

# Compressive Properties of Sawdust Composites Consisting of Sodium Silicate Solution and Corn Starch as Binder

Chowdhury Al Mamun & Md Arifuzzaman

## Abstract

Novel composite materials were manufactured using saw dust, sodium silicate solution and corn starch. Corn starch works as a reinforcement to the sodium silicate solution. The floatation method was utilized to obtain the wet mixture for manufacturing composites by compaction. The quantity of saw dust and sodium silicate solution were fixed and the starch powder content in the binder solution was the working variable. Starch powder content in the binder solution were 1.4 g, 1.6 g, 1.8 g and 2.0 g. The gelatinization of starch is investigated to confirm the gelatinized solid starch content in the binder solution. Compression tests were carried out on the composites in the Universal Testing Machine at a cross head speed of 1 mm/min. The density, compressive strength and modulus were found to increase with increasing gelatinized solid starch content. On the other hand, specific compressive strength decreased with increasing density of the composite while specific compressive modulus showed an opposite trend. Comparing with the literature, the developed composites showed superior properties and were found to have practical applications.



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## 1. Introduction

Saw dust is generated from wood shavings and cutting in wood industries. It is being treated as waste in many countries and burned or disposed to landfill. However, saw dust has potential to be used as a building material for furniture, decoration as well as load bearing structures if composites are designed using it. Sawdust is widely used to manufacture particleboards using various binder such as cement (Jorge et al., 2004), Isocyanates (John, 1982), urea-formaldehyde (Rios, 2015; Veigel et al., 2012), gypsum and magnesia (Simatupang and Geimer, 1990), starch (Yimsamerjit, 2007) etc. Sawdust is also being used as a filler in wood plastic composites (Bouafif et al., 2009; Adhikary et al., 2008; Saeed, 2013) for many years. However the process is very expensive and bonding between saw dust particles and polymer is also a major concern (Chotirat et al., 2007). The performance and stability of sawdust-reinforced composite materials depend on the development of coherent interfacial bonding between sawdust and matrix.

Corn starch and sodium silicate solution may be potential binders for manufacturing saw dust composite/particleboard using floatation method (Kim, 2014) because of their low cost and availability. Starch is used as a matrix for manufacturing green composites along with other binder materials or additives (Maa, Yua, & Kennedy, 2005; Selamat, et al., 2016). Gelatinized starch is a biodegradable polymer which provides excellent mechanical properties as well as stability and being utilized to manufacture syntactic foams (Islam & Kim, 2007; Shastri & Kim, 2014). On the other hand, sodium silicate solution is a chemical compound, which is inorganic, low cost, environment friendly and being used for many years as a binder in various applications (Arifuzzaman & Kim, 2015). It has potential to enhance the properties of the sawdust composite, especially fire retardant characteristics because sodium silicate is a fire retardant material (Burriesci, 1982). The combined effect of gelatinized corn starch and sodium silicate solution may impart superior properties to saw dust composites in terms of bonding, strength, and fire resistance.

The goals of this work are to fabricate a novel composite material using sawdust, corn starch and sodium silicate and investigate its physical and mechanical properties to see the effects of gelatinized corn starch content and density.

## 2. Materials and method

### 2.1 Constituent materials and characterization

Saw dust (SD) was collected from local saw mill in Khulna and dried in sunlight for at least a week and then sieved by strainers to separate smaller (less than 0.4 mm) particles. The fiber size range was 0.4 mm to 5 mm. SD was from Lebbek tree and its scientific name is *Albizia lebbek*. The bulk density of the SD was found to be 0.017 g/cm<sup>3</sup>. Sodium silicate solution (SSS) and corn starch were collected from local scientific store, Rupsha Scientific, Khulna, Bangladesh.

### 2.2 Starch gelatinization and solid content

The required amount of starch powder as shown in Table 1 was mixed with 100 g of water and stirred for 30 min at 80°C inside an oven for gelatinization of starch. From the gelatinized transparent solution 20g was taken in a test tube and dried inside the oven at 100°C until there is no mass change. The remaining amount of gelatinized starch in the test tube represents solid starch. Solid starch content in the gelatinized solution for various starch powder content in water before and after gelatinization is given in Table 1. In the gelatinized solution of starch, solid starch content is reduced as seen from Table 1. The observation

indicates that there may be some starch powder that has not been gelatinized and remained as residue within 30 minutes of gelatinization. However when starch powder in water before gelatinization is increased the loss percentage showed a decreasing trend. The reason for this is that powders that had not been gelatinized within 30 minutes are trapped in the gelatinized solution.

