



## POTENTIAL APPLICATIONS OF SELF-CLEANSING NANO LOTUS LEAF BIOMIMICKED COATING IN DIFFERENT CONSTRUCTION SECTORS

Safiuddin, Md.<sup>1,3</sup>, Hossain, K.<sup>2</sup>, and Collins, C.M.<sup>2</sup>

<sup>1</sup> Angelo Del Zotto School of Construction Management, George Brown College, Toronto, Ontario, Canada; Department of Civil Engineering, Ryerson University, Toronto, Ontario, Canada

<sup>2</sup> Department of Civil Engineering, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, Newfoundland and Labrador, Canada

<sup>3</sup> [safiq@yahoo.com](mailto:safiq@yahoo.com) ([corresponding author's email](#))

**Abstract:** Lotus leaf has a nanostructure with randomly oriented cone-like protrusions (nano-mountains) and nano-valleys between nano-mountains. The nanostructured lotus leaf surface possesses an extremely high water-repelling capacity due to super hydrophobic property. This is well-known as "lotus effect", which has been mimicked by applying certain recently developed coating products. The "lotus effect" makes nano lotus leaf biomimicked coating suitable for applications in different categories of construction. The benefits of nano lotus leaf biomimicked coating are emphasized in this paper. It highlights the possible applications of nano lotus leaf biomimicked coating in various construction sectors, including buildings and infrastructure, such as roads, bridges, tunnels and sewers. In particular, the self-cleansing effect of nano lotus leaf biomimicked coating is focused to reveal its applicability in different types of construction. In addition, the self-cleansing mechanism of nano lotus leaf biomimicked coating for the protection of substrates is explained with illustrations. The present study also includes the different types of substrate, the techniques for the preparation of substrates, and the application methods for installing nano lotus leaf biomimicked coating on various substrates. Above all, some recommendations are given to improve the performance of nano lotus leaf biomimicked coating.

### 1 INTRODUCTION

Nanotechnology is a recent thrust in materials science although it has been in nature since long. It deals with the "boundary between atoms and molecules and the macro world, where ultimately the properties are dictated by the fundamental behaviour of atoms" (Ashby et al. 2009). Nanotechnology involves the behavior of materials at nanoscale. A radical change might occur in material performance and new applications in construction sectors would be possible if nanotechnology can be applied innovatively.

Current research shows that lotus leaf itself is using nanotechnology to obtain non-wetting, super water-repellent or super hydrophobic surface for self-cleansing (Kumar et al. 2011; Mozumder et al. 2011; Neinhuis and Barthlott 1997). The self-cleaning property of lotus leaf is linked with its special surface structure. Lotus leaf has a nanostructure with randomly oriented cone-like protrusions (Cheng et al. 2006; Li et al. 2017; Stratakis et al. 2009; Yamamoto et al. 2015), as shown in Figure 1. The nanostructured lotus leaf surface possesses an extremely high water-repelling capacity, as illustrated in Figure 2 and Figure 3, due to super hydrophobic property (Button et al. 2004, Zorba et al. 2008). As a result, lotus leaf powerfully

repels water, which carries away dirt as it rolls off the leaf, allowing the lotus to remain clean despite growing in turbid water (Robbins, 2001). This is widely known as "lotus effect" that has been mimicked on different substrates using some recently developed coating products. The "lotus effect" makes nano lotus leaf biomimicked coating suitable for manifold applications in different construction sectors such as buildings, bridges, pavements, and drainage infrastructure (Gonzalez et al. 2013, Gonzalez et al. 2016, Zhang et al. 2016).

