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AREAL STUDIES OF SOILS IN NEW JERSEY

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SUMMARY.

This paper gives the reason for and the progress of the Joint Highway Research Project in the State of New Jersey.

One of its principal objectives is the preparation of Engineering Soil and Drainage Maps for the State of New Jersey.

This paper contains data on the above subject as well as references to other research underway.

GENERAL CONDITIONS IN NEW JERSEY

New Jersey is located on the Atlantic Seaboard between the two great cities of New York and Philadelphia, and adjacent to the heavy industrial and coal areas of Eastern Pennsylvania. In addition, the great concentration of population in the northern and central part of the state as well as seasonal travel to the eastern shore and northern New Jersey lake resorts add to the traffic difficulties.

Traffic counts have registered volumes at many locations of 10,000 to 50,000 vehicles per day, including 1,000 to 10,000 trucks carrying 300 to 3,000 8-ton (or over) axle loads.

Climatic conditions are variable in New Jersey. There is an annual rainfall of 45.58 inches. Temperatures range from a few degrees below zero in winter to a few degrees above 100 degrees Fahrenheit in summer. Temperature changes of 30 to 40 degrees within twenty-four hours have been recorded. During moderate winters, as many as three periods of alternate freeze and thaw conditions have been experienced.

Topographically, the State is divided into two broad provinces. The first of these, the Atlantic Coastal Plain, is mantled with Quaternary deposits which are chiefly sands and gravels. Sands, clays, and marls, ranging in age from Cretaceous to Tertiary, underlie the Quaternary deposits and outcrop in the extreme northwestern part of the province in a narrow belt, 15 to 25 miles in width; they dip southeasterly from their outcrops. The second province consists of three sub-areas. These sub-areas are: The Piedmont Plain of Triassic shales, sandstones, and traprock, the Highlands of Pre-Cambrian crystallines and some Paleozoic sedimentaries, and the Appalachian Valley of Paleozoic limestones, shales and sandstones. Pleistocene glaciation mantled about one fifth of the northern part of the state with surficial deposits of unassorted drift and stratified sands, gravels, and clays.

SOME CHARACTERISTICS OF NEW JERSEY SOILS

The sands and gravels of the Atlantic Coastal Plain as well as those encountered elsewhere, have a tendency to densify under the action of heavy duty traffic, resulting in settlements at joints and cracks in pavements. The outcropping of the underlying silts, clays and marls in the 15 to 25 mile belt makes aerial studies of this locality very complicated. The materials have little bearing value, swell considerably, are subject to frost action, and if not covered with a granular material, will develop "pumping".

The shales of the first sub-division of the second province break up or easily weather into a silty clay having very little bearing value, swell moderately, pump under traffic, and are subject to frost action. This material is easily mapped, and considerable of the mapping work done to date has been done in this subdivision.

The remaining two sub-divisions should be more difficult to map than the shale areas. The silts and clays of these areas are all low in bearing value, pump under traffic, have moderate to heavy swell characteristics, and are subject to differential frost heave.

From the above traffic, climatic, and soil statistics it can be readily seen that in providing adequate highway facilities, New Jersey has become an excellent laboratory for the testing of soils used as foundations for pavements or highway structures.

PAVEMENT SUBGRADE PROBLEM

In the year 1931, evidence developed on highways carrying heavy axle loads that natural soils were incapable of sustaining pavements under all climatic and traffic conditions. Studies of pavement design resulted in some improvement, but it became more and more evident that the type and condition of the soil under the pavement was the direct cause of the pavement failures. Some improvement in foundation design was made about 1938, when granular materials were first introduced as a subbase under pavements.