**Table 1 Solid starch content before and after gelatinization.**

Starch powder added in 100 g of water (g)	Solid starch content in gelatinized solution of 100 g (g)	Loss percentage (%)
1.2	0.90	0.25
1.4	1.15	0.18
1.6	1.40	0.13
1.8	1.65	0.08
2.0	1.90	0.05

Source: Current work

Therefore, it is necessary to find the relation between solid content before and after gelatinization for the sake of manufacturing of composites and property analysis. Towards that solid starch content in gelatinized starch solution is plotted as a function of starch powder content in water before gelatinization in Figure 1. The solid starch in gelatinized solution increased with increasing starch powder content linearly for fixed gelatinization time of 30 minutes with least square line  $y = 1.25x - 0.6$  and correlation coefficient  $R^2 = 1$ . A high correlation coefficient indicates high linearity. This relation is important for further characterization of the composites prepared using gelatinized starch and also useful for manufacturing cost optimization.

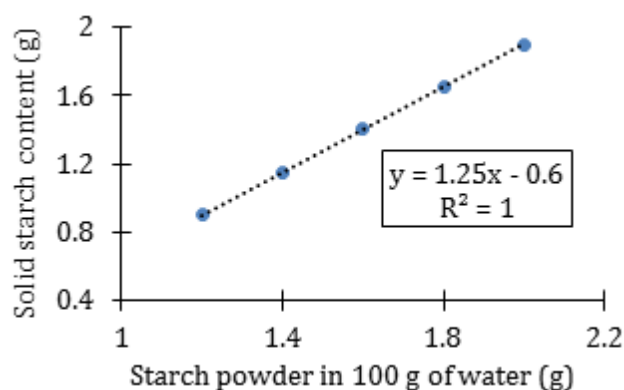


Figure 1 Solid starch content after gelatinization as a function of starch powder content in water before gelatinization.

### 2.3 Specimen Preparation and Testing

In this study, the working variable is the amount of starch powder per 100 g of water. Therefore, four different solutions were made (i.e. 1.4 g, 1.6 g, 1.8 g and 2.0 g of starch per 100 g of water). These solution were stirred at 80°C for 30 minutes for gelatinization. SSS was mixed with the gelatinized solution with a ratio of Solution/SSS = 3:1 with all solutions. The solution was mixed with sawdust and transferred into the mold of inside cross section 110 X 110 mm. The mixture is then compacted to 15mm final height using UTM. The mold is removed and the composite was placed into the oven for drying at 100°C until the mass

becomes constant. After drying, the specimens were cut into pieces of dimension 32 X 32 mm to conduct testing. Some specimens are shown in Figure 2. Compression test was carried out in the Universal Testing Machine with a speed 1 mm/min.



Figure 2 Manufactured specimens

**Table 2 Density, compressive strength and modulus, specific compressive strength and modulus with various solid starch content.**

Solid starch content (g)	Density (kg/m <sup>3</sup> )	Compressive strength (MPa)	Sp. compressive strength (MPa/(g/cm <sup>3</sup> ))	Compressive modulus (MPa)	Sp. compressive modulus (MPa/(g/cm <sup>3</sup> ))
1.15	319.79	4.39	13.73	18.83	58.88
1.40	335.29	4.55	13.57	20.11	59.98
1.65	358.62	4.85	13.52	21.24	59.23
1.90	381.00	4.67	12.26	23.59	61.92

Source: Current work

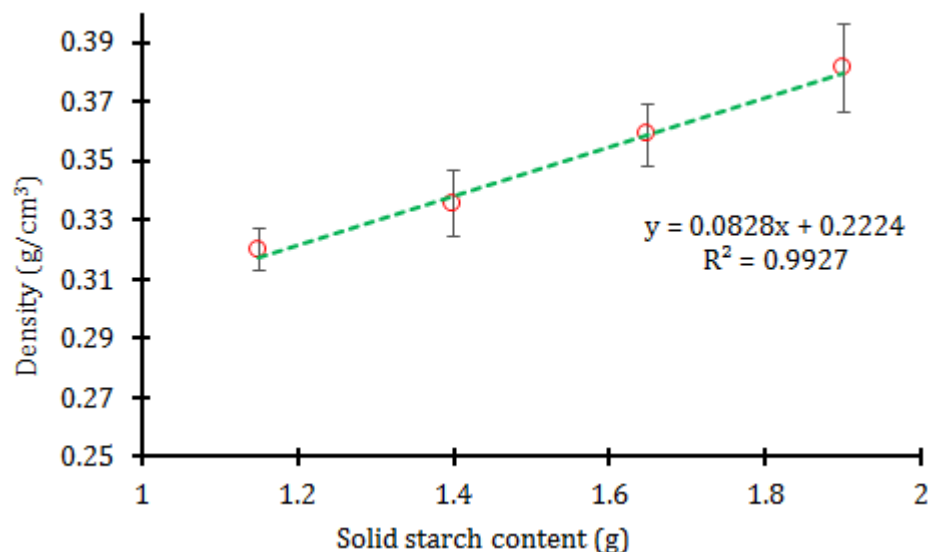


Figure 3 Density as a function of solid starch content. Error bar indicates standard deviations.

