Journal of Engineering and Applied Sciences 14 (21): 7917-7921, 2019
ISSN: 1816-949X

The Addition of Bentonite to Improve the Compaction Energy of Soil

Saeed Abdul Ali Jaber
Department of Civil Techniques, Nasiriya Technical Institute, Southern Technical University,
Basra, Iraq, saeed.jaber8@stu.edu.iq

Abstract: The aim of the current study is to investigate the addition of 4, 8, 12 and 16% bentonite to the soil in compaction to improve the strength of soil, standard Proctor test and modified Proctor test were used with 4, 8, 12 and 16% moisture. The soil used in this study was brought from the connecting road between Nasiriyah and Souk Al-Shuyukh cities as a random sample from deferent depths. The research found a set of conclusions such as bentonite content at 8 and 12% would rise the maximum dry density which leads to increase the strength of soil in compaction process and the maximum dry density was (1.9 g/cm^3) at the bentonite ratio (8%) represents the optimal values of additives of bentonite percentage to the soil to improve its strength ability.

Key words: Bentonite, compactive energy, soil strength, dry density, improve, ability

INTRODUCTION

Soil compaction is the process in which a stress applied to a soil causes densification as air is displaced from the pores between the soil grains. When stress is applied that causes densification due to water (or other liquid) being displaced from between the soil grains, then consolidation, not compaction has occurred. Normally, compaction is the result of heavy machinery compressing the soil but it can also occur due to the passage of (e.g.) animal feet (McCarthy, 2007).

The controlling on process of local compaction is a result due to estimation the field dry density which leads to evaluate degree of compaction for the soil. It effect on Earth works and that depends on experimental compaction curve (ASTMD 2216-05, 2004) which connect between the water content and dry density that they considered the source to find optimum water content and maximum dry density (ASTM D 2216-05, 2004). Applied mechanical energy is required to reach the optimum degree of compaction throughout the machines of compaction which compact the soil by layers with 20-30 cm thickness for each layer at a determined time in order to obtain the required degree of compaction (Anonymous, 2004).

Soil compaction is defined as the way in which soil density is increased mechanically and is an important part of the construction stages. If it is implemented incorrectly, it will cause the soil to fall, requiring unnecessary maintenance costs or failure of the outlet. Almost all construction buildings and construction projects use mechanical soil compaction techniques (Yani, 2015). The important factors that an engineer needs to take into consideration regarding moderation include (Jeward, 2014):

- Soil type
- Moisture content
- The required effort of compaction

The importance of soil compaction is summarized as follows (Fadhel, 2015):

- Increased the ability of soil to resist the loads
- Prevention descent of soil
- Make the soil in stability case
- Reduce bleeding, swelling of water

The types of compaction which can be classified according to applied on the soil can be summarized as follows (Fadhel, 2015):

- Compaction by vibration
- Compaction by impact loads
- Compaction by kneading
- Compaction by pressure

These kinds of compaction effort can be summed up under two concepts, the static force and the vibratory force. The only way to change the strength of the effective compaction is by adding or subtracting the weight of the compaction machine, the static force is determined by the upper layers of the soil then its effect does not reach large depths, kneading and pressing are two examples of compaction by static force. The vibratory force uses a special technique in addition to the impact of the weight of the compaction machine to create an extra vibration force. The machine thus provides a series of successive loads on the surface. The effect extends from the top of the layer surface to the deeper layers where the vibration force moves the soil parts of their locations and assembles them to provide the highest possible density. The incorrect compaction of soil can lead to damage to buildings such as cracking, fractures and cracks in the floors, bleeding in pipes, cracks in the foundations and others (Jeward, 2014; Fadhel, 2015).

So, the researchers interest in the field of civil engineering were studied the additives on the soil to improve its properties. Some of them deal with the topic as technical side, another as designed side according to, mathematical and logical calculations, the goal of all researchers is to reach to the best results in productivity in Earth works with less energy, high quality and maximum performance.

