An Experimental Investigation of Intelligent Compaction Technology for Subgrade and Embankment Soil Layers

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Abstract— An experimental study on embankment and subgrade soil is conducted to study the principles of soil compaction to establish a relationship between dry density and moisture content. A conventional test method for subgrade and embankment construction covers less compaction (about 1%). The intelligent compaction technology offers a method to measure 100% of compaction. The increased compaction zone leads to decreased maintenance costs and an extended service life. In this study the effectiveness of rollers, their specification and degree of compaction is observed. In the present study, project site at Honnali Taluk Basavapattan village(latitude 14.244 and longitude 75.677) is selected. A soil sample from site is brought and tests are conducted to know their index properties. The soil is classified according to Bureau of Indian Standard soil classification. A prototype smooth drum vibratory SD 110 roller is utilized that allowed for simultaneous real time machine driven power measurements, which permitted independent and simultaneous evaluation of the degree of compaction of soil. Total station equipment is used to monitor the thickness of each layer after compaction. In the field core cutter and rapid moisture meter instruments are used to determine the field in-situ density and moisture content. The result revealed some correlation exists between MDD and OMC. The number of rolling versus machine driven power. The degree of compaction was 100% with 8 number of roller passing.

Key words: Intelligent compaction, rollers, Density, Moisture content

I. INTRODUCTION

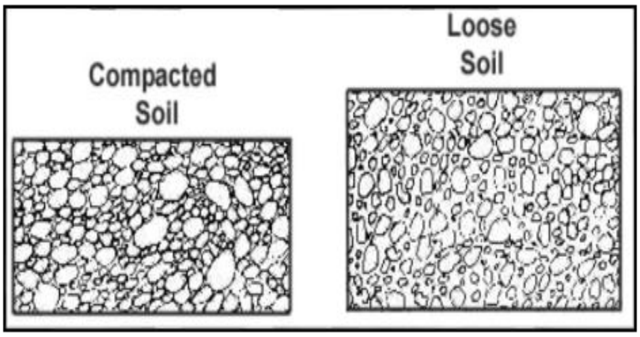

Fig. 1: Compaction Process

Compaction is the process of increasing the density of soil by mechanical means by packing soil particles closer together with reduction of air voids and to obtain a homogeneous soil mass having improved soil properties. Compaction process is shown in figure. Intelligent compaction (IC) refers to an inventive pavement construction technology in which conventional rollers are outfitted with instrumentation that is used to monitor and manage the material compaction process. The reduction of voids in soil mass, commonly known as a compaction, results in an all-round improvement of soil properties and its performance as a pavement supporting bed. Different types of compacting equipments are available at the present for compacting various types of soils to be used in earthwork. Using the construction machineries, resembling Scrapers, JCB's, Backhoe, Dozers, Graders, and Dumpers. Road construction work can be completed in comparatively less time and expenditure using these compacting equipments.

Suggested equipments	Type of soil
Smooth wheel roller	Crushed rock, gravelly sand, Gravels
Pneumatic tyred rollers	Sands, gravel, silty soil, clayey soils
Sheep foot rollers	Silty soil, Clayey soil
Rammer	Soils in confined zone Sands
Vibratory rollers	Cohesion less soil

Table 1: Types of Rollers For Different Types Of Soil.

A. Objectives of The Dissertation

- Accelerate the intelligent compaction specifications for embankment subgrade soils. The focus will be on providing a reliable method to capture the maximum potential value added from current intelligent compaction technology based on currently used field testing equipments.
- Compare the actual field conditions under intelligent compaction technology to laboratory conditions.
- Develop relationships between in-situ and intelligent compaction technology measurement values, including dry unit weight and moisture content.
- Evaluate the correlation between speed of rollers and density to determine the minimum speed of rollers on subgrade layer to achieve the maximum density.
- Identify the influence compaction energy and method on laboratory moisture-density relationships.
- Document machine vibration amplitude influence on dry density.