### 3. Results and discussion

The variation of density with solid starch content in the gelatinized binder solution is given in the Figure 3. As expected, the density increased with increasing solid starch content linearly with a least square line  $y = 82.79x + 222.42$  and correlation coefficient  $R^2 = 0.9927$ . The high linearity can be understood from the high correlation coefficient. The compressive properties of the Saw dust composites with solid starch content are listed in Table 2.

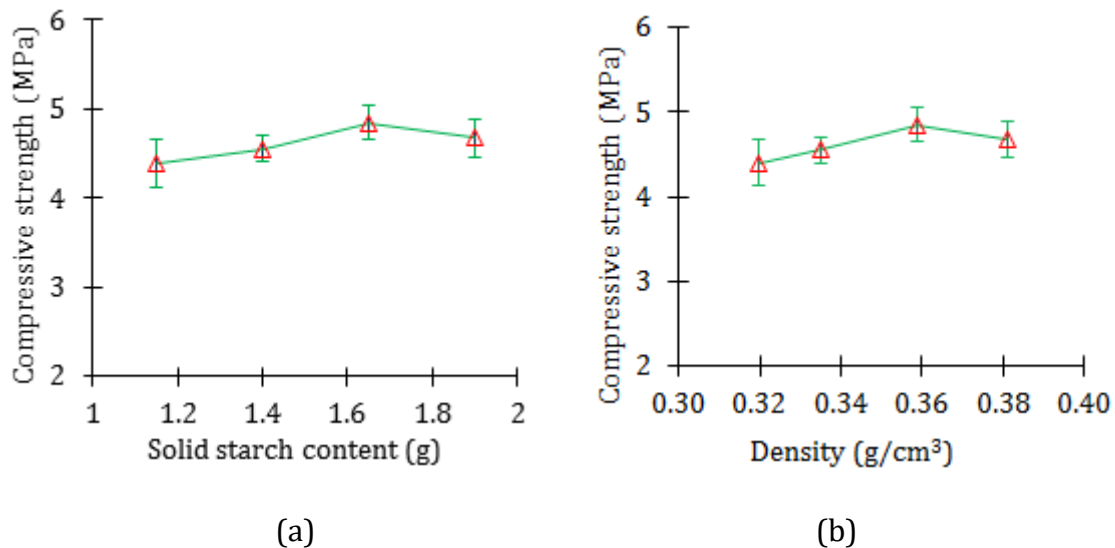


Figure 4 Compressive strength as a function of (a) solid starch content and (b) density. Error bar indicates standard deviation.

The compressive strength increased with increasing solid starch content up until the solid starch content 1.65, while for 1.90 g solid starch shows a decrease in compressive strength [see Figure 4(a)]. Similar nature can also be seen when compressive strength is plotted as a function of density because the density and the solid starch content are related linearly as seen in Figure 3. Compressive modulus is plotted as a function of solid starch content and density in Figure 5. It is seen that compressive modulus also increased with increasing both solid starch content and density linearly giving a high value of correlation coefficient as shown in Figures 5 (a) and (b) respectively. The specific properties are very important for comparison between various composite materials and therefore specific compressive strength and modulus of the manufactured saw dust composites are plotted in Figure 6 as a function of density.

