" The effect of zeolite on some physical properties of soils with different gypsum content "

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Abstract

A laboratory experiment was conducted to investigate the effect of adding one of the soil conditioners, zeolite mineral, on selected physical properties of gypsum soils, which are **known for their weak structure, high bulk density, low porosity, crust formation, restricted** water movement, low infiltration rates, and poor hydraulic conductivity.

Three sites within the University of Tikrit were selected, where soil samples with gypsum content of 2.27%, 13.29%, and 25.60% were collected. Zeolite was added at four levels: 0%, 1%, 2%, and 3%, and incubated with the soil for 60 days. The treated soils were placed in pots weighing 1 kg, followed by laboratory measurements.

The results showed significant differences in bulk and particle density due to varying gypsum content. The soil with the highest gypsum level (S3) recorded the highest bulk density at 1.496 $g.cm^{-3}$, while soils S1 and S3 had the highest particle densities, reaching 2.531 and 2.524 $g.cm^{-3}$, respectively. In contrast, the lowest bulk density was observed in soil S1 (1.464 $g.cm^{-3}$), and the lowest particle density was in soil S2 (2.495 $g.cm^{-3}$).

Zeolite addition levels also had a significant effect in reducing both bulk and particle densities. The control treatment (Z1) exhibited the highest values of bulk and particle density, 1.496 and 2.296 $g.cm^{-3}$, respectively, while treatment Z4 showed the lowest bulk density (1.468 $g.cm^{-3}$). The highest particle density was observed with treatment Z3 (2.536 $g.cm^{-3}$), though no significant difference was found between Z3 and Z4.

The results also revealed significant differences in aggregate stability due to soil gypsum content. Soil S2 achieved the highest mean aggregate stability at 1.832 mm, while soil S1 recorded the highest overall value at 2.413 mm.

Zeolite levels significantly influenced aggregate stability. Treatment Z4 (3% zeolite) showed the highest aggregate stability at 2.589 mm, whereas treatment Z1 (control) recorded the lowest at 1.64 mm.

Keywords: Zeolite , Gypsum , bulk density , particle density , physical properties.

Introduction

gypsiferous soil occupy vast areas in Iraq and are commonly utilized for agricultural production across several regions. These soils suffer from deteriorating physical properties due to high gypsum content. They often behave similarly to sandy soils in terms of water and physical characteristics, as the increase

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in gypsum content typically leads to a significant decrease in clay content. This, in turn, reduces the soil's capacity to retain water and nutrients, negatively impacting plant growth.

Several soil amendments have been used worldwide to enhance soil quality, including zeolite, which has shown effectiveness in improving water and nutrient retention.

Zeolite is a naturally occurring or synthetically produced mineral formed through the alteration of volcanic rocks rich in silicon dioxide, particularly through interaction with seawater under alkaline conditions and suitable temperatures (Badillo-Almaraz et al., 2003). There are 167 types of zeolite, including 48 natural and the rest synthetic. Both types share similar structural and functional properties such as high porosity and crystal structure, but they differ in pore size and the presence of impurities. Synthetic zeolite typically has larger pores than its natural counterpart.

Zeolite has low density due to its crystal system being full of cavities. The primary reason for open pores is the electrostatic repulsion between oxygen atoms within the tetrahedral unit and the surface layers. This makes zeolite a highly active material in adsorption, with strong ion exchange capacity and the ability to transport ions and other substances through its porous network (Abdel-Hassan&Raid, 2018).

Zeolite has been applied to sandy soils to improve their physical characteristics, enhance water availability and retention, and reduce nutrient leaching (Abdi et al., 2006). It also boosts the soil's cation exchange capacity, promotes slow ion release, and improves water-use efficiency, especially in degraded soils that require intensive reclamation efforts. Mixing zeolite with sandy soils increases surface area and cation exchange capacity while reducing nitrogen and nutrient loss through leaching, thereby improving the overall soil structure and plant growth potential (Anonymous et al., 2004). Its high adsorption capacity for macro- and micronutrients has made it successful in agricultural applications (Manolov et al., 2005).

