# STATIC COMPACTION TEST AND DETERMINATION OF EQUIVALENT STATIC PRESSURE

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ABSTRACT: Soil compaction is a vital part of construction process. The compaction curve between moisture content and dry unit weight should be prepared for all types of soil in the project area, before earth work commences as it forms the basis for specification and field compaction control. The relationship between moisture content and dry unit weight of the soil is a function of the compactive effort. The modified Proctor test, the reduced modified Proctor test, the standard Proctor test and the reduced standard Proctor test are dynamic methods which uses different compactive efforts. These tests require considerable time and effort and also these have some imperfections. In the present study, a laboratory procedure is devised to determine the relationships between moisture content and dry unit weight by using static compaction method for different static pressures. The static compaction pressure test is devised in the Proctor mould itself to statically compact the soil at different water contents. This method is less laborious and the time involved is less. For this seven fine grained soil samples of various plasticity characteristics were tested. The analysis show that the relation between water content and dry unit weight in static compaction for different static pressure is parabolic in nature. In this study, the equivalent static pressures to the modified Proctor test, the reduced modified Proctor test, the standard Proctor test and the reduced standard Proctor test are determined, to obtain the maximum dry unit weight and the optimum water content corresponding to the four different compactive efforts.

*Keywords: static compaction test, standard Proctor test, modified Proctor test, equivalent static pressure.*

## 1 INTRODUCTION:

The Modified Proctor test (MP), the Reduced Modified Proctor test (RMP), the Standard Proctor test (SP) and the Reduced Standard Proctor test (RSP) are dynamic methods of soil compaction which uses different compactive efforts. These dynamic Proctor tests require considerable time and effort. An attempt has been made to obtain compaction characteristic using static compaction method. It is also attempted to determine the equivalent static pressures by applying which the static compaction curves equivalent to the four Proctor's curve of fine grained soils can be obtained.

Different research workers intended to predict the compaction properties of soil by static compaction. However literature in static compaction is very scarce. Kenneth and Steven (1968), Reddy and Jagadish (1993), Oliver and Mesbah (1999), Kenai et al. (2006), Hafez et al. (2010),Yuce and Kayabali (2010) are a few research workers in this direction. Talukdar et al. (2014) in their studies reproduced the compaction characteristics through static compaction test and derived an equivalent static pressure by applying which a static compaction curve equivalent to the standard Proctor's curve of fine grained soils could be obtained. In this study, the equivalent static pressures to the MP, RMP, SP and the RSP are determined, to obtain the maximum dry unit (MDU) weight and the optimum water content equivalent to the four different Proctor's compactive efforts.

## 2 TEST PROGRAM AND TEST RESULTS

Altogether, 7 fine grained inorganic soil samples were tested to determine static compaction characteristics and their relevant physical properties. The MP, RMP, SP and the RSP tests were also performed to determine the dynamic compaction characteristics. The SP test has been carried out according to IS 2720(part 7) 1980 and MP test has been carried out according to IS 2720(part 8) 1983. The procedure and equipment for RSP and RMP tests are essentially same as that used for SP and MP test respectively. However each layer received 15 number of blows of a rammer instead of 25. The liquid limits of the soils varied from 30% to 79% and the plastic limits varied from 16% to 23%.There is a wide range of variation in the plastic properties of the soils. Table 1 shows the physical properties of the soil samples. The static compaction test consisted of placing of a known weight of soil with known water content into the standard Proctor mould of 1000 mL capacity.

