Lecture 5

NPTEL Course

GROUND IMPROVEMENT

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Approach to specifications and quality control in compaction

Specifications and control tests are intended to ensure adequate performance of foundation or embankment of compacted soil according to the chosen design criteria. In order to comply with these objectives, control tests have to be

- *Relevant.* Density and water content have to be related to stability, volume change etc.
- *Cost-effective.* Testing expenses must be reasonable in relation to construction costs and consequences of failure.
- *Representative.* Sample size should be related to the known or estimated variation of the soil properties being evaluated.

Suitability of soils as fills

- When high strength and low compressibility are required, but seepage and erodability are not significant, coarse granular fills are most suitable.
- As impermeable liners for canals or as core material for dams, clayey gravels and poorly graded gravel-sand-clay mixtures are ranked the highest.
- Silty soils and dispersive clays, even if compacted well, are vulnerable to erosion by surface runoff or internal seepage.
- Soils containing organic matter are unsuitable for engineering fills, because of their high compressibility under loads and large volume changes due to environmental influences.

Compaction control tests

•Compaction control tests are essential to check whether the objectives of compaction are achieved.

•It is difficult to check the objectives directly and properties strength and compressibility are assessed indirectly.

•Control tests in terms of water content, density, penetration resistance are conducted.

Compaction Control Procedures

- Laboratory tests are conducted on samples of the proposed borrow materials to define the properties required for design.
- After the earth structure is designed, the compaction specifications written.
- Field compaction *control tests* are specified, and the results of these become the standard for controlling the project.
- These specifications are expected to ensure an expected level of performance (in terms of shear strength, compressibility, permeability which are related to bearing capacity, settlements and drainage and seepage etc)

Types of Specifications

(1) End-product specifications

- This specification is used for most highways and building foundation, as long as the contractor is able to obtain the specified *relative compaction*, how he obtains it doesn't matter, nor does the equipment he uses.
- (2) Method specifications
- The type and weight of roller, the number of passes of that roller, as well as the lift thickness are specified. A maximum allowable size of material may also be specified.
- *It is typically used for large compaction project.*

Relative Compaction (R.C.)

Relative compaction or percent compaction

$$R.C. = \frac{\rho_{d-field}}{\rho_{d\,\max - laboratory}} \times 100\%$$

Correlation between relative compaction (R.C.) and the relative density Dr

$$\mathrm{R.C.} = 80 + 0.2\mathrm{D_r}$$

It is a statistical result based on 47 soil samples.

As $D_r = 0$, R.C. is 80

$D_r = (e_{max} - e)/(e_{max} - e_{min})$

Typical required R.C. = 90% ~ 95%

Determine the Relative Compaction in the Field

- **Where and When**
  - First, the test site is selected, it should be representative or typical of the compacted lift and borrow material.
  - Typical specifications call for a new field test for every 1000 to 2000m^2 or so, or when the borrow material changes significantly.
  - It is also advisable to make the field test at least one or two compacted lifts below the already compacted ground surface, especially when sheepsfoot rollers are used or in granular soils.

Experience and engineering judgment suggest the approximate minimum numbers of field density and moisture content tests are as follows

Earth structures	Volume of fill per test, cum
Embankments	500-2000
Impermeable liners	200-1000
Subgrade	500-1500
Base course	500-1000
Backfill	100-200

A few methods are as follows

Destructive methods

•Core cutting method IS 2720 (Part 29)

•Sand replacement method IS 2720 (Part 28)

