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IOP Conf. Series: Materials Science and Engineering 661 (2019) 012120 doi:10.1088/1757-899X/661/1/012120

Modification of WPC Materials by Introduction of Dioctyl Phthalate Plasticator

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Abstract. The study of the properties of materials of wood-polymer composites (WPC), modified with mineral filler and plasticizer. The materials modified with mineral filler possess very low water absorption of 0.013% compared with 1.25% for ordinary material based on the WPC. The stress relaxation of a modified material was investigated and it was found that the master relaxation curve of the modified sample is located in the stress range from 900 to 1300 MPa, which is higher than for the standard sample. Thermal expansion of samples containing the plasticizer dioctyl phthalate (DOP) is in the range from 26 to $68 \cdot 10^{-6}$ K^{-1}; those, the same as for the control sample that free of mineral filler. The water absorption of the samples plasticized with DOP of 0.013% is also at the level of the samples containing the mineral filler, and significantly less than the water absorption of the control sample. Specific impact strength is 5.8 kJ/m^2, flexural strength is 32 MPa.

1. Introduction

In this work, we obtained and investigated the properties of wood-polymer composites (WPC), in which polyvinyl chloride (PVC) is the matrix polymer. In particular, terraced boards are made from these WPCs, which are widely used in the construction industry. Flooring of terrace rooms, siding, decorative fencing, intake systems, steps, universal profiles, various accessories and components are successfully manufactured from WPC. The Russian manufacturer of products from WPC is the company Savewood.

The properties of WPC based on PVC were investigated in [1-5]. WPC manufacturing methods are available in [6–8]. The most detailed mechanical properties of PVC-based WPC were studied in a wide temperature range in [9, 10]. Thermal properties, water absorption, hardness, abrasion, resistance to climatic influences, the use of secondary polymers were studied in [11,12].

Recently, serious attention has been paid to modifying the composition of the components of decking. As modifiers used mineral filler added to the wood filler. In [13,14], the properties of decking boards, in which a mixture of chalk and wood flour is used as a filler, were studied. This filler leads to a noticeable decrease in swelling from 1.25 to 0.01%. However, modification of the composition of decking is not limited to mineral filler. It is known that in many cases polyvinyl chloride (PVC) is used in plasticized form. Therefore, materials were obtained at Savewood Company containing the plasticizer dioctyl phthalate at a concentration of 0.5% of the total mixture of the polymer, fillers and all additives.

It could be assumed that the introduction of such a small amount of plasticizer will not have a very significant effect on the properties of building products, but it will make it possible, as a result of a decrease in the viscosity of the extruded composition, to markedly reduce electricity consumption during their production.

In this work, the properties of such a material modified with dioctyl phthalate (DOP) have been studied in detail and compared with the properties of materials modified only with mineral filler (chalk). A comparison was also made with the properties of a standard sample containing ordinary organic wood filler without any additives. The mechanical properties, thermal expansion and water absorption were investigated. Experimental data are presented in tables and graphs.

2. Experimental part

First of all, measurements were made of the thermal expansion of the modified sample prepared by adding DOP to the composition. Heating was carried out to 50°C. The measurement results are shown in table 1.

Table 1. The results of measuring the thermal expansion of the samples modified by DOP

l_{0rs}. mm	l_{0brs}. mm	l_{rs}. mm	l_{brs}. mm	l_{rs}. mm	l_{brs}. mm	$_{rs}\cdot10^6$ K^{-1}	$_{brs}\cdot10^6$ K^{-1}	$_{mut}\cdot10^6$ K^{-1} (DOP)	$_{mod}\cdot10^6$. K^{-1} for compositions ($CaCO_3$/wood flour)	$_{contr}\cdot$ 10^6 K^{-1}
Length measurements										
105.5	111.1	106.5	112.1	0.95	0.97	30.0	29.11	29.55	24.48 (80/20) 31.9 (*) 29.08 (40/60) 28.05 (double processing) 30.65 (70/30) 25.94 (30/70)	26.4
Width measurements										
–	106.3	--	107.8	–	1.5	–	–	47.02	37.28 (80/20) 42.85 (*) 45.59 (40/60) 50.27 (double processing) 46.55 (70/30) 52.03 (30/70)	47.74
Thickness measurements										
–	4.58	–	4.67	–	0.09	–	–	65.5	60.93 (80/20) 65.54 (*) 68.93 (40/60) 61.12 (double processing) 62.14 (70/30) 70.62 (30/70)	68.33

* PVC based sample prepared be another manufacturer

Table 1 introduces the following notation: l_{0rs} – initial size of the stiffener board, l_{0brs} – initial size between stiffeners, l_{rs} – the final size of the size on the stiffener of the decking board after heating, l_{brs} – the final size of the size between the ribs after heating, l_{rs} – resizing on stiffener after warming up, l_{brs} – resizing between stiffeners after warming up, $_{rs}$ – coefficient of linear thermal expansion (CLTE) on the edge of the board, $_{brs}$ – CLTE between stiffeners, $_{mut}$ – average CLTE; $_{mod}$ – CLTE of samples modified with mineral filler at different content; $_{contr}$ – CLTE of a control sample free of chalk and DOP.