Quanshe Sun studied the effect oil in various temperature on the mechanical properties of high performance under the effect of compaction process. Schindler *et al*. (2009) interested with the effect of compaction under some weight machines on mechanical properties of soil. Kurc *et al* (2010) explained the influence of organic wastes in compaction of soil. While the researcher Roberto Gerardo Bruna (Bruna, 2011) showed the effects of salty sand on the required compaction energy. So, the microstructure and other mechanical properties such as toughness, yield strength and impact strength for some additives to the compacted soil were studied by Oyetunji (2012).

Through this quick overview of the range of researches and studies, mentioned above and other studies not mentioned in this study where all focused on compaction process using the method of the additives to the soil to predict the mechanical properties such as the strength of soil. Researchers have obtained the results that will improve and develop the ability of soil to strengthen the loads. With the following scientific research methodology in the field of the additions of some materials to improve the compaction energy of soil, current study has study the addition of bentonite to improve the compaction energy of soil, in order to:

- Predict the ability of using the bentonite to improve the compaction soil
- Improve the dry density of soil
- Decrease required compactive energy
- Reach the compaction degree in less time and less costs

The fact that, the previous researchers did not address this additives in this field and they did not use it as a model in the researches.

MATERIALS AND METHODS

Experimental procedures: The standard Proctor test shown in Fig. 1 is a instrument device used in the current search to test the samples of compacted soils as well as the modified Proctor test. The soil used in the research was brought from the connecting road between Nasiriyah and Souk Al-Shuyukh cities as a random sample from deferent depths.

Fig. 1: Standard Proctor test instrument

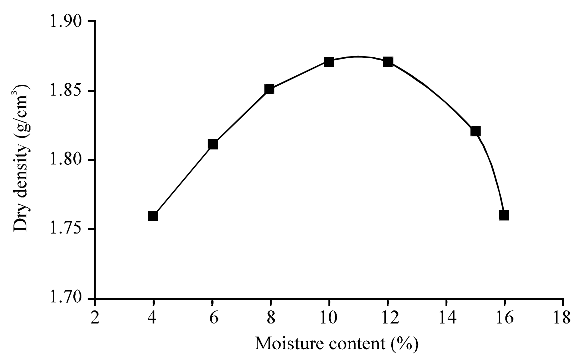

Fig. 2: Dry density vs. moisture content before additives

Soil gradation: The used soil was classified as sandy poorly graded (uniform particle sizes) soil and bad gradation (SP-SM) according the Unified Classification System (UCS) has a gradation of 4.2 gravel, 83.7 sand and 12.1 silt with 2.56 specific gravity.

Unit weight: By using modified Proctor test for the moisture ratio of 4, 8, 12, 16% of the sample weight, to find the relationship between the dry density and moisture content. Figure 2 shows that the maximum dry density is equal to 1.875 g/cm^3, at 10.4% of moisture content.

Table 1: Chemical composition of bentonite

SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO
70±2%	15.9±1.5%	2.3±0.1%	0.95±0.1%	0.96±0.1%	1.91±0.1%
NaO	P_2O_3	TiO_2	K_2O	Caustic soda	
1.80±0.1%	0.04±0.01%	0.04±0.01%	0.78±0.1%	0.55±0.1%	

Chemical tests: The chemical tests have been processed in the Central Laboratory in Nasiriya city, on the samples of compacted soil before and after adding bentonite. Table 1 shows the chemical composition of bentonite. According to the property (BS1377 Test No. 9) which provide that the percentage of SO_3 in the natural soil might not to be accede 10% and according to, the general property of the roads and bridges (SORB/R5) which concern with soil works. The test found the percentage of sulphate content, SO_3 = 0.178%, So, the bentonite doesn't have a percentage of SO_3 in the chemical composition.

