

First Decade : 1970-1979

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The shear strength characteristics of the Recent normally consolidated marine clays in the major deltas and coastal plains of South East Asia are reviewed. The undrained shear strength increase parameters, c_u/σ' , are shown to increase with the distance from the coastline and are, generally, much higher than values quoted for the Recent marine clays in temperate climates. This is thought to be due to the pronounced secondary consolidation effect in these highly plastic and organic marine clays. A weathered crust has developed in surface horizons as a result of the weathering and leaching processes, and a classification into various crust types on the basis of undrained shear strength is proposed. Total and effective stress shear strength parameters at a number of sites in South East Asia are summarized.

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The results of swelling tests performed on remoulded, saturated, overconsolidated samples of a local clay in one-dimensional consolidometers are discussed here. The variation of swelling with time is observed for different equilibrium pressures and pressure-decrement ratios for a duration of two weeks. A linear relationship is obtained for the variation of swelling with the square-root of time for small values of time. For large values of time swelling is found to vary linearly with the logarithm of time for most of the test samples.

The experiments show that the swelling-time curve can be defined satisfactorily by the theory suggested by GIBSON and LO (1961) to explain the consolidation behaviour of clays. Values of the soil parameters are determined from the swelling tests and their behaviour with equilibrium pressures and pressure-decrement ratios are studied. The coefficient of secondary swelling is found to increase with increasing ultimate voids ratio and the variation is represented by a linear relationship.

Blast Tests at Ternughat Dam Site

SHAMSHER PRAKASH and MANI KANT GUPTA 41

Tenughat dam site, Bihar, India is likely to be subjected to earthquakes. Blast tests were carried out at the site, and laboratory tests were conducted on a horizontal vibration table at the School of Earthquake Research and Training, Rookee to ascertain the suitability of the Tenughat sand to withstand the anticipated ground shock without liquefaction and excessive settlement. Surface acceleration, pore pressure and surface settlement were measured in the field with distance from each blast point, and the maximum settlement and acceleration occurring in each case were found by extrapolation to the point of detonation. The field data obtained were assumed to be for a single cycle of loading and the effect of number of cycles was determined from laboratory tests. The possibility of liquefaction is discussed, and the total settlement expected in the lifetime of the dam has been estimated by correlation of the field and laboratory data.

Load Testing in the Bangkok Region of Piles Embedded in Clay

SOREN HOLMBERG 61

An analysis of the results obtained from load tests carried out in the Bangkok region on piles embedded in clay shows that it is possible to establish a relationship between the mobilized shaft friction, αs_u , and the *in situ* shear strength, s_u . The tests also give an indication of the ultimate point bearing capacity and suggest that only part of this is mobilized when failure starts to develop. Load tests carried out at different times after piling show that practically full bearing capacity is reached one week after piling. The tests yield enough information to help suggest the mechanism involved when a pile in clay fails.

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F. K. CHIN, A. H. ONG and H. C. LIANG 79

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The effect of the velocity of penetration on the dynamic resistance is also discussed and a method of plotting the experimental results is presented which will detect any confining effect of the soil container or any inconsistency in the soil.

Stability Investigations of the Whampoe Slip

S. B. TAN 95

This paper describes a slip in soft, blue clay along a length of the Whampoe River bank which had been excessively loaded with stacks of granite stones. A total stress stability analysis, based on undrained shear strengths obtained by field vane, is carried out for both the slip and the unloaded stable slope. The minimum factor of safety obtained for the slip is 0.97 and that for the stable slope is 1.45. The results show that the slide was caused by the external loading and that the ' $\phi = 0$ ' method of analysis gives a correct estimate of the stability of the river bank.

Vibration of Machine Foundation on Elastic Media

P. KARASUDHI, S. Y. SON and S. L. LEE 103

Vibrations of a long machine foundation are studied for which the excitation force caused by the unbalanced mass of the machine is frequency dependent. The medium supporting the foundation is assumed to be isotropic and elastic. The three modes of vibration involved are vertical, horizontal and rocking; the horizontal and rocking motions are coupled for this analysis. The response curves for the vertical motion contain one resonant peak, while two resonant peaks exist in the coupled horizontal and rocking motion. It is found that the foundation behavior depends heavily upon the operating frequency, foundation mass and dimensions, the Poisson's ratio of the medium having less influence. The results are presented in the form of charts to facilitate the analysis and design of actual foundations.

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Some Engineering Characteristics of Soils in the Vicinity of Kota Kinabalu, Sabah, Malaysia	Page
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Some engineering characteristic of soils found in the vicinity of Kota Kinabalu, Sabah, East Malaysia are described. The geology and geomorphology of the area is briefly noted. The characteristics of the soils are reviewed with reference to foundations, slope stability and general construction problems.

A Comprehensive Experimental Study of the Strength Characteristics of Remoulded Specimens of Kaolin

R. G. JAMES and A. S. BALASUBRAMANIAM **21**

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A Rigid Disc Embedded in an Elastic Half Space

R. BUTTERFIELD and P. K. BANERJEE **35**

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Undrained Shear Strength Characteristics of Sand

ALAGAIAH THURAIRAJAH and BRIAN LELIEVRE 101

The undrained deformation behaviour of a saturated sand was investigated under non-cavitating conditions using strain-controlled triaxial tests. Compression and extension tests were carried out, with back pressure, over a wide range of void ratio and consolidation pressure. At small strains, loose samples reached a peak deviator stress followed by a decrease in deviator stress to a minimum value. With further strain the deviator stress increased with shear strain at an increasing rate and a negative pore water pressure was developed. This unstable behaviour was absent in dense samples.

The limiting equilibrium states for the sand determined from undrained compression and extension tests are compared to investigate the failure criterion applicable to sand. The Mohr-Coulomb criterion describes failure much closer than the extended von Mises or the extended Tresca criterion. The angle of internal friction determined from extension tests for any void ratio is a few degrees higher than that determined from compression tests. Thus, the Mohr-Coulomb criterion underestimates the strength of soil in many field problems.