However, no organized investigations of the underlying soils were attempted until after a highway, which had functioned normally under light traffic for fifteen years, suddenly failed when it was subjected to heavy duty wartime traffic in 1943. The location of this 13-mile length of highway (N.J. Route 4, Alternate, and Route 24) was in an area of frequent and abrupt soil changes. The highway had carried a normal average traffic of 35 8-ton (or over) axle loads on the southbound lane, and 20 8-ton (or over) axle loads on the northbound lane, requiring only normal maintenance and repairs. From December 1943 to August 1944, the 8-ton (or over) axle loads per day increased to 247 on the southbound lane and to 70 on the northbound lane. Of the 247 loadings on the southbound lane, an estimated 200 were 30 tons, carried on two axles. A rapid thaw in the spring of 1944, followed by heavy spring rains, softened the natural subgrade soils, and the pavement failed badly at numerous locations.

BEGINNING OF REGIONAL SOIL STUDIES

During the summer of 1944 when repairs to the above pavement were in progress, 75 samples of all types of soil were taken from under the slabs and subjected to laboratory soil tests for grain size, consistency limits, moisture-density relationship, California Bearing Ratio, and swell. A summation of these test values indicated a positive relationship between the soil types and pavement failure.

The data developed in this original survey, after being correlated with pavement performance, was submitted to the Soils Department of Rutgers University (The State University of New Jersey) and further investigations at the University resulted in a confirmation of

the results developed in the original survey. This investigation consisted of sampling the soils of the area adjacent to the highway independently of the original work done by the Highway Department, and subjecting the samples of soils to tests similar to those used in the original work. The route was then divided into areas of similar soil profile and the percentage of slabs showing distress (cracks, stepping, pumping, etc.) was determined for each area. Correlation of soil profile using various classification systems and per cent distress was then developed.

In general, all of the classification systems showed a fair correlation with pavement distress. However, the range of performance within any soil group was sufficiently large to discount the reliability of all but one of the classification systems as an index of performance. The one exception was the California bearing ratio.

Figure 1 summarizes the relation of distress in per cent to bearing ratio in the soaked condition for the southbound and northbound lanes.

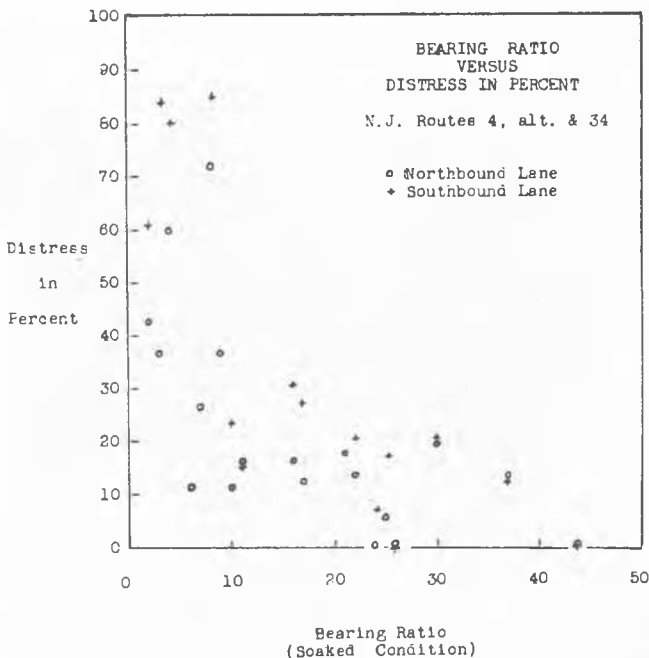


FIG.1

#### FORMATION AND OBJECTIVES OF THE JOINT HIGHWAY RESEARCH PROJECT

The New Jersey State Highway Department, realizing that many soil problems could not be advantageously solved by routine field and laboratory procedures, invited Rutgers University to participate in the initiation of a soils research program to study specific soil problems and to assist in the training of highway department personnel for field application of soils engineering techniques.

As a result, the Joint Highway Research Project, under the direction of a 13-man committee, was established to sponsor and guide research projects. The committee consists of six representatives of the New Jersey State Highway Department, six representatives of Rutgers University, and one representative of Princeton University. The three major projects, "The Preparation of Engineering Soil and Drainage Maps for the State of New Jersey", "A stu-

dy of the Relationship of Pavement Performance to Subgrade Soil Type", and "The Consolidation of Highway Subsoils by Means of Mechanical Vibrations", are sponsored jointly by the Public Roads Administration of the Federal Works Agency, the New Jersey State Highway Department, and Rutgers University. The committee plans to expand the Project activities to include additional investigations in the field of soils relative to highway engineering as the above projects near completion.

