

# INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING



*This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:*

<https://www.issmge.org/publications/online-library>

*This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.*

Since  $\frac{H}{B_0} = \frac{64}{5.75} = 11.13$ , and  $p = 1.1$  the value of the settlement ratio can be obtained from a diagram similar to that shown in Fig. 7, and is found to be between 0.2 and 0.3 for this culvert.

No. L-4

THE APPLICATION OF SOIL MECHANICS TO HIGHWAY FOUNDATION ENGINEERING  
John O. Morton, Soils Engineer, New Hampshire State Highway Department, Concord, N.H.

Development of the science of Soil Mechanics has provided a scientific method for analysis of highway foundation problems. Construction of roads over swamp areas, use of fine grained soils in deep fill sections, determination of ledge and boulder areas, effectiveness of sub-drainage structures, consolidation and compressibility of fine grained soils, manipulation of soils to provide stabilized base or surface materials are problems common to all highway engineers. In the northern states, frost action is of major importance.

Previously, methods of soil classification were geological in nature and proved more confusing than helpful. Under these conditions it was general practise to design roads with a uniform section regardless of variables presented by natural foundation conditions. As a result, failures occurred at weak points in the subgrade and from improper use of natural subsoils. Large sums of money were wasted by over-design in sections of good natural foundation material and unnecessary construction of under-drains.

In 1929 the U.S. Bureau of Public Roads provided a scheme of classifying soils into groups for highway studies; each group representing a different soil characteristic capable of a definite mechanical action. Because of its national scope, this group classification was broad. Its tendency has been to evaluate soil as a surfacing material.

Frost action problems of northern states have necessitated revisions in this group classification. Fig. 1 illustrates group revisions made for New Hampshire foundation studies. Attention is called toward the attempt made to conform with the U.S. Bureau of Public Roads group classification. Figure 2 illustrates the soil classification of the U.S. Bureau of Soils that has been adopted by the U.S. Bureau of Public Roads and is in general use in State Highway organizations for foundation studies.

Application of group classification to New Hampshire highway foundation problems is accomplished in the following manner. (Frost action referred to is the heaving that occurs under average winter conditions, when a pavement 4" - 6" thick is constructed directly on the natural subsoil).

Group A-2. Graded materials that contain binder (silt and clay), capable of frost action in varying degrees. Amount of frost action is a direct function of: 1. Depth and rate of frost penetration. 2. Elevation of ground-water table. 3. Silt and clay content of the material. Free water is encountered as a ground-water table. Underdrains are effective in lowering the water table and reducing frost action. The degree to which this material is cemented, its percentage of fine material and its natural water content influence the period of readjustment necessary for its safe use as fill in deep sections. Glacial till soils represent this group. Sub-divisions have been made as follows:

- Group A-2G. Graded material that contains 10% or less, soil with a grain size smaller than 0.05 mm; light frost action (2"-4" heaving). Soils known locally as sand or gravel hardpans represent this group.
- Group A-2F. Graded material that contains between 10% and 25% soil, with a grain size smaller than 0.05 mm. Frost action to the extent of 4"-6" heaving. Soils known locally as silt hardpans represent this group.
- Group A-2P. Graded material that contains over 25% soil with a grain size smaller than 0.05 mm. Excessive frost action (6" - 9" heaving). Soils known locally as clay hardpan or boulder clay represent this group.
- Group A-3. Coarse materials only. Cohesionless sands and gravels. Free from frost action. Porous, will not support a ground-water table. Readily adjust themselves when used in deep fill sections. Excellent support for rigid pavements.
- Group A-4. Silt without coarse material. High and rapid capillary action. Excessive frost action (8" - 14" heaving). Free water as a ground-water table not encountered. Underdrains constructed at standard depths (4'-5' below finished grade) are not effective in reducing frost action. Long period of readjustment necessary when used as fill in deep sections.
- Group A-6. Clay without coarse material. Capillary action not as rapid as that encountered in silt group, 6" - 9" frost heaving. Free water as a ground-water table not encountered. Underdrains constructed at standard depths are ineffective in reducing frost action. Long period of readjustment necessary when used as fill in deep sections.
- Group A-8. Muck and peat. Highly unstable. High organic and vegetable content. Capable of displacement or excessive settlement.

