INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES

IJPAES

Volume-4, Issue-2, April-June-2014

ISSN 2231-4490

Coden : IJPAES www.ijpaes.com

Received: 26th Feb-2014 *Revised: 27th March-2014* *Accepted: 29th March-2014*

Research article

AN ASSESSMENT ON STABILIZATION OF EOLIAN FINE-GRAINED SOILS USING WIND TUNNEL

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ABSTRACT: Control of soils wind erosion particularly in arid and semi-arid regions has been seriously paid into attention due to several causes including to prevent the destruction natural resources, reducing air pollution, reducing aerosol transmission and the problems it causes in transportation. Measurement of factors affecting on wind erosion in field conditions is difficult and uncontrollable. Hence, use of wind tunnel device is addressed as one of feasible methods. In fixed wind tunnels, in order to measure soil erosion, trays containing soil shall be placed in the tunnel floor and the wind blows with a given specification. Tray weight difference between the two times of weighing indicates erosion rate of a given level. In present research, wind tunnel was manufactured and launched in laboratory. Wind speed in the tunnel is in 0-40 km/h range. Experimental results showed that the rate of soil erosion and loss is reduced with increased other soil particles versus wind erosion. General and localized erosion phenomena on soil surface were investigated according to soil particles size and uniformity of the samples coating surface.

Keywords: Wind tunnel, Wind erosion, Dust control.

INTRODUCTION

Wind tunnels are manufactured to study wind effects on soil replacement by plenty of groups such as Brigadier. Bagnold produced one of the first wind tunnels to study threshold of soil movement. Bagnold (1941) [1] launched another wind tunnel in Kansas University at soil erosion research institution along with considerable soil erosion in Central America during 1930s. After him, other researchers worked on wind tunnel including Chepil(1945), Horikawa and Shen (1960) and Logie (1981) [2]. Loki et al (2005) [3] used wind tunnel of The University of Debrecen to conduct soil erosion physical experiments. Length, width and height of the tunnel are 12 m, 0.8m and 0.5m, respectively. The wind speed is 0-16 m/s and soil samples are placed into the 30*50*5 cm molds inside the wind tunnel. Vali et al (2010) [4] used a fixed wind tunnel with 100*85*100 cm dimensions in their studies. For sediment transport into the tunnel, a source of sediment injection was used which was mounted above the tunnel in a 10cm distance from blower. The resource injected 10 g sediment into the tunnel per second. In order to ensure the sediment distribution on all testing cares, accuracy gauges were used which were composed of a 20cm height leg and a sampler located in 4 edges across the cares. In order to make wind with specific speeds in specific times, Ekhtesasi (1991) [5] used Wind Erosion Meter (W.E.M) which is typically a portable wind tunnel and can be used in laboratory and desert. This device is composed of three main parts including: wind generator fan, metal casing of wind tunnel and plastic chamber of sediment storage. By the wind speed regulator connected to the fan, the wind speed inside tunnel can be regulated and maximum and minimum speed reaches to 12 m/s and 0.5 m/s, respectively, at 20cm height.

Mahmoudabadi et al (2011) [6] used the wind tunnel of ShahidBahonar University of Kerman to study wind erosion. This simulator can make different wind speeds up to 20 m/s at 20cm height. In order to study soil behavior against wing blowing, a 40*100 cm tray was used to locate soil samples. A double-walled plastic chamber is mounted at the end part of sediment sampler in which, along with reciprocating flow of wind, sediment particles are collected and clear air is released. Movahedan et al [7] designed, constructed and used an experimental wind tunnel. The tunnel floor in central part lacks floor with 0.3 * 0.4m and the sample is located experimentally. Also, this part has a mental framework with a height of 4 cm which allows tunnel floor to be placed above ground surface in order to provide sufficient space for experimental sample. The wind generation was done using a 3phases fan with a flier diameter of 56 cm, a current of 4 Amperes, a power of 1.5 KV and an aeration capacity of 1600 Cubic meters/ hour. Table 1 presents length, width, height and maximum wind speed in wind tunnels made so far.

