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Effects of Paint on Slip Resistance of Concrete and Wood Surfaces

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Abstract: There are a variety of reasons to consider painting outdoor walkway surfaces, including some that are specific to occupational settings. From a slip resistance perspective, there is limited information in published literature regarding the effect of painting outdoor walkway surfaces. The purpose of this study was to measure the effect of paint on the slip resistance of wood and concrete walking surfaces under wet and dry conditions. Four brands of paint were applied to concrete and treated wood surfaces. Measurements of slip resistance are reported and demonstrate that painting these surfaces is generally a viable option to achieve a satisfactory walkway surface compared to an unpainted surface.

1. Introduction

Workers commonly ambulate on paved and treated wood exterior surfaces. It is usually unnecessary to paint either of these two types of outdoor walkway surfaces, yet some employers may find it desirable for aesthetics, protection, ease of cleaning, delineating pedestrian/vehicle/hazardous/restricted areas, etc. If an employer does choose to paint a paved or treated wood surface, there is limited data regarding its effect on slip resistance.

For example, a recent study reported that painting some common exterior walkway surfaces significantly increases slip resistance (Curry, Reinke, Shah, & Kidd, 2007). However, Curry et al. only tested paved surfaces. In spite of limited data and even data to the contrary, some walkway safety publications assert or imply that paint can reduce the slip resistance of wet walkway surfaces to an unacceptable level (Di Pilla, 2010; English, 1989; ASTM F1637-2010).

In light of this situation, the purpose of this study was to measure the effect of paint on the slip resistance of two common exterior walkway surfaces: concrete and treated wood. The slip resistance of a variety of national floor paint brands for concrete and wood surfaces were tested under dry and wet conditions, and their results compared.

2. Methods

2.1 Study Design

This experiment was conducted under laboratory conditions and employed a complete factorial design in which the independent variables were floor surface material (concrete or wood), floor surface treatment (paint brand A, B, C, or D, or unpainted), and floor surface condition (dry or wet). The dependent variable was slip resistance.

2.2 Preparation of Floor Surfaces

Ten test surfaces were prepared for this study: five concrete and five wood treatments. The five treatments included the four paint brands plus unpainted. The concrete test surfaces were prepared using prefabricated 16x16x2 inch square concrete patio stones, while the wood test surfaces were prepared using standard 5/4-inch thick (nominal) treated deck wood; both surface types were purchased from a national home improvement chain store. A multi-surface primer and sealer and each brand of paint were marketed for exterior application to concrete or treated wood and were applied according to product instructions. Paint color, viscosity, etc. were not altered. The painted concrete and wood surfaces cured for several months at room temperature prior to experimentation.

Prior to testing, each test surface was rinsed thoroughly, washed and scrubbed with dish detergent to remove any contaminants, and rinsed thoroughly again. Each test surface was air-dried overnight before testing began.

2.3 Testing Device and Equipment

The testing device used to measure slip resistance was an English XL Variable Incidence Tribometer (Figure 1), a biofidelic slip meter suitable for both wet and dry measurements (Grieser, Rhoades, & Shah, 2002; ANSI/ASSE TR-A1264.3-2007). The English XL uses a circular test foot with a diameter of 1.25 inches. The contact surface of the factory-supplied test foot is composed of a 1/8-inch thick piece of test-grade Neolite® rubber, a material found to provide reliable and repeatable slip resistance data in a variety of conditions (Grieser et al., 2002; ANSI/ASSE TR-A1264.3-2007). The tribometer was outfitted with a Sequencer, which is designed to consistently actuate the test foot for 0.5 seconds upon each depression of the palm button, thus reducing variability associated with inconsistent human performance related to actuation duration. One week prior to testing, the device was factory calibrated, and the test foot calibration was checked according to the English XL VIT User Guide before each day of testing.

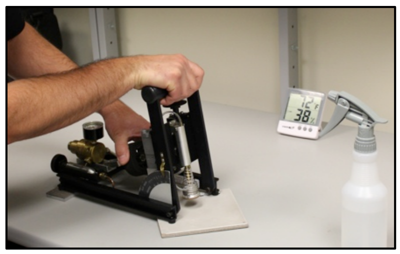

Figure 1. English XL tribometer, shown with calibration tile.

The viscometer used in this study was a Beokel® Zahn Cup Viscometer #2. The Zahn cup has a capacity of 44mL and is used to measure the viscosity of a variety of liquids, including paints.

