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DIVISION NAME CHANGE

The Technical Activities Committee, at its July 9-10, 1973 meeting, held in Tulsa, Oklahoma, approved the change in name of the Soil Mechanics and Foundations Division to the Geotechnical Engineering Division. However, we are continuing to use the "old" name for the Journals for the balance of 1973. The January 1974 issue will carry the new name.

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DISCUSSION

Proc. Paper 10038

[a]Discussion period closed for this paper. Any other discussion received during this discussion period will be published in subsequent Journals.

TECHNICAL NOTES

Proc. Paper 10042

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The key words, abstract, and reference "cards" for each article in this Journal represent part of the ASCE participation in the EJC information retrieval plan. The retrieval data are placed herein so that each can be cut out, placed on a 3 × 5 card and given an accession number for the user's file. The accession number is then entered on key word cards so that the user can subsequently match key words to choose the articles he wishes. Details of this program were given in an August, 1962 article in CIVIL ENGINEERING, reprints of which are available on request to ASCE headquarters.

[a]Discussion period closed for this paper. Any other discussion received during this discussion period will be published in subsequent Journals.

ASCE POLICY ON TECHNICAL NOTES

To provide a place within ASCE for publication of technical ideas that have not, as yet, advanced to the point where they warrant publication as an ASCE Proceedings Paper in a Division Journal, the publication of Technical Notes was authorized by the Board of Direction on October 16–18, 1967, under the following guidelines:

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2. The two copies will be sent to an appropriate Technical Division for review.
3. If the Division approves the contribution for publication, it shall be returned to Society Headquarters with appropriate comments.
4. The technical publications staff will prepare the material for use in the earliest possible issue of the Journal, after proper coordination with the author.
5. Each Technical Note is not to exceed 4 pages in the Journal. As an approximation, each full manuscript page of text, table, or illustration is the equivalent of one-half a Journal page.
6. The Technical Notes will be published in a special section at the end of each Journal.
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9. Digests of Technical Notes will not be published in Transactions.
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a. Titles must have a length not exceeding 50 characters and spaces.
b. The author's full name, Society membership grade, and footnote reference stating present employment must appear on the first page of the manuscript. However, authors need not be members of the Society.
c. The manuscript is to be submitted as an original copy (with two duplicates) that is typed on one side of 8-1/2 in. by 11 in. white bond paper.
d. Mathematics are recomposed from the copy that is submitted. Because of this, it is necessary that letters be drawn carefully, and that special symbols be properly identified. The letter symbols used should be defined where they first appear, in the illustrations or in the text.
e. Standard definitions and symbols should be used. Reference should be made to the lists published by the USA Standards Institute and to reports from ASCE Divisions.
f. Tables should be typed double spaced (an original ribbon copy and two duplicate copies) on one side of 8-1/2 in. by 11 in. paper. Specific illustration and explanation must be made in the text for each table.
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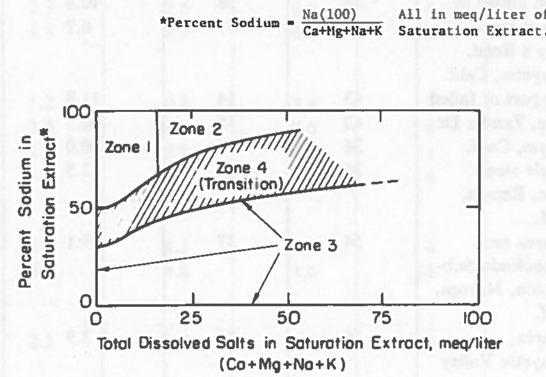
Clay Chemistry and Slope Stability

By James K. Mitchell[1] and Richard J. Woodward,[2] Fellows, ASCE

Introduction

In a recent paper Sherard, Decker, and Ryker (1972) have called attention to piping failures in earth dams and erosion that may develop under conditions



Zones 1 and 2 include nearly all of the clay samples from dams which failed by breaching in Oklahoma and Mississippi. Samples generally have high dispersion when tested in the laboratory. Highly erodible clays.

Zone 1 includes all samples from 16 clay dams which were damaged by tunnel erosion from rainfall in Venezuela, Oklahoma, Mississippi, Arkansas, Tennessee and Texas.

Zone 3 includes the test results for most of the "control" samples. Probable range of ordinary, erosion resistant clays.

Zone 4 is the transition zone. Most samples in this zone had low dispersion when tested in the laboratory. The lower boundary of the zone is not well established by the data.