Table1. Length, width, height and maximum wind speed in wind tunnels made [8]

Reference	Tunnel Design	Width (m)	Height (m)	Length (m)	Umax (ms^{-1})
Zingg (1951a)	Pusher	0.91	0.91	9.12	17
Armbrust and Box (1967)	Suction	0.91	1.22	7.32	18
Gillette (1978b)	Suction	0.15	0.15	3.01	7
Fryrear (1984,1985)	Pusher	0.60	0.9	7.00	20
Nickling and Gillies (1989)	Suction	1.00	0.75	11.90	15
Raupach and Leys (1990)	Pusher	1.20	0.9	4.20	14
Pietersma et al. (1996)	Pusher	1.00	1.2	5.60	>20
Leys et al. (2002)	Suction	0.05	0.1	1.00	19
Maurer et al. (2006)	Suction	0.60	0.7	9.40	15
Fister and Ries (2009)	Pusher	0.70	0.7	3.00	8

MATERIALS AND METHODS

A wind tunnel was manufactured, installed and launched in laboratory in order to conduct studies about behavior and impacts of different effective factors on eolian soils. This tunnel is alike the wind tunnel made by Ekhtesasi and Movahedan [5,7] with some amendments in design and construction. The launched device is composed of four main parts. Part 1 includes single-phase wind generation motor with 2800 round per minute (rpm), a current of 18 Amperes, a power of 3 KV and flier diameter of 35 cm. According to the rotatable motor in both directions, system can perform in both suction and pusher modes. Given the tests and specifying the wind speed by handheld anemometer, the wind speed in suction mode is about 10 km/h higher than aeration mode. However, this mode provides the capability to use multiple wind speeds to do desired tests. In addition, with longer wind path in device, variable but lower speeds can be reached. The maximum measured speed on sample and tangent with the bottom layer of wind tunnel is measured 38-42 km/h. The sitting platform of device is adjusted in such a way that rotation axis of flier would be placed in center of wind tunnel box. The using flier is designed and constructed with cast iron and resistant against impact of tested soil particles also with blades having 45 degrees direction relative to along the center line of rotation. In this open circuit wind tunnel, the air flows from outside to inside the tunnel and has the following parts:

1. Cone-shaped openings for wind flow entrance
2. Test part
3. Distributer
4. Flier

Axial tube fan is used in manufactured wind tunnel. Axial tube fan is alike the flier fan but instead of frame, electromotor and flier are located inside a cylindrical chamber whose propeller has 4-8 blades with aerodynamic or flat design. The cylinder increases the fan performance and is designed in such a way to have a low distance with blades tip. Part 2 includes inlet openings of wind tunnel with initial circular section and secondary square section to connect to other parts. Inlet section surface with a diameter of 45 cm^2 and outlet section surface with a dimension of 30*30 cm are about 1590 and 900 cm^2. Different parts of wind tunnel are of galvanized iron. The parts are connected to each other through special sockets.

The part 3 includes a rectangular box with 1*0.3*0.3 meter dimensions along with three chambers for imaging and measurement of required specification in sample. This part includes sample tray or chamber with 0.3*0.4 meter dimension which is almost located in central area. The final part (4^{th}) includes horny sections to transfer air to inside the device. The initial section surface is 30*30 cm^2 and outlet section surface is about cm^2. A view of the different parts of the device is shown in Figures 1 and 2.

Figure-1. Different parts of the manufactured wind tunnel

The using anemometer to specify wind speed in tunnel, with maximum speed of 90 km/h and 32*72*180 mm dimensions, is shown in figure 3. The soil samples of 1 tone were fine aggregate clay soils with low plasticity which transferred to laboratory and after identification tests, a given amount of soil was collected and scanned after passing through sieve. The tests were conducted for three soil ranges located between sieves 8-30, 30-50 and below sieve 50.

Figure-2.Different parts of the manufactured wind tunnel

The cause to select such ranges was proper soil volume for several tests, particles magnitude limitation due to high noise and dispersing and size change range of eolian soils. Below items are specified by manufactured wind tunnel:

- Amount of soil erosion
- Wind speed profile higher than soil samples
- Air moisture and temperature percentage

Figure-3. Handheld anemometer used for test

RESULTS AND DISCUSSION

In order to study the changes made in wind tunnel, the device was modeled in Software. Wind speed changes in wind tunnel and incoming pressure changes are shown in Figures 4 and 5, respectively. As it can be seen, speed changes in wind tunnel are variable from 0 m/s to 32.2 m/s. around the sample tray, these changes were about 10-16 m/s which have a proper consistency with the values measured by (about 40-50 km/s). Accordingly, the incoming pressure caused by wind force in wind tunnel was variable from -233 Pascal to 148 Pascal which is -40 Pascal as mean around the sample tray.

