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Effect on Maximum Dry Density and Optimum Moisture Content at Different Compaction Energy Levels

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Abstract—*Compaction energy refers to the amount of mechanical energy applied to soil mass. In this investigation, 5 kg of soil sample is taken from Noida, Uttar Pradesh and Proctor test was carried out. This soil was provided with 5% water and was filled in the mould in 2 layers initially with 25 blows to each layer to attain first compaction energy level. The dry density and moisture content of this soil was obtained. In the next step, we increased the number of layers to increase the compaction energy level, keeping the number of blows per layer constant, i.e., 25 no. of blows.*

To further increase the compaction energy level, we accordingly increased the no. of blows and layers filled in moulds. The same procedure was carried out with addition of increasing amount of water by weight. Using the data obtained from these experiments, the graphs between (a) Dry Density and compaction energy (b) Moisture content and compaction energy are plotted. The point where the slope of the curve changed, gives us the γ_{dmax} *and* w_{opt}. *Based on the results, it is observed that* γ_{dmax} *and* w_{opt} *hold a linear relationship with log E.*

1. INTRODUCTION

Compaction refers to the process of applying compaction energy to soil. It is done to increase unit weight of soil by removal of air voids and rearrangement of soil particles by applying mechanical energy or force.

It is an instantaneous phenomenon. When being compacted, the soil should be partially saturated.

Compaction has various advantages. It improves load bearing capacity of pavement sub-grade. It provides strength to soil and improves its stability. Volume changes or swelling and shrinkage tendency of soil is reduced on properly compacting it. Compaction is done to improve the strength and stiffness properties of soils, like elasticity modulus and shear modulus. Compaction improves bearing capacity and decreases soil settlement.

The various factors which affects compaction are moisture content present in soil, type of soil being compacted, nature of compactive effort i.e; by what method the soil is compacted and the amount of compactive effort applied. To provide the best path to enter energy into soil and compact it, optimum water content is required. A constant value of energy applied to a particular type of soil, at optimum water content, leads to a maximum dry unit weight.

As per Proctor, a definite relationship exists between the soil moisture and the degree of dry density to which a soil may be compacted. Maximum dry unit weight depends on compaction energy and method of compaction for a particular type of soil. We carry out Proctor's compaction test in laboratory so as to know what should be the density achieved in the field and by what method should the compaction take place to achieve the desired maximum dry density of soil.

Water content has significant effect on the compaction process as addition of water content helps soil particles move past each other easily and compact. As soil compacts, voids decreases and dry unit weight increases.

As we add water to soil (at low moisture content), it becomes easier for the particles to move past one another during the application of the compacting forces. As the soil compacts the voids are reduced and this causes the dry unit weight (or dry density) to increase. Initially therefore, as moisture content increases so does the dry unit weight. However, the increase cannot occur indefinitely because the soil state approaches the zero air voids line which gives the maximum dry unit weight for given moisture content. Thus, as the state approaches the no air voidsline further moisture content increase must result in a reduction in dry unit weight. As the state approaches the no air voids line a maximum dry unit weight is reached and the moisture content at this maximum is called the optimum moisture content.

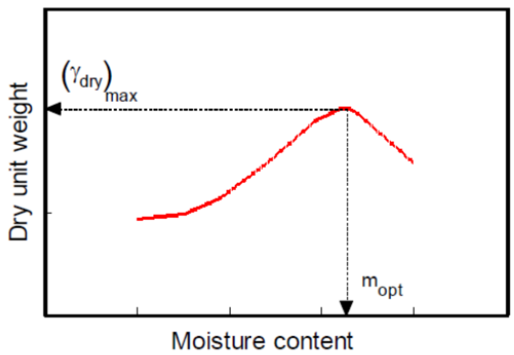

Fig. 1.1: Optimum moisture content

Increased compactive effort enables greater dry unit weights to be achieved which because of the shape of the no air voids line must occur at lower optimum moisture contents. It should be noted that for moisture contents greater than the optimum the use of heavier compaction machinery will have only a small effect on increasing dry unit weights.For this reason it is important to have good control over moisture content during compaction of soil layers in the field.