Analysis of Uncertainty in Settlement Prediction

J. NEIL KAY and RAYMOND J. KRIZEK 119

A method is presented to analyze the uncertainty associated with the settlement prediction determined by use of the conventional deterministic approach. Probability distribution functions, instead of individual values, are used for the variables in the formula to obtain a probability distribution function for the settlement due to primary consolidation. The distributions for soil properties are established from a statistical treatment of test results, while those for the stress parameters are deduced on a more subjective basis. The study is generalized by repeating the process for a large number of cases. Values calculated therefrom are then used in regression analyses to develop empirical equations which provide a measure of the uncertainty associated with a wide range of input parameters for this particular problem. Finally, these equations are represented in the form of nomographs which facilitate their usage.

**A Contribution to the Study of the Physico-Chemical
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MENSA D. GIDIGASU **131**

Studies have shown that the structure and engineering properties of lateritic soils are influenced considerably by weathering and by genesis. In this paper, an attempt is made to assess the significance of tropical weathering on the physico-chemical properties of two genetic soil types in Ghana. The study has revealed that the physico-chemical properties are of more significance in the siliceous, tropical, clay soils of the coastal zone than in the sesquioxide-rich soils of the forest zone. Correlation of base-exchange capacity and hygroscopic moisture content with clay content shows that the influence of the clay content on these properties is more pronounced for the poorly laterised soils. The differences in the relationships between the clay contents and the physico-chemical properties is attributed to the degree of laterisation (free iron coating of the clay mineral) and to the type of clay mineral in the soil types.

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For two embankments constructed on deep deposits of clay, comparisons are made between predicted and measured settlement, rate of settlement, horizontal movement and excess pore pressure dissipation. It is found that despite the apparent one-dimensional geometry of the embankments, a one-dimensional analysis underestimates the settlement, whereas three-dimensional analyses give reasonable agreement between measured and predicted settlement, rate of settlement and excess pore pressure dissipation. However, even such relatively refined analyses do not give good correlation between measured and predicted horizontal movements.

**Mechanistic Interpretation of the Compression
Characteristics of a Soft Marine Clay**

Z.C. MOH, E.W. BRAND and A.S. TEVES 21

The Bangkok Clay occurs as a thick, leached, marine deposit of low strength and high compressibility over the Chao Phraya Plain in central Thailand. The results of an extensive program into the one-dimensional compression behavior of the Soft Bangkok Clay are reviewed here. It is shown that this clay exhibits a relationship between void ratio and stress which is typical of a sensitive clay, and that this relationship is generally only little affected by pressure increment duration or pressure increment ratio. The clay deposit is virtually normally consolidated although some overconsolidation ratios slightly greater than 1.0 have been measured. The coefficient of consolidation decreases with increase in the consolidation pressure but becomes almost constant at high pressures; loading conditions have little effect on these measured values. The coefficient of secondary compression increases with consolidation pressure to a maximum before decreasing with further increase in stress; it is found that loading conditions play a significant role in the occurrence of secondary compression. An attempt is made to interpret the test results from a mechanistic point of view by consideration of the forces acting on the clay particles during the process of consolidation.

Effect of Pore Size Distribution Index on Bubbling Pressure

ANAT ARBHABHIRAMA and TON-TAI LIN 41

An equation is developed to represent the bubbling pressure of a porous medium as a function of measurable soil parameters and fluid properties. The soil parameters involved are porosity, characteristic grain diameter and a coefficient which is a function of the pore size distribution index and the residual degree of saturation of the medium. The theoretical relationship was verified by experiments.

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Drained Deformation Characteristics of Sand

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Deformation of sand when subjected to isotropic stresses was studied under loading and unloading conditions. A relationship between the elastic volumetric deformation and the ambient pressure is developed. Deformation behaviour of sand was also investigated by conducting strain-controlled drained triaxial compression and extension tests. A unique relationship exists between the rate of dilatation at failure and the void ratio for these two types of test. Comparison of the compression and extension tests shows that the Mohr-Coulomb criterion describes failure much closer than the extended von Mises or the extended Tresca criteria. The angle of internal friction determined from extension tests for any void ratio is a few degrees higher than that of the compression tests, except at the very loose state when they are equal. Thus, the Mohr-Coulomb failure criterion underestimates the strength of soils in many stability problems. The corrected deviator stresses, which represent the frictional component only, satisfy the Mohr-Coulomb failure criterion.

Pavement Design for Roads in Bangkok

F.H.P. WILLIAMS 105

An analysis of the subgrade strength for the soil conditions occurring in Bangkok is made from considerations of the soil suction characteristics of clays, the surcharge of the pavement structure and the water table. It is shown that this is not likely to be greater than 1.5% CBR. On this basis comparative designs for flexible and rigid pavements are developed using three widely used design methods for four levels of traffic. The differences between the pavement thicknesses given by the different design methods are discussed. It would appear that unreinforced concrete slabs should be marginally more economical than flexible construction. The machinery required is simpler and the construction lends itself to labour-intensive methods. An experiment is recommended to compare the comparative designs.

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Surface Area Determination of Clays

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Stability Charts for Inhomogeneous Soil Conditions

P.K. KRUGMANN and R.J. KRIZEK 1

Based on a $\phi = 0$ analysis with its associated restrictions, a direct search optimization procedure is used to develop a series of charts for evaluating the stability of a system in which a soft soil layer of infinite lateral extent is underlain by a firm substratum and overlain by a sloping embankment.

Traffic Induced Vibrations at Wat Po, Bangkok

J.D. NELSON and SUVIT VIRANUVUT 15

The Buddha image at Wat Po, Bangkok has begun to exhibit some cracking within the past 4 or 5 years. Because the primary consolidation should have been completed about 100 years ago, it was believed that the distress was caused by vibrations induced by heavy traffic on nearby streets. Measurements of the vibrations at various locations showed that the vibrations currently produced by the traffic were not of sufficient magnitude to cause structural damage. However, it is shown that the vibrations in the past could have been much greater than at present because of the poor condition of the roadway until recently. It is concluded that the structural damage was caused by either one or both of (i) deterioration of the ancient foundation structure, or (ii) settlements caused by a weakening of the soil structure due to the traffic induced vibrations.

