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Effects of Silica Clay on Thermo-Physical Properties of Iroko Sawdust Cement Board

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ABSTRACT

This work investigates the effects of silica clay on the thermo-physical properties of Iroko sawdust cement board. The properties investigated were thermal conductivity, thermal resistivity, water absorption, percentage shrinkage, density, modulus of rupture and compressive strength. Ten samples, labeled A to J, of Iroko sawdust with varying percentage of silica clay using 15% (by mass) cement as binder were cast into a wooden-mould (150mm^2) to form particle boards. A Lee's disc apparatus was used to determine the thermal conductivity while tensometer apparatus and a digital weighing balance were used to determine the compressive strength and density respectively. The result shows that a sample with 45% of clay, 15% cement and 40% sawdust tagged sample J has the highest value of thermal resistivity, compressive strength, percentage shrinkage, modulus of rupture and density with numerical values of 3.1027W/mk, 1.389MN/m^2, 4%, 1.017MN/m^2, and 0.425kg/m^3 respectively. The sample with 0% clay, 15% cement and 85% sawdust tagged sample 'A' has the highest thermal conductivity and percentage water absorption value of 0.4923W/mk and 68.75% respectively. As the silica clay content of each sample increases, its thermal resistivity, percentage shrinkage, density, modulus of rupture and compressive strength values increases while its water absorption and thermal conductivity decreases.

Keywords: *Silica clay, iroko sawdust, thermal conductivity.*

1. INTRODUCTION

Wood is one of the most widely used engineering materials. It is used in construction of houses, as a fuel, as an insulator, and can be processed into plywood, particle board, paper, etc. Sawdust is a small discontinuous chips or small fragments of wood produced during sawing of logs of timber into marketable sizes. The chips flow from the cutting edges of the saw blade to the floor of the environment during sawing operation, hence its name. It is an agricultural waste product that has a variety of practical uses like in making particle, in production of biogas, packaging filler etc [1,2,3,4].

Sawdust has hitherto been classified as a waste and a nuisance to man and his environment, but in recent years, a lot of researches have been carried out on the properties, uses, and applications of sawdust. Ogunleye and Awogbemi, researched into the thermo-physical properties of eight varieties of sawdust and determined their thermal conductivity, specific gravity, specific heat capacity, and density [2]. Also, Adekimi worked on the use of sawdust in energy generation and manufacturing industries [5]. A lot of researches have been carried out on the use of sawdust seeded with other biological waste to generate biogas. In a research works where obeche wood (Triplochiton Scleroxylon) was mixed with poultry drop and cassava peels to generate biogas, it was reported that the wood accelerated biogas yield [6].

It has also been discovered that some additives like cement, silical sand, latent clay can be added to sawdust to further improve its properties and widen its applications. Adeyemi, S.O [8] investigated the effects additives on sawdust cement boards while Ogunleye [7] in his research titled additives effects of cement and silica clay on the thermo-physical properties of sawdust and reported that an increase in clay content resulted in an increase of specific gravity, the thermal conductivity but a reduction in the specific heat capacity. It has since be discovered that waste material such as coconut husks, rice haul, wood chips, sawmill shaving, or even sawdust can be used along side with suitable binder (cement) and additives e.g clay to manufacture particle cement board [9, 10].

This present research, however, is aimed at investigating the effect of silica clay on the thermo-physical properties of Iroko sawdust cement board.

2. MATERIALS AND METHODOLOGY

The Iroko sawdust specimen was collected from one of the saw-mill in Ikole Ekiti while the silica clay specimen was collected from Ire Ekiti, in Ekiti state, Nigeria. The sawdust and silica clay collected were sun-dried to about 5.0% moisture content. The sundried silica clay, sawdust with cement as a binder were weighed according to the percentage ratio specified below and were thoroughly mixed in large pan manually using hand stirrer after which water (10% by mass) was added and the mixture casted into a mould of 150mm square by 12.7mm (one inch). Before the mixing, the sun-dried silica clay was sieved through a 500μm sieve mesh while the sun-dried sawdust was sieved through a 1000μm sieve mesh. The tests carried out were thermal conductivity, thermal resistivity, water absorption, density, percentage shrinkage, modulus of rupture, and compression test.

