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BEACH SAND AS A CONSTRUCTION MATERIAL

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BEACH SAND AS A CONSTRUCTION MATERIAL

U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Memorandum No. 3-271.

The following conclusions directly applicable to the Eglin Field sand were derived from the results of this investigation.

The compaction of the Eglin Field sand subgrade material to the minimum requirements for VHB paving requires the use of heavier equipment than ordinarily employed at Eglin Field in grading operations. Little if any increased compaction resulted from use of equipment of the same type and weight as used to grade the site.

The study indicates that wheel loads of 35,000 lb will satisfy the minimum density requirements for VHB paving at Eglin Field, and that a tractor loaded to 80,000 lb very nearly satisfies the requirements.

When 6 coverages of the compacting equipment do not obtain the desired degree of compaction, heavier equipment rather than more coverages is required. Very little, if any, improvement was noted when coverages in excess of 6 were used, but increased weight of compacting equipment showed considerable improvement.

The Eglin Field sand subgrade did not compact more readily when water was used, either by sprinkling or ponding; therefore the use of water as an aid to compaction is not justified. Since the free-draining soil conditions at the site of these tests did not permit a very high degree of saturation at any appreciable depth below the ground surface the results did not indicate whether or not any benefit would result from complete or nearly complete saturation down to appreciable depths in the sand.

The results show that there is some difference in the two sands represented by the subgrade at Eglin Field and the subgrade at Auxiliary Field No. 2. Consequently, it is probable that lighter loads than those indicated in the Auxiliary Field No. 2 investigation may satisfy the VHB requirements at the main field.

U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Report No. 3-545, Report 5. Stresses Under Moving Vehicles.

Measurements of the magnitude and distribution of normal stresses at the tire-soil interface of an 11.00-20, 12-PR smooth pneumatic tire towed on air-dry mortar sand are presented. Deflection gages inside the tire measured its deflection, and pressure cells embedded in the surface of the tire measured the stresses at the tire-soil interface. Also, pressure cells installed at several depths within the soil mass beneath the center of the tire path measured stresses induced in the soil mass. Results indicate that the distribution of stresses at the tire-soil interface is related to the shape of the deflected tire and thereby to tire load, inflation pressure, and soil strength. Peak stress in the soil mass occurred well ahead of the axle of the test wheel, with the total load on the wheel having the greatest influence on its magnitude. The average stress waves for a tire-soil system such as used in this study can be expressed mathematically in terms of a Fourier series. Application of the Fourier series in stress wave analysis is discussed in Appendix A.

3. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Report No. 3-652, Report 1. Measuring Soil Properties in Vehicle Mobility Research.

In this investigation, strength-density relations were developed for Yuma sand in the air-dry condition. These relations were determined from measurements obtained with triaxial shear, direct shear, bevameter shear, and vane shear apparatus; the WES cone penetrometer; and several sizes of bearing plates. Most of the measurements were obtained as a routine part of the soil-tire performance tests being conducted at the Waterways Experiment Station. Several special laboratory tests were also conducted to study specific questions that arose and to give some assurance that the relations observed from the routine data were accurat

The triaxial and direct shear tests, especially as reflected by the friction angle, were not sensitive to density change. The friction angles determined by means of the bevameter were generally lower than those obtained in the triaxial and direct shear tests and showed no apparent relation to changes in density. Of the measurements made in the routine tests, the vane shear strength, cone index, and plate bearing pressure were most sensitive to density variation. The soil value n and the bevameter shear value s_b were the least sensitive. The vane shear strength, the cone index, plate pressure, and the soil values k_c and k_ϕ are related to soil density and consequently to each other.

4. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Report No. 3-639. Strength-Moisture-Density Relations of Fine-Grained Soils in Vehicle Mobility Research.

This study was undertaken to determine the relation of soil strength measurements obtained with the bevameter, the vane shear apparatus, the WES cone penetrometer, and the triaxial shear machine to the moisture content and density of two soils, a heavy clay and a lean clay, and to establish correlations between the various types of strength measurements.

Directly measured soil strength values such as vane shear strength, cone index, pressure on a bearing plate (from the bevameter tests), and bevameter and triaxial shear strengths at a certain load or confining pressure reflect changes in soil moisture content and density with fair precision, whereas indirectly measured or derived values such as cohesion, friction angle, and the bevameter sinkage values are characterized by less definite trends.

All soil values could be correlated with each other to some extent, except that friction angle apparently was not directly related to either of the penetration tests or to the vane shear test results. The bevameter sinkage parameter n was not found to be influenced in a consistent manner by any of the test variables The most precise correlations involved vane shear strength, cone index, and direct measurements of bearing pressure or bevameter and triaxial shearing strengths. Equations relating the several soil values were derived whenever practicable.

5. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Miscellaneous Paper No. 4-477. Trafficability Tests with the 5-Ton Goer (XM520) on Fine- and Coarse-Grained Soils.

Tests were conducted in soft, fine-grained soils and clean sand to determine performance characteristics of the 5-ton GOER for two tire sizes. In fine-grained soils the GOER performed better with 18.00-26 tires than with 15.00-34 tires. With 18.00-26 tires it performed better than standard military 6x6 wheeled vehicles of 2-1/2- and 5-ton capacity. In sand the GOER also performed better with 18.00-26 tires than with 15.00-34 tires. In one specific clean sand its performance with either size tire was better than any wheeled vehicle tested to date by WES. Additional testing, particularly in snow, sand, and muskeg, is needed to evaluate the vehicle fully. The computations for determining the vehicle cone index of the GOER for operation in fine-grained soils are included as Appendix A.

6. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Memorandum No. 6-419, Report 5. Tests of Sanded Grouts; Effects of Fly Ash in Grouting Coarse Sands and Fine Gravels.

A fly ash with a carbon content 8.13% in excess of current specification limits, and with the amount of material retained on the No. 325 sieve 4.2% in excess of that specified, was added to neat cement grout, and tests were performed to determine (a) its effect on the quality of the grout, and (b) the effectiveness of the grout in penetrating voids in granular materials, as compared with the performance of neat cement grout without fly ash. Proportioning studies indicated that an addition of 25% fly ash to a portland-cement grout produced the optimum fly ash grout mixture. Test results indicated that (a) the use of the fly ash with a carbon content 8.13% in excess of specifications did not appear to affect the quality of the grout, and (b) the fly ash mixture and the mixture containing no fly ash exhibited essentially the same penetration characteristics.

7. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Report No. 3-666, Report 2. Performance of Soils Under Tire Loads; Analysis of Tests in Yuma Sand Through August 1962.

A total of 709 tests performed with single pneumatic tires in yuma desert sand placed in movable sand bins in the laboratory are analyzed. Basic plots are presented to show the correlations obtained between individual variables. Representative cross plots are included to show the effects of tire width and diameter and to illustrate the relative effectiveness of the various tires tested. Initial steps in the development of a numeric that will define a single relation between dependent and independent variables for all tires and test conditions are reported.

8. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Report No. 1-674. An Experimental Study of Arching in Sand.

Arching, the ability of a material to transfer load from one area to another in response to relative displacements between areas, is investigated. The study is primarily experimental, results being used to assess the applicability of existing theories.

The major experimental results are a series of dimensionless load-deflection curves obtained by moving an axially symmetrical trapdoor, which was initially mounted flush with the bottom of a cylindrical test chamber, up into or down away from a series of sand specimens of various depths. The sand surface was subjected to several levels of pneumatic surcharge (40, 75, 100 psi), the majority being at 75 psi. Two sands and two trapdoor sizes were used. Also the redistribution of vertical stress on the test chamber base was measured by several pressure cells located at various distances from the trapdoor.

Analysis of the dimensionless load-deflection data leads to the conclusions that extremely small deflections have great significance, a deflection as small as 0.0002 times the trapdoor diameter may change the load on the trapdoor by as much as 50%; that the trapdoor size is not important if the ratio of depth of soil to diameter (H/B) is held constant; that the influence of the H/B ratio on the shape of the dimensionless load-deflection curves is very significant for small values of H/B (H/B less than 2); that for values of H/B larger than 2, shape of the deflection in the range of practical interest.

Comparison with analytical approaches leads to methods of predicting both initial slope and ultimate values of the dimensionless load-deflection curve, and indicates that this slope depends upon the ratio of the constrained tangent modulus of the soil at the pressure of interest to the value of pressure, although a rather linear relation between the two tends to mask the trend at the levels of pressure studied.

A semiempirical method of predicting the dimensionless load-deflection curve is developed which works satisfactorily with these soils, and is believed applicable to any fairly dense sand.

The measurements of pressure changes associated with arching lead to conclusions concerning the extent, magnitude, and characterof these pressure changes. The suitability of various approaches for predicting these quantities is assessed.

9. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Contract Report No. 3-130. A Dimensionless Consolidation of WES Data on the Performance of Sand Under Tire Loads.

A semiempiric, dimensionless load coefficient is developed from extensive WES field and laboratory data on the performance of pneumatic tires in dry sands. The coefficient appears to collapse these diverse data to a useful degree. The physical meaning of the numeric is discussed, and its relation to some earlier work is shown. A preliminary consolidation of the data using the final form of the numeric is presented.

). U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Memorandum No. 3-240, 17th Supplement. Trafficability of Soils; Tests on Coarse-Grained Soils with Self-Propelled and Towed Vehicles.

Standard trafficability and special tests with 21 military vehicles were conducted on coarse-grained soils. Areas of investigation included: (a) the correlation of slope-climbing and towing-force data; (b) effects of tire size, traction devices, tire treads, and wheel load; (c) vehicle performance on "honeycomb" sand; and (d) trafficability of gravel beaches. Self-propelled wheeled and tracked vehicles and one towed vehicle were tested at five locations in the United States and France. Principal conclusions were: (a) maximum towing force of self-propelled wheeled vehicles on level sand was about 2% greater than maximum slope negotiable; (b) vehicle performance increased with decreases in ground-contact pressure; (c) vehicle performance was better with smooth tires than with treaded tires or the traction device tested; and (d) vehicle performance on wet sand that tended to liquefy under the vehicle load (honeycomb sand) was similar to that on fine-granned soils

.1. U.S. Waterways Experiment Station, Vicksburg, Mississippi. Technical Memorandum No. 3-240, 14th Supplement. Trafficability of Soils, A Summary of Trafficability Studies Through 1955.

The trafficability factors, bearing and traction capacity, are functions of shearing strength. A simple instrument, the cone penetrometer, measures an index of shear strength. Cone indexes on fine-grained soils and sands with fines, poorly drained, are related to vehicle performance, but an auxiliary test, remolding, must accompany the cone penetrometer test to predict changes in cone index under traffic. Slipperiness and stickiness cannot be measured, but can be anticipated approximately from simple soil tests. Tests with wheeled vehicles on sands showed fair correlation between maximum slope and cone index with tire pressure duly considered. Means are presented for: classifying soils from the trafficability standpoint; computing cone index required for any militrry vehicle; quickly estimating maximum slopes vehicles can climb, maximum tow loads, and towing forces required on various soils strengths; making actual trafficability measurements and mapping them for strategic and tactical purposes; and for estimating trafficability without contact with the soil.

2. Reeves, Gary N. INVESTIGATION OF SANDS SUBJECTED TO DYNAMIC LOADING. Texas A&M University Thesis, Civil Engineering. August 1967.

The ultimate strength of sands subjected to dynamic loading, while in a triaxial confinement is herein studied. Particular attention is given to the effects of variable loading velocities, initial sample densities, and effective confining pressure (intergranular pressure). The machine used for the testing was developed for this particular research, and a general description of it is included.

The currently used rheological models for describing a soil's resistance to dynamic loading, consist of employing an elastic spring constant and a viscous damping constant. This viscous damping constant is experimentally determined herein, and a comparison to the theoretical model, as used in current research at the Texas Transportation Institute, is made. As a result of this comparison an empirical constant is found for use in the mathematical model so that experimental data may be better correlated.

3. Long, Robert Eugene. THE EFFECT OF FINES UPON THE COMPACTION CHARACTERISTICS OF A WELL GRADED SAND. Texas A&M University Thesis, Civil Engineering, 1954.

The best means for determining whether a material will react as a cohesive or cohesionless material when compacted is to perform a compaction test on the material in question.

The kind and critical percentage of soil fines yielding the maximum densities are as follows: (a) sand, 12 percent, (b) silt, 4 percent, (c) clay, 8 percent.

No correlation was found between the Atterberg Limits of the binder material and their effect on the compaction characteristics of the well-graded sand other than that the one with the lowest plasticity index gave the maximum density.

Compaction characteristics of the binder material give an indication of their effect upon the well-graded sand.

The addition of fines to the well-graded sand increased the density in all cases.

