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APPLİCABİLİTY OF LOTUS LEAF MODEL ON ROAD PAVEMENT

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A b s t r a c t

One of the plant types that is started to be used in technology recently is lotus. With understanding of nano structure of lotus leaf, it has been started to be used in building facing technology and other many areas. Due to roughness in nano dimension on lotus leaf surface, the leafs of plant never get wet. As water drops slip around leaf, they also take dust, mud or other dirt along. The reason of lotus leaf always seeming dry and clean is nano model on its surface. The properties of lotus leaf can be used in pavement technology. So pavement surfaces can always be dry and clean. It is known than snow and rain damage pavement surfaces. By applying lotus model on pavement surfaces, rigid pavement surface that are resistant to snow and rain, can be constructed. In this study the applicability of nano surface model of lotus leaf on pavement surfaces was examined.

1. Introduction

It is known that the road pavements are affected negatively by the climatic factors such as snow and rain. The flexible and rigid road pavements are exposed to the abrasions due to raining. The abrasions can occur on the pavement surface as a result of the highway's contamination due to the powder, the sludge, the leakage of vehicle fuel oil and oil. Moreover, the transportation problems arise from the snowing onto the road pavement. The snow cleaners and chemical salts are used in cleaning the snow on the road. The snow cleaner

vehicles and chemical salts damage on the road pavement and also, they increase the economic expenses. It is possible to remove rain and snow water in the natural ways without damaging on the road pavement, and to clean the dirt such as the powder, sludge and oil on the road. The necessary thing to be done is to imitate the nature. One of factors which removes water and also which cleans the surface that the water rolls as going away is the lotus leaf.

The lotus leaves have got the property to be able to clean themselves. The hard stains which are applied by the researchers can be easily cleaned by the raindrops. After the nano structure of its leaf was learnt, it started to be used in many fields such as the building Pavement, planes, cars and textile (Özdoğan *et al*. 2006). The lotus plant is accepted as the symbol of purity in the various religions in Asia. Its reason can be stated as the capability to clean itself which is available in the lotus plants (the lotus effect). The leaves of this plant don't definitely get wet thanks to the sunk and stigmatic structures at the micron and nano level on its surface, and the water drops carry the sludge, small beetles and other pollutions on it while the drops slip to the soil with the leaf's curved shape. Thus, the leaves of lotus plant are very clean although it grows in muddy rivers and deserts. The scientists who work in the nano-science have developed the new methods by imitating the property of lotus leaf in order that the paints, fabrics and many other surfaces can remain dry and also can get the property to be able to clean themselves (Süzer, 2006).

The Nelumbo Nucifera is known as a symbol of cleaning in many Asian countries as the leaves have got property to be able to clean themselves. Even if it gets dirty by the sludge, any dirtiness isn't seen. When the SEM photos of lotus leaves were reviewed, it was observed that nano and micro structures provided the roughness to the surface (RTD Info, 2005). Barthlott, Wilhelm and Christoph Neinhuis found that the lotus leaf's surface and sprouts are covered by a thin cuticula. The cuticula includes an insoluble polymer (cutin) and waxes. Epicuticular wax comprises the characteristic micro structures in many plants. The wax layer comprises a multifunctional interface between the plant and environment, it affects on the light reflection with the air flow and it provides high water repellency. When water contacts on this kind of surfaces, it creates dribbles and it goes through the leaf as rolling. Barthlott, Wilhelm and Christoph Neinhuis found that there was a connection between the water repellency and self-cleaning. The lotus effect can be seen in many plants and it depends on the hydrophobic surfaces in the micro structure. While the contact angle is 110° on the smooth surfaces, the roughness in the micron diameter reaches to the super hydrophobic with 170° contact angle. The field which is necessary for the water's adhesion can be minimized in such cases and the air is caged between the drop and each of wax crystal. This case is valid for the particles. The contact field between the particle and rough surface gets a minimized manner and particles can hold on to the water drop which rolls on the leaf's surface. Particles can be removed with little rain through the super hydrophobic surface

