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THE IMPACT OF CARBONATE MINERALS CONTENT ON SOIL PORE SIZE DISTRIBUTION

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ABSTRACT
The porosity and pore space of soil as well as pore size distribution is an important factor for soil hydraulic conductivity and water retention. This study includes an experimental investigation of the effect of carbonate minerals on pore size distribution. Soil material with loam texture was used to prepare nine soil materials containing wide range of carbonate minerals (3.2 -352 gm kg^{-1}). The soil-water retention curve (θ(ψ)) was estimated. Computer program (RETC code) was used to determine the best-fit for experimental data of water potential versus volumetric water content which have nonlinear relationship to determine the parameter of van Genuchten equation [α, n and m with m=1-(1/n)]. The capillary rise equation (young-laplace equation) was used to estimate the effective pore diameter (D). The results show that pore space was affected by carbonate minerals contents. Air pores (> 30μm) increased 1.4 fold with increasing carbonate minerals at the same time capillary pores filled with water (< 30μm) decreased by 1.3 folds. The relative of water volume to total soil volume ranged between 0.27 and 0.21 cm^3cm^{-3} for carbonate minerals content 3.2 and 352 g kg^{-1} respectively. At 10 Kps the amount of water lost increased with increasing carbonate minerals content, where soil sample with 352 $g.kg^1$ carbonate minerals lost water more than soil sample with 3.2 $gm.kg^{-1}$ carbonate minerals by 42%. The percentage of pores (<30 μm) ranged from 67% to 79% and the pores (>30 μm) ranged from 33% to 21%. In conclusion, the high carbonate minerals content in the soil led to change in pore size distribution, where air-filled pores increased and capillary pores filled with water (water holding capacity) decreased at different degree from sample to another.

KEYWORD: Water retention curves, Young-Laplace equation, effective pore diameter, void ratio.

INTRODUCTION

Soil contain varying amount of carbonate minerals and if these amounts increased it will affect in some of soil properties and make environmental changes in which reflected on the growth and the production of plant (Kishchuk, 2000). Iraqi soil content a high percentage of carbonate minerals which ranges between 15 – 35%, and it could be found less then 4% or more than 60% depending on prevalent environmental circumstances and soil forming conditions. Calcite mineral constitutes the greater portion of carbonate minerals existing in the Iraqi soil which reaches the amount of 90% while the other amount consists of Dolomite and Calcite holding magnesium (Al-Kaysi, 1983). Carbonate minerals in soil could be primary inherited from the mother material or secondary accumulated by the operations of soil forming (Al-Samarraie, 1975). So carbonate minerals found as a cover shape which cover the particles and the accumulations of soil or accumulate in cracks, like flakes or accumulated grains in knots or veins (Gile, 1961).The presence of carbonate minerals in various portions affect in soil water properties such as the ability to hold water, total porosity and pores size distribution (Singh *et al.*, 2008). The results of some researches (Al-Kubaisi, 1986; Khattab and Aljobouri, 2012; Muhmed and Wanatowski, 2013) have shown a different effect of carbonate minerals in the ability of soil to hold water sometimes increases and sometimes decreases which means that the porous system of soil have been affected by carbonate minerals content and that leads to a combination of reasons one of them is that the sedimentation of carbonate minerals in the internal voids and capillary pores endings causing clogging so water movement is obstructed and raise the probability of keeping it or it is lining the capillary and non-capillary tubes causing decrease in cross section area and volume leading to decrease the moisture content, or it covers the surface area of clay particles which decrease the surface area that holds water carbonate minerals work to form soil macro aggregate which have a wide pore space that have low ability of keeping water when exposed to water tension.

