Physical and Mechanical Characteristics of the Panel Made of Waste Textile Fibres

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***Abstract*— In order to produce the panels from waste textile fibres, six types of fibres were collected from textile mills. The fibres used in this research work were PP, PET, PAN, cotton, wool as well as fibreglass. To make the panel, it is necessary to produce an oriented layer of perfectly blended fibres with certain portion of each fibre. The blended fibres, then, put in a special mould, designed and manufactured for this purpose, and was pressed under a hot presser for certain period and pressures to produce different panels. The physical and mechanical properties of the panels were, then, measured and compared with used conventional panels. The results showed that some of our panels have remarkable characteristics in comparison with conventional panels, whereas their cost is about third of them.**

***Keywords*— waste fibres, panels, physical and mechanical properties**

I. Introduction

Using the waste textile fibres, as the raw material, in the textile mills is not possible. Since, it causes the quality of the products to decrease. Therefore, it is essential to use in other industries with higher benefit.

One of these industries is the composite, spreading and extending in the various branches increasingly. The composite parts have unique characteristics and are used in different industries such as building, car, aircraft, aerospace, military, etc. However, manufacturing the composites is not limited to waste textile fibres, as the extent of such waste fibres is not adequate for these applications. Also the crucial and vital application of the composites in some important industries such as aerospace and military industries needs specific fibres having high technical performance. Although we use the waste textile fibres to produce the composites which can be replaced the conventional panels used in making fibreboard, particleboard, HDF, and the similar products.

In this work we investigated the influence of parameters affecting the characteristics of the panels and they are compared with common commercial panel.

II. Materials and Methods

After a survey in connection with the amount of textile wastes fibres in the local mills(Province of Yazd, Iran), the possibility of using these fibres in producing panel(composite) were studied. Then different fibres like cotton, wool, PET, acrylic and fibreglass PP, were provided and blended with PP in various portions from zero to 100%. The homogenised blends of the fibres were formed as layers with different thickness(gm/m^2) using a simple tool(handy brush). The layers were placed inside a laboratory mould, which was designed and manufactured for this research work. The mould containing blend of fibres was put under pressure for a while. To melt the PP component of the blend, the upper and lower plates of the mould were equipped with heating element coils. The temperature of the plates can be adjusted and controlled by a special thermostat. In addition to the temperature, the extent of pressure and the period of pressure applied on the layers are other parameters in producing the panels. Fig. 1 displays the mould attached to body of the press machine. The mould consists of a cylinder and piston made of special steel.

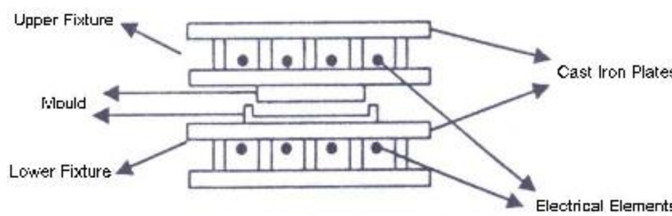

Fig. 1: The parts of mould attached to the press machine

After the heat melted the PP fibres in the blends, it sticks the non-melting component fibres (such as cotton, wool, acrylic, fibreglass, etc.) in the blend and reinforces the layer. The thickness of the layer under pressure and temperature decreases and becomes stiff and strong similar to the panel when it is removed from mould.

The parameters affecting these properties are considered in analysing the results. The parameters are pressure, the portion of each fibre in the bi-component blends, temperature, the period of pressing the layer, etc. It should be mentioned that several samples were produced to determine the proper conditions of temperature, pressing time, pressure, etc. According to the primarily trials, we found out the temperature of 185 Celsius degree is suitable to melt the PP fibres and produce the panel. This temperature was used in producing all the samples during this work.

Another parameter was the extent of the pressure applied on the layer. The pressure plays a vital role in producing the panels. If insufficient pressure is applied on the layer, the molten component fibres (PP) will not be spread evenly and the layer will not be strengthened. The results suggest that the amount of pressure should be about 850kg/m^2.

