

Estimation of Water Content Curve Using Soil Properties Analysis Data

Muhannd Waleed Majeed¹, Lubna Mohammed Abd², Mohammed Nsaif Abbas³

¹Lecturer, Water Resources Engineering Department, College of Engineering / Mustansiriyah University, Baghdad, IRAQ

²Assistant Lecturer, Environmental Engineering Department, College of Engineering / Mustansiriyah University, Baghdad, IRAQ

³Assistant Professor Doctor, Environmental Engineering Department, College of Engineering / Mustansiriyah University, Baghdad, IRAQ

ABSTRACT

Soil moisture content is one of the most important ecological factors affecting natural ecosystems. This study deals with the soil moisture distribution and its effect on the different types of soil used such as sandy soil, clayey soil, expansive soil and gypsum soil. Each type is brought to the laboratory to determine the physical properties then prepared for compaction test to determine the maximum dry density and optimum water content and discussed the result by comparing the values with them. The largest value of maximum dry density was for clayey soil while the smallest value was for gypsum soil. The largest optimum moisture content was for expansive soil while the smallest value was for gypsum soil too.

Keywords : Water Content, Sandy Soil, Clayey Soil, Expansive Soil, Gypsum Soil

I. INTRODUCTION

Water content or moisture, content is the quantity, of water confined in a material, such as soil (called soil, moisture), rock, ceramics, crops, or wood. Water content is used in a wide range, of scientific, and technical areas, and is expressed, as a ratio, which can range, from 0 (completely dry) to the value of the materials' porosity at saturation.

Water content can, be directly measured, using a known ,volume of the material, and a drying, oven. Moisture, may be present, as adsorbed moisture, at internal, surfaces, and as capillary, condensed water in small, pores. At low relative, humidity, moisture consists, mainly of adsorbed water. At higher, relative humidity, liquid water becomes more and more important, depending, or not depending on the pore size can also be an influence, of volume [1].

Soil moisture content, is one of the most important, ecological factors, affecting natural ecosystems. Dafis (1986) [2] determines, the importance, of soil moisture content in forest, ecosystems which depends, on the type of forest, species present, density, age, altitude, climatic, conditions as well as the soil, conditions. Smiris (1975) [3], reports, that all the physiological, functions of the plants, depend, on normal, water, supply.

II. METHODS AND MATERIAL

2.1 Factors affecting the moisture content in soils

The most common laboratory test for determination of moisture content of soil is the oven-drying method complying with British Standard (BS 1377 –2: 1990) or American Society for Testing and Materials (ASTM

D 2216). ASTM method D-2216 which determines the free water or pore water content as a percentage based on moist and oven dried soil weight differences may generate erroneous information for soils with a high organic material content. The BS 1377 -2: 1990 also states that a microwave oven should not be used as definitive method in determining the moisture content of soils containing organic matter such as peat. This is caused by the difficulty in ensuring temperature of soil does not exceeds 110°C. However, peat soil samples may experience particle burning even at temperatures well below 110 °C. Another factor of importance is the method of sampling by boring which may affect the measurement of field moisture content. This is because once a sample is taken at the particular point, the soil has been disturbed and its properties may be altered. This introduces another variable, the heterogeneity of the soil into the moisture measurements; also there may be internal migration of water or moisture loss during sampling. The loss of moisture due to free draining during removal of the sample from the borehole also may be of importance. As a result of the above, factors that will significantly affect the determination of moisture content of fibrous peat must be identified. The use of present testing techniques for peat moisture is unsatisfactory, and therefore it is necessary to establish more reliable methods for obtaining the moisture content of fibrous peat in the field [4].

Soil moisture can also vary in response to other factors including bulk density, organic matter, and proportions of sand, silt, and clay. An indicator variable, soil water capacity, was determined at each sample point to account for these undetermined properties. This approach is similar to that of Helvey et al. (1972) [5], who determined a factor to "remove the relatively unaccountable variation in moisture content resulting from the soils' ability to retain water against drainage and evapotranspiration." This variable, which I call "soil water capacity", is the

amount of moisture in the soil when it is wetted to near field capacity.

2.2 Soil moisture content

The soil moisture content indicates the amount of water present in the soil. It is commonly expressed as the amount of water (in mm of water depth) present in a depth of one meter of soil. For example: when an amount of water (in mm of water depth) of 150 mm is present in a depth of one meter of soil, the soil moisture content is 150 mm/m, see fig.1.