Pore space refers to the volume of soil voids that can be filled by water and, or air. It is effect and affected by the soil physical, chemical and biological properties. All operations and reactions occur through pore space such as the movement of water and air, dilution and sedimentation. In addition, pore space well known as a residential place for plant roots and soil organisms (Abdollahi *et al.*, 2014; Malik *et al.*, 2015). The soil pore space characterized in to two features porosity and pore size distribution. The pore size distribution considered the most important feature for it’s complicated and strong relation with other soil characterize especially with soil structure, stability of aggregates and particle size distribution (Nimmo, 2004). Eynard *et al.* (2004) have found the importance of soil pore size distribution for it’s affection on controlling fluid movement and storage in soil which provides a space within the void occupied by air

The void ratio (e) calculated by:

$$e = \frac{V_v}{V_s} \quad (\text{dim}\,\textit{ensionless}) \qquad (4)$$

Where V_v is void volume (cm^3), V_s is solid part volume of soil (cm^3). Water volume ratio v_w also calculated in each soil sample when exposed to different water tensions from zero to -1500 Kps by applying eq. 5 that mentioned in Hillel (2004):

$$v_w = \frac{V_w}{V_s} \qquad (5)$$

Where V_w is water volume (cm^3).

RESULTS & DISCUSSION

The moisture retention curves of soil samples that have several contents of carbonate minerals as shown in (fig. 1). There were differences between the curves of the moisture retention for different soil treatments. The ability of soil samples to keep water decrease by the increasing of carbonate minerals at every water tension level (from -0.1 to -1500 Kps). Important changes happened to retained water volume at different tensions especially at decreased water tensions in which the amount of retained water decreased with the increasing of carbonate minerals. And the volumetric moisture content θ was 0.4808 cm^3 cm^{-3} at water tension 0.1 Kps of soil sample 3.2 gm kg^{-1} carbonate minerals content. The moisture content decreased continually and reached 0.3787 cm^3 cm^{-3} of soil sample 352 gm kg^{-1} carbonate minerals content with decreasing percentage 21%. The volumetric moisture content has changed at 10 Kps with the change of carbonate minerals which reached 0.4065, 0.3896, 0.3768, 0.3644, 0.3336, 0.3229, 0.3084, 0.2970, and 0.2733 cm^3 cm^{-3} for soil samples contents carbonate minerals 3.2, 51, 103, 152, 203, 251, 305, 334, and 325 gm kg^{-1} respectively. It's clear from Fig.1 that the moisture content at 1500 Kps got the same behavior which the residual water content θ_r decreased with the increasing of carbonate minerals from 0.1330 to 0.0592 cm^3 cm^{-3} of soil sample content from 3.2 to 352 gm kg^{-1} carbonate minerals with decreasing percentage of water content by 55%. The occurred changes in volume of retained water at different water tensions due to the change in total porosity of soil sample and the change in the pores size distribution due to the change of carbonate minerals. The effective diameter (eq.3) at water tension 10 Kps shows that pore size larger than 30 µm, which losing water content and the difference water content between 0.1 and 10 Kps represents non-capillary pores and it's also known as air-filled porosity (air porosity). While the difference of water content between 10 and 1500 Kps represents the water holding capacity which equal the amount of water and it's capillary pores filled with water and it's volume less than 30 µm (Abdollahi *et al.*, 2014; Eynard *et al.*, 2004; Startsev and McNabb, 2001).

