The survey of dynamic compaction on microstructure characteristics of loess of Golestan–Iran

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Abstract

Due to dynamic compaction, the structure of loess is changed and by increasing the number of dynamic blows, the soil is involved in axial deformation. This deformation is done as collapse and strain. To 6 blows, the axial strain rate is more and after that it is decreased to achieve a constant rate. Generally, due to the blows, cracks, grains bending, the torsion of grains, the break of grains, crush of peds and grains compaction are occurred. The severity, type and amount of soil strain depend upon the number of blows and the type of soil. In loess of Golestan, three different behavior is seen.The loess collapsing due to the structure blow. The other group in which axial deformation is created and the other group show the collapse and axial deformation.

Keywords: Loess; Golestan province; Microstructure; Dynamic compaction; Engineering geology

1. Introduction

Loess is a homogenous eolian deposit with well sorting, high porosity in silt sizes covering more than10% of earth (Smalley et al.2001). The development of loess is occurred in Golestan province located in the north of Iran about 20% of soil area. These soils in geotechnic are considered collapses. Collapse soils are one of the problematic natural materials in dry regions (Hormdee,2008). There are other risks except collapse in the soils, there are various reports of human inability to cope with the risks of loess in keeping the structures in these soils, some phenomena like liquefaction, dispersivity, piping, erosion, Non-uniform settlement, Karstification and the life are other risks created based on the environment conditions and geology characteristics of loess. All the risky phenomena are related to microstructure parameters of loess (Olsezewska, 1975).

Due to heavy dynamic or static loads in saturation conditions, the structures of the loess are collapsed and the soil microstructure is turned from open fabric to close fabric (Jehring,2006).One of the Laboratory methods in the investigation of the soil behavior against dynamic impacts is Laboratory dynamic compaction test (Hu et al.,2001).

In this test, the soil porous structure of loess soil is involved with axial strain and in addiction to the fracture in its tissue, axial deformation is occurred in it (Hu et al.,2001).The amount of deformation is related to the sorting of the particles and cement between the particles. The cement is mostly made of calcium carbonate and clay and is important in the intensity of collapse. Thus the recognition of the components of loess soil microstructure is of great importance.

The engineering property of most of the soils is controlled by their microstructures (Hu et al.,2001).In the past, some studies were done on the relationship between the engineering properties and soils microstructure (Hu et al.,2001).It is less in loess or the components of microstructures is studied incomplete.

Generally, loess microstructure is consisted of grains, cement and pores. The frequency, the type and distribution of each of them control geology-engineering behavior of this soil against applying dynamic loads. The grains are mostly made of quartz, feldspar and mica and there are four bands in terms of the type of cement and its amount between loess grains (Jehring, 2006).In addition to clay and lime cement, other soils are put on the particles as solid and semi-solid (Karstunen & Leoni,2009;Nouaouria et al.,2008). Based on the amount of clay silt and loess sand, there are three kinds of clay loess, silty loess and sandy loess (Angelova, 2007; Roy & Hunt, 2007; Sweeney & Smalley, 1988). Normally, clay loess are of CL-ML type (Angelova, 2007). The characteristics of the microstructure of these soils are completely different from each other. The mechanical behavior of loess is dependent upon their grains structure and the quality of bands (Bell, 2007) creating the fabric of loess structure and is consisting of fine grains and particles. The internal friction angle of loess is mostly dependent upon plasticity index, connectivity of the grains and their density (Bell, 2007) Due to unique structure, they are identified well in the field and have structure (Iriondo & Krohling, 2007). Friability directly is associated with connectivity of the grains. These soils cannot classified as other soils and considering the parameters and microstructure characteristics help more in evaluation of this soil. We should consider physical and mechanical characteristics of them in soil classification (Jefferson et al., 2004). Although the study recorded on loess was started since 1820 by Karl Von Leon hard (Smalley et al., 2001) but microstructure studies by SEM electron microscope is related to the previous decades (Romero & Simms, 2008). As Barden et al. dealt with different kinds of connectivity between the grains in saturated soils and investigated their collapse mechanism under the connectivity between the grains (Barden et al., 1973). Rob and Kemp 1999 by Micromorphology of loess – paleosol sequences studied about different kinds of pores in loess (Rob & Kemp, 1999). Hu et al. (2000, 2001, 2010) studied in detail the loess soil behavior by electron microscopic images due to dynamic loads (Hu et al.,2001, Hue et al.,2010). Gao (2011) by measuring the statistical indices evaluated loess microstructure parameters (Gao et al., 2011).

