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Research Article

Relationship between Compaction Ratio (RC) and Compacted Layer Thickness

Yahya K. Atemimi
Ph.D. in geotechnical engineering – civil engineering department, University of Babylon – Iraq

***Corresponding Author:**
Yahya K. Atemimi
Email: yehyeaaltemimi@yahoo.com

Abstract: The soil utilized as underneath the layer of sub-base in many civil engineering applications such as; roads, foundations of buildings, walkways, airfield, etc. The thickness of sub-base layer depends on the design load, project type and the soil type. Which will effect on the field density. This study was applied on a sub-base soil grade B as classified according to AASHTO which a wide spread in Iraq. Different tests were conducted on this soil to evaluate its properties such as sieve analysis, Atterberg's limits, compaction and chemicals. Three energies of compactive efforts were used in the laboratory work (EN1= 585.17 kJ/m^3, EN2 =5898.5 kJ/m^3, and EN3=1799 kJ/m^{3,}) to study the effect of different compactive efforts on the maximum dry density. Furthermore, built field model with the compactive effort of 1711.3kJ/m^3 was used to determine the compaction ratio (RC). This model was 3m*1m * 0.80m which was from the confining base and sides by plain concrete to prevent the energy from transmitting to the soil behind and below the model. Four layer thicknesses (0.1m, 0.15m, 0.2m, and 0.3m) were used to study the effect of compactive effort on the layer thickness and then to evaluate the RC. The results obtained from this study showed that RC was Inversely proportional to the thickness of layer when it was equal or less than 0.2m. RC was (97%, 94.2% and 88.5%) at 0.1m, 0.15m, and 0.2m respectively. However, this was not the case when the layer thickness exceeded 0.2m. The results also showed that the adequate thickness was less than 0.2m.
Keywords: compaction, sub-base, compaction ratio, compaction effort.

INTRODUCTION

The most basic form of mechanical stabilization is compaction, which increases the performance of a natural material. Soil compaction is one of the most critical components in the construction of roads, airfields, embankments, and foundations. The durability and stability of a structure are related to the achievement of proper soil compaction. Structural failure of roads and airfields and the damage caused by foundation settlement can often be traced back to the failure to achieve proper soil compaction [1].

Sub-base soil is a granular soils constitute an important group of soils of one of the desert districts of Iraq. Its spread as a 20% from the area of Iraq [2]. This soil is widely used as a layered under a construction member, as flexible pavement, footing, river path, airfields… etc. The layer thickness affects the strength of it, therefore; select adequate thickness is very important to economy and durability [1].

The nature of a soil itself has a great effect on its response to a given compactive effort. Soils that are extremely light in weight, such as diatomaceous earths and some volcanic soils, may have maximum densities under a given compactive effort as low as 60 pcf. Under the same compactive effort, the maximum density of a clay may be in the range of 90 to 100 pcf. [3]. The sub-base is an important layer in both flexible and rigid pavements. It mainly acts as a structural layer helping to spread the wheel loads so that the subgrade is not overstressed. It also plays a useful role as a separation layer between the base and the subgrade and provides a good working platform on which the other paving materials can be transported, laid and compacted. It can also act as a drainage layer. The selection of material and the design of the sub-base will depend upon the particular design function of the layer and also the expected in-situ moisture conditions [4].

This paper presents the results of a laboratory and field testing program carried out to obtained on the relation between the energy applied in the laboratory and the equipment energy in the field to select the better compactor machine then has adequate equipment to determine compaction ratio in right method. Furthermore, to determine the effect of layer thickness on the compaction ratio of soil used as a sub-base layer.

MATERIALS AND METHODOLOGY

The sub-base used in this study was a commercial material class B as shown in Figure 2. The sub-base properties were classified into class B, according to the American Association of State Highway and Transportation Officials (AASHTO), as illustrated in Table1 and Figure 2. The compaction test was conducted on the sub-base in different energies due to different molds sizes and different hummer weights as recommended in ASTM D 1557 of 1000cm^3 mold with standard hummer is named EN1,1000cm^3 mold with modified hummer is named EN2 and CBR mold with modified hummer is named EN3 as illustrate in Table1. Liquid and plastic limits were also applied on this soil according to ASTM specification to agree with the requirement of AASHTO [8]. Field density was obtained by using sand cone test method according to ASTM D1556-90 [6]. Chemical test to evaluate the salts percent and pH number as recommended by ASTM was conducted. Field model was made with 1m wide by 3m long with 0.8m depth, plain concrete with 10cm thickness was done in the surface and sides of it to confine the sub-base layer and prevent energy from transporting to the next layer (soil underneath) as shown in figure 1. The field energy utilized was 1711.3kJ/m^2 this energy was maintained constant at all layer thicknesses due to change the cycles number with thickness of layer and used one-ton compactor machine. Formulas 1 and 2 used to determine the energy. This energy obtained from compactor was adequate in size to the area of model and was near to the energy obtained from the modified proctor with CBR mold (EN3)1798.6 kJ/m$^{2.}$

$$EN)l = \frac{N * Nl * h * W * 9.81}{V * 1000} \qquad 1$$

$$EN)f = \frac{1 * 2\pi r * W * Nf * 9.81}{Vf * 1000} \qquad 2$$

Where
EN)l = Lab. Energy (kJ/m^3), N=blows number, Nl= Number of layers, h = drop distance, W = hummer weight , V = mold volume and EN)f = Field energy (kJ/m^3), $2\pi r$ = perimeter compactor roller, W = weight of compactor, Vf = volume of layer field, Nf = number of cycles in field

