Study of the abrasion resistance of wood-polymer composites and mixtures of ABS-plastic with polyvinyl chloride

Andrey Matseevich[1,2], *Tatyana* Matseevich[1,*], and *Andrey* Askadskii[1,2]

[1]Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia
[2]A.N. Nesmeyanov Institute of Organoelement Compounds Russian Academy of Sciences, Vavilova str., 28, Moscow, Russia

Abstract. The abrasion of materials based on blends of ABS plastic with polyvinyl chloride (PVC) as well as terraced boards based on wood-polymer composites (DPC) has been studied. The measurements were carried out on a drum-type machine, and on a Taber's abrasimeter. For blends of ABS plastic with PVC at abrasion path length 600 m wear is 0.85%. For terracotta boards based on WPC, the wear during the test (loss of mass) was 0.0042 g. The abrasion of the sample was 9.29×10^{-5} g/cm^2. Thus, the obtained blends should be recommended for application for floor coverings, since they possess negligible abrasion.

1 Introduction

The purpose of the paper is to consider the important operational characteristics of terraced boards made of wood-polymer composites (WPC) – wear resistance (abrasive resistance). Wear of wood-polymer composites is a very important performance characteristic of polymer building materials. This characteristic is especially important for floor coverings that, when applied externally, are subjected to various types of mechanical influences in combination with the effects of sprinkling, UV irradiation, low temperatures, etc. The duration of operation of products from the KDP depends on the quality of the product and on the type of loading. These regularities are partially described in monographs [1, 2]. In accordance with the theory of Kragelsky, the contact of the WPC and the man's shoes goes through a microscopic dust-air layer [3, 4]. The main destructive stresses in the DCC are tangential stresses [5]. Naturally, the level of tangential stresses directly depends on the level of normal stresses. To estimate abrasion, it is necessary to know the number of periodic loads of the surface of the floor covering. In this case, since the loads are carried out by people with different weights, the distribution curve must be taken into account in terms of the mechanical load. Only in this case, the forecast of abrasion and mechanical performance of the coating will be more reliable [6,8,9]. In work [7] the course of calculation is shown and the received resource of work of a floor covering from WPC,

* Corresponding author: MatseevichTA@mgsu.ru

possessing the certain characteristics is resulted. As for determining the actual lifetime of floor coverings, such data are practically absent.

2 Problems

As objects of research, mixtures of ABS plastic with polyvinylchloride (PVC) will also be used. This characteristic is mentioned by almost the majority of manufacturers of products from WPC, but do not conduct any tests of this property. In their advertising brochures and on Internet resources, the manufacturers are only limited to the phrase "our products possess high wear resistance". The concept of wear resistance, the dependence of this indicator on a number of factors and methods for determining this characteristic should be considered in more detail.

Abrasion – the property of the material to be decreased in volume and mass under the action of abrasive forces. The abradability of $A(m)$ is estimated by the loss of the initial mass of the sample of the material referred to the surface area of abrasion F, and is calculated by the formula:

$$A(m)= (m_1 – m_2)/F, \quad (1)$$

where m_1 and m_2 are the masses of the sample before and after abrasion, respectively.

The abrasive resistance of material is estimated by standard methods: abrasion circle and abrasives (quartz sand and emery). This property is important for assessing the exploitation of floors, stairs, terraces, etc. Wear is the property of the material to resist the simultaneous impact of abrasion and shocks (see the article "The Resistance to the impact of terraced boards by Savewood", published on the website of Savewood). Wear is determined with use of specially prepared samples of materials. The wear indicator is the loss of mass of the sample of the material as a result of the test.

One of the main causes of wear is abrasion due to external friction of the material on other surfaces, which is accompanied by a decrease in its mass. In accordance with modern concepts of friction, abrasion is the result of repeated disruption of friction bonds between contacting surfaces when they are displaced relative to each other. When the molecular-frictional bonds that occur in the areas of contact of the surfaces are broken, the micro-particles are torn off, the surface films are destroyed. When the bonds of mechanical engagement of micro- and macro-toughness are broken, the character of abrasion depends on the ratio of the stiffness of the elements of the contacting surfaces.

If the material contacts a more rigid surface, then the introduction of a solid element to a depth of less than half the diameter of the wood fiber (fibers included in the WPC) can, when displaced, lead to micro-cutting of the fibers. With a deeper penetration of the solid element (more than half the diameter of the fiber), the wood fiber may break or pull it to the surface, depending on reliability of the fiber fixing in the material structure. This kind of destruction can occur even with the first violation of the frictional bond.

