UNH T^2 Center Technical Note

Achieving and Measuring Proper Road Compaction

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Proper compaction is critical in road construction. An unstable road base can cause pavement deterioration. Improperly compacted base materials leads to distresses resulting in pavement failure. Surface treatments cannot rectify a problem caused by an inadequately compacted base. The only solution is to replace the base with properly compacted material.

Compaction increases soil density, simply the volume of air within the soil is decreased. Compaction increases the load bearing capacity of the soil and prevents roadway settlement.

Factors Affecting Compaction

- Soil Type,
- Water Content,
- Compaction Method, and
- Thickness of Compaction Layer.

Soil type

AASHTO (American Association of State Highway and Transportation Officials) has an extensive classification system for soils. Soil types are classified by grain size. This is determined by a sieve analysis as seen in figure 1. Soils are categorized into 15 groups, which can be generalized into two major groups, cohesive and granular.

Cohesive soils include clays and silts. They are dense and bound by molecular attraction. Particle size is very small. Average particle size is .00004" to .002" for clay. Silt ranges from .0002" to .003". Cohesive soils do not have good drainage properties.

Granular soils consist of sands and gravels. They contain larger particles than cohesive soils with a fewer percentage of fines. Average particle size for sand is .003" to .08" and .08" to 1.0" for fine to medium gravel. Clean granular soils typically have excellent water-draining properties.

The type of soil used controls how the other compaction factors are applied.

Water Content

To achieve maximum compaction, the moisture content must be at the correct level for the specific soil type. There is an optimum moisture point for the best compaction. Adding water to the dry soil lubricates the particles allowing more of them to be packed into a given space.

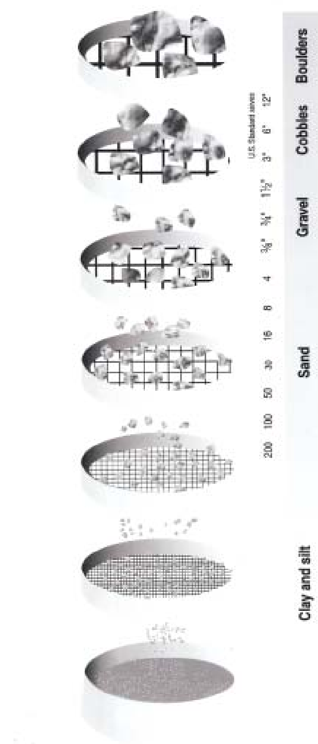

Figure 1

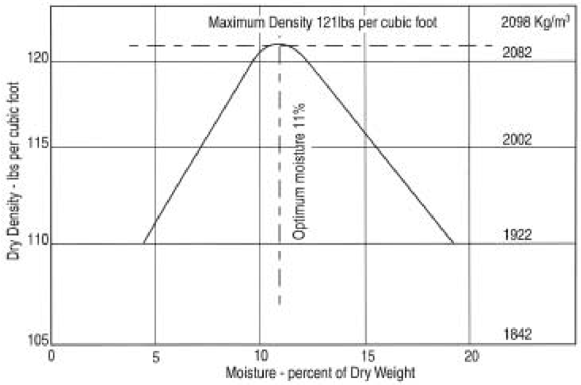

Figure 2

Figure 2 shows the relationship between relative density and percent moisture added. The graph illustrates that too little or too much moisture directly effects the density of the soil. A soil with too much moisture contains water filled voids which weakens the load-bearing capacity. Water fills spaces that would be otherwise occupied by solid particles and decreases the soil density.

Cohesive soils are especially dependant on optimum water content. Cohesive soils have a high testing curve similiar to the one shown in figure 2. Clean granular soils are much less dependant on water content. Their test curves are relatively flat so maximum density is obtained with less emphasis on water content.

Compaction Method

Compaction uses force to compress soil particles to the desired density. Different soil types respond better to certain compaction methods.

<u>Cohesive soils</u>

The particles in cohesive soils stick together with the proper moisture content. To compact, use an impact or kneading force. A rammer or sheepsfoot roller is recommended to provide the shearing force to arrange the particles into a tight format.

A rammer is a hand operated machine with a high impact force through a gas powered piston. The sheepsfoot roller is a large drum with many protruding studs. The studs provide high point loads to the soil surface. Several passes are necessary to fully compact.

<u>Granular soils</u>

Use vibration to compact granular soils. A vibratory plate is a hand operated machine that uses one or two eccentric weights. The spinning weights propel the machine forward.

A vibratory plate with two eccentric weights moves directionally forward and reverse. The effectiveness of the machine is directly related to the weight of the plate. Use the vibratory plate in tight areas, such as a trench.

A vibratory roller consists of a large weighted drum and two drive wheels. The pressure force of the drum is further assisted by vibration.

Figure 3

Thickness of Compaction Layer

Compaction equipment is only effective to a certain depth--called a lift. Therefore, compact in lifts. For example, vibratory and rammer-type equipment compact soil in two directions. The force travels through the layer under compaction to the hard surface below and returns upward. The particles are forced tightly together and compaction occurs. If the lift exceeds the effective depth of the compaction equipment, it will not fully compact. Figure 3 shows correct and incorrect lifts.

Ensuring Proper Compaction

New Hampshire Department of Transportation (NHDOT) requires at least 95% maximum density on all road surfaces. All soils have a differing maximum density value. This is determined through a standard proctor test as specified in AASHTO T-99. Once the maximum density value is known for the specific soil, the in-place density of the material is tested.