•Volumenometer method

•Rubber-balloon method

•Proctor-needle method

Non- destructive methods

•Nuclear gauge method

•Impact Tester

Destructive Methods

Methods

(a) Sand cone

(b) Balloon

(c) Oil (or water) method

Calculations

•Know M_s and V_t

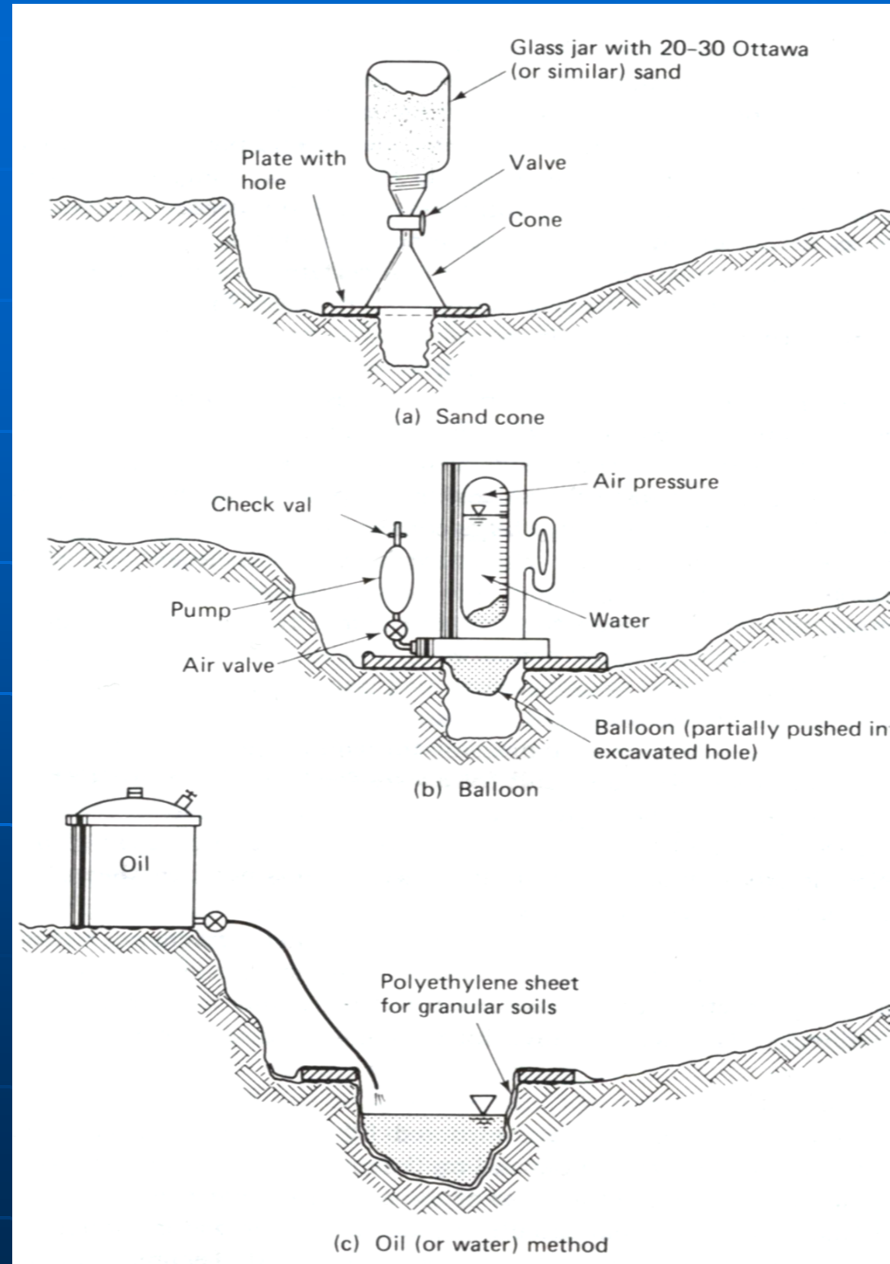
•Get $\rho_{d\ field}$ and w (water content)

•Compare $\rho_{d\ field}$ with $\rho_{d\ max\text{-}lab}$ and calculate relative compaction R.C.

(a)

(b)

(c)



Core cutting method

•A steel tubular cutter of 107mm dia X 125mm is driven into compacted layer using rammer. The sample is retrieved and bulk density is measured as well as water content is determined.

