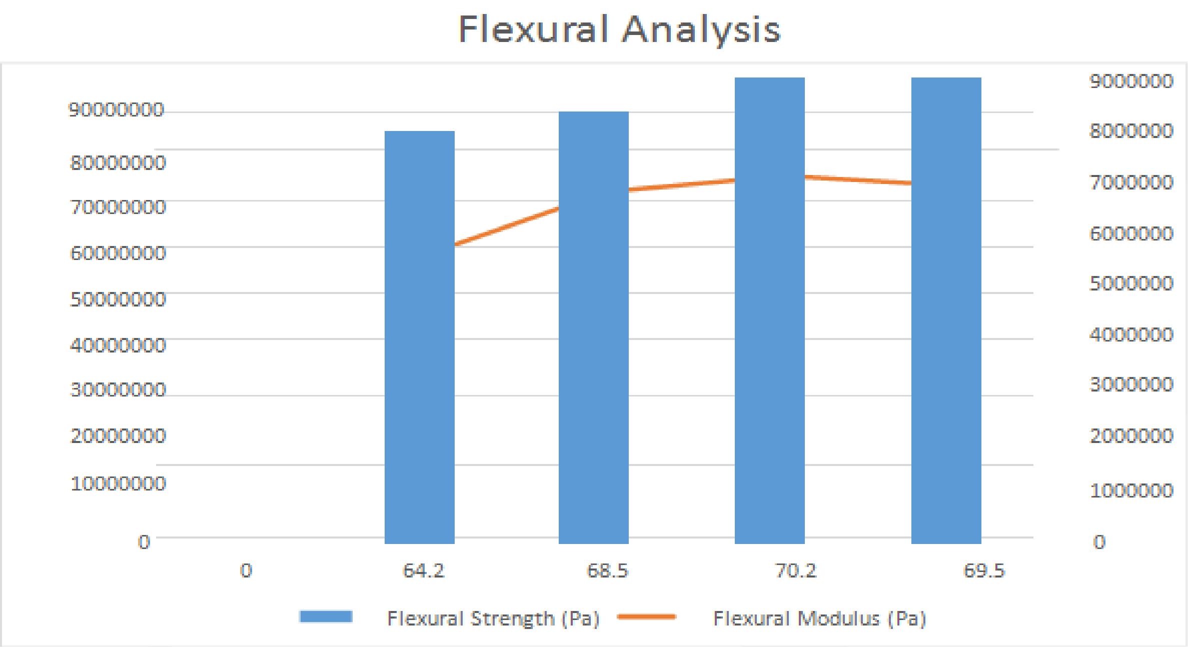

Figure 9. Regression modelling of S9 flexural strength and modulus

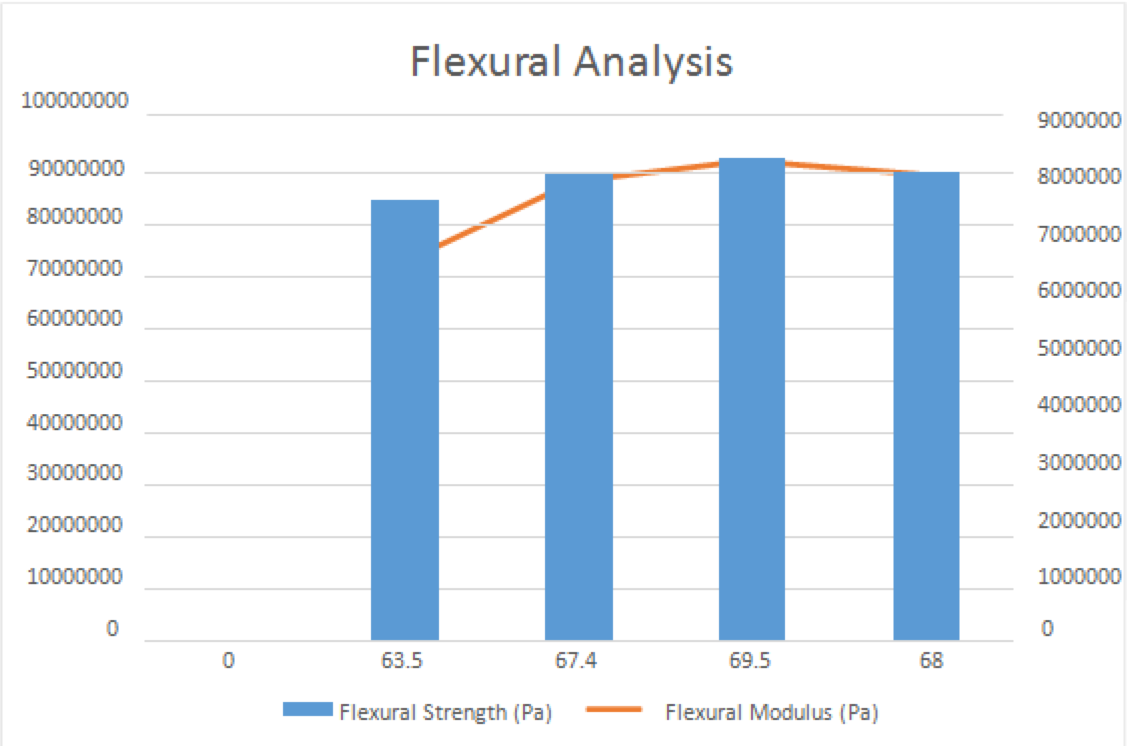

Figure 10. Regression modelling of S10 flexural strength and modulus

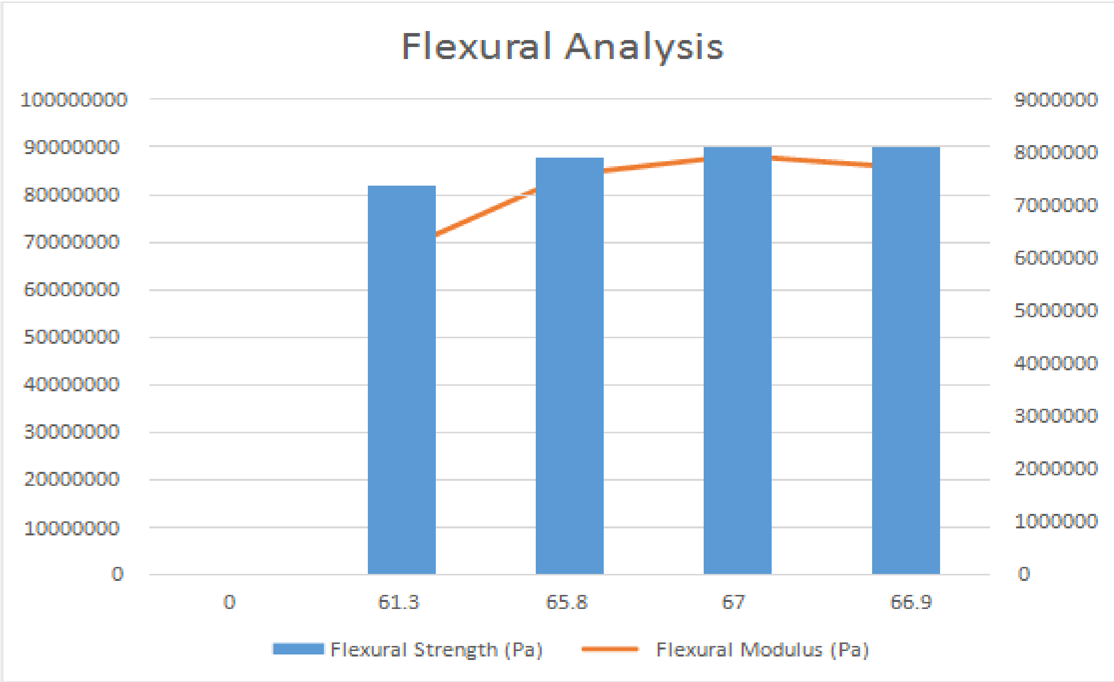

Figure 11. Regression modelling of S11 flexural strength and modulus

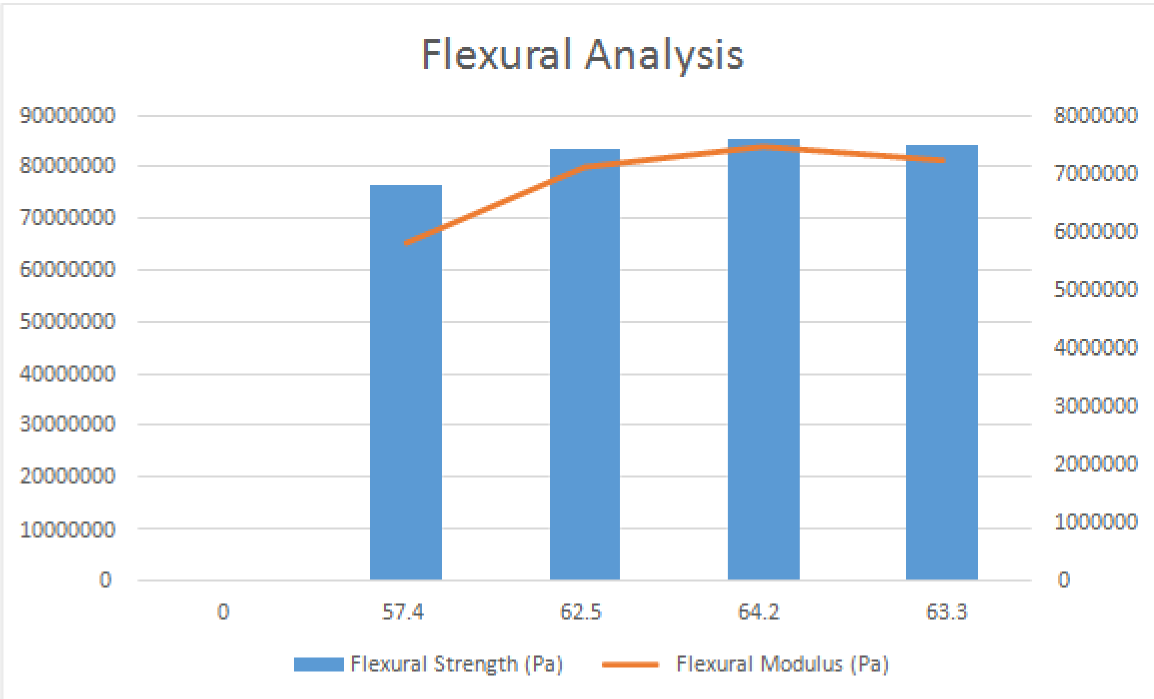

Figure 12. Regression modelling of S12 flexural strength and modulus

Table 2: Flexural strengths and modulus obtained from modelling analysis of a hybrid-nano polyester composite

Samples	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Flexural strength(MPa)	58	113.13	108.97	106.90	104.37	100.23	96.43	93.63	90.80	89.47	87.00	82.47
Flexural modulus(MPa)	6.28	9.75	9.42	9.21	8.95	8.65	8.29	8.06	7.82	3.41	7.35	6.90

