Journal of Engineering Sciences, Assiut University, Vol. 34, No. 6, pp. 1787-1797 , Nov. 2006

THE INFLUENCE OF STONE CONTENT ON COMPACTION CHARACTERISTICS OF GRANULAR SOIL

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(Received October 10, 2006 Accepted November 2, 2006)

ABSTRACT – *Building on/or with compacted fill is common to many major construction projects. The engineering behavior of a soil depends on (among other things) the size distribution and the composition of the particles. The properties of a given soil can usually by significantly change by adding some selected soil. Large size particles have considerable importance in physical properties such as permeability, shear strength and load response especially for fine-grained soil.*

The objective of this paper is the determination of the effect of stone content on the results of a compacted soil implementarly different compaction effort. Compaction tests were conducted on soil stone mixtures. A soil matrix is uniformly prepared by mixing selected amount of stone to the soil.

KEY WORLD: *Granular soil, compaction, maximum dry density and optimum moisture content.*

1 INTRODUCTION

Fine grained soils, notably clays are very commonly encountered are used as construction geomaterial. Due to their common occurrence and relatively impermeable nature, such soils are utilized in many major engineering projects, applications include embankment dam, liner for disposal landfills. Such fill materials especially boulder clay has on inclusions of very coarse materials in size of to cobbles and larger.

The large size of such inclusions may be of considerable importance in relation to physical properties such as permeability, strength and load response. The presences of very large particles reflect difficulties in the determination of strength and stress deformation properties by conventional laboratory equipment. Complications arising from the fact that the size of the laboratory specimen must big enough to ensure that the specimens represent the field situation of the mixed soil with stones, in order to assure valid results.

In order to determine the engineering properties of soil such as permeability, strength, compressibility and load response, using conventional apparatus, laboratory specimens have to be prepared excluding coarse particles. In effect correction should be implemented to the test results, a procedure which has been used in [1 to 5].

Kumar and Muir [6] performed fall-cone tests on mixtures of kaolinite and fine gravel passing from 3.35 mm, and retained 2 mm size sieve. They stated that the liquid limit of the mixtures show a linear variation with clay content above 40% and a sharp change was observed with clay content below 40 %. They also, concluded that the presence of the coarse fraction will modify the mechanical behavior of the mixtures, the clay matrix governs the behavior if the coarse fraction is below 30 % the gravel material acts as volume filler). Beyond this point the gravel starts to dictate the behavior.

The maximum dry density increases with the increasing aggregate content and peaks at 60-80 %. However optimum moisture content, O. m. c., and void ratio decreases with the increasing aggregate content until 60-70 %, beyond this range the void ratio increased sharply [7,8].

Anjajah et al [9] investigated the effect of aggregate content of up to 70 % ranging from 4.75 –19 mm size on the shear strength of compacted coarse-grained soils. Large and small shear boxes were used. In both series of the tests the increase in the vale of shearing resistance was noted up to aggregate content of 30 % beyond this percentage the value of angle of shearing resistance decreased. No conclusive relationship could be established since at 70 & aggregate, the angle of shearing resistance once again increased.

Fragaszy and Pond [10] investigated change in strength associated with the addition of 15 % and 40 % gravel particles to uniform sand. The results stated that the difference in strength showed to be significant only when 40 % rounded particles were used.

The objective of this paper is the determination of the effect of stone content on the results of the compacted test ($\gamma_{d_{max}}$, O .M .C.) with different effort of compaction. Compaction tests were conducted on soil stone mixtures. A soil matrix is uniformly mixed to incorporate varying percentages of gravel.

2 LABORATORY TESTING PROGRAM

2.1 Equipment And Materials Used

21.1. Equipment

Proctor apparatus and tools used for the compact tests.

2.1.2 Geomaterials

The particles size distribution of the soil was used in the tests as shown in the **Fig. (1)**. This soil has specific gravity, G_s, = 2.65, uniform coefficient, C_u, 2.5 and coefficient of curvature, C_z, = 1.003. Classified of soil is (SC) using unified soil classification. The consistency limits for the fine partion-passing sieve No. 40 are the following, Liquid limit and plastic limit are 30, 20.2 respectively. The size of gravel varies from 9.52mm to 4.75 mm size and specific gravity, G_s, = 2.65 was used in the tests.

