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Annotated Bibliography on Slope Stability of Strip Mine Spoil Banks

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State Project 231: Reclamation and Use of Strip Mined Land in Ohio
Subproject 4: Factors Influencing Structural Stability of Spoils

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1. Ackermann, E. "Quick Soils and Flow Movements in Landslides," Zeitschrift, Deutsche Geologische Gesellschaft, 100:427-466, 1948, (in German).

Most ordinary landslides are not associated with thixotropic phenomena. Only under quite exceptional circumstances does thixotropic liquefaction of quick soils dominate the motion so that the "ideal case of earth flow" develops. Sliding and flowing movements frequently participate together in the landslide type movements of moist, fine-grained loose sediments. Both forms of motion can be affected by thixotropy. The composition of loose sediments subject to movement may vary from fat clays to sands of low clay content and also includes calcareous mud deposits and fine-grained soils with a content of organic substance.

Flow-prone quick clay strata can be detected before and after soil movements by determining the Atterberg indices, and the negative relative consistency. However, proof of quick consistency or thixotropy is obtained only by determining the stiffening limit.

Thick zones of quick clays which become thickly liquid may suddenly break through the dry surface crust and flow downwards as a mud stream over a surface which is not at all steeply inclined. Thixotropic flowing movements take place suddenly with no change of water content. The flowing movements may be initiated by kinetic action, by pressure from one side, or by interstitial water pressure in one direction. Quick soils flow under their own weight alone, while loose sediments in the plastic state flow under pressure from one side applied locally. (Abstract from "Highway Research Abstracts.")

2. Akai, K. On the Stress Analysis and the Stability Computation of Earth Embankments. Disaster Prevention Research Institute, Bulletin No. 17, 1957, Japan.

The first part of this paper discusses stress distribution in earth embankments, taking into account the residual strength in the embankment in its natural state, externally applied forces, and internal pore pressures. In the second part of the paper, consideration is given to the effect of pore pressure on the stability of embankments. (Abstract from "Highway Research Abstracts.")

3. Alden, W. C. "Landslide and Flood at Gros Ventre, Wyoming," Transactions, American Institute of Mining and Metallurgical Engineers, 76:347-360, 1928.

Heavy rains and melting snow saturated clay layers in Carboniferous strata which dipped toward the valley. On June 23, 1925, an enormous mass of rock slid into the valley. The slide formed a 250-foot high dam. In May 1927, rapid melting and rain caused a rapid rise of the then 200-foot deep lake, and the water cut through the dam and flooded downstream areas.

4. Allen, G. H. "Arresting a Slide on an Indiana Highway," Civil Engineering, 6:384-385, June, 1936.
   Vertical settlement and lateral displacement of an Indiana highway occurred because of a sliding plane which formed when a fire clay stratum was lubricated with seepage water. Installation of a drain to intercept the seepage stopped the movement.

5. Almagia, Roberto. "Les Eboulements en Italie," Materiaux pour l'Etude des Calamites, Geneve, Societe de Geographie, No. 2, pp. 99-121, 1924, (in French).
   A study of the lithologic and morphologic conditions which are favorable to landslides in Italy are discussed as well as the causes which produce them. The landslides in Italy are characteristic of the hilly regions of average altitude, composed of clayey formations and cut by recent valleys, and also of areas of higher altitude with steep slopes and where rocks that weather easily are prevalent. The landslides generally occur after long and persistent rainfalls; some were caused by deforestation or by seismic movements. A few slides are described and a map shows the distribution of the main zones of landslides in Italy. (Abstract from "Landslides" Highway Research Board Bibliography No. 10.)

6. Armco Culvert Manufacturers Association. Landslides: Types, Causes and Cures. Handbook of Culverts and Drainage Practice, pp. 353-364, 1930.
   The types of landslides are described using Ladd's classification. The article suggests that drainage is the major cure of landslides. The necessity for geologic study in analyzing landslides is emphasized.

7. Arnold, M. "Slope Stability Analysis by a New Graphical Method," Proceedings, American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, 87:1-17, October, 1961.
   The stability of slopes is commonly analyzed by the "method of slices," which involves certain simplifying assumptions and, as normally applied, leads to conservative values of the factor of safety. A method of analysis developed by A. W. Bishop leads to more realistic values of the factor of safety but involves a tedious tabular form of computation.
   The derivation of Bishop's equation for the factor of safety of a slope is outlined briefly, and a graphical solution, similar to that introduced by D. R. May for the "method of slices," is developed in detail. This graphical method is then applied to the stability analysis of two hypothetical slopes.

8. Atwood, W. W. and K. F. Mather. "Physiography and Quaternary Geology of the San Juan Mountains, Colorado," U.S. Geological Survey, Professional Paper No. 166, 147-165, 1932.
   Landslides of the area are mapped according to Howe's classification: movements of detritus, movements of solid rock, and movements of both detritus and solid rock. Typical landslide topography for the area is described. Factors controlling landslides in the San Juan region are: (1) occurrence

of soft incompetent beds; (2) prominent fault systems; (3) topography; (4) saturation of the ground by meteoric water, and (5) earthquake shocks. Rock streams and mudflows are also described. (Abstract from "Landslides" Highway Research Board Bibliogrpahy No. 10.)

9. Auger, P. E. "Effet Mecanique de l'Eau sur les Argiles dans les Eboulis," Association Canadienne-Francaise Pour l'avancement des Sciences, Annales, 12:73, 1946, (in French).

The angle of sliding in clays is very small when material is in practically a fluid state. The fluid state in material can be reached by absorption of water by colloidal clay particles until saturated. A small excess of water can then give considerable fluidity to the mass. Absorption is probably facilitated by shrinkage cracks. (Abstract from "Landslides" Highway Research Board Bibliography No. 10.)

10. Baker, R. F. "Determining Corrective Action for Highway Landslide Problems," National Research Council, Highway Research Board, Bulletin 49, January, 1952.

This paper discusses the basic procedure and the problems encountered in correcting landslides. Ten basic fundamentals in landslide analyses are presented and discussed. Corrective measures are classified into two main groups of elimination methods and control methods and details of these corrective measures are given in appendixes. Several stability analysis procedures are presented along with figures of cross sectional views of many types of slides created by different types and layering of slope material.

11. Baker, R. F. "The Design of the Slope of Highway Rock Excavations in West Virginia," Proceedings, Third Annual Symposium on Geology as Applied to Highway Engineering, February, 1952.

This report covers the West Virginia problem of slope design in rock cuts and outlines the procedures that are followed. The summary of the report contains the following conclusions.

The proper design of a slope in rock is directly related to the weathering characteristics of the bed-rock, and the weathering characteristics are undoubtedly related to the geologic formation of the bed-rock and the climate to which the bed-rock is exposed.

There are three principle types of slope design in rock excavations for highways: (a) a uniform slope from the ditchline to the base of the overburden, (b) a cut with varying slope angles for the various types of bed-rock encountered, and (c) a cut consisting of near-horizontal benches connected by straight slopes. The use of the benching method is preferred in West Virginia for the following reasons: the method is more economical, construction is easier, maintenance costs will be lower, and knowledge is not sufficient on the ultimate weathered slope for a given bed-rock to permit good design in using the other two methods.

12. Baker, R. F. "Analysis of Corrective Actions for Highway Landslides," Proceedings, American Society of Civil Engineers, 79: Separate No. 190, May, 1953.

Slides, debris slides, creep flows, and rock slides are defined. Water is shown to contribute to slides by adding weight to the soil, reducing the shear strength of soil, and lubricating the sliding plane.

The factors about which information is needed to analyze a landslide for corrective measures are the geology and geologic structure of the area and the location of seepage strata. In addition, a topographic survey of the ground surface and information about the soil are required.

13. Baker, R. F. "Analysis of Corrective Actions for Highway Landslides," Transactions, American Society of Civil Engineers, 119:665-689, 1954.

Landslides are analyzed to establish the corrective measures required. A tabulated summary of data needed for design computations when using a selected corrective measure is presented. The estimated cost of the corrective measure is also included in the table.

14. Baker, R. F. and R. Chieruzzi. "Regional Concept of Landslide Occurrence," National Research Council, Highway Research Board, Bulletin 216, pp. 1-16, 1959.

The report covers the initial phases of a basic study of landslides. The underlying principle of the research is that the types of landslides that occur in a given geographical region are relatively limited, and the number of variables present in a given region can be reduced, or the range of values limited. The basic concepts and the efforts to use physiographical provinces of the United States as the basis for regional considerations is covered in the report.

15. Baluscheff, B. "The Stability of Earth Embankments," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:531-533, 1961.

The immense influence of certain shearing forces operating in the contact plane between an embankment and the subgrade beneath it, is considered. Plastic earth flow in the subsoil, mainly in the lower part of embankments built on transversely sloping ground, is regarded as the most frequent cause of failure. These shearing forces are: active earth pressure from the center towards the slopes; the component of the weight of the embankment, and the hydrodynamic pressure caused by seepage. The beneficial effects of counterweight embankments and soil drainage are considered.

16. Barber, E. S. "Electrical Stabilization of Soil," Roads and Streets, 91:64-65, June, 1948.

This paper briefly describes the theory involved in the use of electricity to stabilize soil. Applications of this method in the consolidation and drainage of certain types of soil are presented.

17. Barber, E. S. and C. E. Mershon. "Graphical Analyses of the Stability of Soil," Public Roads, 21:147-157, 1940.
This report presents methods of analyses in which charts are used to facilitate computations in the application of the formulas for the evaluation of pressure against retaining walls, the design of cuts and embankment cross sections, and the estimation of the supporting value of undersoil. A summary of the development of the formulas and a brief discussion of the assumptions on which the theories are based are first presented. An explanation of the construction and use of the charts then follows.

18. Baumgarten, Karl. "Thunder Mountain Landslide," Mining and Scientific Press, 101:698-699, 1910.
A mudflow moving at an estimated rate of 6 feet per minute dammed Monument Creek and flooded the town of Roosevelt below Thunder Mountain. Evidence of previous similar flows were abundant. Signs of movement of the same mass previous to the mudflow are described. (Abstract from "Landslides" Highway Research Board Bibliography No. 10.)

19. Bazant, Z. "Scale Model Tests of the Dynamical Stability of Saturated Sand," Proceedings, Fifth International Conference on Soil Mechnics and Foundation Engineering, 2:539-540, 1961.
The dynamical stability of sand slopes is not susceptible to analytical treatment. Scale model tests of dynamical stability suggest dimensionless factors which may be computed from measured data. The data from three examples of dynamical stability show applications of this method.

20. Beard, F. D. "Predicting Slides in Cut Slopes," Western Construction, 36:72, September, 1961.
An instrument called a "Seismitron" has been tested in tunnels and mines to measure stability and to forecast failures. Detection is based on the principle that rock undergoing strain makes noises. The "Seismitron" picks up such telltale sounds long before they become audible.
In practice, the instrument is simple enough to be operated by one trained man. The probe is pushed 3-4 feet into a drilled hole and the opening is sealed with waste material. The operator counts the number of microseisms heard during a 15-minute time period. Each location is checked periodically for an increase in microseisms which forecasts instability.
Conclusions drawn thus far are: (1) the use of the instrument can predict failure in cuts on slopes in "crystalline" materials, (2) it is best to drill a 1-3/4 inch or larger hole for test purposes to cut down on extraneous noises, and (3) even though failures occur as a result of water saturation, those cuts that fail as a result of water usually have microseismic activity in the dry season. (Abstract from "Highway Research Abstracts.")

21. Beard, F. D. "Microseismic Forecasting of Excavation Failures," Civil Engineering, 32:50-51, May, 1962.
Same article as Beard (20).

22. Beaty, C. B. "Landslides and Slope Exposure," Journal of Geology, 64:70-74, 1956.
A study was undertaken in an area east of Berkeley, California, to attempt to determine if a recognizable relation exists between landslide occurrence and slope exposure. Seventy per cent of the landslides observed were found to occur on slopes with northerly and easterly orientation. (Abstract from "Highway Research Abstracts.")

23. Becker, G. F. "Mechanics of the Panama Canal Slides," U. S. Geological Survey, Professional Paper No. 98, 253-261, 1916.
After describing the essential features of the breaks on the Culebra Cut, the author points out that there is a limit to the depth of a vertical cut in an homogeneous isotropic mass which has a plane for an upper surface. The limit is reached when the pressure is sufficient to produce simple shear in the mass. Reasons are given for the belief that $6\sqrt{2}$ multiplied by the resistance to such shear is about equal to the ultimate strength under linear compression. Several examples are analyzed and solved.

24. Behera, B. "A Mathematical Formula For Design of Earth Slopes," Irrigation and Power, 12:600-610, 1955.

25. Beichmann, U. F. "A Study of Various Methods for Calculation of Safety Against Sliding of Embankments Caused by Shear Rupture," Proceedings, Engineering Society of China, 35: nESC 2b, 1937.

26. Beles, A. A. and I. I. Stanculescu. "Thermal Treatment as a Means of Improving the Stability of Earth Masses," Geotechnique, 8:158-165, 1958.
The paper outlines some characteristic aspects of the available methods for improving the stability of earth masses through thermal treatment. Laboratory tests results are discussed, and some of the published data on the technological processes are described. Details are given on a new procedure of thermal treatment by burning gas oil in borings, using a free draught air supply. The paper includes the description of some practical applications of the new thermal treatment procedure as a method for improving the stability of clay soil masses. (Abstract from "Highway Research Abstracts.")

27. Bendel, L. "Protracted Sliding Surface," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:53-57, 1948.
The formulas deduced by the author are applied to determine the tendency of slopes containing clayey material to slide. The formulas are furthermore applied to determine the stability of hillsides crossed by watercourses, roads, or reservoirs. Finally the equations have been applied to the calculations of the degree of safety of dams from shocks caused by earthquakes

or battered with projectiles. In addition, instead of the pressure of trickling water, the intensity of the wave of concussion has been given.

28. Benson, W. N. "Landslides and Allied Features in the Dunedin District in Relation to Geological Structure, Topography and Engineering," Transactions, Royal Society of New Zealand, 70:249-263, 1940.

The article describes types of slides, including rockslides, debris-avalanches, creep, and slump. The Abbottsford mudstone was most prone to slide. Some measurements of the amount of sliding have been made where slides concerned engineering structures. (Abstract from "Landslides" Highway Research Board Bibliography No. 10.)

29. Berger, L. A. "Three-Dimensional Aspects of Landslides," Prcceedings, Highway Research Board, 34:1955.

30. Bernatzik, W. "The Extreme Inclination of Slopes with Groundwater Passing Through Them," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 5:19-20, 1948.

Equations are presented which define the maximum slope which will remain stable while allowing groundwater to pass parallel to the surface of the slope. An equation is derived for cohesionless material. The maximum angle of inclination of a slope is shown to be dependent only on the density of the material, the unit weight of water, and the frictional angle of the material.

31. Berrar, Alfred. "Standsicherheit-suntersuchung von kaimauern in weichem Lehmboden," Die Bautechnik, 3:728-729; 4:348, 436, 1925, (in German).

This paper discusses the stability of soil at Shanghai. The stability analysis method used assumed a curved surface of rupture and took into consideration the change in the internal angle of friction with depth.

32. Bhattacharya, S. K. "The Geometry of a Slip-Line Field in Soils," Geotechnique, 10:75-81, 1960.

The paper gives the geometrical interpretation of Kotter's equations of equilibrium for a nonorthogonal slip field, as in soils, and gives methods for constructing a slip-line field graphically.

The paper discusses (1) the state of stress along any straight slip line being constant; (2) why the straight slip line is always embedded in a family of straight slip lines; and (3) in a slip-line field, where both are straight lines, the state of stress is shown to be constant throughout the field.

Several examples, common in practice, are given.

33. Binger, Wilson V. "Analytical Studies of Panama Canal Slides," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 2:54-60, 1948.

The East and West Culebra slides alone contributed more than 50,000,000 cubic yards of additional excavation in building the Panama Canal. These slides occurred in the Cucaracha formation, the weakest rock encountered along the Canal, largely poorly bedded, variably bentonitic, slickensided, soapy-textured clay shales.

From available cross sections showing monthly excavation progress during construction, three sections through the slides were selected for study. The geology of each section was determined from drill holes and surface reconnaissance. Stability analyses of the conventional Swedish circle type were applied to the East and West Culebra slopes as they existed immediately before slides in 1912 and 1915, and also to the slope of 1947, which is apparently stable.

The slopes were analyzed in two ways. First, assuming factors of safety of approximately 1.0 just prior to any failure, the available shear strength was determined for each date for comparison with the strength used in the design of excavation slopes for a new canal. Second, the values for cohesion and angle of friction of the Cararacha, as used in the latest slope design studies, were used to determine factors of safety of the sections before any slides had occurred. The factors of safety were found to be less than 1.0, indicating that the strength assumptions used were conservative.

34. Binger, Wilson V. and Thomas F. Thompson. "Excavation Slopes," Transactions, American Society of Civil Engineers, 114:734-754, 1949.