FIG. 1.—Summary of Correlation Between Chemical Test Results and Dam Performance Experience (Sherard, et al., 1972)

of high sodium content in the soil. They show that usual engineering index test tests are of little value in identifying these problem soils, that the erosion

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TABLE 1.—Description of Soils Tested

Sample number (1)	Sample location (2)	Liquid limit, as a percentage (3)	Plasticity index, as a percentage (4)	Dispersion, as a percentage (5)	Sodium, in milli-equivalents per liter (6)	Potassium, in milli-equivalents per liter (7)	Calcium, in milli-equivalents per liter (8)	Magnesium, in milli-equivalents per liter (9)	Na + K + Ca + Mg, in milli-equivalents per liter (10)	Total soluble salts,[a] in milli-equivalents per liter (11)	Sodium in saturated extract,[b] as a percentage (12)	SAR[c] (13)
1	Small slide in cut adjacent to Highway 24 near Happy Valley Rd., Lafayette, Calif.	57	35	15.4	4.8	0.4	1.3	1.1	7.6	6	63	4.4
2		65	40	11.1	2.0	0.2	1.3	1.0	6.5	5	31	1.9
3	Erosion tunnel in natural slope, St. Mary's Road, Lafayette, Calif.	58	38	10.8	1.8	<0.1	2.3	2.6	6.8	6	26	1.2
4		67	47	6.7	2.0	<0.1	1.8	2.3	6.2	5	32	1.4
5	Lower part of failed slope, Zander Dr., Rheem, Calif.	43	14	11.8	0.8	<0.1	1.2	0.3	2.4	2	33	1.0
6		42	15	20.5	2.5	0.1	3.4	1.0	7.0	6	36	1.7
7		36	6	30.0	1.5	<0.1	1.7	5.9	9.2	11	16	0.8
8	Unstable steep slope, Rheem, Calif.	36	15	12.5	0.6	<0.1	1.8	1.1	3.6	4	17	0.5
9	Slide area near Campolindo Subdivision, Moraga, Calif.	54	37	9.1	0.6	<0.1	2.1	1.3	4.1	4	15	0.4
10					2.2	0.1	4.5	4.8	11.6	11	19	1.0
11	Slide area, Lafayette Valley Estates, Lafayette, Calif.	56	36	3.9	1.1	<0.1	2.3	1.4	4.8	4	23	0.8
12	Stabilized excavation slope, Shopping Center, Moraga, Calif.	29	16	25.0	2.4	0.1	1.8	2.0	6.3	6	38	1.7
13		53	35	13.9	1.9	<0.1	2.1	1.8	5.9	4	32	1.3
H	Hydrauger water from slope where samples 12 and 13 taken				9.6	0.1	2.0	1.0	12.7	10	76	7.8
14	Natural slide area at end of Springfield Drive, Moraga, Calif.	47	16	19.8	1.5	<0.1	1.2	1.2	4.0	4	38	1.4
15		34	16	30.0	2.4	<0.1	1.1	0.8	4.4	4	54	2.5
16		50	30	40.6	1.5	<0.1	1.1	0.5	3.2	4	47	1.7
17	Scarp of slide, Tahos Road, Orinda, Calif., Sample 19 from an erosion tunnel	43	21	7.4	1.0	0.1	3.2	1.9	6.2	6	16	0.6
18		50	35	11.0	1.1	<0.1	0.8	0.5	2.5	2	44	1.4
19		41	21	16.1	1.5	0.1	4.0	4.0	15.0	8	10	0.7
20	Slide on cut slope, Tahos Rd. near Freeway, Orinda, Calif.	48	27	11.0	0.4	0.2	4.5	4.4	9.5	8	4	0.2
21	Slide adjacent to Wildcat Canyon Rd., Orinda, Calif.	86	62	6.2	2.0	<0.1	2.8	3.7	8.6	8	23	1.1
22		68	48	28.0	6.5	0.1	0.6	0.2	7.4	5	88	10.0