Table 1: Composition of Various Samples

Samples	% by mass of clay	% by mass of cement	% by mass of sawdust
A	0	15	85
B	5	15	80
C	10	15	75
D	15	15	70
E	20	15	65
F	25	15	60
G	30	15	55
H	35	15	50
I	40	15	45
J	45	15	40

Ten samples of Iroko sawdust cement board of different ratio as stated above were casted after which they were air-cured by leaving the boards in the free air for a period of 28days in an empty room before test was carried out on them.

i. Thermal Conductivity

Lee's disc apparatus which consists of steam flask, brass plate, thermometers (T_1 & T_2), stop watch and rubber hose was used for this experiment. The Lee's disc apparatus was suspended on a tripod stand wit h the flat surface of the disc horizontal. Steam was passed through the cylinder and the temperature indicated by the two thermometers T_1 and T_2 were read at interval of five minutes (300s) and recorded until the temperature of T_1 and T_2 are steady. Their steady temperature was also recorded.
After the temperature has been steady, heat was removed from the system. The temperature of the samples were taken at 30seconds one after the other.
When the steady state has been attained, the rate at which heat is conducted across the circular Iroko sawdust cement board inside the hollow disc is equal to the rate at which it is emitted from the exposed surface of the brass plate.
Then, the rate at which heat is conducted across the Iroko sawdust cement board is given as;

$$\text{Rate of heat conduction} = \frac{-K(\pi D^2)(\theta_1-\theta_2)}{4d} \qquad (1)$$

The rate of loss of heat from the lower surface and sides of the brass plate is given as;

$$\text{Rate of heat loss} = MC\left({}^{d\theta}\!/_{dt}\right) \qquad (2)$$

Hence, from equating (i) and (ii) we have

$$\frac{-K(\pi D^2)(\theta_1-\theta_2)}{4d} = MC\left({}^{d\theta}\!/_{dt}\right)$$

$$K = \frac{-4dMC\left({}^{d\theta}\!/_{dt}\right)}{\pi D^2(\theta_1-\theta_2)} \qquad (3)$$

ii. Thermal Resistivity

Thermal resistivity is the reciprocal of thermal conductivity. The reciprocal of the thermal conductivity of each of the Iroko sawdust cement board was evaluated and recorded using the equation;

$$R = {}^{1}\!/_{K} \qquad (4)$$

iii. Water Absorption

A portion of each board was taken and weighed in air and weighed when saturated with water and the corresponding masses were taken and recorded. The formula below gives the needed relationship; $W_a = \frac{M_2 - M_1}{M_2} \times 100$ (5)

iv. Density

A direct method of weighing and linear dimensional measurement was used in finding the density of each board produced. The mass of each cement board was accurately determined by using a weigh balance of capacity 1000g. The average length, breadth and thickness of cement boards were obtained using hand rule measurement to determine the volume of each cement board.

The density of each board was evaluated from the expression:

$$Density\ "W" = \frac{m}{v} = \frac{m}{l \times b \times t} \qquad (6)$$

v. Percentage Shrinkage

The lengths and breadth of the casted square cement boards were measured initially and again after 28days of curing. The average values of the percentage shrinkage for all the prepared cement board were determined by equations given below;

% shrinkage in length $= \frac{L_0 - L_1}{L_0} \times 100$ (7)

Percentage shrinkage in breadth $= \frac{B_0 - B_1}{B_0} \times 100$ (8)

vi. Modulus Of Rupture

The apparatus used include test rig, hanger, dial indicator, and a loop of cord. The cement board specimens were mounted centrally over the steel angle sections of the static bending test rig with constant span of 170mm. static central loading of the board specimen was carried out by using a loop of cord, hanger and known weights. The central deflection readings corresponding to the various applied loads were obtained by means off a dial gauge indicator, which was supported via the retort stand and a suitable clamp on the specimen. The deflection readings corresponding to the various applied loads were monitored, until the specimen was fractured. The maximum applied loads at fracture for all the cement boards were determined and recorded to obtain their modulus of rupture. The moduli of rupture, R_u, for various produced sawdust cement boards were determined, using the equation below.

$$R_u = \frac{3PL}{2bt^2} \quad (9)$$

vii. Compression Test T

The apparatus used include the Tensometer, precision, light compression attachments, drum, pointer and mercury indicator. Standard test specimens of size 50mm square in dimension were cut from the sawdust cement boards produced and used to determine the maximum compressive loads applied to the test specimens to fracture with the aid of a Monsanto Tensometer machine plus its accessories. The maximum load on each specimen before crushing was recorded and used to determine the maximum compressive strength, σ_c, given by the equation below.