2.4 Procedure

Testing was performed according to the English XL VIT User Guide (Excel Tribometers 2012). During testing, four repetitions were performed on each test surface. The four repetitions were each performed in a different nominal compass direction (North, East, South, West – in that order) relative to the floor surface. Test runs were randomized by floor sample, and all dry testing preceded all wet testing. After each slip during dry testing, the test foot was sanded using The Sander® with 180 grit sandpaper in a circular motion five times clockwise. The Sander® helps ensure that the test foot is consistently sanded.

Each repetition consisted of a series of “strokes” of the slip meter, starting at a slip resistance value below that of the surface being tested. The mast angle (from vertical) was then increased in slip resistance increments of approximately 0.01 until a slip occurred. The recorded slip resistance value was that at which a complete slip first occurred. A minimum of three non-slip strokes was required prior to a slip in order to record a slip resistance value. If the slip occurred without at least three non-slip strokes preceding it, the test was repeated beginning at lower mast angle until the slip occurred after the third non-slip stroke. During dry testing, the test foot was sanded after each slip using The Sander® with 180 grit sandpaper in a circular motion five times clockwise. During wet testing, the test foot was not sanded after each slip but was only sanded if it became noticeably scored.

All measurements were taken in the same area of each test surface. The test areas were chosen to avoid substantial surface irregularities (e.g., splits or knots in the wood, unusual asperities). For the wood testing, three contact areas were measured, one on each of the three 5/4-inch deck boards. All measurements were taken at standard room temperature (72°F). For dry testing, the humidity ranged from 38% to 48%.

2.5 Viscosity Testing of Deck Wood Paints

The researchers noticed that brush strokes could be seen in the wood surfaces painted with brands B and C. It was hypothesized that paint brands B and C may have had a higher viscosity than brands A and D, thus explaining the visible brush strokes only found with brands B and C, which would likely create slightly more texture and thus slightly more slip resistance.

To test this hypothesis, the viscosity of each brand of paint was tested using the Zahn #2 cup according to its instructions. Some paints were too thick to maintain a constant stream of liquid falling through the hole of the viscometer. Since relative rather than absolute viscosity was of interest for this study, each paint was diluted with equal parts paint and water. This allowed each paint to readily flow through the viscometer. A stopwatch was used to measure the efflux time (time for 44mL of fluid to pass through the viscometer). Efflux time was defined as the time elapsed from when the top edge of the cup broke the surface of the paint until there was a sudden break in the steady flow of paint out of the bottom of the cup.

The efflux time for each paint was measured four times and then averaged. All samples were taken at standard room temperature (72°F).

3. Results

3.1 Slip Resistance of Painted Concrete Surfaces

The mean slip resistance values of each concrete floor treatment and condition are shown with standard error bars in Figure 2. The results showed that there is relatively low variability in the slip resistance for wet and dry conditions across the various paint treatments.

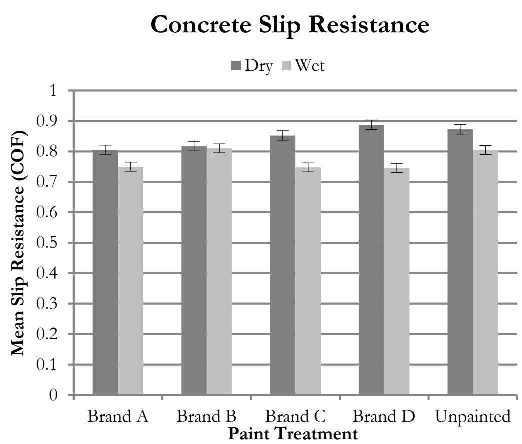

Figure 2. Slip resistance of concrete surfaces.

3.1.1 Within Dry Concrete Treatments

A one-way analysis of variance (ANOVA) was conducted among the painted concrete treatment brands A, B, C, and D. Dry treatments were determined to have equal variance using a Levene's test for equal variance ($p = 0.576$). The one-way ANOVA revealed that at least one mean was different ($p = 0.001$). Next, a Tukey pairwise comparison was conducted to determine which means among the painted concrete treatments differed significantly. The results of the Tukey comparison revealed that the only significant differences were between brands D and A and brands D and B, where brand D exhibited a greater slip resistance at ($p \leq 0.05$).