The geologic and soil mechanic studies conducted to establish stable slopes for the formations that would be excavated for a sea-level canal at Panama are described in this paper. The authors discuss the early and current geological investigations, the geological features of the area, the difficulties experienced in the slides that occurred during construction of the present canal, and the development of slope standards used in the preliminary design of a sea-level canal.

35. Bishop, A. W. "Pore Pressure Changes During Shear in Two Undisturbed Clays," Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, 1:94-99, 1953.

Results are reported of two investigations in which the measurement of pore-water-pressure changes during shear has aided in the solution of practical problems. In the first case, measurements were made of the residual pore pressure remaining in a saturated soil after the transient application of a shear stress. In the case of a heavily overconsolidated clay, the residual pore pressure was negative and, in the presence of free water, led to softening of the clay. In a normally consolidated clay, the residual pore pressure was positive and led

to further consolidation. The results are related to the problem of estimating the safe loads to be applied to formations and subgrades of clay. In the second case, the pore-pressure changes in sampling and testing of normally consolidated strata were considered and related to ways of estimating the in-situ strength of **natural** deposits, where the horizontal and vertical stresses generally are not equal. (Abstract from "Highway Research Abstracts.")

36. Bishop, A. W. "The Use of the Slip Circle in the Stability Analysis of Slopes," Geotechnique, 5:7-17, 1955.

The author discusses how errors may be introduced into an estimate of stability by both the sampling and testing procedure. The error is likely to be of particular importance where deep slip circles are involved. The author proposes a modified analysis to correct for the errors present in the conventional method of analysis.

37. Bishop, A. W. and N. Morgenstern. "Stability Coefficients for Earth Slopes," Geotechnique, 10:129-147, 1960.

A set of coefficients that can be used to investigate the stability, in terms of effective stress, of most simple sections encountered in earth dams and embankment problems is presented. The application of these coefficents gives results that are correct for simple sections composed of only one material and whose pore-pressure distribution can be described by the pore-pressure ratio being constant throughout the given section.

A method is presented to determine the average pore-pressure ratio when the ration distribution is variable within the cross section. This allows the application of the stability coefficients to the more usual type of design or analysis that the engineer faces. Several cases of this type investigated revealed that only a comparatively small error is incurred in estimating the factor of safety.

38. Bjerrum, L. and B. Kjaernsli. "Analysis of Stability of Some Norwegian Natural Clay Slopes," Geotechnique, 7:1-16, 1957.

Three slides were analyzed by the c'Ø' analysis. A c'Ø' analysis uses the shear strength as introduced according to the coulomb equation ($s = c + \sigma \tan \phi$ where s = shear strength, c = cohesion, σ = normal stress, in terms of effective stress and the pore pressures which actually exist in the slope. This method yielded satisfactory results for investigating the long-term stability of slopes in normally consolidated and over-consolidated, intact clays. The author concluded that the stability of natural slopes, and the long-term stability of cuttings, should, for all types of clay, be analyzed by the c' ϕ' analysis.

39. Blackwelder, Eliot. "The Gros Ventre Slide, and Active Earth-Flow," Geological Society of America Bulletin, 23:487-492, 1911.

The Morrison and Sundance clays and shales dip at angles of 18 to 20 degrees toward the Gros Ventre River Valley in Wyoming. Slippage in these beds caused a slow earth-flow in

a tributary gulch. The flow began in 1908 and continued until 1911. Movement was very slow and continuous, particularly in the lower part. At the lower end of the flow, marginal slopes were steep and the entire surface of the flow was abundantly crevassed. Movement was most rapid in the wet spring months. The slide was composed of unassorted clay and coarser debris.

Abstract take for "Landslides" Highway Research Board Bibliography No. 10.

40. Blackwelder, Eliot. "Mudflow as a Geologic Agent in Semiarid Mountains," Geological Society of America Bulletin, 39: 465-480, 1928.

Mudflows are important agents of erosion in semiarid and arid regions. Mud-flows from Arizona, Utah, and California are described. A mudflow usually contains just enough water to make the mass slippery; it flows much like lava; and may carry large boulders on the surface. Thicknesses of mudflows vary from 6 to 20 inches. Conditions which favor mudflows are: (1) unconsolidated material that becomes slippery when wet; (2) slopes steep enough to induce flowage in such viscous material; (3) abundant water, and (4) insufficient protection of the ground by trees.

41. Bogdanovskiĭ, V. K., A. M. Nikolaev, and G. G. Skvortsov. "Opyt, Issledovaniya Opolznevykh Yavlenii v Kar'ere," Razvedka i Okhrana Nedr, 26:37-40, May, 1960, (in Russian).

The experience of the authors while investigating landslide phenomena in a quarry is reported. The causes of landslides in the amber open pit of Kaliningrad in former East Prussia are described. Drainage is suggested as the method of controlling future landslides. (Abstract taken from "Engineering Index.")

42. Bokman, J. "Sandstone Classification: Relation to Compostion and Texture," Journal of Sedimentary Petrology, 25:201-206, 1955.

Composition and texture are two interdependent properties on which any sound classification of sandstones must be based. The extent to which a sediment approaches maturity is measured by the complexity of these properties. Sandstone types are defined in terms of the positions they occupy relative to the crushed-rock complex and the perfectly mature sediment. These positions reflect the influence of both source terrain and the basin of deposition. (Abstract was taken from "Highway Research Abstracts.")

43. Bostwick, N. "Earth Pressures at the Whittier Narrows Dam Recorded by New Measuring Device," Southwest Builder and Contractor, 117: No. 24, June 8, 1951.

The design and application of an earth-pressure gage and a fluid-pressure gage to measure pressures within an earth fill were presented. Both gages work on the transducer principle and are electrically equipped to permit instantaneous readings of the pressures within the fill.

For the fluid-pressure gage, the transducer is contained in a case made of brass pipe with capped ends. Fluid pressure is admitted through tiny holes designed to exclude granular material.

For the earth-pressure gage, the container is a steel disc. One side of the disc is chambered out and covered with a steel diaphragm welded around the rim of the disc. The chamber is filled with a light oil that transmits pressure from the steel diaphragm to the bulb of a glass transducer.

44. Boyce, Stephen G. and David J. Nebee. "Trees for Planting on Strip-Mined Land in Illinois," Central States Forest Experiment Station, U. S. Forest Service, Technical Paper 164, November, 1959.

Seventeen species of trees were found suitable for planting on strip-mined land in Illinois. Ten species were suitable for planting in all parts of the state; seven additional species were suitable for the southern counties. The best survival and growth was obtained where species were carefully selected for the various sites and only the best quality stock was planted. The species selected and their suitabilities are discussed and summarized in this paper.

45. Bradley, Harold. "Notes on the Causes and Control of Landslides," Surveyor, 75:345-346, 1929.

The causes and control of landslides in road cuts are discussed. Slides caused by the weathering of soft strata are most effectively prevented by cultivation of vegetation on the slope. Some unstable slopes can be rendered stable by drainage. Slides caused by subsurface movement were difficult to counter. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

46. Brant, R. A. and R. M. DeLong. "Coal Resources of Ohio," Ohio Division of Geological Survey, Bulletin 58, Columbus, 1960.

This report presents a generalized summary of previous reports dealing with either individual coal beds or groups of coal beds, and estimates of their potential reserve. This report also summarizes all the face-sample analytical data in the Division's files.

The geography and geology of the coal region is one topic of concern dealt with in this report along with the individual county descriptions.

Information about the generalized stratigraphic column of Ohio can be obtained from Table 9 which begins on page 25 of this report.

47. Brawner, C. O. "The Landslide Problem in B. C. Highway Construction," British Columbia Professional Engineer, 11:11-17, March, 1960.

Analysis of landslide problems in British Columbia consists of (a) assessment of stability of surfaces along proposed highway locations, (b) preventive measures during construction, and (c) stabilization of active landslides.

Assessment of stability requires determination of the history of landsliding along proposed routes from sources such as airphotos, local residents, and field inspection. Field inspection includes study of the type slide, and amount of movement; study of local drainage and geology; and efforts to determine such subsurface data as depth of water table, depth and shape of failure zone,

and location of underground seepage channels.

The guiding principle for prevention of landslides is that construction should be carried out in a manner that will cause the least disturbance to the normal forces of nature, such as drainage patterns. Special attention should be given the strength of highway fills, and the control of surface and subsurface runoff.

If economic considerations permit, the slide may be stabilized. Commonly used methods include counterbalancing surface and subsurface drainage, construction of retaining structures, and slope seeding. (This abstract was taken from "Highway Research Abstracts".

48. Caldenius, C., R. Lundstrom, B. Fellenius, and E. Mohren. Landslide at Surte on River Gota Alv. Stockholm, Sveriges Geologiska Undersokning, Arsbok, No. 27, 63 pp., 1955, (in Swedish).

An area of ground, 400 meters in width and 600 meters in length, was cut into slide elements, which slipped towards the river. The maximum fall of the ground level in the interior part of the slide was 12 meters and the maximum rise in the exterior part was 4 meters. The volume of earth masses involved in the slide was estimated at 3,000,000 cubic meters. The causes and geotechnical problems of the slide were analyzed and discussed. (Abstract taken from "Engineering Index".)

49. Capper, P. L. and W. F. Cassie. The Mechanics of Engineering Soils. New York:McGraw-Hill Book Company, 270 pp., 1949.

Chapter eight is devoted to the stability of slopes. The Swedish method and the Ø-Circle method are discussed. The procedure for locating the critical slip surface of an embankment is presented. Examples of stability calculations and Taylor's curves for the stability number versus the slope angle are given. A few remedial measures are given at the end of the chapter.

50. Caquot, A. "Exact Method for Calculating Failure of an Earth Mass by Cylindrical Sliding", Geotechnique, 5:29-32, 1955, (in French).

The classical slip circle analysis of the stability of earth slopes is modified to include the effect of a riprap layer at the surface. It is assumed that the slip circle passes through the weaker soil in the interior of the slope, and that the riprap layer fails with active and passive pressures at the upper and lower intercepts of the failure circle with the riprap, respectively. A numerical example is presented indicating a somewhat higher factor of safety for the Panama Canal slides than that determined by classical methods.

51. Carrillo, N. "Differential Equation of Sliding Surface in Ideal Saturated Plastic Soil," Journal of Mathematics and Physics, 21:6-9, March, 1942.

A differential equation is derived which shows the change of the shearing component of stress with respect to the angle

measured from the vertical axes, along the circular plane of failure of the slope. The equation is derived assuming a plastic soil which fails along a cylindrical arc. The equation is valid under submerged conditions if the buoyant unit weight of soil is used in place of the total unit weight. The equation is identical to Kotter's equation if the soil is dry.

52. Casagrande, A. "Characteristics of Cohesionless Soils Affecting the Stability of Slopes and Earth Fills," Journal of the Boston Society of Civil Engineers, 23:13-32, January, 1936.

This article analyzes the reduction in shearing resistance of cohesionless materials due to reduction in density, where the density of the material is below the critical density. The initiating cause of the reduction in density was often found to be vibration. If voids of soil mass are filled with water and the escape of water lags behind deformation, temporary transfer of the load on to water takes place and the resulting reduction in friction may lead to a flow slide. If the density of a cohesionless soil is above the critical density it can stand disturbance without danger of a flow slide. Cohesionless soils in a state below the critical density can be efficiently compacted and thereby stabilized by means of special vibration machinery.

Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.

53. Casagrande, A. and N. Carrillo. "Shear Failure of Anisotropic Materials," Journal of the Boston Society of Civil Engineers, 31:74-87, April, 1944.

54. Casagrande, L., R. W. Loughney, and M. A. J. Matich. "Electro-Osmotic Stabilization of a High Slope in Loose Saturated Silt," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:555-561, 1961.

The paper describes a successful electro-osmotic stabilization of a slope in inorganic silt which had developed serious instability during construction. The slope forms the east bank at the site of the Little Pic River near Marathon, Ontario, Canada.

55. Cassel, F. L. "Slips in Fissured Clay," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 2:46-50, 1948.

The circular slip theory and tests on undisturbed soil samples do not provide means of assessing a factor of safety and preventing slips in fissured clays. The progressive deterioration of such clays originates, according to the observations reported in this paper, in the zone of fluctuating ground water levels. Two types of failure in two distinctly different groups of fissured clays are described, and methods of drainage for them are proposed.

Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.

56. Chernogradsky, V. I. "Computation of Stability of Earth-Fill Dams," Izvestiya Nauchno-Issledovatelskovo Instituta Hydrotechniki, 19:273-282, 1936, (in Russian).

57. Chugaev, R. R. "Approximate Determination of Stability of Earth Dams," Transactions, Second Congress on Large Dams, 4:593-611, 1936.
The stability of dam slopes is analyzed by altering the circular theory presented by Terzaghi to include the forces caused by the presence of gound water. In some of the problems studied, if the seepage forces are neglected, the computed factor of safety will be 50 percent greater than if such forces had been included. The author refers to the fact that capillary pressures, being of a negative nature, assist in the stability of dam slopes and he has shown how to include such pressures. However, where the maximum value of the capillary rise is sufficient to saturate the entire dam above the phreatic line, a heavy rain will destroy the menisci at the surface and cause the capillary water to loose its capillary properties and set up positive active seepage forces which are in addition to those usually considered in designs.

58. Clark, T. H. "Two Recent Landslides in Quebec," Transactions, Royal Society of Canada, XL 1:9-18, May, 1947.
The St. Louis de Bonsecours slide, a horizontal flow of clay into the Yamaska River, and the Grande Riviere du Chene Cliff-Fall are described. Primary cause of the former was saturation of the clay until plastic flow became possible. Geologic sections are given. The author points out the importance of the former type of slide as a land-forming process.
Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.

59. Clarke, R. C. "Stability Analysis in the Design of Earth and Rockfill Dams," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:240-245, 1948.
A derived stability analysis is based on a cylindrical slip surface which provides a practical method of computing a quantitative indication of the stability of an embankment constructed of varying materials placed in definite zones. The application of this analytical method is shown by its use in designing a 260-foot high earth and rockfill dam.

60. Cleaves, A. B. Landslide Investigations. U. S. Bureau of Public Roads Handbook, Dept. of Commerce, July 1961. 67 pp.
This handbook is condensed in a deliberate effort to provide a work that may be used in the field. It is divided into four parts. The first is a very brief introduction to geologic processes, rocks, and soil types, and geologic structures which provide the setting for landslide. The second involves the recognition of phenomena presaging the advent of slide movements, and those characteristics of the landslide itself. The third is devoted to methods of landslide prevention, control, and correction. The fourth discusses details of mapping and reporting landslides. The brief glossary defines the words and their usage that might be unfamiliar to the highway location engineer. Five principal references are listed at the back of the manual. In them, in addition to their own valuable content, the interested reader will find bibliographies covering books, articles, and other references on landslides far beyond the intended scope of the manual. ("Abstract taken from "Highway Research Abstracts".)

61. Collin, Alexandre. Landslides in Clays. 1846. Translation by W. R. Schriever, Toronto: University of Toronto Press, 1956.
Collin defines spontaneous movements of clay and makes the distinction between deep slides and superficial slides. The general form of the surface of sliding is deduced from observations. The author explains the graphical relation between the line of simple sliding and cycloidal arcs. Several examples of clay slides are discussed in relation to the distinctive features of the surface of sliding and the methods of preventing and repairing slides.

62. Coulomb, C. A. "Essai sur une Application des Regles de Maximis et Minimis a' Quelques Proble'mes de Stratique; Relatifs a l' Architecture," Memoirs, de l' Academie des Sciences, 7:343-382, 1776, (in French).
This paper is the first attempt at rational analysis of earth pressures on retaining structures and sliding of earth messes. The empirical relationship between strength and applied stress, which is still in use today, is first suggested here. In modern notation: $s = c + p \tan \phi$ where s is the shear strength of the soil, c is the internal cohesion, p is the applied normal pressure on the failure plane, and ϕ is the slope of the observed relationship angle of internal friction).

63. Crandell, D. R. "Landslides and Rapid-Flowage Phenomena Near Pierre, South Dakota," Economic Geology, 47:548-568, 1952.
Landslides in Pierre shale are typical of the slump variety in which the surface of movement is concave upward and chiefly rotational. Deposits due to rapid flowage were described as being less conspicuous than slumps but have as great or greater areal distribution. (Abstract taken from "Engineering Index)

64. Croce, A. "Analisi di una frana per scorrimento in rocce sciolte," Geotecnica, 7:5-11, 1960, (in Italian).
An analysis was made of a landslide which occurred in loose rock in the mountains near Salerno, Italy. The slip plane occurred on the contact area between the soil and rock formation where the shearing resistance was lower than the resistance of the soils or the rock. The physical and mechanical properties of the soils and the morphological characteristics of the slide are discussed. (Abstract taken from "Engineering Index")

65. Davis, E. H. "General Theory of Undrained Strength of Soils and its Application to Stability Analysis," New Zealand Engineering, 11: 250-256, 1956.
The relationship between true soil constants and constants for undrained apparent cohesion and angle of shearing resistance with respect to total stresses was investigated theoretically for the general case of unsaturated dilating soil. For two-dimensional strain conditions in slope stability analysis problems, an envelope-shaped curve was found consisting of a family of straight lines with slightly changing slopes. (Abstract taken from "Engineering Index")

66. DeBeer, E. E. and E. Lousberg. "Definition of the Factor of Safety Against Slope-Sliding Starting from the Charges Provoking Rupture," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:541-549, 1961.