$$\sigma_c = \frac{P_c}{bt} \quad (10)$$

3. RESULTS AND DISCUSSION

i. Thermal Conductivity

The thermal conductivity of the samples is shown in table 2. Sample A with 85% sawdust, 15% cement and 0% clay has the highest thermal conductivity of 0.4923W/mk while the sample J with 40% sawdust, 15% cement and 45% clay has the lowest thermal conductivity of 0.3223W/mk. This shows that an increase in the quantity of clay coupled with a decrease in the quantity of sawdust result in decrease in the thermal conductivity as shown in Figure 1.

Table 2: Thermal Conductivity of Samples

Samples	dθ/dt (k/s)	K (W/mk)
A	-0.02077	0.4923
B	-0.01788	0.4662
C	-0.0172	0.4473
D	-0.0153	0.4199
E	-0.0136	0.4052
F	-0.0126	0.3982
G	-0.0106	0.3685
H	-0.0122	0.3534
I	-0.0111	0. 3355
J	-0.0106	0.3223

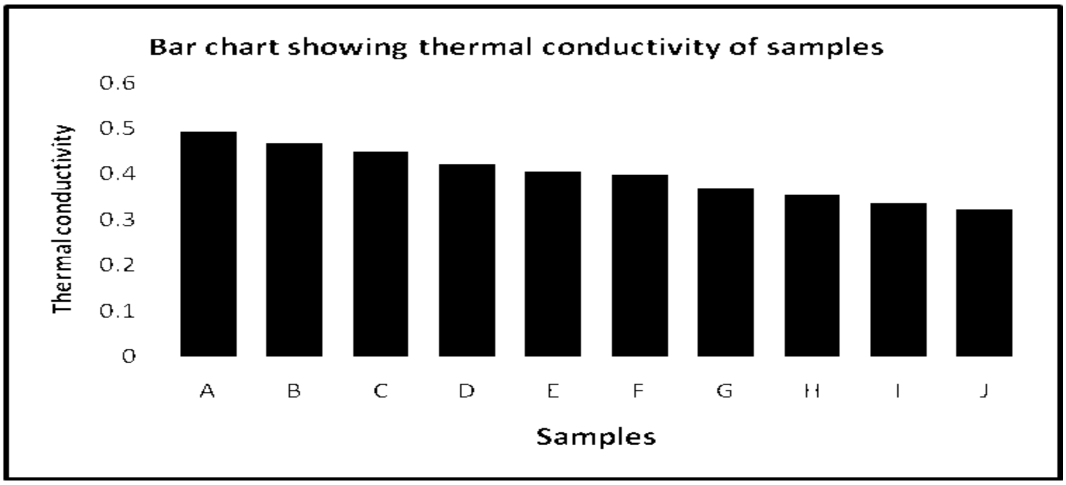

Figure 1: Bar Chart Showing Thermal Conductivity of Samples

ii. Thermal Resistivity

Table 3 gives the summary of the thermal resistivity of the samples. Sample A with the lowest percentage of clay and highest percentage of sawdust has the lowest value of thermal resistivity of 2.0313W/mk while sample J with the highest percentage of clay and lowest percentage of sawdust has the highest value of 3.1027W/mk. This shows that thermal resistivity increases with an increase in the percentage of clay and an increase in the percentage of sawdust while keeping the percentage of cement constant. This is further shown in figure 2.

Table 3: Thermal Resistivity of Samples

Sample	r (W/mk)
A	2.0313
B	2.1450
C	2.2356
D	2.3815
E	2.4679
F	2.5113
G	2.7137
H	2.8297
I	2.9806
J	3.1027