Sand replacement method

A hole of 15cm dia is made in the layer in which the test needs to be conducted. The soil is removed carefully and collected to determine the weight as well as water content. To determine the volume of the hole, a known amount of calibrated sand is used. Based on the relationship between index properties such as bulk density, dry density and volume, the bulk density of in-situ soil can be calculated.

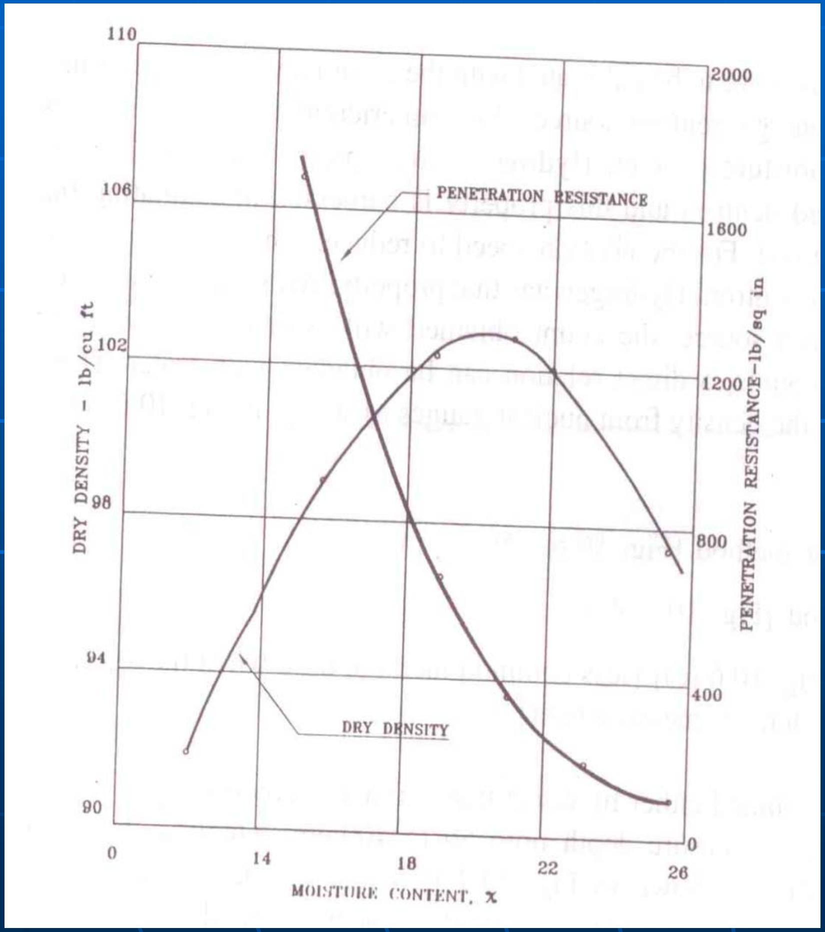
Volumenometer method

Useful for clayey soils. A soil of about 295cc is taken out from the compacted layer of embankment. It is quoted with wax and reweighed. The actual volume of the sample is known by immersing it in volumenometer. A sample cut from the specimen can be used for water content determination.

Rubber balloon method (IS 2720)

In this method, a rubber balloon is used to measure volume of the hole made in the compacted layer. The volume of the hole is found out from the difference between the initial and final water levels in the gas cylinder.

