Experimental Study on Normal sand and Hydrophobic sand

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***Abstract* - A soil is composed primarily of minerals which are produced from parent material that is weathered or broken into small pieces. Plants and animals have important roles to play in soil. Both plants and animals change the composition and structure of soil in many different ways. Plants with roots obtain nutrients and moisture from soil through their roots. Soils are characterised by their physical, chemical and biological properties. In addition, soils are good materials used in engineering projects. The phenomenon of soil water repellency, starting from the fundamental principals of water transport and storage in soil. Soil water repellency is a reduction in the rate of wetting and retention of water in soil caused by the presence of hydrophobic coatings on soil particles. The complexity of testing required for a particular project may range from a simple moisture content determination to sophisticated triaxial strength testing. A laboratory test program be well-planned to optimize the test data for design and construction.**

***Index Terms* - soil, hydrophobic soil, types of soils and laboratory testing.**

INTRODUCTION

Water scarcity has always represented an issue in most parts of the Middle East where the draught and high temperature form the main weather conditions throughout the year and lack of natural water resources has caused considerable shortage of water supplies. With the continuous climate change that is affecting the whole globe and scarcity of rainfall, the problem of water shortage will have a greater impact in the future and will also affect wider regions.

Normal sandy soil is known with its high rates of seepage for water. Plants' roots in sandy soil have considerably limited time to exploit irrigation water because of the high permeability of sand. Water tends to drain quickly into deeper layers, sweeping soil nutrients. Hydrophobic sand is normal sand treated with organic chemical materials which turn it into hydrophobic soil to water. Hydrophobic sand assists to preserve water for longer time; consequently the plants' roots will have relatively enough time to utilize water and the nutrients which exist in soil.

OBJECTIVES

- Maximum release and the rate of release of these chemicals into the soil and consequently to the groundwater and whether they produce any type of pollution into the soil and groundwater.
- Also implying experiments in order to achieve the optimal soil permeability by mixing different quantities of the original normal sand and hydrophobic sand and implying permeability tests until the most suitable permeability, for plants' irrigation purposes, is obtained.

MATERIALS AND METHODS

Normal sand

The surface of the sand grains is bonded to hydrogen atoms by covalent bonds, which are polar bonds, where pairs of electrons are shared between the atoms. Since water molecules have also polar bonds and are considered polar molecules, thus they tend to be attracted to the normal sand grains. Consequently, normal sand is considered as a hydrophilic material and water spreads into the sand layer without forming drops or bead on top of normal sand surface.

Hydrophobic Sand

A hydrophobic surface has the characteristic of not adsorbing water or be wetted by water In other words, if the forces accompanied with the interaction of surface with water are higher than the cohesive forces accompanied with the bulk liquid water, this will result spreading of water into the surface and no drops of water will be formed. If the cohesive forces accompanied with bulk water are higher than the forces accompanied with the interaction of water with the surfaces, then water drops over the surface will be formed and the surface will form a hydrophobic layerThe hydrophobic sand is obtained by coating normal sand with hydrophobic compounds. When hydrophobic sand surface is exposed to water, sand particles on the top layer will tend to adhere to each other as a result of hydrophobicity to water This will cause minimizing the surface area of the sand which will reduce soil's water requirements. When the pure silica particles in normal sand are exposed to a volatile liquid of an organ silicon compound.

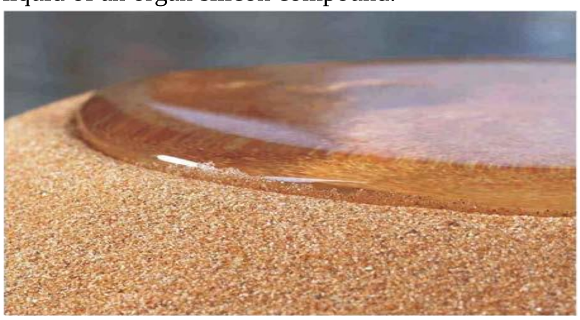


Fig:2. Hydrophobic sand (Global forum, 2015)