2. 2 Test arrangement

Twenty-four (24) tests were conducted to determine the effective of the stone percentage on the results of compaction. These tests were conducted on seven different groups with different % of stone as shown in **Table 1**. The effort of compaction of all groups equal to 594, 2104 and 2630 kN.m/m^3 respectively.

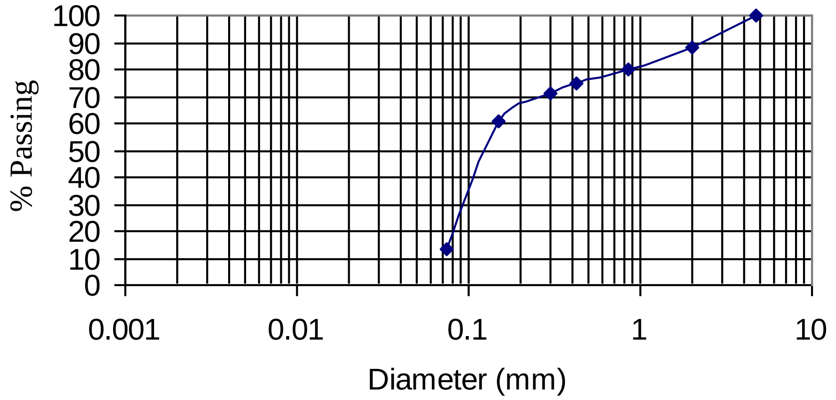

Fig.(1) Particle size distribution

Table 1: Results of the compaction tests.

Test No.	% of stone	Type of test	n	N	W (kg)	H (cm)	C. E kN.m/m^3	$\gamma_{d_{max}}$ t/m^3	O. m.c. %
1		SPCT	3		2.5	30.5	594	1.62	13
2	0	BSMPCT	4	25	4.5	45	2104	1.72	11
3		MPCT	5		4.5	45	2630	1.78	9
4		SPCT	3		2.5	30.5	594	1.63	12
5	5	BSMPCT	4	25	4.5	45	2104	1.73	10.5
6		MPCT	5		4.5	45	2630	1.79	9
7		SPCT	3		2.5	30.5	594	1.72	13
8	10	BSMPCT	4	25	4.5	45	2104	1.79	11.2
9		MPCT	5		4.5	45	2630	1.82	9.6
10		SPCT	3		2.5	30.5	594	1.79	13
11	15	BSMPCT	4	25	4.5	45	2104	1.82	11.5
12		MPCT	5		4.5	45	2630	1.84	10
13		SPCT	3		2.5	30.5	594	1.80	14
14	20	BSMPCT	4	25	4.5	45	2104	1.85	12
15		MPCT	5		4.5	45	2630	1.90	10
16		SPCT	3		2.5	30.5	594	1.74	13.5
17	25	BSMPCT	4	25	4.5	45	2104	1.80	13
18		MPCT	5		4.5	45	2630	1.82	11
19		SPCT	3	25	2.5	30.5	594	1.69	12
20	30	BSMPCT	4		4.5	45	2104	1.76	10.5
21		MPCT	5		4.5	45	2630	1.80	9
22		SPCT	3	25	2.5	30.5	594	1.645	11
23	35	BSMPCT	4		4.5	45	2104	1.765	10
24		MPCT	5		4.5	45	2630	1.825	9.5

Where:

n	number of layers in mold
N	number of drops for each layer
W	weight of hammer
H	high of hammer travel
C.E	compaction energy effort for the standard proctor compaction test
$\gamma_{d_{\max}}$	maximum dry density
O. m. c.	optimum water content
SPCT	standard proctor compaction test
MPCT	modified proctor compaction test
BSMPCT	between standard and modified proctor compaction test

2.3 Test Procedure

Stone

In order to eliminate surface dust from the stone a washer drum was used. Stone aggregate was washed for approximately 5 minutes, with the aggregate being moved during washing. The washed stone aggregate was spread out to allow free water to drain off. The clean, stone were then mixed thoroughly within soil sample to study the effect of % of stone on the compaction results.

Specimen preparation

The dry soil and the required amount of water were mixed for about 10 minutes. Stone was saturated and then surface dried before mixed. Clean surface dried stone aggregate weighed separately and then mixed thoroughly with the soil mixture for each particular percentage of soil stone mixtures. The soil- stone mixtures were then subjected to compaction using standard specification procedure.