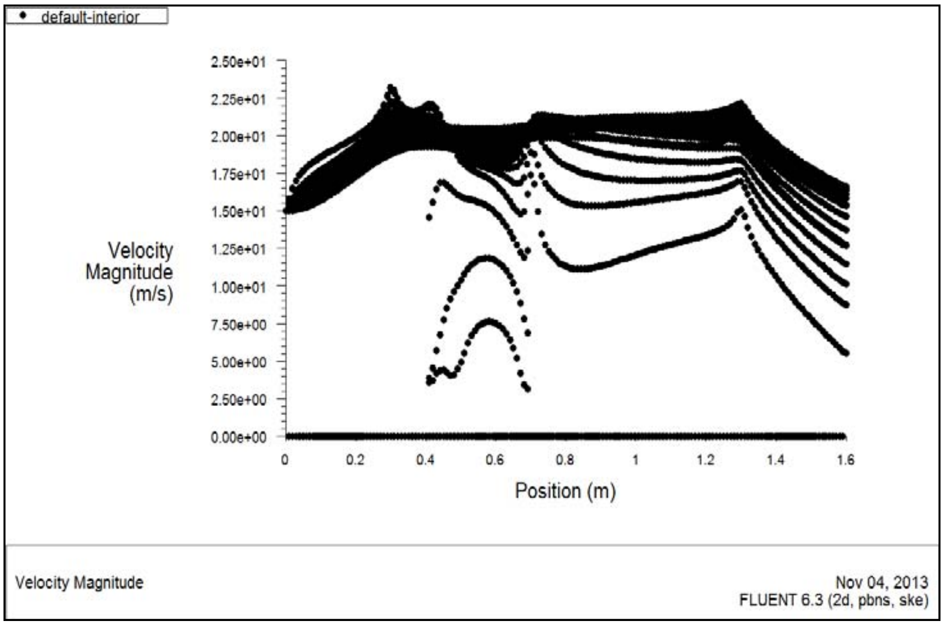

Figure-4.Wind speed (velocity) magnitude changes in longitudinal section of tunnel

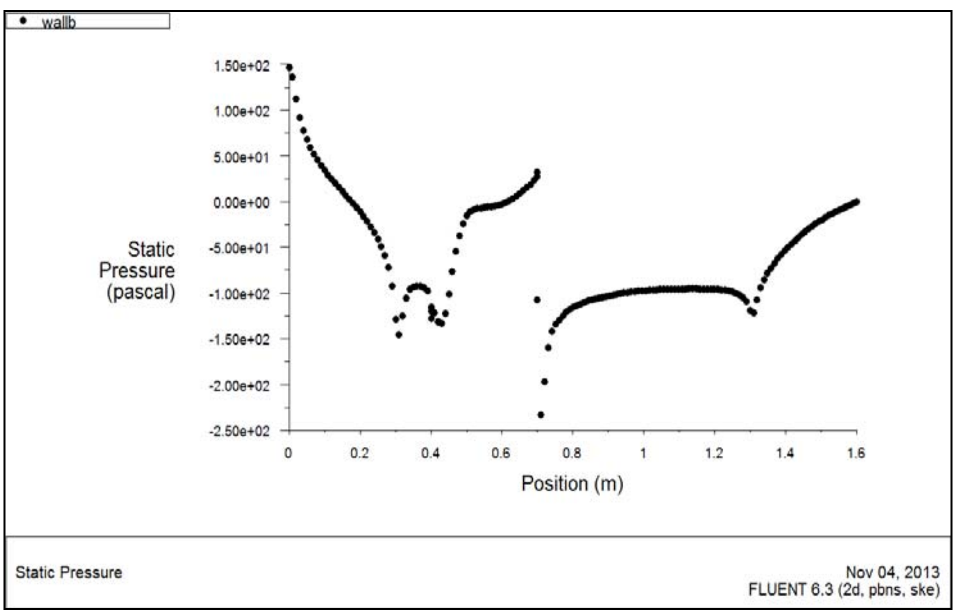

Figure-5. Static Pressure changes in wind tunnel floor wall

During the tests done in wind tunnel, effects of such parameters as loss height of polymer solutions, polymeric materials concentration and the soil particles size versus the penetration depth of solution and the amount of wind erosion were investigated. Materials loss height was sampled at 0.5, 1.5 and 2.5 heights. Also, solutions concentration for distilled water and the water was selected along with 20 and 50 g of polymer. Solutions pouring were done through handheld sprinklers. Figure 6 shows how to pour solutions on soil as well as changes on soil surface.

