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Use of Technical Textile to Obtain Sustainable Easy to Clean Concrete Surface

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Abstract

To keep concrete building façades clean from dirt and algal growth intense maintenance is needed. An easy to clean façade is an aspiration of designing future building materials. Application of technical textile as building material is to date mainly focused on textile as reinforcement material of concrete or mortar. Textile reinforcement is used for production of light weight prefabricated elements that possess comparable and competitive mechanical properties to non-textile reinforced composites. The goal of this study was to modify a concrete surface by casting concrete in textile mould, giving the surface fine structured imprint and impregnate it with two different hydrophobic agents. The analysis of the surface properties was performed by means of contact angle measurements, confocal laser microscopy and optical microscopy. Three different textiles including one nanostructured were used for moulding and imprinting. The results demonstrated significant variations in hydrophobicity and oleophobicity between the samples. Micro- and nano-structuring of the surface did not result in hydrophobicity by itself therefore a hydrophobic treatment was necessary to achieve water- and oleorepellence. After the treatment all samples became hydrophobic but not oleophobic. Only a few samples reached superhydrophobic effect (CA $\geq 150^{o}$). The nano imprinted pattern combined with the nano-impregnation gave most promising results.

Keywords: surface treatment, textile imprint, Lotus effect, concrete, mortar, easy to clean, contact angle, confocal microscopy

1 Introduction

Technical textiles are assumed to have a potential to be used for enhancement of self-cleaning properties on the concrete surfaces. Concrete buildings, brick façades and roofing tiles take on a greenish or grey coloured surface after exposure to outdoor climate. This often causes high maintenance costs. A solution towards decreased maintenance might come from an analysis of self-cleaning mechanisms occurring in the nature, where e.g.:. plants are found with spiky surface structures covered with hydrophobic waxes, making dirt deposits fall off with rain water droplets. One such solution in the nature is the Lotus plant, having a self-cleaning property. By introducing the spiky textures in combination with a hydrophobic coating on the concrete surface a nature inspired self-cleaning building façade could be developed. It is assumed that if a rain drop hits the concrete surface it will immediately run off. On its way down the drop will catch dirt deposit from the surface, and thus leaving the surface clean. The reason for this is the minimal contact angle between the surface and a droplet of water [1]. To date very few attempts have been made to produce this type of concrete surfaces. In a Danish study a micro structuring inspired by the Lotus-plant was carried out on a concrete tile by means of laser notching. Subsequently, a wax coat was applied to the tile surface in order to make the material hydrophobic. Concrete is a hydrophilic material meaning that a micro structuring of the surface will increase the spreading of water drops and thereby enhancing problems with dirt deposition. Therefore, in order to take advantage of the Lotus-effect it is necessary to combine the micro structuring with a hydrophobic coating. The Danish pre-study showed that a good structure could be achieved and that the Lotus inspired self-cleaning effect possibly could be reached. However, the method turned out to be very time-consuming thus commercially unfeasible.

The finely textured textiles can give specific pattern to a concrete surface in a cost effective, sustainable and practical way. Textiles are flexible to handle, lighter, cheaper and when used as moulds, they alter a concrete surface with precise prints of the textile design. Additionally textiles might have some advantages in the hardening process by bringing water out through the breathable textile mould. This gives lower water to concrete ratio in the surface concrete, giving higher strength, shine and lower porosity [2]. Self-cleaning technical textiles have been developed to mimic the nature via nanostructured surface treatment [3] and are manufactured either by application of fluorocarbon based treatments, or photocatalytic nanotechnology [4]. Among the later one, titanium dioxide treatments are the most commonly researched and a number of production technologies have been employed [5-6].

The aim of textile moulding has so far been used for the new interesting architectural applications, easier manufacturing and possibility of 3D flexible shaping of concrete [7-8].

The aim of this project was to obtain and evaluate the feasibility of different technical textiles for production of self-cleaning concrete surfaces with well defined patterns on the concrete surface.