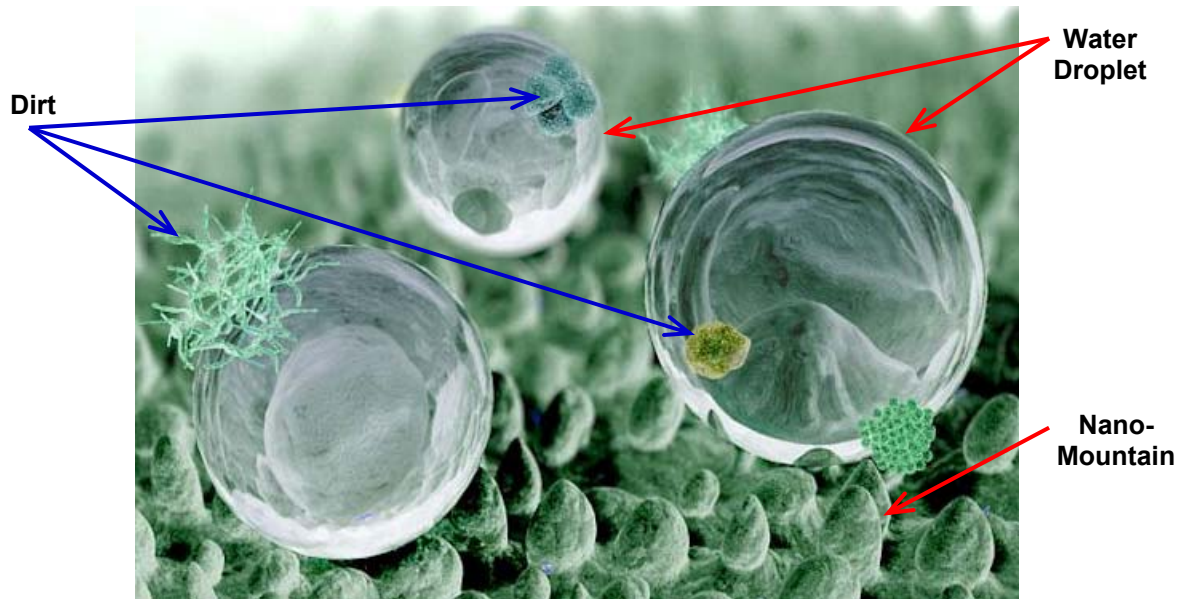


Figure 1: Water drops suspended on nanostructured lotus leaf (adapted from Rame-Hart 2015)

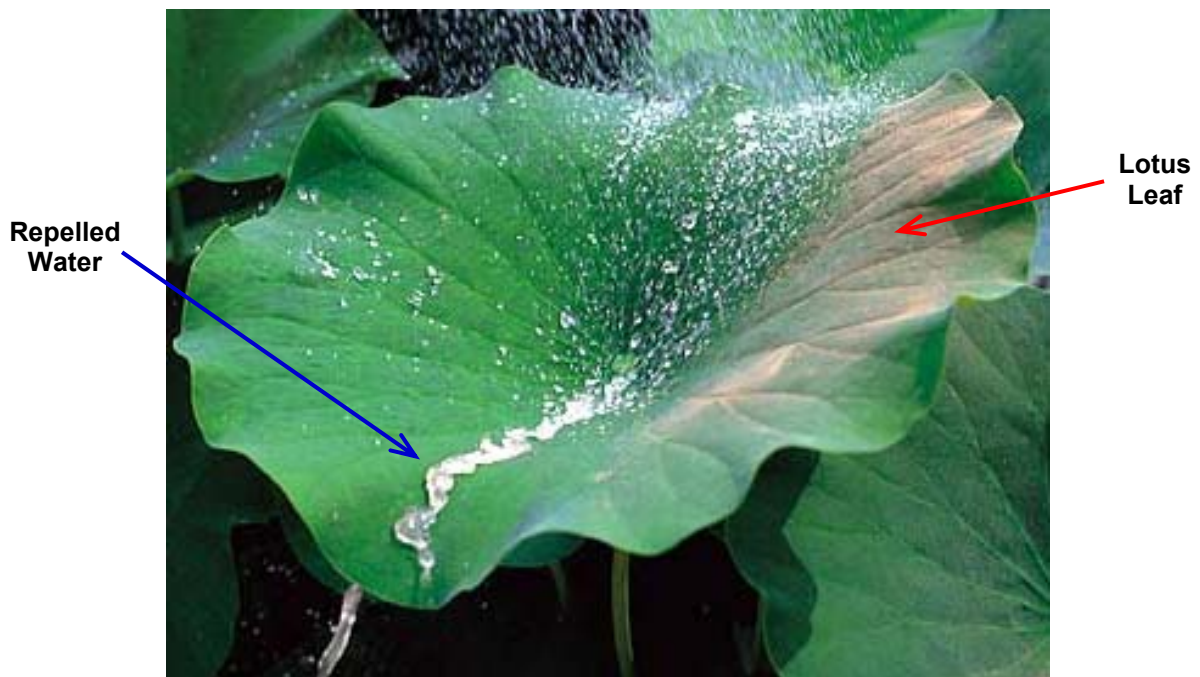


Figure 2: Natural cleansing of lotus leaf (adapted from Design and The Universe 2017)