2. Materials and methods

The evaluation of axial strain is done due to the application of consecutive impacts on loess soil by a simple device in the similar Laboratory of proctor compaction test. Laboratory dynamic compaction tests (LDCT) is consisting of a base plat, form, bearing plate, guide, hammer, base and a magnetic holder (Fig.1).

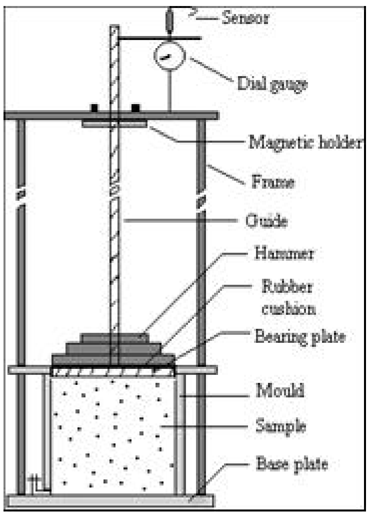


Figure 1: Schematic of dynamic compaction apparatus (Hu et al. 2001).

The blows are done by hammer from a definite height (about 1m) as axial and vertical on the surface and axial strain for each blow is recorded. For each region, sampling was selected for maximum 8 similar samples and the blows were applied on each of the samples as 2,4,8,10,13,16,20,26. At the end of each of the dynamic compaction test, the specimen was removed from the apparatus for microstructural analyses and physical and mechanical tests.

At first the undisturbed case are proved as maximum 5mm and after preparation was imaged under the microscope. By image tool software, microstructure image processing system was provided (Fig. 2).

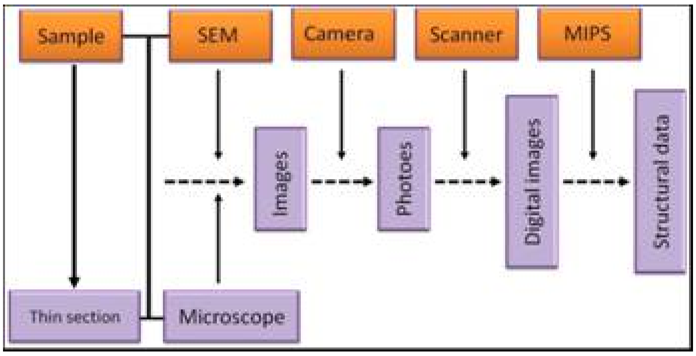


Figure 2: Steps in quantifying microstructure parameters using MIPS (L23)

The image taken of the sample under the microscope is the 2-D view of the sample and it is a normal grey image. The image processing is changing a normal image to digital image. Digital image is an evaluated image consisting of a great number of small squares (pixels). Each pixel is consisting of a numerical number and shows the lightness of the pixel. Each digital image has row and column. To investigate the microstructure characteristics, there are four statistical, geometry, modeling and signal processing methods. In this study, two methods of geometry and modeling are used. In these two methods by porosimetry and scanning electron microscope-SEM, loess microstructure is investigated (Romero & Simms, 2008). The results of this study are done by electron microscope scanning. The selected samples are related to Golestan province provided by electron microscope of Ferdowsi University of Mashhad and microstructure characteristic images are measured.

This study is a part of the subject of phd thesis of engineering geology titled An investigation on effect dynamic compaction and static loads on shear strength of loess's soils in Golestan Province.

A soil component at microscopic scale is called microstructure. Normally, microstructure depends upon microfabric, composition and bonding between the grains. Microfabric in geology sciences is called micromorphology. Normally, there are 10 microstructure parameters affected by dynamic compaction load including the grains diameter(D_g), density of grain arrangements of vertical (p_{dv}) and horizontal(p_{dh})directions and, pores diameter(D_p), pores density arrangement in horizontal (P_{ph}) directions and vertical (P_{pv}) direction, the linkage of grains (L_c), cement density distribution in vertical (C_{cv}) and horizontal (C_{ch}) directions (Table 1).