Application of soil and group classification to highway engineering is accomplished through the soil survey. The soil survey consists of studies aimed at identifying and solving variables presented by natural foundation conditions. In scope it covers location, classification, condition, action and quantity of: 1. Natural subsoils. 2. Swamp areas. 3. Solid and boulder ledge areas. 4. Top soils. 5. Materials used for previous road construction. The presentation of this data is accomplished by means of: 1. A soil profile. 2. A soil profile report.

The soil profile is produced by making borings and test pits at sufficiently close intervals and to a depth that permits accurate knowledge to be obtained about material that will be moved or affected by new construction. To further clarify classification, a soil profile legend (Fig. 3) has been adopted for

FIG. 1

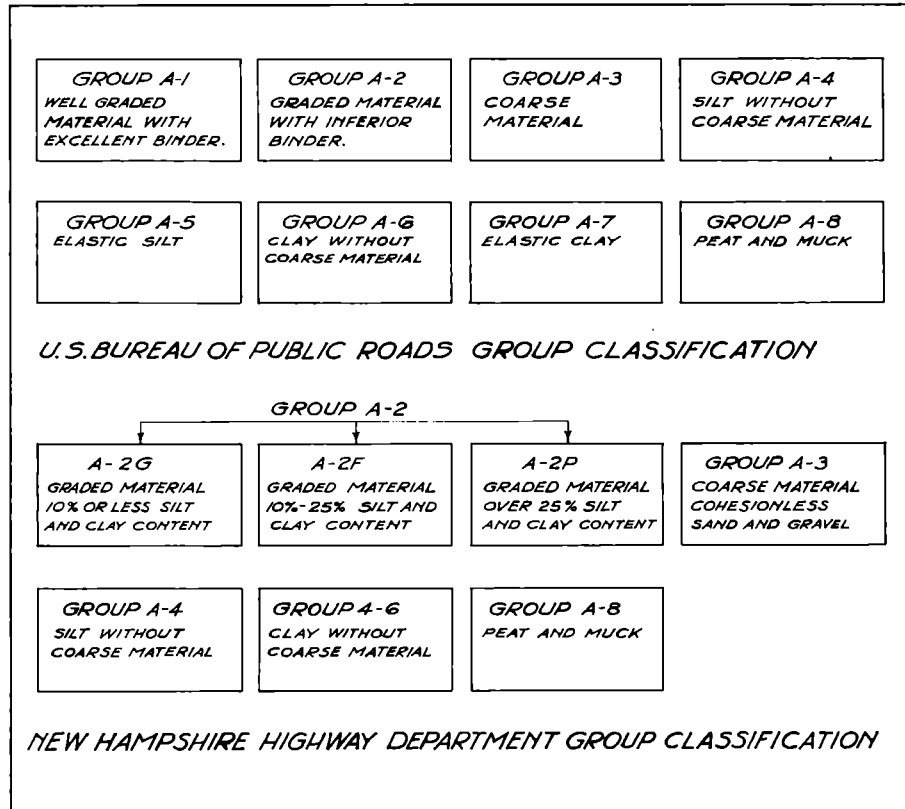


FIG. 2

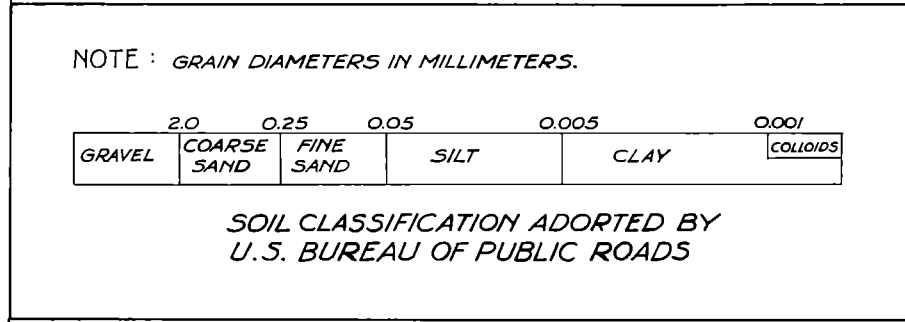
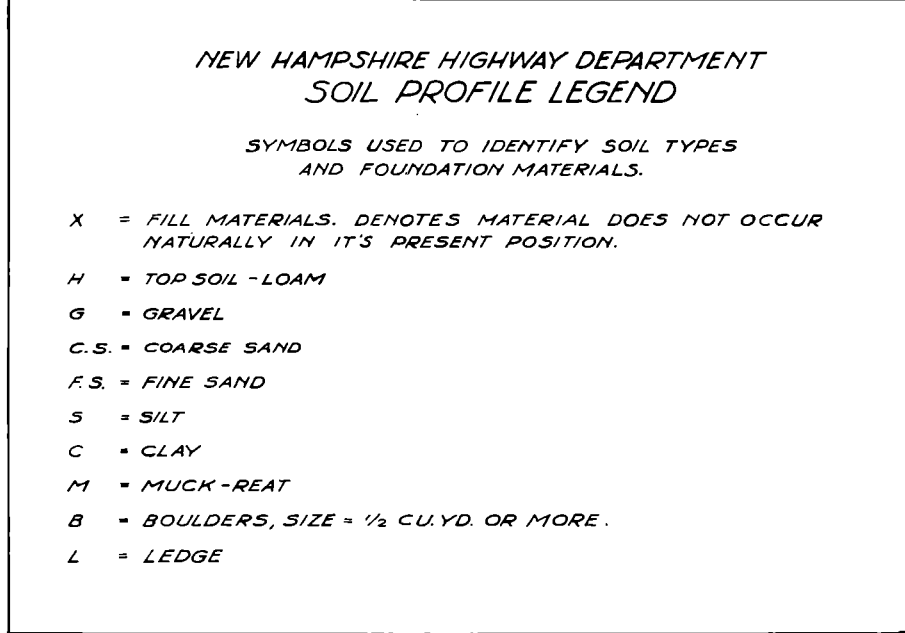


FIG. 3



use in conjunction with the group classification. The method of recording permits other conditions to be noted as location of natural water pockets, side hill areas, surface drainage conditions, nature of muck and top soil areas. Attention is called to the advisability of raising or lowering the grade. Fig. 4 and 5 are typical illustrations of soil profiles on New Hampshire projects. Instead of the crossing hatching employed on the illustrations, colors are employed for the increased speed obtained by their use.