II. METHODOLOGY

Fig. 2: Road Stretch for the Project Work

A. Soil Investigations for Subgrade Low Embankments

- Gradation test based on wet sieve analysis test (IS: 2720(PART 4)-1985)
- Liquid limit and plastic limit (IS: 2720(PART4)-1985)
- Standard proctor density and optimum moisture content (IS: 2720(PART 7)-1980)
- Deleterious constituents (only in salt infected areas, where presence of salt is suspected) (IS: 2720(PART 27)-1977)

B. Particle Size Distribution Curve

The results of the mechanical Analysis are plotted to get a particle-size distribution curve with percentage finer N as the ordinate and the particle diameter as the abscissa, the diameter being plotted on a logarithmic scale. For coarse grained soil, certain particle sizes such as D10, D30 and D60 are important .The D10 represents a size, in mm such that 10% of the particles are finer than this size. Similarly, the soil particles finer than D60 size are 60 percent of the total mass of the sample (fig. 3)

III. DATA ANALYSIS AND RESULTS

A. Moisture Density Relationship

Soil is compacted into a mould in 5 layers, each layer receiving 25 blows of a hammer of standard weight. The compactive energy supplied in this test is 2072kj/m³.

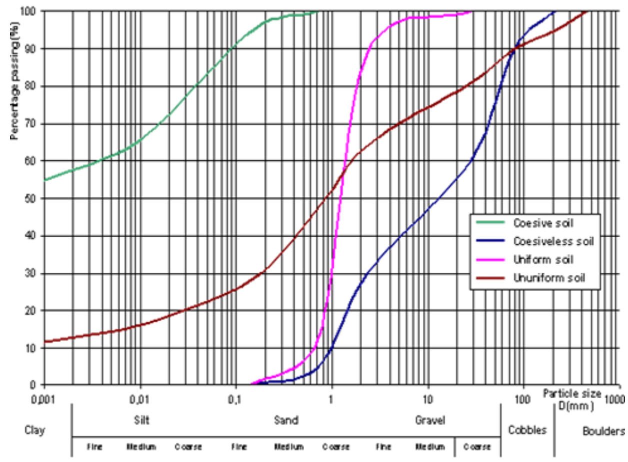

Fig. 3: Particle size distribution curve

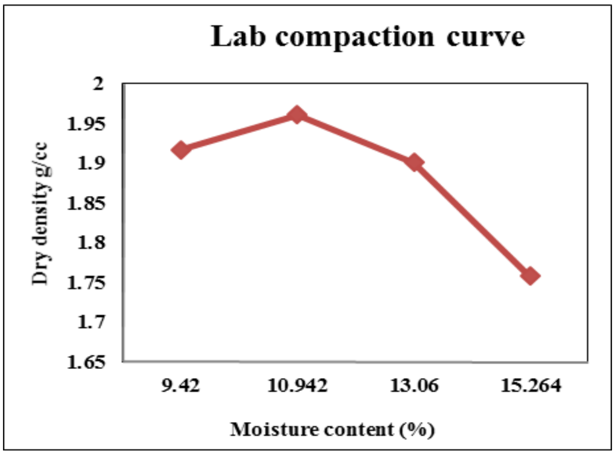

Fig. 4: Graph 1 Standard Proctor Test Results MDD 1.961g/Cc OMC 10.94%.

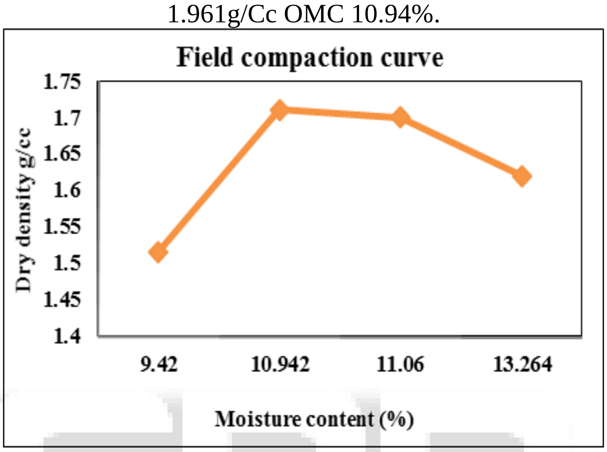

Fig. 5: Graph 2 Standard proctor test results MDD 1.71g/cc OMC 10.94%.