D'Appolonia, David J. and Whitman, Robert V. SAND COMPACTION WITH VIBRATORY ROLLERS. ASCE Journal of the Soil Mechanics and Foundations Division (345 E. 47th St., New York, N.Y. 10017), Vol. 95, No. SM1, Proc. Paper 6366, pp. 263-284, Jan. 1969. HR Abstracts, June 1969.

An investigation of some of the factors influencing sand compaction with vibratory smooth-wheeled rollers is reported. Soil density determinations were made in test pits before and after compaction of an 8-foot high test embankment and two successive 2-foot lifts. Comparisons are made between compacted density-depth profiles for 2, 5, 15, and 45 roller covereges and for several different roller operating frequencies. Measurements of roller drum acceleration and dynamic stress and acceleration in the soil at various depths below the roller are used to identify some of the mechanisms controlling vibratory compaction.

Andresen, A. and Bjerrum, L. SLIDES IN SUBAQUEOUS SLOPES IN LOOSE SAND AND SILT. Norwegian Geotechnical Institute (Oslo, Norway), Pub. No. 81, 1968. 9 pp. HR Abstracts, June 1969.

The types of slides occurring in loose fine sands and coarse silts that are characterized by a liquefaction of the sand at small strains are described. It has proved useful to distinguish between two different types of slides: flow slides and liquefaction slides. Included is a review of present knowledge of the mechanical properties of loose sand. It is believed that the susceptibility of loose sand to liquefaction is the result of a small strain at failure, a low frictional resistance, a rapid rise in pore pressure during shearing, and a rapid loss in strength after failure. A descritpion is given of the method used in Norway to determine whether or not a sand deposit may be subject to liquefaction

Schroeder, W. L. and Schuster, R. L. LIQUEFACTION PHENOMENA IN SATURATED SANDS. Proceedings, 6th Annual Engineering Geology and Soils Engineering Symposium, Idaho Dept. of Highways, Univ. of Idaho and Idaho State Univ. April 1968, (Idaho Dept. of Highways, P. O. Box 7129, Boise, Ida., 83707) pp. 1-22, 1968. HR Abstracts, February 1969.

At several locations throughout the world, man-made structures and natural land forms associated with loose, saturated sandy deposits have been severely damaged during earthquakes. Various investigators have concluded that much of this damage was a direct result of liquefaction of the sand. In the course of this investigation, the stress effects of an earthquake on a granular soil deposit have been determined by means of simplified theory. This theory provided the basis for the design of a laboratory apparatus which was used to simulate the stress effects of a seismic disturbance. With this equipment, a series of tests was carried out which established the relative importance of several factors which control the response of saturated sand to earthquake loading.

Mazurkiewicz, Bolesaw K. SKIN FRICTION ON MODEL PILES IN SAND. Danish Geotechnical Institute (Academy of Technical Sciences, 11 Rigensgade, Copenhagen K, Denmark), Bulletin No. 25, pp. 13-48, 1968. HR Abstracts, July 1968.

The test series as a whole seems to suggest that a relevant procedure for determining the minimun bearing capacity of piles with negative friction, would be a loading test in-situ, in which the pile is first loaded to ultimate pulling capacity and then to secondary compression capacity. This might allow an estimate of the reduced bearing capacity in compression and with negative friction. The model tests have shown that a number of pile mantle bearing capacity types may be distinguished. This classification follows the type and sequence of loading. It is important whether the working load on the pile is applied directly after the pile is placed in the soil, or after the pile has been subject to forces causing skin friction stresses of opposite direction to that required in the working state. The ratios between the different bearing capacities are not constant but dependent at least on the density of the soil.

18. Moore, Lyndon H. and Grosert, Thomas. AN APPRAISAL OF SAND DRAIN PROJECTS. New York State Dept. of Transportation (1220 Washington Ave., State Campus, Albany, N. Y. 12226), Physical Rssearch Project No. 5, Feb. 1968. 70 pp. HR Abstracts, June 1968.

In the past 18 years, sand drains have been used on nine projects as a method of stabilizing soft foundation soils to support highway embankments. Four major projects were investigated in detail to determine the effectiveness of sand drain design, construction and performance. On three of these projects, the treatment was successful from the standpoint of providing foundation stability and elminating detrimental pavement settlement. On the fourth project, serious post-construction settlements developed after the road was open to traffic. Undisturbed samples were obtained in the stabilized areas one to two years after construction as part of the investigation. The final sections of the report discuss design and construction considerations for sand drain projects

19. Rowe, P. W. THE INFLUENCE OF GEOLOGICAL FEATURES OF CLAY DEPOSITS ON THE DESIGN AND PERFORMANCE OF SAND DRAINS. Proc. of the Institution of Civil Engineers (Great George St., London, SW1), Vol. 39, Proc. Paper 7058 S, pp. 465-466, March 1968. (Abstract) Paper available for the Institution. $2.50 approx. HR Abstracts, June 1968.

Following a review of the literature, the results of recent field measurements of rates of settlement and pore pressure dissipation of clay foundation for earth embankments with and without sand drain installations are compared with predictions based on laboratory and in situ tests. The identification tests, liquid limit, plastic limit and clay fraction, give no indication of drainage properties of undisturbed strata, because the tests are necessarily conducted on remolded samples after destruction of all the essential geological features. Variations in in situ and large sample test values will occur in depth with variation in major stratification and all testing should be preceded by visual examination of continuous cores which may be 2 in. in diameter. The drainage of the mass may be dominated by specific permeable layers. Sand drains are effective in deposits with coefficients of consolidation of the order of 100 sq ft/year or less, as may apply to laminated lacustrine clay deposits with only occasional silt dustings, organic, nonlayered clays under medium to higher effective stress, and uniform clays. Where sand drains are to be used, the driven mandrel method of construction induces excess pore pressures during driving, increases settlement, and remolds the clay around the drain.

20. Meade, Robert H. FACTORS INFLUENCING THE EARLY STAGES OF COMPACTION OF CLAYS AND SANDS, A REVIEW. Journal of Sedimentary Petrology (Dept. of Geology, Rensselaer Polytechnic Institute, Troy, N.Y.), Vol. 36, No. 4, pp. 1085-1101, Dec. 1966. HR Abstracts, July 1967.

Petrologic and geochemical factors strongly influence the compaction of clays and sands under pressures between 0 and 100 kb/cm^2. Particle size is the most pervasive of these, both in its consistently inverse relation to porosity and its control of the influence exerted by the other factors. The water content of saturated clays is a complex function of the physicochemical influences on the sorption of water on clay-mineral surfaces. It seems to be directly related to specific surface increase, exchangeable cation valence and the concentration of interstitial electrolytes in most clays.

Preferred orientation of clay-mineral particles seems to develop at a very early stage of compaction, at pressures near 1 kg/cm^2. Development is enhanced by greater initial water contents, greater amounts of carbonaceous organic matter, and perhaps by lesser concentrations of interstitial electrolytes. A tendency to be compressed into domains or submicroscopic oriented aggregates may be typical of fine-grained clays mixed with concentrated Na solutions or solutions of other cations. Well sorted sands have greater porosities than poorly sorted sands. Angular sands have greater initial porosities and are more compressible than rounded sands of the same size. Admixtures of platy mica particles increase the porosity, compressibility, and elasticity of sands.

21. Beredugo, Y. O. AN EXPERIMENTAL STUDY OF THE LOAD DISTRIBUTION IN PILE GROUPS IN SAND. Canadian Geotechnical Journal (c/o Civil Engineering Dept., Univ. of Toronto, Toronto 5, Canada), Vol. 3, No. 3, pp. 145-166, Aug 1966. HR Abstracts, April 1967.

A series of model tests was conducted to determine the distribution of load among piles grouped in sand. The effects of initial sand density, pile roughness, driving order, spacing, and the position of the pile in the group on the load distribution were studied. The results showed that for small loads the load distribution was random. As the load increased, the distribution was governed mainly by the driving order, but as the ultimate group load was approached the effect of driving order diminished and the position of the pile in the group became the predominant factor on which the load distribution depended.

22. Parsons, A. W. AN INVESTIGATION INTO THE EFFECT OF VARIATIONS IN THE DRYNESS OF THE SAND USED IN THE SAND-REPLACEMENT TEST. Roads and Road Construction (147 Victoria St., London SW1), Vol 44, No. 521, pp. 125-127, May 1966. HR Abstracts, February 1967.

This article describes an investigation into the effect of variations in the dryness of the sand used in the British standard sand-replacement test on the accuracy of the determination, in situ, of the density of compacted soils and road-base materials. During a number of major road projects the dry density.

of cement-bound granular base materials, determined by the sand-replacement test procedure, differed significantly from that determined from cores cut from the compacted bases. The accuracy of the sand-replacement test depends on the extent to which the bulk density of the sand, determined during calibration, holds when the sand is used to fill the density hole. The dryness of the sand is a factor likely to affect its bulk density. The investigation described in this article was made to determine its significance.

23. Brown, B. W. and Welby, C. W. IMPROVEMENT OF SANDS AND GRAVELS FOR USE WITH ASPHALT. University of Southern Mississippi (Hattiesburg, Miss.), Dec. 1965. 57 pp. HR Abstracts, September 1966.

The purpose of this investigation was the evaluation of various commercial surfactants as aids in the bonding of asphalt to Mississippi quartzose gravels. An air-bubble technique was proposed to investigate the relative effects of possible surfactants.

Hysteresis effects made the air-bubble technique of doubtful use. However, a sessile drop method was developed, and it appears to provide a technique for rapid quantitative evaluation of surfactants.

The various types of quartz behave similarly when treated with a surfactant, and thus it is possible to study the surfactant effects using a standard piece of quartz.

Several amines were investigated, but theory shows that these compounds will deteriorate with time under natural conditions and will not solve the asphalt bonding problem. However, theoretical considerations point to fluorocarbons as possible surfactants. In this investigation they were given only preliminary study and evaluation.

24. Prandi, E. INVESTIGATION ON CRACKING OF GRAVEL-SAND MIXTURES TREATED WITH GRANULATED SLAG. Bulletin de Liaison des Laboratories Routieres (58 Bd. Lefebvre Paris XV^{e}), No. 15, pp. 5-5 - 5-8, Sept.-Oct. 1965. (In French). HR Abstracts, August 1966.

Cracks caused by thermal contraction appear during cold periods on roadways built with gravel-sand mixtures treated with granulated slags. The occurrence of this damage depends on the ratio between the tensile strength and the value of Young's modulus. The paper describes the approach to the ratio: critical examination of the method used at the beginning which was based on the measurement of both properties, followed by calculation of the ratio. A new measuring method, more closely related to actual conditions, is described.

25. Evans, H. E. and Lewis, R. W. A THEORETICAL TREATMENT OF THE ELECTRO-OSMOTIC CONSOLIDATION OF SOILS. Civil Engineering and Public Works Review (8 Buckingham Street, London, W.C. 2), Vol. 60, No. 711, pp. 1495-1498, Oct. 1965. HR Abstracts, July 1966.

A theoretical treatise of the phenomenon of soil consolidation brought about by application of an electric potential is presented. Using the analogy between Terzaghi's empirical consolidation equation and a rheological model, an expression is derived of the settlement produced by electrophoretic migration of soil particles.

6. DePuy, G. W. EXPERIMENTS WITH THE ALKALI-SILICA REACTIVE CONSTITUENTS IN A SAND-GRAVEL AGGREGATE. U.S. Bureau of Reclamation. Presented at the Highway Research Board meeting, January 1966.

Experiments were conducted to investigate the effect of alkali-reactive particles in a Republican River sand-gravel type aggregate in cement-aggregate reaction. Cement-aggregate reaction refers to processes causing expansion, cracking, and early deterioration of concrete made with certain natural aggregates in the Kansas-Nebraska area. Alkali-silica reaction is involved, at least in part, since most of these sand-gravel aggregates are alkali reactive. The particles and testing the processed aggregate by the mortar bar expansion tests. As a control, the reactive particles removed from the Republican River aggregate were blended with an innocuous Platte River aggregate. These pilot tests indicate alkali-silica reaction to be a major factor in cement-aggregate reaction, but also note a remaining amount of expansion in the Conrow cycle test which apparently may be due to a cement-aggregate reaction characteristic of sand-gravel aggregates.

7. Weber, William G. EXPERIMENTAL SAND DRAIN FILL AT NAPA RIVER. California Division of Highways. Presented at the Highway Research Board meeting, January 1966.

Sand drains have been widely used in California to accelerate the consolidation of soft fine-grained soils. Difficulty has been encountered in predicting the action of sand drains during the design of these projects. The experimental fill at Napa River was constructed to obtain information on this action. It was found that sand drains did not accelerate the consolidation of the soft foundation soil as rapidly as the theory would indicate. The method of placing the sand drains with a closed mandrel appears to be the cause of this reduction.