Gypsum has been shown to significantly influence bulk density. Nettleton et al. (1982) and Barazanji (1984) reported that bulk density decreases with higher gypsum content, while Paliwal et al. (1981) found the opposite trend—an increase in bulk density with higher gypsum content. Hussain et al. (2001) recorded the lowest bulk density value of 1.41 $g.cm^{-3}$ when gypsum was added at 25%, which also led to improved water conductivity, porosity, and pore space.

Al-Quraishi (2005), in a study on three sites with gypsum contents of 29.9%, 28.7%, and 20.4%, found similar bulk density values of 1.27, 1.27, and 1.25 $Mg.m^{-3}$, respectively. The consistency was attributed to the increased presence of coarse gypsum crystals. On the other hand, Al-Badri (1987) found that bulk density increased with fine gypsum crystals, which occupied more pore space. Abdel-Hamid (2016) observed a decrease in bulk density with increasing gypsum content, while Al-A'dhami (2006) found that bulk densities in soil horizons Cy, By, and A of the Dour soil series were 1.42, 1.18, and 1.27 $Mg.m^{-3}$, corresponding to gypsum contents of 3.18%, 48.05%, and 46.32%,

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respectively. Bulk density was lower in sub-surface horizons compared to the surface due to higher gypsum content.

Therefore, the objective of this study is to evaluate the effect of zeolite mineral on improving selected physical properties of gypsum soils, such as bulk density, particle density, and mean weight diameter, in soils with varying gypsum content.

Materials and working methods

A laboratory experiment was conducted in the Soil and Water Resources Department Laboratory – College of Agriculture – University of Tikrit, during the period from 1/10/2022 to 1/10/2023, to investigate the effect of adding a soil conditioner, zeolite mineral, on some physical properties properties of gypsiferous soils.

Three sites were selected within the University of Tikrit, and soils were collected with gypsum contents of 2.27%, 13.29%, and 25.60%. Zeolite was added at four levels: 0%, 1%, 2%, and 3%. The treated soil was incubated for 60 days in 1 kg pots, after which laboratory measurements were carried out. Table 1 shows the most important physical and chemical properties of the studied soils.

The soil was air-dried and sieved through a 2 mm mesh. Then, 1 kg of the gypsiferous soil samples was placed in plastic containers and treated with zeolite at four levels (0%, 10%, 20%, 30%) with three replicates. The samples were incubated for 60 days with regular wetting at field capacity limits, drying, and repeated mixing. Then, laboratory measurements were performed, including:

* Bulk density was measured for the study sites using the core sampler method according to Black (1965).

* After drying the soil samples and passing them through a 2 mm sieve, the following physical and chemical properties were determined:

* Soil reaction (pH) was measured in a 1:1 soil-to-water suspension using a pH meter, following Page et al. (1982).

* Electrical conductivity (EC) was measured in a 1:1 soil-water extract, adjusted to 25°C, using an EC meter as described by Richards (1954).

* Gypsum content was determined by the acetone precipitation method according to Richards (1954), as mentioned by Ryan et al. (2003).

*Mean weight Diameter (MWD):

The weighted diameter rate was measured in the laboratories of the College of Agriculture, Tikrit University, using the wet sieving method after passing the moisture through a sieve with an opening diameter of (4-9) mm. The weighted diameter rate was estimated from passing (25) grams of a group of less than the diameter of its openings of 9.5-4.75-2-1-0.42-0.25 mm. The ratio of the diameter of the aggregates present on each sieve was calculated after sieving it for a period of 6 micrometers as the average weighted diameter rate.

According to the equation:-

MWD=$\sum_{i}^{n} XiWi$……………………………….(1)

Where:

Xi = average diameter of sieves in mm

Wi = weight of aggregates on each sieve in g

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Table 1. Some physical and chemical properties of the studied soils.

