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# Experimental Investigation of Tensile and Hardness Behaviour of PF Based Wood Plastic Composite

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**Abstract:** The present work deals with the fabrication of Phenol Formaldehyde (PF) based wood plastic composite (WPC) from wood flour (WF) at different ratios by hotpress method.The wood plastic composites of 8 mm thickness were fabricated after mixing the wood flour with PF resin followed by hotpress method.The coconut shell powder is used as secondary reinforcement materials. Experimental investigation has been done to determine the relation between Brinell hardness and tensile strength of WPCs.The linear regression analysis is used to correlate the Brinell hardness and tensile strength values of different wood species WPCs. It was found from regression analysis that there is strong correlation between Brinell hardness and tensile strength values at 30-50 vol % of WPCs.

**Keywords:** Hardness, Wood flour, Wood plastic composite, Phenol formaldehyde

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## I. INTRODUCTION

Wood plastic composites (WPCs) are becoming one of the promising sector in today's plastic industry. A composite material consists of wood flour/fibre and thermoset or thermoplastic referred to as wood plastic composite[1].P. R. Hornsby et al.[2] investigated mechanical properties like tensile, flexural and impact strength of polypropylene composites using natural fibres such as wheat straw, flax straw and glass fibres with 25 wt % each. Inclusion of flax straw into polypropylene yields high stiffness and strength values than wheat straw polypropylene composite. Wood polymer composites are prepared by using wood flour and polymer material. Light weight, corrosion resistance, durability and low maintenance of wood polymer composite (WPC) made them as a promising material for the next generation. WPCs can be used in some of the applications such as decking, window and door profiles, railing and roofing tiles[3].Glass and mineral fillers used in the automotive industry replaced by natural fibres because of their light weight and low cost[4]. Surface quality of wood plastic composites (WPCs) of polypropylene based were studied by Nadir Ayrilmis et al. as a function of formulation variables like wood flour size, WPC content, WPC density and hot-pressing temperature. Hot-pressing temperature from 190° to 210° C improves the surface smoothness of PP based composite[5].

Nadir Ayrilmis et al. [6] investigated physical, mechanical and fire resistance properties of polypropylene based WPCs. Tensile strength values of these composites decreases with increasing fire resistance content. The mechanical and water resistance property of WPCs can be improved by using coupling agents. Poor interfacial bonding between matrix and reinforcement material leads to decrease in mechanical properties. Compatibilizers or coupling agents enhances the mechanical properties[7].

The tensile behavior of kenaf and jute fibre reinforced PP composites were investigated by Byoung-Ho Lee et al [8]. The tensile strength of composite reduces with increase of fibre fraction. Voids present in the composites deteriorates the load transfer capability of composites. The important mechanical properties such as tensile strength and Brinell hardness of polypropylene based wood flour composites with and without coupling agents were investigated by Alperen Kaymakci and Nadir Ayrilmis [9].In their work, they correlate the Brinell hardness and tensile strength of WPCs by using linear regression analysis. Fibre length, fibre loading, fibre dispersion, fibre orientation and fibre matrix interfacial bond decides the tensile properties of short fibre reinforced composites. Experimental data and theoretical modelling were used to compare the tensile behaviour of short sisal fibre reinforced low density polyethylene composite[10].

Jan T. Benthien et al. [11] investigated the influence of raw materials and process parameters on the physical and mechanical properties of flat pressed WPC panel. The properties like modulus of elasticity and modulus of rupture decreases with increase of wood flour content from 50 to 70 wt %. The effects of different wood species like poplar, Douglas-fir, black locust, white oak, and ponderosa pine on mechanical, thermal behaviour of WPCs were investigated by James S. Fabiyi et al [12].Performance of wood plastic composite

mainly depends on wood species used for fabrication. Analysis and optimization of PET based wood plastic composites were studied by Cruz-Salgado Javier et al [13].Multiple linear regression models used in their study indicate suitability of the experimental results. Raw materials used and mixing ratio plays major role on physical and mechanical properties PET based wood plastic composites. The modulus of elasticity of composite decreases with increasing saw dust content from 40 to 70 wt %[14].

The main objective of this work is to investigate the relation between Brinell hardness and tensile strength of different wood species PF based WPCs as these properties plays important role in characterizing the composites.