This study focuses on the possible applications of nano lotus leaf biomimicked coating in various construction sectors. The working mechanisms and benefits of nano lotus leaf biomimicked coating are discussed in this paper. The self-cleansing effect of nano lotus leaf biomimicked coating is particularly highlighted to reveal its applicability on different structural systems. Furthermore, this paper imparts various substrate types, substrate preparation techniques, and application methods for applying nano lotus leaf biomimicked coating. Especially, some recommendations for improving the performance of nano lotus leaf biomimicked coating are given in this paper.



Figure 3: Cleaned lotus leaf in dirty water (adapted from Rame-Hart 2015)

## 2 SELF-CLEANSING MECHANISM

Lotus leaf has super hydrophobic surface. It remains clean and dry in spite of frequent exposure to dirt and rain (Forbes 2008). This is because lotus leaf contains nano waxy bumps (nano-mountains) and nano-valleys between them that prevent the accumulation of dirt and water. The nano-valleys between the nano-mountains are much smaller than the dirt particles. Therefore, the dirt particles stay on the tops of the nano-mountains since they cannot get into the nano-valleys. The nano-valleys between the nano-mountains are also too small for water droplets to get into, hence the water drops stay suspended on the tops of the nano-mountains creating very high surface tension.

Surface tension generally affects the top part of a water droplet – the bottom part sticks to the material with a flatter contact surface. In the case of lotus leaf, nanoscale bumps or nano-mountains prop the water drops up on the leaf surface, thus making them entirely surrounded by air (Cheng et al. 2006; MRSEC Interdisciplinary Education Group 2017). This induces surface tension in all sides of the water drops and makes them up even more on the leaf. As a result, the water drops attain a spherical shape with a minimum adherence to the leaf.

Water drops stay up with a contact angle in the super hydrophobic range of around  $160^{\circ}$  when rainfall occurs on lotus leaf (Cheng 2005; Cheng et al. 2006; Li et al. 2017; Yamamoto et al. 2015). In this position, the water drops are so loosely adhered to the leaf surface with a little contact area that any tiny movement or minor disturbance causes them to roll easily off. Consequently, the water drops swiftly roll off the lotus leaf gathering dirt along their way, thus making the leaf self-cleansing. A similar self-cleansing mechanism

works in the case of nano lotus leaf biomimicked coating when it is applied on different structural elements or systems of bridges, pavements, and buildings. It has been illustrated in Figure 4 considering the exterior wall of a building. The wall remains clean because the water droplets cleanse the dirt when they roll down the vertical surface coated with nano lotus leaf biomimicked coating. Also, the penetration of water into the wall is substantially decreased because the water droplets swiftly move and cannot pass through the nanostructure of coating.

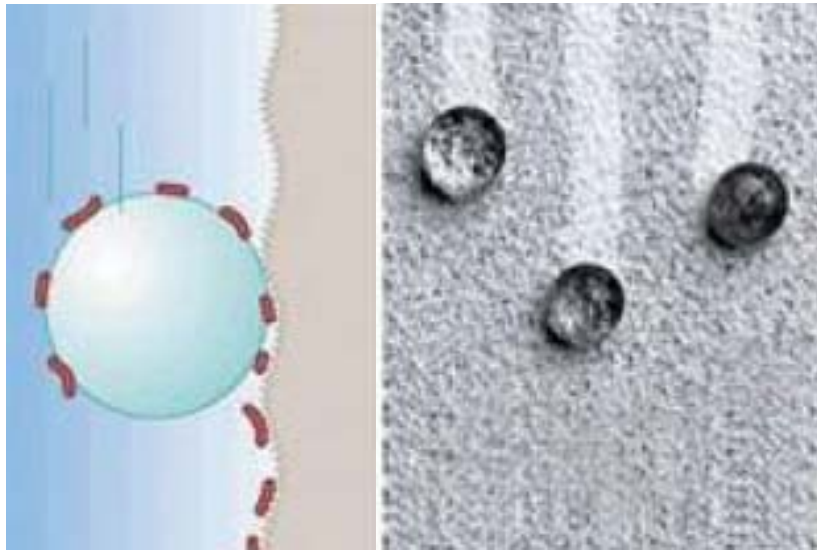


Figure 4: Self-cleansing mechanism of nano lotus leaf biomimicked coating (adapted from Design and The Universe 2017)