Next, to determine whether each painted concrete treatment significantly affected slip resistance when compared to unpainted concrete under dry conditions, a Dunnett multiple comparisons test was used with the unpainted treatments as the control. The results showed that only paint brands A and B significantly reduced slip resistance from that of the unpainted concrete ($p \leq 0.05$).

3.1.2 Within Wet Concrete Treatments

To determine whether the slip resistance varies significantly among painted concrete treatments under wet conditions, a one-way ANOVA was conducted. A Levene's test for equal variance revealed that wet treatments did not have equal variance. The one-way ANOVA, using Welch's test because equal variance was not assumed, revealed that no means were statistically different.

Next, to determine whether each painted concrete treatment significantly affected slip resistance when compared to unpainted concrete under wet conditions, a Dunnett multiple comparisons test was performed where the unpainted concrete treatment was the control. The results showed that paint brands A, C, and D significantly reduced the slip resistance of concrete under wet conditions ($p \leq 0.05$). No difference in slip resistance was observed between paint brand B and unpainted concrete under wet conditions.

3.1.3 Between Dry and Wet Concrete Treatments

To determine whether the mean slip resistance of each concrete treatment was significantly affected by its condition (dry or wet), a one-way ANOVA was conducted to compare each treatment under dry and wet conditions. This showed that every treatment, except brand B, yielded a lower slip resistance under wet conditions than dry by a statistically significant margin ($p \leq 0.05$).

Additionally, a one-way ANOVA was conducted to determine whether the application of paint had a significant effect on the amount of decrease (i.e., the “decrement”) in slip resistance from dry to wet. The test compared the difference in slip resistance between dry and wet treatments of all painted to those of unpainted surfaces. The results showed that the application of paint did not have a significant effect on the decrement of slip resistance from a dry surface condition to wet.

3.2 Slip Resistance of Painted Deck Wood Surfaces

The mean slip resistance values of each wood floor treatment and condition are shown with standard error bars in Figure 3.

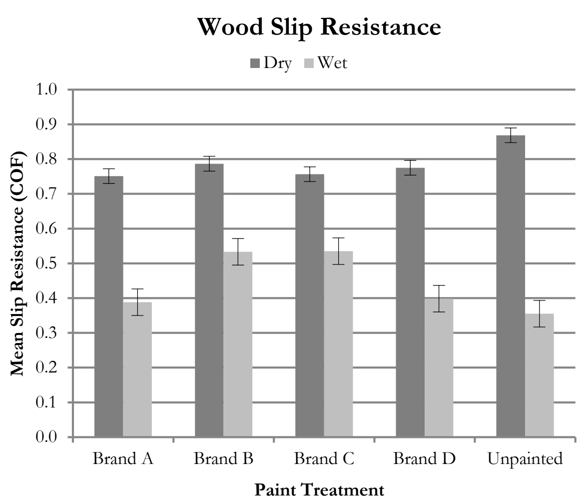

Figure 3. Slip resistance of wood surfaces.

The results showed that while each painted floor treatment produced very similar slip resistance under dry conditions, water reduced slip resistance across all brands, though to varying degrees. Also, unpainted wood was the most slip resistant under dry conditions, but the least slip resistant under wet conditions.

3.2.1 Within Dry Wood Treatments

Dry treatments were determined to have equal variance using a Levene’s test for equal variance. A one-way ANOVA ($p \leq 0.05$) revealed that no mean slip resistance was different among the four brands of paint. A Dunnett multiple comparisons test, in which the unpainted treatment was the control, showed that every brand of paint produced a lower mean slip resistance than the unpainted wood by a statistically significant margin under dry conditions ($p \leq 0.05$). The mean decrement in slip resistance was -0.1011.

3.2.2 Within Wet Wood Treatments

Wet treatments were determined to have equal variance using a Levene's test for equal variance. The one-way ANOVA revealed that at least one mean was statistically different.

Next, a Tukey pairwise comparison was conducted to determine which means among the painted wood treatments differed significantly. The results of the Tukey comparison revealed that brands A and D and brands B and C were not statistically different ($p \leq 0.05$).

Next, to determine whether each painted wood treatment significantly affected slip resistance when compared to unpainted wood under wet conditions, a Dunnett multiple comparisons test was performed. The unpainted wood treatment was the control, and the results showed that only paint brands B and C produced a significantly higher slip resistance than unpainted wood. While the mean slip resistance for every brand of paint was greater than that of the unpainted wood under wet conditions, brands A and D were not found to be statistically different ($p \leq 0.05$).