## II. MATERIALS AND METHODS

Waste wood flour of saguvani and honne collected from local sawmills. The collected wood flour screened to remove any impurities which are present in them to avoid ill effects during the fabrication of composite specimens. Figure no 1 shows different wood flour collected from sawmills. These wood flour used as reinforcement materials in this work. In addition to this, coconut shell powder used as secondary fillers, as they are potential candidates for the development of new composites because of their high strength and modulus properties. Coconut shell powder is agricultural waste. Shell particles of size between 200-800µm are prepared by using grinding machine. Their effective and eco-friendly utilization has always been a challenge for scientific applications. Figure no 2 shows coconut shell powder used for research.

**Figure no 1: (a)** Saguvani wood flour **(b)** Honne wood flour.

**Figure no 2:** Coconut shell powder.

Phenol Formaldehyde (PF) resins are synthesized by the reaction of phenol with formaldehyde. These resins can be divided into two main groups according to reaction conditions that are used, such as pH of the catalyst and the formaldehyde/phenol ratio.PF resin supplied from AKOLITE, Mangalore, was used as matrix material in this work. The typical properties of PF resin like ease of moulding, good chemical resistance, good weather resistance made it to use as matrix material.

***Fabrication and experimental procedure:***

The preliminary tests like density and grain fineness number (GFN) tests were carried out for reinforcement and filler materials as these values will help in the mechanical characterization of composite materials. The density test for materials conducted by using Archimedean's principle. Table no 1 shows density of reinforcement materials used in this work.

**Table no 1:** Density of reinforcement materials.

| Sl. No. | Reinforcement material | Density(g/cm$^3$) |
|---|---|---|
| 1 | Saguvani wood flour | 1.10 |
| 2 | Honne wood flour | 1.00 |
| 3 | Coconut shell powder | 1.60 |

The moisture content if any present in the wood flour and coconut shell powder is removed by keeping them in the hot air oven for about 24 hours at temperature of 100° C .Table no 2 shows formulation of composite for the fabrication of specimens. According to weight fraction, reinforcement and filler materials are thoroughly mixed with PF resin and kept it for about 24 hours for curing. The resin mixed material compacted in the designed metallic mould of size 300 mm × 350 mm × 8 mm. The metallic mould with compacted material is placed in the hot press machine for about 15 minutes curing time at temperature of 110° C. The fabricated composites are kept for a period of one week at room temperature for aging before test. Fabricated composites were cut according to ASTM standards to investigate the tensile and hardness behaviour.

**Table no 2:** Formulation of composites.

| Sl. No. | Composite | Composition |
|---|---|---|
| 1 | S-30 | 70 % PF + (25 % WF + 5 % CSP) |
| 2 | S-40 | 60 % PF + (35 % WF + 5 % CSP) |
| 3 | S-50 | 50 % PF + (45 % WF + 5 % CSP) |
| 4 | H-30 | 70 % PF + (25 % WF + 5 % CSP) |
| 5 | H-40 | 60 % PF + (35 % WF + 5 % CSP) |
| 6 | H-50 | 50 % PF + (45 % WF + 5 % CSP) |

PF-Phenol formaldehyde,WF-Wood flour,CSP-Coconut shell powder.

According to ASTM D 618 the test specimens were conditioned at 23±2°C for 4 days. The mechanical behaviour of the wood plastic composites were characterized through tensile and Brinell hardness tests in accordance with ASTM standards. Strength measurements of samples were conducted using an universal testing machine.The universal testing machine of capacity 100 kN and test speed of 2 mm/min is used for conducting tensile test. Each test value mentioned in table no 3 representes the average of five samples.The Brinell hardness tester is used to measure the hardness number of wood plastic composite samples.

## III. RESULTS AND DISCUSSION

***Tensile strength of composites:***

Table no 3 shows tensile strength values of different wood species WPCs. The tensile strength of S-50 WPC is high comparatively with other composites. The increase in tensile strength may be due to strong bonding between wood flour and matrix material PF. It can be observed that H-50 WPC has high tensile strength value. However, H-30 composite has lowest tensile strength value. The increase in wood flour content increases the tensile strength values of WPCs upto certain % wood flour content. The poor interfacial bonding between matrix material PF and wood flour reduces the tensile strength. As the inclusion of wood flour content increases up to 50 % in the WPC, tensile strength increases. Due to poor compatibility between wood flour and matrix material, there is considerable reduction in tensile strength values of WPCs as the inclusion of wood flour content increases beyond 50 %.There is reduction in the efficiency of stress transfer from polymer matrix to reinforcement material due to weak interfacial regions[9].