Density control using Proctor needle resistance

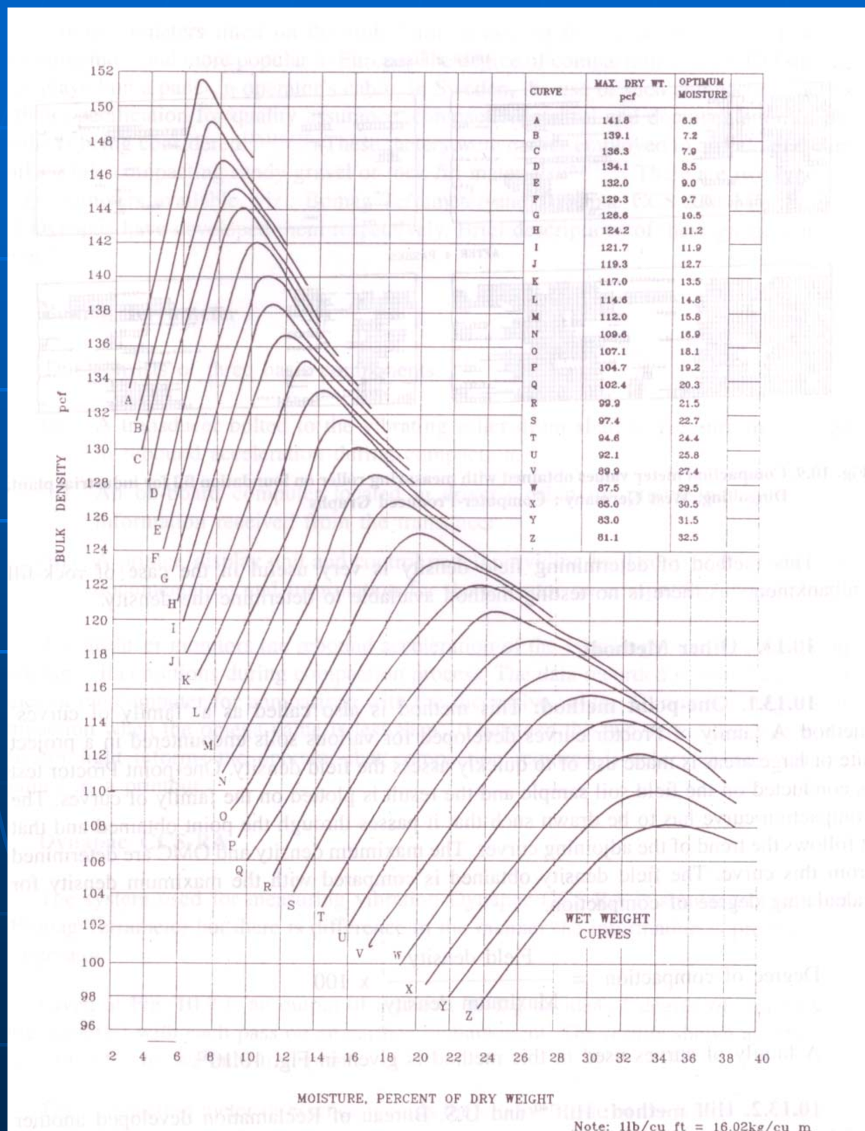


- Useful for clayey soils
- A proctor needle consisting of spring loaded plunger and dial gauge to measure penetration resistance is used.
- A calibration curve giving relationship between penetration resistance and moisture content is prepared and used for quality control.

One point method

- Sometimes, the laboratory maximum density may not be known exactly. It is not uncommon, especially in highway construction, for a series of laboratory compaction tests to be conducted on “representative” samples of the borrow materials for the highway. If the soils at the site are highly varied, there will be no laboratory results to be compared with. It is time consuming and expensive to conduct a new compaction curve. The alternative is to implement a ***field check point***, or 1 point Proctor test.

One point method



Family of Curves method

Difficulties with Destructive Methods

- The measuring error is mainly from the determination of the volume of the excavated material.
- For example,
- For the sand cone method, the vibration from nearby working equipment will increase the density of the sand in the hole, which will gives a larger hole volume and a lower field density.
- If the compacted fill is gravel or contains large gravel particles. Any kind of unevenness in the walls of the hole causes a significant error in the balloon method.
- If the soil is coarse sand or gravel, none of the liquid methods works well, unless the hole is very large and a polyethylene sheet is used to contain the water or oil.

