Compaction Control Field Testing:

• During the construction of the project, a control must be in place to measure whether or not the compaction requirements have been met.

• That control is density testing.

• If the results of the density test determine that the compaction process has produced a density within the range specified, then the compaction is complete.

Relative compaction
or
Degree of compaction

The relative compaction: is the percentage ratio of the in situ maximum dry density of the compacted fill material to the maximum dry density obtained with the relevant laboratory compaction test.

\[
\text{Relative compaction} = \frac{\text{Achieved dry density}}{\text{Laboratory max dry density}}
\]
In-place (In-situ) density of a soil

Several different methods are used to determine the in-situ density of a soil:

- **Rubber balloon method**
- **Sand-replacement (sand cone) method,**
- **Core cutter method**
- **Nuclear moisture-density meter method.**
Balloon Density Apparatus

- The balloon density apparatus determines the in-place density of soil using a volume displacement method, similar to the sand cone density method.

- The apparatus consists of a graduated cylinder, an aluminum guard, reversible aspirator type pump, density plate and 10 rubber balloons.
Sand Replacement Method

- This along with the Core Cutter is one of the older, more labour intensive methods of determining compaction.

- This method, often called the sand-cone method, may be used for both fine-grained and coarse-grained materials.

- In general, the test consists of digging out a sample of the material to be tested, using calibrated sand to determine the volume of the hole from which the sample was removed and to determine the dry unit weight of the sample.

SAND REPLACEMENT METHOD

- A cylindrical hole is dug out from the surface by a technician, using a chisel, lump hammer and small scoop.

- This is not a sophisticated test, but accurate all the same, if performed with care.

- All material excavated is very carefully saved in a moisture retaining container, and weighed in the laboratory.

- Sand of a known density is poured into the hole, from the weight of the sand taken to fill the hole its volume can be determined.

- Bulk density of the layer tested can be quickly calculated, and after determining the moisture content, the dry density and air voids.
Sand Cone

- Weigh with sand before
- Weigh with sand after
- Subtract sand to fill cone and plate
- Weigh of sand to fill hole

SAND MUST BE DRY
CORE CUTTER METHOD

Core cutters are used for testing the compaction of cohesive/clay soils placed as fill.

The cylindrical cores of standard volume, 13cms long and 10cms diameter, they have a sharpened edge at one end to improve penetration of the soil surface.

These cores are driven fully into the surface to be tested, they are removed from the ground without disturbing the core contents. In the laboratory they are cut flush top and bottom and weighed.

Bulk density can be quickly calculated, and by determining the moisture content of the soil the dry density of the fill can be calculated and hence the voids percentage.

A high percentage of voids indicating poor compaction.
Core-cutter method.

• Core-cutter method. Details of the core-cutter apparatus, which is suitable for cohesive soils, are given in figure.

• After the cutter has been first presses into the soil and then dug out, the soil is trimmed to the size of the cutter and both cutter and soil are weighed; knowing the weight and dimensions of the cutter, the bulk density of the soil can be obtained.
Nuclear Density (ASTM D2292-91)

Nuclear Density meters are a quick and fairly accurate way of determining density and moisture content.

The meter uses a radioactive isotope source (Cesium 137) at the soil surface (backscatter) or from a probe placed into the soil (direct transmission).

The isotope source gives off photons (usually Gamma rays) which radiate back to the meter's detectors on the bottom of the unit.

Dense soil absorbs more radiation than loose soil and the readings reflect overall density.

Water content (ASTM D3017) can also be read, all within a few minutes. A relative Proctor density with the compaction results from the test.
Nuclear Moisture-Density Meter Method

• Another method for determining the moisture content and density of in-place soil uses a nuclear moisture-density meter.

• The meter contains sealed radioactive materials, typically cesium and a combination of americium mixed with beryllium powder.

• The cesium emits gamma radiation that the detector in the meter can count when it is passed through the soil. This count can be translated to density. The americium, interacting with the beryllium, emits neutrons following collision with hydrogen that are moderated and detected by the meter. The moisture content can be determined by measuring the hydrogen concentration in the soil.

• When you are using the moisture-density meter, counts or readings are obtained and used with a calibration chart to determine the wet density and moisture content. The dry density is computed from the wet density.

Soil Compaction can be achieved either by static or dynamic loading:

• 1- Smooth-wheel rollers: Used primarily for Granular Soils.

• 2- Sheepfoot rollers: used mainly for Clayey and Silty Soils.

• 3- Pneumatic Rubber-tired rollers for clay soil.

• 4- Vibratory Rollers for granular soils.

• 5- Vibroflotation (deep compaction)
### Advantages
- Large sample
- Direct reading
- Accurate
- Open graded material
- Fast
- Deep sample
- Under pipe haunches
- Fast
- Easy to redo
- More tests (statistical reliability)

### Disadvantages
- Many steps
- Large area required
- Slow
- Balloon breakage
- Small sample
- No gravel
- No sample
- Radiation
- Moisture suspect
- Encourages amateurs

### Errors
- Void under plate
- Sand bulking
- Sand compacted
- Soil pumping
- Void under plate
- Overthrow
- Rocks in path
- Plastic soil
- Miscalibrated
- Rocks in path
- Surface prep required
- Moisture suspect

### Cost
- Low
- Moderate
- Low
- High