From the results obtained from the MATLAB analysis of the flexural strength and modulus of the unfilled polyester , nano calcium , hybrid nano and nano rice husk composite, the order on the increase in flexural strength and modulus are as follows:S2 > S3> S4 > S5 > S6> S7 > S8 > S9 > S10 > S11> S12 >S1

Flexural strength being the ability of the material to withstand bending forces. The presence of 100 % calcium carbonate in the composite withstood the bending force due to high density of calcium carbonate as confirmed by Hanin *et al*., (2008). S3 has the second highest flexural strength and modulus values (108.97 & 9.42 MPa respectively). Flexural strength and modulus increased with increases in weight percentages of calcium carbonate in the hybrid ratio. It means that nano rice husk has no impact or effect in the composite flexural strength and modulus. Hybridization of $CaCO_3$ with RH is insignificant in determination of flexural strength and modulus and nano $CaCO_3$ reveals more effectiveness in filling the polyester. The results show that flexural strength and modulus of hybrid nano composite are greater than those of the unfilled polyester. This is due to the $CaCO_3$ and RH fillers helping the polyester matrix to with stand the bending load to a higher magnitude but the unfilled polyester yielded stress concentration sites that led to premature failure and is in agreement with Osman *et al*., (2012).

4.0 Conclusion

Incorporation of nano rice husk and $CaCO_3$ into polyester improved its flexural strength and modulus. The highest flexural strength and modulus occurred at 100 % calcium carbonate but least at unfilled polyester (neat polyester) which proved insignificance of hybridizing the nano calcium carbonate with rice husk in polyester since it has negative effect on the polyester composites.

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