Non-Destructive methods

- **Principles**
- Density
- The Gamma radiation is scattered by the soil particles and the amount of scatter is proportional to the total density of the material. The Gamma radiation is typically provided by the radium or a radioactive isotope of cesium.
- Water content
- The water content can be determined based on the neutron scatter by hydrogen atoms. Typical neutron sources are americium-beryllium isotopes.

Nondestructive Methods

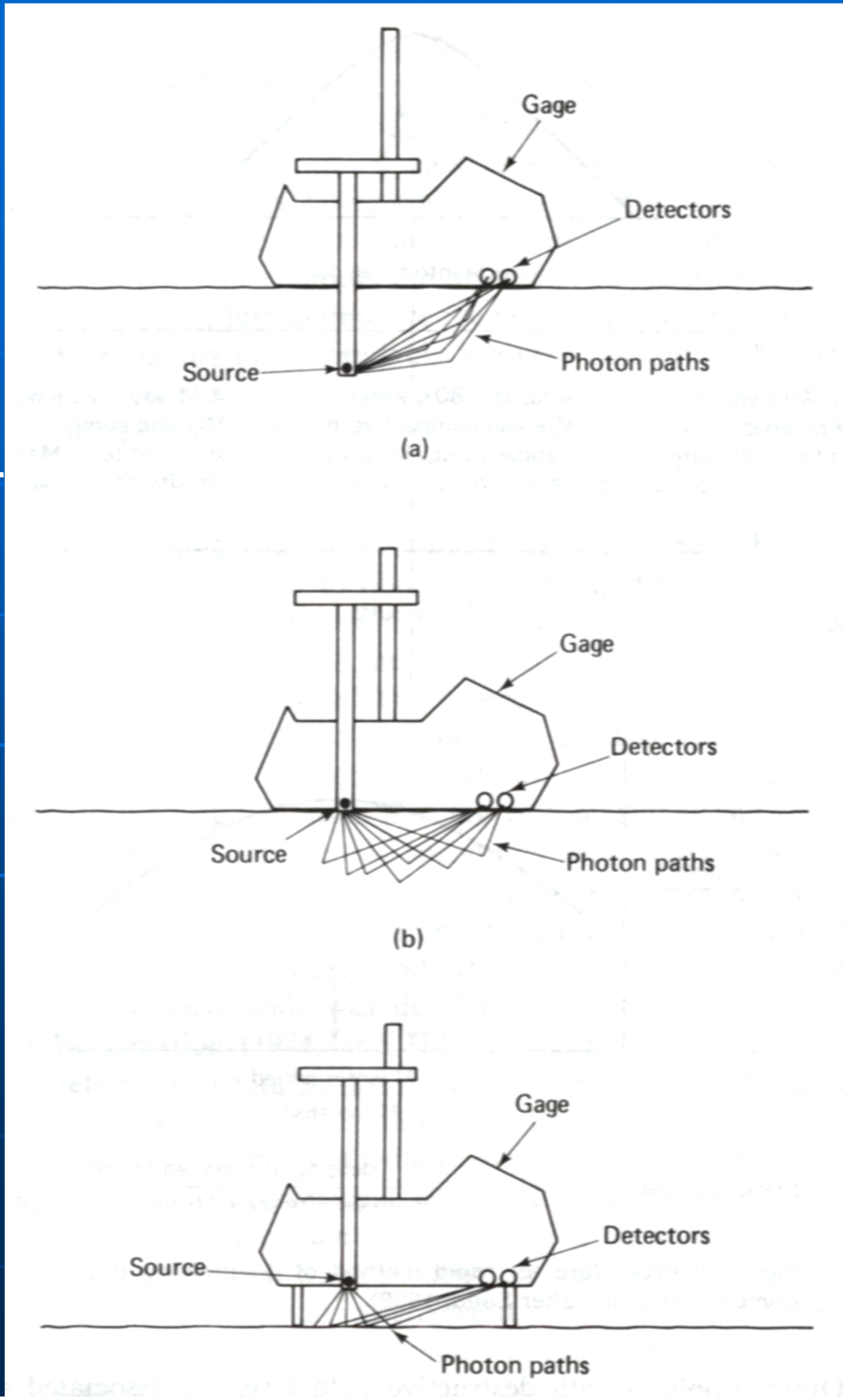
Radio isotopes are used to find moisture content an density of soil. It is useful for large number of tests and the result can be obtained in a few minutes time compared to 16 to 24 hours..