independently from the size and chemical structure. The effect of self-cleaning arises from the nano structure of surface and its hydrophobic property. This effect which occurs depending on the lotus plant's leaves' physicochemical properties can be applied onto the technical surfaces and the studies related to the practices of surface dressings have gone on. The lotus-effect surfaces are surfaces which can be cleaned by the water mobility, have a hydrophobic and nano structure. This kind of surfaces is stated generally with the words such as “easy to be cleaned", “dirt repellent", “dirt-proof", "self-cleaning" or "the lotus-effect ". Each of these explanations is similar to the other one and they are different from each other actually, and they are used to explain the motion of a surface. The surfaces which are easy to be cleaned are the hydrophobic and smooth surfaces which have been known well for years. As it is known, it is not difficult to remove the dirt from this kind of surfaces. “The lotus-effect” and “the effect of self-cleaning” are used in a similar way. There is no need for any effects which will be done by people for the cleaning of the surface which gets dirty (http://nanotechweb.org/articles).

2. Hydrophobic Surface

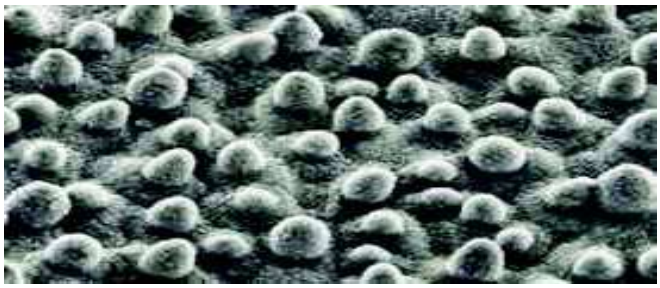
Abzamson described the hydrophobicity in 1982 that it creates the surface of the Lotus leaf and water drop's 150° contact angle together. However, he didn't reveal the reason of self-cleaning action. In 1997, Wihhelm Barhlott who is a botanist from The University of Bonn became the first person to define the self-cleaning action of Lotus leaf (http://nanotechweb.org/articles). As the water drop is seen at Fig. 1, it doesn't cling on the lotus leaf (Özdoğan *et al*. 2006).

Fig.1. The water drop on the lotus leaf

Source: Tekstil ve Konfeksiyon. Nanoteknoloji ve Tekstil Uygulamalari, Özdoğan E., Demir A. G. A., & Seventekin, N., 2006, p. 3.

The Lotus leaf compels water to make a drop. The Lotus leaf has got hydrophobic top surface and nano-structured surface (Fig. 2)

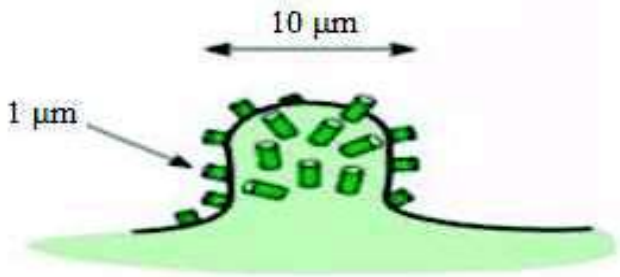
Fig.2. Nano- image of the lotus leaf



Source: Lotus Effect-Surfaces, Macromol. Symp., Nun E, Markus O. and Schleich B., 2002, 187, p. 677- 682.

Riddles on the lotus leaf have got a nano-structured surface and this case is seen at Fig. 3 (Nun et al. 2002).

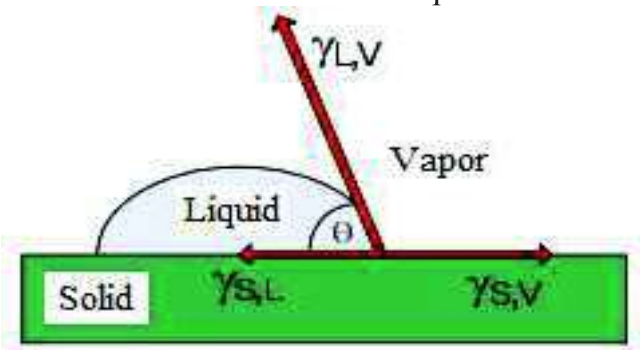
Fig.3. The simulated nano sizes of the lotus leaf's stigma



Source: Lotus Effect-Surfaces, Macromol. Symp., Nun E, Markus O. and Schleich B., 2002, 187, p. 677- 682.