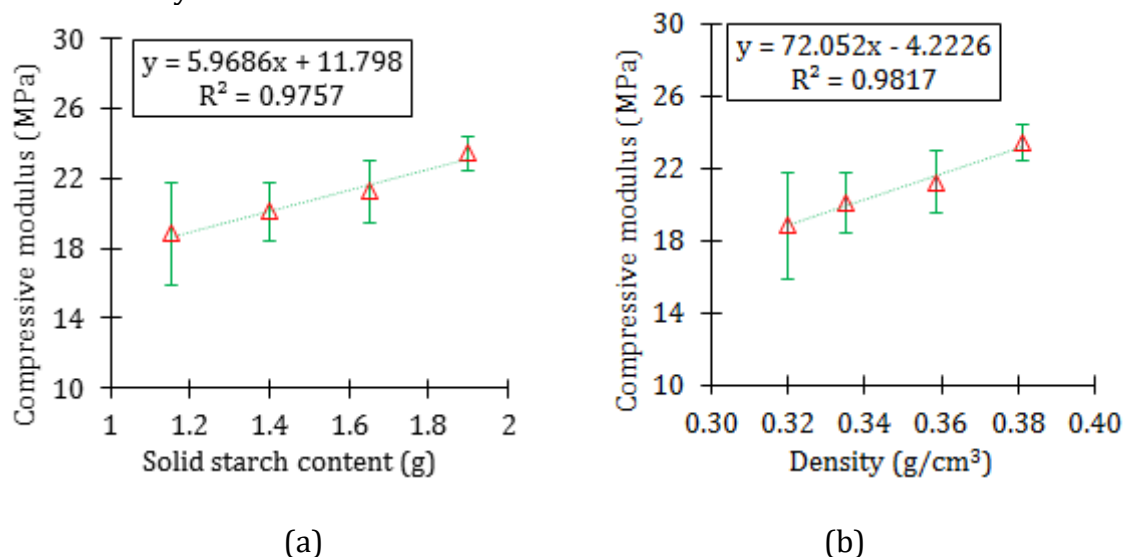


Figure 5 Compressive modulus as a function of (a) solid starch content and (b) density.

It is seen that the sp. compressive strength decreased with increasing density however an abrupt drop in sp. compressive strength is noticed when density increased from 358.62 to 381.00 kg/m<sup>3</sup>. On the other hand sp. compressive modulus increases with increasing density although for a density of 0.36 g/cm<sup>3</sup>, it shows an anomaly. Maci et al., 2016 has reported mixed wood and *Posidonia* PU composites of various combination of constituents and composites showed a sp. compressive strength range from 2.42 to 8.51 MPa/(g/cm<sup>3</sup>) while this work shows a range of 12.26 to 13.73 MPa/(g/cm<sup>3</sup>) which is well above the reported composites. This indicates that the novel composites developed in this work using saw dust, sodium silicate solution and gelatinized corn starch has practical applications.

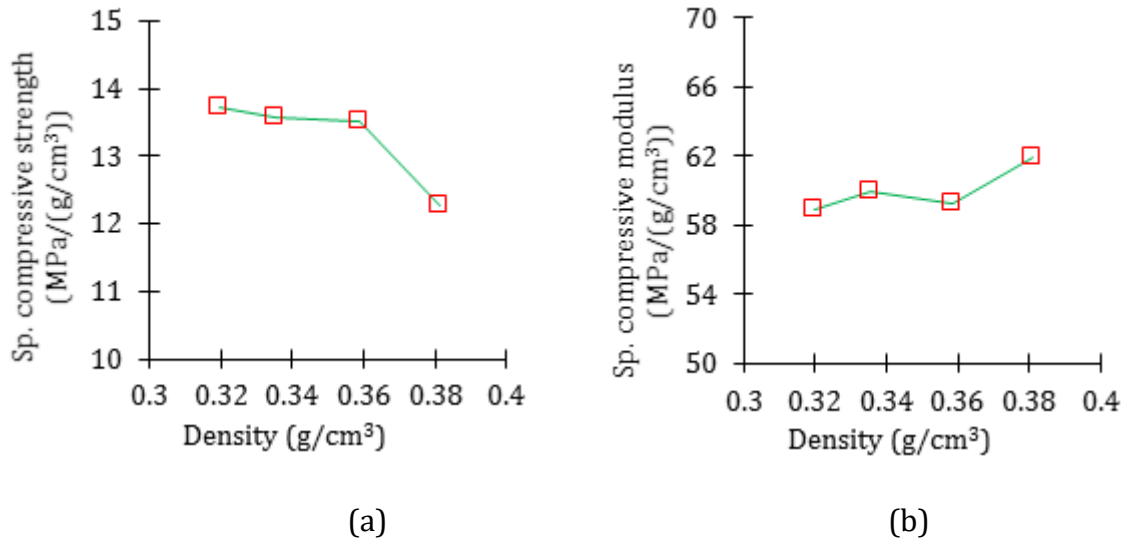


Figure 6 Specific compressive (a) strength and (b) modulus as a function of density.

#### 4. Conclusions

In this study, Novel saw dust composites were manufactured using gelatinized corn starch and sodium silicate solution as binder and their physical and mechanical behavior were investigated. The density, compressive strength and modulus increased with increasing solid starch content in the composite. Specific compressive strength decreased with increasing density of the composite but specific compressive modulus showed the opposite trend. Specific compressive strength was found to be superior when compared with other saw dust composites reported in the literature. The novel saw dust composites developed in this work has a good potential in the construction and building industries.

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