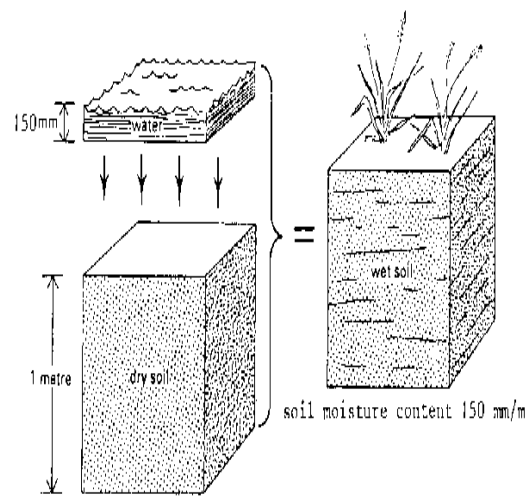


Figure 1. A soil moisture content of 150 mm/m

The soil moisture content can also be expressed in percent of volume. In the example above, 1 m³ of soil (e.g. with a depth of 1 m, and a surface area of 1 m²) contains 0.150 m³ of water (e.g. with a depth of 150 mm = 0.150 m and a surface area of 1 m²). These results in soil moisture content in volume percent of:

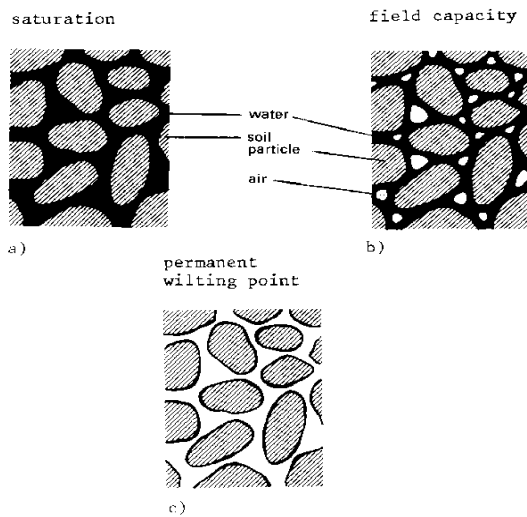


Figure 2. Soil moisture characteristics

2.3 Sandy Soil

Sandy soils specially the loose one have low resistance to applied loads caused by buildings [7]. The soil used in this study is a fine to medium poor graded gray sand brought from Abo-Nooass reign in Baghdad city. The sand was sieved according to (ASTM D 422-02 standard test method for particle-size analysis of soils), Standard tests were performed to determine physical and engineering properties of the sand, see fig. 3. The details of soil properties are listed in table 1.



Figure 3. Sandy soil sample

Table 1: Physical properties of Sandy soil

No.	Index property	Specifications	Value
1	Specific gravity Gs	ASTM D 854-2005	2.66
2	D10 mm	ASTM D 422-2001	0.11
3	D30 mm	ASTM D 422-2001	0.15
4	D60 mm	ASTM D 422-2001	0.22
5	Coefficient of uniformity Cu	ASTM D 422-2001	1.165
6	Coefficient of curvature Cc	ASTM D 422-2001	1.210
7	Maximum dry unit weight γ_{max} kN/m ³	ASTM D 4253-2000	15.5
8	Minimum dry unit weight γ_{min} kN/m ³	ASTM D 4254-2000	13.6
9	dry unit weight kN/m ³ at R.D = 65%		14.8
10	Maximum void ratio e_{max}		0.92
11	Minimum void ratio e_{min}		0.75
12	Relative density R.D %		65%
13	Angle of internal friction ϕ at R.D 65%	ASTM D 3080-98	30
14	Soil classification (USCS)	ASTM D 422-2001	SP

2.4 Clayey Soils

The consistency of clays can be described qualitatively by terms such as very soft, soft, stiff; very stiff etc. the classification of clayey soils in terms of consistency is given by the British Standard (C.P.8004,1986) [8].

The behavior of clayey soil is complex comparing to the cohesionless soils, in addition saturated clays are generally weaker than sand or gravels and thus are more to cause a problem. The clay particles undergo greater volume change during loading, the low permeability impedes the flow of water into the voids and the undrained condition applied in short term and significant excess pore water pressure will develop in this soil.