The basic principle that the lotus effect is based on is related closely to the forces which affect the liquid on a solid surface. Forces between the solid-liquid phases ($\gamma_{S,L}$), between the solid-vapor phases ($\gamma_{S,V}$) and between the liquid-vapor phases ($\gamma_{L,V}$) define all of surface tension. The contact angle (θ), changes depending on these forces (Özdoğan *et al*. 2006). The surface tension between the water drop and leaf is seen at Fig. 4.

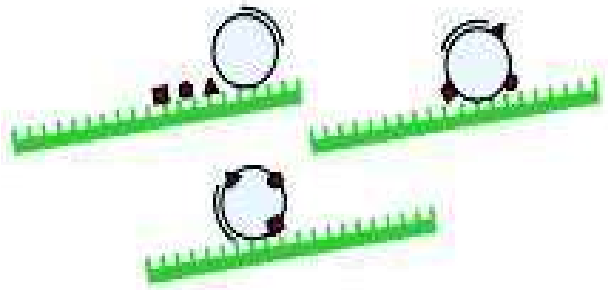
Fig.4. The surface tension between the water drop and leaf



Source: Lotus Etkili Yüzeyler, Özdoğan E., Demir A., and Seventekin N., 2006, p. 287-290.

The drop on the super hydrophobic surface doesn't slip, it goes on by rolling. When the dirtiness is carried on the drop, the dirt is removed from the surface if the absorption force between particle and surface is higher than the static friction force. The necessary force to remove the dirt is generally very low as the contact field between the dirt and surface is at a minimum level. As it is seen at Fig.5, the water drop takes the dirty particles with itself as it rolls and its surface is cleaned (Özdoğan *et al*. 2006).

Fig.5. The revulsion of water drop through the super hydrophobic surface



Source: http://lotus-shower.isunet.edu/the_lotus_effect.htm

3. The Applicability of Lotus Leaf Model on The Road Pavements

The first approach on the Lotus leaf's properties not to keep water on the surface and to clean itself became in a way to replicate its surface. But it was understood a short time later that its capability to resist against a mechanical stress is very low due to its isolated structure. It is necessary to know how a stable hydrophobic surface will be done, the relief work and how a relief device will be. On the other hand, the effect of structure size was evaluated and it was found that the property of self-cleaning is not restricted with the Lotus plant leaf's structure size. It is difficult that the nano-structured hydrophobic particles hold on any surfaces. It is demanded that the linkage is a stable one. Generally, surfaces have got little or much hydrophobic structure. Thus, the hydrophobic particles and pavement systems are accorded (Özdoğan *et al*. 2006).

All of materials and devices that we use them today have got a large-scale structure. The nano-structured materials which have got different and superior properties from the large-scale structures are named as the nano material (Baykara *et al.* 2010).

The production methods which are different from the traditional production technologies which have been used in order to obtain the nano materials are used. With this purpose, the different production methods have been developed as to use in the nano technological field today. The structures with the new physical, chemical and biological properties can be obtained with these different production methods which have been developed (Tüylek, 2016).

When a liquid drop is put on a solid surface; the liquid's surface tension, density and fluidity change depending on the surface properties and the liquid's physical and chemical properties (Adomaviciene et al. 2006).

Two important surface properties which determine the solid surface's wet ability are the surface's chemical structure and the surface's roughness (Wang and Jiang, 2007).

The wet ability is determined by water and contact angle's measurement. Onda and others stated that the super hydrophobic surfaces would be done artificially (Onda *et al.* 1996).

Surfaces which their water and contact angle is more than 90° are defined as hydrophobic. Surfaces which their water and contact angle is 150° or more than it are known as a super hydrophobic surface. The research of the super hydrophobic surfaces in the industry has accelerated with "the lotus effect" which was basically discovered in the lotus leaf, in the last two decades (Wang *et al.* 2011).