Field Compressibility of Soft Sensitive Normally Consolidated Clays

YUDHBIR 31

An effort is made to predict field compressibility of soft, sensitive, normally consolidated clays by utilizing the Atterberg limits, natural water content and sensitivity values of the material. A relationship between the ratio of remoulded compression index to field compression index, liquidity index and sensitivity is developed. Values of compressibility estimated on the basis of the developed relationship show very good agreement with actual values of field compressibility for three soft, sensitive, normally consolidated clays.

The Relationship between Undrained Strength and Plasticity Index

A. SRIDHARAN and S. NARASIMHA RAO 41

The well-known linear correlation between linearly increasing s_u/p ratio and plasticity index in normally consolidated, undisturbed clays is critically examined. The relationship between s_u/p and I_p is studied with the aid of the data available from published literature. The results show marked deviations from the correlation proposed by SKEMPTON (1954). An attempt is made to explain the variation of s_u/p with I_p by means of theoretical considerations which relate s_u/p to A_f , K_o and $\bar{\phi}$. Results of isotropically consolidated undrained triaxial compression tests on seven remoulded clays with I_p values from 20 to 495% are reported. These results, along with other published data, show that s_u/p tends to decrease as I_p increases. A similar trend is obtained from theoretical analysis. The results also bring out the significant influence of A_f on the value of s_u/p . Since many factors such as soil structure, stress level and type of testing govern the undrained strength behaviour of normally consolidated soils, any attempt to relate s_u/p with I_p should give a band rather than a unique relationship.

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Load Distribution in Rectangular Footings on Piles

TONGCHAT HONGLADAROMP, N.J. CHEN and S.L. LEE 77

The interaction with the subgrade of rectangular footings resting on piles is studied in order to determine the distribution of column loads on the piles and the subgrade. The piles are treated as independent elastic springs while the subgrade is treated as an elastic half-space. The finite difference technique is employed in the solution of the problem. A parametric study is carried out by varying the parameters which characterize the properties of the piles and the subgrade. The results obtained indicate that the resistance of the subgrade has considerable effect on the settlement of footings and should be taken into consideration in the analysis in order to predict the elastic settlement more realistically.

Stress History Effects on Stress-Strain Behaviour of a Saturated Clay

A.S. BALASUBRAMANIAM 91

This paper summarizes data illustrating the effects of stress history on the stress-strain behaviour of remoulded specimens of kaolin tested in the conventional triaxial apparatus under stress controlled conditions. The effects considered are initial one-dimensional consolidation stress used in sample preparation, load increment, magnitude of isotropic consolidation stress prior to shear, and type of applied stress path. It is shown that these factors influence the deformation characteristics of a saturated clay. Methods which take account of these effects are proposed to correlate the test results. The results are useful in investigating the possibility of including these effects in the existing stress-strain theories.

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On Residual Shear Strength of Saturated Remoulded Clays

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Coupled Sliding and Rocking of Foundations on Layered Media RICHARD A. PARMELEE, RAYMOND J. KRIZEK and DINESH C. GUPTA	1

A two-dimensional, lumped-parameter model is used to investigate the steady-state coupled sliding and rocking behavior of an infinitely long, rigid foundation bonded to the surface of a linearly elastic, layered half-space. Wide ranges of soil properties, foundation dimensions, and thicknesses of the top layer are considered, and typical results are presented for the maximum amplitudes of the sliding and rocking oscillations and the frequencies at which these maximum amplitudes occur. The natural frequencies of the system with radiation damping are dependent on the shear wave velocity and Poisson's ratio of the half-space material, the geometric proportions of the foundation, and the thickness of the top layer. The total peak amplitude of vibration for the coupled motion is expressed in terms of a linear function whose coefficients are dependent on Poisson's ratio, the foundation dimensions, and the thickness of the top layer, and graphical relationships are presented to facilitate the determination of these coefficients. The results clearly illustrate that stratification of the soil may significantly affect the total peak amplitude of the foundation for a given exciting force, but this influence becomes negligible when the top layer is thicker than one and a half times the width of the foundation.

A Critical Study of the Uniqueness of State Boundary Surface for Saturated Specimens of Kaolin A.S. BALASUBRAMANIAM	21
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This paper is concerned with a detailed study of the uniqueness of state boundary surface for saturated specimens of Kaolin. Specimens of Kaolin prepared from a slurry were sheared from several isotropic stress states under a wide variety of imposed stress paths in a conventional axisymmetric triaxial apparatus under stress controlled conditions. The data corresponding to the state paths followed by over 25 test specimens are presented and discussed. The effects of several other factors such as the initial one dimensional consolidation stress used in sample preparation, the load increment size, the load increment duration etc. on the state boundary surface are also considered in detail.

Deformation of Statistically Heterogeneous Earth Structures

LELAND M. KRAFT, JR. and JIMMY YEW-HANG YEUNG 39

An analytical investigation of the statistical uncertainty of earth structure deformation is reported. Soil slopes are modeled as isotropic linearly elastic materials, but the elastic properties vary spatially in a statistically heterogeneous manner. This investigation illustrates the use of the finite element technique and statistical concepts to estimate the uncertainty of deformations by simulating soil heterogeneity with a random distribution of moduli properties for the elements. Three excavated earth slope angles and three embankment slope angles were analyzed with three coefficients of variation of the elastic modulus; two values of Poisson's ratio were used for the majority of the cases studied. The results of the analyses provide a quantitative measure of the uncertainty in the deformations, as influenced by spatial variations within earth structures. The advantages to be gained by analyzing the slopes in this statistical manner are suggested with the results of this study.