### 3 POTENTIAL APPLICATIONS AND BENEFITS

Super hydrophobic nano lotus leaf biomimicked coating has potentials for manifold technical applications such as self-cleaning window glasses or paints (Cheng et al. 2006; Li et al. 2017) and anti-corrosion metal surfaces or corrosion barriers (Vazirinasab et al. 2018). In fact, some such products, e.g. Lotusan (Sto Corporation 2017) and Hydrofoe (Lotus Leaf Coating 2018) are already commercially available in the market. A number of potential applications and associated benefits of using nano lotus leaf biomimicked coating are depicted hereafter.

- Nano lotus leaf biomimicked coating can be applied on the exterior walls or facades of buildings, as shown in Figure 5 and Figure 6, to minimize the dampness due to water sorption and to obtain a dust-free, self-cleansing wall surface. Water droplets will roll down swiftly with dirt and dust will not be collected on nano lotus leaf biomimicked coating because of its high water repellence. The buildings painted with a nano lotus leaf biomimicked coating product will self-cleanse during rain and stay dry due to the lotus effect. This one of a kind coating also resists the growth of mold, mildew and algae on the building surface.
- It can be applied on the exterior windows to keep them self-cleaned as shown in Figure 7. When water droplets will move down, they will carry the dust particles on their way, as they do on wall, thus keeping the windows self-cleaned.
- Nano lotus leaf biomimicked coating could be applied as a water-repelling coating on pavements for fast drainage, thus allowing them be dry quickly during wet season; this would contribute to safe driving and enhanced durability. For similar purposes, it can also be used on sidewalk for safe walk; however, it needs to be ensured that the friction property of the pavement surface is not affected in the presence of nano lotus leaf biomimicked coating.
- Nano lotus biomimicked coating can be used on the roof of buildings to accelerate the drainage of snow-melt water or rainwater; hence, it will minimize the algae or bacterial growth and thereby improve



the health of buildings for longer service life; also, the hydrostatic stress on the roof caused by water ponding will be reduced due to accelerated drainage in the presence of nano lotus leaf biomimicked coating.

- It can be used as a floor finishing material to produce water-repellent floor for enhanced service life. Water is involved with the damage mechanisms of many flooring materials. Water repellence will reduce the penetration of water into flooring materials and thus increase the service life of floor system with better durability.



Figure 5: Application of nano lotus leaf biomimicked coating and its effect on the facade of a building (adapted from Sto Corporation 2017)



Figure 6: Comparison of conventional and nano lotus leaf biomimicked coating (adapted from European Consumers Choice 2017)

- Nano lotus leaf biomimicked coating can be applied on the inner surface of building drainage structures, such as storm and sanitary sewers, to enhance the flow of storm water, waste water or sanitary waste by reducing surface friction.
- It can be applied on tunnel lining for keeping the tunnel structures dry and to resist the growth of mold and mildew in tunnels.
- Nano lotus leaf biomimicked coating can be considered for use in culverts to enhance the flow of overland water from upstream level to downstream direction. For similar reason, it can also be used in irrigation channels.
- It can be used on different components of bridge structures such as pier, deck, railing, divider, and abutment to enhance their service life with greater water resistance.
- Nano lotus leaf biomimicked coating can be applied on different metal and alloy surfaces as a corrosion barrier to improve their resistance against corrosion through super hydrophobicity.
- Due to super water-repellency of nano lotus leaf biomimicked coating, water droplets will not be retained on the glass surface; therefore superior optical clarity will be achieved in many applications such as windows, skylights and glazed curtain walls.