8. Gray, J. E. and Bell, J. E. STONE SAND. National Crushed Stone Association (1415 Elliot Pl. N.W., Washington, D.C. 20007), Eng. Bull. No. 13, 1964, 70 pp. HR Abstracts, August 1965.

Since the publication of the original edition of this bulletin in 1936, the use of stone sand has increased to become commonly accepted in areas where it can compete on an economic basis with natural sand. Much of the data, information, and conclusions have been summarized and retained. However, much new data have been developed in the intervening period. Air entrainment has become a standard practice. Stone sand has found acceptance for use in masonry mortar, and the production of concrete block using stone sand has grown into an industry of tremendous proportions. Problems of slipperiness, involving certain sands used in pavements subjected to high-speed high-density traffic, have developed and have been solved largely through research conducted in the Association's laboratory. Pumping of concrete mixtures into otherwise almost inaccessible places has become commonplace, and recently completed research in this field at the National Crushed Stone Association has led to the development of apparatus for evaluating the pumpability of concrete mixes in the laboratory. New data have been presented on the thermal and chemical properties of different types of aggregates and new specifications are now in force. The Association has developed.

a method of test for particle shape of sand and the acceptance and use of this test method has insured better workability for cnncrete mixes. Data concerning these and other developments are presented in summary form to provide the basis for a more enlightened use of stone sand.

29. Robinsky, E. I., Sagar, W. L. and Morrison, C. F. EFFECT OF SHAPE AND VOLUME ON THE CAPACITY OF MODEL PILES IN SAND. Canadian Geotechnical Journal (Civil Eng. Dept., Univ. of Toronto, Toronto 5, Ont.), Vol. 1, No. 4, pp. 189-204, Nov. 1964. HR Abstracts, June 1965.

Load tests were performed on instrumented model piles, both straight-sided and tapered, driven into standard Ottawa sand in both loose and medium dense states. The distribution of load between pile points and walls and the overall pile capacities at various depths of embedment were studied. Tests revealed continuous changes in the intensity of unit load transfer through the walls as the piles were advanced. These changes, as well as the limited ability of the straight-sided piles to transfer large loads through their walls, are presumed to be the result of the development of a system of arching in the sand surrounding the piles. The most interesting, and as yet unexplained, results obtained in these tests revealed that all piles, straight-line relationships exist between embedded pile volumes and their capacities.

30. Alpan, I. ESTIMATING THE SETTLEMENTS OF FOUNDATIONS ON SANDS. Civil Engineering and Public Works Review (8 Buckingham St., London, W.C. 2), Vol. 59, No. 700, p. 1415-1418, Nov. 1964. HR Abstracts, May 1965.

An attempt is made to correlate the results of the Standard Penetration Test with the settlement of a 1-ft square loading plate and to estimate the settlement of a foundation from a model law.

Buildings to be founded on sand strata often cover a fairly large area and transmit a wide variety of loads to a large number of individual footings. As the mechanical properties of such strata are known to vary rather erratically, the most serious foundation problem for these buildings is that of differential settlements. A solution would obviously require the determination of the settlement of each footing. Even if an analytical solution were available, the determination of the required deformation parameters of the sand would involve sampling and testing operations of a quality and to an extent entirely prohibitive for any practical purpose.

The alternative approach is to carry out SPT soundings at all locations of interest and interpret them in the light of the available statistical correlations. The model law, relating test plate settlements to those of real footings, and the confining effects of the overburden pressure have been sufficiently verified to be used with confidence. Corroborative evidence may also be seen in the fact that whenever measured settlements were compared with computed ones, the former were found to be smaller.

31. Schmidt, B. and Kristensen, Pilgaard. THE PULLING RESISTANCE OF INCLINED ANCHOR PILES IN SAND. Danish Geotechnical Institute (Copenhagen), Bull. No. 18, 1964. 25 pp. HR Abstracts, May 1965.

Problems of skin friction on inclined tension piles in sand are considered. The behavior of the composite structure, consisting of a sheet wall directly anchored to inclined piles, is studied theoretically, and model tests on single piles and on the composite structure are described. Scale effects are eliminated by comparing results obtained from two different model scales. Semi-empirical formulas for the skin friction coefficient are developed. The composite action of the pile and the wall increases the skin friction coefficient of the pile by about 27 percent. The formulas are compared with field tests and results found in literature. A design method is given.

32. Janson, L. E. FROST PENETRATION IN SANDY SOIL. Kungl. Tekniska Hogskolans, Handlingar 231, Royal Institute of Technology, Stockholm, Sweden, 1964. 167 pp. Building Science Abstracts, Vol. 37, No. 11, Abst. 2091, p. 335, Nov. 1964. HR Abstracts, February 1965.

A method of calculating frost depth in sand, with particular regard to the annual thermal balance of the ground, is described. The equations are used to indicate the effect of porosity and moisutre content on frost depth. Frost depth generally decreases with decreased porosity, because moisture contents and frost resistance rise accordingly. Results show that between soil types of high capillary (frost heaving), where the flow of water to the freezing line occurs under capillary saturated conditions, and noncapillary coarser soil types, where gravitation is the predominant process, a further type can be defined. A characteristic of this type is that a considerable quantity of moisture, so far as frost depth is concerned, can be transferred in liquid phase to the freezing line under saturated conditions, i.e., despite low capillarity and great depth of groundwater table.

33. Cornforth, Derek H. SOME EXPERIMENTS ON THE INFLUENCE OF STRAIN CONDITIONS ON THE STRENGTH OF SAND. Geotechnique (The Institution of Civil Engineers, Great George Street, London S.W.1), Vol. 14, No. 2, pp. 143-167, June 1964. HR Abstracts, January 1965.

The plane strain apparatus developed at Imperial College, London, and the techniques employed to prepare the test specimens of sand are described briefly. The characteristics of Brasted sand sheared under plane strain conditions are described. The value of the intermediate principal stress in plane strain is considerably less than one-half the sum of the other two principal stresses.

The drained strengths of Brasted sand in plane strain compression tests are compared with strengths measured in triaxial tests at the same placement density. The strength-density curves have the same general shape but the plane strain strengths are always higher, the differences in strength increasing progressively from about $\frac{1}{2}^{\circ}$ in loose sand to more than 4° in the densest specimens tested. However, triaxial compression and extension tests agree approximately to a common strength-density curve. The ultimate strengths measured in plane strain compression tests are constant, irrespective of placement density, and have approximately the same value as those measured in triaxial compression tests.

The development of strength in an intergranular structure is discussed. Strain condition seems to be a major factor influencing the strength of sands.

34. Zak, John M. and Bredakis, Evangel. SAND DUNE EROSION CONTROL AT PROVINCETOWN, MASS. University of Massachusetts. Presented at the Highway Research Board meeting, January 1965.

Stabilization of sand dunes is discussed, showing results of methods most economical and feasible for the Provincetown area. Machine planting of beach-grass with a spacing of 18 by 36 in. and the use of fertilizer is an excellent method for revegetating dunes. Several species of grasses have been screened for direct seeding on dune areas. Panicum amarulum, tall fescue and weeping love-grass have produced satisfactory results. The use of various mulches in grass establishment for direct seeding has been of little value. Repairing and revegetating of dunes are discussed. Shrubs and trees for climax vegetation have been evaluated for dune plantings.

35. Beattie, R. B. FLEXIBLE PAVEMENTS BUILT ON SAND SUBGRADES IN THE PERTH AREA, WESTERN AUSTRALIA. Australian Road Research (60 Denmark St., Kew, E. 4, Victoria, Australia), Vol. 1, No. 10, pp. 30-48, June 1964. HR Abstracts, November 1964.

This report describes one phase of the evaluation of flexible pavements built on sand subgrades in the Perth area, Western Australia.

A laboratory study of laterite gravel pavements overlying a sand subgrade was made. The pavement-subgrade system was contained in a tank designed to simulate field conditions. The deformations under plate loads corresponding to the maximum permissible vehicle wheel loads were observed. The effects of pavement thickness, moisture content and density were investigated. The test results gave an optimum pavement thickness of 6 in. independent of all variables except sequence of construction.

Pavements made of other materials, including cement-treated gravels, were formed on the sand subgrade in the tank. The optimum moisture content for the treated gravels was determined on strength relationships derived from Hveem cohesiometer tests. An evaluation of the various pavements on a basis of deformation under the maximum permissible plate loads was made.

A field study of a laterite gravel pavement overlying a sand subgrade similar to the laboratory study was made. The deformations under vehicle wheel loads corresponding to the maximum permissible loads were observed. The deformations were measured using a Benkelman beam. The effect of pavement thickness was investigated. A 6-in. thick pavement was found to be adequate.

Reasonable agreement was reached between the field and laboratory tests when single-wheel loads equivalent to the field dual wheel loads were considered. Both the field and laboratory deformations of a 6-in. pavement were close to Hveem's limiting value of 0.05 in.

36. Shil'nikov, V. A. and Kublanova, M. B. THE STABILIZATION OF SANDY SOILS WITH CEMENT AT TEMPERATURES BELOW 0°C. Avtom. Dorogi (Moscow, U.S.S.R.), 1963, 26 (11) 11-13 (in Russian). Road Abstracts, Vol. 31, No. 2, p. 31, Feb. 1964. HR Abstracts, November 1964.

Research by the Leningrad branch of SOYUZDORNII has shown that stable foundations can be prepared at temperatures below 0°C from various cement-stabilized materials if appropriate quantities of calcium or sodium chloride are added. Tables and curves show the results of laboratory tests of cement-stabilized samples of various types of sand. Recommended proportions of either of the salts in total water content are 1.5 to 2 percent with 7 to 8 percent cement by weight at 5 to 0 C, 4.5 to 6 percent with 8 to 9 percent cement down to -5 C; 9 to 12 percent, with 9 to 10 percent cement down to -10 C; and 12 to 16 percent, also with 9 to 10 percent cement down to -15 C.

37. Mateos, Manuel. HEAT CURING OF SAND-LIME-FLY ASH MIXTURES. Materials Research and Standards (1916 Race St., Philadelphia 3, Pa.), Vol. 4, No. 5, pp. 212-217, May 1964. HR Abstracts, September 1964.

Mixtures of sand, lime, and fly ash were made from eight fly ashes and two limes and cured at 10, 22, 40, 60, and 120 C. Strength increased with temperature for all the mixtures, but there was much variation among the fly ashes. Dolomitic monhydrated lime gave higher strengths than calcitic hydrated lime at ambient temperature, but at temperatures of 60 and 120 C calcitic lime was always better. It appears that soil stabilized with lime and fly ash early in the summer should develop twice the strength of soil stabilized late in the summer.

38. McConnell, B. and McKisson, R. L. INVESTIGATION OF THE RESISTANCE OF ARKANSAS AND REPUBLICAN RIVER SANDS TO ALKALI-AGGREGATE REACTION AND FREEZE-THAW DETERIORATION. Bureau of Reclamation, Denver, Colo. BR D LR C1058. Aug. 26, 1963. 28 pp. U.S. Government Research Reports, Vol. 39, No. 8, p. 77, April 20, 1964. Available from Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C. Ad-428 487. $2.60. HR Abstracts, August 1964.

Results from alkali-reactivity and freeze-thaw tests are summarized. Results of petrographic examinations of concrete specimens and of physical properties tests performed on the test aggregates are appended. Concretes containing Republican River sand were somewhat more resistant to freezing and thawing than comparable concretes containing aggregate from the Arkansas River when these aggregates were used in combination with high-alkali cement, a quarried limestone coarse aggregate, or an innocuous natural coarse aggregate. However, when used in combination with a reactive coarse aggregate, the reverse was true. Results of the alkali-aggregate reactivity tests indicated sands from both sources are highly reactive.

39. Dell, Carol I. A STUDY OF THE MINERALOGICAL COMPOSITION OF SAND IN NORTHERN ONTARIO. Canadian Journal of Soil Science (176 Gloucester St., Ottawa 4, Canada), Vol. 43, No. 2, pp. 189-200, Aug. 1963. Canadian Building Abstracts, Abstract 436, p. 1, Dec. 1963. HR Abstract, July 1964.

A preliminary study of the mineralogical composition of the fine sand fractions of 51 samples of tills and stratified sands in northern Ontario was carried out. About 40 different minerals were identified in widely varying amounts. In all but a few samples, feldspar was the most abundant mineral while quartz was never the most abundant. Several deposits containing Palaeozoic limestone and dolomite fragments from the rocks of the James Bay lowlands were quite similar in composition to the calcareous southern Ontario deposits. Other samples, containing large amounts of pyroxenes, shale fragments or "greenstones," differed greatly from similar deposits in southern Ontario. The composition of the fine sand correlated well with the field classification of soils in this region, with a few exceptions.

40. Budnikov, P. P. and Zil'berfarb, P. M. THE KINETICS OF THE HYDRATION OF LIME AND LIME-SAND MIXTURES. Stroit, Materialy (Moscow, U.S.S.R.), 9 (9), 36-9, 1963. Chemical Abstracts, Vol. 60, No. 2, p. 1438h, Jan. 20, 1964. HR Abstracts, July 1964.