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Embankment Deformations due to Water Loads

J.R. BOOKER and H.G. POULOS 73

A number of solutions are presented for the deformations and stresses within an embankment subjected to water loading. For a homogeneous embankment, the influence of water level, embankment slope and Poisson's ratio is investigated. The influence of a central core is also examined, and is found to be relatively small for the cases considered. It is further shown that the solutions for a homogeneous embankment may be used to estimate the movements within an embankment in which the modulus varies.

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This paper summarises the method adopted and the local strains measured in cylindrical specimens of kaolin 1.5 inch and 4 inch diameter during one dimensional consolidation and subsequent isotropic consolidation. The local strains were measured by an X-ray technique where the strains were determined from the displacement of lead shot markers embedded in the clay. Since it is customary to prepare remoulded specimens of clay by one dimensional consolidation and subsequent isotropic consolidation prior to shear in the conventional triaxial apparatus, the results presented here will be of value in ascertaining the uniformity of the sample at the end of consolidation and prior to shear. From the local strains, local voids ratios are calculated and from these values pore pressure isochrones are determined. The results also indicated that for isotropic stresses of similar magnitude to the initial one dimensional stress, the strains induced by increments of isotropic stresses were anisotropic. However, for specimens which were isotropically consolidated to approximately three times the initial one dimensional stress the effect of anisotropy was found to be small.

Long Piles under Tensile Loads in Sand	
R.H.S. TAN and T.H. HANNA	109

The relationships between initial residual stress state along the length of a pile and volume change effects near to the pile walls are studied experimentally for piles in tension. It is shown that the mechanism of load development is not in agreement with any of the standard bearing capacity theories but agrees with concepts presented earlier by the authors. Data are given for piles of length/diameter ratio up to 110 as well as for piles with bells spaced along the length of the shaft.

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Strip Footings with Concentrated Loads on Deep Elastic Foundations

P.T. BROWN 1

Graphical results are presented for reaction, bending moment and displacement distributions, due to concentrated loads applied to smooth strip footings having a wide range of flexibility, which rest on a very deep homogeneous isotropic elastic foundation. Methods of interpolation between the graphs presented are discussed. The results given are for length/breadth ratio of 10 and transversely uniform reaction. Corrections to be applied for other aspect ratios and large transverse stiffness are also discussed.

A Critical Re-Appraisal of the Incremental Stress-Strain Theory for Normally Consolidated Clays

A.S. BALASUBRAMANIAM 15

The incremental stress-strain theory of ROSCOE & POOROOSHASB (1963) is presented (in a slightly different form) with respect to shear strains. A comprehensive series of stress-controlled triaxial tests was carried out and the results were compared with the predictions of the theory. The stress ratio-shear strain relationship of normally consolidated specimens sheared under undrained condition was unique and was independent of the consolidation pressure. Also, provided that the effect of the initial one-dimensional consolidation stress is absent, the state boundary surface is unique for all types of tests including anisotropic consolidation. During anisotropic consolidation, the strain increment ratio was a constant and the void ratio varied linearly with the logarithm of the mean normal stress (the slope of the line is the same as that for isotropic consolidation). The volumetric strains in all types of tests on normally consolidated clays may be successfully predicted from the state boundary surface as obtained from undrained tests. However, the shear strains may only be predicted for paths in which the stress ratio increases or remains constant.

Finite Element Analysis of the Effects of Installation on Pile Load-Settlement Behaviour

N.P. BALAAM, H.G. POULOS and J.R. BOOKER 33

A finite element analysis for an axially loaded pile has been developed in which the pile and soil are analyzed as separated bodies and equilibrium and displacement compatibility at the pile soil interface is then imposed to obtain a solution for the settlement of the pile. This analysis has been used to investigate the effects of installation of a pile on its load-settlement behaviour. Installation of the pile has been simulated by introducing a zone of disturbed soil around the pile, having different strength and deformation properties from the undisturbed soil.

The theoretical results indicate that the load-settlement behaviour of the pile is influenced by the nature and extent of the disturbed zone, but to a lesser extent than the ultimate load of the pile which depends almost entirely on the strength properties of the disturbed zone. For practical predictions of pile settlements, it appears adequate to use the theoretical solutions for a pile in a homogeneous soil with an equivalent constant Young's modulus. However, for detailed investigation of soil settlement distribution around a pile, it is essential to take account of the non-homogeneous nature of the soil arising from pile installation.

Measured distributions of soil settlement around a pile in London Clay are consistent with those predicted from the finite element analysis.

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Use of a Phenomenological Model to Analyse Soil Creep

L.P. DE AMBROSIS and H.G. POULOS 95

A phenomenological model of soil behaviour is postulated which reproduces the commonly-observed characteristics of a linear creep strain versus log time relationship and which appears to fit the observed undrained and drained behaviour of soil in triaxial tests. The model is used in an approximate analysis of the complete time-settlement behaviour of a circular footing on a clay layer. Theoretical solutions are presented to illustrate the effects on footing behaviour of the soil parameters and the ratio of footing radius to layer depth. Comparisons are then made between the results of a series of model footing tests and the behaviour predicted by the theory and reasonable agreement is found.

Analysis of Footings on Vesicular Laterite

P.V. JOHN and V.S. RAJU 119

A finite element programme was developed for the analysis of footing on vesicular laterite incorporating the strength and stress-strain laws arrived at by performing drained triaxial tests on undisturbed samples of the laterite. Footings of different diameters were analysed by the method. A number of plate load tests were carried out to compare the results. The agreement is good. The load-settlement curves show the influence of cementation at lower loads and crushing of the material at higher loads. The conventional method of bearing capacity analysis is not applicable to laterites. The limiting load carrying capacity is mainly controlled by settlement considerations.