Table 1 Physical properties of the soil samples

| Soil No. | Sp. Gr. | LL (%) | PL (%) | Sand (%) | Silt + Clay (%) | IS Classification |
|---|---|---|---|---|---|---|
| 1 | 2.63 | 46 | 19 | 27 | 73 | CI |
| 2 | 2.80 | 30 | 23 | 23 | 77 | ML |
| 3 | 2.65 | 57 | 16 | 21 | 79 | CH |
| 4 | 2.75 | 72 | 19 | 23 | 77 | CH |
| 5 | 2.77 | 79 | 20 | 24 | 76 | CH |
| 6 | 2.73 | 40 | 18 | 24 | 76 | CI |
| 7 | 2.72 | 49 | 18 | 20 | 80 | CI |

The maximum height to which soil could be filled in the compaction mould was 100mm. Experiments were carried out varying the layer thickness, however it was observed that compacting the soil in three different thicknesses did not result in any significant variation in the dry density. Two metal plates of diameter 98 mm and thicknesses 5 mm and 16 mm respectively were placed one above the other, on top of the soil sample in the mould. The entire assembly was placed under a cylindrical plunger of diameter 50 mm of the loading frame. Load was then statically applied to the soil through a proving ring having a proving ring constant of 0.99 kg/div. The height of penetration of the metal plate from the top surface of the mould was measured corresponding to different load levels. Since the soil was filled at a known water content, the corresponding dry unit weight of the soil gets determined. The static pressure was gradually increased till no further increase in dry unit weight occurred with further increase in static pressure. The static pressure was calculated by dividing the applied load by the area to which it was applied. The procedure was repeated for more than five different water contents.

The relationship between static pressure and dry unit weight, corresponding to different water contents have been plotted in the form of curves.The relationship is found to be non-linear. Typical plot of static pressure vs dry unit weight at a particular water content is shown in Figure 1. Similar results have been obtained for other water contents. It is observed from the curves that the dry unit weight increases to its maximum value and then remains constant with further increase in static pressure.

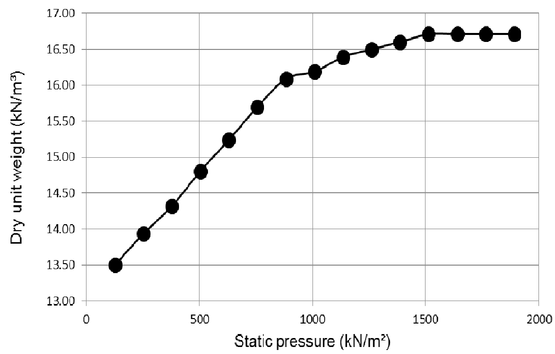


Fig.1 Static pressure vs Dry unit weight curve of sample 2 at 22.45% water content

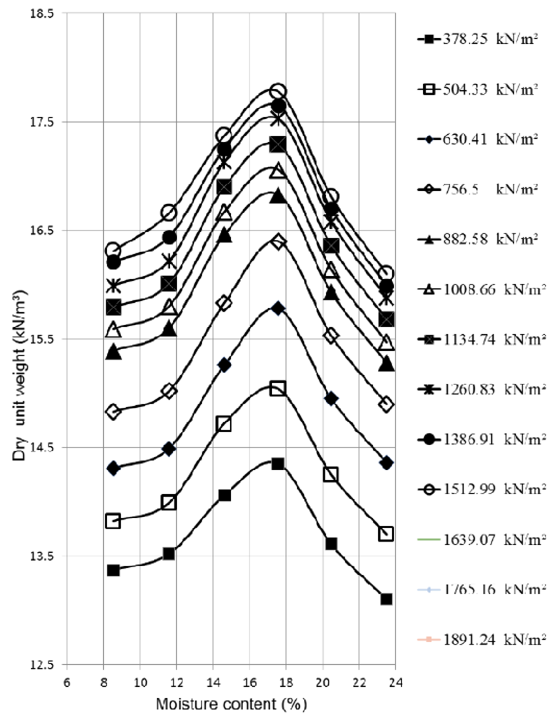


Fig.2 Parabolic relationship between Moisture content and Dry unit weight curves for sample 6

Next for a particular static pressure and water content, the dry unit weight was obtained. The relationship between water content and dry unit weight for a particular soil at a particular static pressure is found to be parabolic in nature. Similarly, at all other static pressures, this relationship is found to be parabolic. This parabolic relationship is shown in Figure 2 for the soil sample 6. One common characteristic in all the curves in all the soil samples was that, beyond a static pressure of around 1513kN/m$^2$, further increase in dry unit weight was not possible. In order to understand this behavior, plot of static pressure vs degree of saturation value at each water content for all the seven