The gypsum content in soil before adding bentonite equal to 1.2% which less than the allowed limits (5%) according to, the general property of the roads and bridges (SORB/R5) which concern with soil works. Percentage of soluble salts in soil before adding bentonite equal to 1.44% which less than the allowed limits (10%) according to, the general property of the roads and bridges (SORB/R5) which concern with soil works. Therefore, the chemical of the soil before and after adding bentonite to the soil may not to be effected, that's means the sulphate, soluble salts and gypsum contents were in the allowable limits of Iraqi property.

Preparing samples: The samples were placed in the oven and then dry them and pass through the sieve No. 4 with 4.75 mm, the amounts of dry soils were mixed with percentages weighs (4, 8, 12 and 16%) bentonite until reaching to the homogenous state with a percentage of water.

Compaction procedures: The soil was compact by using standard compaction die in form three layers in order to calculate maximum dry density and optimum water content from the Lab. Curve compaction for 10 models which divided into two groups, the first group involves (5) models at compaction energy less than reduced standard Proctor test, equal to E = 355.5 kJ/m^3 with percentages weighs (4, 8, 12 and 16%) bentonite, the second group involves (5) models at compaction energy less than reduced standard Proctor test, equal to E = 592.5 kJ/m^3 with the same percentages weighs of bentonite as in (Lambe, 1951).

In other side, the compaction work includes another (10) models which divided into two groups too, the first group involves (5) models at compaction energy less than modified Proctor test, equal to E = 1197.03 kJ/m^3 with percentages weighs (4, 8, 12 and 16)% bentonite, the second group involves (5) models at compaction energy less than modified Proctor test, equal to E = 2681.4 kJ/m^3 with the same percentages weighs of bentonite as in (Lambe, 1951).

Table 2: No. of blows for Proctor test

No. of blows	Compact energy (kJ/m^3) reduced standard Procto test	Compact energy (kJ/m^3) modified Proctor test
15	355.5	-
25	592.5	1197.03
56	Sub base	2681.4

Compaction energy: The compact energy has been controlled through the increasing or reducing the number of blows, for each compacted layer, according to Table 2 as in specification of structural materials (Anonymous, 2000).

RESULTS AND DISCUSSION

Compaction energy (E = 355.5 kJ/m^3): Figure 3 shows the relationship between the dry density and moisture content in the first group which involves (5) models at compaction energy less than reduced standard Proctor test, equal to E = 355.5 kJ/m^3 with percentages weighs (4, 8, 12 and 16%) bentonite. Referring to the previous figure, the maximum dry density was determined for each addition of bentonite percentage and the relationship between them was plotted in Fig. 4 which explains that the (1.88 g/cm^3) maximum dry density might be the optimal at the bentonite at (12%).

Compaction energy (E = 592.5 kJ/m^3): Figure 5 shows the relationship between the dry density and moisture content in the second group involves (5) models at compaction energy less than reduced standard Proctor test, equal to E = 592.5 kJ/m^3 with the same percentages weighs of bentonite with 25 blows, in which noted that the dry density is highest in bentonite ratio 4% and moisture ratio 8%.

It is noted that all values of dry density drop after those percentages for all remaining moisture and bentonite percentages. It is noted from Fig. 5 that the dry density after compaction is exactly equal when the moisture content is 8% with the bentonite ratio of 4 and 12%. In other words, the optimal moisture content values

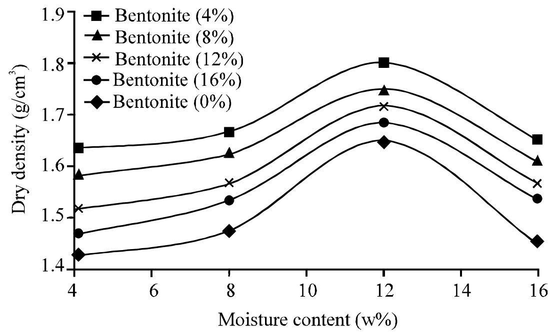

Fig. 3 : Dry density vs. moisture percentage at compaction energy (355.5 kJ/m^3)