Table 1. shows the components of soil microstructure

Factor	Parameter	Symbol	Meaning
Shape of grain	Maximum Grain diameter	D_g	The biggest length of grains
	Sphericity	S_r	Represents a level close to the grain is a sphere.
	Circularity	R	The level of sharp or flat edges of grains
Arrangement	Grain oreintation	O_g	The direction of thick side of grains

of grains			in the long line
	Density of grain arrangement	P_d	The grain density in a hypothetical
Porosity	Pore geometry	B_p,L_p,S_p	The biggest length and width and the pore area
	Density of pore arrangement	P_p	The pore density in a hypothetical length
Connectivity	Linkage of grains	L_c	The frequency and distribution of cement between the grains
	Density of cement arrangement	C_c	Density of the cement in a hypothetical length

Some parameters as Sphericity(Sr) and Circularity(R) are not affected by dynamic compaction and their changes are not interpreted.

Generally, due to some blows, some phenomena as cracking, grains bending, grains torsion, grains fracture, crushing of peds and grains compaction are created (Fig. 3).

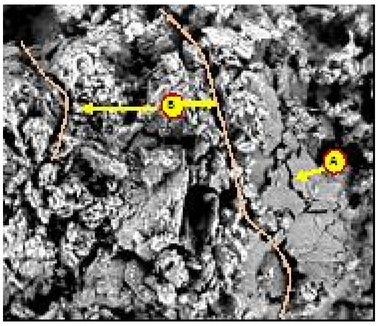


Figure 3: The fracture of grains (A) and vertical crack (B) due to 10 blows on Aq Emam hill

The severity, types are not dependent upon the number of blows and type of soil.

The size of grains is changed by the increase of the number of blows but the changes are low in the investigated samples. In Aq Emam hill with more clay, the soil has plastic behavior against the blow and by increase of N , the diameter of the grains is reduced little and this is due to the compaction or crushing of peds and fine-grains (Fig.4).

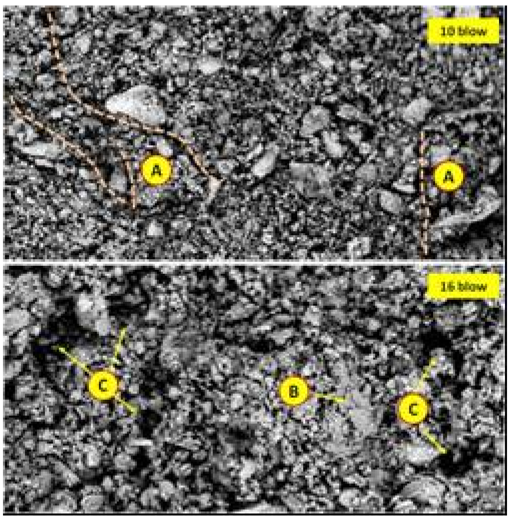


Figure 4: Microstructure changes due to 10 blows (above figure) and 16 blows (bottom figure) on Aq Emam samples. Explanation: Cracks (A), grains fracture (B) and crack (C)

But in Hutan samples, the reduction of the size of grains is considerable and this is due to the break behavior in the soil. In this sample, the aggregate is broken and is changed into fine grains (Fig. 5).

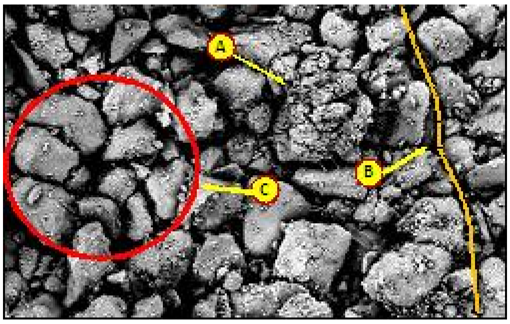


Figure 5: Aggregates fracture (A), vertical crack (B) and new arrangement of grains (C) due to 2 blows on Hutan sample

The particles are fractured and bended (Fig.6).