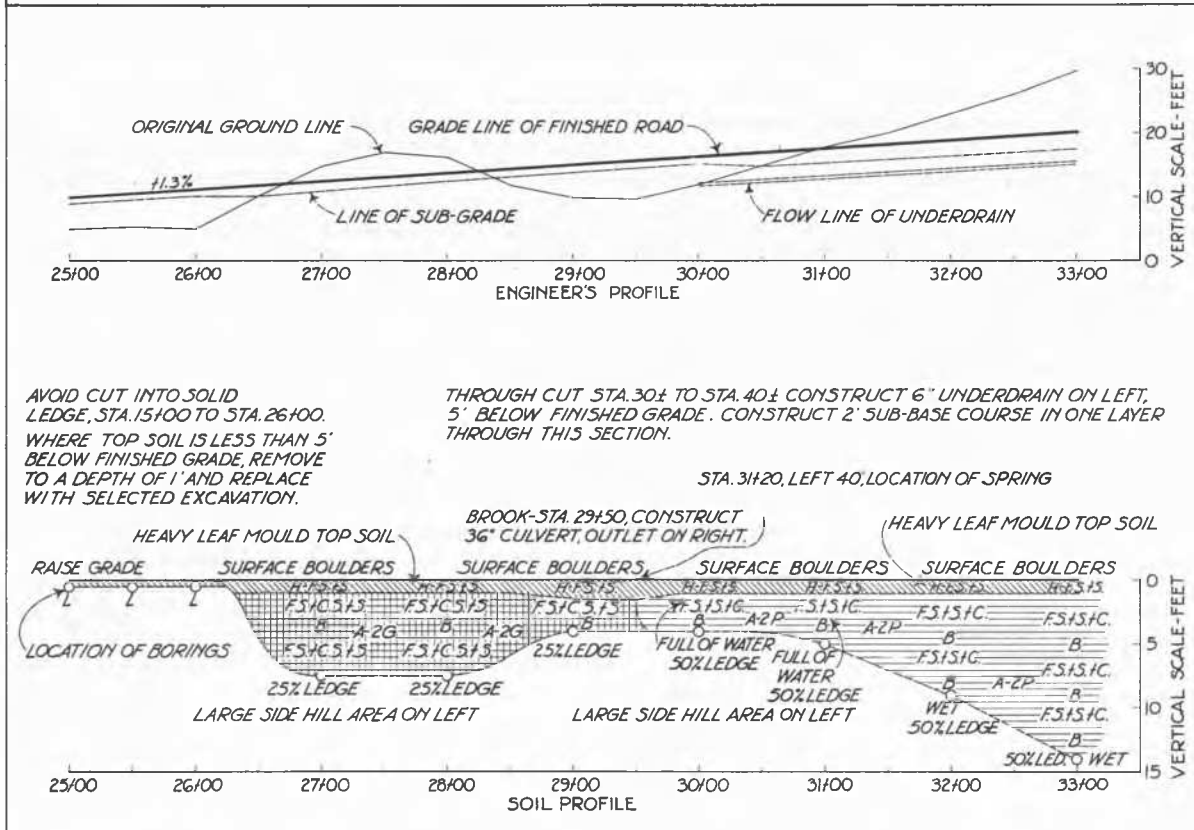
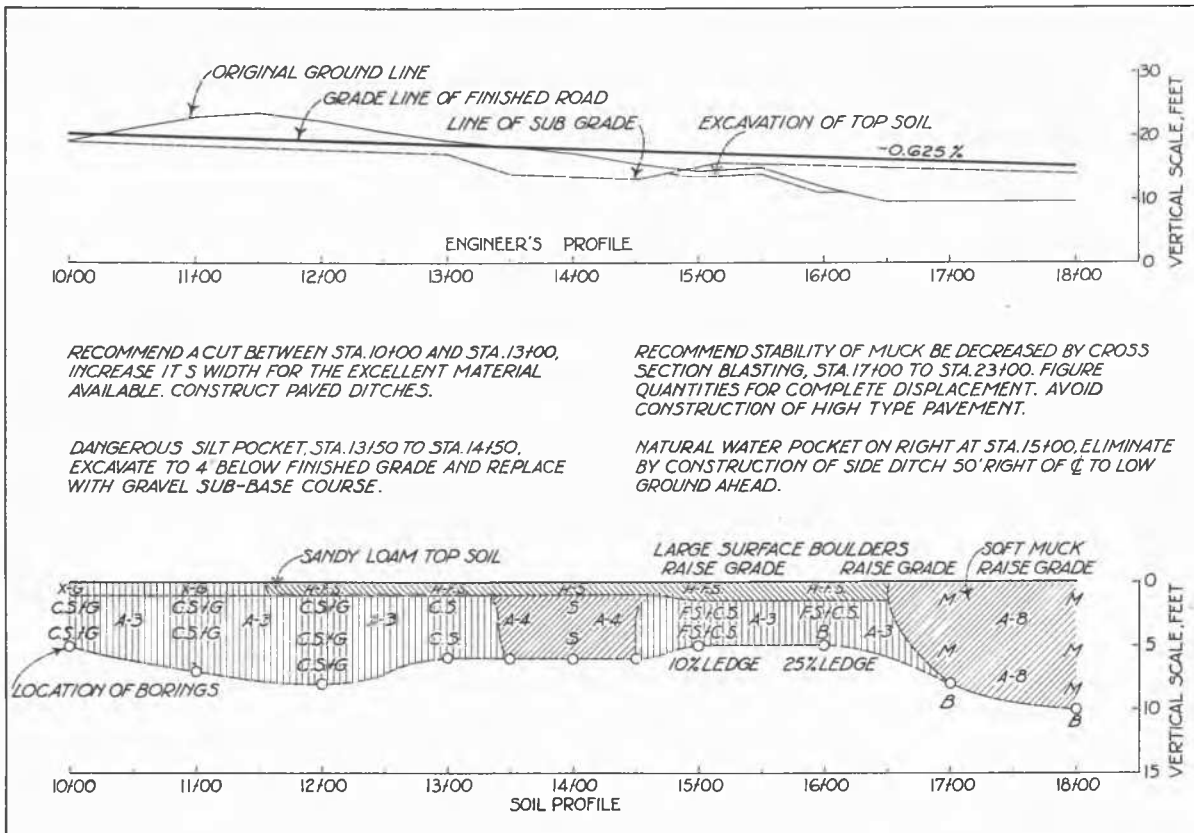
The soil profile report is furnished in conjunction with the soil profile. It amplifies profile data and covers phases of design and construction not permitted on the profile. Under the following headings it consolidates a wide range of vital information.