Results of studies of the effects of the addition of sulfite waste liquor, gypsum, $CaCl_2$, naphtha soap, and other substances to CaO in the process of hydration show that in cases where it is necessary to retard or accelerate it, effective control can be obtained. As an accelerator $CaCl_2$ is among the best due to the formation of the highly soluble oxychlorides of Ca. Sulfite liquor and naphtha soap are retarders although at the beginning they speed up the process of hydration.

1. Robinsky, E. I. and Morrison, C. F. SAND DISPLACEMENT AND COMPACTION AROUND MODEL FRICTION PILES. Canadian Geotechnical Journal (Civil Engineering Dept., Univ. of Toronto, Toronto 5 Ont.), Vol. 1, No. 2, pp. 81-93, March 1964. HR Abstracts, July 1964.

By means of radiography techniques the displacement and compaction of sand around strain gage instrumented model piles has been studied. Tests reveal a possible explanation for the low transfer of load through "skin friction" developed by a straight-sided pile, and the high transfer of load developed by the tapered pile. The limits of "visible" soil movement (displacement envelopes) have been found to exist between the magnitude of the displacement envelope and pile capacity, indicating interdependence of transfer of load through the pile point and pile wall.

2. Reddy, K. Ramaswany and Radkakrishnan, S. ROAD CONSTRUCTION PRACTICE IN SANDY AREAS IN MADRAS STATE. Journal of the Indian Roads Congress (Jamnagar House, Mansingh Road, New Delhi, 11, India), Vol. 27, No. 3, pp. 289-320, Aug. 1963. HR Abstracts, March 1964.

This article deals with the different methods followed and the developments made in the stabilization of sandy soils with a very small percentage of fluxed bitumen and lime or cement or lime-fly ash combinations for road construction in Madras State. The new techniques evolved, the design criteria adopted, the details of the laboratory experiments, and the field works carried out with cost comparison, etc., are discussed in detail.

Stabilization of sandy soil with addition of a small percentage of cement and lime-fly ash combinations mixed at optimum moisture content and then treated with bitumen has wide scope in roadmaking projects especially in the coastal areas where good roadmaking materials are not available economically. The main points are that a small percentage of either of the stabilizing material alone is not fully satisfactory but a combination of both gives satisfactory durability and stability. Hence it can be concluded that the addition of cement or lime-fly ash contributes necessary strength characteristics by hydration with water in the wet mix process, whereas the bitumen provides necessary cohesion and has a definite advantage than the addition of either alone.

3. Johnson, R. W. PHYSICAL CHARACTERISTICS OF SAND-SOIL MIXTURES UNDER REPEATED DYNAMIC LOADS. Dissertation Abstracts (University Microfilms, 313 N. First St., Ann Arbor, Mich.), 1962, 23, 2051. Journal of Applied Chemistry, Vol. 13, No. 8, p. ii-139, Aug. 1963. HR Abstracts, January 1964.

When the mixture is subjected to repeated loads there is a volume reduction and the structure change results in an increase in soil strength. The volume change is less if the soil is given a preliminary compression. There is a critical stress. The strength of these soils and the mechanism of failure are discussed.

4. Potter, Paul E. and Mast, Richard F. SEDIMENTARY STRUCTURES, SAND SHAPE, FABRICS, AND PERMEABILITY. Journal of Geology (University of Chicago Press, 5750 Ellis Ave., Chicago 37, Ill.), Vol. 71, No. 4, pp. 441-471, July 1963, HR Abstracts, November 1963.

Sand shape fabrics were related to direction of cross-bedding and parting lineation. Fabric direction was also investigated in a subsurface sand trend.

These studies indicate that in natural sandstones, as in artifically deposited ones, the long axes of sand grains statistically lie parallel to current direction and are imbricated up-current, generally at angles of 10°-25°. Variability in orientation is greater in horizontal thin sections than in those cut vertical to bedding. Clustering of sand-grain orientation was investigated with both parametric and non-parametric statistical tests and found to be negligible. Although exceptions do exist, there is a good correspondence between current direction, defined by cross-bedding and parting lineation, and fabric direction. This implies the likelihood of general, persistent, rational reactions between the depositional, constructional forms of sedimentary structures and the orientation of their constituent sand grains.

A two-dimensional method of measuring sandstone shape fabrics, utilizing photographs of thin sections, was developed and applied to 138 samples collected from Pennsylvanian and Chesterian (Mississippian) sandstones of the Illinois Basin.

A block diagram illustrates the monoclinic symmetry of three-dimensional fabric diagrams of grain orientation in sandstone.

5. Behnke, Jerold J. and Schiff, Leonard. HYDRAULIC CONDUCTIVITY OF UNIFORM, STRATIFIED, AND MIXED SANDS. Journal of Geophysical Research (1515 Massachusetts Ave., N. W., Washington, D. C., 20005), Vol. 68, No. 16, pp. 4769-4775, Aug. 15, 1963. HR Abstracts, November 1963.

Hydraulic conductivities and velocities for the lower limits of very coarse, coarse, medium and fine sands (U. S. Department of Agriculture classification), were determined from a model study using transparent plastic cylinders. In uniform sands, the velocity under 1.0 ft of surface head ranges from 43 to 2118 ft/day and the hydraulic conductivity ranges from 19 to 970 ft/day for the fine and very coarse sands, respectively. Velocity values in four successive stratified layers of equal thickness are essentially equal in magnitude and closest to those determined for the uniform, fine sand. The velocity in a stratified medium composed of a "limiting layer" of medium sand placed between two layers of very coarse sand was 10.4 percent of the velocity calculated for an equivalent thickness of the coarse sand alone. Hydraulic conductivity and velocity values in a mixture composed of 25 percent of each of the four sizes were nearly identical to the values determined from a uniform, fine sand. The velocity in a binary mixture composed of 65 percent very coarse and 35 percent fine is only 9.3 percent greater than the velocity for the fine sand alone. Values for other binary mixtures are included. Application of the data to the design and performance of recharge facilities is discussed.

6. Van Der Merwe, D. H. EXPERIMENTS ON THE STABILIZATION OF COLLAPSING SAND WITH SODIUM SILICATE. CSIR Research Review, South African Council for Scientific and Industrial Research (Pretoria, S. Africa), No. 49, p. 18, Jan. 1963. HR Abstracts, August 1963.

The properties of collapsing sands and their distribution in South Africa are given. The Langer and Hoosten methods of stabilization were tried in laboratory and field experiments. The Langer method was successfully applied in the field, but the compressive strengths obtained were very low. When the Joosten method was used, fairly high compressive strengths were obtained in testing small samples in the laboratory, but unfortunately the method holds little promise for practical application in the sand would make it difficult to get adequate penetration of the chemicals through the soil.

47. Mehra, S. R. and Natarajan, T. K. PRACTICAL LESSONS IN VERTICAL SAND DRAIN INSTALLATION. Journal of Indian Roads Congress (Jamnagar House, Mansingh Rd., New Delhi 11, India), Vol. 27, No. 2, pp. 163-195, Oct. 1962. HR Abstracts, July 1963.

Observations based on experience with the Vertical Sand Drain Installation in the Eastern Express Highway Project in Bombay are given. The different aspects, such as the interrelation between stability and settlement, comparison between computed and observed rate and magnitude of settlement, arching of granular fills on soft ground etc., are discussed.

Vertical sand drains represent an effective and reliable means of stabilization of soft deposits provided the design is based on proper methods of foundation analysis.

Certain clays (especially the plastic and insensitive ones) are found to have low creep strength. As such, it seems unsafe to rely merely on the strength value of the clay determined by conventional tests. Instead the creep strength should be used as the criterion in stability analysis. This is particularly important when the factor of safety with respect to stability (on the basis of conventional strength tests) works out to be as low as 1.3 or 1.4.

48. Sandover, J. A. ELECTRICAL DETERMINATION OF THE MOISTURE IN SAND. Proc., American Society of Civil Engineers (345 E. 47th St., N. Y. 17, N. Y.), Vol. 88, Journal of Construction Division, No. CO2, pp. 25-39, September 1962. HR Abstracts, June 1963.

The necessity for quality control in concrete points up the need of a method of instantly and continuously measuring the moisture content of the sand in the mix. The electrical gage described herein will register immediately the moisture content of sand or any similar inert granular material by means of the results are presented in graphical form.

The type of equipment described will be invaluable on building sites, particularly where it is important to maintain the high quality of the concrete.

49. Valente, Abel and Honigs, Earl. COMPACTION OF SANDS BY VIBRATION ALONE. University of Notre Dame. Presented at the Highway Research Board meeting, January 1963.

This research started as a continuation of the work of Lino Gomes. It has been found that the sand used in the original work can be compacted in a Proctor mold to the same density attained by Gomes (120.8 pcf) providing the critical frequency of 25 cps is used. Thus a way of determining the maximum and minimum densities (for relative density determinations) of one sand has been found. However, the 25 cps is not the critical density for other gradings and sands.

It has been found that the size of sand particles affects the time required for compaction at a given frequency. Larger particles compact in less time. Sands with higher specific gravities compact to greater densities during vibration. Sands with better gradings compact better under vibrations. The compaction of sands may depend on both amplitude and frequency of vibration. An attempt is being made to establish the relation between critical frequency and/or amplitude and such sand properties as grain size and specific gravity for use in field compaction. It is also indicated that the relation between depth of maximum density and tamper dimensions found by gomes, witth partly two-dimensional models, is true for three-dimensional models.

50. McCarthy, David F. COMPACTION AND COMPRESSION CHARACTERISTICS OF MICACEOUS FINE SANDS AND SILTS. Dames & Moore. Presented at the Highway Research Board meeting, January 1963.

Residual soils developed from metamorphic and igneous rocks frequently contain large amounts of mica. The presence of mica in soils is considered to be detrimental, because highly micaceous soils may be excessively compressive; however, the critical percentages of mica for various soil types have not been determined.

Laboratory tests on synthetic and natural micaceous soils indicate that soils containing less than 10 percent mica show no significant changes in dry density or compressibility. With increasing mica content, the dry density decreases and the compressibility increases. The presence of fine mica has a greater influence on compressibility than coarse mica. Correlation of results between synthetic and natural soils is very good.

51. Vesic, Aleksandar B. BEARING CAPACITY OF DEEP FOUNDATIONS IN SAND. Georgia Institute of Technology. Presented at the Highway Research Board meeting, January 1963.

Large-scale model experiments have been made to provide information on factors that influence bearing capacity of deep foundations in sand. Cylindrical and prismatical foundations of various sizes resting at different depths in homogeneous sand masses of different relative densities were loaded statically to failure. Special loading cells permitted separate registration of point and skin loads throughout the tests. Additional tests with models of sand colored in layers were made to study the mechanism of shear failure in the soil mass. The model experiments were accompanidd by standard laboratory tests for determination of physical characteristics of the soils used.

An analysis of shear patterns observed indicates that depending on relative density of sand, all three types of failure previously described in the literature may occur at shallow depths: general, local, and punching shear failure. However, at greater depths only punching shear failure occurs, irrespective of the relative density of the sand. Analyses of observed ultimate loads indicate that a fair estimate of bearing capacity can be made by assuming failure surfaces in accordance with observed shear patterns.

52. Lenczner, D. VARIATION OF SUBGRADE MODULUS WITH DEPTH OF SAND. Civil Engineering and Public Works Review (8 Buckingham St., London, W. C. 2), Vol. 57, No. 667, pp. 210-212, February 1962. HR Abstracts, October 1962.

A series of tests have been carried out to study the variation of subgrade modulus with depth of sand, using a rigid rectangular footing.

A new theory has been developed which relates the subgrade modulus of a long footing of constant width with the depth of sand on which it rests. This relationship should also hold for square footings. Experiments carried out on a rigid rectangular footing show good agreement with the theory.

3. Azmon, Emanuel. FIELD METHOD FOR SIEVE ANALYSIS OF SAND. Journal of Sedimentary Petrology (Society of Economic Paleontologists and Mineralogists, P.O. Box 979, Tulsa, Okla.), Vol. 31, No. 4, pp. 631-633, December 1961. HR Abstracts, September 1962.

A field method for the mechanical analysis of sand is attained by using a sieve and cylinder combination. The sand is passed through a nest of sieves, and the fraction remaining on each is measured in a graduate cylinder. This method is simple and rapid, and the results obtained are comparable with the settling tube analyses.

Comparing this method of measuring sand in a graduate cylinder with that of accurately weighing the sample on an analytical balance may give an erroneous impression that the latter method is more accurate than the former. But, considering the inherent errors due to collecting and splitting the sample and additional errors due to extrapolating a continuous cumulative curve on the basis of five or six points, it follows that the accuracy of reading the graduate cylinder is satisfactory. If a greater accuracy is desired it may be achieved statistically by collecting more samples rather than by refining the methods of collecting, splitting or graphing.

