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Evaluation of the slip resistance of modified wood decking products

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HIGHLIGHTS

- The μ_s values of CCA treated and heat treated spruce lumber were larger than those of untreated spruce lumber and WPC lumber.
- The μ_s values of all specimens under wet surface condition were larger than those under dry surface condition.
- The μ_s values increased with increasing the weight of sliding block from 14 to 20 kg.
- There was no significant difference in μ_s among three sliding speeds, 10–50 or 250 mm/min.

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ABSTRACT

With increasing global concerns on environmental issues, Chromated Copper Arsenate (CCA) treated wood decking products have been step by step replaced by Wood Plastic Composite (WPC) lumber and heat-treated lumber. The slip resistance of decking is no doubt a critical safety index. Overall, there has not been a proper standard for measuring the slip resistance of WPC products. Canadian Construction Materials Centre (CCMC) uses the static coefficient of friction (μ_s) to evaluate the slip resistance of WPC products, which stipulates that μ_s should be larger than 0.50. This study was aimed at measuring the slip resistance of WPC decking products in terms of μ_s and then comparing with others. There were four types of testing specimens including WPC lumber (WPC), CCA treated spruce lumber (CCAS), heat-treated spruce lumber (HTS) and untreated spruce lumber (UTS). μ_s was measured, according to ASTM D2394 standard, under two surface conditions (*SCs*) (dry and wet), two weights of sliding block (*WSB*) (14 and 20 kg), and three sliding speeds (*SSs*) (10, 50 and 250 mm/min). It was discovered that (1) The μ_s values of CCAS and HTS were always larger than those of UTS and WPC, and only at some specified testing conditions, the μ_s values of them could reach or exceed 0.50; (2) The μ_s values of all specimens under wet *SC* were larger than those under dry *SC*, and the increase of μ_s under wet *SC* was less significant than that under dry *SC* as the *WSB* increased from 14 to 20 kg; (3) The μ_s values increased, regardless of the types of specimens, with increasing the *WSB* from 14 to 20 kg; (4) There was no statistically significant difference in μ_s among three *SS* values used, 10–50 or 250 mm/min.

1. Introduction

Due to the phase-out of Chromated Copper Arsenate (CCA) treated lumber that was/are widely used for decking material, more and more new environmentally friendly products emerge in decking market to build decks in residential construction. These new decking products include Wood Plastic Composite (WPC) and heat-treated lumber. WPC lumber owns its unique properties, such as resistance to rot fungi, marine borers and termites, without pesticides and hazardous chemicals [1]. Heat-treated lumber also has some improved properties by heating it to a certain temperature (e.g. 180 °C), such as more durability, less moisture deformation, and better weather resistance, comparing with untreated wood [2]. From the viewpoint of safety, slip resistance is critical to evaluate the performance of decking in service, which is reflected by the coefficient of friction defined as the ratio of one force overcoming the friction to lead to a relative motion between two objects and the other force compressing them together. There are two types of coefficient of friction, one of which is the static coefficient of friction describing the friction opposing the initial relative motion/impending motion, and the other is kinetic or sliding coefficient of friction representing the friction opposing the continuance of relative motion once the motion has started [3]. To evaluate the safety issue of WPC decking products (extrusion

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mode) intended for outdoor end-use, the Canadian Construction Materials Centre (CCMC) employs the static coefficient of friction (μ_s) to evaluate the slip resistance in its Technical Guides and stipulates that the μ_s should not be less than 0.50 [4].

Studies on the slip resistance of WPC products are very limited. Since there is not a specially developed standard for measuring μ_s, μ_s of WPC products is normally evaluated in reference with the standards for wood and wood fiber/particle board, such as ASTM D2394-05 "Standard methods for simulated service testing of wood and wood-base finish flooring" [5]. Some testing results of WPC and CCA treated decking products can be found in the book of "Wood–plastic composites" [3], which revealed that the μ_s values of different types of WPC products varied from 0.22 to 0.52 under dry surface condition and from 0.46 to 0.54 under wet surface condition, respectively. Comparatively, the average μ_s of CCA treated wood measured under dry and wet surface condition was about 0.72 and 0.88, respectively [3]. In addition, Carroll et al. [1] reported the average μ_s of WPC lumber made of recycled plastic/sawdust was 0.39, which was measured at room temperature according to ASTM D2394-05 [5]. However, the surface condition (dry or wet) was not mentioned in their study.

As a material- and system-dependent dimensionless scalar value, μ_s may be affected by the surface performance of a material (such as grain orientation and surface roughness), and external factors (such as dry/wet surface condition and sliding speed) [6,7]. This study was aimed at evaluating, in terms of μ_s, the slip resistance of WPC and other modified wood products, such as CCA treated lumber, heat-treated lumber, at three testing factors, and providing an in-depth understanding about the effects of these factors on μ_s.