Property	S1	S2	S3	Unit
EC	6.02	6.31	5.39	$dS \cdot m^{-1}$
pH	7.25	7.36	7.19	—
CEC	23.97	21.87	22.50	$cmol \cdot kg^{-1}$
Bulk Density (Pb)	1.48	1.50	1.51	$g \cdot cm^{-3}$
Particle Density (Ps)	2.50	2.48	2.51	$g \cdot cm^{-3}$
Porosity	40.60	39.17	39.63	%
Gypsum Content	22.7	132.9	256.0	$g\ Kg^{-1}$
Organic Matter	11.0	9.3	7.9	$g\ Kg^{-1}$
Sodium	1.2	1.4	1.5	$mg \cdot kg^{-1}$
Potassium	27	25	18	$mg \cdot kg^{-1}$
Lime ($CaCO_3$)	210	202	187	$g \cdot kg^{-1}$

Results and Discussion:

Table 2 shows the effect of soil gypsum content and zeolite addition levels on soil bulk density. The results indicate significant differences due to variations in soil gypsum content. The S3 soil (with the highest gypsum content) recorded the highest average bulk density at **1.493333 g/cm³**, while the S1 soil recorded the lowest at **1.464167 g/cm³**. This is attributed to the increase in fine gypsum crystals, which occupy part of the soil porosity. These findings are consistent with Al-Badri (1987) and Paliwal et al. (1981).

The zeolite addition levels also had a significant effect on reducing soil bulk density. The control treatment (Z1) had the highest average value at **1.496667 g/cm³**, while the highest zeolite addition (Z4) resulted in the lowest value at **1.468889 g/cm³**. This reduction is due to the high porosity of zeolite, which leads to the formation of a crystal system full of voids. The main reason for the open pores is the electrostatic repulsion between oxygen atoms adjacent to the tetrahedral unit and the surface. This agrees with Sartbaeva et al. (2006).

Figure 1 also illustrates a significant interaction between soil gypsum content and zeolite addition levels. The combination S3Z1 recorded the highest soil bulk density at **1.51 g/cm³**, while S1Z3 and S1Z4 had the lowest values at **1.44667 g/cm³**. This is again attributed to the high porosity of zeolite, which contributed to decreasing soil bulk density. These findings are consistent with Mirzaei et al. (2013).

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Table 2. Effect of soil gypsum content and zeolite addition levels on soil bulk density.

Treatment	S1	S2	S3	Z Mean
Z1 (Control)	C 1.47	B A 1.50	A 1.51	A 1.49
Z2	B C 1.48	B C 1.48	B A C 1.49	A 1.48
Z3	D 1.44	B C 1.48	B A C 1.49	B 1.47
Z4	D 1.44	C 1.47	B C 1.48	B 1.46
S Mean	B 1.46	A 1.48	A 1.49	