All tests carried out according to standard specification methods [11]

Test results

Dry density of the compacted soil with a certain % of stone is plotted against mould water content at constant effort of compaction, as shown in **Figs. 2** to **9**. The maximum dry density and optimum moisture content were taken from the curves and recorded in **Table 1**. All plotted curves indicated that the maximum dry density ($\gamma_{d_{\max}}$) increases as the effort of compaction increases at the same percentage of stone. But the optimum moisture content decreases with the increasing of the effort of compaction at certain % of stone.

3 ANALYSIS AND DISCUSSION OF TEST RESULTS

The following discussion illustrates the effect of the % of stone and effort of compaction on the results of compaction, ($\gamma_{d_{\max}}$, O. M.C.).

3.1 Results Of Compaction

A summary of maximum dry density and optimum water content results are given in **Table 1**.

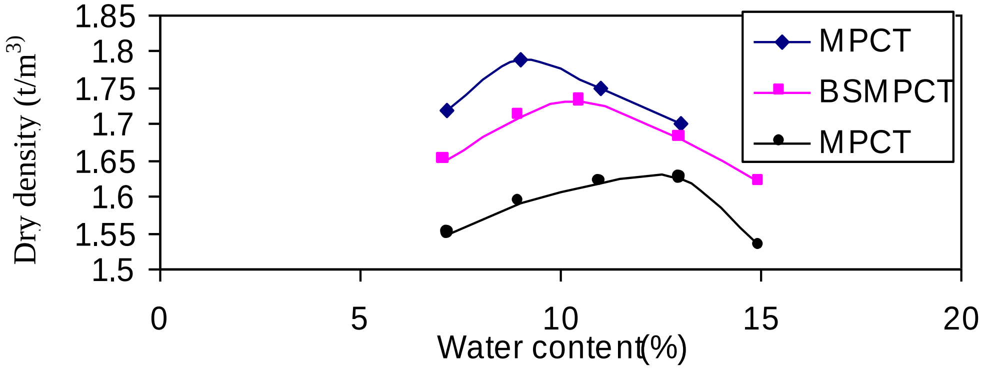

Fig. 2: Dry density vs water content at 0 % of stone.

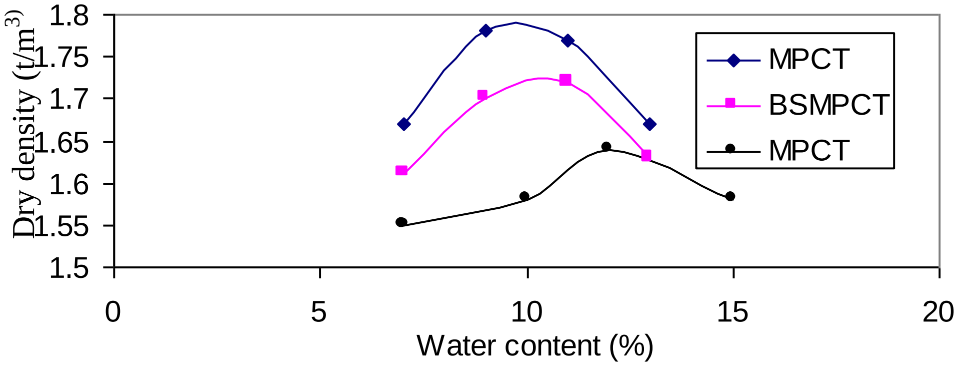

Fig. 3: Dry density vs water content at 5 % of stone.

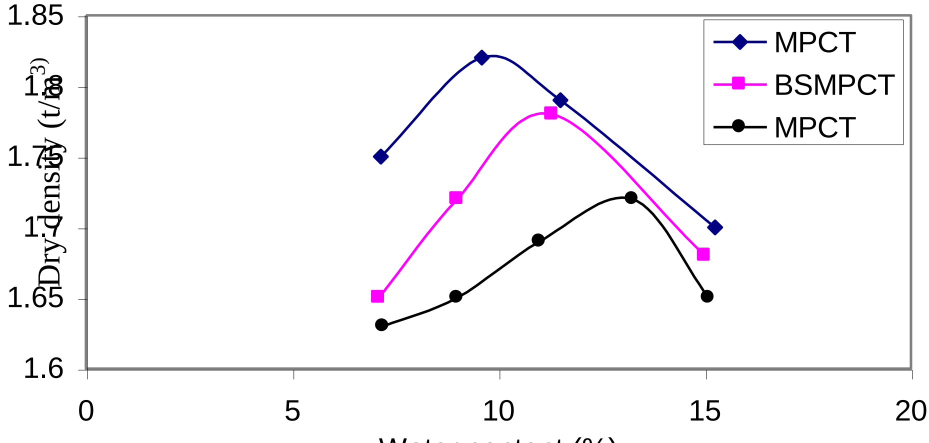

Fig. 4: Dry density vs. water content at 10 % of stone.