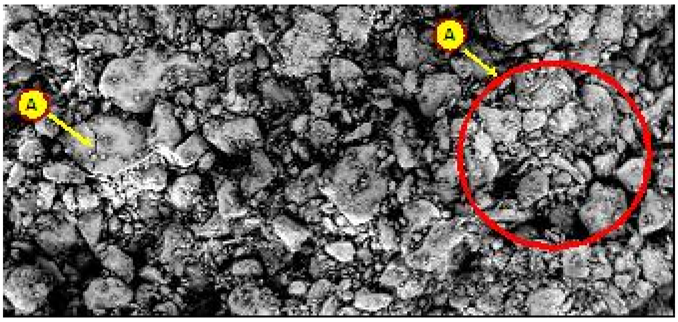


Figure 6: Compact arrangement of the grains (A) and breaking resistant grains (B) due to 8 blows on Hutan sample.

Even resistant grains go into the aggregate and crush it (Fig. 7).

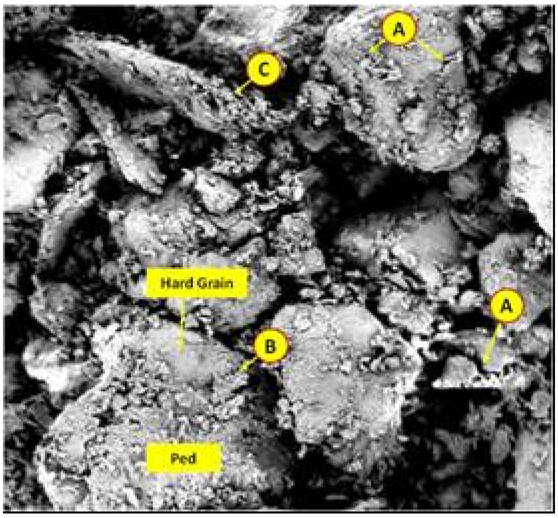


Figure 7: Breaking the grains (A), submerge of resistant grains in aggregate (B) and disintegration of mica particles (C) due to 8 blows on Hutan sample.

The direction of the grains due to dynamic blows is seen obviously and reduction trend is with the increase of blows (Fig. 8).

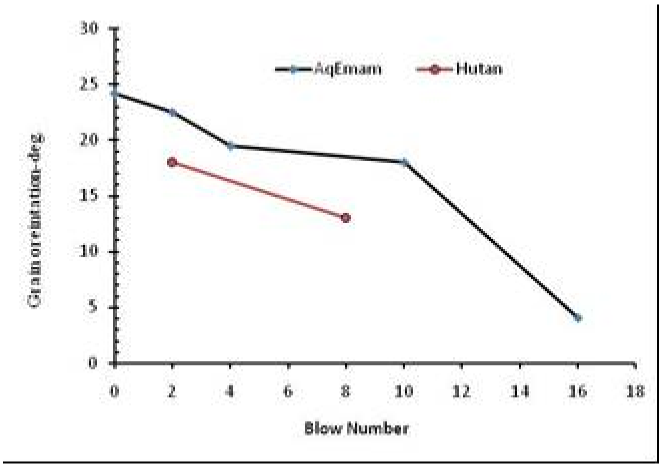


Figure 8: The dynamic force effect of blow on Loess direction

The compaction of the grains is not similar in within the sample. Some of the grains are compacted rapidly and some other more slowly and they are moved and some of the grains are crushed and more open space is created for the torsion of the grains.

The changes of the arrangement of grains density in horizontal and vertical directions due to the blows are different (Fig. 9).

