Soils For Road Work

Anyone who builds or maintains roads works with soils. Soil is the foundation material for all roads and is the riding surface for about two-thirds of the local roads in Vermont.

Steel, concrete and wood are easy construction materials to work with because they are of a "homogeneous", uniform composition. Their behavior can be generally predicted. Soil is just the opposite. In its natural state soil is rarely uniform and can only be observed and worked by comparing it to a similar soil.

Rock was formed in three different ways. Igneous rocks, like granite are of volcanic origin and are solidified from molten masses. Sedimentary rocks, such as limestone, are formed in layers as the result of minerals and other elements settling out of water solutions. Metamorphic rocks, such as marble, are transformed from materials of the first two by heat and pressure. Time, chemistry and weather have attacked these different kinds of rocks and have worked much of their surface into minute particles creating the soil. These particles have been well mixed by glaciers, wind, water, gravity, and man. Decaying plant and animal life have further complicated the soil composition by contributing "organic" material to the mixture.

TYPES OF SOIL

Gravel is any rock-like material down to ¾ inch in diameter. For simplification purposes, shot-rock boulders are included in this group also. Shot rock is a jagged material that has many angular faces (much like crushed limestone) and is usually fairly large in diameter. As the name implies, it is either "shot" out of a pit or the rock formation may be in the existing roadway. Boulders are rounded rocks larger than 10 inches in diameter. The rounding is usually caused by past or present water running over the rocks. The rocks from 10 inches in diameter down to the ¾ inch size are referred to as stones. Generally, there is not enough smaller material present to fill the chinks or "void" spaces. This material is easily recognizable at a glance.
Sands are mineral grains from 1/6 inch in diameter down to 0.074mm in diameter. This is about the smallest size that can normally be seen with the naked eye. Both rounded and angular materials are included in this group. Sand ranges from coarse to fine grains, but it feels gritty and its strength is not affected by wetting. A close visual examination will reveal whether it is all one size like beach sand or whether it is a mixture of large, medium, and small-sized sand particles. In general, it is called granular material because the grains have little to no attraction for each other. This leaves the soil with no dry strength. Granular material can be vibrated into a dense form because the particles jiggle themselves about until they find the most compacted grain arrangement, thereby minimizing voids. Granular material does have internal friction due to this stacking of the compacted particles. In the case of clean sands, very little, if any, dust or crusty coatings should be visible on the individual particles. If the soil is wet, pick up a handful, knead it a few times and then shake it off the hand. No muddy residue should remain. If water is poured onto a clean sand it will sink in immediately without making any mud.

Silt is actually a very fine sand that exhibits a floury appearance when dry. If pure, silt will settle out of muddy water and leave it clear. Although silt particle size is .074mm down to 0.005mm it is still granular material. Silt compacts very poorly, has next to no dry strength because of lack of "cohesion" between the grains, and is easily broken down and pulverized when in dry lumps. All granular material permits easy passage, or flow, of groundwater and therefore is very "permeable."

Clay is the finest size soil particle. It consists of tiny microscopic, flat, scale-like particles which give clay its "plastic" properties. In a moist condition, clay becomes very sticky and a small lump may be rolled between the hands to form a small thread. Clay particles have a great deal of attraction for each other and thus clay is a cohesive material. Clay has a high dry strength, low erosion, good workability, and it compacts very readily at the proper moisture content. However, when not properly compacted clay has very little internal friction and is therefore subject to slides. Clay also is subject to wide "plastic" limits. It is low in permeability, when compacted, since water has difficulty flowing through the tight pattern created by the individual particles, held in place by the surface tension bond from the natural moisture.

Organic Matter is partially decomposed plant or other previously living matter. It can exist as peat, organic silt, or organic clay. Organic material is
generally soft, emits an odor when heated, appears fibrous, and is usually black or very dark brown. Organic material should not be considered for fill material since it will further decompose, resulting in voids.