Figure 7: Comparison of conventional and self-cleaning glasses (adapted from Pro Clean Window 2018)

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## 2 SUBSTRATE TYPES

Nano lotus leaf biomimicked coating can be applied on manifold substrate materials such as concrete, stucco, metal, glass, fiber cement board, masonry, exterior insulation and finish system (EIFS), and primed or pre-painted wood depending on the purpose of applications. In any kind of application, it must be ensured that nano lotus leaf biomimicked coating is well-adhered with the substrate to avoid premature blistering and de-lamination. A suitable bond coat as a primer can be used before applying nano lotus leaf biomimicked coating to guarantee good adhesion.

### **3 SUBSTRATE PREPARATION TECHNIQUES**

Substrates must be cleaned to remove dirt, salt, and oil or grease. If the coating is applied on old surfaces, they must be free of mildew, algae, and efflorescence. The substrates must not have any contaminants on the surface that might affect the adhesion of nano lotus leaf biomimicked coating. Pitting, spalling, cracking, blistering, peeling, delamination, water damage, laitance, or any other surface defects should be repaired appropriately before applying the primer on substrate materials. Also, the substrates must have an adequately rough surface profile for the required level of coating adhesion (Safiuddin 2017). Abrasive-blasting, shot-blasting, high pressure water-blasting or at least sanding should be employed as per requirements for the preparation of substrates to achieve good adhesion of coating.

### **4 COATING APPLICATION TECHNIQUES**

Nano lotus leaf biomimicked coating can be applied by dipping, brushing, rolling, spraying, and spinning as per applicability to the substrates. A variety of spraying equipment such as industrial sprayer, aerosol can, and non-aerosol pump sprayer can be used to spray-apply nano lotus leaf biomimicked coating. Acrylic-based compatible primer should be used on concrete, stucco, and masonry substrates before applying nano lotus leaf biomimicked coating. It can be applied onto the primed substrate in two coats. The first coat must be dried before applying the second coat to obtain the targeted surface structure and thickness of coating.

### **5 RECOMMENDATIONS**

- An appropriate nano lotus leaf biomimicked coating product should be selected considering the type of substrate; it must be ensured that the coating and the substrate are compatible to provide better adhesion for improved performance.
- The substrate must be properly cleaned and made free of any contamination before applying any nano lotus leaf biomimicked coating product.
- The substrate must have an adequately rough surface profile for the required level of coating adhesion to obtain an extended service life of the treated surface.
- Nano lotus leaf biomimicked coating should be applied on the primed substrate surface for better performance and economy.
- A suitable applying technique such as dipping, brushing, rolling, spinning, or spraying as per the guidelines of the product's manufacturer should be used for the enhanced performance of nano lotus leaf biomimicked coating.
- The bond strength or adhesion of nano lotus leaf biomimicked coating after applying on the targeted substrates should be examined for extended service life.
- Lab-based experimental studies and monitoring of the field performance are required to validate the potential applications of nano lotus leaf biomimicked coating for guaranteed benefits in different construction sectors.

### **6 CONCLUSIONS**

This study was carried out to explore the potential applications of nano lotus leaf biomimicked coating in various construction sectors. The self-cleansing mechanism of nano lotus leaf biomimicked coating has been explained in this study. The types of substrate, the preparation techniques for substrates, and the applying techniques of nano lotus biomimicked coating are also discussed in this study. Furthermore, some recommendations for improving the performance of nano lotus leaf biomimicked coating are given. Based on the present study, the following conclusions are drawn:

- Nano lotus leaf biomimicked coating significantly lessens the ingress of water into various substrates because of its super hydrophobic nature, and thus it minimizes the damaging effects of water involved in many deterioration mechanisms.

- Self-cleansing mechanism, associated with high surface tension and a contact angle of about  $160^\circ$ , is achieved in the case of nano lotus leaf biomimicked coating due to its special surface texture with nano-mountains and nano-valleys.
- Nano lotus leaf biomimicked coating has good potentials for application in different structural elements or systems of buildings, pavements, bridges, and drainage infrastructure.
- Nano lotus leaf biomimicked coating products would perform better when they possess good bond strength or adhesion with the primed substrates.
- Appropriate selection of coating products, proper surface preparation, compatibility of coating products, and evaluation of coating adhesion before application will be conducive to improve the performance of nano lotus leaf biomimicked coating.

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