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Effectiveness, durability and wear of anti-slip treatments for resilient floor coverings

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ABSTRACT

Adequate slip resistance of floor coverings is a prerequisite for safe walking. The incidence of slips and falls, however, indicates that insufficient slip resistance is a problem frequently arising in practice. Poor slip resistance can be a consequence of inadequate floor material and surface properties, or it can be caused by wear and maintenance. Various treatments and products are commercially available in order to improve or restore the slip resistance of problematic surfaces. In this study, the effectiveness and durability of different categories of anti-slip treatments for resilient floor coverings were investigated in a long-term field test. Repeated measurements of friction coefficients showed that anti-slip coatings initially improved the slip resistance before gradually losing their positive effect, typically with a half-life period of about 3 months. Safety coatings as well as slip-resistant adhesive tapes increased the slip resistance effectively and proved to be relatively durable, although being affected by significant mechanical wear. Scanning electron microscopy showed that the predominant wear mechanisms of the investigated floor coverings and anti-slip treatments are roughening of smooth surfaces, smoothing of rough surfaces, and intrusion of hard particles into polymers. The main and probably general result of our study is that all kinds of anti-slip treatments (coatings, tapes) gradually lose their positive effect due to wear during use.

1. Introduction

Slips and falls are a major cause for occupational and leisure accidents with personal injuries (Kemmlert and Lundholm, 2001; Leamon and Murphy, 1995; Lipscomb et al., 2006; Yeoh et al., 2013). In Switzerland with general and working populations of 8 million and 4.8 million persons, respectively, the Swiss National Accident Insurance Fund estimated 264,000 accidents within the working population in the year 2011, of which 26% were caused by slips and falls (Suva, 2013). According to the statistics of the Swiss Council for Accident Prevention (bfu, 2012), every year about 610,000 home and leisure accidents occur in Switzerland. 29% of these accidents are caused by falls on the same level, 12% by falls from a height and 12% by falls on stairs. Considerable costs for health care as well as non-productive time of persons concerned are important economic consequences of fall accidents.

In many cases, slips and falls can be attributed to floor coverings with insufficient slip resistance. Even though liquid or solid contaminants might contribute to slippery conditions, critically low friction coefficients between foot and ground are fundamentally connected with the material and surface properties of a floor covering (Chang et al., 2001b; Kim et al., 2013).

A specific problem arising in practice is that the slip resistance of floor coverings deteriorates over time owing to material ageing, surface wear, soiling, and maintenance (Leclercq and Saulnier, 2002). Derler et al. (2005) investigated the shift of friction coefficients for various floor coverings and different test sites over a period of 30 months, in order to study the short- and long-term effects of use and maintenance in detail. It was found that mechanical abrasion and coating by care products lead to the continuous reduction of slip resistance, a typical outcome for many floor surfaces in use. These results are confirmed by field studies in which the friction of floor coverings were investigated at different test sites; mechanical wear, soiling and maintenance strongly affect the slip resistance, and the complex interplay of these factors can lead to considerable local variations of the surface properties (Chang et al., 2003, 2008; Li et al., 2004).

In order to reduce safety problems associated with surface changes and low slip resistance of floor coverings, numerous anti-slip treatments and products are available on the market. Depending on the floor material and the local situation, the measures comprise grids and mats, chemical treatments, mechanical treatments such as sanding and blasting, flame and laser

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treatments, coatings, and the application of adhesive films (Skiba, 1996a).

In the present study, the slip resistance of different categories of anti-slip treatments for resilient (elastic) floor coverings were investigated in a long-term field test. Our objective was to study the effectiveness, the durability and the surface wear of different treatments and products under realistic conditions in order to gain new insights for the prevention of slips and falls. Resilient floor coverings are very common in private, public and occupational environments, but the possibilities for subsequent improvements of the slip resistance are limited because aggressive chemical, mechanical and thermal methods are not applicable.

The anti-slip treatments investigated include different types of protective coatings, anti-slip coatings, slip-resistant adhesive tapes, and safety coatings. To our knowledge, such anti-slip treatments have not been scientifically investigated so far. Treated samples of floor coverings and untreated reference samples were laid in a corridor and subjected to pedestrian traffic over a period of one year. The change of the slip resistance of the surfaces was monitored by periodic friction measurements using a portable tribometer. After the completion of the friction measurements, samples of the worn surfaces were analysed in comparison with samples of new surfaces using scanning electron microscopy (SEM) in order to draw conclusions about the involved wear mechanisms.

2. Methods

2.1. Field test design and investigated materials

Anti-slip treated samples of floor coverings and untreated reference samples were installed in an indoor corridor of an institute building (Fig. 1) in order to study their effectiveness and durability by means of periodic friction measurements over a period of one year. The pedestrian traffic in the corridor was monitored by a photoelectric beam which registered around 700 passages per day and about 250,000 passages during the entire experiment. The shoes of the persons passing through the corridor were not monitored. Mechanical wear, soiling, and periodic cleaning were the main factors the floor surfaces were subjected to.

Four types of anti-slip treatments were investigated, see Table 1:

- A protective coating (sealing), applied for the protection of the floor coverings and for an appealing aspect (PC).
- Three different anti-slip coatings, applied for the enhancement of friction; coatings with or without quartz sand, optically transparent and therefore favoured for home use (AC).
- Two different safety coatings, applied for the enhancement of friction; coatings with aluminium oxide, not transparent but grey or brick-red (SC).
- Three different slip-resistant adhesive tapes (AT).

All investigated anti-slip treatments were commercially available products which are applicable to resilient floor coverings. Representative or typical products were selected based on information of the specialised trade. The protective coating, the two different safety coatings and the three different slip-resistant adhesive tapes were applied on the floor samples according to the specifications of the different manufacturers in the laboratory. In the case of anti-slip coatings, only products of one manufacturer were available for resilient floor coverings. These anti-slip coatings were applied in the workshop of this manufacturer according to their own prescripts.

The coatings and tapes were applied to new samples of four types of resilient floor coverings: cushioned vinyl (CV), polyvinyl chloride (PVC), linoleum, and rubber with classical round pastilles (Table 1). However, for practical reasons and due to the limited test area not all treatments were applied to all floor coverings (which would have resulted in $9 \times 4 = 36$ samples), but a total of 24 different treated surfaces were laid over the length of the corridor. They are listed in Table 3 (which presents the results). In addition, an untreated piece of each floor covering was included in the experiment as well. Finally, two areas of the untreated linoleum floor covering, as it was in use in the corridor since 3.5 years at the beginning of the experiments, were used as reference areas. In total, 30 different sections were present in the corridor. A standard PVC floor covering (Table 1) was used for reference measurements in the laboratory.

2.2. Friction measurements

The slip resistance of the surfaces was determined using the portable tribometer FSC 2000 (Fig. 1) which was discussed by Skiba et al. (1994a, 1994b) and Chang et al. (2001a). The device was operated at a velocity of 0.2 m/s over a distance of 0.3 m in

Fig. 1. Long-term experiment concerning the effectiveness and durability of anti-slip treatments (left) and the portable tribometer FSC 2000 used for friction measurements (right).