2 Samples

For the study, three different textile materials were used. All textiles were synthetic fibre material, but with a variety of density, patterns, surface pattern and breathability. The textiles could simply be named after their main chemical and physical characteristics, as:

1) Thin poly-acetate (PA) fabric
2) Lining poly-ethylene (PE) fabric
3) Nanostructered PET fabric

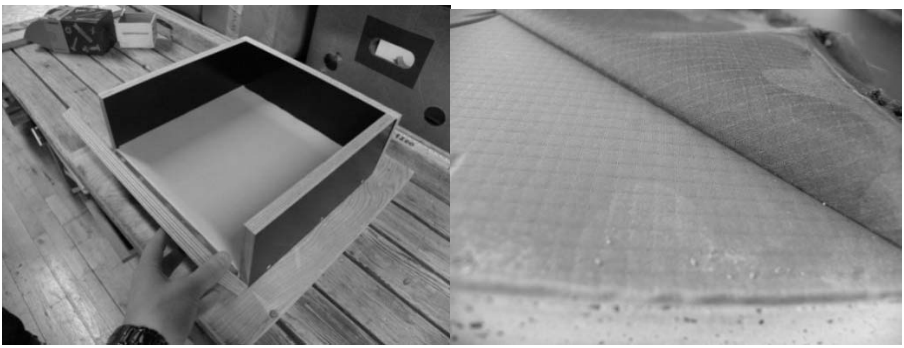

Figure 1: Moulding form with the stretched textile in the bottom (left) and the removal of the textile from the concrete surface (right)

The textile materials were placed and tensioned in a wooden form of size 30x30x10 cm (Figure 1). The samples were prepared of a cement type Aalborg Rapid and in order to minimize variations of the quality all were made from the same batch of concrete. The textile was removed from the cast concrete after 24 hours and then all samples were wrapped in plastic foil and stored in a climate room with 65±5% of humidity and a temperature of 20±2°C for 28 days, which is the time needed for the curing process of concrete. After hardening and conditioning for seven days in a room climate one half of every specimen was coated with a hydrophobic product (or agent), and the other half left without any treatment. Two hydrophobic products were used: Nano (fluorinated silane) and TEOct (triethoxyoctylsilane).

3 Test methods

The analysis of 3D topography of the textile imprinted on the concrete surface was done by means of the confocal microscopy and the surface pattern by the optical microscopy. The hydrophobic and oleophobic effects were analysed by means of an OCA-20 Contact Angle System from Data Physics Instrumentsusing the static sessile drop method. Water and 1-bromonaphthalene drops were placed at six different points of one specimen, and the contact angle was measured immediately after droplet placing at about 21 °C. The average values of measured contact angles have been used for data interpretation. During this test, the size of liquid drops was kept constant at about 3 µl.

4 Results and discussion

The use of textile fabrics for moulding resulted in the physically and aesthetically interesting textures imprinted on the concrete specimens. The concrete surface has attained the texture of the material. To give an impression of the surface modification, the selected images are shown in Figures 2-4 also including measurements of the 3D roughness.

The goal was to achieve a variety of rough surfaces with a repeatable pattern that could mimic to some degree the Lotus plant. The observation of the imprints complied with the assumption that the textile used for the moulding could perfectly modify the concrete surfaces. However, the observed patterns varied depending on the characteristics of the used textiles. The mimicking of the natural surfaces is also variable of the particle size of the concrete. The measurements of the roughness indicated significant differences between the patterns:

1) The PA fabric gave in general 45 µm high tops and the distance between the tops was ca 0.3 mm (Figure 2).
2) The PE fabric created ca 40-50 µm high tops and the distance between the tops was ca 0.7 mm (Figure 3).
3) The nanostructured fabric (PET) resulted in nano-sized texture of the concrete surface. The tops were ca 10-100 µm high tops and the distance between the tops was very dense, ca 0.02 mm (Figure 4).

The surfaces, in most cases, became aesthetically attractive, except for some samples where the textile was not enough stretched and bubbles were created.