The two main advantages of the sieve and cylinder method, and the reason for resorting to it, are its simplicity of procedure and portability of equipment. It can be executed right on the beach or in the trunk of the car, and may be used with either dry or set sand. There is no need for a preliminary elimination of silt, as the silt is collected directly in the pan. If individual fractions must be examined, in order to determine carbonates, glauconite grains, of heavy mineral grains for example, this can easily be done by keeping the fractions separated. Lastly, in the sieve and cylinder method both the sorting of the grains and the measuring of the fractions are based on one criterion--grain dimensions.

4. Bjerrum, L. Kringstad, S. and Kummenje, O. (Norway). THE SHEAR STRENGTH OF A FINE SAND. Proc., 5th Int. Conf. on Soil Mech. & Found. Eng., Paris, Vol. 1, pp. 29-37, 1961. (Available from Stechert-Hafner, 31 E. 10th St., New York, N.Y.), HR Abstracts, June 1962.

The author gives the results of a series of triaxial tests on a fine sand. Tests were carried out on drained and undrained samples, and the sand was tested in both dense and loose condition, but maximum attention was devoted to tests on very loose sand. Whereas the tests on dense and medium dense sand gave "normal" results, the tests on loose sand showed several unexpected results. The angle of internal friction was found to decrease rapidly as the porosity increased above 44 percent. In the undrained tests with pore-pressure measurements, values as low as 11 degrees were found in the very loose sand. Another characteristic property of the loose sand is the high pore pressures developed in undrained tests. The pore pressure parameter, A, was found to be as high as 2.7 in the very loose sand with initial porosity 47-48 percent.

5. Bally, Rene-Jacques L. and Antonescu, Ion P. (Hungary). THE APPLICATION OF ELECTRO-OSMOSIS TO SOIL STABILIZATION. Proc. 5th Int. Conf. on Soil Mech. & Found. Eng., Paris, Vol. 1, pp. 7-11, 1961. (Available from Stechert-Hafner, 31 E. 10th St., New York, N. Y.) (In French). HR Abstracts, June 1962.

The authors review the development of electro-osmosis in clay soils and its application to the consolidation of fine, silty sands with reference to work undertaken at the Institute of Applied Mechanics and then at the Institute for Hydrotechnical Studies and Research in Bucharest.

They consider that the hypothesis of Helmholtz is not adequate for the interpretation of the characteristics of electro-osmosis in clay soil, and taking into consideration their colloidal nature, additional hypotheses have been elaborated. These hypotheses offer to the re-orientation of the forces acting on the adsorbed water molecules under the influence of the exterior electrical field and to the unequal development of electro-osmosis in the soils owing to their heterogeneous microscopic nature.

The hypotheses were verified by outlining the phenomena and by studying the simultaneous effect of the hydraulic and electrical gradients upon the soils. There were also established certain electro-osmotical coefficients as well as their variation according to the nature of the soil.

Electro-osmosis has been applied to the consolidation of fine, silty sands ($k == 10^{-4}$. . . 10^{-3}cm/s) with the help of electro-silicification. The part played by the electro-osmotical phenomenon in the silicification process has been verified as well as the extent to which sand may be petrified. The method has been used in the stabilization of quicksands in mining galleries with very successful results.

The simultaneous application of the electrical current, the injection of solutions at the anodes and suction at the cathodes proved to be a very sound method of stabilization.

6. Friedman, Gerarld M. DISTINCTION BETWEEN DUNE, BEACH, AND RIVER SANDS FROM THEIR TEXTURAL CHARACTERISTICS. Journal of Sedimentary Petrology (Society of Economic Paleontologists and Mineralogists, P.O. Box 979, Tulsa, Okla.), Vol. 31, No. 4, pp. 514-529, December 1961. HR Abstracts, May 1962.

Criteria for the recognition of the depositional environment of sandstones are improtant in the reconstruction of paleoenvironments. Petrographic characteristics of recent sands from dune, beach, and river environments have been studied to determnne if there are mineralogical or textural characteristics which will permit diagnosing the environment of deposition. At present satisfactory depositional petrographic criteria are nonexistent. Since near-shore sands are shifted from one environment to the other, it is necessary to relate the petrographic characteristics to the terminal environment.

The mineralogy of elastic sediments for the most part seems to reflect the nature of the source rock, whereas textural parameters are chiefly related to the mode of transportation and energy conditions of the transporting medium. Grain-size distribution analyses represent a plot of abundance or frequency against grain-size. Dune sands commonly can be distinguished from beach sands on the basis of such plots. The distinction between the sand types can be numerically stated by computing the third moment (skewness) of the distribution curve. On the phi scale the third moment (skewness) for dune sands is generally positive, whereas that of beach sands in generally negative. This seems to hold whether the dune samples are from barrier islands, coasts, lakes, rivers or deserts. Beach sands of positive skewness occur on Padre Island, Texas, near the delta of the Rio Grande River, and on Horn Island, Mississippi. Sporadic positively-skewed beach sands have been found elsewhere, but for medium- to fine-and very fine-grained sands these appear to be relatively uncommmnn. Within the widely scattered samples a number of dune samples with slight negative skewness (-0.28 or less) have also been found. A plot of mean grain-size against third moment (skewness) results in an almost complete separation of the fields representing dune sands and beach sands. The sign of the skewness is not affected by the mineralogy of the sample. Sands of Quartz, carbonate, gypsum, and olivine all follow the same general rule.

The distribution curves of river sands like those of dune sands are generally positively skewed, but a number of exceptions to this rule have been noted. Within limitations, medium- to fine- and very fine-grained river sands can be distinguished from beach sands on the basis of plots of third moment (skewness) against standard deviation (sorting). The third moment (skewness) of coarse-grained sand is inconclusive as an indicator of depositional environment. Dune sands can commonly be distinguished from river sands by their sorting characteristics; dune sands tend to be better sorted than river sands. Since dune and river sands are skewed in the same direction, a further criterion is needed for distinguishing river from dune sands which have overlapping sorting characteristics. This has been found by separating the light mineral grains from those of the heavy minerals and determining the mean grain-size ratio of quartz and that of a specific heavy mineral in the same sand, such as garnet or magnetite. The ratio of the radius of quartz to that of a specific heavy mineral is usually larger for river sands than for dune sands.

Transportation of dune and river sands represents, for the most part, unidirectional flow. The upper size range of grains carried in suspension or by slatation is governed by the competency of the transporting medium. Such limitation does not affect fine particles in transport. The result of this limiting competency is reflected at the coarse-grained end of the frequency distribution curve by the lack of a "tail" usually present in a normal curve, resulting in positive skewness.

7. Hutchinson, B. and Townsend, D. SOME GRADING-DENSITY RELATIONSHIPS FOR SANDS. Proc., 5th International Conference on Soil Mechanics (Stechnert-Hafner, 31 E. 10th St., New York, N.Y.), Vol. 1, pp. 159-163, 1961. Road Abstracts, Vol. 28, No. 8, p. 173, August 1961. HR Abstracts, February 1962.

The effect of the grain size distribution of certain fine and medium sands on their maximum, standard compaction, and minimum densities is analyzed. The regression equations relating the grading of the sand to these respective densitiss are given and discussed. Although absolute limiting density tests have not been evolved, some important factors influencing these test techniques have been illustrated. Due to the arbitrary nature of the limiting density tests used in present investigations, any direct comparison between the physical properties of sands from various separate investigations is erroneous when only relative density data are reported.

8. Daniel, L. E. and Weber, W. G. MARSH AREA FILL: SAND DRAINS AID IN SOIL STABILIZATION. California Highways and Public Works (P.O. Box 1499, Sacramento, Calif.), Vol. 40, Nos. 9-10, pp. 74-79, September-October 1961. HR Abstracts, Feb. 1962.

There are still uncertainties in calculating the rate of consolidation and the resulting increase in strength of the foundation soil when using sand drains; that has resulted in some unsuccessful sand drain projects.

It was desired to conduct a test section to attempt to determine why sand drains have frequently not strengthened the foundation soil as anticipated. A comparison of areas with and without sand drains was desired to determine the amount that sand drains accelerate the consolidation of the foundation soil.

The following prerequisites were considered necessary for this experimental fill:

1. The test section should be part of a future construction.
2. Sufficient time should be available to construct the test fill and to have time to observe its behavior prior to completion of the project.
3. The height of required fill should vary from low enough to be stable without foundation treatment to high enough that it was questionable whether a stable fill could be constructed with sand drains.
4. The soil conditions should be sufficiently uniform so as not to present a variable.
5. The project should be in an area where construction would cause the minimum interference with traffic.
6. The site should be one where stabilization of the foundation soil would result in economic savings.

This experimental sand drain project produced several items of information of benefit to the design and construction of future sand drain projects.

1. The consolidation of the foundation soil in sand drain areas will occur at a slower rate than estimated from theoretical studies.
2. Sufficient time must be available to construct fills on soft soils at a slow rate. It may be necessary to construct fills on soft soils under separate contracts and utilize stage construction.
3. Wider struts will be required than had generally been used in the past.
4. With the slow rate of consolidation of the foundation soil sand drains may be required under struts as well as under the main fill.

59. Gomes, Lino. STABILIZATION OF BEACH SAND BY VIBRATIONS. Soil Testing Services, Chicago, Illinois. Highway Research Board Bulletin 325.

This report is concerned with the densification of a dry sand with almost weightless tampers operated mechanically at the sand surface at varying frequencies. Also investigated were procedures for determining the minimum and maximum densities of the sand to allow the determination of relative density after vibration. The sand used all passed the No. 4 sieve and all all retained on the No. 200 sieve (uniformity coefficient 4.35). The vibrations were applied by a modified radio loudspeaker.

The critical frequency was found to be 25 cps. The in-place density was found to be higher than D'Appolonia's and the maximum density occurred after 6-min vibration at a point some distance below the tamper face. Tables and plots were developed to show the change in density with time and tamper dimensions.

The following conclusions may be derived from the experiments:

1. Compaction of dry sand by vibration is controlled by the frequency of vibration and is the greatest at the critical frequency.
2. The critical frequency is the one that gives the greatest settlement of surcharge load.
3. Maximum compaction is not obtained immediately below the tamper, but at certain depth below the surface.

4. Percent compaction is a function of time.

5. Almost 100 percent compaction is obtained at the end of 6 min.

6. Surcharge is effective in transmitting the maximum compaction to lower depths.

7. The maximum depth and maximum width to which compaction is effective is an exponential function of tamper dimensions.

8. In evaluating the relative density and minimum laboratory density may be determined by using D'Appolonia's funnel method with no circular motion and no free fall, while the maximum laboratory density may be obtained by vibratory equipment used in this experiment run at critical frequency.

0. Parkin, Blaine R. IMPACT WAVES IN SAND: IMPLICATION OF AN ELMMENTARY THEORY. Proc., American Society of Civil Engineers (33 W. 39th St., New York 18, N.Y.), Vol. 87, No. SM4, Journal of the Soil Mechanics and Foundations Division, pp. 147-163, August 1961. HR Abstracts, November 1961.

The paper describes the general applications of vertical sand drains and the methods used in their design together with a detailed description of the successful use of the method beneath an embankment on the north approach to the Auckland Harbor Bridge.

The results of this work indicate that more time should be available for similar work in the future. The draining operations should be carried out as far as possible in dry weather in the summer season. More time should be allowed between the placing of the layers of filling, and further tests of the shear strength of the underlying mud should be made as filling proceeds. The placing of an overlaod and its subsequent removal would accelerate settlement.

It is recommended that hollow casing be pushed or driven down to the full length required before drilling in the mud to minimize mud flow into the holes.

In spite of the failure, the filling was in position and the carriageway sealed in time for the opening of the Harbor Bridge. Building up with hotmix has been necessary from time to time since then, but has been carried out with little interference with traffic.

On one occasion when the lift required would have been too expensive for the use of hotmix, a metal overlay was carried out to a maximum depth of 1.5 ft and the roadway resealed. Some inconvenience to traffic was caused but this was kept to a minimum and the traffic negotiated the length of roadway at all times during the operation. A further metal overlay and reseal will be necessary before final settlement is complete and this will be carried out in the same way.

Although difficulties have been experienced in this work, and the end result is not quite so good as hoped, the use of sand drains has enabled the work to be carried out, has considerably accelerated the rate of settlement, and has produced most of the results expected of it.

If further precautions are exercised as set out above it is considered that the use of sand drains in this type of construction is a successful method of dealing with the problem.