An Efficient Method of Seismic Analysis of Structure-Foundation Systems

PISIDHI KARASUDHI, THAMBIRAJAH BALENDRA and SENG-LIP LEE . . 133

An efficient method is presented to analyse a structure-foundation system represented by a multi-story shear building resting on the surface of an elastic soil medium. Two types of soil-structure interaction are studied. Recognizing that the superstructure admits classical normal modes, the problem is reduced to the solution of two coupled integro-differential equations by which the effect of the number of these modes on the seismic response of the total system can be readily investigated. It is found that the first few of these modes are sufficient to produce a good approximation to the exact response. The effect of the Poisson's ratio of the soil medium is found to be significant when its shear wave velocity is low.

A Procedure for Estimating the Design CBR-Value of a Dune Sand

JACOB GREENSTEIN and MOSHE LIVNEH 155

The findings of the standard *CBR* test for granular material usually show values which are up to 5 times the field values. The latter are relevant for design purposes. Procedures adopted by several organizations recommend *CBR* values for dune sand, which are based on indicative properties and accordingly, the *CBR* values vary from 7% to 40%. It is obvious that this range cannot provide a reliable basis for design.

This paper proposes an alternative method for estimating *CBR* values for Israel's dune sands. It has been found, that the theoretical bearing capacity concept works for estimating *CBR* values. This concept, while modified by *in situ CBR* data, provides a basis for estimating Design *CBR* values. Finally, a relationship between the Design *CBR* value and uniformity coefficient is given, where Design *CBR* values of 7% and 14% correspond to uniformity coefficients of 1.1 to 2.6, respectively.

Vibrations from Pile Driving in the Bangkok Area

R. PETER BRENNER and BOONCHAI CHITTIKULADILOK 167

Vibrations due to pile driving by drop hammer were evaluated in terms of peak particle velocities for two sites in the Bangkok area. A large number of measurements were performed on the ground surface, below the surface and on structural elements of adjacent buildings. The results showed that the expected vibration levels as given by previous investigators are conservative for the Bangkok area. Measured vibration intensities in buildings were compared with various damage criteria and human sensitivity levels, and it was found that peak particle velocities were well below those usually tolerated for buildings in a good state of repair. Only in buildings which have undergone some differential settlement should special care be taken to avoid further cracking in weak elements such as panel walls. Attention should also be given to possible resonance effects. Recorded vibrations were well within a human sensitivity level of "clearly perceptible" or even "annoying".

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Some Geotechnical Aspects of Road Construction in Bangladesh	
TIMOTHY HUNT	1

The geology, geomorphology, hydrology, seismicity and climate of Bangladesh are briefly noted. The distribution of the soils and sources of natural construction materials are described. Their characteristics are reviewed with respect to road construction.

Prediction of Negative Skin Friction and Settlement in Piles due to Fill Surcharge

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The magnitudes of pile force and settlement of a compressible pile due to negative skin friction are presented in graphical forms for the purpose of design and analysis of such structures. Based on a rigorous elastic load-transfer theory, the problem is analysed in the form of a circular elastic rod embedded in a homogeneous soil layer, which is underlain by an ideal elastic substratum of infinite depth. The rate of development of pile force and settlement is related to the rate of consolidation of the embedding soil layer, in accordance with Terzaghi's one-dimensional consolidation theory.

The problem is decomposed into three systems, namely a consolidating top soil layer in the absence of the pile, an extended top elastic soil layer characterized by the elastic constants of the soil skeleton, and a fictitious pile designated by a Young's modulus equal to the difference between the Young's moduli of the real pile and the elastic soil skeleton. The unknown fictitious pile force is determined from the condition that the axial strain in the fictitious pile is equal to the summation of the vertical normal strain in the consolidating soil layer and the average vertical normal strain in the elastic soil layer over a pile cross-section at the original pile location. The real pile force is then obtained by integrating and combining the axial stress in the fictitious pile, the effective vertical normal stress in the consolidating soil layer, and the vertical normal stress in the elastic soil layer at the original pile location. The settlement of the pile is determined from the axial deformation of the pile, which can be obtained by integrating the axial strain in the pile, and the pile-tip settlement

Most existing methods of predicting negative skin friction in piles are confined to the case of end-bearing piles on a rigid substratum, whereas this paper allows the consideration of the compressibility of the substratum. Moreover, the proposed solutions could be applicable to the case of a group of closely spaced piles.

Torsional Vibrations of Embedded Footings

N.R. KRISHNASWAMY 47

A single-degree-of-freedom lumped parameter analogue with combined viscous damping and Coulomb friction damping is suggested to explain the dynamic response of embedded foundation-soil systems subjected to torsional vibrations. A method by which the constant frictional moment of the Coulomb friction damping can be evaluated has been described. The theoretical solutions are graphically presented in dimensionless form which can be readily used for purposes of design and analyses.

Field vibratory test data on concrete footings subjected to torsional vibrations, as reported by FRY (1963), are used to discuss the effect of embedment on the dynamic response. The measured responses of the embedded foundation soil system are found consistent with those predicted from the proposed theoretical model.

Behaviour of a Malaysian Residual Granite Soil as a Sand-Silt-Clay Composite Soil

W.H. TING and T.A. OOI 67

A Malaysian residual granite soil is studied as a sand-silt-clay composite soil. The shear strength parameters obtained using various methods of shearing are compared. Plate load tests were carried out on the soil and the results are compared with the predicted bearing capacity using shear strength parameters obtained from the various shear tests. Terzaghi's ultimate bearing capacity formula and Terzaghi's method for bearing on sand were used in the prediction of bearing capacities. It is necessary when using Terzaghi's methods to identify the granite soil either as a sandy or as a clayey soil.

Foundations in Coastal Margins

S. VONGVISESSOMJAI and S. THINAPHONG 81

The problem to be discussed is that typically presented by nearshore instability due to the action of the sea. The paper blends relevant concepts together and provides information to assist the engineer in assessing the stability of structures lying low in the areas along the coastlines. It also aims to encourage joint research of the geotechnical and coastal engineering.