The results from analyses of hydrophobicity and oleophobicity are presented in Table 1. All reference samples, without any hydrophobic treatment, were hydrophilic with the water contact angle between 0-20 ° .

However, all samples became hydrophobic after the treatment with fluorinated silane and triethoxyoctylsilane. The superhydrophobicity was only observed for the concrete surface created by the imprint of the nano-fabric and impregnated with the Nano product (fluorinated silane). It should be pointed out that the measurement of the contact angle for these samples was very difficult due to the instability of the placed water drops on the nano tops of the concrete. The water drops had a tendency to fall off of the tops. Therefore it is assumed that the water contact angle could be in reality higher for these samples. The same problem was observed measuring the oleophobicity for Nano treated surfaces. In general, the oleophobicity became lower for all samples. Clearly oleophobic surfaces were obtained after the treatment with a Nano product especially for the PA and PE surface. However, samples treated with the triethoxyoctylsilane displayed no oleophobicity.

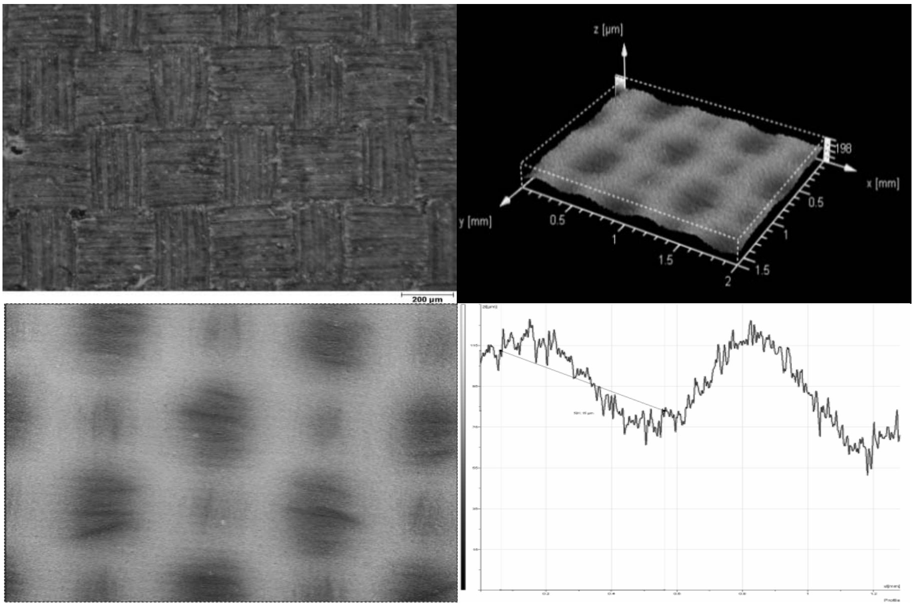

Figure 2: Optical microscope image of the imprint of the concrete surface moulded in PA textile (upper left); 3D view (upper right and down left); roughness (down right)