2. Hansbo, S. CONSOLIDATION OF CLAY, WITH SPECIAL REFERENCE TO INFLUENCE OF VERTICAL SAND DRAINS. Swedish Geotechnical Institute (Stockholm, Sweden), Proc. No. 18, 1960. 160 pp. Road Abstracts, Vol. 27, No. 12, p. 272, December 1960. HR Abstracts, July 1961.

Results are given of tests made in preparation for the construction of an airfield near Stockholm and a study is made of the consolidation problem as a whole. The chapter headings are: (1) Introduction. (2) Investigation of consolidation process by means of consolidometer tests. (3) Investigation of permeability of clay at small hydraulic gradients. (4) Consolidation of clay by drain wells based on new theory of permeability presented in Chapter 3. (5) Full-scale tests at Ska-Edeby. (6) Summary. (7) Appendix.

Chapter 5 includes a description of the test field and equipment, a geological description of the site, a geotechnical description of the clay, and sections on pore water pressure, flow of clay in lateral direction, vertical settlements, and the effect of driving of drains and consolidation on the undrained shear strength of clay. A bibliography is appended.

3. Meyerhof, G. G. COMPACTION OF SANDS AND BEARING CAPACITY OF PILES. Proc., American Society of Civil Engineers (33 West 39th St., New York 18, N.Y.), Vol. 85, No. SM6, Journal of the Soil Mechanics and Foundations Division, pp. 1-29, December 1959. HR Abstracts, May 1960.

Some laboratory and field investigations of the compaction of sands are analyzed in order to obtain information on the fundamental compaction characteristics, especially under impact. A method is developed to estimate the compaction of cohesionless soils near the shaft and base of driven piles and displacement caissins of the Franki type. The theoretical results are compared with field observations.

The author's previous bearing capacity theory of piles is extended to include the effect of compaction and greater friction angles of granular soils near the shaft and base. A method is suggested for estimating the settlement and allowable load of single driven piles and displacement caissons and of groups in cohesionless soils. The theory is compared with the results of some field observations.

4. Schaad, W. PRACTICAL APPLICATIONS OF ELECTRO-OSMOSIS IN FOUNDATION ENGINEERING. Bautechnik (Verlag von Wilhelm Ernst & Soh., Hohzenaollerndamm 169, Berlin, Germany), Vol. 35, No. 6, pp. 210-16; No. 11, pp. 420-9, 1958, (In German.) Road Abstracts, Vol. 26, No. 4, p. 76, April 1959. HR Abstracts, Nov. 1959.

This survey includes a historical review and examines the characteristics and principles of electro-osmosis and the practical application of electrokinetic procedures in foundation engineering. It is concluded that: (1) Electrical drainage methods extend the effective application of stabilization to those types of soil which cannot be drained by normal drainage procedures. (2) Electro-osmosis injection increases the range of stabilization to include soils of low permeability which cannot be treated with normal methods of injection. A bibliography of 46 references is appended.

5. Abramov, L. T. MOISTURE PROPERTIES OF NON-EXPANSIVE SAND LAYER IN ROAD FOUNDATIONS. Avtom. Dorogi (Moscow, U.S.S.R.), Vol. 22, No. 2, pp. 16-7, 1959. (In Russian.) Road Abstracts, Vol. 26, No. 6, p. 125, June 1959. HR Abstracts, October 1959.

An investigation has been made of the possibilities of using medium and fine-grained sands in road foundations. The test procedure is described in which samples were placed in inclined troughs measuring 13 yd by 3 yd. Data are tabulated on the coefficient of filtration, capillary rise and saturation level. Curves record moisture level and filtration coefficient relative to the thickness of the sand layer. Formulas are given for determining time required for the drying of soil and for freezing to a given depth.

6. Trask, Parker D. EFFECT OF GRAIN SIZE ON STRENGTH OF MIXTURES OF CLAY SAND, AND WATER. Bulletin of the Geological Society of America (Dr. H. R. Aldrich, Secy., 419 W. 117th St., New York 27, N.Y.) Vol. 70, No. 5, pp. 569-580, May 1959. HR Abstracts, September 1959.

Many factors affect the strength of what engineers call soil. This report deals primarily with the effect of the grain size of sand or silt particles mixed with the clay in the soil. In order to understand the effect of grain size, the influence of (1) water content, (2) type of clay mineral, and (3) ratio of clay to sand in the soil must be known. The effect of these 4 variables was the water content, clay types, clay-sand ratio, and grain size of admixed sand were changed from one experiment to another. For given water content, kaolin and illite are essentially equal in strength, and both are much weaker than montmorillonite. Ball Clay--a kaolin containing organic matter--is intermediate in strength. For all clays the strength increases, for given water content and given grain size, as the ratio of clay to sand increases. For given water content and given clay-sand ratio, the strength increases as the grain size of the sand decreases below 135 microns. For coarser sand, grain size has little effect. The cause of the greater strength for increasing fineness of sand is ascribed to the well-known principle of greater surface area upon which forces can act.

7. Allely, B. H. and Newland, P. L. SOME STRENGTH PROPERTIES OF WEAK-GRAINED SANDS. New Zealand Engineering (New Zealand Institution of Engineers, Technical Publications Ltd., C.P.O. Box 1001, Wellington, N. Z.), Vol. 14, No. 4, pp. 107-110, April 15, 1959. HR Abstracts, September 1959.

Drained triaxial tests on weak-grained sands are described. A considerable reduction in the angle of shearing resistance and volume expansion during shearing has been measured for tests carried out with increased confining pressure. This is in contrast with usual findings with strong-grained sands. The effect has been attributed to the shearing of weaker grains to higher confining pressure.

8. Karttunen, Toivo and Sneck, Tenho. INFLUENCE OF SAND CONTAINING HUMIC COMPOUNDS ON STRENGTH OF CONCRETE. Nordish Betong (Stockholm, Sweden), Vol. 2, No. 4, pp. 389-396, 1958. (In Swedish.) American Concrete Institute Journal, Current Reviews, Vol. 30, No. 11, p. 1231, May 1959. HR Abstracts, July 1959.

The sodium hydroxide test for organic impurities ignores the chemical nature of such impurities. Therefore, a sand which yields a negative reaction can be potentially undesirable. The paper reviews some investigations dealing with the mechanism of the action of humus. Forsen has shown that humic substances may act as accelerators in the presence of alkalies. The author believes that this effect may be due to the effect of inorganic salts present on the surface of humic sand. It is pointed out that a more reliable test method is needed.

9. Dogra, R. N. and Uppal, I. S. CHEMICAL STABILIZATION OF SAND AND SANDY SOILS. Journal of the Indian Roads Congress (Jamnagar House, Mansingh Rd., New Delhi 2, India), Vol. 23, No. 1, pp. 161-172, November 1958. HR Abstracts, May 1959.

Laboratory investigations have been conducted to find out the suitability of sodium silicate as a stabilizer for sand and sandy soils as compared to the use of cement. It has been found that in the case of pure sand and non-plastic soils, use of even low quantities of sodium silicate gives better strength to the stabilizer mass than the use of higher quantities of cement. Use of sodium silicate also imparts better resistance to abrasion than the use of cement.

0. COMPACTION OF SAND FILL IN AN EXISTING EMBANKMENT. Journal, Institution of Engineers, Australia (Science House, Gloucester & Essex St., Sydney, Australia), Vol. 30, No. 12, p. 352, December 1958. HR Abstracts, May 1959.

The installation of a terminal silo for the Queensland State Wheat Board at Pinkenba, near Brisbane, involves the construction, around the bulk storage, of an embankment 15 ft high and over 500 ft long. The material used in this embankment is river-dredged sand almost entirely contained between the No. 14 and No. 25 B.S. sieves.

1. Hart, E. G., Kondner, R. L. and Boyer, W. C. ANALYSIS FOR PARTIALLY PENETRATING SAND DRAINS. Proc., American Society of Civil Engineers (33 W. 39th St., New York 18, N.Y.), Vol. 84, No. SM 4, Journal of Soil Mechanics and Foundations Division, Pt. 1, p. 1812-1--1812-15, October 1958. HR Abstracts, February 1959.

A numerical method of analysis for partially penetrating sand drains, giving highly accurate results regardless of drainage conditions, has been developed. The linear approximation, which gives reasonably accurate results, has also been proposed.

An illustrative problem has been presented and laboratory model studies conducted to substantiate the above proposals. The sections of the drain nearest the surface and nearest the bottom of the layer contribute least to the consolidation. If a drain is extended only a short distance into the layer it will barely affect the consolidation, but if a drain is extended nearly to the bottom of the layer it will give more consolidation per foot of drain than a completely penetrating drain.

This indicates that partially penetrating drains could be of economic advantage in some cases. However, for any particular design, a complete analysis would be necessary to determine the feasibility of using partially penetrating sand drains.

2. Chadda, L. R. and Aggarwal, H. R. SAND BITUMINOUS STABILIZATION FOR ROAD CONSTRUCTION. Journal Indian Roads Congress (Jamnagar House, Shahjahan Rd., New Delhi 2, India), Vol. 22, No. 3, p. 527-38, 1957. Road Abstracts, Vol. 25, No. 5, p. 102, May 1958. HR Abstracts, November 1958.

Laboratory tests have been carried out to determine the suitability of cutback bitumen, tar and bitumen emulsion for stabilizing sand in the construction of base courses in sandy regions. The best results were obtained with RC-3 bitumen, used at the rate of 5 percent. Fine-grained sandy soils were more suitable than sand.

3. Uppal, I. S. REDUCING THE CAPILLARITY OF SAND BY CHEMICAL TREATMENT. Indian Concrete Journal (Cement Marketing Co., 121 Queens Rd., Bombay 1, India), Vol. 30, No. 8, pp. 261-263, August 1956. HR Abstracts, March 1957.

During investigations on surface-active agents for use in soil stabilization recently carried out by the author in the Karnal laboratory, it was observed that the addition of small quantities of anionic surface-active agents such as sulfated vegetable oils and soap to sandy soils considerably improved their water resistance and compressive strength, besides reducing shrinkage on drying. The effect of these agents on silty and clayey soils was not so appreciable, thus indicating that the beneficial effect of these agents on sandy soils was mainly due to the large proportion of sand contained in them. It was, therefore, considered desirable to study the effect of these surface-active agents on the water resisting property (capillarity) of clean sand. The effect of the two most common anionic surface-active agents (sulfated castor oil and soap) was studied on three types of sand.

The treatment can find application in the damp-proofing of floors and in the construction of roads in waterlogged areas where a thick layer of sand (6 to 12 in.) is generally recommended below the structure to reduce the capillary rise of water. Instead of this thick layer, a 1 1/2- to 2-in. layer of coarse sand treated with 0.1 to 0.2 percent soap can be used much more effectively. In the building industry, the use of treated sand will yield more water resistant mortar and concrete, requiring less water to bring it to workable consistency, and resulting in better strength.

4. Eide, O. BEARING CAPACITY OF PILES IN SAND. Norwegian Geotechnical Institute (Oslo, Norway), Publication 18, 1956, 15 pp. (English summary). HR Abstracts, March 1957.

In order to determine in a simple and approximate way the required length of piles in sand, the Norwegian Geotechnical Institute perform dynamic penetration tests by driving 32-diameter steel rods using a hammer weighing 75 kilo. The driving resistance is shown diagrammatically by plotting, for different depth, the ratio of the weight of the hammer times falling height to the settlement per blow.

By applying a torsional moment to the steel rod, the frictional resistance is determined and, from a calculation of the static bearing capacity given by a pile formula, a measure of the point resistance is obtained. Another simple and more reliable procedure for calculating the bearing capacity of piles in sand is to perform loading and pulling tests on the steel rod at different depth, and so obtain the point resistance and the frictional force.

For larger and more important investigations, deep sounding has been employed, the point resistance being measured by electric resistance strain gauges.

A theoretical calculation of the bearing capacity of piles, by determining the angle of friction and the density of the sand, is based on N_q values given by A. W. Skempton, and on the frictional force calculated according to Hansen.

Skempton's empirical curves of the ratio settlements of a pile group to settlements of a single pile, for the same load per pile, are also recorded.

Three cases treated by the Norwegian Geotechnical Institute are recorded, in which it has been possible to compare the various methods of calculating the bearing capacity of piles in sand, and also the ratio settlements of a loaded pile group to settlements of a corresponding test pile.

At a factory building at Notodden, the ratio of settlement of a pile group to settlement of a corresponding test pile has been found to vary between 8 and 20

At a silo in Larvik, a calculation of the bearing capacity of two concrete piles based on loading and pulling tests on a steel rod was in close agreement with loading tests on the concrete piles. A theoretical calculation of the bearing capacity of the concrete piles based on the angle of friction of the sand determined by triaxial tests, gave a result 93 percent on the unsafe side.

In the three cases, the pile formula gave very good results for a number of wooden piles, but for the two concrete piles the formula gave values 72 percent on the unsafe side.