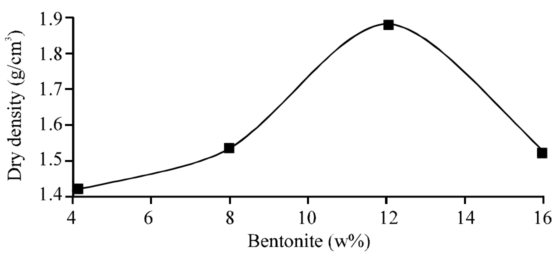

Fig. 4: Maximum dry density vs. bentonite (wt.%) at compaction energy (355.5 kJ/m^3)

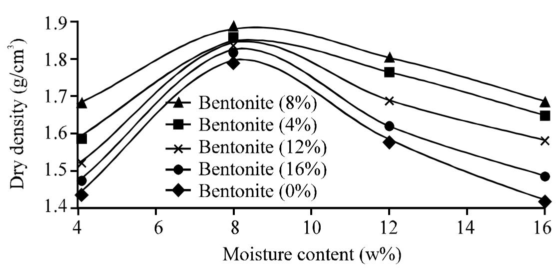

Fig. 5: Maximum dry density vs. bentonite (wt.%) at compaction energy (592.5 kJ/m^3)

are constant for any addition ratio of bentonite in compaction energy of E = 592.5 kJ/m^3. When plotting the relationship between the maximum dry density and the weight ratio of the added bentonite as in Fig. 6 noted that the maximum dry density was (1.9 g/cm^3) at the bentonite ratio (8%) which represents the optimal values of additives of bentonite percentage to the soil in order to improve its strength ability.

Compaction energy (E = 1197.03 kJ/m^3): Depending on Table 2, the operations of compaction energy were done by using the modified standard Proctor test with (25) blows on modified Proctor test just for E = 1197.03 kJ/m^3

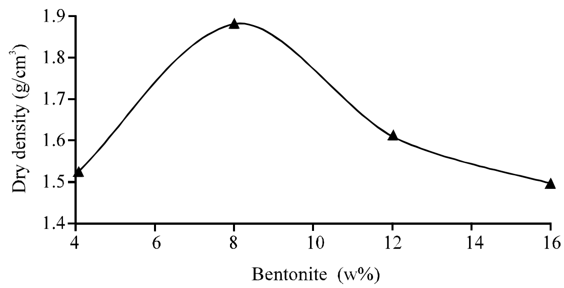

Fig. 6: Maximum dry density vs. bentonite (wt.%) at compaction energy (592.5 kJ/m^3)

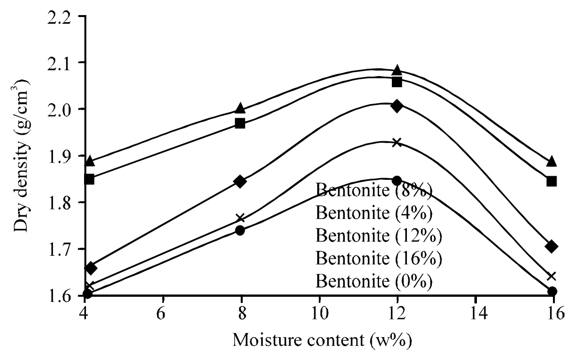

Fig. 7: Maximum dry density vs. bentonite (wt.%) at compaction energy (1197.03 kJ/m^3)

because the other procedure of 2681.4 kJ/m^3 concern with the sub-base soil that was not included in the current research procedures.

Accordingly, the compaction work includes another (10) models which divided into two groups too, the first group which this study deal with involves (5) models at compaction energy less than modified Proctor test with (25) blows equal to E = 1197.03 kJ/m^3 with percentages weighs (4, 8, 12 and 16%) bentonite as by Anonymous (2000, 2004). Figure 7 explains that the addition of bentonite (12 and 16%) reduces the dry density by a large amount but the addition of bentonite which ranges from 4-8% increases the value of dry density, so, this conclusion is for all ratios of moisture in the process of laboratory work. It can be said that, the moisture of 12% achieved an increase in dry density for all additives percentage. By plotting the relationship between the maximum dry density and the weight ratio of the added bentonite as in Fig. 8 noted that bentonite content at 8 and 12% would rise the maximum dry density which leads to increase the strength of soil in compaction process.