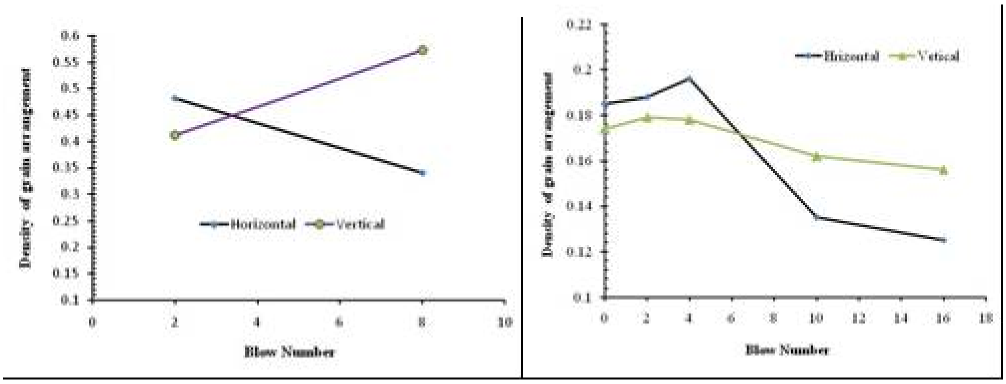


Figure 9: The dynamic compaction effect on density arrangement of AqEmam hill Loess grains (right) and Hutan (left)

Generally, with increasing the number of blows, the grains density arrangement is decreased and it is due to the new crack in the soil but in the vertical direction, the drop is ignored and in Hutan sample is increase. The reason of increase in the density arrangement in the vertical direction is the more compaction of the grains.

Fractal dimensions of the grains (DF_g) are dependent upon the changes of blows but its values are different in various blows (Fig. 10).

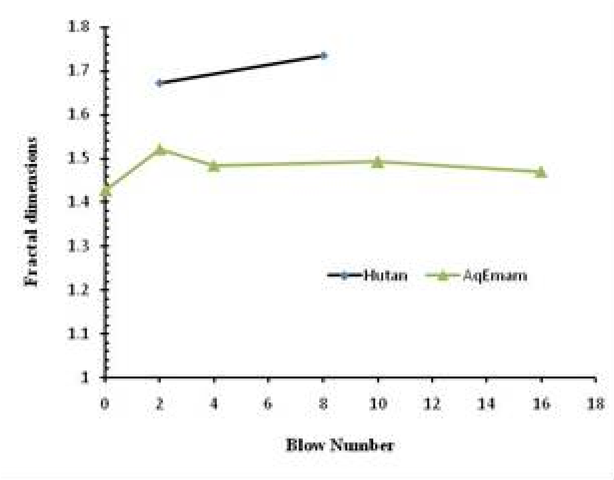


Figure 10: Fractal dimensions of the grains changes due to dynamic blows on Loess samples of Aq Emam and Hutan

In some definite blows, it is more organized. Although the combination of the grains are in the contrary by their disintegration but both of them cause torsion in diffusion of the grains and cause soil compaction but the increase of compaction doesn't lead into the increase of fractal dimensions and fractal dimension shows the geometry in the soil not compaction. Thus in high blows, although the soil is more compact, it fractal dimensions are less. In Hutan sample fractal dimensions of the grains is bigger than Aq Emam and shows more order in the distribution of the grains as the cement and clay fine-grained particles more cause disorder in the samples.

Soil porous space is affected by the number of dynamic blows. In Aq Emam samples, by pores diameter increase, the numbers of blows are decreased but in higher blows, they reach constant limit (Fig. 11).

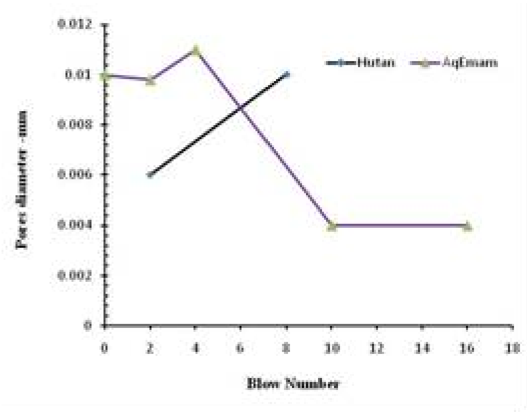


Figure 11: The changes of pores diameter due to dynamic blows on loess samples of Aq Emam and Hutan

In Hutan samples, by increase of blows, the diameter of the pores are increased. This is due to the fact that in Aq Emam hill samples, the soil behavior was plastic and by blows, the pores are small but in Hutan samples, the soil is brittle and bigger porous space is created.

Pores density arrangement is increased to definite blows and is reduced after that (Fig. 12).