Figure-6. Changes on soil surface due to different heights for solutions fall

Different size screened soils were poured on special sample tray and were reached to initial density by lifting the tray and releasing it as many as 10 impacts then they were weighted. The solutions were poured on sample with different heights and densities and samples were weighted. Penetration depth measurement of solutions inside the soil was performed on cut soil section by caliper. Figure 7 depicts operation stages.

Figure-7. Cut soil section for solutions penetration depth measurement

Next figures show soils erosion changes relative to solution fall height in 0.5 and 1.5m codes from sample surface as well as soil erosion changes relative to solution concentration change in ranges of distilled water and 20g per liter.

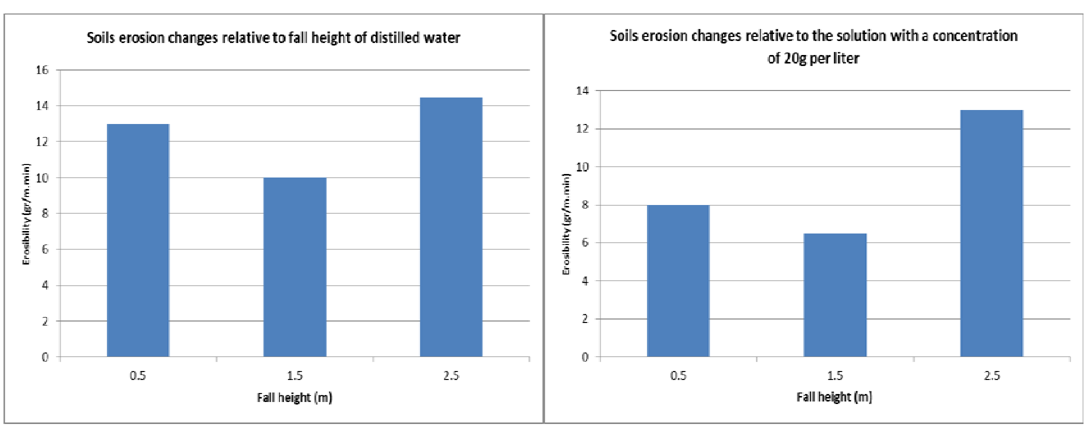

Figure-8.Soils erosion changes relative to fall height of distilled water and the solution with a concentration of 20g per liter

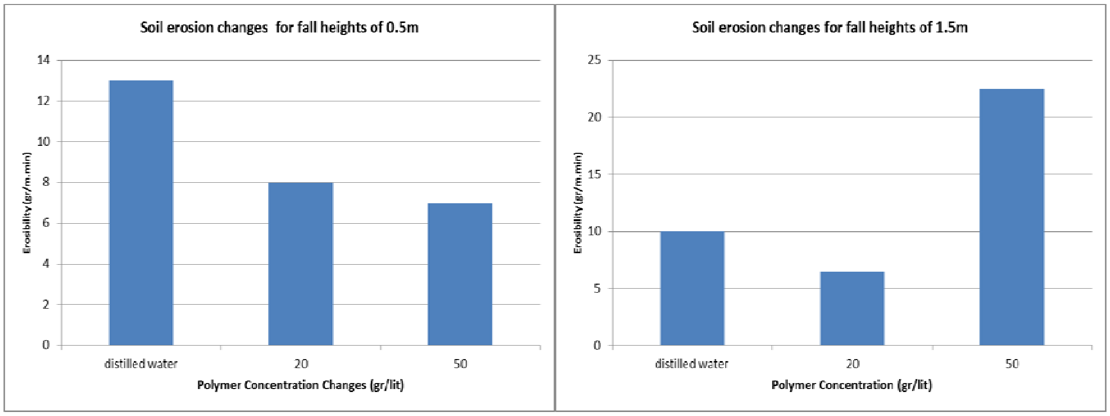

Figure-9. Soil erosion changes relative to concentration changes for fall heights of 0.5m and 1.5m

Above figures indicate soil serodibility according to different parameters. Soils erosion amount is variable for solutions fall in different heights. In some modes, erodibility increases or decreases with height increase. The effect of sample surface non uniformly increases with increased height due to having polymeric solutions which may be cause of increased erosion for fall height of 2.5m from ground surface. However, what is clear in tests is more energy of solution drops with increased height which causes to collapse and localized deformations in contact moment with sample at fall point. This issue resulted in increased solutions penetration depth with increased fall height. Figure 10 shows changes on solutions penetration depth and effectiveness of different parameters.