There have been numerous so-called "classic" definitions of the factor of safety against slope-sliding, some of them using the mechanical properties of soil, others taking into account the shear stresses along the sliding surface. The authors have defined a factor of safety based on the loads which cause failure, claiming thereby to eliminate the inaccuracy of classical methods.

Two factors of safety "at rupture" can be defined in relation to the cause of failure: the first is based on an assumed increment of the resultant of the loads without changing the line of action; and the second is based on an assumed displacement of this resultant parallel to itself without changing its value.

67. Deere, D. U. "Seepage and Stability Problems in Deep Cuts in Residual Soils," American Railway Engineering Association, Bulletin, 58: No. 535, February, 1957.

A study of a series of deep cuts in residual soils has shown that there are several inherent conditions likely to be present in these soils that may result in slope failures. The residual soils are essentially cohesionless silts or fine silty sands below a depth of 15 feet. If a high water table is present, seepage at the base of the cuts may cause backward or subsurface erosion which tends to undermine the slope. In addition, the presence of joints introduces planes of weakness in the soil mass which further results in a lower stability. (Abstract taken from "Highway Research Abstracts")

68. Denisov, N. J. "Surface Phenomena and Landslides of Argillaceous Formations," Comptes Rendus, l' Academie des Sciences de l' U. S. S. R., 33:295-296, 1941, (in Russian).

The mechanism of landslides in argillaceous soils or in loess are reported. The effect of thin water films between soil particles is that the films wedge apart the particles and reduce the internal friction of the mass. The thickness of this film is less, consequently the internal friction is higher, if the liquid in the pores is an electrolyte rather than pure water. Landslides may thus be initiated by a lowering of the concentration of electrolytes in pore-water thru dilution by atmospheric precipitation without any increase in actual moisture content of the rocks. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

69. Drouhin, G., M. Goutier, and F. Dervieux. "Slide and Subsidence of the Hills of St. Raphael Telemly," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 5:104-106, 1948.

Results obtained by the cooperation of topography and geology test laboratories for geotechnics and soil mechanics, and geochemistry in solving problems of the slide and subsidence of St. Raphael Telemly are described. Action of groundwater on a glauconitic marl caused decrease in the bearing strength of

the marl and flowage of the marl. Stabilization works directed toward shutting off the supply of ground water were presented. (Abstract taken from "Landslides" Highway Research Board Biblography No. 10.)

70. Drucker, D. C. "Limit Analysis of Two and Three Dimensional Soil Mechanics Problems," Journal of Mechanics and Physics of Solids, 1:217-226, July, 1953.

Previous work on the implications of assuming soil to be a perfectly plastic body is extended. A brief discussion is given of suitable general forms of the yield or sliding criterion for soils. Coulomb's equation is interpreted in terms of a modified Tresca as well as a modified Mises rule. Particular attention is given to a soil unable to take tension but which exhibits both cohesion and internal friction in sliding action. Indication is given of an interesting development of complete solutions.

The stability of unbraced vertical-walled cuts is then treated. A brief description of the application of the general limit theorems to nonhomogeneous soil is also included to demonstrate their power.

71. Duvivier, J. "Cliff Stabilization Works in London Clay," Journal of the Institute of Civil Engineers, 14:412-446, 1940.

A description is given of the stabilization of a cliff of London clay by means of surface drains which prevented saturation of clay during rainy seasons. Further stabilization was accomplished by reseeding surface area. Borings were used to investigate the area prior to stabilization operations. The article points out the futility of using retaining walls to stabilize a clay cliff face. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

72. Eckel, E. B., A. W. Root, R. F. Baker, and others. "Landslides and Engineering Practice," National Research Council, Highway Research Board, Special Report No. 29, 232 pp., 1958.

The economic and legal aspects of landslides are reviewed. The economic importance is discussed along such lines as cost to the nation, cost as related to types of landslides and relative costs of prevention and correction. Recognition and identification of landslides, airphoto interpretation, field and laboratory investigations, stability analyzes, and design of control methods are also included in the report.

73. Ehrenberg, J. "Calculation of the Stability of Dams," Transactions, Second Congress on Large Dams, 4:331-386, 1936.

The importance and problems of measuring the unit weight and shear strength of soil for slope stability analysis is discussed. Both circular surfaces and logarithmic spiral surfaces are used to represent sliding surfaces in dam design procedures in Germany. Several recent German dams are discussed.

74. Emel'yanova, E. P. "Rol Klimaticheskikh Faktorov v Opolzneuykh Protsessakh," Sovetskaya Geologiya, 1:107-127, 1958, (in Russian).
English summary of the Russian article on the role of climatic factors in landslide phenomena and the distribution of landslides in relation to climatic conditions. The connection between the time of slope displacements and meteorological conditions is also discussed. (Abstract taken from "Engineering Index").

75. Emel'yanova, E. P. "O Periodichnosti Opolznevykh Protsessov," Razvedka i Okhrana Nedr, 25:41-46, June, 1959, (in Russian)
Discusses the periodic character of landslide processes; the influence of the moon and sun on stability of slopes; and the dependence of frequency and magnitude of landslides on intensity of sunspots. Several examples of the periodic character of landslides in different areas of the Soviet Union are given. (Abstract taken from "Engineering Index").

76. Emerson, Frank B. "180-ft. Dam Formed by Landslide in Gros Ventre Canyon," Engineering News Record, 95:467-468, 1925.
The article describes a slide of earth and loose rock. The slide blocked a river in Wyoming.

77. Engineering and Contracting. "Method of Remedying Railway Slip in Clay Cut," Engineering and Contracting, 55:321, 1921.
Slips in clay embankments remedied by excavating the slide to undisturbed ground, building a fire on the excavated surface, and burning clay by method used for burning bricks in kilns. Slope is then refilled to former surface. Clay swells in burning eliminating slips.

78. Engineering News Record. "Further Data on Failure of the Gros Ventre Dam," Engineering News Record, 99:600-601, 1927.
The article discusses a slip of an earth barrier on a river in Wyoming. This barrier was formed by a landslide. The article stresses the need for care in grading earth dam material.

79. Escario, V. "Errors Arising from the Simplified Method of Slices," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:585-589, 1961.
The author has studied the short-term stability of a pile of materials placed on soft soil and describes the procedure followed in determining the partially dissipated pore pressures at the end of construction by means of the method of finite differences and the use of the pore pressure coefficients. He reviews the results obtained in calculating the factor of safety by slip circles, using the slices method following three different procedures. The author concludes that the simplified method of slices is inadmissible to the work which he has undertaken and that by allowing for pore pressure on both sides of the slices, but neglecting normal and shear stresses on the soil, the results were too conservative.

80. Fagnoul, A. "Contribution to the Study of the Stability of Slopes," Bulletin, Centre d' Etudes de Recherches et d' Essais Scientifiques des Constructions du Geme Civil et d' Hydraulique Fluviale, Liege, 10:89-267, 1959, (in French).

For a material obeying Coulomb's law of strength, the author uses Rankine's limiting conditions to determine critical depths beneath a slope for various chosen inclinations of the rupture surface. A series of tangential parabolae are then used to obtain a unique rupture surface conforming at the critical points with the principles of soil mechanics. Trial and error is not needed. A quick, approximate method for getting pore pressures resulting from rapid drawdown is offered, together with an indication of a method of incorporation in the stability analysis. (Abstract taken from "Highway Research Abstracts").

81. Fellenius, W. Erdstatische Berechnungen mit Reibung und Kohasion und Unter Annahme Kreiszylindrischer Gleitflachen. Berlin: Ernst and Sohn, 40 pp., 1927, (in German).

This book amplifies earlier investigations by assuming the presence of cohesion either alone or in combination with friction, both in the case of plane and curved surfaces of rupture. The book is particularly useful for calculating stability of embankments, quarry walls, and dams on weak subsoil and for investigating the danger of slides. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

82. Fellenius, W. "Calculation of the Stability of Earth Dams," Transactions, Second Congress on Large Dams, 4:445-459, 1936.

A number of diagrams and equations to facilitate the determination of the most dangerous circle of sliding applicable to special cases is presented. Other forms of sliding surfaces have been employed, but the author considers that, for heterogeneous earths, which are of frequent occurrence, such methods are scarely applicable. The author recommends a factor of safety or ratio of total shearing strength as shown by laboratory test to the required total shearing strength of from 1.2 to 1.5. Two examples of the determination of safe slopes, one for a dam without seepage and one with seepage flow, are discussed. The latter required about 50 per cent greater shearing strength.

83. Finzi, D. "Slope Consolidation of the Banks of the Monguel fo Reservoir, Italy," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:591-594, 1961.

Slope stability of the banks of the Monguel fo Reservoir in Italy was analyzed. General site conditions were examined in advance by means of both geological and geoseismical investigations. The dangers of slope failure as well as of superficial erosion arising from reservoir operations were studied. As stability analysis was performed using the modified Swedish Method.

84. Folwell, A. P. (Editor), "Draining to Prevent Slippage of a Road Fill," Public Works, 73:23-24 and 27, July, 1942.

This article discusses a particular installation of horizontal drains in two large earth and rock fills on the Los Gratos-

Santa Cruz Highway in California to eliminate slippage. A side-hill road embankment 200 feet high slipped down and out due to underground water. To prevent recurrence, over 4,500 feet of drains were placed under the 55,000 cubic yards of new fill.

85. Forbes, Hyde. "Landslide Investigation and Correction," Proceedings, American Society of Civil Engineers, 72: No. 2, 169-198, 1946. See Forbes (86).

86. Forbes, Hyde. "Landslide Investigation and Correction," Transactions, American Society of Civil Engineers, 112:377-406, 1947.
The occurrence, cause, and correction of landslides and earth movements in the San Francisco Bay region of California are described in this paper. Examples are cited of (1) a shear slide in which hydrostatic uplift on an unbalanced slope resulted in mass movement of the unconsolidated slope material; (2) a shear slide caused by the overstress of clayey material on a slope that had absorbed a water load; (3) a slide that developed along the contact between two rock formations; (4) a detrital slide caused by the seasonal saturation of soil; (5) a detrital slide resulting from a geochemical breakdown of rock cut slopes; (6) slides started by groundwater pressure; and (7) soil creep. The method used for investigation, the procedure followed, the costs involved in the corrective work, and the results obtained are described in the instances where economic factors required the investigation and correction of slides.

87. Forster, Donald F. "Treacherous Slides Delay Cloverdale-Hopland Realignment," Pacific Street and Road Builder, Vol. 32, No. 2 1933.
The article describes slide problems in two cuts on a road realignment project. In one location unstable slopes caused by underground springs made it necessary to construct a slide bridge anchored to bedrock. In the other location, control was attempted by the removal of material in a road area. In principal slide areas, drainage systems are installed to destroy impounding reservoirs which allow seepage into volcanic tuff. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

88. Freund, Albert. "Untersuchung der Erddruck-theorie von Coulomb; zu ihrem 150 jahrigen bestehen von 1773 bis 1923," Die Bautechnik, 2:101-109, 1924, (in German).
The origin, nature, and evaluation of the Coulomb theory is presented. Winkler's method of analysis is included. The theory is rectified and improved with the aid of the laws of elasticity. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

89. Frohlich, O. K. "The Factor of Safety with Respect to Sliding of a Mass of Soil Along the Arc of a Logarithmic Spiral," Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, 2:230-233, 1953.

This paper deals with the problem of sliding of a mass of soil on the following assumptions: (1) Coulomb's law for the shearing resistance S along the sliding surface, $S = C + \sigma \tan \phi$, is valid and (2) the real sliding surface may be replaced by an arc of a logarithmic spiral.

On the basis of the usual definition of the factor of safety against sliding, a simple graphical procedure is developed to find this factor for constant friction and variable cohesion along the sliding arc, and a formula for the factor of safety is given for constant values of cohesion and friction.

It is shown that the problem of sliding along a logarithmic spiral is kinematically indeterminate, whereas, the problem of sliding along an arc of a circle is statically indeterminate.

90. Frohlich, O. K. "General Theory of Stability of Slopes," Geotechnique, 5:37-47, 1955.

The author reviews the principles of the existing theories on stability of slopes including the point to point stress analysis, the determination of the shape and location of the sliding surface, and the choosing of any continuous surface of rupture along which failure may occur and then placing it into the earth mass in such a way that there is a maximum danger of sliding.

The Fellenius rule and the Ohde rule, the necessary tools for the application of the indirect method of computing the safety factor, are presented. The direct methods as well as the indirect methods of determining the safety factors are discussed.

91. Frohlich, O. K. "Basic Principles of the Computation of the Resistance of Earth Slopes to Sliding," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:595-602, 1961.

The author has established a general equation for the factor of safety of earth slopes against sliding along a circular cylindrical surface taking into account the three conditions of equilibrium between the external forces and the resistances, due to cohesive and frictional forces along the sliding surface. The complete mobilization of available shear forces is produced by an "impulse", consisting of an additional single load, acting on the sliding mass at a point, which may be chosen at liberty. The same applies to the inclination of the impulse. By varying the point of application and its inclination, equations for the known methods for determining the factor of safety were reviewed. The results of all these possible equations lie between a minimum and an infinitely great maximum value. It is shown that only the minimum value may be applied in practice.

92. Frontard, J. "Logoides de Glissement des Terres," Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences, 174: 740-742, 1922, (in French).

The equations for the curve of the plane of rupture of coherent earth masses under certain conditions are given. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

93. Frontard, J. "Slip Lines and Dangerous Height of an Earth Embankment Bounded by a Flat Slope", Geotechnique, 5:33-36, 1955, (in French).

The author discusses the differences between his method (proposed in 1922) and that of Fellenius (1926) for calculation of the critical height of an embankment. The Fellenius method yields allowable heights much greater than that of the author. The author suggests that the Fellenius method is appropriate for plastic soils which can sustain tension and mobilize shearing resistance along the entire slip surface, while his method is superior for highly compacted soils which will develop tension cracks.

94. Frontard, M. "Calculations on the Stability of Earth Dams," Transactions, Second Congress on Large Dams, 4:243-293, 1936.

A study of the stability equilibrium of an earth fill itself, excluding the effect of the action of impounded water, is first made, and then these additional actions are studied in regard to their effect on stability. The cycloidal curve method of slope stability analysis is used to determine the most dangerous sliding surface. Attention is called to the progressive nature of a sliding failure.

95. Frontard, M. "Sliding Surfaces and Stability Calculations for Soil Masses of Curvilinear Profile," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 5:20-22, 1948.

The author discusses the problem of describing the sliding of a heavy mass when the free surface follows any curve. Rankine's conditions of slope stability are employed. The author determines for certain cases an upper limit of the error made by considering the variable coefficient in Rankine's theory to be unity.

96. Fryxell, F. M. "Jalaur Landslide, Island of Panay, Philippines," Geological Society of American Bulletin, 52:1902, 1941.

Local oversteepening of weak bedrock and local clearing of vegetation caused a large landslide of the slump type in central Panay. Slide material dammed the stream and a subsequent flood caused considerable damage. (Abstract taken from "Landlsides" Highway Research Board Bibliography No. 10).

97. Fukuoka, Masami. "Landslides in Japan," Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, 2:234-238, 1953.

The characteristics of landslides in Japan and the principal results obtained from the landslide on Mt. Chausu which is chosen as a typical example are summarized. Phenomena of creep, displacement velocities on and under the ground, influences of ground water movement on the subsoil at the beginning of the landslide are especially studied and model tests of a retaining wall against landslides are described.

98. Fukuoka, M. and T. Taniguchi. "Research on Landslides," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:603-605, 1961.

The authors have investigated one of the largest landslides which has occurred in Japan during the past five years, and have undertaken research to discover its mechanism and cause. They used clinometers to determine the area of the landslide. Clinometers were also inserted into deep boreholes to find the planes of sliding. Geological conditions, the mechanism of movement, the properties of the ground water, and the damage sustained by nearby dams were investigated. Proposed remedies included drainage by deep drilling and protective cofferdams to prevent flow of debris due to the collapse of a portion of the ground.

99. Galloway, J. H. H. "Slip Circle Method of Stability Analysis of Earth Dams," New Zealand Engineering, 10:378-381, 1955.

100. Galpin, S. L. "Blister Slips in West Virginia," Proceedings, Soil Science Society of America, 5:418-420, 1940.

The factors in blister slip formation are water under head in highly silty tongues or lenses within and overlain by more cohesive and less pervious soil. The slip movement is primarily a liquid flow in the high silt material. Where internal soil drainage was adequate, no slips occurred. Changes in land use from forested to cultivated or pastured hillsides may promote slippage by reducing root anchorage, temporarily increasing the volume of subsoil water and gradual obstruction of drainage from the high-silt lenses through illuviation. Surface structures which increase the volume of water or which further unbalance the load within the high-silt material also stimulate subsoil flow.