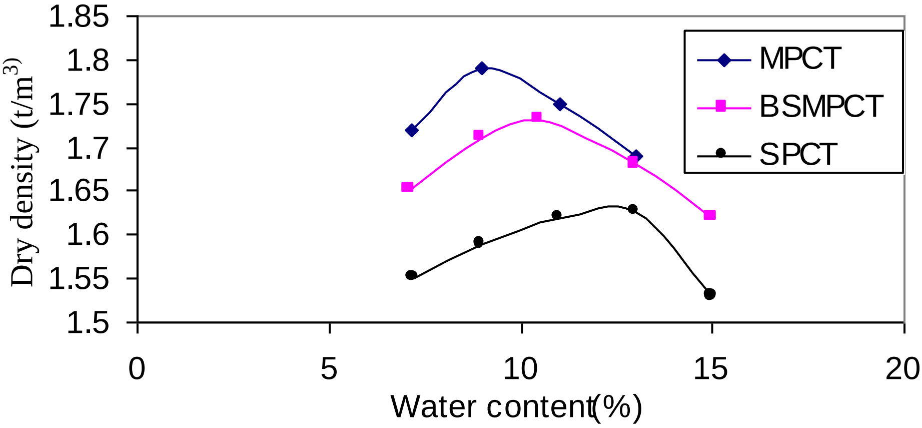

Fig. 5: Dry density vs. water content at 15 % of stone.

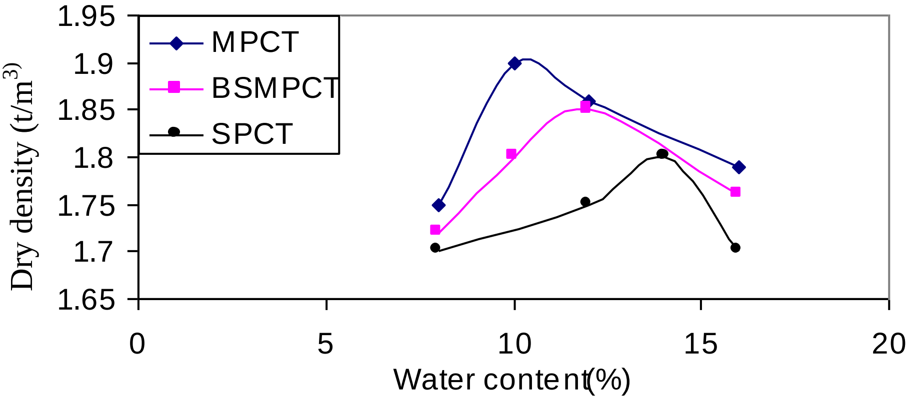

Fig. 6: Dry density vs. water content at 20 % of stone.

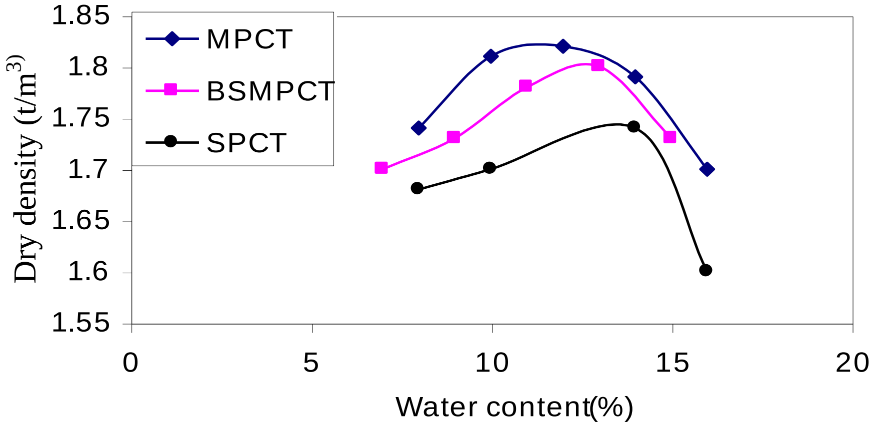

Fig. 7: Dry density vs. water content at 25 % of stone.