3.2.3 Between Dry and Wet Wood Treatments

A one-way ANOVA was conducted to compare each treatment under dry and wet conditions. The results showed that for every floor treatment, slip resistance was significantly lower under wet conditions than dry.

Additionally, a one-way ANOVA was conducted to determine whether the application of paint had a significant effect on the decrement in slip resistance from dry to wet. The test compared the difference in slip resistance between dry and wet treatments of all painted surfaces to those of unpainted surfaces. The results showed that the application of paint significantly reduced the decrement of slip resistance from a dry surface condition to wet. For unpainted wood, the mean decrement in slip resistance was 0.51, and for painted wood the decrement was 0.31.

3.3 Viscosity Testing

A one-way ANOVA confirmed that not all mean efflux times were equal. A series of paired t-tests (significance level = 0.05) revealed that brands B and C yielded statistically longer efflux times than A and D, which were statistically equal.

4. Discussion

4.1 Concrete Surfaces

The results showed that floor treatment had a minor and somewhat inconsistent effect on slip resistance. Overall, various brands of concrete floor paint performed similarly within each floor condition, as the range of mean slip resistances among all floor surface treatments was relatively small.

However, relative performance across treatments changed somewhat with condition. For example, the ranking of paint brand slip resistance was not consistent in dry and wet conditions. Though brand B had the second lowest slip resistance under dry conditions, it had the highest slip resistance under wet conditions. Another notable exception was brand D, which under dry conditions produced a significantly greater mean slip resistance than brands A and B. Yet, under wet conditions, no brands of paint performed any differently.

Floor condition (wet versus dry) resulted in the most consistent differences in slip resistance among the floor treatments tested. Every floor treatment resulted in a significantly lower slip resistance under wet conditions than under dry conditions, except brand B.

While the results showed that there are some statistical differences among the slip resistances of painted and unpainted concrete surfaces between dry and wet conditions, the practical difference was minimal, as all measurements were found to be slip resistant (≥ 0.5) by an approximately 50% margin or more.

These results suggest that for concrete surfaces that are not highly finished (e.g., patio stones), the first primer/paint application does not have a substantial effect on slip resistance. It is expected that subsequent additional coats beyond the initial application recommended by paint manufacturers would generally smooth the textured surface and incrementally reduce slip resistance.

4.2 Wood Surfaces

The results revealed that under dry conditions, all painted wood produced relatively uniform slip resistant surfaces. The results also indicated that surface condition has a strong effect on slip resistance; wet conditions produced significantly lower slip resistances than dry. This suggests that one can expect a substantial decrease in slip resistance under wet conditions, regardless of the paint brand applied to the wood surface or whether any paint was applied.

Unlike measurements under dry conditions, slip resistance among wet wood treatments varied, including unpainted wood, which produced the highest mean slip resistance under dry conditions, yet the lowest under wet conditions. Therefore, the paint significantly reduced the difference between dry and wet slip resistance. To the extent that an unexpected and substantial reduction in slip resistance contributes to a slip and fall, this suggests that painted wood surfaces may be more desirable than unpainted wood surfaces.

Under wet conditions, the slip resistances of brands A and D and unpainted wood were below the level at which a floor surface is usually considered slip resistant (0.5), while those of brands B and C measured above by a small margin.

Therefore, the results of deck wood testing suggest that painted deck wood under dry conditions reliably produces a consistent slip resistant surface, while the introduction of water substantially reduces slip resistance, but less so than unpainted wood.

4.3 Viscosity of Wood Paints

The results showed that, indeed, brands B and C produced statistically longer efflux times than A and D, thus supporting the hypothesis that those paint brands that were more viscous left behind additional texture after drying, which increased slip resistance.

5. Conclusions

Paint can have a significant effect on the slip resistance of the tested floor surfaces under some conditions. While newly painted and unpainted rough concrete surfaces will usually remain highly slip resistant under wet and dry conditions, the slip resistance of wood can be substantially reduced when wet, especially if unpainted. However, no brand of paint tested reduced the mean slip resistance of wood under wet conditions. Moreover, all brands significantly reduced the difference between dry and wet slip resistance compared to unpainted wood, a desirable slip/fall prevention characteristic. Painting concrete and wood floor surfaces continues to be a viable option to delineate pedestrian/vehicle/hazardous/restricted areas and to enhance aesthetics, clean-ability, and/or durability.

6. References

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