In long term, water does flow into or out the soil, allowing the excess pore water pressure generated during loading to dissipate virtually completely, and the drained condition applied [9].

The soil used in this paper is brought from Al-Tagy region to the north of Baghdad. Standard tests were performed to determine the physical properties of the soil which is brown as shown in fig. 4 and table 2.



Figure 4. Clayey soil sample

Table 2 : physical properties of clayey soil

property	specification	Value
Liquid limit L.L	ASTM D 4318-2010	45
Plastic limit P.L	ASTM D 4318-2010	26
Plasticity index P.I	ASTM D 4318-2010	24
Specific gravity Gs	ASTM D 854-2010	2.68
Gravel >4.75 mm	ASTM D 422-2010	0%
Sand (4.75 – 0.075) mm	ASTM D 422-2010	3%
Silt (0.075 – 0.005) mm	ASTM D 422-2010	44%
Clay <0.005 mm	ASTM D 422-2010	53%
Soil classification	USCS	CL

2.5 Expansive soil

The term expansive soils usually refer to those clay minerals which experience significant volume change upon wetting and drying. The amount of swell generally increases with the increases in plasticity index.

Swelling of soils occur in partially saturated plastic soils exposed to wetting during raining seasons or due to leakage of water pipes or rise of water table through the expansive soil layer. A measure of the ability and degree to which a soil might swell when its environment is to be changed is known as swell potential, the free swell is defined as the percent of increase in volume of partially saturated sample of soil when exposed to wetting [10].

The clayey soil used in this study is a natural soil brought from the State Company of Geological Survey and Mining. The grain size distribution test

(sieve analysis) is conducted according to (ASTM, D422-72). 98% of the soil particles are passing 0.075mm sieve see fig. 5 and table 3.



Figure 5. Expansive soil sample

Table 3: Physical properties of expansive soil

Property	Specification	Value
Liquid Limit %	ASTM, D4318	163
Plastic Limit %	ASTM, D4318	65
Plasticity Index %	ASTM, D4318	98
Specific Gravity	ASTM, D854-02	2.84
Max. Dry unit weight (kN/m ³)	BS:1377:1975,Test 12	15.1
Optimum Moisture Content %	BS:1377:1975,Test 12	29.8
% Passing sieve No. 0.075mm	ASTM, D422-63	98
Classification of Soil According to Unified Soil Classification System	USCS	CH

2.6 Gypseous Soil

Alphen and Romero^[11] reported that gypseous soils refer to soil containing more than 2% gypsum, while Barazanji ^[12] distinguished classes of gypsiferous soils based on the gypsum content as shown in Table4. A

soil can be defined as a gypseous soil when the gypsum content suffices to change the properties of the soil. The Russian system of gypseous soil classification in Table 4 relies upon the upper limit of the gypsic horizon, the content of gypsum, the thickness of the gypsic horizon and the measure of gypsiferous accumulation ^[13].

Table 4. Classification of Gypseous Soil ^[12]

Gypsum content %	Classification
0-0.3	Non gypsiferous
0.3-3	Very slightly gypsiferous
3-10	Slightly gypsiferous
10-25	Moderately gypsiferous
25-50	Highly gypsiferous
>50	Gypsiferous soils to be described by the other fractions such as clayey or sandy gypsiferous soil

Gypseous soils are selected from Tikrit city north of Baghdad. The soil is sieved on sieve No.4 (4.75 mm) and the passing soil used in the research work as shown in fig. 6 and table 5.



Figure 6. Gypsums soil sample

Table 5 : Physical properties of Gypseous soil

Property	Specification	value
Specific gravity G _s	ASTM D 854- 2010	2.37
% Sand	ASTM D 422- 98	91
% Silt and clay	ASTM D 422- 98	9
Coefficient of uniformity C _u	ASTM D 422- 98	7.50
Coefficient of curvature C _c	ASTM D 422- 98	2.85
Optimum moisture content %	ASTM D 698- 12	12.3
Max. dry unit weight γ_{max} (kN/m ³)	ASTM D 698- 12	17.2
Main. dry unit weight γ_{min} (kN/m ³)	ASTM D 4245	11.6
D ₁₀		0.15
D ₃₀		0.22
D ₆₀		0.75
Liquid limit L.L		25.2
Plasticity index P.I		5.48
Soil classification according to USCS	ASTM D 422- 98	SW-SM

III. EXPERIMENTAL PROGRAM

3.1 Materials

The soils that are used in the present research is sandy, clayey, expansive and gypsum as they listed above.