Fig: Hydrophobic Sand

Hydrophobic Sand and applications

- Hydrophobic sand can be used in farms for agriculture purposes to reduce water seepage into the lower layers of soil and into the groundwater. Water quantity that flows through sand will be significantly less because of using hydrophobic sand which traps water allowing plants roots to obtain the ultimate benefit of water and reduce the irrigation duration and number of watering rounds per day. It could be used also in gardens and parks as a landscape tool for creating a natural looking stream when water flows over the hydrophobic sand. According to the studies held by the production company in UAE and studies conducted by UAE University, it could save up to 75 % of water usage
- It can be used in foundations, infrastructure and underground utilities protection.
- For flood and coastal protection, using hydrophobic sand in bags will help to prevent the flood from advancing towards residential areas and will act as efficient barriers. Using normal sand is a traditional action against floods and is considered as a quick solution but after a short period of time, normal sand will be saturated with water and its efficiency in repelling water is reduced so water will continue flowing through the bags after a period of time. Hydrophobic sand property in constant repelling of water will assist for a longer duration of preventing floods from advancing (DIME, 2014).
- For parks and playgrounds, usually normal sand is used in playgrounds, golf courses and horse racing tracks but since normal sand could be easily wetted in the event of rains for example and gets muddy, it would be wiser to use hydrophobic sand which remains dray even in rainy seasons. Hydrophobic sand could be used as a surface layer for playgrounds and parks because it does not clump in wet seasons (DIME, 2014).
- Protecting ground water from contamination with pollutants of heavy metals and other pollutants when used as a layer beneath landfills. Contaminated water with wastes from landfills will seepage creating its bath towards the groundwater unless there is a layer of hydrophobic sand that prevents the contaminated water from reaching the groundwater

LETARATURE REVIEW

Abdulmalik A. Alghamdi (2003) Sand Control Measures and Sand Drift Fences Sand drift and sand dune movements are typical logistic problems facing civilian and industrial cities in arid and semiarid countries like Saudi Arabia. Some of these countries are considered active when it comes to sand drift and sand dune movement, due to the high annual sand drift rate. Urban cities have extensive facilities in the middle of these active areas that require good protection and innovative solutions to this problem. This paper briefly reviews sand movement control measures and highlights sand drift fence design guidelines for the first time.

Mitsu Okamura (2004) Degree of Saturation and Liquefaction Resistances of Sand Improved with Sand Compaction Pile. Sand compaction pile (SCP) is a ground improvement technique extensively used to ameliorate liquefaction resistance of loose sand deposits. This paper discusses results of laboratory tests on high-quality undisturbed samples obtained by the in situ freezing method at six sites where foundation soils had been improved with SCP. Inspection of samples revealed that the improved ground was desaturated during the ground improvement.

Yong Wang (2010) Study of Effects of Fines Content on Liquefaction Properties of Sand. To simulate the effects of fines content on the liquefaction properties of sand, specimens of different fines content were prepared. Based on cyclic triaxial compression tests of these samples, the effects of fines content on the liquefaction properties were analyzed.

Qing Zhang (2020) Application of Super-Hydrophobic and Self-Cleaning Coating in Tunnel Engineering Super-hydrophobic and self-cleaning coating has the advantages of economy, beauty, and environmental protection. It has been widely used in many fields, such as high-rise buildings, curtain walls, bridges, cars, and wind power generation. However, it is hardly used in the tunnel engineering. This paper demonstrates the feasibility of super-hydrophobic materials in the application of tunnel wall descaling in that it promotes the drop rolling off, influences the formation process of dirt and reduces the adhesion of dirt.

PHYSICAL CHARACTERIZATION OF HYDROPHOBIC SAND

Hydrophobic sand was characterized using Scanning Electron Microscopy (SEM) and Environmental SEM to inspect morphology of individual sand granules and interaction with condensed water. SEM as by the title is a type of electron microscope. The SEM produces pictures of a sample by scanning the sample with a focused beam of electrons. These electrons interact with the atoms in the sample producing many signals that contain information about the sampl’es surface composition and topography. As shown in Figure, as-is hydrophilic sand showed a pretty small apparent contact angle with water, whereas apparente contact of water on wax-coated sand was significantly higher.