Formula 1 used to determine the laboratory energy while formula 2 used to determine the field energy when change the number of cycles as 30,45,60 and 90 with the thickness of layers were 0.1m, 0.15m, 0.2m, 0.3m respectively with the diameter of roller is 0.5m.

Fig-1: Field compaction test – field model

Table 1: The test specification to design experimental program

Test	Energy kJ/m^3	Hummer Weight kg	Drop distance m	Number of blows N	Number of layers Nl	Specific area m^2	Specificat-ion	Refere-nce
EN1	585.17	2.5	0.3	25	3	0.0082	ASTM D 698 grade B	[6]
EN2	5898.5	4.5	0.45	56	5	0.0082	ASTM D1557 grade B	[6]
EN3	1798.6	4.5	0.45	56	5	0.01767	ASTM D 1557 grade C	[6]
Liquid limit	ASTM D4318							[6]
Plastic limit	ASTM D4318							[6]
Sand cone method	ASTM D1556-90							[6]
Total sulphates (Gypsum content, So_3)	BS 1377:1975, Test 9							[10]

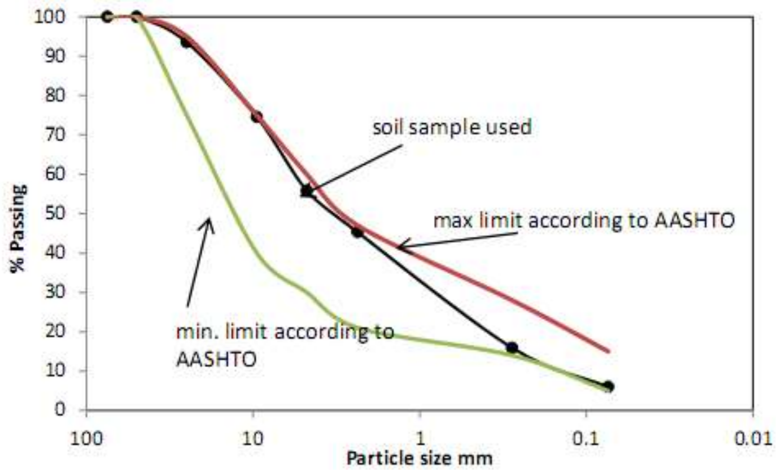

Fig-2: Distribution curve for sub-base used with AASHTO limitations

Table 2: The properties of soil used

Property	Sub-base
Color	Yellow reddish
Gs	2.65
LL%	22
PL%	16
PI%	6
Finer % < 0.074mm	5.95
% < 0.002mm	0
So_3	1.81
Gypsus content	3.89
Satandard PT , ρd max. g/cm^3	2.087
OMC %	7.6
ρd max. g/cm^3 Modified PT	2.195
OMC%	7.14
ρd max. g/cm^3 CBR mold	2.112
OMC%	7.89

RESULTS AND DISCUSSION

Figures 3 and 4 show the relation between the compactive effort and the maximum dry density at lab. The maximum dry density value increased with the increase in compactive effort at high levels while it decreased at low levels. The increase percent was 5% when the results obtained from EN2 (energy = 5898.5kJ/m^3) are compacted with EN3 (energy = 1798.6 kJ/m^3). In low energies, the difference was only 1.2% between compactive effort from EN1(2443.7kJ/m^3) and EN3 (energy = 1798.6 kJ/m^3) although, the difference in energy approximately was same (3 times) but the surface area is more and the difference in number of layers. On the other hand, the size of mold or the contact area is an important reason to decrease the maximum dry density due to dispersion of energy. The difference in results related to the surface area in CBR mold with the hummer contact area was constant although the number of blows were increased. Therefore; must be care should be taken at surface area increase, the contact area of the hummer in the laboratory test increase or in the field with the compaction machine. The optimum moisture content decreased with increasing of compactive effort. This results agree with other researchers [1,4,5,9,11,12].

