e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:03/Issue:01/January-2021 Impact Factor- 5.354 www.irjmets.com

VERIFICATION OF THE RELATIVE DENSITY OBTAINED IN LABORATORY USING DYNAMIC CONE PENETROMETER

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ABSTRACT

The Dynamic Cone Penetrometer also called DCP in short, is an instrument which is used to evaluate the underlying strength of the granular soil material by measuring the penetration of each hammer blow. It basically provides a measure of the material's in situ resistance to penetration. In this study, the tests were conducted by driving a metal cone into the ground through repeated blows. For this purpose, a hammer of weight 78.4N (8Kg) was repeatedly dropped from a height of 575mm & penetration of the instrument was measured and recorded. This process was continued until the desired penetration of the instrument was reached. Before conducting the Dynamic Cone Penetrometer (DCP), the soil sample for the tests were obtained through sand raining (Pluviation) process using Mobile Pluviator. The instrument was first properly calibrated and then used in the laboratory. During calibration of the instrument, curves were obtained between the height of fall (H) and the relative density (γ_{rel}). The idea is, if you increase the height of fall (H) then the relative density (γ_{rel}) will increase correspondingly. From the calibration curves, height of fall (H) corresponding to the relative density of 60% was selected & was maintained in the raining process so that the deposited samples were having relative density (γ_{rel}) of 60%. The only objective of this study was to validate this relative density obtained through the mobile Pluviator using Dynamic Cone Penetrometer (DCP). The results obtained from the Dynamic Cone penetrometer (DCP) are in close agreement with those obtained from the Mobile Pluviator.

Keywords: Dynamic Cone Penetrometer, Mobile Pluviator, Relative Density

I. INTRODUCTION

Since the soil Porosity depends on many factors such as particle size, particle's shape & uniformity of the size. That's why porosity of a soil itself does not indicate whether a soil is in loose or dense state. This information can only be achieved by comparing the porosity or void ratio of the given soil with that of the same soil in its loosest and densest possible state and hence the term, relative density is introduced.

Relative density (γ_{rel}) or density index is the measure of compactness of a cohesionless soil. By definition, relative density is the ratio of the difference between the void ratios of a cohesionless soil in its loosest state and existing natural state to the difference between its void ratio in the loosest and densest states. Determination of relative density is very important since it is helpful in evaluating compaction state of coarse-grained soils and also assessing the safe bearing capacity in case of sandy soils.

$$\gamma_{rel} = \frac{e_{max} - e}{e_{max} - e_{min}}$$

Where,

- e_{max} is maximum void ratio for the cohesionless soil & it corresponds to its loosest state.
- e_{min} is minimum void ratio for the cohesionless soil & it corresponds to its densest state, while
- e is the in-situ void ratio or the void ratio of the cohesionless soil in the field.

By definition, void ratio e is the ratio between the volume of voids to volume of soil solids;

$$e = \frac{V_v}{V_s}$$

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Where,

- V_v is volume of voids, &
- V_s is volume of soil solids

In this present study, dry sand samples were prepared using the Mobile Pluviator. The Mobile Pluviator was first properly calibrated before using it in the laboratory. For this purpose, a number of calibration tests were conducted on the Mobile Pluviator & different curves were obtained between the height of fall (H) and the relative density (γ_{rel}). All the laboratory tests were conducted at 60% relative density. Pluviation (Sand raining) was done for each and every test. And after the completion of Pluviation & before conducting the test, DCP was performed on each test.

II. EXPERIMENTAL SETUP

The experimental work was performed in two stages. The first stage includes the preparation of the sand sample using the Mobile Pluviator while the second stage includes the verification of the density obtained from Pluviation through DCP test.

