Prediction of Compaction Behaviour of Soils at Different Energy Levels

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Abstract— Compaction tests forms one of the important aspects in geotechnical engineering practice. These tests are time consuming and require large quantity of soil also. In this paper based on the results of the compaction tests carried out for different soils of varying plasticity characteristics at different compaction energies and on published data, it has been brought that there is a good correlation between the optimum moisture content and plastic limit for the . In addition to this one can predict the modified compaction parameters just knowing the plastic limit of the soil.

For the present investigation, three different soils from North Cyprus (Tuzla, Değirmenlik and Akdeniz) and a soil from Turkey (highly plastic montmorillonitic clay) were chosen. These soils are heavily in use for civil engineering activities like construction of pavements, embankments and earth retaining structures.

Compaction tests were carried out at three different energy levels for the four soils described.. They are standard Proctor test (SP), reduced modified Proctor (RMP) and modified Proctor (MP). For the standard Proctor, the compaction energy works out to be 593.7 kJ/m^3. In the modified Proctor test, the compaction energy works out to be 2693.3 kJ/m^3. In the reduced modified Proctor test the procedure is same as modified Proctor except the number of layers are three instead of five. The compaction energy works out to be 1616 kJ/m^3. [1]

Based on the experimental results obtained for maximum dry density vs. optimum moisture content for the four different soils with different compaction energy levels it has been found that irrespective of soil type and compaction energy levels both the maximum dry density and optimum moisture content are linearly related with a very high correlation coefficient of R= 0.994.

Results obtained from laboratory tests as well as from literature show that the correlation between maximum dry density and OMC for different soils, compacted for two compaction energy levels is very good.

It is thus seen that one can predict OMC knowing the plastic limit with reasonable accuracy.

Having obtained OMC one can get the maximum dry density from equation(1) obtained in this study.

From experimental results it has been found that both OMC and maximum dry density of Proctor's test results and that of modified Proctor's test results of authors' as well as data collected from literature correlate very well.

It is seen that the correlation is highly satisfactory. Having obtained both OMC and maximum dry density for Proctor's energy level one can get the OMC and maximum dry density for modified Proctor condition also.

***Index Terms*— compaction, plastic limit, compaction energy**
Introductıon

I. INTRODUCTION

Compaction of soils is an important aspect of civil engineering construction. Earthen structures such as earth dams, embankments (highway, railway and canal) loose foundation soils need to be compacted for increase in strength and reduction in compressibility. In cases where permeability needs to be reduced, compaction of soils is required. Thus compaction is used as practical means of achieving the desired increase in strength, decrease in compressibility and also decrease in hydraulic conductivity of soils used.

To achieve effective compaction in the field, compaction characteristics of soils as obtained in the laboratory are essential. Most often compaction characteristics namely optimum moisture content and maximum dry density are obtained through standard Proctor test. Proctor test not only takes more amount of time to carry out, but also requires large quantity of soil. In several instances large number of Proctor tests need to be carried out for projects like earth dams, embankments etc. In cases where higher strength of soil is required compaction energy need to be increased. To take care of this modified Proctor compaction test procedure is developed. In order to simplify the compaction test for preliminary designs, in this paper an approximate but simplified method is described to obtain both compaction characteristics and compaction curves for both Proctor and modified Proctor compaction energy levels.

II. MATERIAL AND METHODS

For the present investigation, three different soils from North Cyprus (Tuzla, Değirmenlik and Akdeniz) and a soil from Turkey (highly plastic montmorillonitic clay) were chosen. These soils are heavily in use for civil engineering activities like construction of pavements, embankments and earth retaining structures. Table 1 present their index and other physical properties. It may be seen from Table 1 that there is wide variation in their properties.

Compaction tests were carried out at three different energy levels for the four soils described.. They are standard Proctor test (SP), reduced modified Proctor (RMP) and modified Proctor (MP). For the standard Proctor, the compaction energy works out to be 593.7 kJ/m^3. In the modified Proctor test, the compaction energy works out to be 2693.3 kJ/m^3. In the reduced modified Proctor test the procedure is same as modified Proctor except the number of layers are three instead of five. The compaction energy works out to be 1616 kJ/m^3 [7].

TABLE I
PHYSICAL PROPERTIES OF THE SOILS TESTED

Soil	Atterberg Limits		Grain Size Distribution		
	LL(%)	PL(%)	Sand (%)	Silt(%)	Clay(%)
Degirmenlik	37	25	13	52	35
Akdeniz	50	28	11	46	43
Tuzla	53	28	10	48	42
Montmorillonitic Clay	98	40	1	23	76

III. TEST RESULTS AND DISCUSSION

Figure 1 shows the four different soils compacted to three different energies. It is seen that the compaction curves forms a family of curves irrespective of type of soil and compaction energy levels. Figure 2 relates the maximum dry density vs. optimum moisture content for the four different soils with different compaction energy levels. Irrespective of soil type and compaction energy levels both the maximum dry density and optimum moisture content are linearly related with a very high correlation coefficient of R= 0.994.

