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Laser surface modification of structural glass for anti-slip applications

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ABSTRACT

The use of soda-lime silicate glass as a structural element has become frequent in modern buildings. The load-bearing applications of glass in floors, footbridges, terraces, or stairs require an optimal combination of non-slippery properties of the surface, element weight, and strength, and structural glazing can be compromised by the incorporation of laser surface patterned ornamental motifs. Laser surface modification has significant advantages for selective surface area modification; nevertheless, the mechanical performance of the processed glass remains unknown, which precludes reliable structural calculations and employment in construction. In this study, we investigated the surface modification of annealed and heat-strengthened glass via CO_2 laser scanning for the production of rough anti-slip surfaces. The surface roughness and the reduction of the bearing load strength were quantified. Slip resistance-enhanced surfaces with roughness values (Rz) above 20 µm and characteristic bending strength preservation up to 74% were obtained. The results pave the way for the use of laser surface-modified plates in laminated glass elements with optimized strength calculation and weight reduction.

1. Introduction

The use of glass in architecture has increased during the recent decades owing to its transparency, durability, and availability. Currently, no modern building is conceived without the use of glass, and its application as a secondary structural element has become frequent. In 2017, more than 10 million tonnes of flat glass was produced in Europe, approximately 70% of which was float glass for the building industry [1]. In glass load-bearing applications such as floors, steps, and glass barriers, the risk of damage due to element failure is elevated, and high levels of structural safety and reliability are demanded [2,3]. Slipperiness is involved in 40%–50% of the fall accidents, and slips -the worldwide leading cause of non-fatal injuries- have important health and economic impacts [4–8]. Thus, the horizontal glazing on floors, footbridges, terraces, and stairs requires slip-resistant surfaces to prevent falls in presence of contaminants. Nevertheless, the modification of the upper surface of these elements involves the alteration of the glass strength due to the induction of stress concentration and additional crack nucleation points. For instance, the use of patterned glass frequently implies a 55% reduction of the annealed glass expected strength, as well as the inclusion of a surface profile factor that reduces the calculated design value by 25% [9–11]. Moreover, in some modern applications of glass laminates, such as glass elements in cruise vessels, weight reduction is a matter of great significance, and oversizing must be avoided [12]. To perform accurate structural calculations and to implement the structural failsafe concept in glass elements, with an optimal combination of the slip resistance, weight, and element strength, it is necessary to determine the impact of surface processing on the mechanical properties [2,13].

Current surface processing methods considered by structural glass standards include mechanical polishing, grinding, etching, and sandblasting. However, these procedures have significant limitations, such as long processing times, the use of dangerous substances, low surface-area selectivity, required mechanical contact, the production of dust, and a noisy working environment [14,15]. Among the different techniques for material surface roughening and texturing, laser surface modification has potential advantages as a non-contact method for selective surface area treatment [16–18]. The use of a femtosecond pulsed laser was reported for the production of microholes on fused silica glass surfaces, and for the texturing of superhydrophobic surfaces on soda-lime silica glass [19–21]. The use of an excimer laser combined with phase masks was reported for the surface structuring of silica glass fibre [22]. Nevertheless, the mechanical performance of the laser-processed glass remains unknown, precluding reliable structural calculations and its employment in construction structural elements.

In this study, we investigated the surface modification and

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