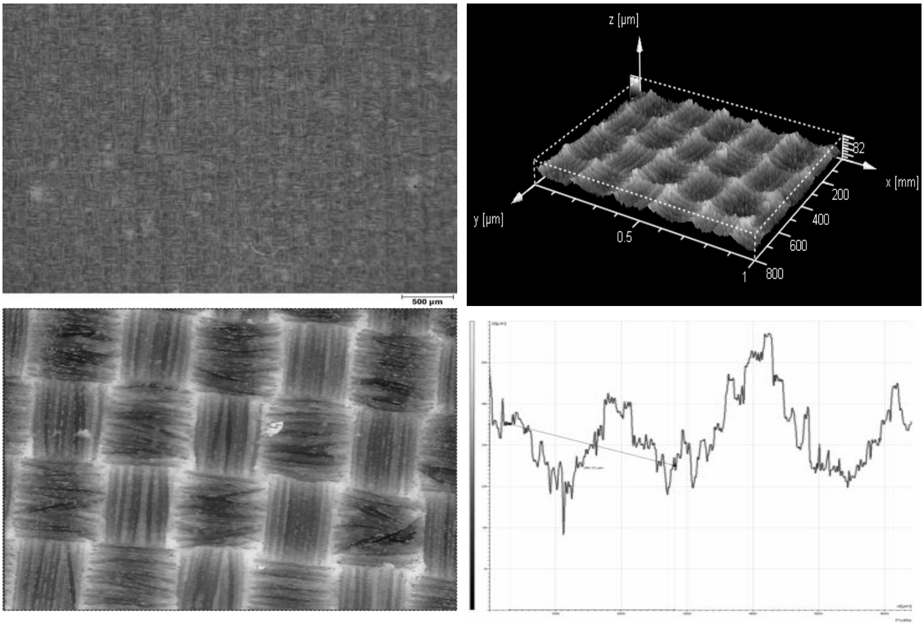

Figure 3: Optical microscope image of the imprint of the concrete surface moulded in PE textile (upper left); 3D view (upper right and down left); roughness (down right)

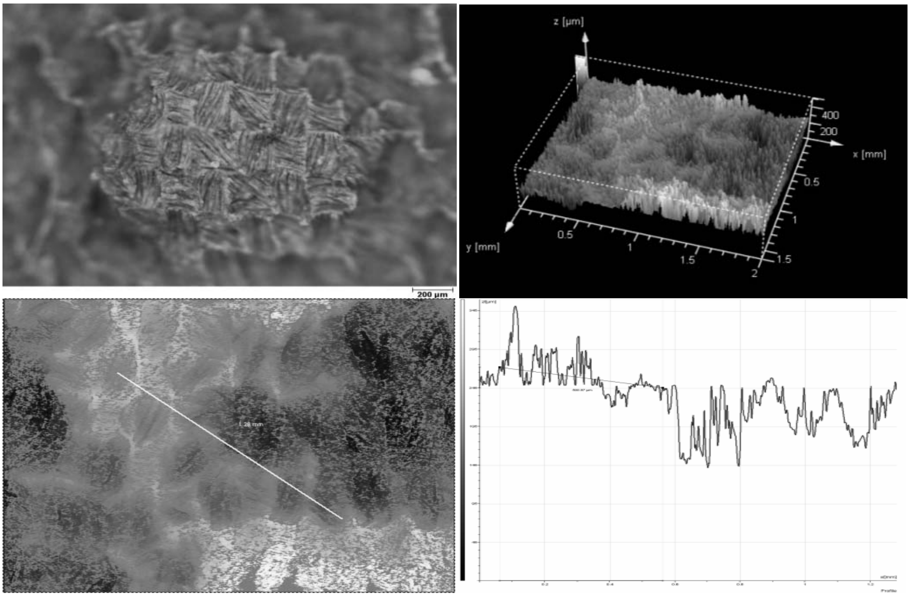

Figure 4: Optical microscope image of the imprint of the concrete surface moulded in PET nano textile (upper left); 3D view (upper right and down left); roughness (down right)

Table 1: Hydrophobicity (water) and oleaophobicity (1-Bromonaphthalene) evaluated by the static contact angle measurement (CA)

Sample	Contact angle CA (°) Nano*	Contact angle CA (°) TEOct**	Contact angle CA (°) Nano	Contact angle CA (°) TEOct
	Hydrophobicity		Oleophobicity	
PA	140	116	125	21
PE	136	137	128	68
Nano (PET)	150	132	104	51

*impregnation Nano; ** impregnation triethoxyoctylsilane

5 Conclusion

The obtained results showed that the quality of the imprint depends very much on the textile fibre, yarn, fabric construction and possible fictionalisation of the fabric with different treatments. Additionally, the surface quality and its appearance are also dependent on the type of concrete/cement used. The results indicated that a suitable combination of the fabric, in this case of nano-sized fabric, with the fluorinated silane could mimic the Lotus effect. However, the concrete surfaces were not tested for dirt repellence yet and conclusions concerning Lotus-inspired self-cleaning effect on the surface cannot be stated.

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