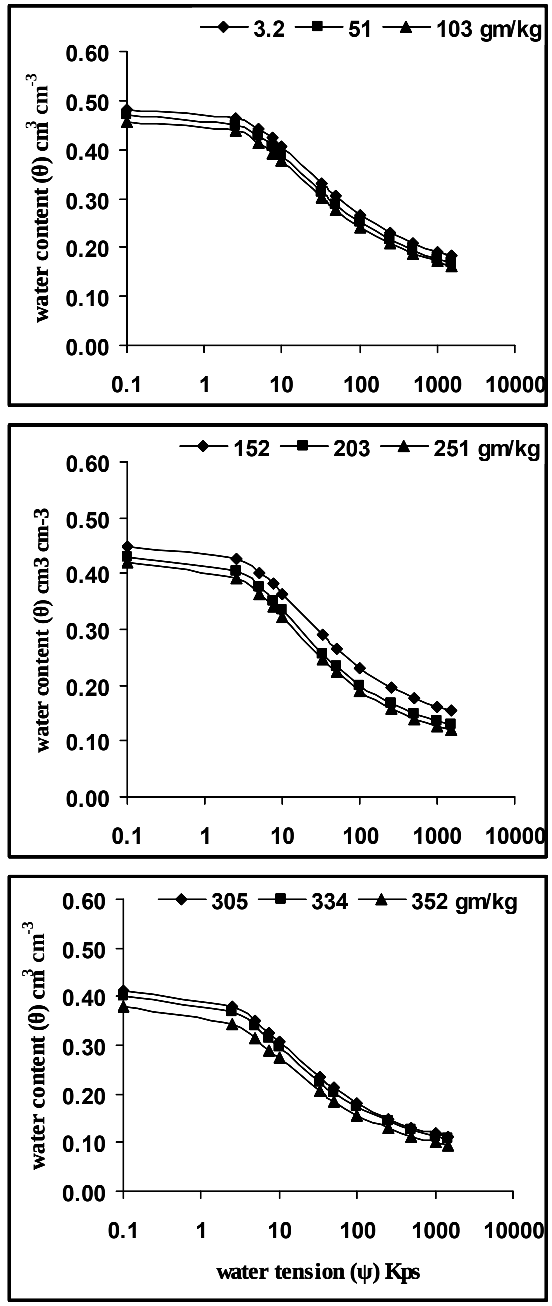

FIGURE 1. Water retention curves of soil samples with various carbonate minerals content.

Fig. 2 shows the volume of air pores and the volume pores filled with water at 10 Kps for soil samples. The non-capillary pores filled with air increased with increasing of carbonate minerals content, for example the soil sample content 352 gm kg^{-1} carbonate minerals has the highest amount of pores filled with air while the sample content 3.2 gm kg^{-1} carbonate minerals has the lowest amount of pores filled with air. The ratio of air pores volume to the total volume of soil is 0.074, 0.080, 0.081, 0.084, 0.097, 0,097, 0.104, 0.104 and 0.105 cm^3 cm^{-3} for samples content 3.2, 51, 103, 152, 203, 251, 305, 334, and 352 gm kg^{-1} carbonate minerals respectively. The capillary pores filled with water (< 30 µm) was highest for soil sample content 3.2 gm kg^{-1} carbonate minerals which reached 0.274 cm^3 cm^{-3} and decreased to 0.214 cm^3 cm^{-3} in the sample content 352 gm kg^{-1} carbonate minerals, which means that the ability of soil to lose water increased with increasing carbonate minerals.

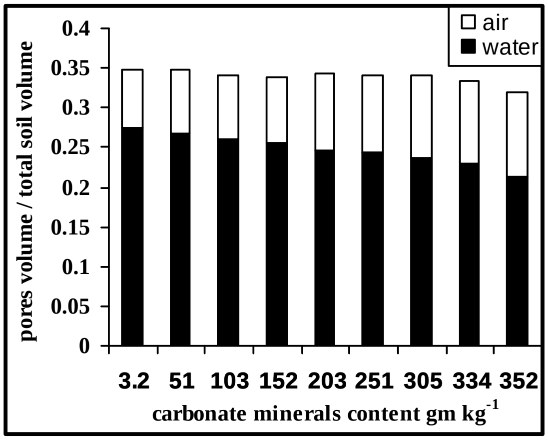

FIGURE 2. Air and water distribution in soil sample content various carbonate minerals, Air-filled pore volume (pores >30 µm diam.) and water-filled pore volume (pores < 30 µm diam.).