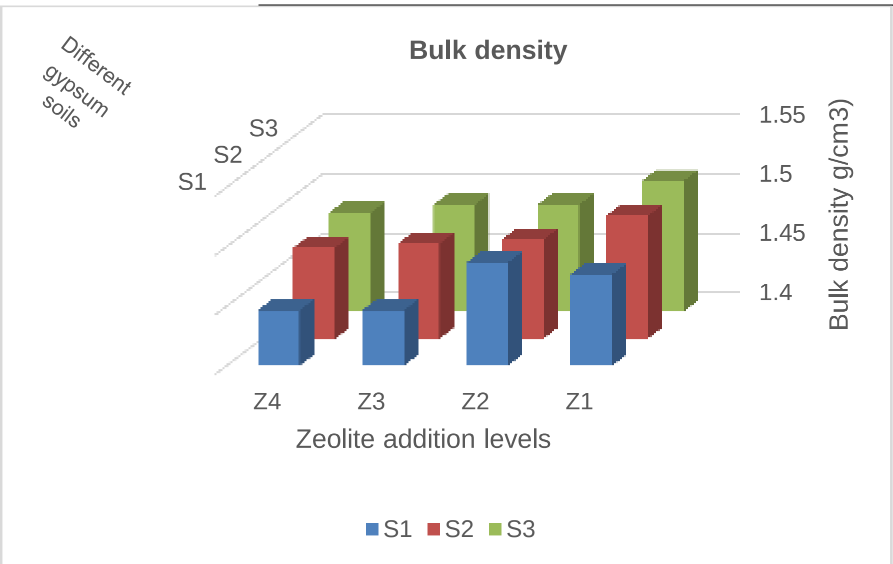

Figure 1: The effect of interaction between different levels of zeolite addition and soil gypsum content on soil bulk density values.

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Table 3 shows the effect of soil gypsum content and zeolite addition levels on the soil's **real density**. There are significant differences in the effect of varying gypsum content on the real density of the soil. The gypsum contents S1 and S3 achieved the highest average real density values of 2.531667 and 2.524167 g/cm³, respectively. While gypsum content S2 showed the lowest average real density at 2.495833 g/cm³. This is attributed to the increase of fine gypsum crystals occupying part of the porosity, consistent with what Al-Badri (1987) and Paliwal et al. (1981) reported.

Zeolite addition levels showed a significant effect on lowering the real density values. Treatment Z1 (control) gave the highest average real density at 2.536667 g/cm³, with no significant difference compared to Z3. Treatment Z4 gave the lowest average value, attributed to the high porosity of zeolite mineral, which reduces the real density of the soil.

Figure 2 shows a significant interaction effect between gypsum content and zeolite levels. Treatment S1Z2 resulted in the

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highest real density at 2.55000 g/cm³, while treatments S2Z1 and S2Z2 recorded the lowest real densities of 2.48333 and 2.48667 g/cm³, respectively.

Table 3: Effect of soil gypsum content and zeolite addition levels on true soil density
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Z Average	S3	S2	S1	Factors
C 2.49	D C 2.50	D 2.48	D C 2.50	Z1
B 2.51	B D C 2.51	D 2.48	A 2.55	Z2
B A 2.51	B A C 2.53	D C 2.50	B A C 2.52	Z3
A 2.53	B A 2.54	B D C 2.51	A 2.55	Z4
	A 2.52	B 2.49	A 2.53	S Average

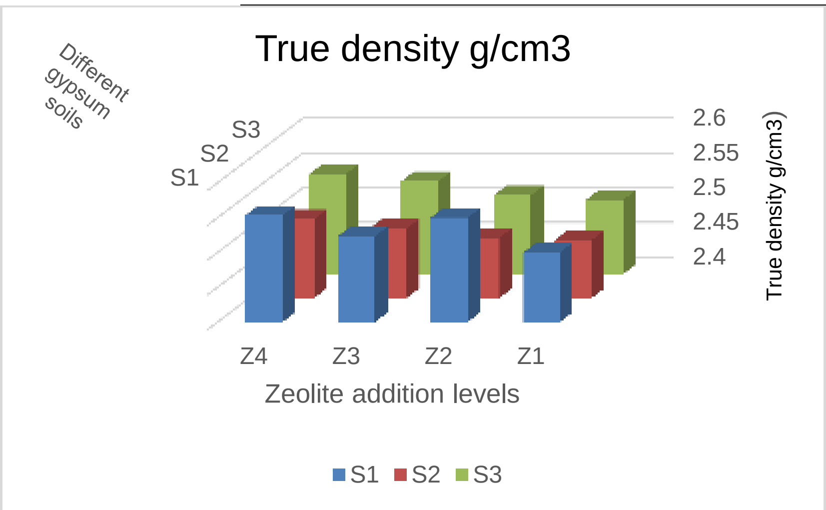

Figure 2: The effect of interaction between zeolite addition levels and soil gypsum content on average soil true density values.