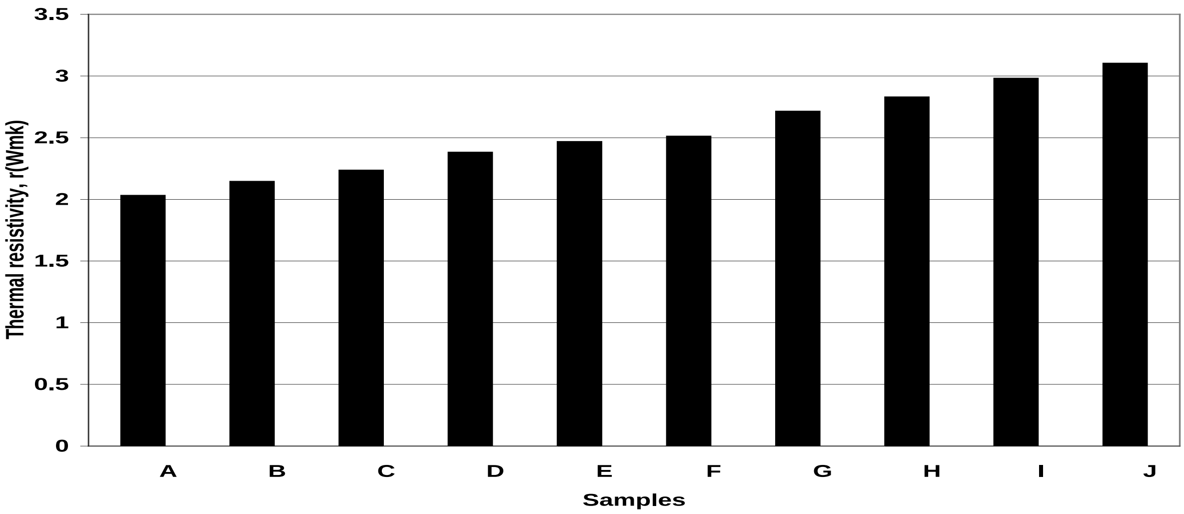

Figure 2: Bar chart showing thermal resistivity of samples.

iii. Water Absorption

From Table 4 and Figure 3, the percentage of water absorption decrease from sample A to J in that order. This implies that an increase in the percentage of clay together with a decrease in the percentage of sawdust at constant percentage of cement cause a decrease in the water absorption capacity of the samples.

Table 4: Percentage Water Absorption of Samples

Samples	M_1(g)	M_2 (g)	water absorption (%)
A	20.00	64.00	68.75
B	20.00	63.00	68.25
C	20.00	60.00	66.67
D	20.00	58.50	65.81
E	20.00	55.50	63.96
F	20.00	54.00	62.96.
G	20.00	52.00	61.54
H	20.00	47.00	57.45
I	20.00	45.50	56.04
J	20.00	44.50	55.06

iv. Density

The length, breadth and thickness of the samples used for the density of the samples were 50mm, 50mm, and 12.7mm respectively. Table 5 and Figure 4 show that the density of the samples increases from sample A to J in that order.

Table 5: Density of Samples.

Samples	Density (kg/m^3)
A	0.189
B	0.205
C	0.220
D	0.236
E	0.252
F	0.283
G	0.315
H	0.362
I	0.394
J	0.425

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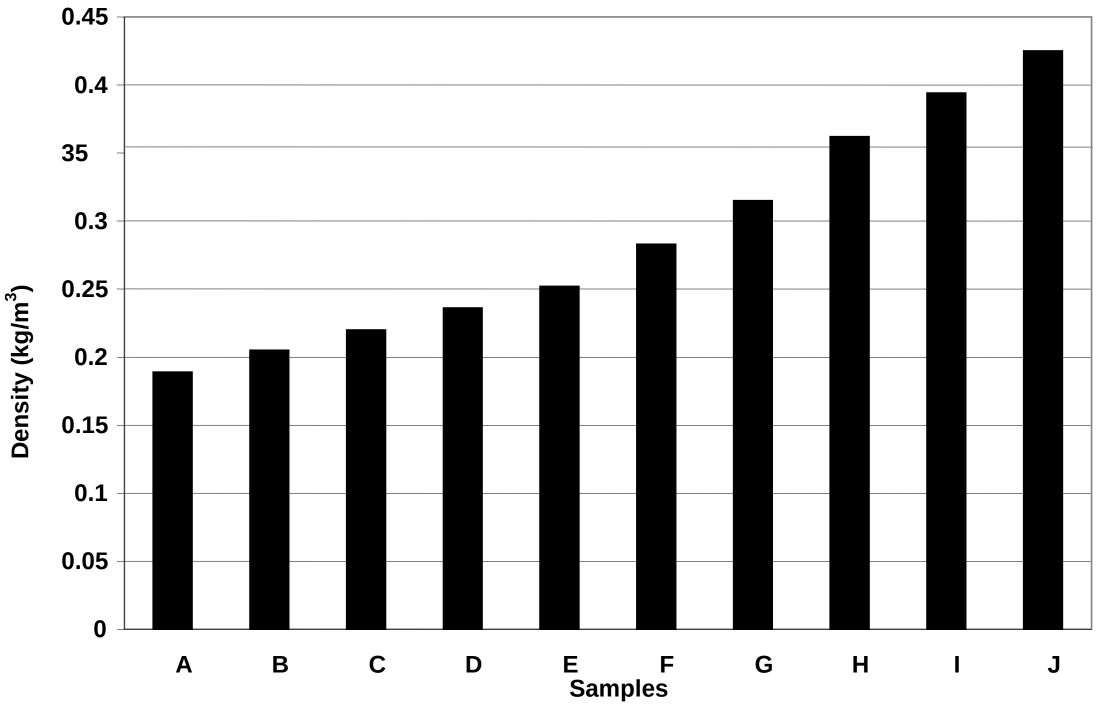