Nuclear density meter

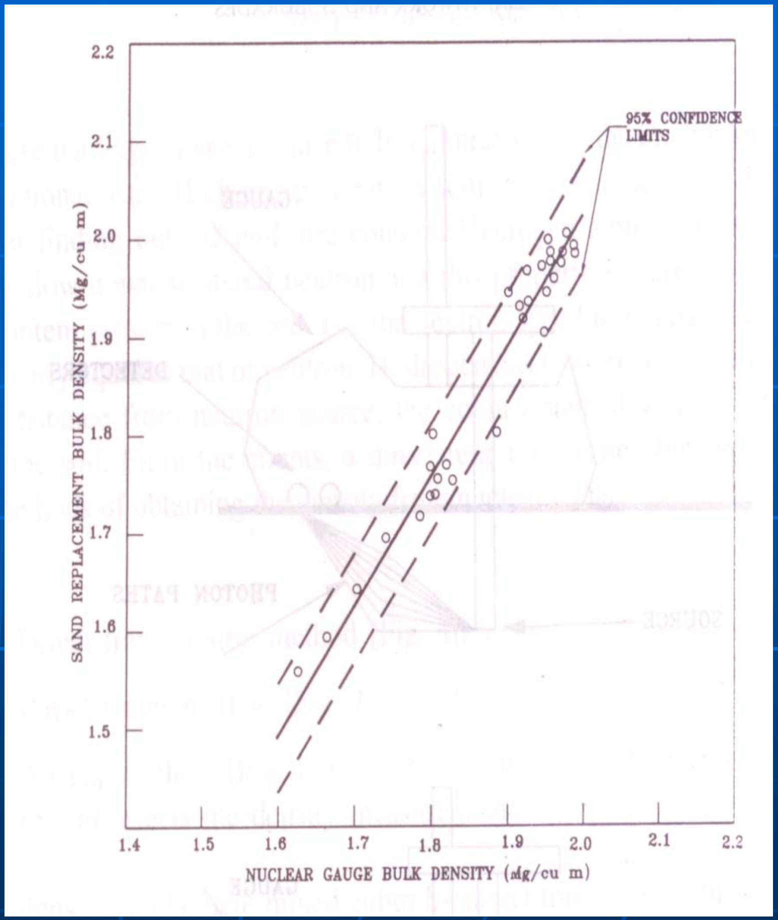
(a) Direct transmission

(b) Backscatter

(c) Air gap



Radium or radio active isotope of Caesium is used to emit gamma radiation. This radiation gets scattered when it passes through soils and is proportional to the density of soils. A counter measures the scatter of gamma rays and with constant source, it depends on the absorption capacity of the soil. A calibration plot helps in concerting the count to density of soils



Nondestructive Methods

- **Calibration**
- Calibration against compacted materials of known density is necessary, and for instruments operating on the surface the presence of an uncontrolled air gap can significantly affect the measurements.

Specifications in terms of density and water content

Specifications of compaction requirements in terms of density and optimum moisture content (as obtained in lab test) are the most common way of ensuring that earthworks perform adequately.