When the material frictions against a smooth surface or when the hardness of the rubbing surfaces is approximately the same (material by material), wear fatigue is observed. The shear of the embedded element of the abrasive surface causes variable deformations of the micro-sections of the material: in the area in front of the element – compression and bending, behind the element – stretching. If the resulting deformations disappear after the passage of the element, there is an elastic displacement of the material. However, repeated exposure to variable deformations results in plastic displacement, which causes fatigue of the material and its destruction. The tips of the wood fibers protruding on the surface under abrasion experience multiple bends in different directions, as a result of which their destruction occurs at the fixing sites.

3 Results

The abrasion test (wear) of the Savewood terraced board was carried out in accordance with the agreement on scientific and technical cooperation with the Institute of Organoelement Compounds RAS, the laboratory of filled polymer systems. The test was carried out in accordance with "GOST 11529-86 Polyvinylchloride materials for floors. Control methods". The essence of the method is to determine the amount of reduction in thickness and mass of material during abrasion for a given number of test cycles. The test was carried out for the sample diameter of which is equal to 24.0 ± 0.5 mm cut by a trench knife. The experiment was carried out on a drum-type machine, the scheme of which is shown in Figure 1. The machine's design should provide: drum rotation speed (0,085 ± 0,015) m/s; mass of cartridge with holder (1.00 ± 0.05) kg; moving the holder with the sample along the generator of the drum for a distance (16.0 ± 0.5) mm during one turn; full rotation of the holder with the sample around its axis for two turns of the drum (one operating cycle of the machine).

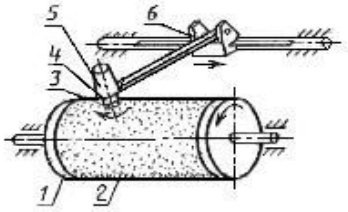

Fig. 1. The drum type machine: 1 is the hollow cylinder; 2 is the grinding skins; 3 is the sample; 4 is the holder; 5 is the cartridge; 6 is the carriage.

The sample holder must be self-aligning. Grinding skins is the paper made from normal electro-corundum grades (15A-13A) with a grain size of 8N and alloy electro-corundum grades (94A-91A) with a grain size of 8N according to GOST 6456-82. In given case, the skin of the brand P500 was used. The diameter of the sample is equal to 24 mm. The sample is glued to the base of the holder and weighed. Next, the holder with the sample is fixed in the chuck of the machine, lowered to the surface of the drum and the electric motor is turned on. The pressure of the sample on the drum was 0.05 MPa, and the rotation velocity of the drum was 0.5 m/s. The abrasion of the sample is carried out each time over an unbetted area of the surface of the abrasive cloth during one operating cycle of the machine. If the number of work cycles differs from the one adopted, this should be indicated in the normative and technical documentation for the material of a particular type. At the end of the test, the holder with the sample is taken out of the cartridge, cleaned from the wear products and weighed. The results are shown in the Figure 2.

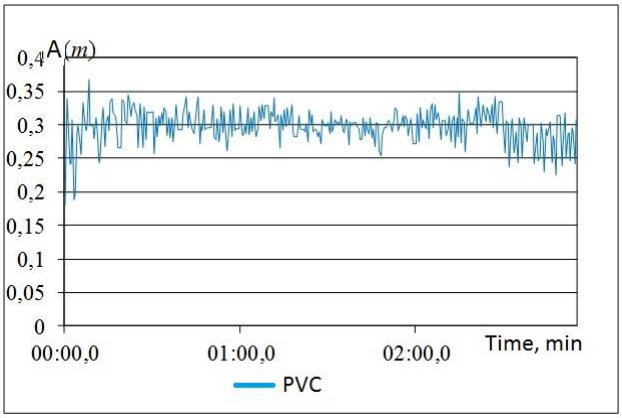

Fig. 2. Dependence of abrasive wear on time; $P = 0.05$ MPa, $v = 0.5$ m/s.

The experiment showed that the wear during the test (loss of mass) was 0.0042 g. The abrasion of the sample in accordance with the formula (1) was 9.29×10^{-5} g/cm^2. As can be seen, the values both of mass loss (wear resistance) and abrasion are negligible. Consequently the products from the WPC of the company Savewood have a very high wear resistance and a significantly reduced abrasion. Obviously, all products (terraced boards, steps, floors, etc.) will not possess tear-holes, "bald spots", rubs and other unpleasant phenomena caused by frequent furniture movement, heavy walking on the surface, etc.
The abrasion test of the Taber's abrasimeter was carried out in order to evaluate the abrasion resistance of coatings made from materials prepared from mixtures of secondary ABS plastic with polyvinyl chloride. For comparison, an ABS-based plastic sample without additives was tested. The results showed that blends containing ABS plastic with addition of PVC with a content of 60 PVC and 40 ABS possess a lower abrasion, which is a positive factor in the production of coatings based on this mixture. The Table 1 shows the data on abrasion of ABS plastic samples and ABS/PVC mixture in a concentration of 40/60.