B. Dry Unit Weight And Comp active Energy Relationship

As the compaction energy increases, the maximum dry unit weight also increases. At low percentage of clay content (3-8%), the increase in dry unit weight with increasing energy keeps a steeper trend.

Modified proctor test:-

Weight of hammer=4.9Kg=0.048KN

Height of drop=45cm=0.45m

Number of layers=5

Diameter of mould=15cm

Volume of mould=3092.5cm³

$$\text{compactive energy} = \frac{\text{number of blows} * \text{number of layer} * \text{sheight of drop} * \text{weight of hammer}}{\text{volume of mould} * 10^{6}}$$

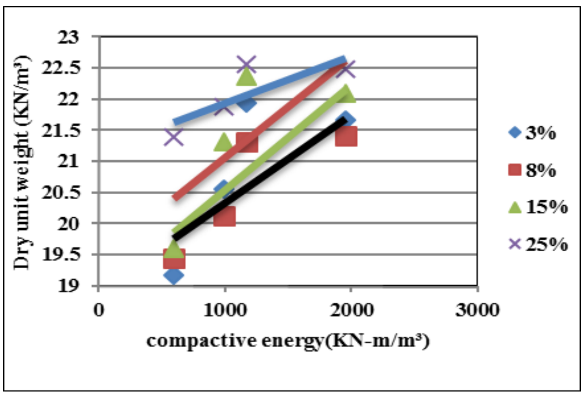

Fig. 6: Graph 3 Dry density v/s Comp active energy as a function of clay content.

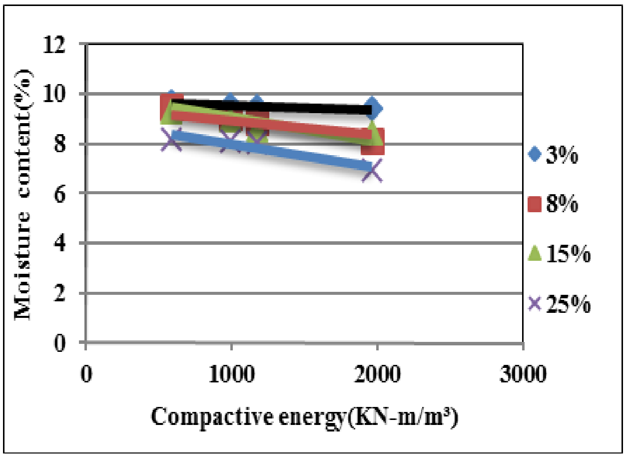

Fig. 7: Graph 4 Moisture content v/s Compactive energy as a function of clay content

C. Relationship between Speed Of Rollers And Dry Unit Weight:

As the speed of roller increases the degree of compaction will decrease and need more number of passes to achieve required compaction. If the speed is more than more length of embankment can be compacted in less time. But if speed is less then soil can be compacted to achieve better compaction. The gross weight of roller ranges between 8-10 tones. The thickness of soil is decided depending on requirement. For 20 cm thick layer 8 numbers of passes are sufficient. The speed of roller should maintain between 3-6 kmph.