Soil can therefore be divided into two groups, cohesive material and non-cohesive. The cohesive soils will have the characteristic of sticking together. Examples would be clay, coarse clay sediment, loamy sand, and sandy clay. The non-cohesive soils take on the characteristic of graded sand, gravel, sand mixtures, sandstone, and crusher run material. Generally, the soil types are found in nature in some mixed proportion. Care should be taken in placing fill embankments to make the most advantageous use of soil properties.

**SOIL PROPERTIES**

*Shear Resistance* is the ability of soils to resist internal movement or slippage when subjected to an imposed load or to pressure from "static" or impact compaction. This resistance comes about or is the result of friction between the soil particles. There is also an amount of resistance in cohesion when the soil particles resist being pulled away from each other. This type of resistance is very obvious in clay soils when the "elasticity" is very high. By comparison, the cohesion in sand and gravel particles is very low.

The measure of the shear resistance of a soil is its amount of resistance to individual particles sliding over each other. The rate at which the material is subject to movement is dependent upon the amount of applied force, the internal friction between the individual soil particles, and the cohesion of the material. Therefore, it should be fairly easy to recognize material of a high shear resistance versus one with a low shear resistance. A loosely graded non-plastic granular material, which is easily compacted, would be classified as having a low shear resistance. On the other hand, a clay material which is very elastic and difficult to compact would be classified as having high shear resistance. The point is, the more force that is required to shear the soil material from adjoining particles, the higher the shear resistance will be.

*Elasticity*, as the term implies, is a soil's ability to return approximately to its original form after the applied load is removed. An example would be to press down on a piece of sponge, and after removing the pressure, the sponge will spring back to its original shape. Soils of this type are very
undesirable in construction and road building. For example, as automobiles and trucks roll over a road surface the base material gives way to the applied load and rebounds after removal of the load, continually flexing, which eventually causes a breakdown of the road surface.

**Compressibility.** As a volume of material is subjected to a downward force (load), the voids within the material are decreased, being compressed together, and take up less volume than the original volume. As a result, the soil particles are forced together after the load has been removed. An example would be tamping the soil in a hole around a fence post. When the soil is first placed in the hole, it will occupy a given area, after being tamped down with a tamping pole it will eventually occupy less space than it did at the beginning. In some cases a measurement of soil density is possible by calculating the amount of the soil's compression to a given load.

**Capillary Action** refers to a soil's ability to absorb and disperse water. The particle surface forces, acting upon the spaces between the water and the surfaces of the soil particles, produce the capillary action in the voids of the soil material. The water between the particles forms an elastic bond. The capillary forces acting between the soil particles can be removed by application of compression and shear forces, driving or displacing the water out of the soil material.

**Permeability** of a soil is the rate at which water is permitted to flow through the soil either from gravitational forces from percolation or water pressure from a subsurface water table. In compaction, this is a very important factor. The moisture must be permitted to flow through the soil material, to some extent, in order to reach the optimum moisture content for satisfactory compaction. Many times water may saturate an area with little or no penetration into the depth of the soil, as in the case of a heavy clay. A soil of this nature is not very permeable and will probably need to be tilled in order to be satisfactorily compacted at the correct moisture content. This is why it is recommended to add a granular material to a clay soil. The granular material allows the water to infiltrate the soil material more effectively.

**Shrinkage** is usually limited to the finer grain soils in which the water content is reduced by means of evaporation. Different soils swell and shrink at different rates. Generally, clay materials shrink a great deal while sand and gravel shrink slightly. Material which expands and contracts a great deal such as clay offers an undesirable base for supporting surfaces such as a roadbed. Soils may be fully compacted, but as water penetrates the soil material, the material swells and as the water is evaporated, the material shrinks causing flexibility and thus damage to the surface. This is extremely critical on rigid surfaces such as concrete or asphalt roads or structures which are incapable of absorbing any flexing motion without cracking.