From table 1 it can be seen that adding DOP in a given concentration has practically no effect on CLTE, and its data are absolutely comparable with those for both the control sample and the modified formulation with the addition of mineral filler.

Table 2 shows the compositions of the investigated WPC samples.

Table 2. Compositions of samples № 1-6.

Sample number	Proportion of chalk, %	Wood flour share, %	1st transition temperature, °C	The temperature of the 2nd transition, °C	3rd transition temperature, °C
1	80	20	80	225	560
2*	-	-	81	202	-
3	40	60	78	230	-
4 (2-fold process.)	40	60	78	217	-
5	70	30	78	210	-
6	30	70	79	216	-

* Sample No. 2 was not produced by Savewood Company, but by another domestic company. It also contains PVC as a matrix polymer.

Table 3 contains data on the water absorption of the sample with the addition of DOP.

Table 3. Water absorption of the sample with the addition of DOP

Water absorption. swelling in water 24 hours	Water absorption %	Savewood (cotrol)	Sample number 1 (80/20)	The sample is not our number 2	Sample number 3 (40/60)	Sample number 4 (2-fold processing)	Sample number 5 (70/30)	Sample number 6 (30/70)	DOP Plasticized Sample
		1.25	0.08	0.01	0.013	0.005	0.025	0.98	**0.09**
	Swelling in length %	0.12	0.02	0.04	0.02	0.004	0.014	0.06	**0.07**
	Swelling width %	0.165	0.02	0.02	0.02	0.008	0.018	0.12	**0.13**
	Thickness swelling %	0.94	0.31	0.55	0.28	0.47	0.11	0.68	**0.88**

From table 3 it can be seen that water absorption of the sample when added to the formulation of DOP is almost completely at the level of water absorption of standard samples that do not contain mineral supplements, and not significantly more than the water absorption of samples containing mineral filler.

Table 4 contains the results of measuring the hardness of the samples studied.

Table 4. The results of measuring the hardness

Savewood (free of filler)		**Savewood (DOP)**		**Terradeck**	**Twinson**
Shore D (average)	Brinnell, MPa	Shore D (average)	Brinnell, MPa	Brinnell, MPa	Brinnell, MPa
85	580	**79,1**	**550**	129	145

From table 4 it can be seen that the hardness of the sample when added to the formulation of DOP is slightly lower than the hardness of the sample free of DOP, but still far exceeds the data for the brands Terradeck and Twinson.

Table 5 contains data for specific impact strength.

Table 5. Specific impact strength in comparison with this property of samples containing only mineral filler in different concentrations

Sample number	$A_{average\ control}$, kJ/m^2	Sample number 1 (80/20). Aav. kJ/m^2	Sample number 2 Aav. kJ/m^2	Sample number 1 (40/60). Aav. kJ/m^2	Sample number 4 (2-fold processing). Aav. kJ/m^2	Sample number 5 (70/30). Aav. kJ/m^2	Sample number 6 (730/70). Aav. kJ/m^2	Sample with DOF. Aav. kJ/m^2
1	6.0	3.71	6.25	6.83	7.74	3.23	4.23	5.8
2	8.9							
3	4.7							
4	4.8							
5	4.6							
6	5.3							

From table 5 it can be seen that the specific impact strength of the plasticized sample is approximately the same as for all other samples studied.

Table 6 contains data on the flexural strength of the studied samples.

Table 6. Flexural strength

Sample number	The average value of the control sample $\sigma_{f.contr}$ MPa	$\sigma_{f.av}$, MPa Sample number 1 (80/20).	$\sigma_{f.av}$, MPa The sample is not our number 2	$\sigma_{f.av}$, MPa Sample number 3 (40/60)	$\sigma_{f.av}$, MPa Sample number 4 (2-fold processing)	$\sigma_{f.av}$, MPa Sample number 5 (70/30)	$\sigma_{f.av}$, MPa Sample number 6 (30/70)	Sample with DOF. $\sigma_{f.av}$, MPa
1	68.9	25	43.7	48.1	64.8	31.8	42.7	32
2	58.3							
3	68.8							
4	57.5							
5	64.1							
6	65.7							

From table 6 it can be seen that the flexural strength in some cases coincides with other samples that free of plasticizer, but in other cases is lower than the binding strength for samples that do not contain a plasticizer. However, its value (32 MPa) is sufficient to use plasticized material in building structures.

3. Conclusions

As a result of the study, it was found that the modified materials on the basis of WPC, in which the wood filler is partially replaced by mineral one, possess very low water absorption of 0.013% compared with 1.25% for ordinary material based on the WPC. This is very important in their operation in structures used in conditions of rain and moisture.

The master relaxation curve of the modified sample is located in the stress range from 900 to 1300 MPa, which is higher than for the standard sample. Thermal expansion of samples containing the plasticizer dioctyl phthalate (DOP) is in the range from 26 to $68 \cdot 10^{-6}$ K^{-1}; those, the same as for the

control sample that free of mineral filler. The water absorption of the samples plasticized with DOP of 0.013% is also at the level of the samples containing the mineral filler, and significantly less than the water absorption of the control sample. Specific impact strength is 5,8 kJ/m^2, bending strength is 32 MPa. The modulus of elasticity remains at the level of the modulus of elasticity of solid structural polymeric materials. Consequently, plasticized material can be successfully used for the production of decking.

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