Temperature Effects on Primary Consolidation

KARIM HABIBAGAH **95**

The influence of temperature on void ratio and coefficients of compressibility, consolidation and permeability of a slightly organic soil is examined. Consolidation tests were performed on normally consolidated samples and samples which were overconsolidated in the laboratory. Special testing apparatus was designed for testing the slightly organic soil and maintaining constant temperature. Test results are presented and discussed. The concept of effective voids ratio is introduced. It is found that temperature affects the void ratio, and the coefficients of consolidation and permeability.

Technical Note:

Determination of Stresses and Deformations Using Photo-Viscoplasticity

T. NISHITANI **109**

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Some Engineering Properties of Soft Bangkok Clay

SOREN HOLMBERG **1**

This paper describes the results from a laboratory testing series of Soft Bangkok Clay. Although the number of samples was relatively small the test results are thought to give some valuable information about the consolidation properties and the effect of anisotropy and strain rate on the undrained shear strength.

Specifying Marginal Quality Soils in the Tropics

JAMES V. PARKIN **21**

In an effort to keep the cost of bulk earthworks to a minimum, the use of marginal quality natural materials is often required. At present, commonly used specifications utilise testing limits which are too narrow and rigid to cope with the natural variability of marginal materials. Examples are presented to show the type of variability to be expected and a method is proposed for the re-wording of specifications to achieve the maximum use of materials which would otherwise be rejected.

Indirect Determination of K_0 from Multi-stage Triaxial Compression Tests

RAYMOND J. KRIZEK and M. SALAH ABDELHAMID 31

Consolidated-undrained multi-stage triaxial compression tests were conducted on specimens trimmed from laboratory consolidated blocks of a kaolin clay with two distinctly different pore fluid chemistries, and the resulting strength parameters were used in conjunction with various established empirical relationships to compute values for the coefficient of lateral earth pressure at-rest. These determinations were found to compare favorably with K_0 values measured directly during the process of consolidating the blocks from a slurry with a water content of several times the liquid limit to a vertical effective stress of 220 kN/m². The direct measurements were taken by means of total pressure cells and pore pressure probes embedded in the wall of a rigid consolidation chamber with a diameter of 20 cm and a height of 50 cm. The nature of the particle associations (flocculated or dispersed) exerted no significant influence of measured K_0 values, which were about 0.7 in both cases. The generally good agreement between indirectly and directly determined K_0 values suggests that a multi-staging technique can be used in conjunction with existing empirical correlations to obtain a reasonably acceptable estimate for the coefficient of lateral earth pressure at-rest.

Technical Note :

Economy of Hyperbolic Paraboloidal Shell Footings

NAINAN P. KURIAN 53

Load-Deformation Characteristics of Model Anchors Under Horizontal Pull in Sand

GOPAL RANJAN and Y.P. KAUSHAL 65

The load-deformation characteristics of vertical anchor plates buried in sand and subjected to horizontal pull were studied through model tests. Four different sizes of anchor plates ranging from 25 cm to 10 cm embedded at various depths were tested. Two different states of packing of sand were used, and anchors were subjected to horizontal pull only. The test results were analysed to study the influence of important factors on anchorage capacity and also displacements at failure. The experimental results were compared with those of other investigators. Anchorage capacities were computed by several methods and were compared with the experimental observations.

Digital Computer Simulation Model of an Aquifer — A Case Study

SELVADORE SELVALINGAM, SIMPLICIO T. ROLINAR and ANAT
ARBHABHIRAMA 79

The Nakhorn Luang aquifer, which is one of the eight aquifers under Metropolitan Bangkok, Thailand, and which is vitally important because it probably supplies more fresh water than any other aquifer, is the case studied in this paper. The study is based on the water level data recorded during the periods of 1968/1969, 1973/1974 and late 1974. The governing equation has been reduced to a steady-state equation and the overall identification of the transmissibility distribution is obtained using a numerical procedure. Resulting values of the transmissibility are used to estimate the discharge rates during the said periods and the increasing trend in the pumping rate from the Nakhorn Luang aquifer is also shown.

Stabilization of Heavy Clay with Potassium Chloride

SAM FRYDMAN, ISRAELA RAVINA and TUVIA EHRENREICH 95

Some basic considerations of clay mineralogy suggest that potassium chloride, which is readily available in Israel from the Dead Sea, may significantly improve the engineering properties of heavy clay.

This paper describes the results of a laboratory investigation into the effect of potassium chloride on the engineering properties of an Israeli heavy clay. The investigation indicated that the addition of potassium chloride results in a significant decrease in the activity of the clay, and apparently in a change in its mineral structure. The overall stabilizing effect appears to be a result of this mineralogical change together with the increase of electrolyte concentration.

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Estimate of Soil Compressibility from Standard Penetration Test

HOUSSAM H. EL-MOURSI, RAYMOND J. KRIZEK and ROSS B.

COROTIS 1

A probabilistic model is developed to relate the compressibility of a soil deposit to blow counts obtained from standard penetration tests. The established relation is based on a variable proportionality coefficient, the value of which depends on the nature of the soil. The variations in the blow count and the proportionality coefficient are examined through the calculated statistical parameters, and it is found that these variations can be explained in terms of a normal probability distribution. The method of derived distributions is then used to develop a probabilistic model for predicting the total settlement in a compressible clay layer in terms of uncertain standard penetration test results and loads. The compression ratio is found to be well described by a normal distribution, and the total settlement is likewise well approximated by a lognormal distribution.

Deep Compaction of Ground by Vibroflotation

R.K.M. BHANDARI 13

Initial soil investigations carried out at the Bongaigaon Refinery Site indicated medium to dense sand extending to an average depth of 10.0 m below the natural ground surface. The water table was close to the ground surface. In view of the susceptibility of the region to earthquakes, liquefaction of the sand governed the foundation requirements for the refinery tankages. The paper discusses the effectiveness and limitations of the vibrocompaction method used at the site to counter liquefaction by ensuring 80 % relative density all over the treated area. The observed settlements resulting from hydrostatic testing of a tank are also discussed.