The Joint Highway Research Project, "Preparation of Engineering Soil and Drainage Maps for the State of New Jersey", entails a coordinated application of field, laboratory and soil mapping techniques. Representative samples, located after a combined study of geologic maps, and aerial photographs, are classified in terms of grain size and consistency limits. Moisture-density relationship, bearing ratio, and tri-axial tests are performed to determine pertinent engineering values. Field observations and laboratory test values provide a guide for establishing typical profiles which are translated by aerial photograph study into characteristic patterns. The airphoto patterns thus established permit delineation of the particular soil profile on an aerial basis.

The major problem is the definition for map subdivision of a level of generalization which will just recognize the minimum variation in soil properties reflecting a variation in pavement performance. On the basis of the area mapped to date (about 5% of the State) the degree of detail obtainable by interpreting aerial photographs appears to be slightly greater than that required for the desirable level of generalization.

The drainage map is prepared by stereo-study of aerial photographs delineating rivers, streams, and normally dry surface flow paths.

The completed maps, with companion tables and descriptions, present data useful to design engineers, field engineers, and contractors as a preliminary evaluation of soil and drainage problems in a particular area. Although the research is devoted primarily to developing data for highway design and construction, the findings are also useful for evaluating general foundation problems.

On the basis of project experience to date, the most desirable procedure appears to be:

1. Use of air photo interpretation as the major mapping procedure.
2. Concurrent study of geologic and agronomic references, particularly in the areas where interpretation is more difficult.
3. Limitation of study time on any one photo to about one hour. Although complete and accurate identification of all areas may be possible by air photo interpretation, it is believed that supplementary field inspection may save much time in the more difficult areas.
4. Experience has indicated that the soil variations which are barely discernible in air photos will show slight but conclusive differences in laboratory test results. For this reason, it is desirable that the air photo mapping precede field sampling and be used as a method for selecting typical sample locations.

The principal objectives of the "Study of the Relationship of Pavement Performance to Subgrade Soil Type" are: first, to correlate pavement designs and traffic conditions, and, secondly, to define the minimum pavement foundation requirements for different categories of traffic weights, types, and numbers. This research program is coordinated with the soil mapping program, thereby providing guidance in defining a practical level of generalization for mapping.

The research project "The Consolidation of Highway Subsoils by Means of mechanical vibrations on soils followed by the development of a practical device for consolidating highway subsoils and embankments. The current program includes the development and calibration of instruments for generating and recording mechanical vibrations. The instruments will be used: first, in the laboratory to determine sensitivity to vibrations, resonant frequency, etc., of various soil types, and secondly, in the field to explore the nature of vibrations resulting from actual traffic loadings. It is hoped that combination of laboratory and field results will permit definition of the requirements for a practical consolidation device.

#### CONCLUSION

1. This work, together with the normal soil studies by the Soil Division of the Depart-

- in its Maintenance and Construction program, has proved that the methods of aerial mapping now in use and outlined in this paper are satisfactory for the purpose intended.
2. While assisting in the above work, eight employees of the Department have received sufficient training in Soil Mechanics to fit them as inspectors on construction projects where soil controls are specified.
3. Also, the relationship between bearing values (soaked condition) and pavement performance has established a satisfactory method of correlation. However, it is now thought that the correlation work should be based on as wide an area as possible, thereby developing a broad coverage of traffic conditions.
4. The work accomplished to date on the third project, "The Consolidation of Highway Subsoils by Means of Mechanical Vibration", is confined to the design, developing and testing of apparatus with which to conduct the Project.

Note: The writer appreciates the assistance rendered in the preparation of this paper by Franklin C. Rogers, Professor of Civil Engineering, Rutgers university, New Brunswick, New Jersey, U.S.A.

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