101. Garrett, P. B. (Editor). "Power Company Reforests 3000 Acres Despoiled by Strip Mining," Electric Light and Power, 29:80-81, February, 1951.

Spoilbanks composed entirely of sandstone and an acid silt-shale near Cumberland, Ohio, are being planted with trees. All planting is done in the spring of the year. Seedlings for the spoil banks include black locust, yellow poplar, sycamore and jack pine, red oak, silver maple, white ash and green ash. All spoil banks are planted within two years after mining operations are completed.

102. Geuze, E. C., C. M. DeBruyn, and K. Joustra. "Results of Laboratory Investigations on the Electrical Treatment of Soils," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:153-157, 1948.

The results of the electrical treatment of soils are studied in the cell test and in the electrosmometer test. The first mentioned test was shown to be especially suited for the study of the effects of electrical treatment on consolidation and internal friction properties of soils. The electrosmometer test is very suitable for measurements of the electrical and the hydraulic permeability.

103. Geuze, E. C. and Tan Tjong Kie. "The Shearing Properties of Soils," Geotechnique, 2:141-161, 1950.

Part I describes the apparatus for the cell-test and the procedure for carrying out "quick" tests on cohesive samples. The methods of interpreting the results of the tests are described, and the application of the results to practical problems is discussed briefly. Part II deals with the triaxial tests, including the mechanism and course of the tests. Results of the "quick" cell-test and undrained triaxial test are compared in detail with regard to the test conditions. It is concluded that both tests have their particular practical application depending upon the nature of the problem and the local conditions encountered.

104. Gibson, R. E. and N. Morgenstern. "A Note on the Stability of Cuttings in Normally Consolidated Clays," Geotechnique, 12: 212-216, 1962.

The author shows that the factor of safety against failure of an undrained slope cut in an ideal normally consolidated clay, whose undrained shear strength increases linearly with depth, depends not upon the height but only upon the inclination of the slope, the ratio of the undrained shear strength divided by the effective overburden pressure, and the bulk density of the clay. The calculation of the factor of safety is facilitated by the use of a stability number which is related to the slope inclination alone. This relation is presented graphically in the paper.

105. Gilboy, G. "Stability of Embankment Foundations," Transactions, Second Congress on Large Dams, 4:577-592, 1936.

Embankments constructed on yielding foundations often subside considerably due to lateral displacement of the supporting soil. The phenomenon is essentially a failure in shear, and is to be anticipated whenever the shearing strength of the foundation does not compare favorably with the shearing stresses induced by the superimposed load. Approximate values of the stresses were obtained by mathematical computation and by photoelastic studies on models. The two methods agreed closely for comparable conditions. For a symmetrical triangular embankment on a layer of weak soil, mathematical analysis led to the following rough rule: the shearing strength of the layer should exceed the smaller of the two values--(a) one-quarter the maximum vertical pressure; or (b) the maximum vertical pressure multiplied by the ratio of thickness of layer to base width of embankment.

106. Glover, B. and May. "Stability Analysis Developments," U. S. Bureau of Reclamation Open House Pamphlet, No. 23, 1940.

107. Goguel, Jean. "Sur une Influence Possible du Reboissement sur les Glissements de Terrains," Comptes Rendus Hebdomadaires des Seances de l' Academie des Sciences, 216:124-125, 1943, (in French).

Discusses the influence of reforestation on landslides. A case in the southern Alps in which reforestation of an area to prevent excessive stream erosion resulted in sliding of the Oxfordian marls is cited. Such reforestation is advantageous in calcareous terrains, but caution should be exercised in clayey zones. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

108. Golder, H. Q. and D. J. Palmer. "Investigation of a Bank Failure at Scrapsgate, Isle of Sheppey, Kent," Geotechnique, 5:55-73, 1955.

About thirty sites of slips which occurred in banks of earth built for sea defenses were investigated. Applying several slope stability analysis procedures to a failure at Scrapsgate gave a factor of safety of unity by compression tests while the vane results were too high. The failure occurred three days after the bank was raised to its maximum height which suggested progressive failure. The relationship between liquid limit and plasiticity index for the soils studied was presented and discussed.

109. Golder, H. Q. and A. W. Skempton. "The Angle of Shearing Resistance in Cohesive Soils for Tests at Constant Water Content," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 1:185-192, 1948.

Several hundred sets of test results showed that soils fall into seven groups with similar shear characteristics. The seven groups are: soft fully-saturated clays, stiff fully saturated clays, fully-saturated remoulded clays, partially saturated undisturbed soils, partially saturated remolded soils, clay shales and siltstones, and saturated undisturbed silts. Test results of the angle of internal friction, $\emptyset$. showed that $\emptyset = 0$, for all fully saturated clays; and $\emptyset > 0$ for all partially saturated clays, for clay shales and siltstones, and for saturated silts.

110. Golder, H. Q. and W. H. Ward. "The Use of Shear-Strength Measurements in Practical Problems," Geotechnique, 2:117-133, 1950.

This paper describes the methods used in Great Britain for the analysis of stability problems in which the shear strength of soils is used. The influence of the type of soil and the type of problem on the choice of method is discussed. Particular reference is made to the method of analysis where the angle of internal friction equals zero. Eight examples of the methods, taken from practice, are given.

111. Goldstein, M. and G. Ter-Stepanian. "The Long-term Strength of Clays and Depth Creep of Slopes," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 2:311-314, 1957.

In the first part, the relationship between the strength of clays and the duration of action of the load is discussed. An empirical relationship given. The influence of reloading samples and of rest periods on the long-term strength is described. Experiments have shown that the strain at the moment of failure of a sample is independent of the duration of action of the load. A method of determining the long-term strength using only one sample is proposed.

In the second part, the so-called depth creep of slopes, a preparatory phase to the sliding, is discussed. The depth creep deformations are determined by values of the mobilized shear coefficients, which corresponds to the tangent of angles of maximum deviation. The nature of the difference between depth creep zones and sliding surfaces is explained and the expression for the velocity of the depth creep is given.

112. Grishin, P. A. "Influence of Vibration on Stability of Submerged Slopes," Scientific Works of the Institutue of Civil Engineering in Leningrad, 28:70-86, 1958.

113. Hacker, W. A. "Symposium: Walther D. Penck's Contribution to Geomorphology, Overloading as a Motor of Mass Movement," Association of American Geography Annals, 30:271-276, December, 1940.

Walter Penck's conception that overloading may be a cause of mass movement is discussed. The article points out Albrecht Penck's formulation which shows that the four factors determining stability of a rock mass are: (1) inclination of the surface of smallest cohesion; (2) cohesion; (3) coefficient of friction; and (4) inclination of the slope. While an increase in weight might release a mass movement, this result would follow only when it succeeded in changing the coefficient of friction. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

114. Haefeli, R. "The Stability of Slopes Acted Upon by Parallel Seepage," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 1:57-62, 1948.

The stability and conditions of inclination of natural and built-up slopes are influenced in a definite manner by the conditions of flow of the water in the pores. In determining the stability of a slope saturated with water, the velocity of flow plays no part; it depends exclusively on the pressure ration in the pore water, or on the run of the lines of uniform water pressure (equi-pressure lines) which are not to be confused with the lines of uniform potential (equipotential lines). This holds good only under the supposition that no fine particles are swept away by the percolation process or are chemically dissolved.

A theory is developed for cohesionless material which is only applicable to a cohesive material if the cohesion increases from zero at the surface of the slope proportionally to the depth. Such cohesion conditions may for instance arise with the compacting of fresh sediment under its own weight.

115. Haefeli, R. "Shearing Strength and Water Content," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:38-44, 1948.

Changes in shearing strengths of loose sediments due to alteration of water content were investigated for kaolinite, alumina, and quartz. Results show that in the unsaturated state dependence of the shearing strength on water content is conditioned by grain distribution and mineralogical composition. Relations between shearing and normal stressing in closed and open systems were investigated; results and conclusions are given including a shear diagram.

116. Haefeli, R. "Investigation and Measurements of the Shear Strengths of Saturated Cohesive Soils," Geotechnique, 2:186-208, 1950.

Through a division of the shear strength into friction and cohesion, it is shown that the cohesive part increases linearly with the pressure. For conditions without stressed pore water the relationship between shear strength and consolidation pressure is set up which is parallel to the relationship between shear strength and water content.

By a number of tests the theoretical relationships are investigated and deviations established. The results of ring shear and triaxial tests carried out with confined and hydrostatically consolidated samples show a satisfactory confirmation. It is proved that for active lateral pressures the triaxial test gives reliable values even for very small heights of the sample.

117. Hall, E. P., L. Cook, S. A. Braley, et al. "The Sheban Project, A Progress Report to October 1960", Unpublished report, 1960.

The Sheban Project in Mahoning County, Ohio, originated when it was decided to undertake a water impoundment and reclamation project in the area as an experimental project and to conduct a cooperative research program in an effort to develop the maximum understanding of the effect of water impoundment and reclamation on an existent and unreclaimed strip mine. This report covers the first two years of this project, one year of which was used to determine the existing conditions before undertaking water impoundment.

At the termination of mining operation which occurred during the year of 1948, the area was rough-graded and reclamation was waived because of the very high toxicity of the spoil. The overburden material in this area has been generally termed as an "acid sandstone". To establish the location of acid-producing material a core sample was drilled from the high wall just to the north of the final cut of the mine. This core sample was split longitudinally by sawing with a carborundum disc. Half of the core sample was used for chemical analysis while the other half was retained for petrographic mineral studies. Certain chemical analyses have been made periodically on the discharge from the Sheban drainage and on the Rapp impoundment (a nearby impounded strip lake of similar characteristics) and several points nearby in the watershed. The results of these chemical analyses are recorded in this report.

118. Hallett, E. R. "Air in Earthfills Assures Stability", Engineering News Record, 144:44-45, June 1, 1950.

Spectacular earthfill failures have been caused by too much water in the fill. But when earthfill voids contain air as well as water, failure is not likely to result in a properly constructed fill. Moisture and air content can be controlled when a fill is placed. But addition of fill material may increase the pressure so all the free air becomes absorbed in the water. This changes a well-made fill to a saturated condition and failure may result. Charts for field use that forecast this possibility have been developed by the author and are the subject of his article.

119. Hank, R. J. and L. E. McCarty. "Shear Failure in Anistropic Materials Possessing any Values of Cohesion and Angle of Internal Friction," Proceedings, Highway Research Board, 28:449-455, 1948.

The radius of Mohr's circle at failure is obtained in terms of the principal shearing strengths existing on the principal planes at failure, induced by the stresses applied in plane deformation such as occurs in the triaxial compression test, for a material possessing any values of cohesion and sliding friction. The required radius is first obtained graphically from a modified Mohr stress circle plotted on the axis of shear stress, and analytical expressions are then developed in terms of cohesion, angle of internal friction, and a principal normal stress, for the radius and for the normal and tangential components of stress acting on the plane of failure. A number of special cases are deduced from the general solution and a Mohr circle of failure is constructed. It is shown that the formula developed applies to anisotropic materials possessing either or both components of shear resistance.

120. Hardy, R. M., E. W. Brooker, and W. E. Curtis. "Landslides in Over-Consolidated Clays," Paper presented at annual general meeting, Engineering Institute of Canada, May 31-June 2, 1961. AGM Paper No. 54. Engineering Journal, 44:74-75, May, 1961.

Many of the major rivers and streams in northern Alberta, the Peace River block of British Columbia, and the southern portion of the Yukon have cut through shale deposits which have been highly consolidated by the weight of glaciers. In recent months very complete investigations have been undertaken at two locations. This paper describes for these two sites the conditions encountered and the investigations made; the inadequacies of conventional methods of stability analyses when applied to these conditions; and presents a modification to the conventional effective stress stability analysis which appears to permit a reasonably accurate assessment of the stability conditions to be made. (Abstract taken from "Highway Reseearch Abstracts").

121. Harrison, J. V. and N. L. Falcon. "The Saidmarreh Landslip, Southwest Iran", Geography Journal, 89:42-47, 1937.

The description of the Saidmarreh Landslip which dammed the rivers in a synclinal valley is given. The periphery of the landslide debris is 43 miles, the volume 4-5 cubic miles. A scar 9 miles long remains on the cliff above. Some catastrophe, probably an earthquake set it in motion. Part of the debris has moved up and over the end of a mountain range in its path. Large cuboidal masses of rock are preserved at the end of the slide; therefore, movement must have been by a rush of the whole sheet. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

122. Harty, V. D. "Slide in Fort Henry Embankment, River Shannon, Ireland," Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, 2:255-258, 1953.

The earth dam, 2,700 meters long and 8.5 meters high was constructed to form a reservoir for a hydro-electric development. A serious slide 50 meters long, involving the whole bank up to crest level occurred in 1948. After temporary repairs were

executed, boreholes and trial pits were sunk, the shear strengths of the materials measured in situ by vane tests, and the bank and foundation materials analyzed. A series of slide plane analyses were made and from these and the shear strengths obtained, it was decided to increase the factor of safety by the addition of a stone berm. The selected berm is calculated to increase the factor of safety to 1.45 on the assumed method of failure.

123. Heim, Albert. Bergsturz und Menschenleben (Rock Fall and Human Life). Zurich, Fretz, and Wasmuth, 218 pp., 1932, (in German).

This book is a monograph on landslides. It gives a classification of landslides in 20 different types based on the kind of material, the type of movement, the velocity of translation, etc. The characteristics of each type are given separately and followed by some examples. The causes and effects of mass movements are studied; erosion, tectonic movements, weathering of layers, seisms, breaking up of blocks, formation of slide lakes, air displacement, damming of valleys, etc. The last part of the book shows that many human lives could have been saved if more attention had been given to premonitory signs. (Abstract taken from "Landlsides" Highway Research Board Bibliography No. 10).

124. Helenelund, K. V. "Stability and Failure of the Subsoil with Special Reference to Railway Embankments in Finland," Report No. 4 of the Geotechnical Department of the Finnish State Railways, Helsingfors, 1953, (in Finnish). Finland.

In case of a distributed strip load on a homogeneous cohesive soil, the author holds that it is possible to compute the bearing capacity of the soil with a high degree of reliability by means of circular slip surfaces. The author provides equations and graphical relationships for determining the shearing stress in the critical slip surface. Similarly, he provides graphical and formulated means for determining the effect of strengthening the soil by means of timber beds, or by means of loading berms. Consideration is also given to solution of cases involving soft foundation soils. (Abstract taken from "Highway Research Abstracts").

125. Henkel, D. J. "Investigations of Two Long-term Failures in London Clay Slopes at Wood Green and Northalt," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 2:315, 1957.

Long-term failures of a retaining wall and a cutting in London clay are described. Using measured ground water levels, effective stress methods of stability analysis are applied to the determination of the cohesion intercept operating at failure and these values are related to the values measured in the laboratory and implied by failure of natural slopes on a geological time scale. Counterfort drains were shown to increase the effective pressure following the changed pattern of ground water flow.

126. Henkel, D. J. "Slide Movements on an Inclined Clay Layer in the Avon Gorge in Bristol," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:619-624, 1961.

The Carboniferous Limestone Series in the Avon Gorge in Bristol consist of thick beds of jointed limestone interbedded with thin layers of clay. The strata dip roughly parallel to the gorge and the joints in the limestone are coated with thin layers of clay produced by weathering. Movement down the line of dip is prevented by the buttressing effect of the rock, but slides can develop in which masses of limestone move obliquely across the clay layer. Surfaces of sliding develop on the surface of the clay layers and on a series of joint planes. A recent movement is decribed and a method of stability analysis is developed.

127. Hennes, R. G. "Analysis and Control of Landslides," University of Washington, Engineering Experiment Station Series, Bulletin 91, 1936.

The bulletin is divided into three parts: (1) the nature of friction and cohesion, (2) analysis of stability of slopes, and (3) landslides. In part 1, internal friction and capillary pressure are defined and the factors which affect them are described. The slope stability analysis methods of plane surface of rupture, curved surface of rupture, and plastic flow are outlined and explained in part 2. In part 3 the types, causes, and controls of landslides are described.

128. Hennes, R. G. "The Control of Landslides," Proceedings, First International Conference on Soil Mechanics and Foundation Engineering, 1:133-135, 1936.

The author presents a semiempirical formula based on the coefficient of cohesion, angle of internal friction, and the unit weight of soil which gives the critical height of a slope at any given angle. Slope leveling, reduction of external loads, drainage, and pile reinforcement are landslide control measures which are discussed. Slides which occur in heterogeneous soils are also discussed, and the equation for resisting forces is given.

129. Hennes, R. G. "Graphical Method Locates Point of Breaking Ground at Crest of Unstable Slopes," Civil Engineering, 17:47, June, 1947.