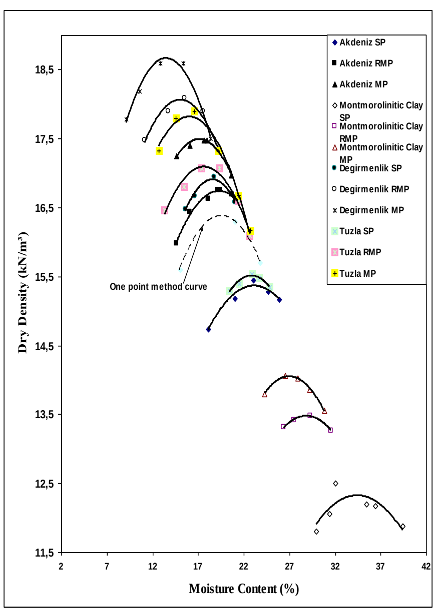

Fig. 1. Family of curves

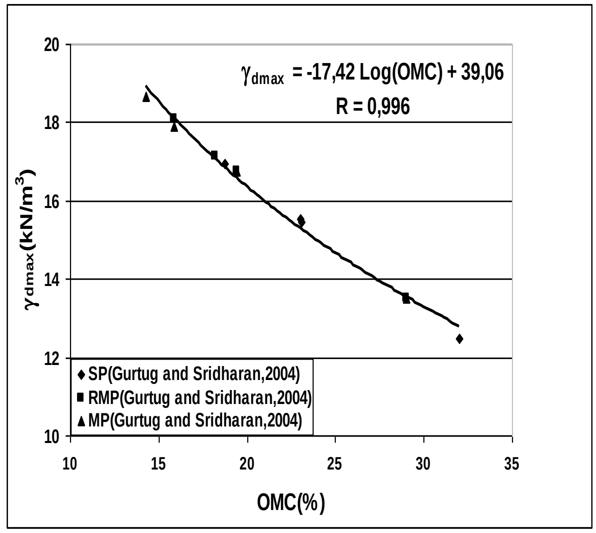

Fig. 2. Correlation between γ_{dmax} and OMC

Figure 3 shows the the correlation between maximum dry density and OMC for different soils collected from literature, compacted for two compaction energy levels. It can be seen that the correlation is very good.

The equation is:

$$\gamma_{d\,\max} = 33.85 - 13.58\log(OMC) \quad \text{and} \quad R= 0.99 \qquad (1)$$

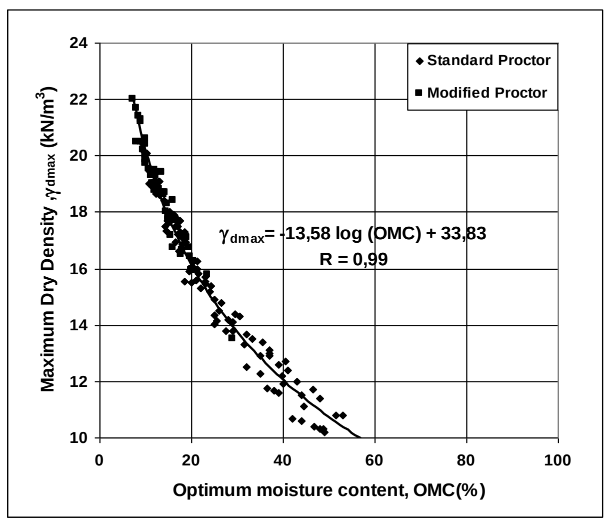

Fig 3. Correlation between maximum dry density and OMC for different soils collected from literature,compacted for two compaction energy levels. [1,2,3,4,5,6,7,8,9,10]

IV. PREDICTION OF PROCTOR OMC AND MAXIMUM DRY DENSITY

Figures 4 show the correlation between optimum moisture content, OMC and plastic limit for several soils collected from literature apart from author's experimental results. It is clearly seen that plastic limit correlates very well with OMC than the liquid limit. The equation relating OMC and plastic limit works out to be:

$$OMC = 0.94w_p \qquad R=0.98 \qquad (2)$$

It is thus seen that one can predict OMC knowing the plastic limit with reasonable accuracy. Having obtained OMC one can get the maximum dry density from equation (1)

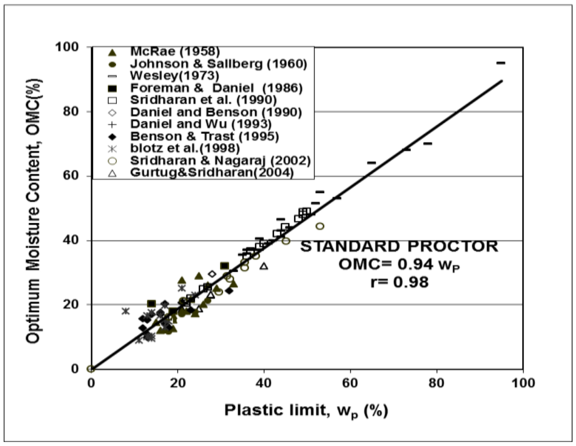

Fig. 4. Correlation between optimum Moisture content and plastic limit.