Table 1. The data on abrasion of ABS plastic samples and ABS/PVC

Name of the mixture:	ABS/PVC 40/60	ABS plastic
m_1, sample weight before test, g	52.227	58.453
Density of the sample, g/cm^3	1.17	1.17
Abrasive stiffness, H **	p100	p100
100 turns = 30 meters		
Sample weight after 100 test cycles, g	52.153	58.370
TAR60,100 (m) - abrasion of one sample at 100 cycles, g	0.074	0.083
G60,100 (V) - abrasion of one sample by volume of wear, cm^3	0.06	0.07
G60,100 (m/S) - abrasion of one sample by mass loss to the surface, g/cm^2	0.003	0.003
200 turns = 60 meters		
Sample weight after 200 test cycles, g	52.148	58.368
TAR600,200 (m) - abrasion of one sample at 200 cycles, g	0.079	0.085
G600,200 (V) - abrasion of one sample by volume	0.07	0.07

of wear, cm^3		
G600,200 (m/S) - abrasion of one sample by mass loss to the surface, g/cm^2	0.003	0.003
2000 turns = 600 meters		
Sample weight after 2000 test cycles, g	51.717	57.928
TAR600,2000 (m) - abrasion of one sample at 2000 cycles, g	0.510	0.525
G600,2000 (V) - abrasion of one sample by volume of wear, cm^3	0.44	0.45
G600,2000 (m/S) - abrasion of one sample by mass loss to the surface, g/cm^2	0.020	0.020

Figure 3 also shows the abrasion resistance of ABS plastic samples, ABS plastic mixtures with PVC and standard building materials samples from the abrasion path length. It can be seen that the samples of mixtures of ABS plastic with PVC are not inferior to standard coatings, which are widely used in practice.

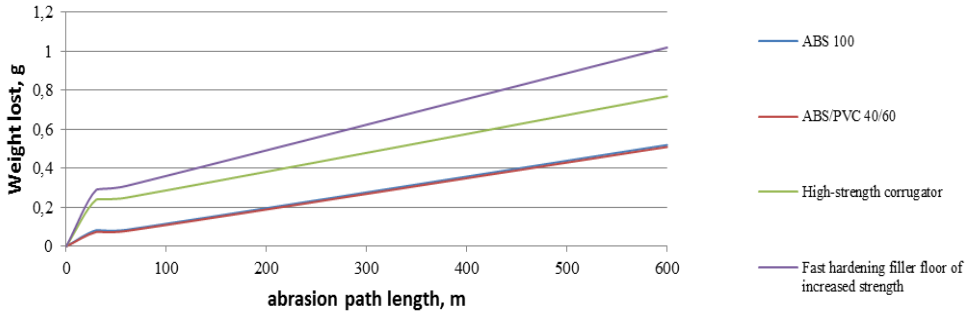

Fig. 3. The abrasion resistance of the samples versus the abrasion path length

4 Conclusions

Thus, the obtained blends can quite find application for floor coverings, since they possess low abrasion.

This work was financially supported by Ministry of Education and Science of the Russian Federation (#NSh-3492.2018.8).

References

1. A.A. Kljosov, *Wood-polymer materials*, 736 (St.-Petersburg, Nauchnye osnovy i tehnologii, 2010)
2. I.M. Galiev, *Establishment of a multi-layer flooring based on wood-polymer composites*, 157 (PhD, Thesis, 2015)
3. I.V. Kragel'skij, M.N. Dobychin, V.S. Kombalov, *Basics of friction and wear calculations*, 526 (Moscow, Mashinostroenie, 1977)
4. I.V. Kragel'skii, I.E. Vinogradova, *Friction coefficients*, 220 (1962)
5. Yu.V. Grinyaev, V.K. Shil'ko, Physical Mesomechanics J., **2**, 27-33 (2005)

6. S.V. Serensen, V.P. Kogaev, R.M. Shnejderovich, *Strength analysis and bearing capacity of machine parts*, 488 (Moscow, Mashinostroenie Publ., 1975)
7. A.P. Kotova, V.K. Shilko, Vestnik TGASU, **4**, 177-185 (2015)
8. A.O. Adamtsevich, A.P. Pustovgar, , S.A. Pashkevich, A.V. Eremin, International Journal of Applied Engineering Research, **11(3),** 1609 (2016)
9. V.N. Yarmakovsky, A.P. Pustovgar, Procedia Engineering, **111**, 864 (2015)