Table 4 shows the effect of gypsum soil content and zeolite addition levels on the average values of soil aggregate stability. There are significant differences caused by varying gypsum content in the soil on the aggregate stability values. The gypsum content S1 achieved the highest average soil aggregate stability with a value of 2.41333%. In contrast, the gypsum content S2 gave the lowest average aggregate stability value of 1.83250%. This is attributed to the increase of fine gypsum crystals occupying part of the porosity, consistent with what Al-Badri (1987) and Paliwal et al. (1981) mentioned.

Zeolite addition levels showed a significant effect on increasing aggregate stability values. Treatment Z4 gave the highest average aggregate stability of 2.58889 mm, while treatment Z1 gave the lowest average of 1.64667 mm. This is attributed to clay addition that coats sand particles and creates bonds or bridges between aggregates and particles during wetting and drying periods. The significant increase in total aggregate stability is related to the increase or content of clay in the soil (Djajadi et al., 2011).

Figure 3 illustrates a significant interaction effect between gypsum soil

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content and zeolite addition levels. The treatment S1Z4 gave the highest aggregate stability of 2.76000 mm, while treatment S2Z1 gave the lowest aggregate stability of 1.35333 mm. These results emphasize the important role of zeolite addition in improving soil structure. Zeolite increases the specific surface area, which enhances the formation of soil aggregates. The high zeolite content makes it the main nucleus for soil aggregates due to its strong electrostatic forces that allow ion exchange (+2, K+, Na+, Ca2+) with the soil solution in a reversible manner. The presence of these ions enhances soil aggregation. These findings agree with Li et al. (2009) and Jakab and Jakab (2010).

Table 4: Effect of gypsum soil content and zeolite addition levels on soil mean weight diameter

Z Mean	S3	S2	S1	Treatment or factors
D 1.64	I 1.53	J 1.35	F 2.05	Z1
C 1.95	G 1.96	H 1.64	E 2.27	Z2
B 2.26	E 2.26	G 1.97	C 2.56	Z3
A 2.58	B 2.64	D 2.36	A 2.76	Z4
	B 2.10	C 1.83	A 2.41	S Mean

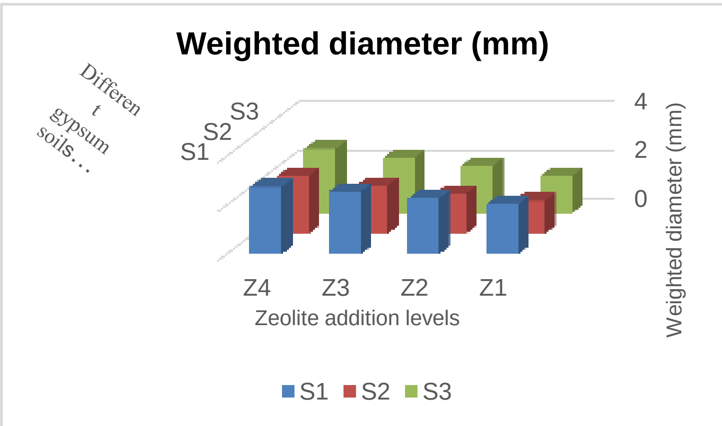

Figure. 3Shows the effect of interaction between different zeolite levels and gypsum content in the soil on the weighted diameter (mm).

Conclusions:

There are significant differences in the effect of varying soil gypsum content on both bulk density and true density of the soil, where gypsum content S3 achieved the highest average bulk density. Meanwhile, gypsum content S1 showed a moderate average. Zeolite addition levels had a significant effect on reducing bulk density values, with treatment Z1 (control) showing the highest average bulk density, while treatment Z4 recorded the lowest value. Significant differences were also observed in the effect of gypsum content on aggregate stability values, where gypsum content S1 had the highest average aggregate stability, and gypsum content S2 had the lowest average.

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