1. Present Road Surface - A history of the old road surface is presented, including its character and condition and the materials used for its construction. The study of the old road is made to secure precise information relative to seasonal breakups, location of weak points in the subgrade and surface-drainage conditions. Such knowledge permits checking of the weak points in the subgrade against the soil profile; it correlates soil profile data with actual field conditions.
2. Subsoil Conditions - A description of natural soil conditions and character of excavation is presented. It points out whether the material is loosely deposited or very compact, cohesionless, cemented or plastic; wet or dry; likely to shrink, swell, slip, subside or produce frost action.
3. Swamp Areas - Location and depth of swamp areas are accompanied by information as to whether or not the material is a peat or muck. The stability of the material is noted, and methods of constructing the road over such areas are suggested.
4. Ledge Areas - The location of solid ledge is given by stations; areas of boulder ledge are located, and an estimate is made of the percentage of boulder ledge that will be encountered by excavation through these sections. Information on the character of ledge is recorded.
5. Topsoils - The condition and location of topsoil material is noted, and recommendations are made as to the desirability of removing these materials when encountered in light fill sections.
6. Alignment of Roadway - Often the soil profile will bring to light conditions that predict costly construction or maintenance items on the proposed line; a description of these conditions with a suggested line change and reasons is recorded.
7. Grade Recommendations - Conditions are pointed out that permit the establishment of a grade with regard to the condition and type of the natural subsoil; recommendations are made to avoid heavy cuts through ledge sections; attention is called to the dangers of construction at low elevations over wet areas, and heavy cuts with the side slopes moved back may be suggested to take advantage of good natural foundation materials.
8. Foundations and Underdrains - Recommendations are made regarding the amounts of base course necessary to meet variables presented by the natural subsoil; underdrains are located; attention is called to conditions where construction of the base course in thin layers will result in such mixing with the natural subsoil that the value of the base course is lost. Methods of construction are suggested to remedy such conditions.
9. Remarks - Attention is called to any unusual condition not covered in other sections of the report. Seasonal variations affect construction methods and upset design plans. Certain types of soils (silts and graded materials), if moved during periods of seasonal rains, may become highly unstable; construction with the same material in dry seasons offers no unusual difficulty. Knowledge of these facts permits work to be performed during favorable seasons.

Application of soil survey data has developed new trends of practice and opened fields of thought that are important advances in highway engineering. Of great importance is the replacement of a uniform base course by a varied design. Advantage is taken of good natural foundation materials; weak points in the subgrade are corrected by the proper use of varying amounts of sub-base materials and the correct location and design of underdrains. A common fallacy has been the attempt to design so that cut and fill sections balance. Desirability of such procedure is dependent on natural foundation materials. With knowledge that excavation will be into dangerous materials, balanced quantities are avoided. Design is made with due regard to soil shrinkage and swell possibilities. Cemented or compacted soils and ledge rock swell upon being excavated. Loosely deposited materials and soils high in water content cause shrinkage. Determination of the shrinkage factor is dependent on this information. Underdrains are constructed in sections where they will be effective. Silt and clay soils have high capillary properties and drains constructed in these materials have but small value or may even prove detrimental. Knowledge of swamp area conditions has enabled the engineer to develop various means of solving these problems. Complete excavation of the material, displacement by blasting, loading the swamp area before the use of explosives, reducing the stability by the addition of water in sufficient quantities to cause the material to flow are different solutions of such problems. Selection of a method of procedure that will be successful and allow an accurate estimate to be made of the quantity of materials involved, is made available by the soil survey.

Use of underdrains, insulating materials, treatment of natural subsoils with bituminous or chemical materials, prevention of base course materials from mixing with the natural subsoil for combating frost action or increasing soil stability, together with methods of fill construction, are problems in need of further development.