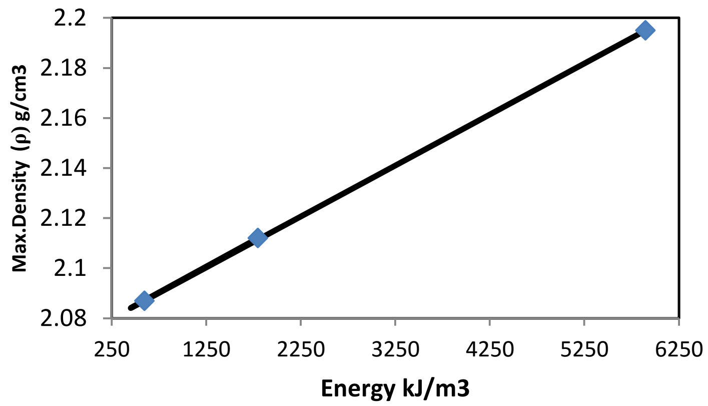

Fig-3: The max. dry density –Energy relationship

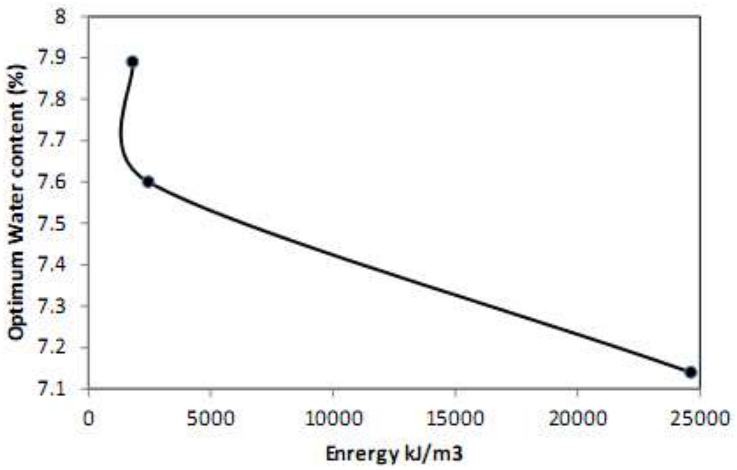

Fig-4: The optimum water content – energy relationship

Figure 5 shows the relation between layer thickness and relative compaction (RC). The relative compaction was reduced as the layer's thickness was increase up to 0.2m while it improved when the layer thickness exceeded 0.2m. This result is attributed to the transition all energy to the small thickness layers then begin to distribute as thickness increases. While at 0.2m to 0.3m the porosity rises as layer thickness increases, air voids increase; this phenomenon effect on compacted soil particles. On the other hand, the thickness of more than 0.2m caused the energy to reach to surface layer and leave the deep points with low density. So the field density decreased due to the increased thickness of layer. in conclusion, decrease in RC depends on the decrease in field density though the compactive effort is constant. The field density test by sand cone method take place to max. 10cm depth in the inspection layer, the results of density do not cover all layer and the results are not real. Therefor the results would not represent the fact of density in specific thickness because to the energy decreased with increasing the depth.

The results showed that the compaction ratio RC reduced as the compactive effort increased when comparing the energy obtained from EN2 and EN3.This result may be attributed to the difference between the field energy (1711.3 kJ/m^2) and the lab. energies. The result showed the lower value of RC due to maximum dry density obtained from modified compaction test (the energy is 5898.5kJ/m^2) and the maximum field density (the energy is 1711. 3 kJ/m^2). This results attributed to the difference in energies between the lab. and the field.

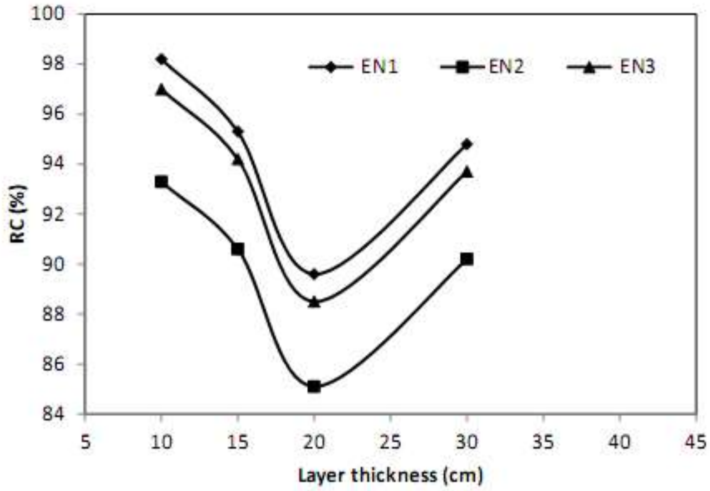

Fig-5: The relation between layer thickness and relative compaction

CONCLUSIONS

Due to the results obtained from this study it can be concluded the followings:

1. The field compactive effort must be related to the lab. Compactive effort.
2. The surface area directly effects on the results.
3. The layer thickness parameter is a major effect on the RC.
4. The layer thickness of less than 20cm is adequate to sub-base layer.
5. The compaction ratio declined as the layer thickness rised.

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