A calculation of the vertical settlement due to elastic deformation of a wooden pile under a loading test for a silo at Trondheim, showed that the frictional force along the pile must be about 50 percent greater than that calculated according to Hansen. This is not surprising, however, as the wooden piles were conical. Loading tests showed that for the load sustained by the piles in the foundation the settlements of the test piles were due only to the elastic deformation of the pile itself and not due to settlement of the pile point. In this case, the ratio of settlement of pile foundation to settlement of correspondi single pile was about 17.

75. Eastwood, W. THE BEARING CAPACITY OF ECCENTRICALLY LOADED FOUNDATIONS ON SANDY SOILS. The Structural Engineer (England), Vol. 33, No. 6, pp. 181-187, June 1955. HR Abstracts, October 1955.

In the past it has been usual, when designing eccentrically loaded footings, to assume that the pressure distribution across the base of the footing would be linear and that the maximum value of the pressure must be limited to that permissible under centrally loaded footing.

Recently, however, Meyerhof has suggested that a more-valid approach is to treat the eccentrically loaded foundation as if it were centrally loaded but had a width equal to the actual width less twice the eccentricaty. The results of experiments on small-scale-model footings are reported which appear to confirm this hypothesis. For footings on sand the Meyerhof theory gives somewhat smaller ultimate loads than the older theory except at small eccentricities.

At the time the Meyerhof paper was published, the author was investigating the effects of eccentricity on strip footings on sand. His experiments on larger scale models gave results which are not in agreement with Meyerhof's findings, and the object of this paper is to report the results of these experiments and to postulate a possible reason for the disagreement.

The author's tests have also indicated that there may not be an ultimate load in the accepted sense if the footing is completely restrained from slipping sideways. The load increases indefinitely with increasing penetration of the footing.

Tests on strip footings indicate that (1) the usual practice of assuming that there is a straight-line distribution of pressure under an eccentriaally loaded foundation; (2) the ultimate value of that pressure is the same as that under a centrally loaded foundation; and (3) the ultimate value of that pressure is the same as that under a centrally loaded foundation are sound for footings on sand and eccentricitires up to b/6. An alternttive hypothesis put forward by Meyerhof (in which the ultimate load for an eccentrically loaded footing is assumed to be equal to that for a footing of width equal to the actual width minus twice the eccentricity) does not agree so well with some of the experiments.

Footings on sand which are restrained from slipping sideways have no definite ultimate load, whether centrally or eccentrically loaded, there being no sudden drop of bearing power when slip surfaces are formed. When only partial restraint against lateral movement is allowed, there may be a well-defined ultimate load somewhat higher than that obtained with no lateral restraint of the footings.

76. Brebner, A. and Wright, W. AN EXPERIMENTAL INVESTIGATION TO DETERMINE THE VARIATION IN THE SUBGRADE MODULUS OF A SAND LOADED BY PLATES OF DIFFERENT BREADTHS. Geotechnique, Lond., 1953, 3 (9), 307-11. Building Science Abstracts, Vol. 27, No. 4, pp. 109-110, April, 1954. HR Abstracts, July 1954.

The object of the experiments described in this report was to determine the variation of subgrade modulus, k, with breadth, b, and especially to find whether this variation is of the same form as in circular-plate loading, namely, tending towards a limiting value with increasing breadth. This was in fact confirmed, the value of k being very high for narrow plates and falling off rapidly as b increases, becoming constant at and above b = 15 inches. The sand can only be regarded as a homogeneous, isotropic, elastic solid, provided that the least lateral dimension does not exceed the critical value of 15 inches for a rectangular plate and 24 inches for a circular plate. For practical plate-design where the beam breadth invariably exceeds 15 inches the limiting value of k (as determined by a circular-plate test) should be used. For narrower plates an empirical formula is given.

77. NEW ROAD-BUILDING PROCESS. Civil Engineering (London), Vol. 48, No. 563, p. 454, May 1953. HR Abstracts, July 1953.

Used extensively for the first time in a tropical area, a bituminous process known as wet-sand mix has proved a satisfactory answer to the many problems of roadmaking in Borneo.

First developed by the Shell Petroleum Company during the war, this process was used with success for rapid runway construction on U. K. airfields. More recent experience in Holland, Belgium, and France confirmed the practical value of wet-sand mix in roadbuilding. At Seria, to date, nearly 10 mi. (16 km.) or about 100,000 sq. yd (84,000 sq. in.) of road have been laid with this process and a further program is now under way.

The first stage consisted in the preparation of the roadbed, in most places entailing the removal of decayed vegetation. Sand was then transported from the shore by sand pump or other means to form an embankment at least 2 ft. above the highest level of the water table. Adequate side drainage was constructed in order to ensure a quick discharge of surface water during tropical rain storms. The wet-sand mixture, consisting of 91 percent sand, 4 percent hydrated lime as an actibator, and 5 percent special cutback bitumen, was then spread over the subgrade by rakes to a depth of 4 1/2 in. and was consolidated by rollers.

After a curing period of about 2 to 3 weeks, during which the roads received occasional rolling in addition to normal light traffic, a seal coat of cutback bitumen was applied and covered with a sand-and-crusher-fines mixture after which the roads were open to all types of traffic, including occasional trucks carrying 20-to-25 tons of material. This treatment proved to be adequate and satisfactory for the medium traffic roads, but in the case of roads carrying intensive heavy traffic, it became the normal practice to lay a 2 1/2-in.-thick chipping carpet, composed of 3/4 in. of wet gravel mixed with special cutback and lime, after a period of 3 to 6 mo. This carpet had an open-textured surface and therefore required a seal coat at an early date. This final coat consisted of a spray application of cutback bitumen covered with 1/2-in. chippings, obtained from the Seria crushing plant.

78. Bishop, A. W. and Eldin, G. UNDRAINED TRIAXIAL TESTS ON SATURATED SANDS AND THEIR SIGNIFICANCE IN THE GENERAL THEORY OF SHEAR STRENGTH. Geotechnique, Lond. 1950, 2(1), 13-32. Road Abstracts, Vol. XIX, No. 6, June 1952. HR Abstracts, July 1952.

The first part of this article is devoted to theoretical considerations. The second part presents the results of a series of undrained triaxial-compression tests on the medium-to-fine fraction of a sand from the Folkestone Beds near Brasted in Kent. These tests indicated that, under appropriate conditions, a granular soil having no true cohesion and a dilatant structure will exhibit zero angle of shearing resistance and will have the shear characteristics of a purely cohesive material with reference to total stresses; if a certain value of negative pore-water pressure is reached during shear, the soil ceases to behave in this way and an apparent angle of shearing resistance is measured.

79. Eastwood, W. A COMPARISON OF THE BEARING POWER OF FOOTINGS ON DRY AND INUNDATED SAND. Struct, Engr., 1951, 29 (1), 1-11. Road Abstracts, Vol. XVIII, No. 9, September, 1951, (London). HR Abstracts, February, 1952.

An account is given of an experimental comparison of the bearing power of narrow footings on dry and on inundated sand carried out at the University of Aberdeen. The observed mechanism of failure for circular, square, and rectangular footings differs from that suggested by other workers.

Observations of the progress of sinking and of the vertical and lateral movements of the footing suggest that: (1) the sand below the footing is extruded plastically, forcing the adjacent material obliquely upwards and outwards; (2) the theories of failure suggested respectively by Krey, Prandtl and Terzaghi demand bearing values much below those obtained experimentally on inundated sands; the values calculated by Prandtl and by Terzaghi for dry sand are above or below the experimental values according to the size of the footing, but the divergence is not great; Krye's values are about 25 percent below the experimental values; (3) for narrow and shallow footings on sand, the reduction in the ultimate bearing power effected by inundating the sand is less than 20 percent as compared with the 50 percent generally assumed; (4) the rate of increase of ultimate bearing power probably decreases with increasing width of footing, but this conclusion should be checked by experiments with a larger container; (5) the results obtained confirm Golder's conclusion that the ultimate bearing power of rectangular footings is independent of their lengths.

80. Mueller, Lt. JG. William A. ANILINE-FURFURAL BEACH-SOIL STABILIZATION. CEC, USN, Research Division, BuDock. U.S. Navy Civil Engineer Corps, Vol. 5, No. 54, May 1951. HR Abstracts, July 1951.

"Roads Rolled Out On The Run" is one of the more striking heads used by the popular press in describing the Navy technique of chemical soil stabilization. Although "on the run" is not an exact description, the BuDocks soil stabilization program has at last emerged from the crawling stage, and is gathering momentum with each passing day.

The May 1950 CEC Bulletin carried a brief report of the work being done for BuDocks by Dr. Hans F. Winterkorn, of Princeton. His work, along with coordinate work at Port Hueneme, has now reached a stage where more information may be given. Following is an historical account of the aniline-furfural beach-sand stabilization work of BuDocks.

The problem arose during our island-hopping invasions of World War II: How to get wheeled vehicles across soft beach sand in the first hours of an amphibious assault? The terrible toll paid for the tiny island of Iwo-Jima would have been greatly reduced if assault-force vehicles and artillery had been able to move away from the congested landing area.

The Marine Corps stated its problem briefly. They wanted the simplest, quickest, and most effective method of consolidating beach sands. During the initial stages of a landing, a 2 1/2-ton truck must be able to move over the sands with a load of 19,000 lbs. Later the heavier vehicles will be put ashore, and must be moved inland as quickly as possible. Ten thousand linear feet of stabilized roadway is a good estimate of the requirements for a unit landing operation. These considerations were the basis for BuDocks experiments in beach-sand stabilization.

These test results were the basis for planning the first field experiments at Port Hueneme. They also served to outline a research project sponsored by BuDocks at Princeton University and directed by Dr. Hans F. Winterkorn, then a professor at Princeton, and a pioneer in the field of chemical soil stabilization. The Princeton contract, running for 2 years, was directed toward developing at least one method of quick stabilization of ocean beaches by use of synthetic resins. Also studied were the effects of alinity and alkalinity of beach sands on several common types of stabilization. Only the first part of the investigation will be treated here.

In conjunction with the Princeton studies, the Naval Civil Engineering Research and Evaluation Laboratory conducted three series of field tests on Point Mugu Beach at Port Hueneme.

After the California trials, the mixer was shipped to the east coast for service evaluation by Naval Mobile Construction Battalion, No. 1 at Little Creek. However, before delivery, the mixer was taken to the Engineer Research and Development Laboratory of the Army Corps of Engineers at Fort Belvoir, Va. Operating for the first time in cohesive soil, the aniline-furfural technique and Wood Roadmixer were used to stabilize several 50-foot strips of low-bearing-value clay. Because of the cohesive nature of the soil, the vibrating compactor was replaced with a smooth-wheel roller.

A full evaluation of the Belvoir tests is not yet available. However, it is interesting to note that the clay strips at Belvoir supported a wheel load of 50,000 pounds several days after stabilization. This load was applied by the center wheels of a special loading cart of the Corps of Engineers.

Present BuDocks efforts in the field of aniline-furfural stabilization are directed along three coordinated lines:

(1) MCB 1 will evaluate the present Model 54 Roadmixer. The Civil Engineering Research and Evaluation Laboratory at Port Hueneme is continuing similar work. with duplicate equipment.

(2) In cooperation with manufacturers BuDocks is attempting to develop equipment that is militarily more suited to beach stabilization as a part of

amphibious operations.

(3) Under contract to BuDocks, Dr. Winterkorn is continuing work on the physics and chemistry of the process. Chemical effects of all types of beach soil on the reaction are being investigated. Also under investigation are suitable catalysts to control the setting time of the aniline-furfural resin, and modifiers to control the consistency of the finished product. Dr. Winterkorn is also preparing a simple manual for the use of Seabees.

The ultimate goal of all this research by BuDocks is to develop techniques and equipment with which amphibious forces can convert mixing beach soils into stable hard surfaces that will support the heaviest wheeled vehicles. The equipment will be light and agile; the process will be fast and sure under any conditions.

Chemical soil stabilization is now moving forward at a painfully slow gait. But if the progress of the next 3 years can match that of the past 3, the catch-head "Roads Rolled Out on the Run" may be more of an actuality than even the over-enthusiastic writer believed.

81. Pillsbury, A. F. EFFECTS OF PARTICLE SIZE AND TEMPERATURE ON THE PERMEABILITY OF SAND TO WATER. Soil Sci., 1950, 70 (4), 299-300. Road Abstracts, Vol. XVIII, No. 6, June 1951. HR Abstracts, July 1951.

With size fractions of acid-cleaned and washed silica sand, uniformly packed, saturated permeability appeared to be an exponential function of particle size. With the same inert sand, under conditions where there could be no activity of micro-organisms, variation of saturated permeability with temperature was wholly a viscosity effect.