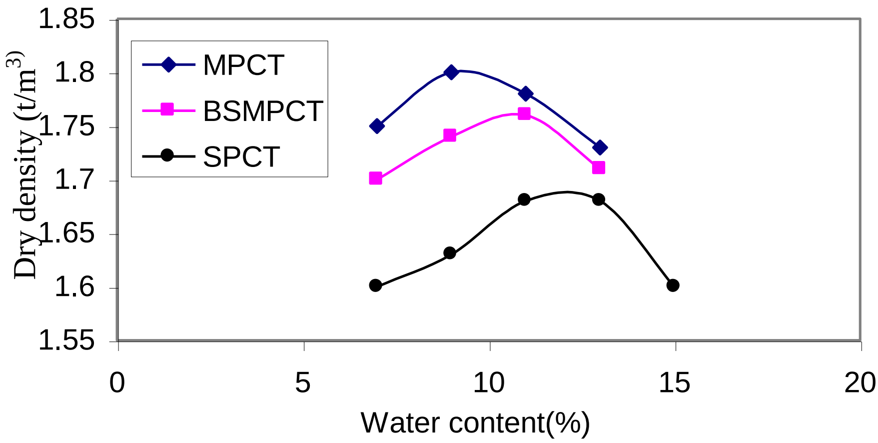

Fig. 8: Dry density vs. water content at 30 % of stone.

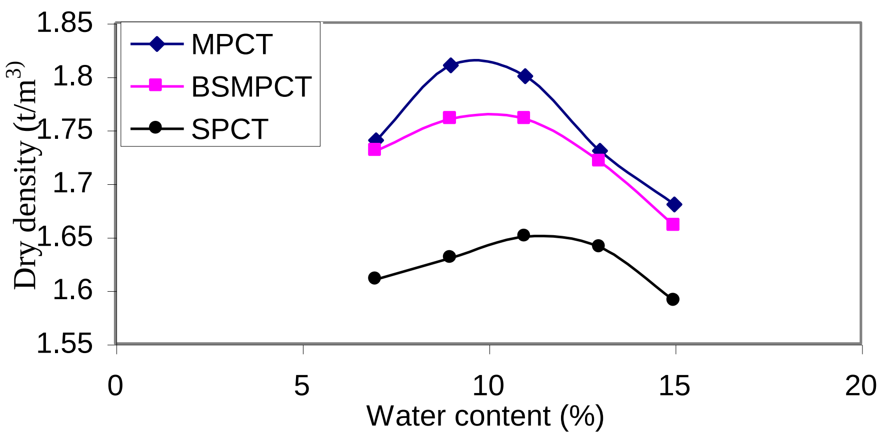

Fig. 9: Dry density vs. water content at 35 % of stone.

3.1.1 Maximum dry density

The values of the maximum dry density are plotted against the study parameters (% of stone and effort of compaction energy), as shown in **Fig. 10**. At all tests the maximum dry density increases as the % of stone increases until % of stone equal to 20 % at certain effort of compaction. This is mainly due to the fine particle of soil fill the void between coarse particles of stone with no change of volume. After that, the maximum dry density decreases with the increasing % of stone. This is due to; there was an insufficient fine material to fill the voids between coarse stone. More and more stone particles were thus in direct contact with each other preventing full compaction of the fines between stone particles. Curves show that the maximum dry density increases as effort of compaction increases at same % of stone

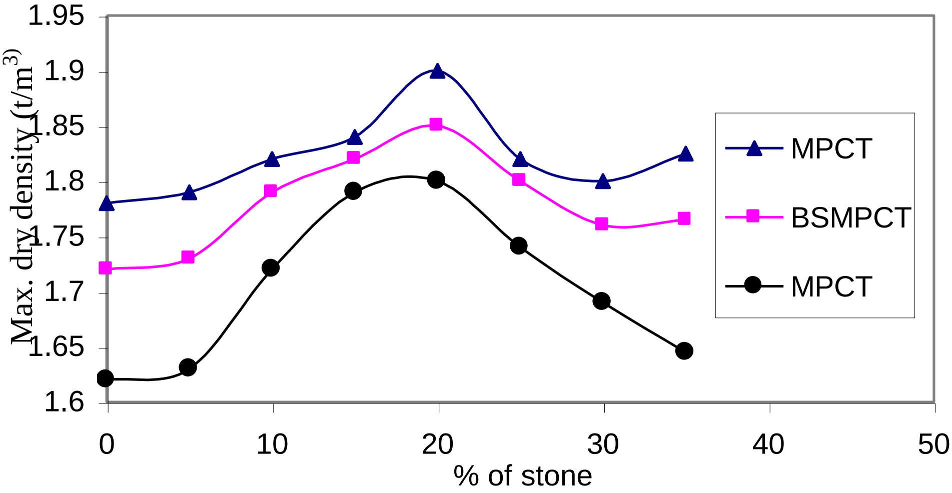

Fig. 10: Maximum dry density vs. % of stone at different effort of compaction.