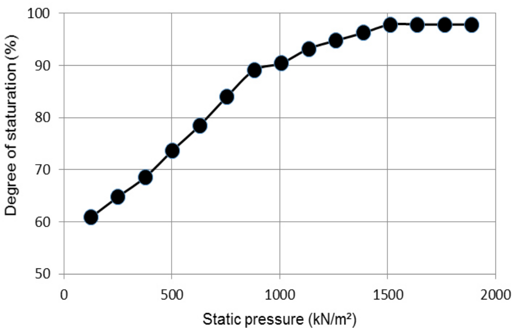


Fig.3 Static pressure vs Degree of saturation curve of sample 2 at 22.45 % water content

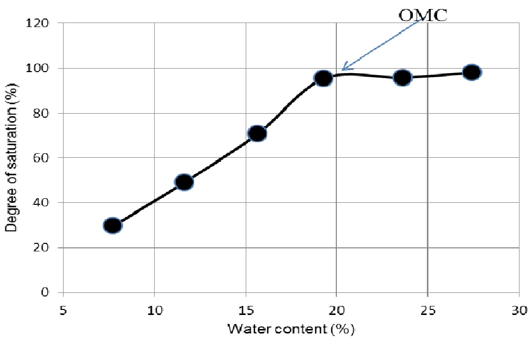


Fig.4 Water content vs Degree of saturation curve

number of soil samples were made. This plots are found to be non-linear in nature. It has been observed that degree of saturation can reach a maximum value of 93% to 98% depending on the soil sample at around the optimum water contents. This behavior is shown in Figure 3. This point is further highlighted by the plot of degree of saturation and water content at the static pressure of 1513 kN/m² (i.e. the static pressure after which dry unit weight does not increase further) shown in Figure 4. It is observed that the degree of saturation reaches a maximum value of 93% to 98% depending on the soil sample at around the optimum water contents. This explains why beyond a static pressure of around 1513kN/m$^2$, further increase in dry unit weight was not possible. Similar observation was made by Talukdar et.al (2014) for 8 soil samples having classification of CH, CI, CL, MI and ML. Next the static compaction curves of a particular soil sample corresponding to different static pressures were superimposed with the dynamic compaction curves of the standard Proctor test, modified Proctor test, reduced standard Proctor test and reduced modified Proctor test. It was attempted to ascertain the static pressure value which gives the nearest value of maximum dry unit weights at optimum water contents from standard Proctor test, reduced standard Proctor test, modified Proctor test and reduced modified Proctor test. Typical plot of moisture content vs dry unit weight is shown in Figure 5.