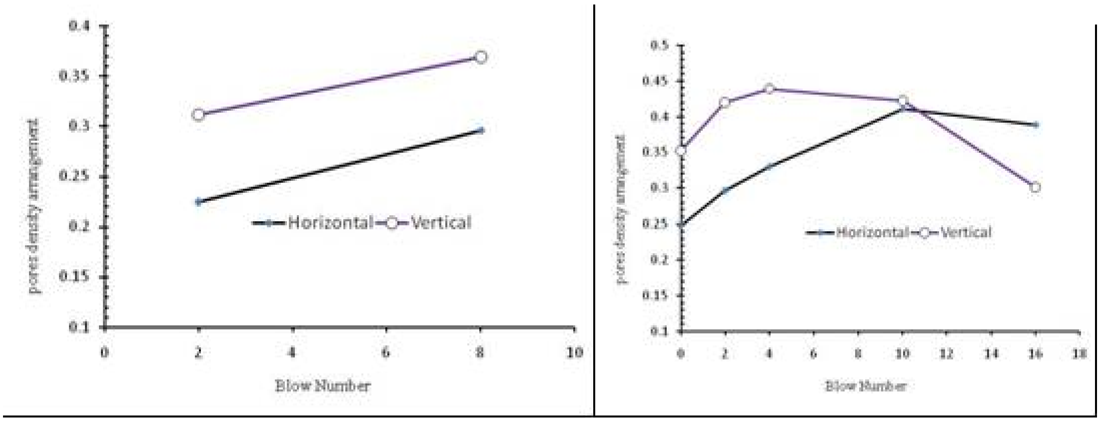


Figure 12: The changes of pores density arrangement due to dynamic blows on Loess samples of Aq Emam (right) and Hutan (Left)

The reason of increase of the new cracks and the initial increase is porosity and in higher blows, the soil is compacted and the cracks are closed. By comparing two Loess of Aq Emam and Hutan, it is observed that in the blows less than 8, density arrangement of the pores is increased and after that decreases.

The cement between the grains is changed due to the blows such that the connectivity index between the grains (Lc) by increase of the number of blows is increased (Fig. 13).

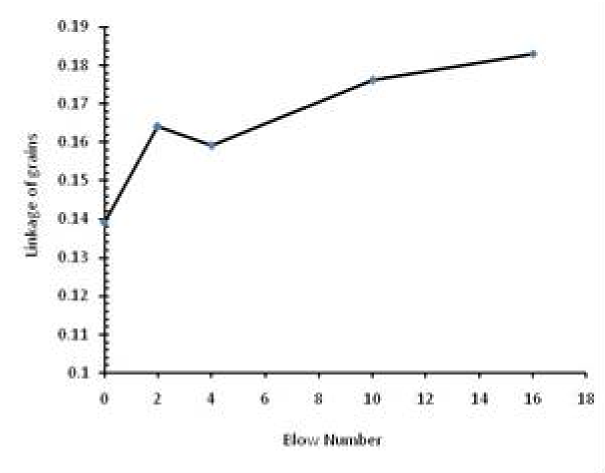


Figure 13: The changes of the connectivity between the grains due to dynamic blows on Loess samples

It is due to the increase of the break of connectivity between the grains and the closeness of the grains. The density of cement distribution between the grains in Aq Emam hill is increased in the initial blows but it is reduced to 10 blows and it reaches the constant value. As cement distribution density in horizontal and vertical directions approach in high blows.

To investigate the effectiveness of microstructure parameters due to dynamic blows by combining all the parameters, a comprehensive parameter is used in each dynamic blow and it is expressed as (Hu et al. 2001).

$$F_d(N) = \sum_{i=1}^{n=9} \frac{P_s(i,N) - P_s(i,0)}{Fs(i,0)} \times 100$$

Where Ps (0،i) is a microstructure parameter i in zero dynamic blow and ps(i,N) is the same as microstructure parameter i in N dynamic blow and by adding all the parameters Fd(N), in each blow is defined (Table 2).