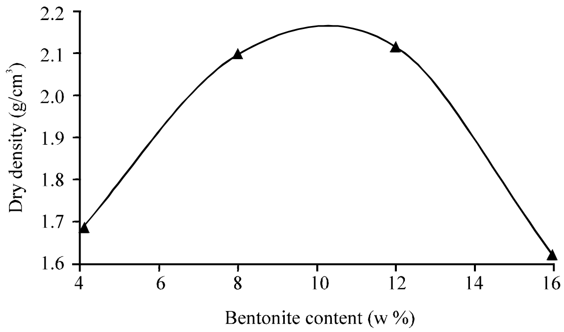

Fig. 8: Maximum dry density vs. bentonite (wt.%) at compaction energy (1197.03 kJ/m^3)

CONCLUSION

Reduced standard Proctor test: The compaction energy of 355.5 kJ/m^3 was increasing the strength of soil with 4% and the addition of bentonite also increase the ability of soil around 4%. Then, the maximum dry density (1.88 g/cm^3) might be the optimal at the bentonite of 12%. The optimal moisture content values are constant for any addition ratio of bentonite in compaction energy of (E = 592.5 kJ/m^3). The maximum dry density was (1.9 g/cm^3) at the bentonite ratio (8%) which represents the optimal values of additives of bentonite percentage to the soil to improve its strength ability.

Modified Proctor test just for (E = 1197.03 kJ/m^3): The addition of bentonite (12 and 16%) reduces the dry density by a large amount but the addition of bentonite which ranges from (4-8%) increases the value of dry density. The moisture of 12% achieved an increase in dry density for all additives percentage. Bentonite content at (8 and 12%) would rise the maximum dry density which leads to increase the strength of soil in compaction process.

RECOMMENDATIONS

- Process another researches by using Sawdust as additives material to improve the compaction of soil
- Study the effect of addition of waste oil to the soil in compaction process

REFERENCES

ASTM D2216-05, 2004. Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass. Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA., USA.

Anonymous, 2000. Specification of structural materials. National Center for Structural Laboratories, Iraq.

Anonymous, 2004. Soil compaction handbook. Multiquip Inc., California, USA.http://www.multiquip.com/multiquip/pdfs/Soil_Compaction_Handbook_low_res_0212_DataId_59525_Version_1.pdf

Bruna, R.G., 2011. The effects of salty sand on the required compaction energy. R. Esc. Minas, 64: 57-62.

Fadhel, G.R., 2015. The Soil Compaction: Importance & Applications. Al Jeel al Jadeed Club, Amman, Jordan, Pages: 305.

Jeward, J., 2014. Factors for best buildings. Build. Eng. J., 3: 1-67.

Kurc, A., M. Kciuk and M. Basiaga, 2010. The influence of organic wastes in compaction of soil. J. Achiev. Civ. Eng., 38: 154-162.

Lambe, T.W., 1951. Soil Testing for Engineering. 2nd Edn., John Wiley, New York.

McCarthy, F.D., 2007. Essentials of Soil Mechanics and Foundations. 7th Edn., Pearson Prentice Hall, Ohio, USA, ISBN: 0-13-114560-6.

Oyetunji, A., 2012. Effects of microstructures and process variables on the mechanical properties of rolled ribbed medium Carbon steel. J. Emerging Trends Eng. Appl. Sci., 3: 507-512.

Schindler, I., M. Mistecky, M. Ruzicka and L. Cizek, 2009. The effect of compaction under some weight machines on mechanical properties of soil. Intl. Sci. J., 36: 41-47.

Yani, M., 2015. The effect of compaction on the mechanical properties of sand soil. Maint. Build. J., 8: 1-26.