TABLE 1.—Continued

Sample number (1)	Sample location (2)	Liquid limit, as a percentage (3)	Plasticity index, as a percentage (4)	Dispersion, as a percentage (5)	Sodium, in milli-equivalents per liter (6)	Potassium, in milli-equivalents per liter (7)	Calcium, in milli-equivalents per liter (8)	Magnesium, in milli-equivalents per liter (9)	Na + K + Ca + Mg, in milli-equivalents per liter (10)	Total soluble salts,[a] in milli-equivalents per liter (11)	Sodium in saturated extract,[b] as a percentage (12)	SAR[c] (13)
23	Slide, San Pablo	41	22	5.8	1.0	<0.1	1.4	0.6	3.1	2	32	1.0
24	Dam Rd. cut about 1 mile south of San Pablo Dam	44	26	9.7	7.0	0.1	2.4	1.6	11.1	11	63	4.9
25[d]	Estimated slide plane San Pablo Dam Road, El Sobrante, Calif.	75	50	18.1	37.4	0.1	2.8	7.9	48.2	60	78	16.2
26[e]	Slide near Bldg. 9, Lawrence Berkeley Laboratory	46	26	15.8	7.4	0.1	2.6	3.4	13.6	12	54	4.2
27[e]	Tramonto-Coperto Slide, Pacific Palisades, Los Angeles, Calif.	45	27	13.3	134.8	1.6	6.5	296.2	439.1	700	31	11.0

[a] Based on conductivity of saturation extract.

[b] Percentage of Sodium = (Na/(Ca + Mg + Na + K)) × 100 (all concentrations in milli-equivalents per liter of saturation extract).

[c] SAR = Sodium Adsorption Ratio = $Na^+/\sqrt{(Ca^{++} + Mg^{++})/2}$ (concentrations in milli-equivalents per liter).

[d] Provided by John Hallenbeck, Hallenbeck and McKay, Berkeley, Calif.

[e] Provided by E. D. Graf, Pressure Grout Co., Daly City, Calif.

and piping failures can be attributed to dispersion of the clay phase, that nonsaline alkali soils are particularly susceptible to dispersion, and that relatively simple chemical tests can be used to classify the dispersion potential of a soil.

The specific conditions favoring clay dispersion are reviewed in detail by Sherard, et al. (1972) and will not be restated herein, except to note that a major criterion is the exchangeable sodium percentage (percentage of the adsorbed cations that is sodium). This percentage is in turn related to the sodium adsorption ratio (SAR) in the free pore solution, as shown by Sherard's Fig. 9. The exchangeable sodium percentage and sodium adsorption ratio have been used extensively in past studies of salt-affected soils in agricultural applications and in Australia for study of piping of dispersive clays in dams and erosion.

Sherard, et al. (1972) have shown that reliable correlations may also be obtained using relationship between the percentage of sodium in the saturation extract and total dissolved salts shown in Fig. 1. They also describe the Soil Conservation Service dispersion test. In this test the ratio of percentage of soil particles finer than 5 μm in a hydrometer analysis without dispersing agent to percentage finer than 5 μm determined using a dispersing agent (the percentage of dispersion) is taken as a measure of susceptibility to spontaneous dispersion. In general if the percentage of dispersion is greater than 30%, the soil may be moderately susceptible, and if greater than 50% to 75%, severe erosion may be expected. Note, however, that in a number of cases reported by them a dispersion value less than 33% was indicated for samples from failed or breached dams or from

erosion tunnels. In general their data indicate the correlation of Fig. 1 to be a better indicator of susceptibility than is the SCS dispersion test, although in all but two cases soils having a dispersion greater than 33% were associated with failures.

The East Bay hills of Contra Costa County, California east of Berkeley and Oakland are well known for unstable soil conditions, and numerous slope failures are observed each year during the rainy season. The susceptibility of specific areas to failure is often not predictable based on usual soil engineering considerations. An investigation has been made, therefore, to determine whether the soil chemistry of several samples from failure areas is such as to indicate a high susceptibility to dispersion.

Sites and Samples Studied

Fourteen sample locations are listed in Table 1 associated with unstable soil in the East Bay hills. A sample from a slide area in Southern California was also studied. For each of these samples the Atterberg limits, percentage of dispersion, concentration of soluble salts, percentage of sodium in the saturation extract, and sodium adsorption ratio were determined, with the results indicated in Table 1. The dominant clay mineral in samples 1 through 26 is probably montmorillonite, as the soils are typical of those found throughout the area which are well known for their expansive characteristics.

Procedures and Accuracy

The Atterberg Limit and percentage dispersion values given in Table 1 were determined by a commercial soil testing laboratory. As pore solution chemical analyses are not presently done by most soil testing laboratories, it was necessary to have these measurements done by a commercial water chemistry laboratory.