Preparation of the sand sample (Mobile Pluviator)

In the first stage, sand sample was prepared using Mobile Pluviator. Mobile Pluviator is an apparatus which is used in the laboratory to achieve a specific uniform relative density through Pluviation process. The different components of the Mobile Pluviator are;

- Adjustable Frame
- Hopper
- Wheels
- Shutter, &
- Sieves

The main function of the adjustable frame is to use the apparatus as per the user requirements. The Pluviator which is used in this study can be adjusted both in the horizontal & vertical direction. The main function of the hopper is to receive the sand. Sand is first feeded into the hopper. The function of the wheels is to move the hopper in the horizontal plane and to ensure that the sand reaches to all the edges and corners of the box. The function of the shutter is to control the flow rate or discharge of the sand falling into the box. Shutters can be of different types based on the size & number of holes (Porosity) in the shutter. Increasing the shutter porosity will increase the discharge but will decrease the relative density & vice versa. The main function of the sieves is to ensure uniform raining.

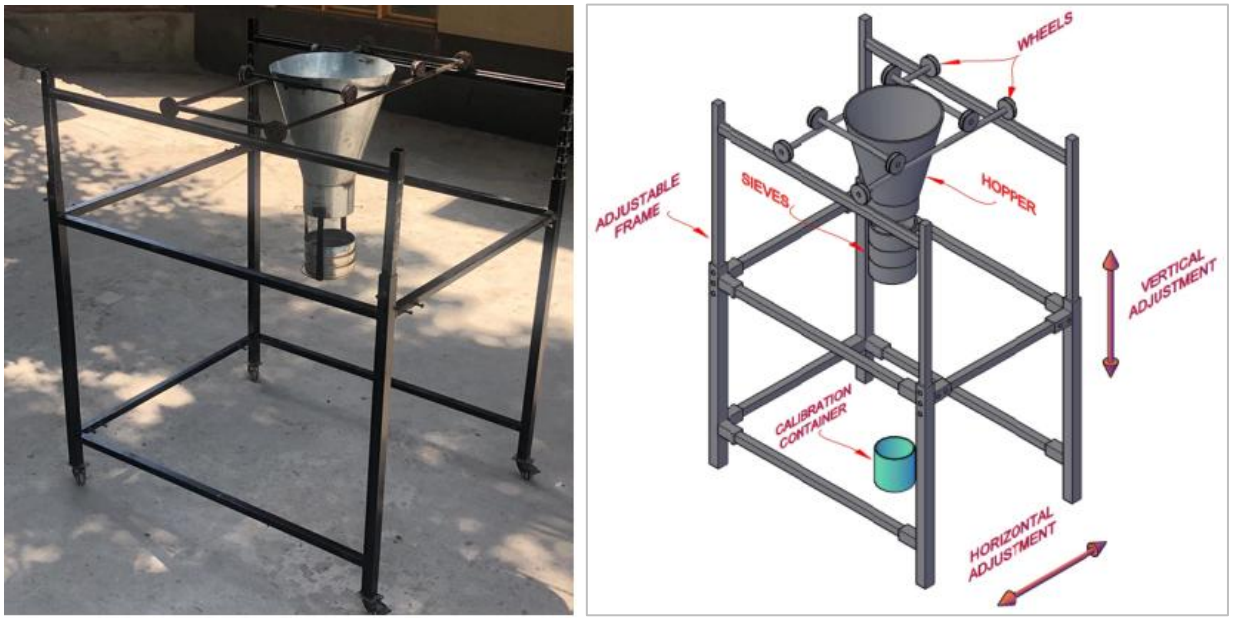

Fig.-1: Mobile Pluviator.

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Dynamic Cone Penetrometer

The Dynamic Cone Penetrometer (DCP) tests were conducted according to the procedure as per ASTM-D6951-3(2003), The apparatus consists of 16mm diameter steel rod to which a 60◦ steel cone having 20mm base diameter is attached at the lower end. The DCP is driven into the ground by 8kg hammer. The hammer was dropped from a height of 575mm. After each drop, penetration of the cone was measured & recorded. Figure 4 shows the complete details of the dynamic cone penetrometer.