It is generally assumed that the trace of the slip-surface on a transverse plane is a circular arc. The lack of any permanent tensile strength in earth causes an error in this conventional analysis when applied near the crest of the slope; because as the limits of stability are approached, a vertical tension crack must occur, replacing the upper part of the usual cylindrical surface as the boundary of the unstable earth mass. The location of this vertical line is obtained by a graphical procedure proposed in this article. In addition to permitting a more precise determination of the factor of safety of the slope, location of this vertical line serves to indicate the boundary of relatively stable ground.

130. Hennes, R. G. "Shear Resistance Is Prime Factor in Control of Landslides," Pacific Builder and Engineer, 59:82, 125, August 1953.

Effective methods of stabilizing landslides involve drainage either by open trenches or vertical walls. Increased use is being made of perforated tubing which is placed in horizontal drill holes for drainage. The most effective method of stabilization of a clay mass is achieved through drainage tunnels. (Abstract taken from "Highway Research Abstracts").

131. Hennes, R. G., S. E. Hawkins, and E. L. McCoy. "Appraisal of Measures for Improvement of Slope Stability," National Research Council, Highway Research Board, Bulletin 216, pp. 17-30, 1959.

The article describes attempts to increase the factor of safety of an earth slope by either drainage or excavation. The object of drainage is a lowering of the water table, with an accompanying reduction in the magnitude of unfavorable forces. In this paper several graphs are presented which enable the engineer to estimate the amount of drainage necessary to achieve a desired factor of safety. These graphs yield safety factors corresponding to various levels of water table in an earth mass where the failure plane would approximate a Swedish arc located in a clay bank underlain by a permeable stratum.

An alternative procedure improves stability by unloading the slope. It is shown that flattening the slope is much less effective than benching per unit of excavation. Graphs are presented which plot factor of safety against quantity of excavation for both benching and slope reduction. Cases where the angle of internal friction was zero and greater than zero were considered.

132. Hijab, W. A. "A Note on the Centroid of a Logarithmic Spiral Sector," Geotechnique, 6:66-69, 1956.

The logarithmic spiral is defined and its application to slope stability is shown. Tables and graphs showing the relative distance of a centroid from the initial and final radii are given.

133. Hilf, J. W. "Estimating Construction Pore Pressures in Rolled Earth Dams," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:234-240, 1948.

Field measurements show that pore pressures are developed in the impervious zone of a rolled-earth dam during construction, coincident with consolidation of the fill under its own weight. These pressures are known to reduce stability. If no drainage is assumed, the relation between pore pressure and consolidation in a soil containing air can be derived from well known physical laws.

When the compressibility of moist soil is determined by the laboratory consolidometer test, the resulting curve can be combined with the foregoing relation to obtain a total stress-pore pressure curve. Use is made of the equality of total stress and effective stress plus pore pressure. Nomographs have been devised which solve the necessary equations and facilitate a statistical treatment of the problem.

134. Hill, R. A. "Clay Stratum Dried Out to Prevent Landslips," Civil Engineering, 4:403-407, 1934.
Two successive landslides occurred along a highway near Santa Monica, California, in 1932. The slides took place on slickensides in a nearly horizontal stratum of blue clay 10 feet above the highway level. The clay contained a considerable amount of moisture. To prevent further slip occurrences, a network of inter-connected tunnels and drill holes was driven into the clay stratum at the base of the slope. Air, heated by a specially built natural gas furnace, was blown through the network continuously to dry out the clay. At the end of the first year of operation, samples indicated a reduction in the moisture content from 20 per cent to 15 per cent.

135. Hinds, N. E. A. "A Large Landslide in the Colorado Plateau," Proceedings, Geological Society of America, pp. 241-242, 1937.
Description of the type of landsliding common in the Colorado Plateau is given. Large bodies of low dipping thick sandstones, limestones, or lavas have slumped down over gentle or steep slopes cut in underlying weaker members. Such large scale landsliding is an important means of cliff recession in the Colorado Plateau. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

136. Hodgson, E. A. "Marine Clays of Eastern Canada and Their Relations to Earthquake Hazards," Royal Astronomical Society of Canada Journal, 21:257-264, 1927.
The author describes carefully examined slides in the St. Lawrence and Ottawa valleys. The slides are in the Pleistocene marine clays and are of two types: (1) clay beds resting on a permeable bed which is steeply inclined, and saturation of the permeable bed lubricates the slippage plane; and (2) clay beds are laminated and interstratified with permeable layers, and saturation of the entire mass results in semiliquid flow of material. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

137. Hodgson, R. M. "Soil-Hardening Process," U. S. Patent 2,437,387, Chemical Abstracts, 42:3928, 1948.
Clayey, water-logged, and sandy soils, as well as artificial deposits such as coal-ash dumps, cinders, and slag, may be hardened by spraying with a strong solution of calcium chloride or magnesium chloride. A second spray of strong sodium hydroxide or potassium hydroxide precipitates the hydroxide of calcium or magnesium which hardens the soils after sodium silicate is poured on the soil. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

138. Hollingworth, S. E. "Some Solifluction Phenomena in the Northern Part of the Lake District," Geologists' Association, London, Proceedings, Part 2, pp. 167-188, 1934.
The surface patterns in stone debris, mudflows or slips, terraced debris, and related forms are described. The period of formation and mode of origin along with the relations to the rate of erosion is discussed for each type of slide. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

139. Holmsen, Gunnar. "The Landslides of Kokstad, Gretnes, and Braa," Norges Geologiske Undersokelse, No. 167, 45 pp. Oslo, 1929, (in Norwegian).

The description of three clay slides is given. All took place in a series of rapid movements. A liquid stratum of clay flowed out to initiate movement in the first two cases; the slide at Braa consisted of relatively large blocks of firm clay. Author's opinion of cause, as determined by borings, was the rising hydrostatic pressure in aquiferous strata in the clays. Stabilization has been attempted by drilling artesian wells at the lowest part of the slide to provide groundwater outlets. (Abstract taken from "Landlsides" Highway Research Board Bibliography No. 10).

140. Holmsen, Gunnar. "Landslides and Subsidences During the Period 1933-1939," Norges Geologiske Undersokelse, No. 166, pp. 5-43, 1946, (in Norwegian).

A limited description of the various kinds of landslides and subsidences which occurred in Norway from 1933-1939. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

141. Holmsen, G. and P. Holmsen. "Landslides during the Years 1940-1945," Norges Geologiske Undersokelse, No. 167, pp. 5-71, 1946, (in Norwegian).

The description is given of 10 clay slides and slidings of similar type which occurred in Norway during the years 1940-1945. Most of the slides were in glacial clay which became liquid and flowed, due to natural and artificial disturbances. Three of the slides were caused by bomb explosions, the detonation causing the clay to become liquid. Some slides were investigated by the Swedish method. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

142. Horn, John A. "Computer Analysis of Slope Stability," Proceedings, American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, 86:1-18, June, 1960.

A computer program has been written that can solve a great variety of slope stability problems. It is possible to analyze a slope with any surface configuration, with one or two soil strata in any pattern, with or without a water table, pore pressures, increasing cohesion with depth, tension cracks, and a rigid base or loads anywhere on the surface. Given these properties of a slope, the computer will automatically search out the minimum factor of safety, and solving the entire problem in from one to three minutes.

143. Hough, B. K. Basic Soils Engineering. New York: The Ronald Press Company, 1957.

A chapter is devoted to landslides in this book. Mass slides and flow slides are defined. Typical values of the safety factor for stable and unstable slopes are given. Methods for analysis of various types of slides are described including the Swedish circle method, slices method of analysis, and translatory slides analysis.

144. Housel, W. S. "Principles of Soil Stabilization," Civil Engineering 7: May, 1937.

The two most important fundamental properties to be considered from the stand-point of ability to resist deformation under load are cohesion and internal stability. Cohesion may be defined as that property of a material which produces resistance to deformation by mutual attraction between particles, involving forces of molecular origin which are characteristic of microscopic and submicroscopic matter. This definition is intended to include both cohesion and adhesion as ordinarily defined. Internal stability is that mechanical property of granular mixtures which produces resistance to displacement by the mutual support of adjacent particles in the mass, involving static forces and reactions, between particles which are too large to be noticably affected by molecular forces.

145. Howe, Earnest. "Landslides in the San Juan Mountains, Colorado: Including a Consideration of Their Causes and Their Classification," U. S. Geological Survey, Professional Paper No. 67, 58 pp., 1909.

Landslides in the San Juans are described and classified, including recent slides, older slides, Pleistocene slides, and rock streams. Heim's classification of landslides and Penck's work are discussed. On the basis of the slides observed, internal and external causes are outlined. Examples of both internal and external causes are presented. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

146. Huang Wen-Xi. "Investigations on Stability of Saturated Sand Foundations and Slopes Against Liquefaction," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:629-631, 1961.

How a saturated sand mass liquefies under dynamic action is discussed, pointing out that the key to the solution of the liquefaction problem is to find out the relationship connecting the developed pore pressure, the density of the sand, the intensity of the dynamic action, and the state of stress of the sand mass. Experimental determination of this relationship is described. Methods of adapting the experimental findings to the stability analyses of saturated sand foundations and slopes are discussed.

147. Hughes, G. T. "Geology and Engineering Properties of Soils in Kingston Area", Canadian Mining Journal, 80:83-87, 1959.

The author discusses soil problems related to landslides which are caused by problems of water leaking from the reservoir above a dam. (Abstract taken from "Engineering Index").

148. Hurtubise, J. E. and P. A. Rochette. "Causes of Landslides as Revealed by Study of Nicolet Disaster," Roads and Engineering Construction, 95:82 84-86 March, 1957

Report on research was performed after Nicolet disaster to determine both the mechanism of soil movement and the soil properties and geological conditions that influenced the sliding action. (Abstract taken from "Engineering Index").

149. Hurtubise, J. E. and G. G. Meyerhof. "Les Eboulements de Terraindans l' Est du Canada, (Landslides in Eastern Canada)", Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 2:325, 1957.

Numerous landslides have occurred periodically in the recent sedimentary soils of Eastern Canada. Examination of stratification and fossils in the soil indicates that the retreat of glaciers was immediately followed by an invasion of the sea. Thus the Champlian Sea was apparently formed at the end of glaciers, and glacial drift was deposited together with marine sediments. These conditions of glacial-marine environment and the relatively rapid retreat of glaciers resulted in the peculiar geotechnical properties of these deposits. The importance of variations in the water table and of erosion at the toe of slopes of unstable material is discussed. The preliminary analysis of three cases of landslides (at Rimouski, Lake St. John and Nicolet) is presented to show the influence of soil conditions and degree of stratification on the slide mechanism. The nature of the sediment, its mineralogical composition, and the physicochemical phenomena which have affected the properties of the soil are factors of its sensitivity.

150. Hutchinson, J. N. "A Landslide on a Thin Layer of Quick Clay at Furre, Central Norway," Geotechnique, 11:69-94, 1961.

The large slide, which took place on April 14, 1959, at Furre on the Namsen River, forms the subject of the paper. The main part of the slide consisted of a single flake of ground which slid out rapidly on a long gently inclined surface formed by a thin layer of nornally consolidated quick clay. The investigations performed reveal the essential features of the slide.

The main slide failed under drained conditions, and from an analysis of its stability in terms of effective stresses an angle of shearing resistance of 7° was obtained for the quick clay. The low angle of internal friction indicated that in the failure surface of the slide, mobilization of the shear strength was simultaneous and the low value obtained resulted from a release of internal energy through contraction of the loose structure of the quick clay.

151. Ireland, H. O. "Stability Analysis of the Congress Street Open Cut in Chicago," Geotechnique, 4:163-168, 1959.

An analysis was made of the failure of a cut slope that occurred under the conditions that the angle of internal friction was zero. The cut was for the most part in glacial clay, and failed when the excavation reached a depth of 47 feet. The factor of safety given by the analysis was close to unity, but the location of the theoretical slip surface differed considerably from the actual location. A statistical study was also presented to indicate the reliability of the values of compressive strength used in the computations.

152. Ishii, Y., S. Kurata, and S. Hasegawa. "Failure of Embankment in Kinkai Bay," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:633-636, 1961.
The authors describe soil investigations and detailed analysis of the sliding action after the failure of the Kinkai reclamation embankment in Japan in 1958. The failure was of the typical circular arc form. The influence of the length of the sliding surface on the factor of safety against sliding computed by the current method is discussed. By considering the results of soil studies and circular arc analysis on the probable causes of failure, the repair work was planned and carried out efficiently.

153. Ivanov, A. I. "Stability Conditions of Earth Bodies and the Analysis of Slopes and Foundations of Earth Dams", Transactions, Second Congress on Large Dams, 4:615-634, 1936.
This paper is a presentation of the principles involved in the study of the stability of earth dams, under the assumption that sliding takes place along cylindrical surfaces with circular sections. General values for the coefficient of earth stability are given in relation to the component forces acting on the sliding section. The normal strain acting on the sliding surfaces is expressed as a vector in contrast to the commonly used scalar interpretation. In practical cases the differences between friction forces obtained by these two methods are small. Several practical cases of slope failure in earth dams are analytically treated. A formula is given to establish a minimum coefficient of stability for all cases of failure.

154. Ives, R. L. "Vegetative Indicators of Solifluction," Journal of Geomorphology, 4:128-132, April, 1941.
In the Southern Rocky Mountains the presence of erratically spaced patches of aspen in the normal evergreen forests of the montane forest zone is a rather consistent indicator of soil motion. Sensible use of vegetative indicators greatly facilitiates locating of solifluction phenomena in the field.

155. Jakobson, B. "Isotropy of Clays," Geotechnique, 5:23-28, 1955.
The difference in the shear strength along and across the strata of clay near a slip surface in a Norwegian landslide was determined. The shear strength was determined by unconfined compression tests and cone tests. The compression test showed that there was a weakness in the samples along the strata, even though the reduction in the shear strength was not very great. The shear strength, permeability, and the compressibility were determined for a homogeneous post-glacial clay to compare with results of the anisotropic clay tested. The test results indicated that it is not necessary to introduce any condition for anisotropy of post-glacial clays in computations of the stability of slopes.

156. Jaky, J. "Stability of Earth Slopes," Proceedings, First International Conference on Soil Mechanics and Foundation Engineering, 2:200-207, 1936.
The cylindrical sliding surface assumption is shown to be more prone to failure than the assumption of a plane of rupture.

Therefore, stability computations should take the curved surface into account. Derivations are presented which show this to be true when the failure occurs within the slope.

157. Jaky, J. "Validity of Coulomb Law of Stability," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 1:87-90, 1948.

Coulomb's linear law of stability is overly simplified. This paper proves that the form of the function yielding the stresses which act on the sliding surfaces is greatly affected by the movement of the earth masses and by the variation of the void ratio. When these two factors are determined, stress conditions can be computed.

158. Janbu, Nilmar, "Stability Analysis of Slopes with Dimensionless Parameters". Harvard Soil Mechanics Series No. 46, Cambridge, Mass., 1954.

In this thesis cylindrical sliding surfaces have been utilized for the investigation of the stability of slopes under the influence of external loads and irregularities of the slope profile. Upon introducing an appropriate set of dimensionless parameters one finds that the mathematical calculations necessary for the determination of the critical stability condition can be carried out once and for all and independent of the individual values of the shear strength characteristics.

In particular, a detailed investigation is made of such conditions as surcharges of constant intensity, water-filled tension cracks of known depth, partial submergence and various drawdown conditions. In analyzing the influence of these conditions on the factor of safety, one can utilize the stability number for simple slopes as an important part of the solution. The critical values of the dimensionless factors included in the working formulas can be obtained by interpolation from numerical solutions presented in the form of simple graphs.

These conditions can also be analyzed with the aid of resistance envelopes, and appropriate formulas are derived for the required modifications of the available resistance envelope diagrams.

159. Jelinek, R. "Ueber die Standsicherheit von Boeschungen aus bindigen Boeden," Bauingenieur, 22:91-95, March 20, 1941, (in German).

Stability of slopes of cohesive soil and degree of safety against sliding is determined using Coulomb's formulas. Variability of Coulomb's coefficients is pointed out. Approximate formulas are given for determining the change in the state of stress which occurs when cutting a section into the slope. The failure surface is presented in the form of an arc according to the Swedish method. (Abstract taken from "Engineering Index").

160. Jennings, R. D. "Stability Analysis of Earth Slopes," The Surveyor and Municipal and County Engineer, Vol. CX, No. 3089, May 19, 1951, England.

The author reviews the circular arc slope failure theory and the friction-circle slope failure analysis. The difference in slope failures between purely frictional and purely cohesive

soils is pointed out and discussed. The historical advancement of slope failure is presented beginning with the research of Gregory and Collin in 1846. (Abstract taken from Highway Research Abstracts).

161. Jones, F. O., D. R. Embody, W. L. Peterson, and R. M. Hazlewood. "Landslides Along the Columbia River Valley, Northeastern Washington," Geological Survey Professional Paper 367, U. S. Geological Survey, 1961.