TABLE 2.—Comparison of Soil Data Obtained by Different Laboratories

	Sample A		Sample B		Sample C	
Variable (1)	Lab X (2)	Lab Y or Z (3)	Lab X (4)	Lab Y or Z (5)	Lab X (6)	Lab Y or Z (7)
Liquid limit, as a percentage	48	53	48	53	40	43
Plasticity Index, as a percentage	28	34	27	35	22	27
Dispersion, as a percentage	17	18	17	21	7	12
Ca + Mg + Na + K, in milliequivalents per liter	72	80	44	52	61	55
Na in saturated extract, as a percentage	48	71	46	61	33	57
Sodium adsorption ratio	8	17	6	11	4	9

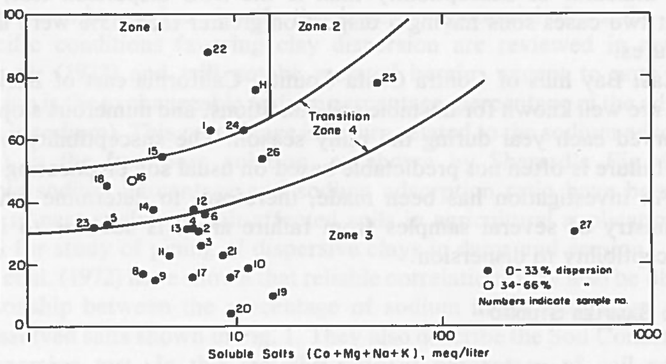

FIG. 2.—Percentage Sodium Versus Soluble Salt Concentrations for Slide Zone Samples

During this investigation three carefully quartered soil samples from Colorado were tested twice. A full set of tests was done by a laboratory (Lab X) equipped to do both the engineering classification and chemical measurements. A second set of Atterberg Limit and dispersion test results was obtained by another soil laboratory (Lab Y) and a second set of chemical data were obtained by a chemistry laboratory (Lab Z) using pore solution extracted by Lab Y. The two sets of values are compared in Table 2.

It may be seen that Lab Y obtained consistently higher plasticity values than did Lab X, that the percentage dispersion values agree reasonably well, that the values for (Ca + Mg + Na + K) are comparable, that the percentage sodium values compare poorly, and that the SAR values, while of the same order of magnitude, differ a great deal on a percentage basis. Since the personnel of each laboratory are believed to be skilled in the performance of the tests, there is no basis for favoring one set of results over the other, except that Lab X had more experience in the extraction of pore solution of samples for the chemical tests than did Lab Y.

The total soluble salt concentration as derived from the electrical conductivity of the saturation extract agreed, with the exceptions of samples 19 and 27, very well with the salt concentration defined in the manner used by Sherard, et al. (1972) (Ca + Mg + Na + K).

Results

Reference to Table 1 shows that only sample 7 from the Zander Drive slide and samples 15 and 16 from the Springfield Drive slide had dispersion values indicative of dispersion behavior. The percentage of sodium in the saturation extract in relation to soluble salt content is shown in Fig. 2. From this figure it may be seen that one sample of the soil from the Happy Valley Road slide (sample 1), the Springfield Drive slide material (samples 14–16), one of the samples (22) from Wildcat Canyon Road, one sample from the San Pablo Dam Road slide (sample 24), and the water draining from the hydrauger in the repaired Moraga Shopping Center slide (Sample H) all indicate conditions that could lead to clay dispersion. It is not inconceivable, therefore, that this could have been a contributing factor to the slope instability at these sites. Since the majority of the samples have sodium percentages plotting in Zones 3 and 4, unfavorable chemistry is not a probable general cause of failure throughout th region studied.

Examination of the soluble salt and sodium percentage data in Table 1 indicates substantial variations within certain sites, e.g., Zander Drive, Campolindo Subsivision slide, Tahos Road slide, Wildcat Canyon Rd. slide, and San Pablo Dam Rd. slide. This is consistent with the findings of Sherard, et al. (1972) that, "The Chemistry and dispersibility of clay frequently varies greatly within short distances in apparently uniform deposits."

Conclusions

Samples from five of 16 sites where unstable slopes exist had unfavorable pore solution chemistry relative to their susceptibility to dispersion. The data are insufficient to establish conclusively that slope failures in these areas were caused as a result of strength loss due to clay dispersion. Further study of the possibility appears warranted, and the simple chemical tests would seem justified in cases in which the possibility is suspected.

Acknowledgment

This investigation was sponsored by the Professional Development Program of Woodward-Clyde Consultants. This support is acknowledged with appreciation.