Fig. 3 shows the relationship between effective pores diameter (D) which calculated using eq. 3 and water content (θ) for soil samples with a various content of carbonate minerals. The increasing effective pores diameter accompanied with increase water content with decrease carbonate minerals in soil sample. Fig. 3 represents soil pores size distribution and it looks that the pore volume increase when the pore diameter decrease, the pore volume can be estimated by the amount of water content that kept in soil when exposed to certain water tension, and that represents the diameter of soil pores which are less than 30 µm confronting 10 Kps (fig.2), the ratio water content ($\Theta = \frac{\theta - \theta_r}{\theta_s - \theta_r}$), where 0 < Θ <1 at 10 Kps 10 reach to the 0.786, 0.769, 0.764, 0.752, 0.716, 0.717, 0.696, 0.689, and 0.670 for soil samples content 3.2 , 51, 103, 152, 203, 251, 305 , 334, and 352 gm kg^{-1} carbonate minerals respectively. While the effective pores diameter that greater than 30 µm are 0.213, 0.230, 0.236, 0.248, 0.284, 0.283, 0.304, 0.310, and 0.329 which equals ($1 - \frac{\theta - \theta_r}{\theta_s - \theta_r}$) for soil samples respectively. It's clear that the air filled pores system type is mesopores which is permeable pores (Startsev and McNabb, 2001) which lost water when soil sample exposed to tension of 10 Kps. the pores proportions in the pore space of soil samples ranged between 21.4 and 33.0 %, while water storing pores which are the pores that keep water when exposed to tension of 10 Kps their proportions ranged between 67.0 and 78.6 %. This soil pores size distribution is considered important to determine the water environment of soil in which the soil sample have got a good proportion of permeable pores and it's important to make water move in soil for that reason the soil samples that have moderate or high content of carbonate minerals (203, 251, 305, 334, and 352 gm kg^{-1}) have good water conductivity and diffusivity because of the increase in pores that convey water which nearly reached as a ratio quarter pores system volume of soil sample. One of the soil pores size distribution evidence is void ratio (eq.4) and it shows the change occurred in each pores volume and solid soil material volume with in soil bulk volume. The void ratio have been effected by carbonate minerals content with a value of 0.93 of 3.2 gm kg^{-1} carbonate minerals then the void ratio of other soil samples decreased and reached the value of 0.61 in the soil sample 352 gm kg^{-1} carbonate minerals with a decreasing percentage of 34% (fig. 4). The change that occurred in pores size distribution (fig. 2 and fig. 3) and void ratio (fig. 4) caused a change in the amount of water in soil sample when the content of carbonate minerals changes.

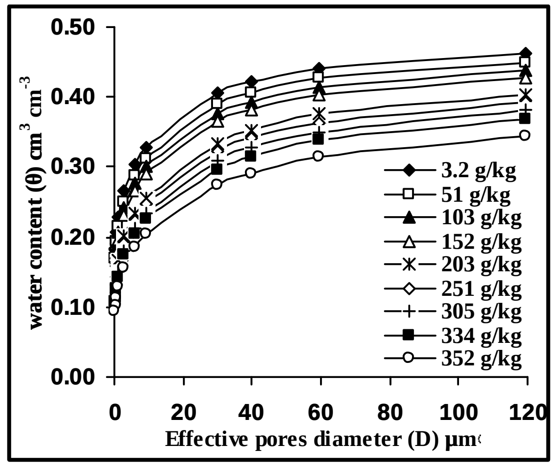

FIGURE 3. Relationship between effective pores diameter D and water content θ for soil sample content various carbonate minerals.

Fig. 5 shows the relation between effective pores diameter and water volume ratio. It seems that amount of water volume ratio was little with in the micropores, the water volume ratio increases by the increasing of effective pore size for all soil samples that have a different content of carbonate minerals. In the same time the amount of water volume ratio decreased by the increasing of carbonate minerals content for all effective soil pore diameters.