3.2 Experimental tests

3.2.1 Determination of water content- dry density relation

This test is performed to determine the required amount of water to be used when compacting the soil in the field and the resulting degree of denseness, which can be expected from compaction at optimum moisture content.

3.2.2 Apparatus

1. Cylindrical metal mould shall be either of 100mm diameter and 1000cm³ volume or 150mm diameter and 2250cm³ volume and shall confirm to IS: 10074 – 1982.
2. Balance of capacity 500grams and sensitivity 0.01gram.
3. Balance of capacity 15Kg and sensitivity one gram.
4. Thermostatically controlled oven with capacity up to 250 0C.
5. Airtight containers.
6. Steel straight edge about 30cm in length and having one beveled edge.
7. 4.75mm, 19mm and 37.5mm IS sieves confirming to IS 460 (Part 1).
8. Mixing tools such as tray or pan, spoon, trowel and spatula or suitable mechanical device for thoroughly mixing the sample of soil with additions of water.
9. Heavy compaction rammer confirming to IS: 9189 -1979.

3.2.3 Procedure

1. Take a representative sample of air dried soil of about 5 kg (soil not susceptible to crushing during compaction) or 3 kg from 15 kg sample (soil susceptible to crushing during compaction) passing through 19mm IS sieve and mix thoroughly with a suitable amount of water depending on the type of soil, generally 4 to 6

percent for sandy and gravelly soils and plastic limit minus 8% to 10% for cohesive soils.

2. For soils susceptible to crushing during compaction take different samples for every determination and for soils not susceptible to crushing during compaction use the same sample for all the determinations.
3. Weigh the 1000cc capacity mould with base plate attached and with out extension to the nearest gram (m1).
4. Place the mould on a solid base such as a concrete floor or plinth and compact the moist soil into the mould, with the extension attached in 5 layers of approximately equal mass, each layer being given 25 blows with the 4.90kg hammer dropped from a height of 450mm above the soil.
5. Distribute the blows uniformly on each layer.
6. The amount of soil used shall be sufficient to fill the mould leaving not more than about 6mm to be struck off when the extension is removed.



Figure 7. Compaction mould

7. Remove, the extension, and carefully, level the compacted soil to the top of mould by means of straight edge.
8. Weigh, the mould and the, soil to the nearest gram (m2). Remove, the compacted, soil from the mould and place on the mixing tray.
9. Collect a representative sample from the soil in the tray and keep in the oven for 24 hours

maintained at a temperature of 1050 to 1100 C to determine the moisture content (W).

3.2.4 Calculations

1. Calculate the bulk density γ_w in g / cm³ of each compacted specimen from the equation,

$$\gamma_w = (m_2 - m_1) / V_m$$

m_1 = Weight of mould with base plate.

m_2 = Weight of mould with compacted soil.

V_m = Volume of mould in cm³.

2. Calculate the dry density γ_d in g/cm³ from the equation,

$$\gamma_d = \gamma_w / (1+W/100)$$

γ_w = Bulk density

W = % of moisture content

The result was written according to the table 8 below:

Table 8 : Compaction test calculations

WATER CONTENT DETERMINATION					
Sample No.	1	2	3	4	5
Moisture Can No.					
Wt. of Can+Wet Soil, g					
Wt. of Can+Dry Soil, g					
Wt. of Water, g					
Wt. of Can, g					
Wt. of Dry Soil, g					
Water Content, %					
Ave. Water Content, %					

DENSITY DETERMINATION					
Wt. of Moist Soil+Mould, g					
Wt. of Mould, g					
Wt. of Moist Soil, g					
Vol. of Mould, cm ³					
Wet Density, g/cm ³					
Dry Density, g/cm ³					

Dry Density, g/cm ³							Diameter of mould, mm	
							Weight of rammer, kg	
							Height of fall, mm	
							No. of blows	
							No. of layers	
							Optimum Moisture Content, %	
							Maximum Dry Density, g/cm ³	
							Remarks:	

The results of the soil samples illustrated in the figures below which explain the relation between dry densities with water content:

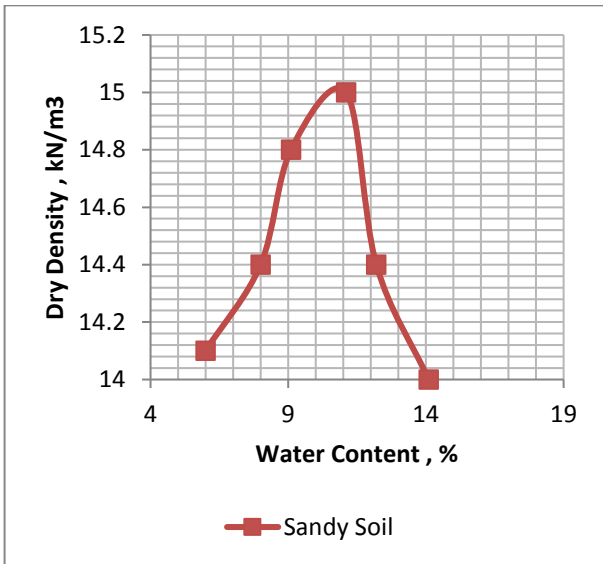


Figure 8. Sandy soil

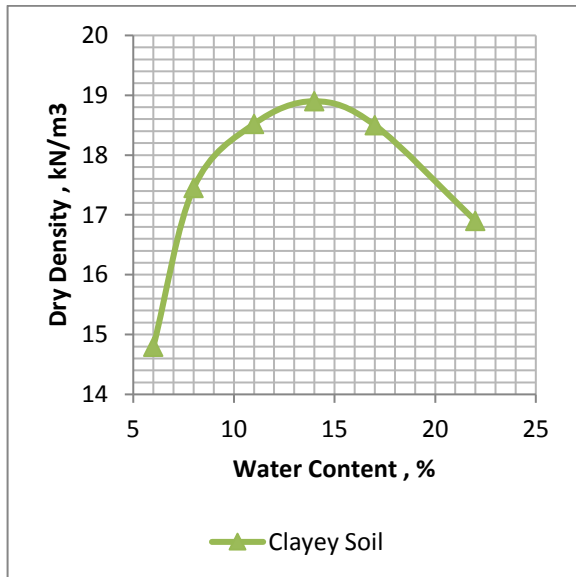


Figure 9. Clayey soil

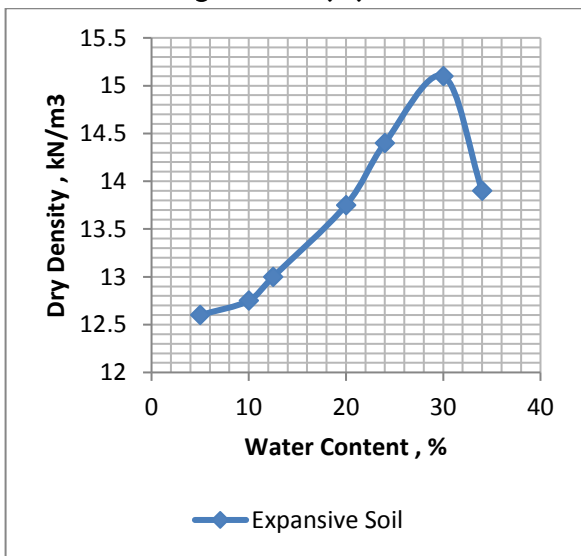


Figure 10. Expansive soil

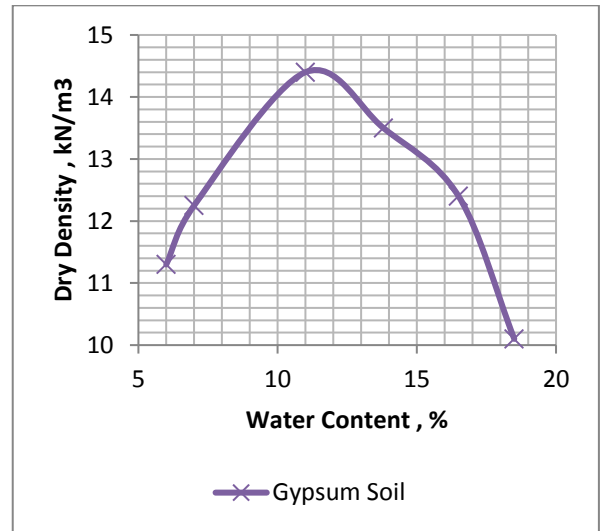


Figure 11. Gypsum soil

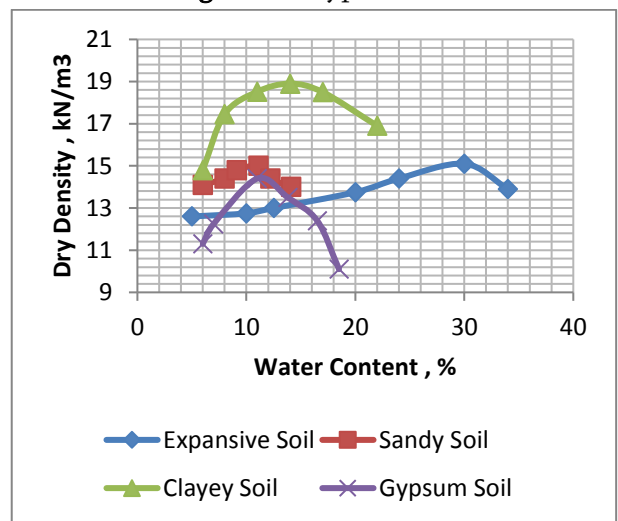


Figure 12. Dry density vs water content for all soil samples

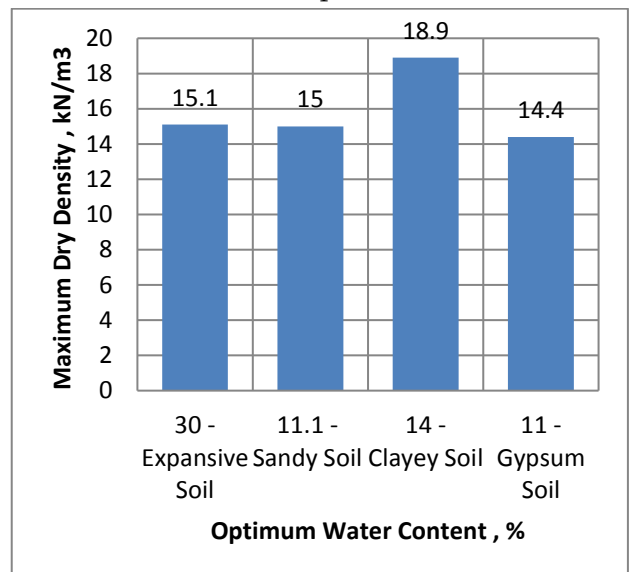


Figure 13. Relation between maximum dry densities with optimum water content

For the figures 8 to 13 the maximum dry density was 15.1, 15, 18.9 and 14.4 for expansive, sandy, clayey and gypsum soil respectively.

The dry density for expansive soil increased with the increasing of water content for reaching to the maximum dry density by 2% increasing with respect to sandy soil, 80% decreasing with respect to the clayey soil and 5% increasing with respect to the gypsum soil.

IV. CONCLUSION

From the experimental results, the following conclusions can be listed below:

1. Dry density increases when water content increases.
2. The oven dry method is the standard for the calibration of all other soil moisture determination techniques.
3. An increase in compactive effort produces a very large increase in dry density for soil when it is compacted at water contents drier than the optimum moisture content. It should be noted that for moisture contents greater than the optimum, the use of heavier compaction effort will have only a small effect on increasing dry unit weights.
4. Sandy soils can be compacted to higher densities than gypsum soils.
5. Clays with high plasticity characteristics have water contents over 20% and achieve similar densities (and therefore strengths) to those of lower plasticity with water contents below 8%.
6. Expansive soil have the main content which is it Montmorillonite in its composition, so the adsorption of water is large as compared with the remain soil types which lead to swelling in soil volume.
7. Swelling Characteristics were found to be influenced significantly by Liquid Limit among compositional factor and by all the environmental factors namely initial Dry Density, Initial Moisture Content.
8. As the % of fines and the plasticity of a soil increases, the compaction curve becomes flatter and therefore less sensitive to moisture content. Equally, the maximum dry density will be relatively low.
9. Gypsum soils usually stiff when they are dry, but these soils may affected greatly when subjected to changes in water content due to water table fluctuation or due to water infiltration which may dissolve gypsum causing pores and cracks.
10. The maximum dry density in gypsum soils occur at the lowest optimum water content as compared with the remain soil types.

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