Pressing time is other factor, which makes the panels homogenised. If the period of applying pressure is less than the required time, the molten component fibres cannot be spread evenly between the non-melting component fibres. If this time

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exceeds from required time, it will damage the non-melting component fibres and the strength of the panels will decrease. The trial results showed that this period should be about 4 minutes.

Following producing the panels, they were marked with codes indicating their characteristics. The information can be seen from the code includes the non-melting component fibres and its portion in the blend (as PP fibres exist in the blends) as well as a number specifying the thickness of the panel. For instance, 15FG4 is a panel made of 15% fibreglass and 85% PP fibres with 4mm thick. In this work 3o panels were produced and 4 panels were purchased from the market. They have been marked as listed in Table 1.

TABLE I: THE PANELS PRODUCED OR PURCHASED

No.	code	No.	code	No.	code	No.	code	No.	code	No.	code
1	5FG4	7	15FG4	13	10PET4	19	20AC4	25	10C4	31	H4
2	5FG5	8	15FG5	14	10PET5	20	20AC5	26	10C5	32	T4
3	10FG4	9	20FG4	15	20PET4	21	10W4	27	20C4	33	F4
4	10FG5	10	20FG5	16	20PET5	22	10W5	28	20C5	34	P5
5	10FG6	11	30FG4	17	10AC4	23	20W4	29	100PP4		
6	15FG7	12	30FG5	18	10AC5	24	20W5	30	100PP5		

The panels No.31-34, purchased from the market, are as follows:
H4: is a panel made of wood and a special polymer resin with 4mm thick
T4: is 3-layer wooden panel with 4mm thick
F4: Fibre-wood with 4mm thick
P5: Panel made of the particleboard with 5mm thick

III. EXPERIMENTAL

Once, the samples were produced, various tests were made according to ASTM and ISO to determine the physical and mechanical properties of the panels. These tests are density of the panel, moisture regain, absorbed water, force-elongation strength and resistance against impact. However, there are many other tests that can be made on the panels.

IV. RESULTS AND DISCUSSIONS

Then the physical and mechanical properties of the panels were investigated. In this section the results are illustrated and discussed.

V. AREA DENSITY PROPERTY

The panels were cut in dimensions of 10cm×10cm and then were weighed. Then the weight was divided by area of the samples. Table 2 shows the results of this test.

TABLE II: THE AREA DENSITY OF THE PANELS PRODUCED OR PURCHASED

No.	Code	Kg/m^2	No.	Code	Kg/m^2	No.	Code	Kg/m^2
1	5FG4	2.85	13	10PET4	2.95	25	10C4	3.02
2	5FG5	2.89	14	10PET5	3.15	26	10C5	3.12
3	10FG4	3.05	15	20PET4	3.07	27	20C4	3.16
4	10FG5	3.15	16	20PET5	3.25	28	20C5	3.27
5	10FG6	3.29	17	10AC4	2.79	29	100PP4	2.75
6	10FG7	3.31	18	10AC5	2.85	30	100PP5	2.92
7	15FG4	3.19	19	20AC4	2.9	31	H4	3.3
8	15FG5	3.26	20	20AC5	3.05	32	T4	2.2
9	20FG4	3.22	21	10W4	2.93	33	F4	3.6
10	20FG5	3.31	22	10W5	3.13	34	P5	3.8
11	30FG4	3.42	23	20W4	3.04			
12	30FG5	3.49	24	20W5	2.59			

As can be seen from Table 2, due to lower density of PP fibres in comparison with other fibres, the panels made of PP and other fibres blend, have higher area density compared with panels made from 100% PP fibres. However other parameters such as the applied pressure influence the density of the panels. The results, also indicates the panels made from waste fibres have lower density in comparison with common panels existing in the market.