Conclusion. Attention is called to the ambiguous method now employed for the group classification of soils in regions where frost action is of major importance. Need of providing a more simplified method of group recording is great. A distinction in group classification that would be applicable to the natural foundation problems present in different sections of the country is suggested. Lack of uniformity in the use of symbols for soil classification provides another real handicap. Correction of these discrepancies is highly desired.



Figs. 4 & 5. Typical Sections of the New Hampshire State Highway Department Soil Profile Showing Information as It Is Presented to the Designing and Constructing Engineers.

The assistance furnished by the application of soil mechanics to highway foundation engineering has provided the means of closing an important gap in the science of highway construction. The maintenance design and construction of modern highways in an intelligent manner demands a thorough knowledge of natural subsoils and their practical application to highway problems.

No. L-5

SOIL PROFILE FIELD METHODS IN NEW HAMPSHIRE

John O. Morton, Soils Engineer, New Hampshire State Highway Department, Concord, N.H.

Upon completion of the engineer's survey, the soil profile is made. Occasionally a preliminary soil profile precedes the engineer's survey. This is to investigate swamp and ledge areas or conditions that have a direct bearing on the proposed alignment.

The following equipment is used for soil profile surveys: 1. Soil auger  $3\frac{1}{2}'$  long with extensions to permit soundings up to 50' in depth (Fig. 1). 2. Picks. 3. Shovels. 4. Light bars. 5. Two pipe wrenches. 6. Roll of 20 inch cross-section paper, ten divisions to the inch. 7. Drawing board. 8. One 100 foot metallic tape. 9. One hand level. 10. Sample bags. 11. Sample cans. 12. Notebooks. 13. Keel. 14. Camera and films. Figure 2 provides a picture of New Hampshire field equipment.

Location and depth of test pits and borings depend upon soil conditions encountered and layout presented by the survey. When the new center line is on the old road surface, soundings are taken on the 100 foot stations and are located on the side that shows the deepest cut or thinnest fill. Examination of the old road surface indicates weak points in the subgrade that require a more careful investigation. On new locations, borings are made every 50 feet. Changes in soil types require borings at shorter intervals to locate transition points. Extreme un-uniform conditions require borings on the survey cross-section line. When possible, borings are made to a depth of 4' below proposed finished grade or the average depth of frost penetration. Soundings must show the total depth of swamp areas. From borings it is difficult to differentiate between boulders and solid ledge when these formations are encountered 3 feet or more below the ground surface. Reconnaissance of adjacent exposed cuts and general terrane, together with the use of large test pits, form the basis of reliable information on such formations.

Soils are classified by feel and visual inspection. Success in soil profile work depends on the ability to recognize and classify soils during field operations. A man trained in soil classification will readily recognize most soil types to the extent that permits group classification. Occasional soils, called border line materials, require laboratory testing for accuracy. To aid classification, field tests may be developed. The degree of plasticity determined by visual inspection aids field classification. Placing a soil sample in suspension in a small bottle of water has proven helpful for field classification. This allows a rough check to be made on the time required for settlement of the fine grained particles and permits visual inspection of the separated soil layers. Soils high in natural water content can be placed on small boards and allowed to dry, being checked at a time when their condition permits a better inspection. Feel of the auger when boring and observation of ground formations, with the type and growth of vegetation, will indicate variations in soil conditions.

For average conditions, a man trained in soil classification with the assistance of two laborers, can map one-half a mile of road per day. Over sections of rough terrane that require the use of large test pits, an increase in the number of laborers helps maintain the speed of operations. Generally, two laborers can operate at a speed that equals the ability of the engineer to map and record the information.

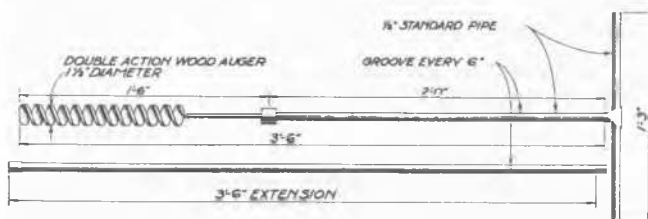


FIG. 1. SOIL AUGER AND EXTENSION



Fig. 2  
Soil Survey Equipment