**Table no 3:** HB and tensile strength values of WPCs.

| Composite | Brinell hardness (HB) | Tensile strength ($N/mm^2$) |
|---|---|---|
| S-30 | 72 | 42 |
| S-40 | 74 | 51 |
| S-50 | 75 | 52 |
| H-30 | 64 | 34 |
| H-40 | 69 | 36 |
| H-50 | 70 | 43 |

**Table no 4:** Regression analysis for WPCs.

| Composite | Best fit equation | R-squared value |
|---|---|---|
| S-30 | y = 2.4027x + 22.53 | $R^2$ = 0.9865 |
| S-40 | y = 2.7132x + 60.94 | $R^2$ = 0.9572 |
| S-50 | y = 2.1471x + 44.39 | $R^2$ = 0.9348 |
| H-30 | y = 1.6747x + 8.096 | $R^2$ = 0.9869 |
| H-40 | y = 1.6711x + 7.685 | $R^2$ = 0.9867 |
| H-50 | y = 1.2163x + 20.69 | $R^2$ = 0.9894 |

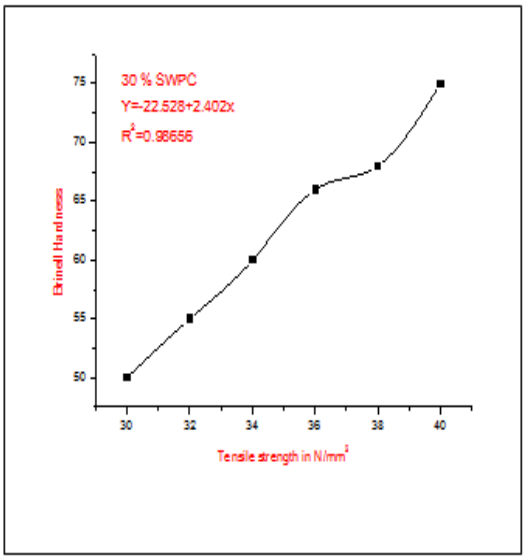
***Brinell hardness:***

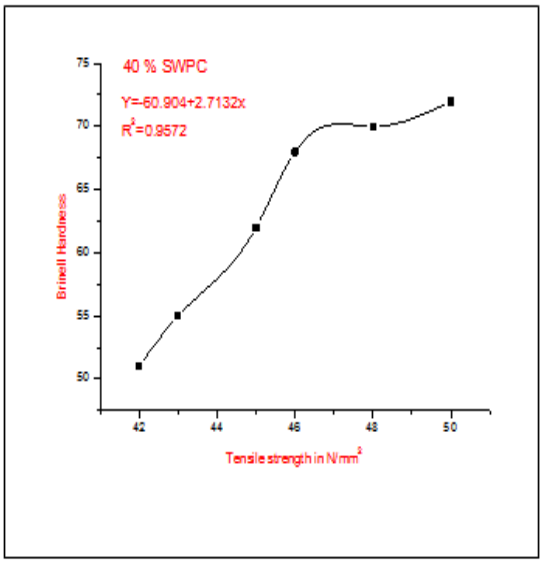
Table no 3 shows Brinell hardness values of different wood species WPCs. The inclusion of wood flour content increases the Brinell hardness values of different wood species WPCs. Comparatively, the Brinell hardness values of 50 vol % of different wood species are high with other composites. The S-30 composite has high hardness number. However; H-30 composite has very low Brinell hardness number. It may be due to lesser

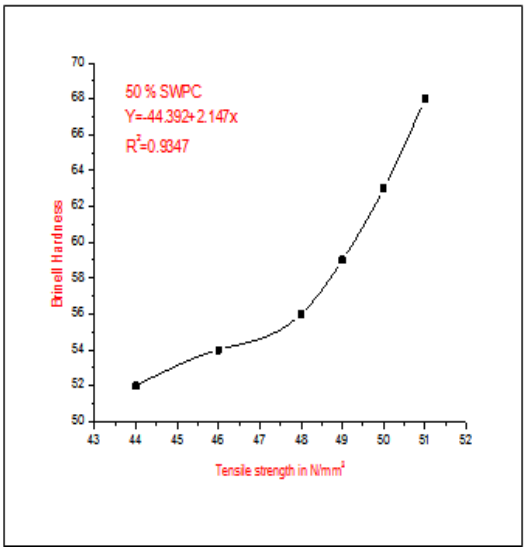
wood flour content reduces the hardness value of composite. There is considerable increase in Brinell hardness value of wood plastic composites due to increase in addition of wood flour[9].