VI. ABSORBED WATER

One of tests to evaluate the performance of the produced panels, is the amount of the water absorbed by the panels. The water absorbency causes the panels to inflate. In order to determine the amount of the water absorbed by the panels, we cut the panels in dimensions of 304mm×304mm or 152mm×152mm and then sank them in the water for 24 hours. The thickness of the samples, which had been kept at standard conditions, was measured before and after sinking in the water. The measurement was made at four different points. Then the following relationships were used to calculate the increase of thickness and the amount water absorbed by the panels.

$$\Delta t = \frac{T_w - T_i}{T_i} \times 100 \tag{1}$$

Where:
Δt : is the thickness variation of the panel due to sinking in the water
T_i: is initial thickness of the panel, and
T_w: is thickness of the panel after being sunk for 24 hours
To calculate the amount of water absorbed by the panels, Eqn. 2 can be used:

$$\Delta W = \frac{W_w - W_i}{W_i} \times 100 \tag{2}$$

where:
ΔW : is the amount of water absorbed by the panel due to sinking in the water,
W_i: is initial weight of the panel,
W_w: is the weight of the panel after being sunk for 24 hours

The above calculations and measurements are important especially for the panels used in the kitchen and the places have high moisture and humidity.

The amount of water absorbed by the 34 panels was measured after 2, 6, 12 and 24 hours. The results showed that the panels containing cotton and wool have absorbed a small amount of water(0.1-0.2 percent) compared with the panels made from fiberboard and particleboard(9-41 percent) which can be ignored. The amount of water absorbed by other panels is zero and, thus, can call them waterproof.

VII. Tensile Modulus Strength And Of Elasticity

$$\varepsilon = \frac{l_f - l_i}{l_{ii}} \times 100 \qquad (3)$$

where:
ε: is the strain of the panel
l_i: initial length of the panel, and
l_f: the length of the panel when breaking
To calculate the amount of stress(δ), we can use Eqn. 4:

$$\delta = \frac{F}{bl} \qquad (4)$$

where:
F is the maximum force applied to break the panel, and
bl: is the section area of the panel.

Table 3 indicates the tensile stress and the strain of the panels at breaking point.

As can be observed from Table 3, using the reinforcing fibres in producing the panels increases their tensile strength. It also can find out that the component reinforcing fibres of acrylic, PET, wool, cotton and fibreglass play an important role, respectively, in this connection. For panels made of PP and fibreglass, the results suggest that the increase of fibreglass in the blend would increase the tensile strength of the panels; however the thickness of the panels cannot be ignored. In this research work, the panels made from the blend with portion of 20/80(FG/PP) have the maximum tensile strength. The results show the panels made of waste textile fibres have significantly higher tensile strength compared with the fibreboard and particleboard panels. Although, the strength of our panels is similar to the strength of H4 and T4 panels.

Another comparison can be made in connection with the panels' strain in the break point. As can be observed from Table 3, some of produced panels have low amount similar to conventional panels but most of them have higher strain compared with conventional panels.

TABLE III: THE STRESS AND STRAIN OF THE PANELS WHEN RAPTURED

No.	Code	δ (kN/m^2)	ε%	No.	Code	δ (kN/m^2)	ε%
1	5FG4	1951	10	18	10AC5	2888	29
2	5FG5	2000	11	19	20AC4	2916	25
3	10FG4	2045	8	20	20AC5	3000	27
4	10FG5	2045	8	21	10W4	2500	14
5	10FG6	2200	8	22	10W5	2727	12
6	10FG7	2407	9	23	20W4	2692	8
7	15FG4	2545	7	24	20W5	2745	9
8	15FG5	2500	7	25	10C4	2653	22
9	20FG4	2553	6	26	10C5	2777	23
10	20FG5	2545	7	27	20C4	2448	16
11	30FG4	2500	4	28	20C5	2553	17
12	30FG5	2558	4	29	100PP4	2037	43
13	10PET4	2608	32	30	100PP5	2264	42
14	10PET5	2727	34	31	H4	2682	9
15	20PET4	2909	23	32	T4	2444	6
16	20PET5	3148	25	33	F4	869	5
17	10AC4	2800	27	34	P5	250	4

VIII. Resitance Against Impact Of The Panels (Hardness)

Another characterisation of the panels is their resistance against strike and impact, which can be carried out by hardness test. The conventional panels are damaged when they are subjected to a moderate strike, whereas the panels made of the fibres showed a good resistance against the strike applied by Janka Ball.

The principle of the measurement and calculation is so simple. Fig. 2, shows the schematic pendulum model used to measure the hardness index of the panels.