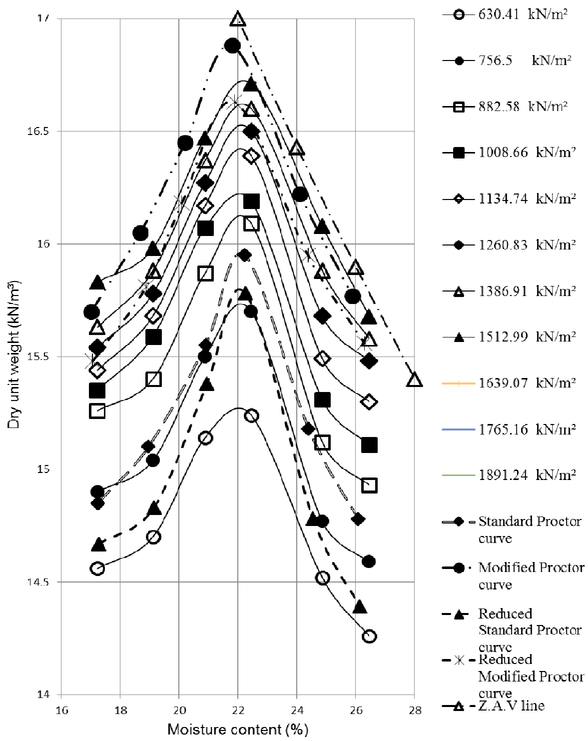


Fig.5 Moisture content vs Dry unit weight curve of sample 2

From the curves it is observed that a static pressure in the range of 750 kN/m² to 875 kN/m² is required to obtain the maximum dry unit weight value at OMC for standard Proctor test and reduced standard Proctor test and a static pressure in the range of 1375 kN/m² to 1500 kN/m² is required to obtain the maximum dry unit weight value for reduced modified Proctor test curves in all the seven soil samples. Further it is observed that the parabolic curve corresponding to the maximum static pressure of 1513kN/m$^2$ lie below the modified Proctor test curve in all the seven soil samples.

## 2.1 Determination of Equivalent Static Pressure

Next it is attempted to determine the equivalent static pressure at which standard Proctor maximum dry unit weight value can be obtained. For this, the method described by Talukdar et.al (2014) have been used. Two maximum dry unit weights were chosen in such a manner that one is above the maximum dry unit weight as obtained from standard Proctor's test and the other is below it. Assuming linear variation of dry unit weights with the two pressures, the pressure corresponding to the standard Proctor's dry unit weight was determined. Similar method was applied to find the equivalent static pressure for reduced standard Proctor test and reduced modified Proctor test respectively.

Table 2 Equivalent static pressure (ESP) for seven different soil samples

| Soil no | ESP for standard Proctor test (kN/m²) | ESP for reduced standard Proctor test(kN/m²) | ESP for reduced modified Proctor test(kN/m²) |
|---|---|---|---|
| 1 | 855 | 780 | 1420 |
| 2 | 836 | 778 | 1423 |
| 3 | 842 | 800 | 1415 |
| 4 | 855 | 805 | 1410 |
| 5 | 858 | 804 | 1430 |
| 6 | 840 | 777 | 1445 |
| 7 | 830 | 770 | 1440 |
| Average ESP of all the samples | 845.14 | 787.71 | 1426.14 |

The values of equivalent static pressures as obtained are shown in Table 2. The average equivalent static pressure comes out to be around 845 kN/m$^2$, 788 kN/m$^2$ and 1426 kN/m$^2$ for SP test, RSP test and RMP test respectively. Hence it can be concluded that in the static compaction test, when a static pressure of around 845kN/m$^2$ is applied, a static compaction curve, equivalent to the SP curve can be obtained. Similar can be said of the RSP test and RMP test respectively. Talukdar et al. (2014) found an equivalent static pressure of around 820kN/m$^2$ for the SP test which is in agreement with the present work.Since the MP test curves for all the seven samples lie above the maximum static pressure curves corresponding to static pressure of 1513kN/m$^2$, it is not possible to determine the equivalent static pressure for the MP curve. Hence it is seen that static compaction curves equivalent to the SP test, RSP test and RMP test can be obtained when static pressures of around 845 kN/m$^2$, 788 kN/m$^2$ and 1426 kN/m$^2$ are applied respectively.

## 3 CONCLUSION

A static compaction method is described to determine equivalent static pressure equivalent to the standard, reduced standard and the reduced modified Proctor test. The relationship between water content and dry unit weight corresponding to different static pressure is found to be parabolic in nature.The averaged equivalent static pressure comes out to be around 845 kN/m$^2$, 788 kN/m$^2$ and 1426 kN/m$^2$ for standard Proctor test, reduced standard Proctor test and reduced modified Proctor test respectively of the fined grained soils having IS soil classification of CH, CI, CL, MI and ML. In the static compaction test it was found that beyond a static pressure of around 1513kN/m$^2$, further increase in maximum dry unit weight was not obtained and the dry unit weight remained almost constant. It is not possible to determine an equivalent static pressure required to obtain the maximum dry unit weight value as obtained from the modified Proctor's test

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