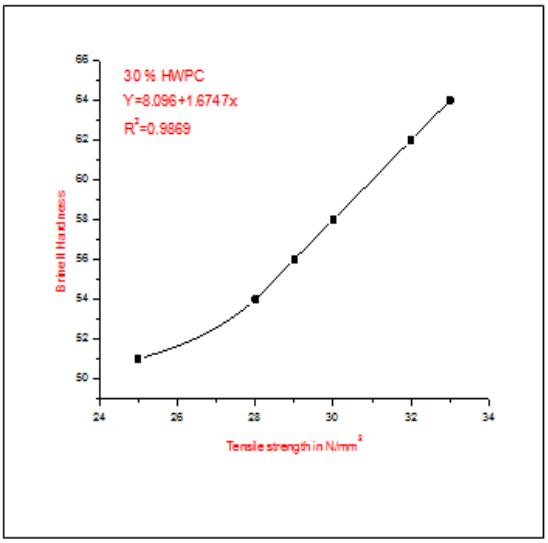
***Brinell hardness and tensile strength:***

Figure no 3 shows relationship between Brinell hardness and tensile strength values of different wood species WPCs. The linear regression analysis is used to determine the correlation between Brinell hardness and tensile values of wood plastic composites. Regression analysis for all data sets of different composites are shown in Table no 4. The linear coefficient for S-30 and H-50 composites are high ($R^2$=0.986 and $R^2$=0.989).The reason for this may be strong interfacial bonding between wood flour and PF matrix material. It can be observed from the Table no 4, that there is good correlation between Brinell hardness and tensile values of composites S-30,H-30, and H-50.The correlation between Brinell hardness and tensile values of WPCs increases with increase in wood flour content.



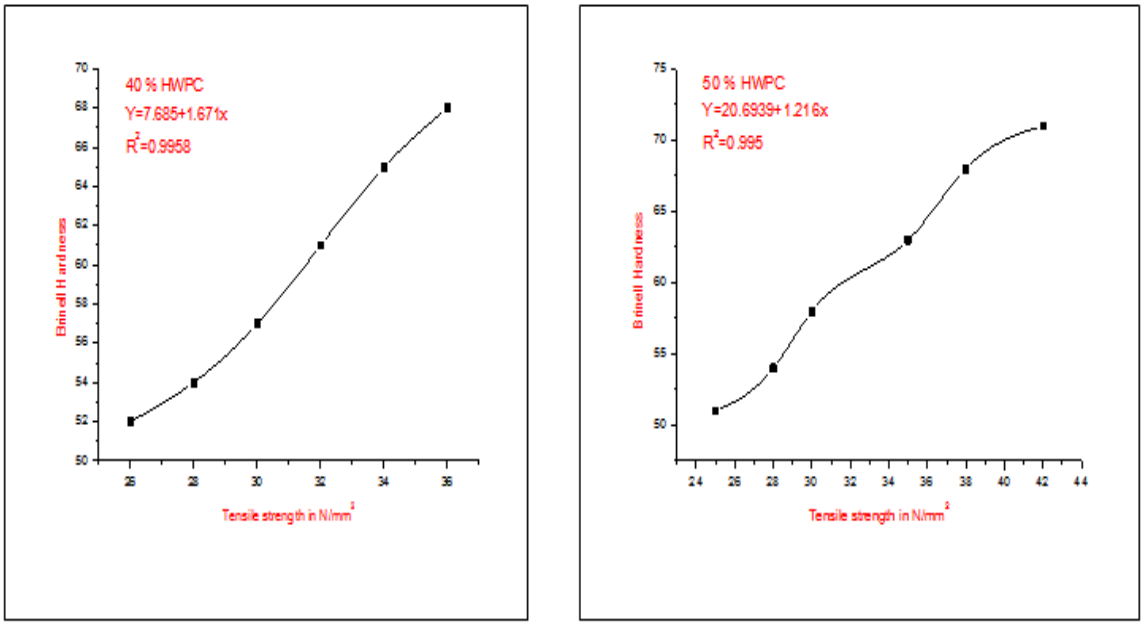



**Figure no 3:** Correlations between Brinell hardness and tensile strength values of WPCs.

## IV. CONCLUSIONS

Wood plastic composites of different wood species with PF as matrix material fabricated by using hot-press method. Different vol % of reinforcement materials are used for the fabrication of WPCs. The linear regression analysis is used to study the correlation between Brinell hardness and tensile strength of PF based different wood species WPCs. The strong correlation observed for S-30 and H-30 composites. There is good correlation between hardness and tensile strength of wood plastic composites between 30 to 50 vol. % wood flour content .

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