V. CORRELATION BETWEEN COMPACTION CHARACTERISTICS OF PROCTOR AND MODIFIED PROCTOR ENERGY

Figures 5 and 6 correlate both OMC and maximum dry density of Proctor's test results and that of modified Proctor's test results of authors' as well as data collected from literature.

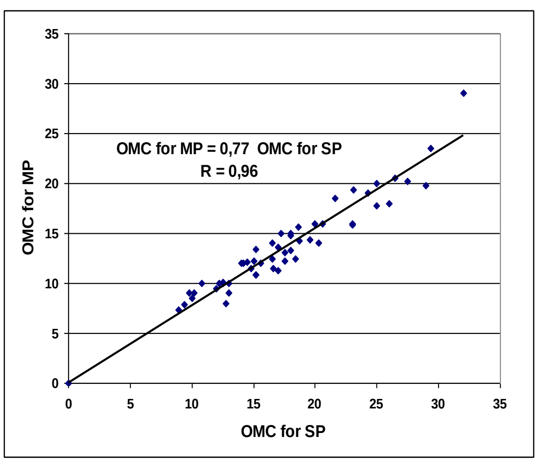

Fig. 5. Correlation between OMC for standard Proctor compaction and OMC for modified Proctor compaction

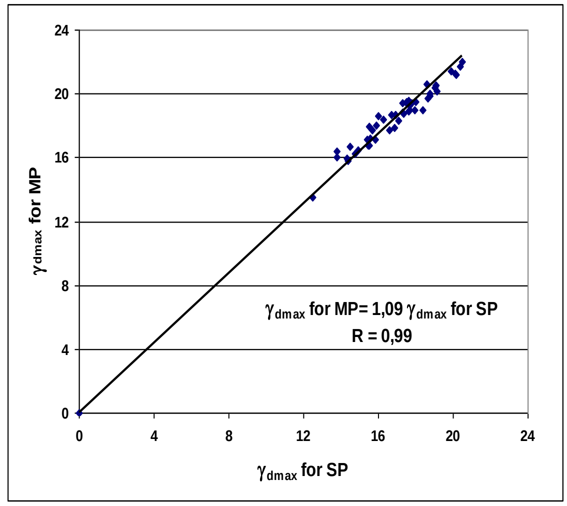

Fig. 6. Correlation between maximum dry density and for proctor compaction and maximum dry density for the modified proctor compaction

It can be seen that the correlation is highly satisfactory. Having obtained both OMC and maximum dry density for Proctor's energy level using Equation (1) and (2) , one can get the OMC and maximum dry density for modified Proctor condition using Equation (3) and (4) respectively.

$$OMCforMP = 0.77 OMCforSP \qquad (3)$$

$$\gamma_{d\max} forMP = 1.09 \gamma_{d\max} forSP \qquad (4)$$

VI. PREDICTION OF COMPACTION CURVES

Having obtained the OMC and maximum dry density for both Proctor's and modified Proctor's condition , one can go to Figure 1 and identify the point for optimum condition and draw the compaction curve almost parallel to top and bottom compaction curves.

Example:

(i) Plastic limit is known and equal to 20 %. From Equation (2) and (1) the value of OMC and γ_{dmax} are : OMC = 20*0.94 = 18.8 %, γ_{dmax} =33.85-13.58 log (18.8)= 17,3 kN/m^3

(ii) After calculation of OMC and γ_{dmax} one can go to Fig. 1 and plot the point for standard Proctor energy. Then parallel lines can be drawn immediate bottom and top of the curves in dotted form as show in Fig 1. This forms the compaction curve for standard Proctor compaction curve.

(iii) Using Equation (3) and (4) one can get the OMC and Maximum dry density for modified Proctor energy level and the same procedure is applied for plotting the modified Proctor compaction curve.

OMC= 14.48% and γ_{dmax}=18.86 kN/m^3

VII. Conclusion

Based on several compaction tests results and extensive published results it has been shown that the optimum moisture content, OMC bears a very good correlation with plastic limit for standard Proctor energy level. Further it has been brought out that the correlation between maximum dry density and OMC is unique for both Proctor and modified Proctor energy levels. There is very good correlation between Proctor OMC and maximum dry density and that of modified Proctor's condition. Using the above findings a simple method has been described to predict the compaction characteristics using plastic limit result.

Acknowledgments

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VIII. References

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