Table 1 provides information for each classification on the usefulness of the type soil for road foundations and bases. It also gives the potential frost action, compressibility, and drainage characteristics and suggests the appropriate mechanical compaction equipment for each type of soil. The divisions and classification prefixes used in the chart are as follows:

A. Coarse-grained soils.
1. Gravels and gravelly soils, prefix G.
2. Sands and sandy soils, prefix S.
   - The gravels and sands are subdivided into the following:
     a) Well graded soils with little or no fines, suffix W.
     b) Medium graded soils, with little or no fines, suffix M.
     c) Poorly graded soils with little or no fines, suffix P.
     d) Poorly graded soils with appreciable fines, or well graded soils with excess fines, suffix F.

B. Fine-grained soils.
1. Inorganic silt soils, prefix M.
2. Inorganic clay soils, prefix C.
3. Organic silts and clays, prefix O.
   - Two subdivisions to the fine-grained soils:
     a) Soils whose liquid limits are less than 50 percent, and which have low compressibility, suffix L.
     b) Soils whose liquid limits are greater than 50 percent, suffix H.

C. Fibrous soils.
1. Peat and swamp soils, prefix Pt. There are no subdivisions of the fibrous soils.
SOIL MIXING

Mixing soils at the barrow pit or on the job is the key step that makes subsequent operations easy or difficult. Best results are not obtained from soil of any one predominant type, but rather, from good sensible mixtures of two or more types of soil if they are readily available. Blending together two or more different soil types can result in a superior end product.

In a coarse grained sand, for example, fine grain sand should be added to improve the density and compactability, since the smaller grains will distribute and orientate themselves among the spaces between the larger grains reducing the amount of voids. If possible, clay should be added as a “binder” to make it more workable.

In every clayey material, granular soil should be added to provide internal friction, prevent slides, and make possible a wider choice of compaction equipment. Gravel and stones alone bear up well, but do not compact well, are unstable, and may injure some compacting equipment. In general, plastic materials are more workable but have a lower “bearing capacity,” while granular materials produce stability due to internal friction and inherent strength.

What to mix in what proportions is decided by knowing what combinations of soil and water is wanted and then using trial and error for refinements to see what combinations give the best results. If the soils to be mixed together appear in the same barrow pit in different layers, they can often be handled efficiently by shovel or belt loader. The machinery, working against the face of the bank with the different layers of soil, mingle and blend the materials directly as they dig and load the soil into the hauling units.
More often, the different soils will come from different sources of barrow and then they must be thoroughly mixed on the fill before being compacted. It is a very poor practice to make alternate lifts of the different materials. The different materials should be dumped out and thoroughly mixed together by use of discs, harrows, or similar equipment.

In earthwork, an hour's time spent in processing is worth 3 to 5 hours of just random rolling. Dozing serves to level out and spread the loose material and "back-dozing" results in a pulverizing effect. Using a grader to evenly spread each layer is important, for then the compaction equipment can give the entire area the same number of passes resulting in a uniform density throughout the fill. In the instances where lumpy (clods) soil is encountered, other types of equipment are generally used. Heavy discs, harrows, or rotary tillers can be used to pulverize the soil before the compaction equipment is used.

HOW CAN I DECIDE IF IT'S GOOD GRAVEL?

There are two ways. Take samples from the pit and submit it to a laboratory. Your district highway office can arrange for tests. The lab will do a sieve analysis which determines the gradations of stone and sand and their percentages. Tests can also be conducted for the wearability and soundness of the stone itself.

Tests can be done visibly but this takes some experience. Look at the gravel. Are the stones uniformly graded from large cobbles to \( \frac{1}{4} \) inch or are they all one size? Does there seem to be an equal number of stones of one size that would give stability? Are there lumps of clay, silt or other contaminants? In handling the gravel do the fines stick to your hands? If so, it's "dirty" gravel and not useful for roads. "Clean" gravel will give good stability and good drainage.

There are some generalizations to make when we talk about the composition of gravel. First, the three materials—gravel, sand, and silts—should be present. It is generally agreed that stones above \( \frac{1}{4} \) inch or so are gravel. Particles smaller than \( \frac{1}{4} \) inch are sands. Real small particles—those that pass through a -200 seive—are called fines or silts. Fines have the consistency of flour. All three are necessary to make good road gravel.