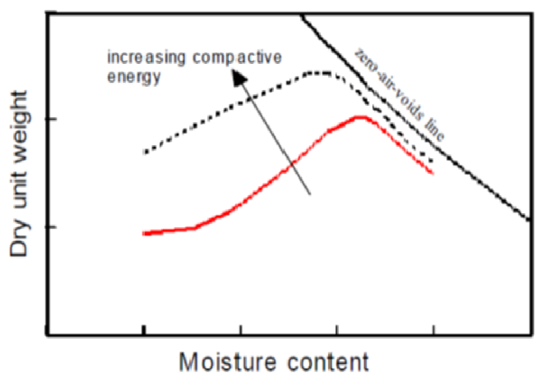

Fig. 1.2: Effect of increased compaction energy on Dry Density vs Moisture content

2. MATERIALS AND METHODS

The requirements to carry out the test involves Proctor mould with a detachable collar assembly and base plate, a manual rammer weighing 2.5 kg and equipped to provide a height of drop to a free fall of 30 cm, a sample extruder, a sensitive balance, straight edge, squeeze bottle, mixing tools(such as mixing pan, spoon, trowel, spatula etc), moisture cans, and drying oven.

For the test, 5 kg of soil sample was taken. The empty proctor mould was weighed without the base plate and the collar. One layer of soil was filled in the mould and 25 blows were given to it. Again second layer was filled and 25 blows were provided to it. This marks the first compaction energy level. The final layer i.e., here the second layer should ensure that the compacted soil is just above the rim of the compaction mould when the collar is still attached. The collar was then carefully detached without disturbing the compacted soil inside the mould and using a straight edge the excess soil was trimmed so as to level the mould. The weight of mould with the moist soil was taken. Then, soil filled in mould is extruded. A moisture can was taken and weighed firstly empty. The moisture can is weighed with moist soil filled in it. Next, the soil sample from soil sliced is put in the oven for 24 hours. Then moisture content of soil sample is determined.

The same procedure is followed at different energy levels.To further increase the compaction energy level, we increased the no. of blows from 25 to 50 to each layer. Again the mould was filled with soil in 2 layers and γdmax and wopt was obtained. Keeping the no. of blows constant, i.e., 50 no. of blows to each layer, we filled the mould in 3 layers and so on in order to increase the compaction energy levels.

All the procedure is followed at water content by weight being 10% and 15%. Using the data obtained from these experiments, the graph between (a) Dry Density and compaction energy (b) Moisture content and compaction energy is plotted. The point where the slope of the curve changed gives us the γdmax and wopt. Based on the results, it is observed that γdmax and wopt hold a linear relationship with log E.

3. RESULT AND DISCUSSION

After performing the experiments at different compaction energy levels at varying moisture content the following observations were obtained, which were further put in mathematical equations to obtain the water content and dry density.

The so obtained values of dry density and water content were plotted on a graph to find out the maximum dry density and the optimum moisture content for each percent of water content mentioned above.

The values of maximum dry density and optimum moisture content at the mention moisture content are the plotted against the different compaction energy levels on a semi log paper to study the variation caused by varying compaction energy.

Table 3.1 Soil + 5% water

Wt. Of Wet Soil+mould(gm)	Wt. of Wet Soil (gm)	Wt. of emptyPan(gm)	Wt. of Pan+ Wet soil (gm)	Wt. of Pan + dry soil (gm)	Water Content	Dry Density (gm/cc)
11093	4489	6.13	18.18	18.160	.105	1.62
11115	4511	6.31	20.13	20.11	.100	1.64
11200	4596	5.92	26.31	26.055	.97	1.57