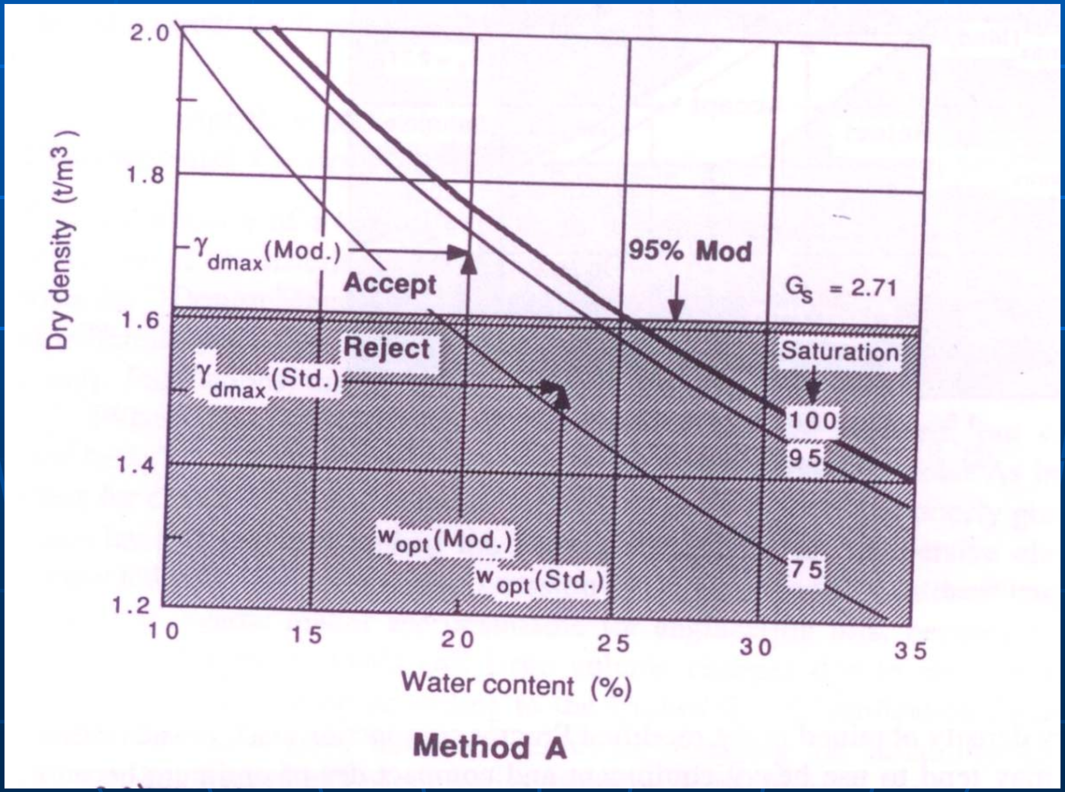
There are three ways of defining acceptance criteria for compaction . They are:

- Method A
- Method B
- Method C

Method A:

It simply states that the soil has to be compacted above a certain minimum dry density

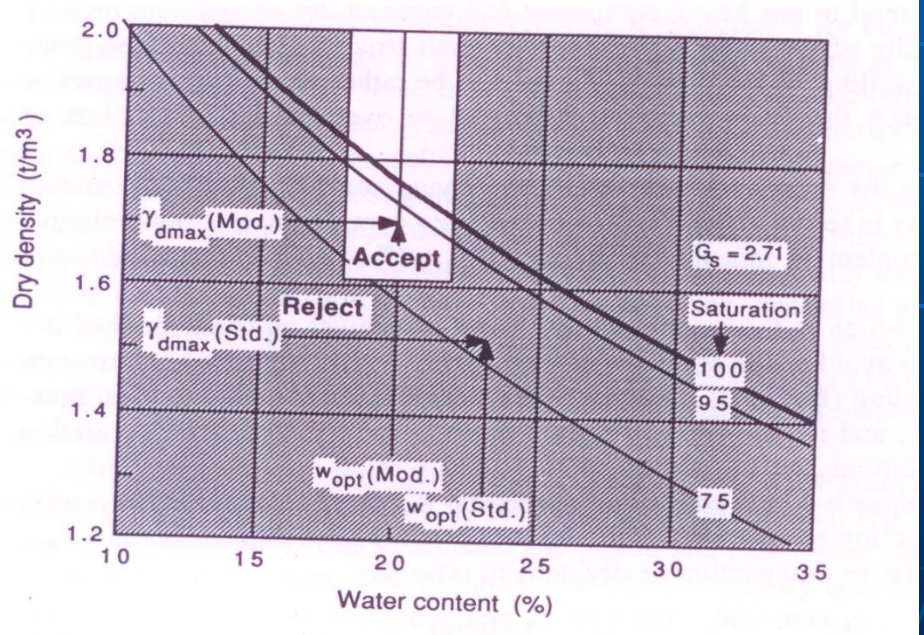
Eg: 95% modified maximum dry density means 95% of the maximum dry density obtained from modified Proctor compaction test