A standard proctor test uses a sample of material to test compaction. The material is placed in a mold and then a weight is dropped onto it. The amount of weight, height of the drop, and number of blows, etc. are specified in the procedure. This test was performed several times with different moisture contents to produce the Moisture-Density curve as seen in figure 2.

The modified proctor test (AASHTO T-180) is used to determine maximum density. The procedure is similar to the standard proctor but designed to correspond with current compaction equipment and methods.

The in-place density of the material can be tested by several methods:

- Nuclear density, and
- Sand-cone.

The nuclear density test (AASHTO T-238 and T-239) is a quick and fairly accurate way to test the density and moisture content of the soil.

The nuclear unit emits radiation into the soil. In figure 4, the emission from a probe is inserted into the ground (direct) or from the surface (backscatter). The source emits photons which radiate back to detectors under the unit. A dense soil absorbs more radiation than loose soil. The unit also calculates the percent water content of the soil.

Sand-Cone Test (AASHTO T-191) is an in-place density test. A soil sample is taken of the compacted material. The sample is weighed and then dried in an oven to remove all moisture. The sample is weighed again and the difference provide the moisture content. Then a device is set up over the hole as seen in figure 5.

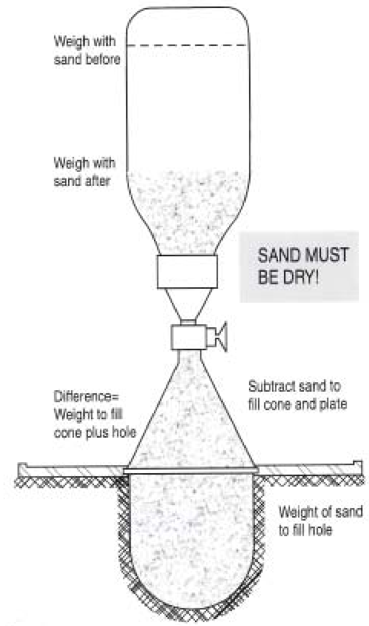

Figure 5

Using the device and the calibrated dry sand, the volume of the hole is calculated. The dry weight of the soil removed is divided by this volume to provide the density of the soil. This is an accurate method to determine density and moisture content. It becomes time consuming when several samples are taken to ensure uniform compaction.

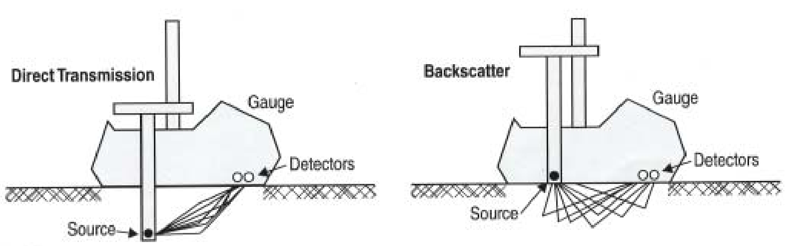

Figure 4

What to use for Roads

Use free draining granular material to prevent water from being trapped in the base. Trapped water creates a weak base and frost heaves, which deteriorates the road surface. NHDOT requires a specific

Table 1E -- Base Course Materials (English)

	Required Gradation						
Item No.	304.1	304.2	304.3	304.3	304.33	304.4	304.5
Item	Sand	Gravel	Crushed Gravel	Modified Crushed Gravel	Crushed Aggregate For Shoulders	Crushed Stone (Fine)	Crushed Stone (Coarse)
Sieve Size	Percent Passing By Weight						
6 in	100	100	---	---	---	---	---
5 in	---	---	---	---	---	---	---
4 in	---	---	---	---	---	---	---
3-1/2 in	---	---	---	---	---	---	100
3 in	---	---	100	100	---	---	85 – 100
2 in	---	---	95 – 100	95 – 100	---	100	---
1-1/2 in	---	---	---	---	100	85 – 100	60 – 90
1 in	---	---	55 – 85	---	90 – 100	---	---
3/4 in	---	---	---	---	---	45 – 75	40 – 70
No. 4	70–100	25–70	27 – 52	27 – 55	30 – 65	10 – 45	15 – 40
No. 200 (In Sand Portion)*	0–12	0–12	0 – 12	0 – 12	---	---	---
No. 200 (In Total Sample)	---	---	---	---	0 – 10	0 – 5	0 – 5

* Fraction passing the No. 4 sieve.

Table 1

gradation of the gravels used for the road construction. The NHDOT's Standard Specifications for Road and Bridge Construction (table 1) shows sieve analysis requirements for each type of material. For a typical road with an average daily traffic (ADT) of 750-1500 the specifications for the base are 12 inches gravel and 6 inches of crushed gravel (304.2 and 304.3, respectfully). Perform a sieve analysis of materials to insure that they meet all percentage passing requirements before using.

Section 304 of Standard Specifications for Road and Bridge Construction requires the compaction depth of gravel or crushed gravel layer not to exceed eight inches. Correct water content, calculated by the proctor test, and vibratory compaction are required to achieve the 95% maximum density.

A road designed and built with proper gravels and correct compaction will insure that it performs to its fullest potential and will reduce maintenance costs. ❖

Sources:
Soil Compaction: A Basic Handbook. Multiquip, www.multiquip.com
NHDOT: Standard Specifications for Road and Bridge Construction