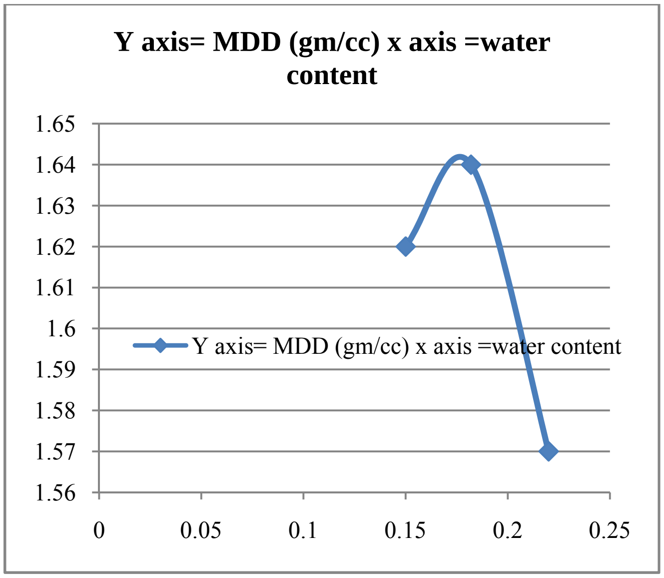

Fig. 3.1 MDD vs Water Content

Table 3.2: Soil+10% water

Wt. Of Wet Soil+mould(gm)	Wt. of Wet Soil (gm)	Wt. of empty Pan (gm)	Wt. of Pan + Wet soil (gm)	Wt. of Pan + dry soil (gm)	Water Content	DryDensity (gm/cc)
11208	4604	6.82	20.62	20.59	.14	1.64
11122	4518	6.51	11.73	11.711	.167	1.68
11205	4601	5.18	12.30	12.274	.211	1.61
11195	4591	5.69	13.3	12.945	.267	1.51

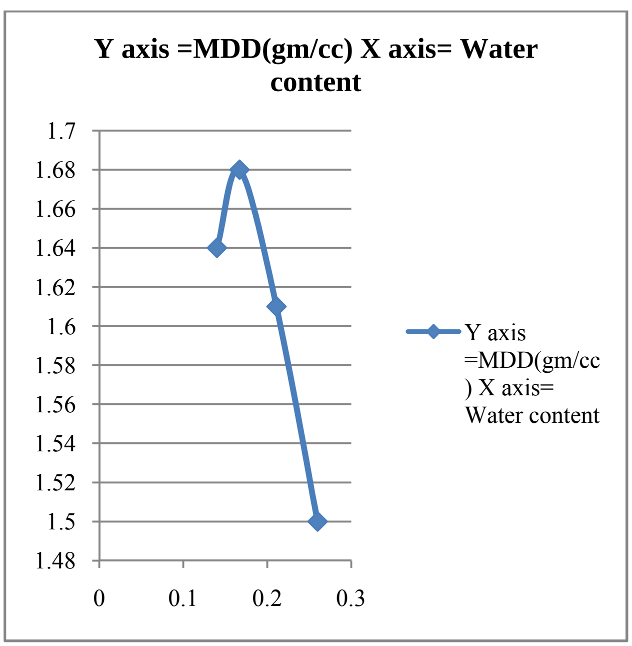

Fig. 3.2 MDD vs Water Content

Table 3.3: Soil + 15% Water

Wt. Of Wet Soil+mould(gm)	Wt. of Wet Soil (gm)	Wt. of empty Pan(gm)	Wt. of Pan + Wet soil(gm)	Wt. of Pan + dry soil (gm)	Water Content	Dry Density (gm/cc)
11280	4676	7.18	19.63	18.89	0.135	1.71
11320	4716	6.5	13.30	12.71	0.09	1.67
11250	4646	8.80	22.50	20.92	0.06	1.63
11279	4639	7.53	20.12	20.086	0.17	1.59

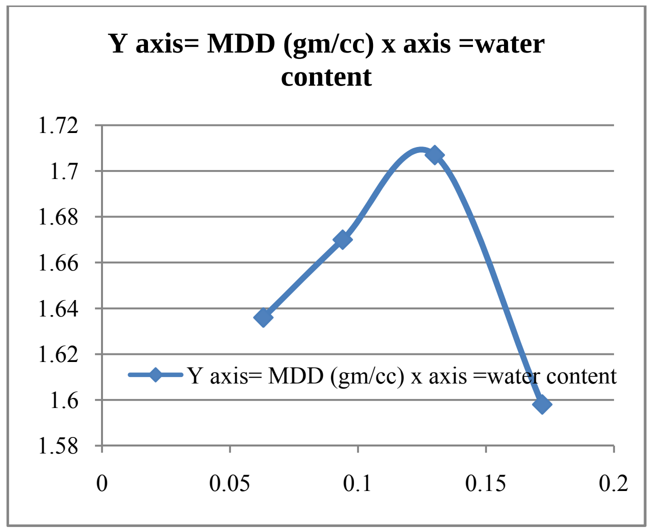

Fig. 3.3 MDD vs Water Content

- **Compaction energy (E) = WHN x no. of layers/V**

Where,

Volume of compaction mold (V) = 1000

Weight of hammer (W) = 2.5 kg

Hammer drop (H) = .305m

No. of blows (N)