Figure 4: Bar chart showing Density (kg/m^3)

v. Percentage Shrinkage

The value of the percentage shrinkage on length and breadth of the squared sawdust cement boards produced, ranges from 4% to 0.67%. The least percentage shrinkage occurred on the sample with 0% clay whilst the sample with 45% clay has the highest

Table 6: Percentage Shrinkage of Samples

Samples	L_0 (mm)	L_1 (mm)	Percentage shrinkage (%)
A	149	150	0.67
C	148	150	1.33
E	147	150	2.00
G	146	150	2.67
I	144	150	4.00

vi. Modulus Of Rupture

For this test, only five samples were used i.e samples A, C, E, G, and J. After the test, it was discovered that sample with 0% silica clay, 15% cement and 85% sawdust has the lowest modulus of rupture of 0.213MN/m^2, while sample J with 40% silica clay, 15% cement and 45% sawdust has the highest modulus of rupture of 1.017MN/m^2 as shown in table 7 and figure 6.

Table 7: Modulus of Rupture of Samples

Samples	Load L (kg)	Weight of fracture P(N)	Modulus of rupture R (MN/m^2)
A	1.21	12.1	0.213
C	2.54	25.4	0.446
E	3.16	31.6	0.555
G	3.95	39.5	0.694
J	5.79	57.9	1.017

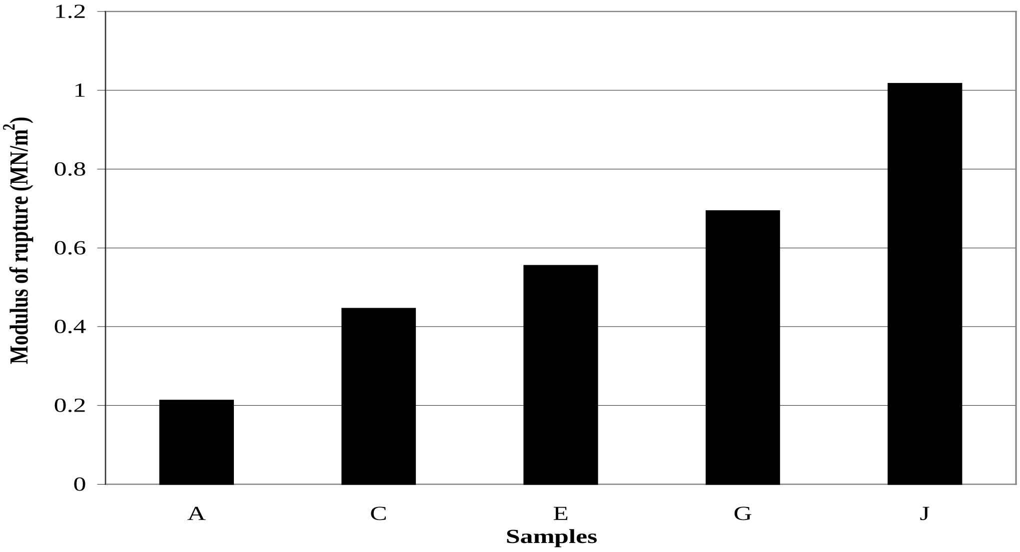

Figure 6: Bar chart showing Modulus of Rupture of Samples

vii. Compressive strength

The compressive strength of the cement board samples varies from 0.372MN/m^2 to 1.389MN/m^2, with sample A having the least and sample J having the highest as shown in table 8 and figure 7.