2. Materials and method

2.1. Materials

Four groups of specimens were prepared, which included WPC lumber, CCA treated spruce lumber (CCAS), heat-treated spruce lumber (HTS) and un-treated spruce lumber (UTS). UTS was used as a control group. The surfaces of these products were not coated with lacquer or other materials. The WPC lumber was made of 95% recycled materials including high density polyethylene (HDPE), rice hull and glass sphere, which was manufactured by using an extruding technology and had simulated wood grain on two surfaces of the WPC lumber. The CCAS was treated by Chromated Copper Arsenate chemicals. The HTS was heated at about 195 °C at a local company in New Brunswick, Canada. The dimensions of WPC specimens were 25 mm (thickness) by 152 mm (width) by 300 mm (length), while the CCAS, HTS and UTS specimens had the dimensions of 50 mm (thickness) by 102 mm (width) by 300 mm (length). 18 specimens for each group were prepared, giving a total of 90 specimens. One side of a specimen was tested under dry surface condition and the other side was tested under wet surface condition. Before testing, all specimens were placed in a conditioning chamber at 20 ± 2 °C and 65 ± 5% relative humidity (RH) until they reached stable moisture content (MC).

2.2. Method

The sliding friction tests were conducted at room temperature according to ASTM D2394-05 [5]. The experimental setup is shown in Fig. 1a. The sliding block used is shown in Fig. 1b, consisting of a bulk of concrete, a piece of plywood, and a piece of prime-grade shoe sole leather with an area of 102 mm by 114 mm. An Instron universal testing machine with 1 kN load cell was used to perform the sliding friction tests. Before each test, the surface of the leather was slightly sanded by a 1/2-grit garnet paper. The moving direction of the sliding block was along the wood grain direction, i.e., longitudinal direction. Table 1 shows a full factorial design of four factors at various levels using Minitab 16.0 Software [8], including four types of specimens (*TS*), two surface conditions (*SCs*) (dry and wet), two weights of sliding block (*WSBs*) (14 and 20 kg), and three sliding speeds (*SSs*) (10, 50 and 250 mm/min). Analysis of variance (ANOVA) on μ_s was subsequently conducted via Minitab. To create a wet surface condition, about 5 ml amount of water was evenly sprayed on the surfaces of specimen and leather, ensuring that no large water droplets could be observed on two surfaces.

2.3. Calculation of static coefficients of friction

μ_s can be calculated by the following equation [7]:

$$\mu_s = F_s/N \quad (1)$$

where, F_s is the first peak force to lead the relative motion between two bodies; and N is the load normal to the interface between two bodies, i.e., the weight of sliding block (*WSB*).

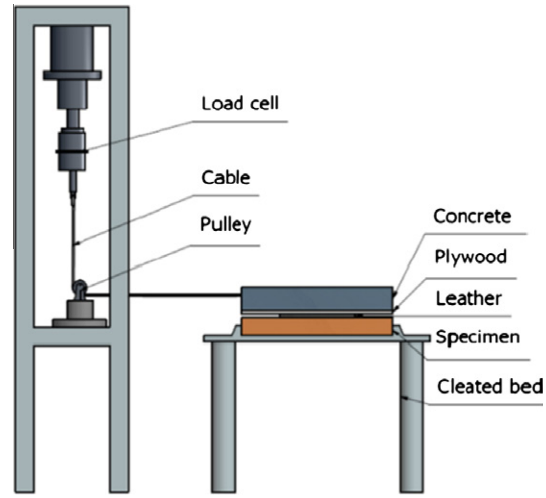

Fig. 1a. Experimental setup of friction test.

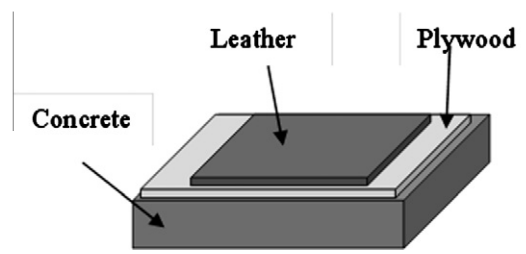

Fig. 1b. Sketch of a sliding block.

Table 1
Design of experiment.

Factor	Level			
Type of specimen (*TS*)	CCAS	HTS	UTS	WPC
Surface condition (*SC*)	Dry	Wet		
Weight of sliding block (*WSB*) (kg)	14	20		
Sliding speed (*SS*) (mm/min)	10	50	250	

Note: There are three (3) replicates at each testing condition.

3. Results and discussion

3.1. Summary of static coefficients of friction

The mean and one standard derivation (SD) values of μ_s for four types of specimens tested at different conditions were divided into two groups based on dry *SC* and wet *SC*, and then they are plotted in Figs. 2a and 2b, respectively.

It can be seen in Fig. 2a that the μ_s of all specimens was lower than 0.50 when it was measured using a 14 kg *WSB* under dry *SC*. The average μ_s of CCAS and HTS only came to about 0.30, which was slightly higher than that of UTS. WPC had the lowest μ_s of about 0.10. Under the same *SC*, with increasing the *WSB* to 20 kg, the average μ_s of CCAS and HTS dramatically increased to about 0.60 or more, while those of UTS and WPCS reached about 0.40 but still failed to meet the requirement of 0.50. Overall, the average μ_s values of CCAS and HTS were about 50% larger than those of UTS