Method B:

It is the most common way of specifying compaction. Besides stating a minimum density in terms of modified proctor compaction test, a permissible range of water content is indicated.

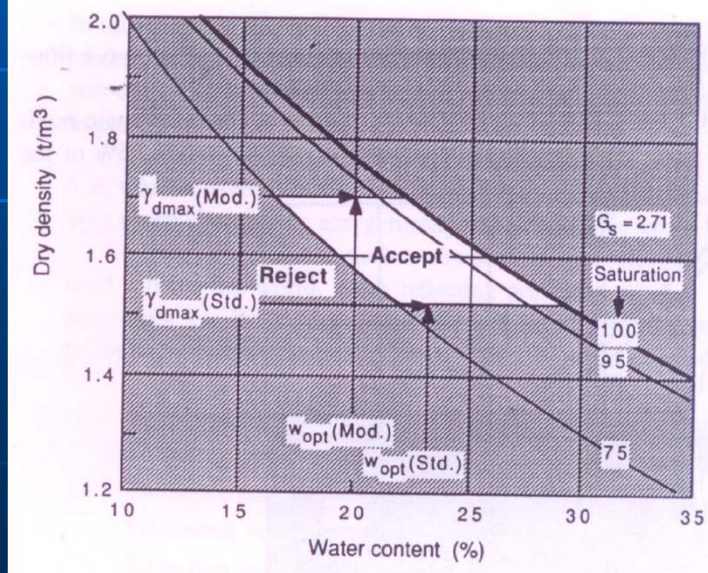
Eg: -2 to +2% of the optimum moisture content.



Method B

Method C:

It is the most comprehensive method. It also gives an upper limit of the dry density in order to avoid loss of soaked strength. Density limits refer to standard and modified maximum dry density, and the allowable moisture range is defined in terms of saturation at placement conditions.



Method C

Compaction trials

For projects where large quantities(> 20,000cum) of relatively homogeneous burrow materials have to be handled, compaction trials may be used to determine the most effective compaction methods. In particular these trials indicate the following:

- The most efficient compaction equipment
- The type and depth effect of the densification
- The minimum number of passes needed to obtain the required density

Plate load test

Photo 1. Checking of Soil

Photo 2. Humboldt GeoGauge

Useful for pavements and it gives stiffness and the modulus of subgrade reaction.

Statistics and probability are useful to

- Determine the mean, standard deviation, and coefficient of variation of set of results (normal distribution).
- Determining confidence limits of the mean of the sample (t distribution).
- Giving confidence estimates of the variance (X^2 distribution)
- Determining sample size for specified confidence limits of the mean, for a given coefficient of variation.
- Evaluating the significance of differences in variances between two samples(F distribution).
- Providing methods of improving successive appraisals of a state of nature based on new data available(Bayes' rule).
- Establishing the probability distribution of a function of several randomly varying parameters(probabilistic design).

Summary

- Mechanical compaction of soils is an efficient way of ensuring good engineering behavior. For shallow compaction control still, advanced methods using sensor technology are being developed in the field.

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