Landslides occur so frequently in the surficial deposits along the upper valley of the Columbia River that they affect greatly engineering developments and land use. More than 300 landslides in the Pleistocene terrace deposits were examined. Slides were classified into type groups, so that each type might be analyzed and compared with the others. The stability of natural slopes was investigated by comparing data from slopes on which slides have not occurred with data from slopes on which slides have occurred. The analysis included a consideration of material, ground water, terrace height, original slope, and submergence. A formula was developed for predicting the stability of natural slopes. (Abstract taken from "Highway Research Abstracts").

162. Jonson, F. "Calculation of the Stability of Earth Dams," Transactions, Second Congress on Large Dams, 4:463-477, 1936.

This paper deals with the stresses in triangular embankments of homogeneous soil under the load of their own weight and full water pressure. The Mohr theory of rupture of soil was assumed to be valid in all the tests performed. By use of stress functions, a method was given for finding the state of stress in soil. This method was found to be more general than the Rankine formulas. It was concluded that for the examples given, triangular, homogeneous embankments are stable under loading by water on the condition that the slopes are not steeper than the angle of repose or the angle defined by the critical line in Mohr's theory.

163. Jordan, Richard H. "A Florida Landslide," Journal of Geology, 57: 418-419, 1949.

A rapid earthflow near Greensboro, Florida, is described. About 4 acres of land laying on a slope of less than 10^{o} moved into the valley, leaving a horseshoe-shaped scar, after a period of heavy rainfall. The material involved was reddish, partially indurated clayey sands of the Hawthorne formation. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

164. Jurgenson, L. "On the Stability of Foundations of Embankments," Proceedings, First International Conference on Soil Mechanics and Foundation Engineering, 2:194-200, 1936.

Equations for determining the shearing strength of foundation materials of sand or clay are presented. The appropriate equations to determine cohesion and external load for various soil conditions are also given.

165. Kardos, L. T., P. I. Vlasoff, and S. N. Twiss. "Factors Contributing to Landslides In the Palouse Region," Proceedings, Soil Science Society of America, 8:437-440, 1943.

Small rotational-shear-type landslides on the steep north-facing slopes of the Palouse topography in Washington are described. A permeable, low cohesion bed between layers of less permeable and more compact soil is the cause of the slides. Pore pressure built up in the permeable bed due to the accumulation of melt water and the overloading of the slope by snow drifts were the direct causes of the slide.

166. Karpoff, K. P. "Pavlovsky's Theory for Phreatic Line and Slope Stability," Proceedings, American Society of Civil Engineers, 80: No. 386, January, 1954.

The author presents methods which involve only a few basic equations to check such design assumptions as: seepage loss, the point of intersection of the line of saturation with the downstream slope of an embankment, the steepness of the slopes, and the stability of the slopes for earth dams, levees, and other earth hydraulic structures.

167. Kesseli, J. E. "Disintegrating Soil Slips of the Coast Ranges of Central California," Journal of Geology, 51:342-352, 1943.

On the gentle slopes of the Coast Ranges of California, a type of mass movement which the author calls "disintegrating soil slips" is common. At the head of the soil slip is a depression similar to the break-away scarp of an earthflow. Rounded pieces of soil and sod extend downhill in a tongue bounded in the upper third by two lateral ridges of debris 1-2 feet high. The depth of regolith involved in the slips is small, 5 feet at the most. The slips occur after heavy rainfall, when infiltration is faster than downward percolation and the shallow zone of the soil becomes saturated. A limited area, seldom larger than 20 to 30 feet, then slides out as a unit, disintegrates into its constitutent parts, and rolls downhill. The slips are more common on the upper part of slopes. (Abstract taken from "Landlsides" Highway Research Board Bibliography No. 10).

168. Kittle, E. "Stability of Soils Composed of Loose Rock in Mountainous Areas," Revista Minera, 12:3-26, 1941, (in Spanish).

169. Kjaernsli, B. and N. Simons. "Stability Investigations of the North Bank of the Drammen River," Geotechnique, 12:147-167, 1962.

A stability investigation of the natural soft silty clay slopes of the north bank of the Drammen River in Norway is described. Both a slip which occurred in 1955 and a stable length of the bank are considered. It is shown that the total stress analysis seriously underestimates the stability of these natural slopes, and the method, therefore, cannot be used to estimate long-term stability. The effective stress analysis in the form derived by Bishop in 1954 gave a reliable estimate of the stability of the slopes, and confirms past experience that the effective stress analysis is the correct approach to long-term stability problems.

170. Kjellman, W. "Do Slip Surfaces Exist?", Geotechnique, 5:18-22, 1955.
According to the author's hypothesis, slip surfaces do not exist. A slope in a brittle soil fails by an excessive change of angle within a very thin rupture layer, whose width depends on the grain size of the soil. A slope in a tough soil fails by an excessive change of angle within a thicker zone, whose width depends on the dimensions of the soil mass and on the load.
The author also points out that the direct shear test gives apparent strength of the soil. It is also apparent strength that should be used in the computation of the stability of slopes. The triaxial test, on the other hand, yields the real strength, through its results are somewhat incorrect because the intermediate principal stress is too small.

171. Kjellman, W. "Mechanics of Large Swedish Landslips," Geotechnique, 5:74-78, 1955.
In small landslides the moving earth mass can be regarded as a single rigid body. This implies that failure occurs simultaneously in all parts of the slip surface. Thus, before the slide can start, the full shear strength at every point of this surface must be exceeded.
In large slides, whose extent is always much greater in a horizontal plane than in a vertical direction, the above argument does not apply as a rule. Large landslides are generally composite. First, a small soil mass starts to slide, and then adjacent masses are set in motion, so that the slide rapidly grows while moving. A slide that grows in the direction of its own motion is designated as a progressive slide, and one that grows in the opposite direction is called a retrogressive slide.

172. Kjellman, W. "Effects of Ground-Water on Stability of Natural Slopes in Swedish Clay Soils," Geotechnique, 5:167-169, 1955.
The article discusses the lowering of the factor of safety in slopes by the influence of ground water. The factors considered in the slope stability analysis are: (1) increased weight of the earth slice, (2) the influence on the total normal force, and (3) the great influence on the maximum shearing force in the slip surface. The stability of clay soil with sand layers is also discussed. The landslide at Surte, Sweden, was given as an example of a slide in clay with sand layers.

173. Kjernsli, B. "Stability of a River Bank in Drammen", Oslo, Norges Geotekniske Institutt, Publication 18, 1956, (in Norwegian).
The article gives a brief account of a series of slides that have occurred along the river bank at Bragernes, Drammen. It has been assumed that these slides were caused partly by erosion, partly by artesian pore pressure, and partly by excess surcharge on the river bank.
The Norwegian Geotechnical Institute has performed field investigations and stability calculations of five profiles distributed along the river in a length of 200 yards. The article concludes that an undrained shear strength analysis in general gives no reliable estimate of the stability of natural slopes. According to the article, stability calculations of natural slopes should be carried out by a CØ-analysis. (Abstract taken from "Highway Research Abstracts").

174. Knappen, T. T. "Calculation of the Stability of Earth Dams," Transactions, Second Congress on Large Dams, 4:505-538, 1936.
A comprehensive discussion of most of the features entering into the design of earth dams is presented. There is included a description of an unusual incipient failure of a dam foundation which he attributes to forces due to excessive rolling of the embankment. The design of slopes is also included but the author's treatment does not consider the effect of seepage forces.

175. Knoke, H. "Uber Zahlenwerte der Kohasion beim Erddruck," Die Bautechnik, 3:120-121, 1925, (in German).
The stability of unsupported earth banks is discussed. Values for the intensity of shear in layers of gravel are given. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

176. Knox, G. "Landslides in South Wales Valleys," Proceedings, South Wales Institute of Engineers, 43:161-247, 1927.
The frequency of landslides depends upon: (1) geological nature of the ground, (2) age of the valley; (3) water supply; and (4) the interference with the stability of a slope by cutting into it. The two types of slides which occur most frequently in South Wales valleys are soil creep and slides of rock and soil. All slides begin as soil creeps with a bulging of the surface at the lower end and a subsidence at the upper end, due to the flow of the mud stream. This movement produces flowage stresses on the already fractured surface rocks and causes them to slide also. The remedy to prevent the landslides is a proper system of drainage. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

177. Kobold, F. "Measurement of Displacement and Deformation by Geodetic Methods," American Society of Civil Engineers, Journal of the Surveying and Mapping Division, 87:37-66, July, 1961.
Many methods of determining terrain movements and deformations in structures have been used. However, geodetic methods provide the only means of determining absolute displacements. All geodetic methods are based upon the measurement of angles or distances, or both. Triangulation involves measurement of angles; trilateration, measurement of distances; and traversing, measurement of angles and distances. It was necessary to provide new equipment in order to meet the extremely high precision usually required in this work. A basic principle in the development of this equipment was to use existing equipment as far as possible, making it suitable for specific purposes by means of inexpensive auxiliary equipment. Moreover, the auxiliary equipment was to be so designed that it could be used for various purposes rather than a single, specific use. Various applications of geodetic methods to terrain movement and deformations in structures are described and specific examples given. The new equipment is described and shown in operation.

178. Kopacsy, J. "Stress Distribution and Slip Surface on Embankments," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:641-650, 1961.
The equations of the theoretical slip surface and of stress distribution in earth works are derived in two dimensions. The results are used in the problem of stability of earth slopes.

179. Krey, H. "Die Widerstandsfahigkeit des Untergrundes und der Einfluss der Kohasion bein Erddrück und Erdwiderstande," Die Bautechnik, 2:462-474, 1924, (in German).
The stability of retaining and quay walls is studied with special reference to the resistance of the foundation soil. The forms of surfaces of rupture, the influence of cohesion and the absence of friction, and the bearing capacity are considered. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

180. Krey, H. "Gebrochene und gekrummte Gleitflachen bei Aufgaben des Erddruckes," Die Bautechnik, 4:279-283, 1926, (in German).
The special case for which the Rankine theory holds good is considered. The shapes of the plane of rupture and the distributions of earth pressure for cases differing from Rankine's case are pointed out. The curvature of the sliding surfaces and the movement of earth particles in various slides is shown photographically. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

181. Krynine, D. P. Soil Mechanics. Second Edition, New York: McGraw-Hill Book Company, 511 pp., 1947.
The stability of cuts and embankments are discussed in chapter nine. The various types of landslides are briefly described. The Swedish method and the friction-circle method for checking the stability of slopes is presented. The determination of the critical height of a slope is also presented. Problems of base failure, sudden water level drawdown, and surface cracking are discussed.

182. Krynine, D. P. "On the Methodology of Landslide Investigations in Soviet Russia," National Research Council, Highway Research Board, Bulletin 236, p. 1-16, 1960.
The writer believes that the idea of stationary (or rather regional) landslide observations deserves attention. It seems advisable to start a few slide observation field stations, not necessarily exactly of the Russian type, in zones affected by landslides that are produced as a natural step in the denudation process of a given region. Another proper location of such field stations would be next to river canyons in which several dams are planned. Quite a few facts became known when, after the constuction of a reservoir and local collapse of its shores, expensive relocation of threatened highways and railroads running parallel to those canyons was necessary. States and counties, and in pertinent cases the railroad companies, should be interested in the idea.

183. Krynine, D. P. and W. R. Judd. Principles of Engineering Geology and Geotechnics. New York: McGraw-Hill Book Company, 1957.
A chapter of this textbook is on "Landslides and Other Crustal Displacements." The various types of slides are discussed with solutions to the stability of the slopes given. The various causes of slides are covered along with methods of preventing and correcting the familiar types of landslides.

184. Ladd, G. E. "Landslides and Their Relation to Highways, Part 1." Public Roads, 8:21-31, 35, 1927.
This is the first of two articles which deal with the causes and control of landslides in West Virginia and Ohio. This article is devoted to the geological characteristics of the region and the causes of slides.

185. Ladd, G. E. "Landslides and Their Relation to Highways, Part 11," Public Roads, 9:153-163, 1928.
This second of two articles deals with the engineering problems involved and the various methods of control which have been tried in controlling and preventing landslides. It was concluded that a very large proportion of the cases of landslides studied could be solved by proper drainage provisions.

186. Ladd, G. E. "Landslides, Subsidences and Rock-Falls as Problems for the Railroad Engineer," American Railway Engineering Association, Bulletin, 37, 72 pp., 1935.
This bulletin is a monograph on landslides, specifically written for engineers. Older classifications of slides is discussed and a new one is presented. Earth materials which slide or promote slides are described. The causes of landslides are listed and commented upon. Types of slides are illustrated by specific examples. A tabulated list of all the control methods seen by the writer is given and commented upon. Bibliography given on pages 61 through 72. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

187. Lamborn, R. E., C. R. Austin and D. Schaaf. "Shales and Surface Clays of Ohio," Geological Survey of Ohio, Fourth Series, Bulletin 39, Columbus, 1938.
This bulletin begins with a discussion of the general character of bedrock along with the shales of Ohio. Surface clays are discussed along with the testing procedure. Summary tables are included in this bulletin of tests by the Bureau of Standards, the Geological Survey, and of screen tests. Maps are also included showing the distribution of bedrocks and the location of samples.

188. Landau, Richard E. "Mathematical Expressions for the Circular Arc Method of Stability Analysis," National Research Council, Highway Research Board, Bulletin 236, pp. 39-68, 1960,
This paper presents rigorous mathematical expressions which will permit direct application to computer programming as well as to organized manual computations for the determination of the weakest failure plane. Simplifying assumptions have been kept at a minimum to fully utilize the accuracy potential of the high

speed computer. Basic equations are presented for solution of the simple stability problem involving a constant earth slope of homogeneous material founded on a stratified subsoil. Special cases are also investigated involving irregular or stratified slopes, the condition of toe failure, dam analysis, and related refinements demonstrating the flexibility of the derived expressions.

189. Lane, K S. "Field Slope Charts for Stability Studies," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:651-655, 1961.

Charts for comparing field measured slopes often afford a simple approach for selecting a design strength for stability studies--basically by analyzing strength necessary to support nature's slopes in equilibrium. For composite formations particularly sedimentary rocks, the uncertain effects of alternating strong and weak beds, jointing, and bedding make this approach more reliable than one based solely on laboratory tests. Examples are given for shales at Ft. Peck, Garrison, and Tuttle Creek Dams.

190. Larew, H. G. "Use of Field, Laboratory and Theoretical Procedures for Analyzing Landslides," National Research Council, Highway Research Board, Bulletin 49, pp. 28-39, January, 1952.

Field and laboratory data obtained from three actual landslides are presented in this paper. The study was confined to a two-dimensional analysis of a shear-type failure in shallow deposits of unconsolidated materials. The data were used to check the validity of the circular-arc method of slope analysis. The soil strength required for stability, as determined from this method of analysis, was compared with the strength of the soil as measured by laboratory tests. The data were insufficient to indicate definitely the range of applicability of the circular-arc method. However, when combined with similar data from previous studies the results indicated the limited applicability of this approach and pointed to the area where further study is needed before quantitative answers to the problem of prevention and correction of landslides can be made.

191. Lazard, A. "Notes on Some Methods for Calculating the Stability of Earth Slopes," Travaux, 31:97-100, 1947, (in French).

The author considers that the different methods for calculating the stability of earth slopes all give indeterminate results when based on a consideration of the equilibrium of the entire mass as it is on the point of slipping either along a straight line, a circular arc, a logarithmic spiral, or polygonal lines. It is concluded that theory accounts very satisfactorily for slipping along logarithmically spiral slide planes and that the method involving slip along polygonal planes should therefore be abandoned. An approximate alternative treatment is proposed for the usual Swedish method which enables a complete solution to be obtained for all types of problems. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

192. Lazard, A. "New Notes on the Determination of the Stability of Earth Slopes," Travaux, 39:707-719, 1955, (in French).

193. Leach, C. E. "Landslides, Ventura Ave. Oil Field," American Association of Petroleum Geologists Bulletin, 30:134, 1946.

Landslides in the soft Pliocene formations of the Ventura Ave. oil field are of two types: bedding plane slides and circular type slides. Bedding plane slides move along bedding planes where the dip in the formation is greater than 15° and in the same directions as the surface slope; circular slides occur independently of stratification. The two principal causes of the slides are: (1) presence of water which lowers the coefficient of friction, reduces shear and tensile strength, increases the weight of the landslide mass, and creates a lifting force in the lower part of the slide due to hydrostatic pressure and (2) the disturbance of equilibrium. The three methods of control used, which seemed to be successful, were: removal of water from the slide, elimination of the source of water, and redistribution of the load. (Abstract taken from "Landlsides" Highway Research Board Bibliography No. 10).

194. Le Clerc, R. V. and R. J. Hansen. "Computer Solution of Swedish Slip Circle Analysis for Embankment Foundation Stability," National Research Council, Highway Research Board, Bulletin 216, pp. 31-43, 1959.