Appendix.—Reference

1. Sherard, J. L., Decker, R. S., and Ryker, N. L. "Piping in Earth Dams of Dispersive Clay," *Proceedings of the ASCE Specialty Conference on the Performance of Earth and Earth-Supported Structures*, Purdue Univ., Lafayette, Ind., June, 1972.

Geotechnical Properties of Hudson River Silts

By Surendra K. Saxena,[1] M. ASCE and Timothy P. Smirnoff,[2] A. M. ASCE

Introduction

The Hudson River flows in a deep rock channel along the contact between sedimentary rocks of the Newark series and the Manhattan Metamorphics (2). Its development began in the Cretaceous period. By the end of the Triassic, its present course was established as a result of a series of stream captures. Due to scouring by the advancement of ice sheets, the river's bedrock channel was deepened during the Pleistocene. The river has been filled with glacial deposits which are overlain by recent deposits of "river silts." Presented herein are the geotechnical properties of these deposits.

Geologic Profiles

The study was done along a section just north of Pier No. 86 on the Manhattan side and north of abandoned Pier K on the Jersey side (Fig. 1). Within the New York Pierhead Line between Piers 86 and 88, the boring information for an existing structure in the area was utilized. In all, seven borings were performed, four in midriver and three on the New Jersey Shore within the Pierhead Line. As shown on the geologic profile, the river silt deposit is almost crescent shaped in cross section, very deep in the main channel, and tapering upward near

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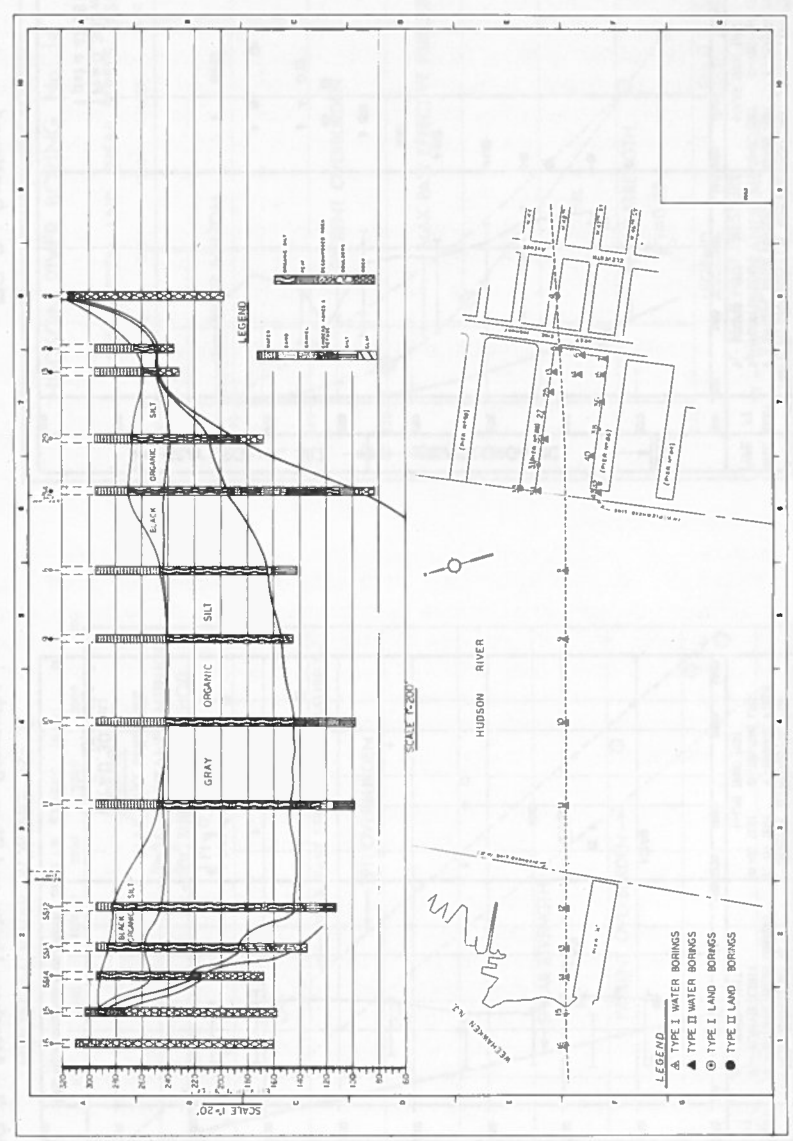

FIG. 1.—Hudson River Geologic Profiles