82. SOIL COMPACTION STUDIES ON CLAYEY SANDS. Soil Compaction Investigation Report No. 2, Technical Memorandum No. 3-271, Corps of Engineers, U.S. Army, Mississippi River Commission, U.S. Waterways Experiment Station, Vicksburg, Mississippi, July 1949. HR Abstracts, October, 1950.

This report is the second of a series to be published on various studies made during a comprehensive investigation of soil compaction. The first of the series was reported in Highway Research Abstracts, November 1949.

Five types of compaction eqiipment were used. They were: (1) 34,500 lb. D-8 tractor with contact pressure of about 8 psi. (2) Double drum American steelworks Model Ad-132 oscillating sheepsfoot roller having a 60 in. diameter drum and four 7-in. long, 7 sq. in. feet in a row and loaded with Baroid to produce foot pressures of 250-, 500-, and 750-psi. with one row of feet in contact with the ground. (3) 10,000 lb. wheel load (rear wheels of DW-10 motorized tractor). Tire inflation pressure 60 psi. Contact pressure 64 psi. Contact area 155 sq. in. (4) 20,000 lb. wheel load (Model Super C Turnapull) tire inflation pressure 55 psi. Contact pressure 65 psi. Contact area 308 sq. in. (5) 40,000 lb. wheel load (32 cu. yd. Turnapull) tire inflation pressure 57 psi. Contact pressure 60 psi. Contact area 580 sq. in.

The soil was described as a silty clay consisting of 8 percent sand, 65 percent silt and 27 percent clay sizes. It had a L.L. of 37, P.I. of 14 and Sp. Gr. of 2.72. The maximum density (AASHO) was 105.3 and (AASHO modified) 116.8 and optimum water content of 17.9 (AASHO) and 14.8 (AASHO mod.) CBR values, unsoaked condition at optimum and maximum density were 11 and 65 percent respectively for the two compactive efforts.

The report presented the following summary and conclusions for the silty clay:

a. The following maximum dry densities, expressed as a percentage of modified AASHO density, were obtained in fills built in 6-in. lifts, with six passes of the compaction equipment:

10,000-lb wheel load	92-94%
20,000-lb wheel load	92-93%
40,000-lb wheel load	93-94%
250-psi sheepsfoot roller	92%
500-psi sheepsfoot roller	91-92%
750-psi sheepsfoot roller	91-92%

A limited amount of data indicate that higher densities were obtained by additional passes of the 20,000-lb wheel load. The sheepsfoot roller did not walk out with an increasing number of passes.

b. Two passes of the 34,500-lb. tractor obtained 86-88 percent of modified AASHO density.

c. The optimum water content developed by six passes of the compaction equipment is 2 to 3 percentage points higher than that developed by a laboratory effort producing the same maximum density. The shapes of the field and dynamic laboratory compaction curves are similar; however, the field curve is shifted 2 to 3 percentage points nearer the zero air voids curve. This, at equal densities the field-compacted soil has higher water content and a higher degree of saturation.

d. A comparison of the optimum water contents as developed by six passes of the sheepsfoot and rubber-tired rollers with the optimum water content as develope in the laboratory by standard AASHO compaction is shown in the following tabulation:

Compactive Effort	Optimum Water Content
Standard AASHO	17.9
250-psi sheepsfoot	19.1
500-psi sheepsfoot	18.5
750-psi sheepsfoot	19.0
10,000-lb wheel load	19.2
20,000-lb wheel load	19.5
40,000-lb wheel load	19.1

e. Increasing roller weights did not result in increased maximum densities. It is possible, in the case of the sheepsfoot rollers that, due to the varying depths of penetration of the feet, little or no increase in contact pressure was actually obtained with increased roller weight. The rubber-tired equipment had a practically constant contact pressure, which is believed to account for the fact that higher densities did not result from the use of heavier equipment.

f. It has been indicated by this test that, generally, an appreciable difference exists in the CBR of a specimen compacted by field equipment a specimen compacted by conventional laboratory methods, even though the specimen being compared have identical water contents and densities. The reason is that even though the water contents and densities are equal the points being compared are at different relative positions on the compaction curves. Thus, it follows that the CBR, as determined by tests on undisturbed samples or field in-place tests, are not predicted satisfactorily from laboratory tests performed on material compacted in molds by conventional methods of static or dynamic compaction.

g. For this soil, at a given water content, the highest CBR is produced by the compactive effort for which the given water content is the optimum. Over Compaction reduces the CBR value.

h. The maximum CBR of soaked statically compacted specimens occurred at molding water contents 1 to 3 percent higher than optimum.

i. The CBR penetration curves for material compacted by sheepsfoot and rubber-tired rollers are very similar. However, the CBR penetration curves from material compacted in the field are not predominantly similar to either one or the other groups of curves obtained from dynamic or static compaction in hhe laboratory.

j. The shear strength as determined by triaxial compression tests for unsoaked samples at the same water content and density is practically the same for samples compacted in the field or in the laboratory by dynamic compaction. Samples statically compacted in the laboratory also had about the same shear strength as the field samples, except at the highest lateral load tested (σ_3 = 3.0 tons per sq. ft.) when the strength was somewhat lower.

k. For a design water content of approximately 16 percent, the moduli of deformation are approximately equal for dynamic and static compaction in the laboratory and for field compaction. At the water contents close to the field optimum of 19 percent, the moduli of deformation for rubber-tired and sheepsfoot rollers are nearly equal and are better approximated by statically compacted specimens than by dynamically compacted specimens. The latter had a modulus of deformation approximately 50 percent less than the specimens compacted by other methods.

83. COMPACTION STUDIES ON SAND SUBGRADE. Soil Compaction Investigation Report No. 3, Technical Memorandum No. 3-271, Corps of Engineers, U.S. Army, Waterways Experiment Station, Vicksburg, Mississippi, October, 1949. HR Abstracts, Oct. 195(

This report is the third of a series to be published on various studies made during a comprehensive investigation of soil compaction.

The compaction study consisted of compaction with the following types of equipment: 34,000 lb. RD-8 tractor; 80,000 lb. RD-8 tractor; and 7,000-, 15,000-, 35,000-, 60,000-lb. rubber-tired wheel load on sections under three moisture conditions. . .natural moisture, sprinkled, and ponded.

The soil consisted of a uniform medium to fine non-plastic sand (largely 20 to 100 mesh) with material passing the number 200 sieve ranging from 2 to 8 percent.

The report presented the following conclusions from the Eglin Field studies:

a. The compaction of the Eglin Field sand subgrade material to the minimum requirements for VHB (Very heavy bombers) paving requires the use of heavier equipment than ordinarily employed at Eglin Field in grading operations. Little, if any, increased compaction resulted from use of equipment of the same type and weight as used to grade the site.

b. The study indicates that wheel loads of 35,000 lb. will satisfy the minimum density requirements for VHB paving at Eglin Field, and that a tractor loaded to 80,000 lb. very nearly satisfied the requirement.

c. When six coverages of the compacting equipment do not obtain the desired degree of compaction, heavier equipment rather than more coverages is required. Very little, if any, improvement was noted when coverages in excess of six were used, but increased weight of compacting equipment showed considerable improvement.

d. The Eglin Field sand subgrade did not compact more readily when water was used, either by sprinkling or ponding; therefore the use of water as an aid to compaction is not justified. Since the free-draining soil conditions at the site of these tests did not permit a very high degree of saturation at any appreciable depth below the ground surface, the results did not indicate whether or not any benefit would result from complete or nearly complete saturation down to appreciable depths in the sand.

e. The results show that there is some difference in the two sands represented by the subgrade at Eglin Field and the subgrade at Auxiliary Field No. 2. Consequently, it is probable that lighter loads than those indicated in the Auxiliary Field No. 2 investigation may satisfy the VHB requirements at the main field.

In addition to the specific conclusions stated above, it is believed that the statements listed below are applicable, in general, to poorly compacted clean sand subgrades: (a) Appreciable compaction can be obtained to depths up to 5 ft. with wheel loads of 35,000 lb. or higher. (b) Weight of compaction equipment is more important in increasing density than additional passes beyond a reasonable minimum.

The principle photographs of equipment and graphical representation of results were included in the report presented in the Proceedings of the Highway Research Board, Vol. 25, pp. 393-398, 1945.

84. PROCESS MAKES SANDY BEACHES INTO PAVED HIGHWAYS. Technical Data Digest, Vol. 15, No. 4, April 1, 1950. (Central Air Documents Office Army-Navy-Air Force). HR Abstracts, April 1950.

An inexpensive method of quickly converting sandy beach strips into paved highways for amphibious landings on enemy shores has been developed by the Navy Bureau of Yards and Docks in cooperation with a Princeton University scientist, Dr. Hans F. Winterkorn.

The method, a chemical process which hardens beach sand within two to three hours, was developed at the request of the Marine Corps to help reduce the heavy loss of life in any future landings on enemy beaches.

Tests show that sand hardened by the process can support the weight of a slow-moving jeep within two hours and a seven-ton truck in three hours. After 24 hr., a truck with a gross load of 13 1/2 tons can make repeated runs without affecting the surface, it was found.

Material used in the hardening processes plentiful, and costs less than 16 cents per lb.

The new beach-stabilization method is a mixing and densification process performed in a single run over the sand with ordinary roadbuilding equipment. The operation can be completed at a forward speed of 12 ft. per dec., with the width depending on the capacity of the road equipment used.

Chemically, the process involves low-temperature condensation and polymerization of two liquids through the introduction of a catalytic agent. Because the rate of hardening can be controlled by the catalyst, the hardening times could be reduced by using a different catalytic agent.

The material now used was chosen because it is the most effective with ordinary roadbuilding equipment. But work is proceeding on the design of equipment which will permit faster stabilization.

85. Kondner, Robert L. RESEARCH ON THE USE OF ELECTRO-OSMOSIS IN THE STABILIZATION OF FINE-GRAINED SOILS. Highway Research Board Proc., Vol. 36, 1957, p. 783-793.

Previous application of electro-osmosis in the field of soil mechanics were primarily intended to increase the shear strength and stability of fine-grained soils to facilitate excavations and slope construction. The purpose of the present research was to investigate the basic phenomenon of electro-osmosis and to explore the feasibility of incorporating this method with the vertical sand drain method as an assistance in the consolidation of fine-grained soils for use in the field of highway construction.

Theoretical considerations of this combination of electro-osmosis and vertical sand drains (electro-drains) are presented.

To investigate the basic phenomenon of electro-osmosis and to obtain certain electrical characteristics of the soil needed in an electro-drain analysis, an instrument termed an electrosometer was constructed. Experimental results of this instrument, operating under various conditions, are also presented.

Relatively large-scale laboratory consolidation tests were conducted on a layer of swamp muck which was 2 ft in depth. These tests were conducted under a surcharge pressure, using the floating embankment, vertical sand drain, and electro-drain methods of stabilization. Comparisons between theoretical and observed values for both rate of settlement and rate of reduction of excess pore water pressure are given for each of these methods of stabilization. A comparison has been made of the effectiveness of the three methods. Some economic aspects of the problem are also discussed.

86. Gomes, Lino and Graves, Leroy. STABILIZATION OF BEACH SAND BY VIBRATIONS. Highway Research Board Bulletin No. 325, p. 44-54.

Stabilization of sands has been achieved by many methods, such as mechanical, chemical, addition of admixtures, grouting, and compaction. Of these methods, the most economical has been compaction, which can be achieved in many ways; for example, rollers, vibrotampers, and vibroflotation.

It has been reported that heavy duty pneumatic rollers imposing a pressure of about 150 psi have compacted sand to a depth of 6 ft below the ground surface. Vibrotampers, weighing 435 lb, operating at 2,100 cpm and producing a compacting force of 10,000 lb are reported to cause compaction of over 95 percent of modified AASHO on lifts up to 15 in. in one pass or two. The vibroflotation process, which imparts a centrifugal force of 10 tons at 1,800 rpm, is reported to compact sand up to a radial distance of 5 ft giving densities of 90 percent of optimum to depths in the range of piling.

Much laboratory research has been done on compaction of sands. One project conducted at the California Institute of Technology (1) by placing on the surface of a sand pit 10 ft square and 6 ft deep, an oscillator weighing 61 lb and driven at frequencies from 170 to 3,450 rpm led to the conclusion that the maximum compaction was obtained at resonant frequency involving several variables such as elastic constant of soil, vibrator dimensions, weight of vibrator, dynamic force, and base plate dimensions. Maximum density from 90 to 95 percent of Modified AASHO was obtained in a few seconds to a depth of twice the width of the oscillator.

The authors felt, after reviewing the field practice and laboratory research on the subject, that it would be profitable to investigate the compaction of sand with almost weightless tampers having several base plate dimensions and operated mechanically at the surface of dry sand at varying frequencies including the supersonic range. It was also decided to include some evaluation of the maximum possible laboratory sand density in view of the fact that though several methods have been suggested, none has been accepted so far as a standard.