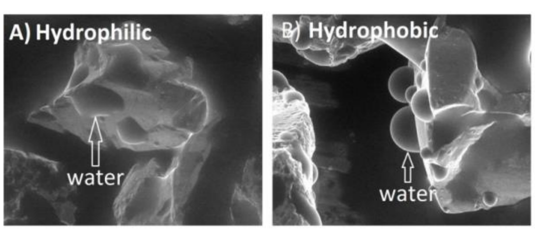


Fig: Physical Characterization of Hydrophobic sand

MATERIAL INVESTIGATION

Sampling and permeability tests have been carried out for pure normal sand, pure hydrophobic sand and mixtures of normal sand and hydrophobic sand with different proportions and configurations.

The soil particle distribution is considered one of the most significant characteristics of soils and the investigations on Hydrophobic sand and Normal Sand were carried out through triaxialtest and Direct shear test these are sampled and the determined the nature of sand.

SAMPLE PREPARATION

The Normal sand was oven dried and then immersed in a reactive solution of 10% n-octyltriethoxysilane and 90% isopropyl-alcohol for 48 hours. This yielded an Engine oil coating on the particles and then the soil was air dried for 72 hours.and it becomes waterrepellent and act as a hydrophobic. Specimens of all hydrophilic particles and all hydrophobic particles were tested under dry (degree of saturation, S= 0%) and saturated (degree of saturation, S = 100%) conditions at three normal stresses in a direct shear device.These hydrophobic sand under saturated condition is also used in the triaxial test for extract the results

RESULTS AND DISCUSSION

Soil classification test

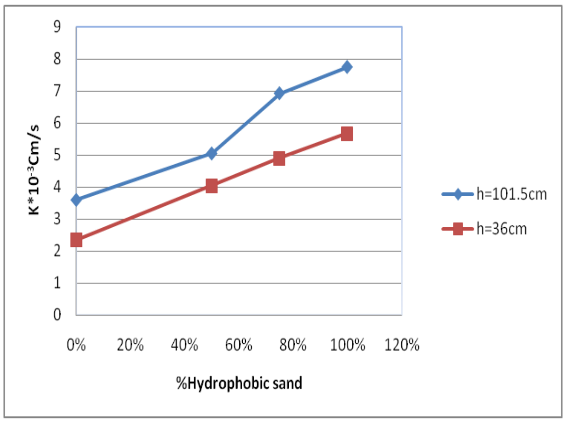
The results of the sieve analysis, undertaken for Normal sand and hydrophobic sand sample, were registered

Sieve opening size (mm)	Accumulative percentage (%)	
	Normal sand	Hydrophobic sand
4.75	100	100
2.00	95.2	97.4
600 µ	90.2	93.1
425 µ	83.5	85.2
212 µ	69.6	73.8
150 µ	50.1	51.7
75 µ	0	0

Sieve opening size (mm) Accumulative percentage
From this sieve analysis we get
D10=0.085,D30 = 0.12,D60 = 0.18
The values of Cu and Cc were calculated
Cu = 2.118,Cc = 0.941

Sand specimen	Specific gravity (Gs)	Void ratio (e)	Porosity (n)
Normal sand	2.728	0.748	0.428
Hydrophobic sand	2.11	0.352	0.260

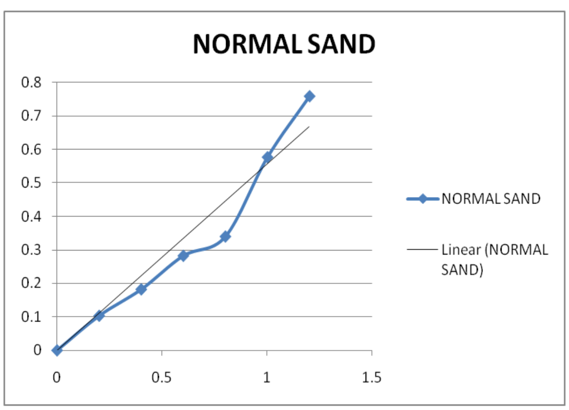
Permeability coefficient (K) values



Graph: Permeability Coefficient for different proportion of sand at different head