$R_{C.E.}$ and R_γ for all tests are given in **Table 2**. The given values are plotted at the different % of stone, as shown in **Fig. 11**.

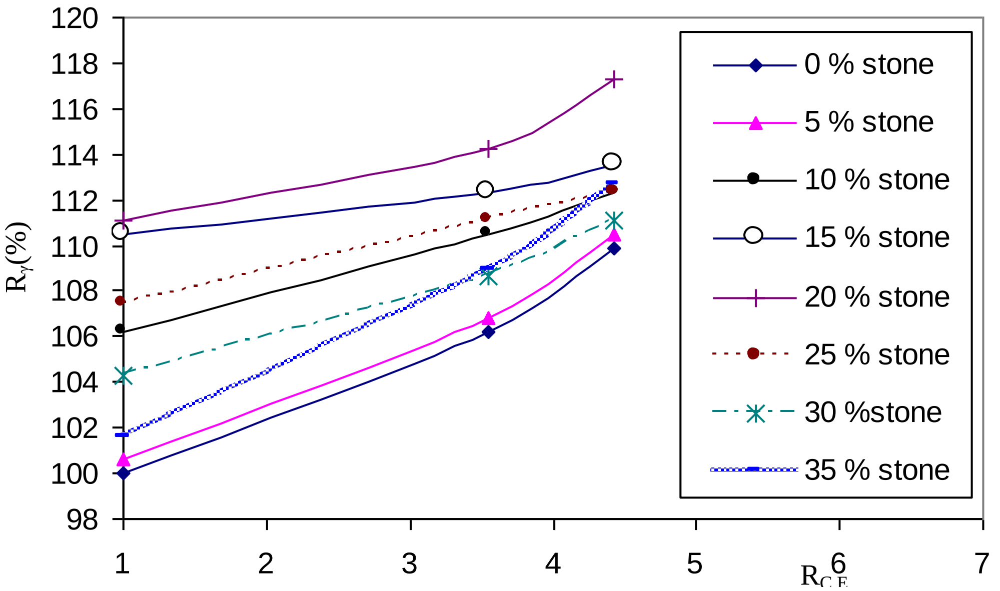

Fig. 11: RC.E. Vs. R_γ (%) at different %of stone.

Table 2: Analysis of the compaction test results.

Test No.	% of stone	Type of test	C.E. kN. m/m^3	$\frac{C.E}{C.E_{SPCT}}$ = ($R_{C.E.}$)	$\gamma_{d_{max}}$ t/m^3	$\frac{\gamma_{d_{max}}}{\gamma_{d_{max(SPCT(0))}}}$ = (R_γ) %	O.M.C c. %
1	0	SPCT	594	1	1.62	100	13
2		BSMPCT	2104	3.543	1.72	106.17	11
3		MPCT	2630	4.428	1.78	109.87	9
4	5	SPCT	594	1	1.63	100.62	12
5		BSMPCT	2104	3.543	1.73	106.80	10.5
6		MPCT	2630	4.428	1.79	110.49	9
7	10	SPCT	594	1	1.72	106.17	13
8		BSMPCT	2104	3.543	1.79	110.49	11.2
9		MPCT	2630	4.428	1.82	112.34	9.6
10	15	SPCT	594	1	1.79	110.49	13
11		BSMPCT	2104	3.543	1.82	112.34	11.5
12		MPCT	2630	4.428	1.84	113.58	10
13	20	SPCT	594	1	1.80	111.11	14
14		BSMPCT	2104	3.543	1.85	114.20	12
15		MPCT	2630	4.428	1.90	117.28	10
16	25	SPCT	594	1	1.74	107.41	13.5
17		BSMPCT	2104	3.543	1.80	111.11	13
18		MPCT	2630	4.428	1.82	112.34	11
19	30	SPCT	594	1	1.69	104.32	12
20		BSMPCT	2104	3.543	1.76	108.64	10.5
21		MPCT	2630	4.428	1.80	111.11	9
22	35	SPCT	594	1	1.645	101.54	11
23		BSMPCT	2104	3.543	1.765	108.95	10
24		MPCT	2630	4.428	1.825	112.65	9.5

Where: -

$R_{C.E.}$ ratio between compaction energy of the test to compaction energy of (SPCT)

R_γ ratio between the max dry density of the test to the max dry density of (SPCT) at 0 % of stone.