Table 3.4: OMC vs Compaction Energy

Sr. no.	Moisture Content	Compaction energy kN/m^2
1.	0.115	500
2.	0.11	570
3.	0.104	590
4.	0.098	760

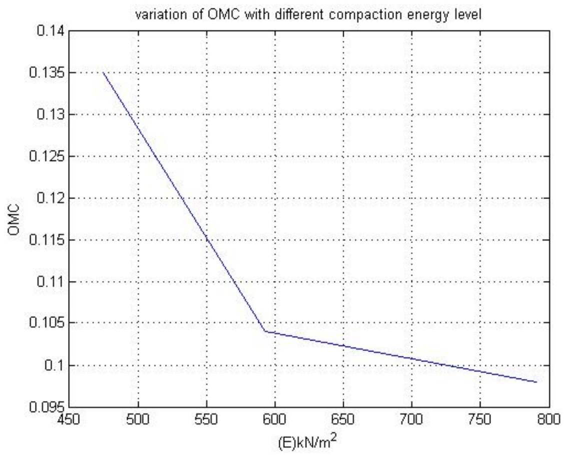

Fig. 3.4 OMC vs Compaction Energy

Table 3.5: MDD vs Compaction Energy

Sr. no	Dry Density	Compaction Energy
1	1.64	450
2	1.68	520
3	1.74	595
4	1.76	725

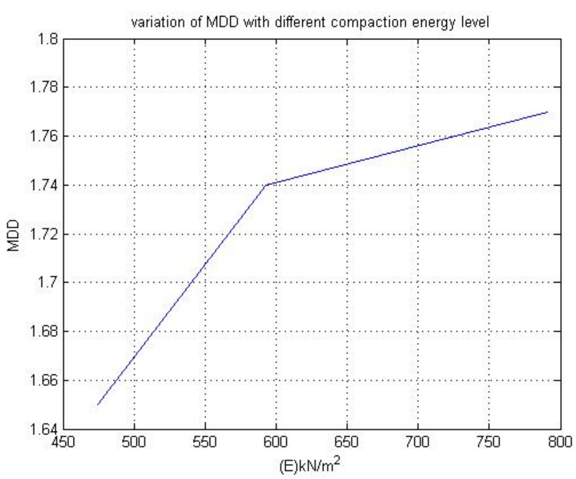

Fig. 3.5 MDD vs Compaction Energy Level

4. CONCLUSION

Swelling and shrinkage of expansive soils is one of the major threats a foundation faces which highly depends on study of OMC and MDD at different compaction energy level and can be applied in the improvement and stabilization of soil. Compaction is one of the efficient ways to improve the strength and stiffness properties of soils, such as elasticity modulus and shear modulus. Also,compaction decreases soil settlement, improves bearing capacity and the stability of sloped embankments. Optimum water content is required to provide the best path for energy to enter into soil and compact it. A constant value of energy applied to a particular type of soil, at optimum water content, leads to a maximum dry unit weight. The aforementioned parameters (γdmax ,wopt) are not unique for various types of soils and vary with the type of soils and the compaction energy.

Maximum dry density (MDD) and optimum moisture content (OMC) are important compaction properties used for field compaction control. This study investigated the relationship between the compaction properties of fine grained soils for standard proctor test.

The above study can also be used in depicting the following:

- The principal reason for compacting soil is to reduce subsequent settlement under working loads.
- Compaction increases the shear strength of the soil.
- Compaction reduces the voids ratio making it more difficult for water to flow through soiland is important if the soil is being used to retain water such as it would be required for an earth dam.
- Compaction can prevent the build-up of large water pressures that cause soil to liquefy at times of earthquakes.

In areas of limited availability of water, heavy compaction is suitable as the OMC is 27% less for heavy compaction as compared to light compaction.

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