Table 8: Compressive Strength of Samples

Samples	Load L (kg)	Compressive Load P_c (N)	Compressive strength σ_c (MN/m^2)
A	23.598	235.98	0.372
C	44.148	441.48	0.695
E	63.348	633.48	0.998
G	81.798	817.98	1.288
J	88.198	881.98	1.389

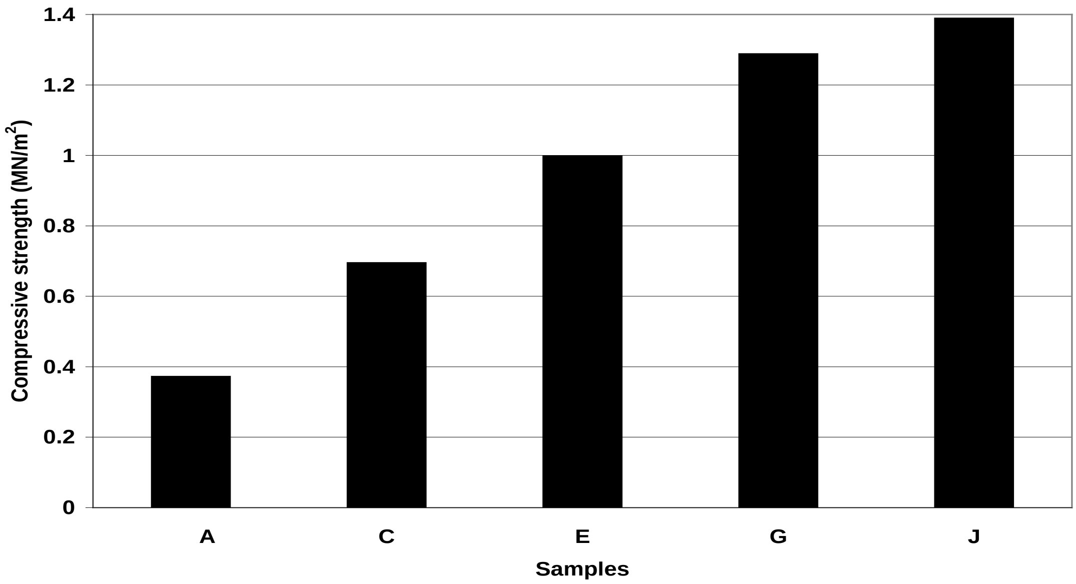

Figure 7 : Bar chart showing Compressive strength σ_c (MN/m^2)

4. CONCLUSION

Sawdust, hitherto regarded as waste, can serve as raw material for the industry in the production of particle board when mixed with some additives. This research work clearly shows that silica clay can be added to Iroko sawdust to vary or alter its thermo-physical properties. The thermal resistivity, compressive strength, percentage shrinkage, modulus of rupture and density of particle board, made from silica clay and Iroko sawdust with cement as hardener, increase with an increase in the percentage of silica clay content. On the other hand, the thermal conductivity and water absorption decrease with an increase in the silica clay content. Particle boards made from Iroko sawdust with 40% silica clay is a good insulating material and for table tops because of its low thermal conductivity and high strength respectively.

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NOMENCLATURE

K = Thermal conductivity, W/mk
D = diameter, mm
d = thickness, mm
θ_1, θ_2 = temperature, ^{0}C
C = specific heat capacity
$d\theta/dt$ = cooling rate, k/s
R = thermal resistivity
W_a = percentage of water absorption, %
M_1 = mass of cement board before saturation, g
M_2 = mass of saturated cement board sample, g
v = volume of sample, mm^3
l = length of sample, mm
b = breadth of sample, mm
t = thickness of sample, mm
m = mass of sample, g
Lo, Li = initial and final length of the board, mm
Bo, Bi = initial and final breadth of the board, mm
P = weight of fracture, N
Ru = modulus of rupture, MN/m^2
σ_c = compressive strength, MN/m^2
P_c = maximum compressive load, N
w = density, kg/m^3