Table 2: The changes of microstructure parameters Ps (0‹i) due to blow dynamic compaction

Comprehensive parameter in different blows					symbol	microstructure parameters(i)
Fd(i)	Fd(16)	Fd(10)	Fd(4)	Fd(2)		
-17.39	-8.70	-13.04	8.70	-4.35	D_g	Maximum Grain diameter
-135.54	-83.47	-25.62	-19.42	-7.02	O_g	Grain orientation
-51.89	-32.43	-27.03	5.95	1.62	P_{dh}	Density of grain arrangement-horizontal
-12.07	-10.34	-6.90	2.30	2.87	P_{dv}	Density of grain arrangement-vertical
-112.00	-60.00	-60.00	10.00	-2.00	D_p	Pore diameter
175.00	56.85	65.73	33.06	19.35	P_{ph}	Density of pore arrangement-horizontal
49.43	-14.49	19.89	24.72	19.32	P_{pv}	Density of pore arrangement- vertical
90.65	31.65	26.62	14.39	17.99	L_c	Linkage of grains
-36.79	-16.06	-21.59	-1.90	2.76	C_{ch}	Density of cement arrangement-horizontal
0.00	10.09	-8.77	-4.82	3.51	C_{cv}	Density of cement arrangement- vertical
-50.60	-126.90	-50.72	72.96	54.05	Fd(N)	Comprehensive parameter

By comparing comprehensive parameters of 10 microstructure indices (Fig. 15), three indices of pores density arrangement in vertical and horizontal directions and the connectivity between the grains in various blows have positive values and show that dynamic blows cause more fracture and porosity in Loess and the cement between the grains is increased.

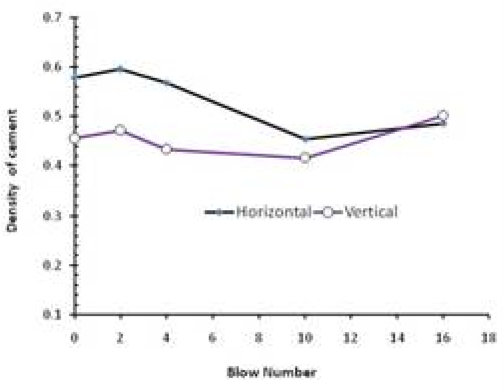
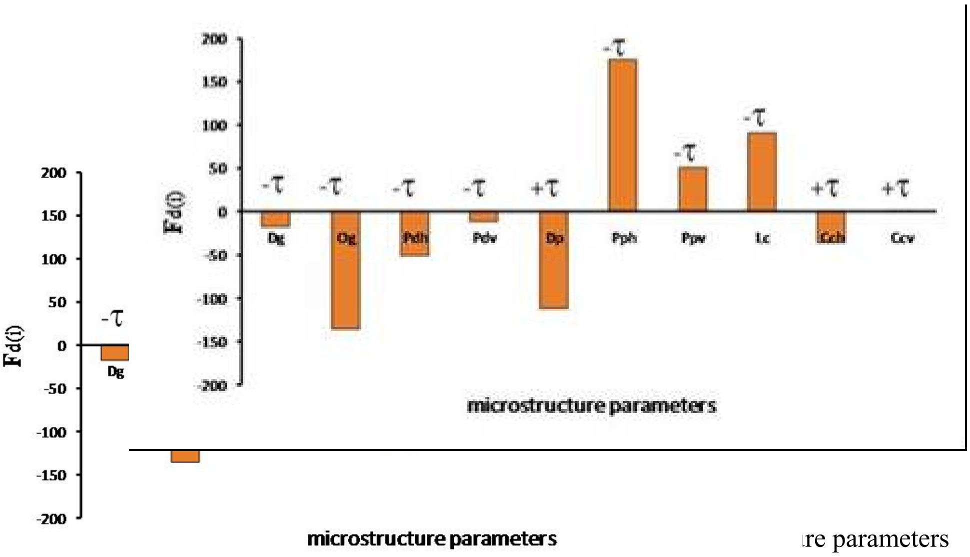


Figure 14: The changes of cement density arrangement due to dynamic blows on Loess samples of Aq

Emam



ıre parameters

Only two parameters of pores diameter (D_p), cement density distribution in horizontal directions (C_{ch}) by increasing blow dynamic low lead into the increase of shear strength (τ) loess and the rest of the parameters by the increase of dynamic load have reducing role in shear strength.