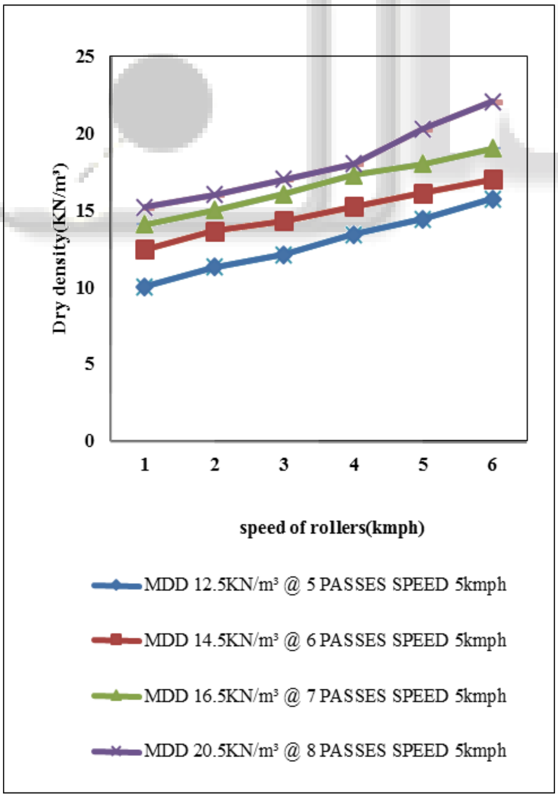

Fig. 8: Graph 5 Relationship between speed of rollers and dry unit weight.

IV. DISCUSSIONS

Soil is very complex material and to know its properties it is necessary to conduct field tests and lab tests. Compaction is the process of decreasing voids ratio by increasing its density and stiffness of soil. An attempt has been made to interpret the results.

1) Moisture content is function of dry density. The increase in dry density increases the moisture content. But once the moisture content reaches the optimum value then there will be no increment in dry density.
2) Modified proctor test gives better density results when compared to the standard proctor test.
3) The dry density is function of number of rollings passing on subgrade. As the number of passings on subgrade increases the dry density keeps increasing. Once the optimum value is reached at 8 number of roller passings there will be less increment in density.
4) The increase in compaction energy increases the dry unit weight. At low percentage of clay content (3-8%), the increase in dry unit weight with increasing energy keeps a steeper trend.
5) In case of vibratory rollers lesser the speed of rollers more vibrations at given point and less number of passes required to achieve the given density.

V. CONLCUSIONS

1) Comparing the standard proctor test and modified proctor test, the modified proctor test shows better MDD and OMC results. The MDD and OMC obtained are 1.96 g/cc and 10.94%
2) The increase in compactive energy increases the maximum dry unit weight. At 1960 KN-m/m³ compactive energy the MDD obtained is 21.39 KN/m³
3) The speed of roller is function of density. The dry density decreases if the speed of roller is more. At 3-6 Kmph speed of rollers better dry density can be achieved.
4) The number of roller passes is function of density. If the number of roller passings on soil increases the density also increases. After reaching the optimum value, there will be less increase in dry density. At 8 number of roller passings the MDD achieved is 20.5 KN/m³.
5) Machine driven power is influenced by the vibration settings used during compaction. At low amplitude mode a=1.29mm, frequency f=30Hz more vibrations at given point is applied. The machine driven power increases MDD value. The MDD value at 10 pass rolling is 22.3 KN/m³.
6) Low percentage of clay content in soil mass increases the density and decreases the optimum water content. At 3-8% of clay content the dry density increases and optimum water decreases. At 35-45% of clay content dry density decreases and optimum water content increases.

VI. SCOPE FOR FUTURE STUDY

1) More research is needed on the steadiness and precision of the intelligent compaction measures, confirmation of improvement in the compaction process, and quantification of IC's economic benefits.
2) There is lot of need to investigate the effect of lift thickness on IC output and to correlate the IC output from different manufacturer's reporting systems to standard measures of recognition.

3) The application of IC technology leads to the decrease of over and under compaction.
4) There is scope for evaluation of in-situ test results and IC data and correlate them for different pavement conditions.
5) There is scope to investigate how the intelligent compaction technology can be used to improve conventional earth work operations.
6) To investigate IC systems and to develop basic specifications for the application of IC in quality assurance of soil.
7) Installation of sensor to the vehicles or machine or roller for temperature, moisture content and other variables can be determined.
8) IC technology can be implemented using IC rollers that are equipped with an in-situ measurement system and feedback control.

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