Second, it is agreed that the smaller materials fill in the voids among the larger material thus compacting the soil. Stabilizers such as calcium chloride, sodium chloride, lime, cements and other materials help in the compaction process.

Third, it is generally agreed that the functions of these three materials in a gravel road are to:

1. support traffic loads
2. resist abrasion
3. shed water
4. enhance capillarity

Finally, there is general agreement about the percentage of the three materials that should be present in good road gravel but, and here's the rub, there is no certainty about the percentages. There is no rule to follow, only a general standard. For example, the New York Department of Transportation uses the following gradations for surface course gravel:

<table>
<thead>
<tr>
<th>Seive Size</th>
<th>% Passing By Weight</th>
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</thead>
<tbody>
<tr>
<td>2&quot; (gravel)</td>
<td>100%</td>
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<tr>
<td>½&quot; (sand)</td>
<td>30-65%</td>
</tr>
<tr>
<td>#200 (fines)</td>
<td>10-20%</td>
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</tbody>
</table>

The State of Vermont's recommended gradations for surface course gravel are similar to New York's for gravel and sand but Vermont's gradations for silts are 0-8%.

Where does that leave us? The important thing to remember is that good gravel requires gradation of materials which means some percentage of fines and silts. The percentage to use comes with experience and in consulting with your State District Transportation Administrator.

Table 2, "Gravel Selection", shows the range of particle sizes necessary for good road gravel. A good bank run gravel would lie in the shaded area.

GRAVEL/BITUMINOUS SURFACE

A gravel base which is to be topped with a bituminous surface should have far fewer fines than a road that is to remain a gravel road. Why? Without a bituminous surface the moisture in the road is drawn up due to the capillary action of the fines and is free to evaporate. Once the road is surfaced, the moisture will continue to be drawn up but its evaporation will be blocked. This means that your gravel road must not have much clay or silt or it will make a poor base, will retain water, and you will be wasting your money if you cover it with a bituminous top.
**Table 2**

**GRAVEL SELECTION**

<table>
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<tr>
<th>Sieve Sizes</th>
<th>#200</th>
<th>#100</th>
<th>#50</th>
<th>#40</th>
<th>#20</th>
<th>#10</th>
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**Sources of Gravel**

Good natural gravel sources are shrinking in Vermont. Only a few towns own their own gravel pits. Gravel used to cost five or ten cents a cubic yard a few years ago and is now costing towns closer to two dollars.

It is possible to obtain gravel from riverbeds under certain conditions. Be sure to contact the Agency of Environmental Conservation to obtain a permit.

A town can make its own gravel. Mix ½ inch or ¼ inch crushed stone with sand using a 50/50 ratio.

When buying gravel remember the "bulking" process. Gravel "swells" or "bulks" from its natural setting to the truck. Gravel in the truck will shrink up to 15% when compacted.

Poor gravel can be improved by mixtures of calcium or sodium chloride, lime, fly ash, and cements.

**Summary**

Not all gravel is good road gravel. It needs certain features to make it work well for roads. Good gravel is hard enough so it doesn't form dust (a sign of disintegration) yet loose enough to drain. It supports the weight of traffic and distributes traffic loads sufficiently so it doesn't destroy the subgrade.

Good road gravel contains a uniform mixture of stones with a mixture of sand and fines to bind the stones together.

Road gravel should contain 40-80% stone,
uniformly graded from ¼ inch in diameter to 4-6 inches in diameter. The 20-60% portion that is not stone should consist of sand particles (smaller than ¼ inch) with not over 8-10% of the sand being fines (finer than flour).

The stones should be hard and not easily fractured or disintegrated. Stone you can crumble with your hands is weak stone. The gravel should be free of contaminants such as loam and vegetation.

In summary, the gradation of soils in road gravel is important; silts or fines are necessary to bind larger particles together; stabilization of materials can be added by the use of chlorides, cements and others; while there is no hard and fast rule for the percentage of fines or silts in road gravel, it is important to remember that a high percentage of fines in a road that is to be paved will make a poor road base.

RESOURCES


“Road Maintenance Techniques” Center For Local Government Technology Oklahoma State University, 1983.


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