Atom and molecules on the liquid and solid surfaces have got a denser link than the interior ones and accordingly, they have got a higher energy. This surplus energy is stated as the surface tension or the surface free energy. The wetting mechanism is explained with the free energy of solid surface and the interfaces between liquid and air (Bhushan and Jung, 2011).

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The liquid-air interface increases and the solid-air interface decreases during the dispersion of liquid drop onto the solid surface. Accordingly, the solid-liquid interface increases. It is possible to design these surfaces as artificial with the bio-simulation which their samples are available in the nature and to produce them the opportunities that the nano-technology has provided. The various approaches have been developed in order to explain the effect of surface roughness on the wetting. One of these approaches is Cassie model. According to Cassie model, the water drop is a suspended one on the surface roughness and a composite interface which consists of solid, liquid and air is a matter (Ersoy, 2015).

According to Cassie model, the surfaces with a micro-roughness are considered as a non-homogenous structure which consists of a solid substance and air which make the surface (Jiang and Gao, 2004).

The surface roughness increases the contact angle on the hydrophobic surfaces. The lotus leaf's property to clean itself is related to this surface roughness at the nano scale. As the surface of road pavement is designed in a model of lotus leaf, it can be prevented that the raining water damages on the pavement. Moreover, the lotus effect would be done on the pavement as the

micro and nano rims are given on the pavement surface. In this way, the pavement surface would remain clean. Methods which would be used in order to make the micro-nano roughnesses on the surface are included at Table 1.

Table 1. Methods which would be used in order to make a micro-nano roughness

Lithography	Abrasion	Deformation	Accumulation	Transfer
Photo E-ray X-ray	Plasma Laser Chemical Electrochemical	Stretching	Adsorption Pavement with dipping Pavement with repelling Electrochemical evaporation	Nano press

Source: Bhushan B., Jung Y.C., (2011), Natural and biomimetic artificial surfaces for super hydrophobicity, self-cleaning, low adhesion, and drag reduction, Progress in Materials Science, 56, 1, 1–108.

Advantages and disadvantages belonging to some of techniques which are stated at Table 1 are showed at Table 2.

Table 2. Advantages and disadvantages of the methods which are used for the micro-nano roughness

Method	Advantage	Disadvantage
Lithography	- A precision working way - Effective in a wide area	- Slow process speed - High cost
Abrasion	- A rapid working method	- Chemical contamination can occur - Its control is difficult
Accumulation	- A flexible working way - A cheap method	- Its control is difficult - It may require the high temperature

Source: Bhushan B., Jung Y.C., (2011), Natural and biomimetic artificial surfaces for super hydrophobicity, self-cleaning, low adhesion, and drag reduction, Progress in Materials Science, 56, 1, 1–108.

Conclusion and Recommendations

It is possible to remove rain and snow water in the natural ways without damaging on the road pavement, and to clean the dirt such as the powder, sludge and oil on the road. The lotus leaf model which removes the water and also, which cleans the surface that the water rolls as going away can be imitated for the modern road pavements.

The leaves of lotus have got the property to clean themselves. The plant's leaves don't definitely get wet with the roughness at the micro-nano level in the surface. The water drops carry the powder, the sludge and other pollutions on it while the drops slip to the soil with the leaf's curved shape. It is possible that the dirt such as the powder, the sludge and oil on the road can be cleaned by the natural ways, as the lotus model is applied onto the road pavement.

The roughness of surface increases the contact angle on the hydrophobic surfaces. The lotus leaf's property to clean itself is related to this surface's roughness at the nano scale. As the surface of road pavement is cleaned in a lotus leaf model, it can be provided that the raining water doesn't damage on the pavement.

The lotus effect can be done on the pavement as the micro and nano rims are given to the surface of road pavement. In this way, the surface of pavement can be clean constantly.

As the lotus model is applied on the surfaces of road pavement, it can be prevented that the snowflakes which cause the transportation problems in winter cling on the surface of road.

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