Bigger Fd(N) absolute value shows more microstructure changes. In 10, 2 blows, the absolute value is the minimum and shows that the ignorable effect of compact energy is in 2 blows and new arrangement in compact structure in 10 blows has the least disorder in its structure (Fig. 16).

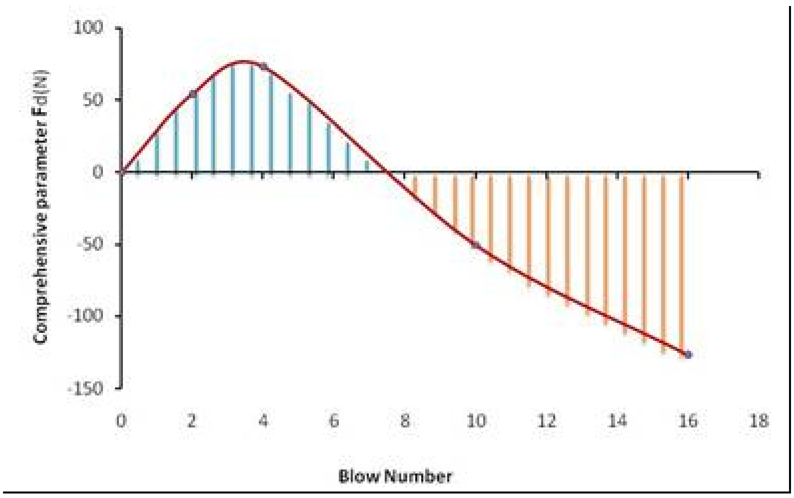


Figure 16: The effect of blow dynamic compact on comprehensive microstructure parameter of Loess

As it is seen, in definite blows, less than 8 Fd (N) values are positive and are negative more than that and this shows that microstructure parameters of soil proceeds the soil in before 7 blows and after that they get weak and have less resistance against applying blow dynamic loads and the biggest value of Fd(N) is in 4 bows and is equal to 73%. The smallest value is in 16 blows about 127% (fig. 17).

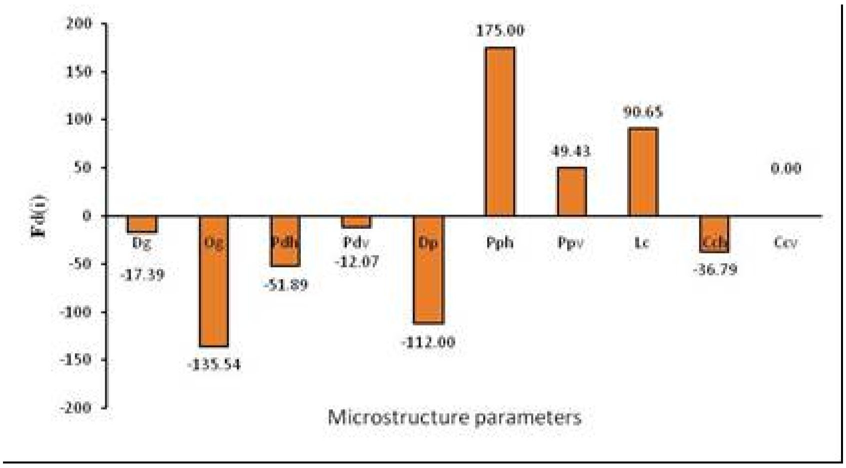


Figure 17: The microstructure parameters changes of Loess

Until now, the researches less considered on the evaluation of the effect of dynamic compaction on undisturebed Loess soil structure. The result of this study shows that dynamic compaction changes most of the microstructure characteristics. It is effective on diameter, direction, grains density arrangement, pores and the cement between the grains. The less the percent of the clay of Loess soil, its behavior is more brittle against dynamic compaction and cause crack, gap and torsion of grains and grains compaction. Due to dynamic load, if there is adequate space, it is rotated to the initial state and the arrangement of the diameter of the maximum grains is compact and its direction is loaded axial vertical. In low blows, by increase of the number of blows, the arrangement of the density of grains is increased but in blows more than 4, due to the crushing of grains and soil structure collapse, the grains density arrangement is reduced. Dynamic blows ca uses disorder in the arrangement of the grains and fractal number is reduced. Some of the parameters are directly associated with the number of dynamic blows and some other have reverse relation.

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