A New Method to Predict Swelling Using A Hyperbolic Equation

V. DAKSHANAMURTHY 29

Light buildings founded on expansive soils may be subjected to undesirable cracking resulting from differential swelling and/or shrinking of the soil. The prediction of probable heave of these soils under given surcharge loads is therefore becoming important in day-to-day soil engineering practice. Several detailed investigations have been made in the past to characterise swelling-swelling pressure-time relationships for expansive clays. These relationships and other methods to predict swelling have had only a limited success since problems involving swelling behaviour are complex and can only be solved by an approach based on the observed properties of these soils.

An attempt is made in this study to predict the maximum swelling from the observed behaviour over a short interval of time. The approach is based on a hyperbolic equation. The test data obtained from several tests have been analysed to examine the validity of the hyperbolic equation. Published data have also been analysed to verify the validity of the equation and the analyses show a good agreement between predicted and observed maximum swelling.

Detection and Prevention of Cracking of Clay Cores in Dams

ARIF AJAZ 39

Cracking of impermeable clay cores in earth and earth-rock dams is one of the serious and complex problems facing engineers. The use of modern heavy compaction machinery and the increasing necessity for construction on sites providing poor foundations have aggravated this problem. In recent years engineers have become increasingly aware of cracking with both old and new embankment dams and many designers advocate the use of defensive methods in the design and construction of new dams. Most of these defensive methods are based on experience gained from the study of case histories of dams constructed in the past. However, it is likely that cracking and malfunctioning of earth dams may not diminish in the near future due to requirements of building higher dams on poorer foundations.

The recent published information on cracking is collated and discussed critically in the paper. The hazards of cracking and some of the means available at present to detect cracks are presented. Instrumentation of earth dams for crack detection is considered to offer a good means but the correct functioning of the instruments must be ensured. Prevention, control and remedial measures against cracking are suggested and discussed.

Technical Note :

Soil Fabric in Thin Sections

G.P. KARUNARATNE 63

Diagnosis of Pile Condition

CHIN FUNG KEE 85

This Lecture presents a method by which the structural condition of a pile can be assessed from the load-settlement observations normally taken in a pile load test. A number of case histories are presented of test piles that have been extracted for examination and found to have been damaged. It is shown that the application of the method for diagnosis of pile condition would have revealed their structural damage without having to extract them for examination.

A theoretical analysis is presented relating load and settlement at the pile head when plastic collapse occurs. How such a type of structural failure can be identified from the normal load-settlement observations is shown.

A method is produced by which the load-settlement relationship of a friction pile of any required length can be predicted from the load-settlement observations of a similar friction pile of known length embedded in the same homogeneous soil.

The Behaviour of Rockfill Dams

A.D.M. PENMAN 105

The paper points out the growing importance of rockfill dams in relation to other types of dams and discusses two aspects of them: the behaviour of the rockfill itself and that of the water retaining element.

The presence of fines in rockfill, at one time regarded as bad, is now recognised as being a desirable feature. They reduce contact stress and minimise relative movement between the larger rock pieces thereby limiting settlement and improving shear strength of the rockfill. Fines also help construction plant, but they must not be allowed to reduce the permeability of the rockfill below 10^{-3} cm/sec. Deformation properties of the rockfills from three dams have been measured by a large oedometer and field behaviour measured by comprehensive instrumentation.

Narrow cores may become partly supported by the rockfill by silo action so that the total stress in them falls to a value lower than reservoir pressure, allowing hydraulic fracturing to occur. It is suggested that to avoid this, cores should be placed wet enough to ensure an end of construction pore pressure equal to the reservoir pressure. Field measurements have shown negligible downstream movement of wet cores during first filling of the reservoirs, which indicates that the horizontal pressures from the core on the rockfill exceeded the horizontal pressures imposed by the reservoir water.

To control core placement conditions it may be better to specify a required shear strength rather than a placement water content.

Mobile Soil and Rock Flows

NORBERT R. MORGENSTERN 123

Mobile soil and rock flows arise in a variety of geological and geomorphological settings. Four case histories are presented by way of example. The first, from Hong Kong, resulted from the collapse of poorly compacted fill during infiltration of rainwater. The second, from Vancouver Island, is due to shallow instability and erosion in debris and is also associated with intense rain. The third, from Brazil, is caused by large scale instability in residual soil followed by channelling of the debris through a steep, narrow gorge. The fourth example refers to the general problem of rock debris avalanches where large volumes of dry rock can achieve remarkable mobility. A historical example from British Columbia is cited. Examples are given which illustrate that protective structures are often best designed utilizing basic principles of fluid mechanics rather than more traditional views of soil behavior. The object of the paper is to draw attention to the class of problems associated with mobile soil and rock flows and the research needed to understand their mechanisms.

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Some Land Subsidence Experiences in Japan and Their Relevance to Subsidence in Bangkok, Thailand

TOSHINOBU AKAGI 1

The development and conditions of land subsidence in three Japanese cities have been reviewed in an attempt to extract some useful means to cope with land subsidence problems arising in Bangkok, Thailand. The geological environment of Bangkok and the present pumping rate and decline of groundwater levels strikingly resemble the conditions of some Japanese cities when they were experiencing disastrous land subsidence. Although the current rate of subsidence and the total subsidence appear to be much less in Bangkok, it is certain that subsidence will continue and the flat, low-lying area will eventually lose its scant freeboard above sea level unless some groundwater control measure is taken urgently.

Land Subsidence in Bangkok, Thailand : Results of Initial Investigation, 1978

JERASAK PREMCHITT 49

A comprehensive investigation program is being conducted to find conclusive answers concerning the land subsidence problems in the Bangkok area. The work program for the first year is now completed. Many field instruments were installed in the area to observe the sinking of ground surface and the decline of piezometric level. It was found that subsidence of considerable magnitude and rate is occurring in the Bangkok area. Good correspondence was observed in the relationship between soil layer compression and piezometric level decline and this clearly reveals the link between groundwater pumping and land subsidence in the area.