A program is presented for the IBM 650 computer which will analyze a given foundation problem in a matter of minutes. At present the program will handle analyses of embankment stability where the foundation is composed of as many as three layers or strata of different material. Although the present program is restricted to homogeneous embankments, suitable modifications should enable it to handle any number of embankments or foundation materials if they occur in a known geometric pattern in the cross-section.

The following data are necessary for the computer analysis: cohesion, angle of internal friction, and unit weight of the soils involved; initial slope to be analyzed; thickness of the foundation strata; height of embankment; and design safety factor.

The program may be used in two ways: (1) to investigate a given range of slopes, automatically advancing to the next flatter slope if the safety factor against failure is found to be less than the predetermined value; and (2) to investigate a range of slopes, in individual analyses for each slope.

195. Legget, R. F. "Stability of Embankments and Fills for Highways," Roads and Bridges, 82:59-61, 90-92, 1944.

196. Lehmann, Otto. "Ueber Boschungswinkel und Boschungshohen im Hinblick auf den Bergsturz von Goldau," Eclogae Geologicae Helvetiae, 35:55-65, 1942, (in German).

The author discusses from a mathematical standpoint the angles of slope under which landslides occur. Other conditions contributing to failure are discussed. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

197. Li, C. Y. "Stability Chart for Designing Earth Slopes," Civil Engineering, 25:54, December, 1955.
The author, using the Swedish circular sliding surface method for the stability analysis of earth slopes, presents a method for the mathematical determination of the cohesion and angle of internal friction for a slope given a factor of safety. For any trial circular surface taking everything constant, the factor of safety varies linearly with the cohesion and angle of internal friction. A set of straight lines can thus be obtained from the analysis of a number of trial arcs for the same factor of safety. The envelope of the straight lines thus determines the combinations of cohesion and angle of internal friction for the critical sliding surface to give the fixed factor of safety.

198. Li, C. Y. "A Concept of Slope Design of Earth Dam Embankment," Proceedings, American Society of Civil Engineers, 79: No. 327, November, 1953.
The article shows that for a cohesive soil embankment the slope profile may be a curve with continually decreasing slopes from the top down rather than the frequent practice of a constant slope from the crest of the earth embankment down. The significance of a varying slope design versus constant slope design lies in the saving of material used without reducing the factor of safety of the slope. The basic principle and a guide to a logical and practical varying slope design for earth embankment and levees is discussed.

199. Limstrom, G. A. Overburden Analysis and Strip-mine Conditions in Northeastern Ohio. Central States Forest Experiment Station, Technical Paper No. 114, 1950.
Similar to report by Limstrom and Merz (201) except it describes Strip-Mining Districts No. I and II.

200. Limstrom, G. A. Overburden Analysis and Strip-mine Conditions in Mideastern Ohio. Central States Forest Experiment Station, Technical Paper No. 117, 1950.
Similar to report by Limstrom and Merz (201) except it describes Strip-Mining District No. IV.

201. Limstrom, G. A. and R. W. Merz. Overburden Analysis and Strip-mine Conditions in the Northwestern District of the Ohio Coal-Mining Region. Central States Forest Experiment Station, Technical Paper No. 124, 1951.
The main purpose of this report was to summarize the reconnaissance data for ready use by practitioners concerned with spoilbank conditions in Strip-Mining District No. III of Ohio. The report also contributes to the general knowledge of Ohio Geology by permanently recording the stratigraphic data collected.

202. Limstrom, G. A. and R. W. Merz. Overburden Analysis and Strip-mine Conditions in Southeastern Ohio. Central States Forest Experiment Station, Technical Paper No. 127, 1951.
Similar to report by Limstrom and Merz (201) except it describes Strip-Mining Districts No. V, VI, VII, and VIII.

203. Limstrom, G. A. "Forestation of Strip-Mined Land in the Central States," United States Department of Agriculture Forest Service, Agriculture Handbook No. 166, February, 1960.

This publication summarizes the knowledge gained during the past two decades and is intended to serve as a guide for technicians engaged in forestation of strip-mined land. It attempts to answer the question: where, when, and how should tree planting be done on such land? Chief emphasis is placed on a detailed discussion of site conditions that affect forestation on strip-mined land. After that, the planting operation itself is described.

204. Little, A. L. and V. E. Price, "The Use of an Electonic Computer for Slope Stability Analysis". Geotechnique, 8:113-120, 1958.

The application of an electronic computer to stability analyses of earth dams with prewater pressure is described. The analyses are based on Bishop's (Bishop, A. W., 1955. "The use of the slip circle in the stability analysis of slopes", Geotechnique, 5:7-17) adaptation of the Swedish method. The presentation of the data to the computer and its method of working are described. There is also a brief discussion on the advantages of using the computer and possible future developments.

205. Lobdell, Herbert L. "Rate of Constructing Embankments on Soft Founda tion Soils," Proceedings, American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, 85: SM 5, October, 1959.

Procedures for predicting and controlling the rate of construction of embankments on soft weak foundation soils are presented. Shear strength, the key factor in such problems is related to consolidation and effective stresses in the foundation soil. An illustrative example of hypothetical embankment stability problem follows, and the assumptions used in such an analysis are discussed.

206. Lowry, G. L. and J. H. Finney. A Lysimeter for Studying the Physical and Chemical Changes in Weathering Coal Spoil. Ohio Agricultural Experiment Station, Research Circular 113. Wooster, Ohio: August, 1962.

In this report, a lysimeter installation is described for studying the changes in physical, chemical, and biological properties of weathering coal spoils. The scope and objectives of this long term study are presented. Construction, instrumentation, and operation of the installation are treated in detail. As changes in the physical and chemical properties of the soils take place with time, the results will be published in future research circulars.

207. Maddalena, Leo. "Protection des Voies contre la Chute des Rochers," Congres International des Mines, de la Metallurgie et de la Geologie Appliques, 7th, Paris, 2:559-561, 1935, (in French).

The possibility of foreseeing rockfalls by predicting the type of fracturing which will occur in a particular rock type is discussed. In the case of easily weathered rocks a superficial coating may be effective in the control of slides. Recommendations for the protection of railroads against rock falls are also given. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

208. Mandel, J. "Equilibre limite des talus dans l'hypothese d'un angle de frottement interne nul," Travaux, 34:690-4, October, 1950, (in French).

The author discusses the limit of the equilibrium of slopes under the assumption of no internal friction. Solutions for the critical height and safety factor of a slope of any shape without internal friction is given. Included is a discussion of the limit of the equilibrium of a slope of homothetic profile. (Abstract taken from "Engineering Index").

209. Marivolt, L. "Control of the Stability of a Sliding Slope in a Railway Cut Near Wetteren," Proceedings, Second International Conference on Soil Mechanics, 2:38-42, 1948.

A slope which had failed along a railway cut in Belgium was analyzed to find the physical explanation for the slope failures and to determine remedial measures. A laboratory examination of grain-size distribution, Atterberg limits, plasticity-index, percentage of organic matter, volumetric weight, natural water content, dry weight, percentage of voids, cone resistance, unconfined compression tests, shear resistance, and permeability tests were performed on soil samples from the area. The Swedish Circle Method was used to determine the safety factor from this data. From the information gathered, the objective of the remedial measures must be to decrease the water pressures in slope. Transversal drains were used to lower the water table.

210. Marx. "The Calculation of Risk of Slips," Bautechnik, 9:103-106, 1931, (in German).

211. Masi, A. "Sul Consolidamento dei Terreni Franosi von Riferimento ai Casi piu Carratteristici," Annali dei Lavori Pubblici, 78: 498-513, June 1940, (in Italian).

Prize paper discussing formation and control of landslides; theoretical discussion of equilibrium conditions in sliding ground; and critical examination of means for impeding movement of sliding ground. (Abstract taken from "Highway Research Abstracts").

212. Matsuo, S. "A Study of the Effect of Cation Exchange on the Stability of Slopes," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, Vol. II, p. 330, 1957.

In this paper the location shift in the plasticity chart of samples which have received cation exchange is discussed first. Then the cause of a landslip in a certain terrain is investigated from the physiochemical standpoint. The measures to be taken hereafter against landslips are considered as follows: (1) the necessary step to prevent future landslips is to maintain the terrain in its present state. To make a big change in the local topography, especially to bank the upper part of the surface of the slope or add other loads, would very likely cause a new landslip. (2) For the period that the present state can be maintained the practice of chemical analysis and the test of soil properties are useful in predicting the occurrence of landslips. (3) A positive measure for maintaining the stability of the slope is to dig holes near the upper border of the slope and supplement Ca-ion in the form of aqueous solution of calcium salts.

213. May, D. R. and J. H. A. Brahtz. "Proposed Methods of Calculating the Stability of Earth Dams," Transactions, Second Congress on Large Dams, 4:539-576, 1936.

Instead of segments of finite width as employed in the Swedish method of analysis of the stability of earth slopes, the senior author introduces in Part I the concept of segments of infinitesimal width. The integration of the forces exerted on these segments is performed graphically with the planimeter by obtaining the areas under curves representing the forces. The curves of forces are readily constructed from values obtained at a few points on the section. The effects of hydrostatic pressure on the forces exerted on the circular arc under consideration are evaluated. These forces are also integrated with the planimeter. Before solving for the total shearing strength along the arc, this "uplift" is subtracted from the total normal pressure found from the saturated weights of the materials.

In part II, the junior author gives a general discussion of the concepts involved in a point-to-point stress analysis including the effect of internal liquid pressure. The unique solution of the problem is discussed but only a practical solution is presented with certain conservative assumptions. Empirical formulas for slopes are presented and a proposed method procedure in design and analysis is outlined in some detail. Examples of application are included.

214. Mayer, A. "Characteristics of Materials Used in Earth Dam Construction-Stability of Earth Dams in Cases of Reservoir Discharge," Transactions, Second Congress on Large Dams, 4:295-330, 1936.

As a result of a number of slides of earth dams in France due to rapid drawdown of the reservoir, investigations were made which involved the subject matter of this paper. The studies considered the use of the circular plane of sliding. The results of the calculations by this method were compared with the conditions found at four dams which had failed in this manner, and this indicated a satisfactory substantiation of the theory.

215. Mayer, A., and Habib, P. "Note on the Variations of Pore Water Pressures in Earth Dams of Low Permeability," Geotechnique, 5:190-193, 1955, (in French).

Experimental results of pore pressure dissipation tests on two soils indicate that the rate of pore pressure dissipation, due, for instance, to rapid drawdown of a reservoir behind an earth dam, will depend to an important degree on the permeability of the soil. Thus it is necessary to consider the pore pressures developed in any stability calculations of the drawdown condition for an earth dam.

216. Mayer, A. and P. Habib. "Stability Investigations of Two Slag Dumps," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:669-672, 1961.

Two stability investigations of steel-plant slag dumps are presented. One of the dumps has been subjected to frequent slides and in order to insure its stability the method of dumping the slag and of loading the soil had to be modified. The results of this study have been applied to the other case under review and have made it possible to stop the trouble which had already started.

217. McConnell, R. G. and R. W. Brock. "Report on the Great Landslide at Frank, Alberta," Appendix to Report of the Superintendent of Mines, Canada Department of the Interior, Annual Report 1902-1903, Part 8, 17 pp. 1904.

A detailed description of a great landslide which killed 70 people is given. The report includes description of the geology; eyewitness accounts of the slide, time, rate and character of movement; the description of the slide rock; and the slide surface. Causes of the slide were attributed to cumulative effects of weathering upon the fractured and fissured rock. The initiating causes were probably the opening of chambers of the coal mine at the foot of the mountain and night frost following warm days. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

218. McKeever, Harold J. (Editor). "Curing Slides With Drainage Tunnels," Roads and Streets, 72, 74, 76, April, 1947.

The Oregon state highway department cures their major hillside areas of movement or instability by developing a well defined procedure of installing drainage tunnels after thorough exploration to locate the plane of slippage. The first step is make a complete contour map of the area. Test pits are then dug into the slopes to determine the height of the slip plane. Stone, shale, and even clay will often have a laminated, twisted appearance near the slip plane location. A drainage tunnel is then dug across the slope beneath the slip plane. Auger holes are drilled down through the slipping mass, puncturing the roof of the tunnel. The holes serve as weep holes, draining the slipping mass and thus stabilizing the slope.

219. McKeever, Harold J. (Editor). "Slide Control Maintenance in West Virginia," Roads and Streets, 89:90-92, 98, May, 1946.

Layers of pervious soil reposing upon sloping layers of impervious material are usually stable. However, the top of the impervious material is a potential slide plane and when water either soaks down through the pervious layer to the slide plane, or gets to the slide plane from wet weather springs or water-bearing strata, it furnishes lubrication which overcomes the friction holding the pervious soil. When the movement begins the earth mass cracks allowing additional water to enter. The slope can generally be stabilized by drainage. If the source of water is wet-weather springs or surface runoff, diversion ditches can be used. If the water source is water-bearing strata the source must be located by digging trenches or drilling a series of holes. Remedial measures for these problems are given in the article.

220. Mellinger, Ross H. "Sycamore for Earth Slips?" Journal of Soil and Water Conservation, 17:179, 1962.

Sycamore trees were planted on a large, deep earth slip in the spring of 1936 in Wirt County, West Virginia. The trees have made remarkable growth and no further significant earth movement has taken place since the area was treated.

221. Merz, R. W. and R. F. Finn. Differences in Infiltration Rates on Graded and Ungraded Strip-mine Land. Central States Forest Experiment Station, Station Note No. 65, 1951.

222. Messines, Jean. "Sur l'Influence du Reboisement sur les Glissements de Terrains," Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences, 218:362-364, 1944.
Contrary to the conclusions of Jean Goguel, the author concludes that the planting of a forest in Brette near LuenDiois, Drome, France, did not cause landsliding. In general, the author concludes that, the role of forests is neutral in the matter of landslides. They neither help, cause, nor deter them. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

223. Meyer, Otto H. "Computation of the Stability of Slopes," Proceedings, American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, 84: SM 4, October, 1958.
A problem that has confronted engineers for a great number of years is that of determining the stability of earth slopes. Past solutions have been based on Coulomb's law and have followed the form of establishing equilibrium equations, where the stresses result from the weight of the material lying above an assumed rupture surface and the resisting forces are those of Coulomb's law. Because these solutions have required complex and laborious computations, there has been presented here a solution expressed in simple terms, accompanied by graphs as aids to ready application.

224. Meyerhof, G. G. "Mechanism of Flow Slides in Cohesive Soils," Geotechnique, 7:41-9, 1957.
The paper outlines the geological factors and soil conditions at sites of flow slides, and indicates the similarity of the physical properties of cohesive soils in the affected regions of Canada, Norway, and Sweden. The causes and characteristics of flow slides are discussed, and the observed mechanism is used for stability analysis. The proposed methods of analysis are applied to flow slides, and the estimates are compared to observations.

225. Meyer-Peter, E. F. H. and R. Mueller, "On the Stability of Earth Embankments," Schweizerische Bauzeitung, 108:35-37, 1936, (in German).

226. Mitchell, Robert H. "An Unusual Landslide," Journal of Geology, 49:382-391, 1941.
A landslide in a road cut near Zanesville, Ohio, which showed some of the characteristics of earthflow and associated slumping also showed some unusual characteristics. Three main divisions of the slide were observed: (1) a pseudograben at the head of the slipped area; (2) sharp-crested ridges with vertical inward faces and broken material in the center portion; and (3) a low earthflow ridge at the toe.
Stratigraphic, topographic, and climatic data were significant in explaining the slide. The toe was a normal earthflow caused

by weathering of a clay shale layer and represented an essentially horizontal movement. Water entering the level ground above the cut saturated the upper surface of a clay layer which dips slightly toward the road. Gravity aided by recent thawing caused a slip with a large horizontal component. The pseudograben at the head is a tension crack. Movement of a cut across the road, under apparently the same conditions, was of a normal slump type. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

227. Miyabe, Naomi. "Study of Landslides," Bulleting of the Earthquake Research Institute, Tokyo Imperial University, 13:85-113, 165 part 1, 1935.

The author attempts to infer causes of landslides by geographical distribution. Two main causes are presented: destructive earthquakes and penetration of precipitation. A discussion of each of these types and related features are given. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

228. Monomobe, N., A. Takata, and M. Matumura. "Seismic Stability of the Earth Dam," Transactions, Second Congress on Large Dams, 4:35-442, 1936.

The results of a theoretical analysis of the seismic stability of earth dams and a comparison of this analysis with the results of experiments on models are presented. The experiments were corroborative of the analysis except for small models. The results of seismic prospecting of four existing dams to obtain the modulus of rigidity are shown. These tests indicated the elastic properties of the dam by measuring the velocities of propagating waves produced artificially.

229. Muir, C. D. Report on pond construction and stability in the Wayne-Hoosier strip mine area near Ironton, Ohio, submitted to: M. B. Arthur, Assistant Regional Forester, August 28, 1958.