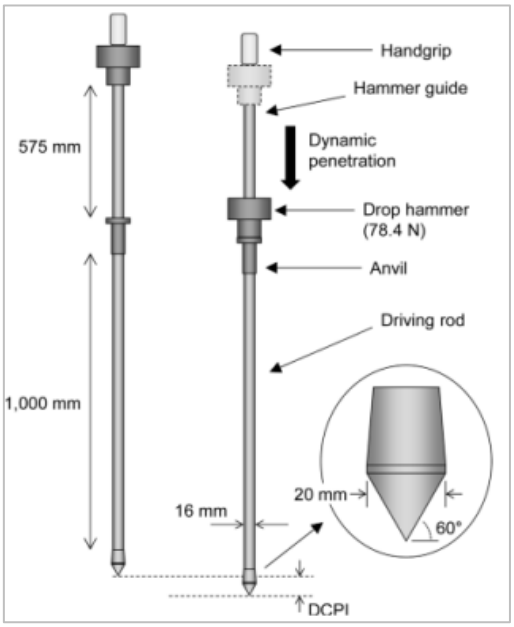

Fig.-2: Dynamic Cone Penetrometer (DCP).

Fig.-3: Performing DCP

Fig.2 shows the complete details of the dynamic cone penetrometer (DCP). The various components of DCP are:

- Handle
- Hammer
- Guiding Rod
- Lower Shaft
- Anvil, &
- Cone

The function of the handle is to properly grip the equipment during testing. The function of the hammer is to drive the cone into the soil. The hammer is manually raised & then dropped imparting its energy to anvil & in this way the cone gets penetrated into the soil. The function of the guiding rod is to guide the hammer during its fall. The guiding rod prevents the hammer falling aside. The lower shaft gets penetrated into the soil & the amount by which the instrument gets penetrated into the soil is recorded with the help of lower shaft. The main function of the cone is to facilitate the penetration process. Two types of cones are generally used in DCP testing depending

on the soil conditions. In stiffer soil 30◦ is used while in medium to stiff soil 60◦ cone is used. In either case,

the cone base diameter is 20 mm. This DCP test was conducted immediately after the Pluviation Process.

III. DATA ANALYSIS

After conducting the DCP test & recording the data, the following relation was used in finding out the relative density (γ_{rel}).

$$\gamma_{rel}(\%) = 97.4035 * e^{\frac{-P_{index}\sqrt{D_{50}}}{80.7707}} + 3.0971$$

Here,

P_{index} is Penetration index or Penetration per blow, & D_{50} is Mean particle size or mean particle size.

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Fig.-4: Sand ready for DCP after Pluviation.

IV. RESULTS AND DISCUSSION

The mobile Pluviator was used in such a way so that the deposited sand achieved a relative density of 60%. This relative density was then verified using the Dynamic Cone Penetrometer (DCP). At the end it was observed that the DCP results were in close agreements with those obtained from mobile Pluviator. Table 1 shows the DCP results in detail.

Table-1: Relative Density from DCP

Blows	Penetration (mm)	P_{index} (mm/blow)	γ_{rel} (%)
1	150	150	41.6
2	250	100	55.5
3	320	70	66.2
4	410	90	58.9
5	480	70	66.2
6	550	70	66.2
7	640	90	58.9
8	720	80	62.5
9	790	70	66.2
10	880	90	58.9
11	950	70	66.2
Average Relative Density (γ_{rel})			60.7

V. CONCLUSIONS

From this experimental work the following conclusions can be made.

- Pluviation or Sand raining technique is highly recommended in situations where same soil conditions are required for a number of tests.
- Dynamic cone penetrometer test is a satisfactory way of verifying the density obtained through Mobile Pluviator.
- For getting better results DCP should be performed at several points in the soil sample.
- Changing the height of fall (H) does affects the relative density.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my MS Supervisor Prof. Dr. Irshad Ahmed for his technical guidance, moral support & continuous motivation throughout this research. I'm much obliged to him for his valuable suggestions in spite of his busy schedule. I'm also thankful to my Respected Co-supervisor Sir Irfan Jamil who shared his valuable ideas with us throughout this research work. I also appreciate the assistance provided to me by my colleagues Engr. Muhammad Irshad & Engr. Muhammad Idris. Finally, I would like to express my special thanks to Engr. Wali Ullah & to Engr. Abdul Muiz Khan who assisted us continuously during the experimental work.

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