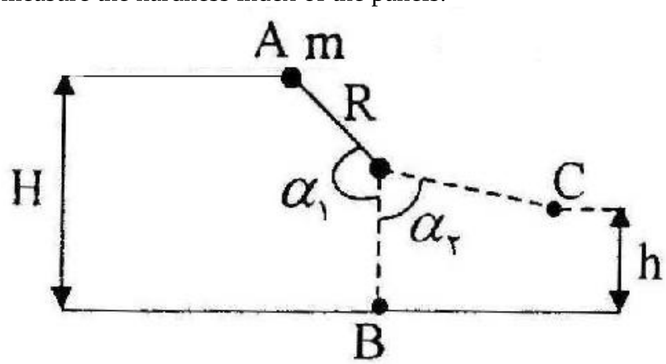

Fig. 2- The schematic pendulum used to measure the hardness of panels

It is assumed that the weight of the pendulum starts dropping from point A. then it breaks the panel at point B and moves up to point C. the velocity of the pendulum at points A and C are zero. According to energy conservation law, the total mechanical energy of a system is constant. If the friction is ignored in this system, we can write the following equations regarding Fig. 2:

$$E_A = E_C + E_Y \qquad (5)$$

$$E_A = mgH = mgR[1 + \sin(\alpha_1 - 90)] \quad (6)$$

$$E_C = mgh = mgR(1 - \cos\alpha_2) \quad (7)$$

$$E_Y = E_A - E_C \quad (8)$$

where E_Y is required energy to break the panel, and is determined by *Kcu* which is calculated from Eqn. 9:

$$Kcu = \frac{E_Y}{A} \quad (9)$$

where *A* is the area of the panel.

The test was made for all the panels and their hardness index(*Kcu*) were measured, as can be observed from Table 4:

TABLE IV: THE HARDNESS INDEX(Kcu) OF THE PANELS

No.	Code	Kcu(J/cm^2)	No.	Code	Kcu(J/cm^2)
1	5FG4	3.83	18	10AC5	4.00
2	5FG5	3.93	19	20AC4	3.95
3	10FG4	3.86	20	20AC5	4.20
4	10FG5	3.96	21	10W4	3.70
5	10FG6	4.15	22	10W5	3.86
6	10FG7	4.53	23	20W4	3.90
7	15FG4	4.93	24	20W5	3.96
8	15FG5	4.05	25	10C4	3.86
9	20FG4	3.86	26	10C5	3.90
10	20FG5	4.00	27	20C4	3.88
11	30FG4	3.88	28	20C5	3.98
12	30FG5	3.98	29	100PP4	2.75
13	10PET4	4.40	30	100PP5	2.90
14	10PET5	4.80	31	H4	4.25
15	20PET4	4.92	32	T4	3.60
16	20PET5	5.20	33	F4	3.85
17	10AC4	3.90	34	P5	2.25

The results suggest only the resistance of panel Hdf, which have polymeric structure, can be compared with the panels produced from waste fibres. However, the panels made of PET/PP fibres have higher resistance against impact in comparison with Hdf panels.

The results also show the portion of FG in the blend FG/PP up to 30% increases the hardness of the panels made of FG/PP. The higher portion of FG in the blend, over 30%, will decrease the hardness of these panels.

A general comparison indicates that the hardness index of the panels made of waste fibres are as follows:

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A general comparison indicates that the hardness index of the panels made of waste fibres are as follows:

PET/PP>AC/PP>FG/PP>C/PP>W/PP

IX. Pull Out Force Of Screw And Peg From The Panels

We also measured the screw and peg holding force from the panels at different directions, according to D1037 and ASTM1994a. The results indicate our panels have higher strength compared with the existing panels used for doors. The impotence of this measurement would be more obvious when we consider the looseness of the screws in the panels specially in the pivot of the doors, etc.

X. Economic Features Of Panel Production

In the meantime an economic assessment was made to estimate the cost of the panels from waste textile fibres. The costs calculation showed the price of our panels are considerably low compared with other existing panels in market, i.e. the price of manufactured panels is about 50% of the conventional panels.

XI. Conclusions

According to the results and calculations the panels produced from the waste textile fibres can successfully compete with non-fibrous panels from both technical and economic aspects. Therefore, we can witness the production of these panels and they can replace the conventional panels in the future.

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