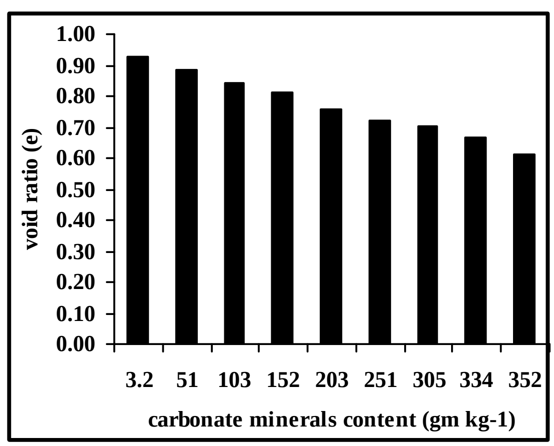

FIGURE 4. Void ratio e (dimensionless) for soil sample with various carbonate minerals content.

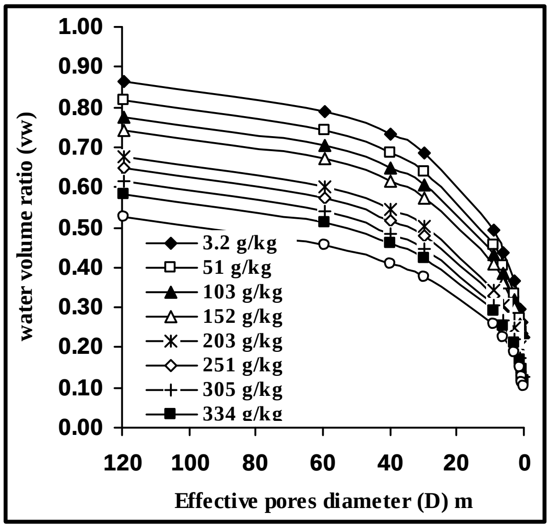

FIGURE 5. Relationship between effective pores diameter D and water volume ratio v_w for soil sample content various carbonate minerals.

CONCLUSION

It's concluded that the pores system of soil samples have effected by carbonate minerals content so that an increase occurred in air pores (greater than 30 μm) with the increasing of carbonate minerals content while the water filled pores (less than 30 μm) decreased. When soil samples exposed to tension about 10 Kps. they lost more amount of water by the increase of carbonate minerals, in the sample of 352 gm kg^{-1} carbonate minerals lost more water with proportion of 22% compared with the sample of 3.2 gm kg^{-1} carbonate minerals.

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REFERENCES

Abdollahi, L., Munkholm, L.J. and Garbout, A. (2014) Tillage system and cover crop effects on soil quality: II. Pore characteristics. Soil Sci. Soc. Am. J. 78:271–279.

Al-Ani, A.N. and Dudas, M. (1988) Influence of calcium carbonate on mean weight diameter of soils. Soil and Tillage Res. 11: 19-26.

Al-Kaysi, S.C.(1983) Physical and Chemical Characterization of Carbonate Minerals in Iraqi Soils. Ph.D. Dissertation, Dept. of Soil Sci. Newcastle upon Tyne, U.N.

Al-Kubaisi, N.H. (1986) Effect of Calcium Carbonate on Some Physical and Mineralogical Properties of Soil. M. Sc. Thesis, Dept. of Soil Sci. College of Agriculture. University of Baghdad. Iraq. p91.

Al-Samarraie, M.Y. Gh. (1975) Micropedolo- gical Study of Highly Calcareous Soil with Particular Reference to Iraq. Ph. D. Dissertation. Univer. of Reading, England.

Brady, N.C. and Weil, B.R. (2014) The Nature and Properties of Soils, 3rd Edition – Soil Water: Characteristics and Behavior. Pearson Education Limited. pp. 197-201.

Chan, T.P. (2005) Modeling of Coarse Textured Soils and Their Hydraulic Properties. Ph. D. Dissertation. Purdue Uneversity. p.177.