Bridge Approaches on Soft Clay Supported by Embankment Piles

SOREN HOLMBERG 77

Differential settlements commonly develop between a bridge and its approaches at sites underlain by compressible subsoil deposits. Anticipating such settlements at bridge sites along a highway north of Bangkok, Thailand, the approaches were partly supported by embankment piles. In addition, approach slabs resting on a floating abutment in the embankment fill were included in the design. Six years after the highway completion, despite settlements of the embankment on the order of one-half meter, the pile supported approaches still provide a smooth transition between the bridges and the road.

Technical Note :

Stress and Deformation Characteristics of an Elastic Punch in an Elasto-Viscoplastic Medium

T. NISHITANI and M. ITO 91

Preliminary Investigation of Saltwater Encroachment into the Nakhon Luang Aquifer, Bangkok

A. DAS GUPTA, A. ARBHABHIRAMA and B. AHMAD 141

The Nakhon Luang Aquifer, one of eight aquifers underlying the Bangkok Metropolis, provides the major portion of groundwater supply for the area. At present (early 1979) the total groundwater pumpage amounts to 1.1 million cubic meters per day. Due to the heavy withdrawal of groundwater for public water supply as well as by private enterprises, a considerable extent of this aquifer has been contaminated by saltwater encroachment. The simplified analysis procedure using the solute transport model for predicting the movement of chloride in flowing groundwater, presented herein, provides an insight into the mechanism of saltwater encroachment. Field data available is not adequate to carry out a precise analysis. Apart from the movement of saltwater from the Gulf of Thailand, a connate water body lying in the western side of the Chao Phraya River acts as predominant source of contamination of freshwater in the aquifer. Furthermore, possibilities of vertical leakage of saline water from other aquifers and confining layers are inferred.

Analysis of Long-Term Compression of Peats

T.B. EDIL and ABDULMOHSIN W. DHOWIAN 159

Long-term one-dimensional consolidation tests were performed on peat samples from four different sources and covering a wide compositional variation, including amorphous granular and fibrous peat types. The analysis of the behavior of peats under such conventional test conditions is considered herein; the prediction of field performance is beyond the scope of this paper. Results from the consolidation tests indicate errors may result from extending the linear portion of the secondary compression curve. In general, there is an increase in the compression rate with the logarithm of time giving rise to a "tertiary" compression. A number of empirical and theoretical methods for predicting settlements due to secondary compression are briefly reviewed and the model of Lo (1961) is used to describe the observed response and to determine the parameters needed to analyze the long-term compression of these peats. These parameters are related to the level of consolidation pressure and no apparent consistent trends are found with respect to the type of peat and initial void ratio.

State-of-the-Art Report on Settlements and Time Rates of Consolidation

T. AKAGI 179

Although the ultimate consolidation settlement can often be predicted with reasonable accuracy, it has repeatedly been pointed out that the rate of settlement of a structure built on soft clay is almost always much faster than that predicted on the basis of the one-dimensional consolidation theory with the use of oedometer test results. The three-dimensional theory appears to give a promising clue to account for the large difference in time rates when a much greater horizontal permeability is taken into account. In order to make such a theoretical approach practicable, it is vital to establish a reliable geological profile with drainage conditions clearly defined. For this purpose the development of a new technique is required to measure the mass permeability of the compressible stratum. This report reviews the effectiveness of vertical drains in terms of settlement rates and undrained shear strength of the stabilized foundation soil. Both the displacement type and non-displacement type sand drains disturb the soft ground when being installed. The adverse effects of the former type does not appear to be as severe as has been accused. Recent studies even indicate some beneficial aspects of displacement type sand drains. This suggests the necessity of reappraisal of this more economical type.

Applications of Steel Pipe Piles in Japan

M. SAWAGUCHI 199

This paper describes and illustrates the utilization of steel pipe piles in foundations built on soft soils in Japan, including the techniques of sheet pile construction and prepacked concrete foundations. To counteract the effects of negative skin friction on pipe piles, the current practice in Japan is to apply a special viscoelastic asphalt coating. The paper also discusses methods of corrosion control and their effectiveness, noise pollution control, and outlines the use of an automatic welding machine.

Review of Japanese Subsurface Investigation Techniques

H. MORI 219

The paper reviews the current practice of subsurface investigation in Japan, with emphasis on particular techniques used during the preliminary and detailed phases of investigation. The method of standard penetration testing and its reliability with respect to testing depth and hammer type must be considered in the interpretation of blow-count values. Borehole geophysical methods, primarily seismic, provide a way to identify low velocity zones beneath a higher velocity zone during the preliminary phase of investigation. Innovations in undisturbed sampling techniques of cohesionless soils, borehole shear testing devices, and *in situ* measurement of earth pressure at rest are examples of continuing refinement in detailed geotechnical investigation methods used in Japan.

The Influence of Fabric on Shrinkage Limit in Clay

S. NARASIMHA RAO 243

This investigation brings out that the shrinkage limit of clays can also be used to identify the fabric. The previous attempts to use shrinkage limit in characterizing the fabric in clays have been reviewed. The experimental results obtained from kaolinite reveal that the clay mineral and the particle size distribution being the same, the shrinkage limit has been affected by the changes in the fabric brought about by the changes in the initial water content, induced shearing strains, drainage conditions during the application of shear stress and stress level. Several triaxial shear tests under both drained and undrained conditions on kaolinitic and montmorillonitic clays have also been conducted and shrinkage limits of these sheared samples have been determined. These strength results show the possibility of arriving at a unique relationship between effective angle of shearing resistance ϕ' , and shrinkage limit.

Technical Note:

Dynamic Response of Footings in a Saturated Soil Medium

K.S. SANKARAN, N.R. KRISHNASWAMY, and P.G. BHASKARAN NAIR 253