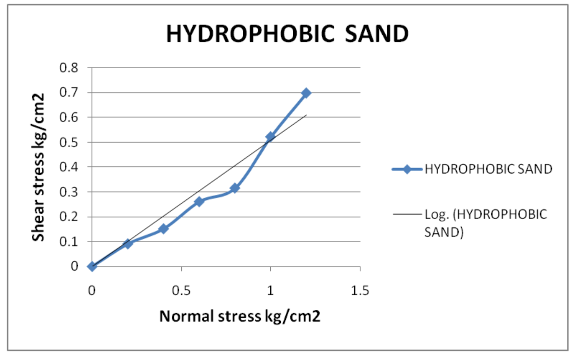
From this graph,Hydrophobic sand has high permeability coefficient at head 101.5cm

Direct shear test



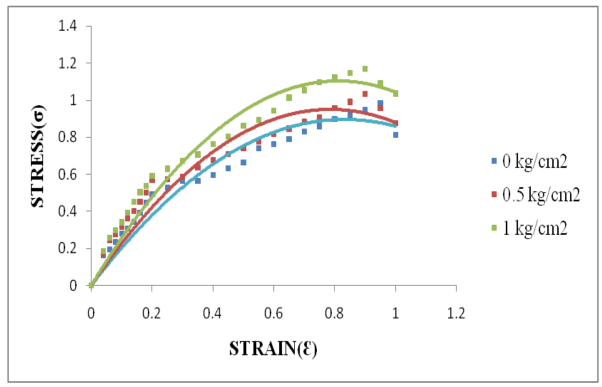
From this graph we got
Cohesion (c) = 0
Angle of internal friction (Φ) =43040'

From this graph we get ,
Cohesion (c) = 0,
Angle of internal friction (Φ) =380

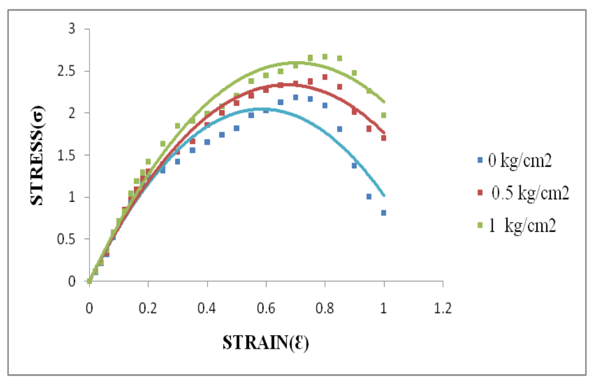


From these graphs it can be determined that hydrophobic sand develops major shear stress with an Angle of internal friction (Φ) =380 and normal sand developed minor shear stress stress with an Angle of internal friction (Φ) =43040'

Triaxial test



Graph: Deviator stress versus axial strain response of Normal sand



Graph: Deviator stress versus axial strain response of Hydrophobic sand

Descriptions	Cell pressure (kg/cm2)		
	0	0.5	1
Normal sand	0.9832	1.0341	1.1697
Hydrophobic sand	2.0918	2.428	2.4742

From these graphs it is determined that hydrophobic sand has high stress than normal sand and has maxmimum value of 2.4742 at cell pressure 1kg/cm2.

CONCLUSION

1. The results from this case study demonstrates that, in order to reduce sand permeability and consequently reduce irrigation water consumption and duration, a separate layer of hydrophobic sand should be placed beneath the normal sand layer. The thicknesses of the layers depend basically on the type of the planted vegetation. Recommendations are provided to avoid mixing hydrophobic sand with normal sand as it would lead to increase of permeability.
2. Specific gravity of normal sand is higher than the hydrophobic sand 2.728 > 2.11.
3. Based on the results achived from the triaxial test it was observed that Hydrophobic sand has grater major deviator stresses when compared to normal sand there is an increase of 40% stresses in Hydrophobic sand than Normal sand.
4. Constant head permeability test is recommended to be used for coarse and grained soil as sand while for finer soils, such as silt and clay, falling head tests are recommended. Since the specimens in interest contain sand so the constant- head test was chosen for permeability measurements, and it was observed at Hydrophobic sand has maximum permeability coefficient of 7.75*10-3 and 5.68*10-3.

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