Eynard, A., Schumacher, T. E., Lindstrom M. J. and Malo, D.D. (2004) Porosity and pore-size distribution in cultivated Ustolls and Usterts. Soil Sci. Soc. Am. J. 68: 1927-1934.

Gile, L.H. (1961) A classification of Ca-horizon of desert region, New Mexico. Soil Sci. Soc. Am. Proc. 30:52-61.

Goncalvesa, R.A.B., Gloaguen, T.V., Folegatti, M.V., Libardi, P.L., Lucas, Y. and Montes, C.R. (2010) Pore size distribution in soils irrigated with sodic water and wastewater. R. Bras. Ci. Solo. 34: 701-707.

Hillel, D. (2004) Introduction to Environmental Soil Physics. Elsevier Academic Press, Amsterdam. 494 pp.

Holford, I.C.R. and Mattingly, G.E.G. (1975) Surface areas of calcium carbonate in soils. Geoderma. 13: 247-255.

Hong, S. Y., Minasny, B., Hwa Han, K., Kim, Y. and Lee. K. (2013) Predicting and Mapping Soil Available Water Capacity in Korea. National Academy of Agricultural Science, Rural Development Administration (RDA), Suwon, Gyeonggi-do, Republic of Korea.

Khattab, S.I. and Aljobouri, M.M. (2012) Effect of combined stabilization by lime and cement on hydraulic properties of clayey soil selected from Mosul area. Al-Rafadain Engineering J. 20(6):139-153.

Kishchuk, B.E. (2000) Calcareous soils, their properties and potential limitations to conifer growth in southeastern British Columbia and western Alberta: a literature review. 2000. NOR-X-370.

Klinkenberg, L.J. (2009) Pore size distribu-tion of porous media and displacement experiments with miscible liquids. J. Petroleum Tech. 9(4): 63-66.

Klute., A. (eds.) (1986) Methods of Soil Analysis: Part 1- Physical and Mineralogical Methods. ASA and SSSA. SSSA Book Series No. 5. Madison, WI: Soil Sci. Soc. Am. p 1188.

Malik, Z. and Sheng-Gao, Lu. (2015) Pore size distribution of clayey soils and its correlation with soil organic matter. Pedosphere. 25(2): 240-249.

McNabb, D.H., Startsev, A.D. and Nguyen, H. (2001) Soil wetness and traffic level effect on bulk density and air-filled porosity of compacted boreal forest soils. Soil Sci. Soc. Am. J. 65: 1238-1247.

Muhmed, A. and Wanatowski, D. (2013) Effect of lime on the strength and microstructure of clay. J. Mech. and Civil Eng. 6(3): 87-94.

Nimmo, J.R. (2004) Porosity and pore size distribution. *In* Hillel, D. (ed.) Encyclopedia of Soils in the Environment: London, Elsevier. 3: 295-303.

Page, A. L., Miller, R. H. and Kenney, D. R. (1982) Methods of Soil Analysis .Part 2. Chemical and

Microbiological Properties. USA. Am. Soc. Agron. Inc. Publisher, Madison, Wisconsin. USA.

Singh, J., Kumar, A., jain, R. and Khullar, N. K. (2008) Effect of lime on properties of soil. The 12th International Conference of IACMAG. Goa, India.

Startsev, A. D. and McNabb, D. H. (2001) Skidder traffic effects on water retention, pore-size distribution, and van Genuchten parameters of boreal forest soils. Soil Sci. Soc. Am. J. 65:224–231.

Stingaciu, L.R., Weihermuller, L., Haber- Pohlmeier, S., Stapf, S., Vereecken, H. and Pohlmeier, A. (2010) Determination of pore size distribution and hydraulic properties using nuclear magnetic resonance relaxometry: A comparative study of laboratory methods. Water Resour. Res., 46(11): 1-6.

van Genuchten, M.Th. (1980) A closed-form equation for predicting the hydraulic conduc-tiveity of unsaturated soils. Soil Sci. Soc. Am. J. 44:892-898.