The relationship between $R_{C.E.}$ and R_γ for the different % of stone may represented for the soil tests by the following expression:

$$R_{\gamma}(\%) = a\, R_{C.E.} + b \qquad (2)$$

where a, b are constant obtained by regression formula, as the following:

% of stone	a	B	R^2
0	2.7787	97.037	0.9835
5	2.7800	97.657	0.9838
10	1.7770	104.32	0.9980
15	0.8622	109.56	0.9749
20	1.6705	109.20	0.9277
25	1.4428	105.97	0.9990
30	1.9182	102.29	0.9865
35	3.1672	98.241	0.9934

3.1.2 Optimum moisture content (%)

The values of the optimum moisture content (O. M.Cc.) for all tests are plotted against the study parameters (% of stone and effort of compaction energy), as shown in **Fig. 12**. It should be noted that for all test the optimum moisture content does not show any definite trend with the increase in stone content.. However, optimum moisture content decreases with the increasing effort of compaction at a certain % of stone.

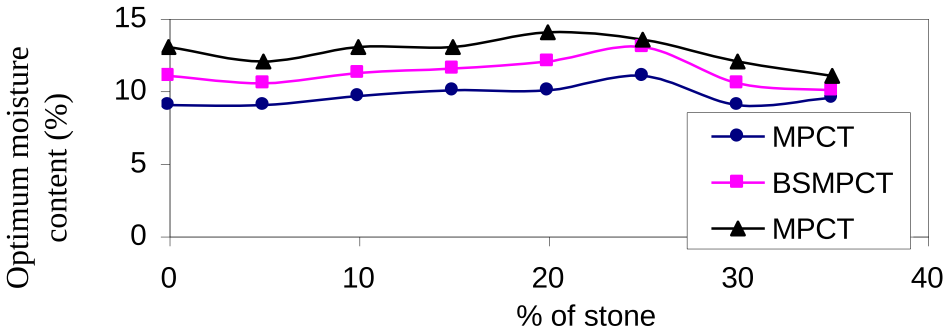

Fig. 12: Optimum moisture content vs. %of stone at different effort of compaction.

4 CONCLUSIONS

The following conclusions can be drawn out from the present study:

- Maximum dry density $(\gamma_{d_{max}})$ increases with the increasing % of stone until 20 % of stone, after that decreases with increasing % of stone at certain effort of compaction.
- Optimum moisture content (O. M.C) does not show any definite trend with the increase in stone content. However, optimum moisture content decreases with the increasing effort of compaction at a certain % of stone.

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تأثير نسبة الحصى على خصائص التربة المدموكة

عديد من المنشات تنشأ من أو على الردم المدموك والخصائص الهندسية للتربة المدموكة تعتمد جزءا على حجم الحبيبات وتوزيعها. ويمكن تغير هذه الخواص بإضافة تربة أخرى مختارة والحبيبات ذات الأقطار الكبيرة لها تأثيرها في الخواص الطبيعية مثل النفازية والخواص الميكانيكية مثل مقاومة التربة للقص والحمل الذي يمكن آن تتحمله وخاصة في التربة الرملية.

الغرض من هذا البحث هو تحديد تأثير نسبة الحصى على نتائج الدمك (أقصى كثافة جافة ونسبة الرطوبة المثالية) مع اختلاف طاقة الدمك. حيث أجريت اختبارات الدمك على خليط متجانس من التربة ونسبة من الحصى وكانت النتائج كالأتي:- كلما زادت نسبة الحصى زادت معها أقصى كثافة جافة حتى نسبة 25% وبعد ذلك بديات أيقصى كثافة جافة تقل. أما نسبة الرطوبة المثالية لم تعطى اتجاه محدد في الزيادة أو النقص مع انه بزيادة طاقة الدمك تقل نسبة الرطوبة المثالية وتزيد أقصى كثافة جافة.