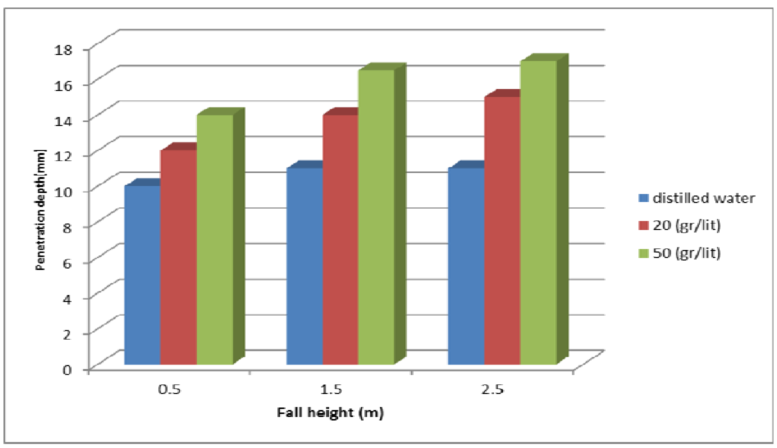

Figure-10.Changes of different solutions' penetration depth changes with fall height changes for different polymer concentration

Also, with fixed solutions fall height, increased concentration results in decreased soils erodibility. The diagram in Figure 11 shows penetration depth changes against soil erosion amount according to results of conducted tests.

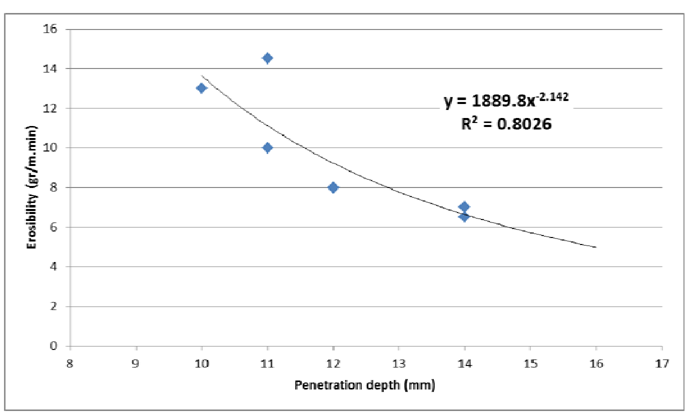

Figure-11.Penetration depth changes against soils erodibility and fitness line with a coefficient of R^2=0.8

CONCLUSION

Wind erosion and its related complications result in heavy losses to the environment, the community and population health each year. Due to the extent of arid regions and the dust which covers a major part of the country each year, optimal dealing and directing this phenomenon is of high importance in Iran. Employing wind tunnel is important to experimentally investigate and study the effective factors on stability of eolian fine-grained soils. By some tests on manufactured wind tunnel for different ranges of soli particle size, some behavioral specifications of such soils were studied. The higher soil particles diameter, reduce soils erodibility. Effect of parameters for polymeric solutions fall height versus solutions penetration depth and wind erosion were paid into attention. In most cases, soils erosion for solution fall is decreased with increased height. The effect of sample surface nonuniformlyincreases with increased height due to having polymeric solutions. With increased solutions penetration depth on soil and due to increased materials fall height, lower amounts of soil will be under erosion. In the soils with finer particles due to flaking caused by polymeric solutions fall, soil aggregates will be a coherent mass due to increased wind speed which for the soils with larger particles, such movements are only as much as soil single particles transfer. This issue should be paid into attention that increased height should be along with solutions coverage homogeneity in soil surface. Otherwise, solutions effect in some points causes to commence the erosion besides fixed soil particles and due to limited penetration depth, erosion and movement of entire the soil mass will be totally occurred. Studies on fine-grained soils erosion behavior against wind and also its stability depend on several factors and in order to continue the activities, conducting field experiments on these soils are suggested, considering parameters of humidity, porosity, and temperature and plant coverage.

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