With regard to landslides and various factors involved in slope stability and landslides, the author presents some useful information and recommendations. He states that a major portion of the soil has large capillary forces combined with poor strength qualities when wet which leads to considerable soil movement in the area. He suggests a few landslide corrective measures, (1) drainage by vegetation, (2) increase distance from pond to outslope by pushing or grading the spoil banks toward the pond so as not to increase acreage of forest destroyed, and (3) embankment height reduction and material placement (terrace pattern occurs when the dragline cast distance is abruptly changed, causing a break in the outslope of the spoil bank). The author is of the opinion that an embankment over 25 feet high on a 1.4:1 slope has a high probability of some soil movement. Some suggested criteria of the author include: (1) that the main embankment should be at least 150 feet wide at the expected pond surface elevation, (2) inslopes should be at least 2.5 to 1, (3) that an embankment should be 15 feet higher than the pond surface, and (4) that spoil banks should be graded towards the ponds.

230. Muller, L. "European Approach to Slope Stability Problems in Open-Pit Mines," Colorado School Mines-Quarterly, 54:115-133, July, 1959.

Arithmetical calculations of permissible slope angles, while cumbersome, are the most practical means of assuring safety with maximum slope. Rock stability and permissible angle are determined by the type of rock, the strength of rock, stratification and foliation, mechanical fragmentation, chemical defects, positional relations between slope plane and structural elements, a time factor, water in rock joints, and vibrations. (Abstract from "Highway Research Abstracts".)

231. Murphy, V. A. "A New Technique for Investigating the Stability of Slopes and Foundations," Proceedings, New Zealand Institution of Engineers, 37:222-285, 1951.

Various methods of measuring the shear strength of soils are presented. The "Vane shear" test is described in detail and "Vane shear" test results are compared with results by other tests. The "Vane shear" method is applied to the investigation of the stability of foundations, embankments, and cuttings. (Abstract taken from "Engineering Index").

232. Musser, J. J. "Description of Parts of Beaver Creek Basin, Kentucky and Strip Mining Operations in Selected Areas, Hydrologic influences of strip mining," U. S. Geological Survey Professional Paper 427A, March, 1961.

The investigation of the effects of strip mining for coal on the hydrology of parts of the Beaver Creek basin, McCreary County, Kentucky, was begun by several State and Federal agencies in 1956. This report describes the topography, drainage, geology, soils, climate, hydrologic environment, and forest vegetation of the study areas and the history and description of the mining. The study areas include: (1) the Cane Branch basin, in which mining has occurred; (2) the Helton Branch basin, which has had no mining and which is reasonably similar to the Cane Branch basin in physical characteristics; and (3) the West Fork Cane Branch basin, in which some prospecting activity has occurred.

The spoil banks in the Cane Branch basin are composed of a heterogeneous mixture of sandstone, siltstone, claystone, soil, and water soluble sulfur compounds. Downstream from the spoil banks, the stream beds and the lower flood plains are composed of fluvial deposits consisting predominantly of clay and silt size particles that were derived from the spoil banks. In Helton Branch, fluvial deposits consist of sand-to-boulder size fragments, and in West Fork Cane Branch these deposits consist of silt-to-boulder size particles. From 1955 to 1960, four phases of prospecting and mining activity occurred in the Cane and West Fork Cane Branch study areas. This mining history and the methods used are discussed in this report.

233. Naylor, A. H., J. O. Stuart, and N. K. Edu. "Stability of Embankments of Frictional Materials Retaining Low-Friction Fill", Geotechnique, 11:114-120, 1961.

The results of calculations of the stability of an embankment supporting a low-frictional fill were presented. The bank material, coarse crushed stone waste, was purely frictional and the retained slurry, fine limestone silt with a proportion of clayey material, had a strength which increased linearly with

depth. Slip surfaces were equally likely at any depth and the problem became one of zonal failure with a complex slip field, a discontinuity at the interface, and a combination of convex and plane surfaces within the bank. The results obtained by graphical analysis were compared with the slip field obtained experimentally using small-scale two-dimensional models.

234. Nelson, A. "Landslides," Mine and Quarry Engineering, 7:235-238, October, 1942.
Landslides as related to mine and quarry engineering are discussed with particular reference to slides in Wales. Pertinent geological and topographical factors are listed. Landslides were classified into four groups: (1) rock and soil slips; (2) earth slips and creeps; (3) rock falls; and (4) compound landslides. The importance of familiarity with the terms: angle of rest, angle of slide, and excavation deformation is emphasized. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

235. Nelson, A. "Landslides and Their Causes," Iron and Coal Trade Review, 151:423-5, 1945.

236. Nelson, A. "Earth Slides, Soil and Rock Slips, Some Geological Aspects of Opencast Mining," Iron and Coal Trades Review, 168: 77-81, January 8, 1954.

237. Nelson, A. "Effects of Landslides on Mining Operations in United Kingdom," Mining Journal, 224:41-42, 1955.
Earth movements of the rockfall, slip, and earth creep types have occurred in a narrow valley. The effect of mining subsidence and spoil heaps on the earth movements is discussed. The cause of the earth movements was analyzed to be an excessive saturation of the strata. Preventive measures are discussed. (Abstract taken from "Engineering Index".)

238. Nelson, A. and K. D. Nelson. "Soil Mechanics in Colliery Practice," Colliery Guardian, 200:65-72, 1960.
Foundation and soil stabilization problems at coal mines are discussed. Landslides in Welsh mining valleys are described and the stability of earth slopes is discussed. Soil sampling and testing procedures and the necessary tests for soil exploration are presented. The author also discusses the classification, properties, and behavior of the soils in the area.

239. Nichols, D. A. "Landslides in Canada," Canadian Field-Naturalist, 42:212-220, 1928.
A description of many landslides which have occurred in Canada is given including slides from the clay belt of Eastern Canada, the alluvial areas of the west, and the alpine areas. The main causes are given. A bibliography on Canadian slides is included. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

240. Nichols, H. L. Moving the Earth: The Workbook of Excavation. Second Edition, Greenwich, Connecticut: North Castle Books, 1952.
This is a comprehensive treatise on earth work equipment and methods of construction. The variety of subject matter is vast. Excellent source for familiarizing engineers and contractors with the diverse construction materials, methods, and equipment in use today. Included are a section describing machines in detail and a large glossary of considerable help to both engineers and laymen.

241. Nonveiller, E. "Certain Considerations Regarding the Calculations of Stability of Fill Dams," Tehnika, 10:665-670, 1950.

242. Nonveiller, E. "The Stability of Slopes of Dams Composed of Heterogeneous Materials," Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, Vol. 2, pp. 268-272, 1953.
The stability analysis of slopes is generally based on cylindrical sliding surfaces. If a dam consists of two materials of different properties the failure will occur along the line of minimum resistance which is shown as a sharp break at the border between these materials. This result has been obtained in investigations carried out by the author on models consisting of a cohesive core supported by a bank of non-cohesive material. Based on the results of tests the author suggests a new method of analysis for the stability of earth dams in heterogeneous materials.

243. Moran, B. J. J. "The Use of Vegetation in Stabilizing Artifical Slopes," Proceedings, Conference on Biology and Civil Engineering, (Institution of) , 1949.

244. Nonveiller, E. and L. Suklje. "Landslide Zalesina," Geotechnique, 5:143-153, 1955.
An analysis was made of a large landslide on a railway embankment in Yugoslavia. The upper crack of the slide followed the contact between the Upper Raibl strata and Noric Dolomite.
The following general conclusions were drawn from the analysis: (1) in tectonically disturbed beds the shear strength of broken and weathered components governs the sliding conditions, (2) the uplift and the seepage pressure can decisively influence the stability equilibrium and therefore have to be considered in the stability analysis, (3) in tectonically disturbed beds the angle of internal friction for the appraisal of the stability is much more important than the cohesion, and more so the deeper the sliding plane, (4) the stability has to be analyzed on the basis of effective pressures by using the results of consolidated shear tests, and (5) the sliding may occur on a broad zone, but the whole sliding mass slides on this zone mainly as a solid body.

245. "Oahe's Slides Enlarge Earthmoving Job," Engineering News Record, 157:40-4, Oct. 11, 1956.

This is a discussion of an earth slide which occurred during the construction of the Oahe Dam along the Missouri River. The slide developed slowly and the movement was quite gradual. It is believed that the movements occurred along a combination of existing fault planes and bentonite seams; triggered, perhaps, by nearby excavation operations along the face of the abutment and aggravated by subsurface water pressures.

Original design called for the exposed faces of the last abutment--into which the rolled-fill embankment of the dam proper will be anchored-- to be trimmed to slopes ranging from 1 on 3 to 1 on 5 (1 vertical to 5 horizontal). Due to the slide, however, these surfaces were laid back on flatter slopes for greater stability. In overburden material, which is a glacial till extending to depths as great as 80 feet below existing ground surface, the slope will be trimmed to 1 on 5. The underlying shale will be sloped to 1 on 6.

246. Odenstad, S. "Logarithmic Curve as the Sliding Surface of Frictional Soil," Teknisk Tidskrift, 74:467-469, 1944, (in Swedish).

247. Oliver, A. R. "Some Recent Methods of Investigation of the Stability of Earth Slopes," Journal of the Institution of Engineers, Australia.

248. Osterman, J. "A Theoretical Study of the Failure Conditions in Saturated Soils," Swedish Geotechnical Institute, Proceedings, No. 20, 1962.

The strength of soils is treated from different aspects. The imperfections of the theories and the limitations of experience are discussed, mainly inconnection with plastic clays. Attention is drawn to some fundamental properties which influence the resistance capacity to shearing. Moreover, a failure theory is introduced in which energy considerations are utilized. The differences between the stability failure on one hand and the yield failure on the other are discussed. Finally, some applications to specific cases of stability are demonstrated. (Abstract taken from "Highway Research Abstracts").

249. Osterman, J. "Notes on the Shearing Resistance of Soft Clays," Acta Polytechnica Scandinavica, Civil Engineering and Building Construction Series, Ci2:263, 1959.

Mainly in commection with investigations of the risk of further landslides in a river valley, it proved necessary to make additional research on the strength of soft clays. Some preliminary results are reported to encourage discussion on the subject. The results indicate, among other things, the value of common quick testing and the cohesion method, and the difficulties in establishing a unique relation between strength and effective stresses because of the secondary settlements and creep. Moreover, some objections to the common method of using the Coulomb formula and of treating triaxial test results are raised, and modified values of the apparent angle of friction are plotted against the plasticity index. (Abstract taken from "Highway Research Abstracts").

250. Pagliaro, F. "Stability of Earth Dams," Transactions, Second Congress on Large Dams, 4:391-413, 1936.

This paper is concerned with a very general discussion of the factors affecting stability of earth dams. The author first calls attention to the fact that, for cohesive materials, the safe slope decreases as the height of the dam increases. He recommends a gradually decreasing slope from the top toward the base. A list of 92 dams showing the height and the inclination of the upstream face, was given. Also presented was a list of 21 laboratory tests which may be made on materials for earth dams.

251. Parizek, E. J. and J. F. Woodruff. "Clarification of Definition and Classification of Soil Creep," Journal of Geology, 65: 653-656, 1957.

Two alternative proposals are presented in an attempt to resolve current inexactness in the definition of soil creep. The article suggests redefinition of the process of soil creep and an increased emphasis placed upon perceptibility as basis for the classification of mass movements.

252. Patton, Boyd. "Earth Slips in the Allegheny Plateau Region," Journal of Soil and Water Conservation, 11:28-30,33, 1956.

Slips which are common over an extensive area of the Allegheny Plateau are the result of a type of mass movement of soil. They are usually crescent-shaped or roughly rectangular, with a short, vertical drop at the upper edge and a bulge, or irregular series of wrinkles and bulges at the lower side. The earth mass usually moves only a few feet, but raw breaks in the cover usually occur at the top, along the sides, and in severe slides, at the bottom. Slips are most common on native grass pastures. They rarely occur in good woodlands. Proper land use and management, drainage, and, where economically justified, deep piling, are the most important known corrective measures. It is difficult to predict where these slips will occur and they are very difficult to stabilize.

253. Peck, R. B. and D. U. Deere. "Investigation of Landslides for Planning Remedial Measures," American Railway Engineering Association, Bulletin 61, 670-677, February 1960. No. 556

The first step is the collection and organization of all the available history of movement in the area. A program of test borings is then set up; the type, number, depth, etc., is dependent on local conditions. Each boring should, if practicable, be converted into a standpipe for observation of groundwater levels. The shape and dimension of the sliding mass are determined; a topographic map is prepared using ground surveys and airphotos. The position of the surface of sliding must be established as accurately as possible. The use of a tiltmeter is recommended for establishing the zone of movement. This also aids in establishing the rate of movement. Examples of investigations are given.

No slide analysis or recommendations can be made unless pertinent factors concerning the slide are known including topography and shape of the sliding mass, groundwater conditions, the strength and arrangement of various strata, and the effect of varying piezometric levels on the rate of movement of the slide. (Abstract taken from "Highway Research Abstracts").

254. Peck, R. B., and H. O. Ireland, "Investigation of Stability Problems," American Railroad Engineers Association, Bulletin 507, 1953.

255. Penman, A. D. M. "Shear Characteristics of a Saturated Silt, Measured in Triaxial Compression," Geotechnique, 3:312-328, 1953.

Drained and undrained triaxial tests were made on a saturated silt to measure its shear strength under extreme conditions of drainage. Pore-water pressure was measured in the undrained tests by a servo-type mechanism which required virtually no movement of pore water to operate it, thereby maintaining the sample at constant volume.

The drained tests have shown that the angle of internal friction decreases with increasing voids ratio, and with increasing lateral pressure, a familiar result. Interlocking is shown to be responsible for the main increase in $\emptyset$ with increasing density, and the magnitude of this effect has been calculated. Even when the interlocking force is subtracted, $\emptyset_o$ is still found to increase with increasing density. An explanation of this effect, as well as the decrease in $\emptyset$ observed under increased pressure is given.

The undrained tests show that there is a fall in pore-water pressure during shearing, corresponding to the dilatancy observed in the drained tests, and provided the applied pressures are sufficiently high, this fall in pore pressure governs the ultimate strength. The fall in pore-water pressure is a function of the voids ratio of the silt. Since the ultimate strength is independent of applied pressures (above a critical pressure) the silt can behave as a $\emptyset = 0$ material to total stresses. Below the critical pressure, the silt behaves as a cohesive material with a given angle of internal friction, and this is probably the condition measured in many earlier routine tests on silts. (Abstract taken from "Highway Research Abstracts").

256. Peterson, R., N. L. Iverson, and P. J. Rivard. "Studies of Several Dam Failures on Clay Foundations", Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 2:348, 1957.

This paper presents the results of two investigations made on the failures of clay embankments on saturated highly plastic clay foundations. The studies indicate that conventional quick shear test results applied in a total stress analysis can give safety factors greater than actually exist. Effective stress analyses utilizing estimated pore pressures may also give safety factors greater than unity for failure conditions.

For the cases analyzed, using the data obtained when movement occurred, the computed factors of safety varied within the limits of 0.9 to 2.1 for both the total stress and effective stress methods of analyses. The computed safety factors would have been higher for both methods of analyses if the maximum deviator stress criterion for shear failure had been used, or if the results of vane tests or unconfined compression tests on tube samples had been applied in the total stress method of analysis.

257. Petterson, Knut E. "The Early History of Circular Sliding Surfaces," Geotechnique, 5:275-96, 1955.

This paper describes the work at Gothenburg leading to the introduction, in 1916, of the use of circular sliding surfaces in the analysis of stability problems in clay. This assumption has become very widely adopted, and the history of its early days is therefore a matter of considerable interest, both to specialists in soil mechanics and to civil engineers generally.

258. Peynircioglu, H. "Earth Movement Investigations in a Landslide Area on the Bosporus," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 353, 1957. 2

The foot of a steep hill on the Bosporus was excavated to provide a terrace for a factory building. The soil forming the slope is a hard fissured clay. One year later, after a rainy season and a snowy winter, earth movements began to take place, and retaining walls and concrete floor were deformed and cracked. In this case it has been possible to estimate the position of the slip surfaces and to represent them by an arc of a circle. Factors of safety have been calculated for different laboratory values of $\emptyset$ and C. Considering that the factor of safety calculated on the basis of actual slide surface and field values of the angle of international friction ($\emptyset$) and the cohesion (C), should be equal to unity, an attempt is made to find a means of choosing a satisfactory $\emptyset$ and C value from among the different test results carried out under different conditions.

259. Porter, O. J. "Treatments Prevent Slides and Slipouts in California," Roads and Streets, 83:57-59, 62-64, 66, 68, 70, 72, April, 1940.

Investigations along California roads indicate that slides and slipouts may result from one or more of four causes. All of these causes are related to drainage and compaction conditions of the slopes. The four causes are: (1) slippage along a thin, well defined, wetted stratum which acts as a lubricated plane; (2) slipouts may occur when the embankment or the foundation soil becomes saturated by the impoundment of hillside seepage behind an impervious fill; (3) slipouts will occur when there is insufficient shearing resistance in the fill to withstand the horizontal stresses produced by its own weight; and (4) failure of an embankment may be due to lateral movement of a saturated or semiplastic foundation soil when the fill load produces a horizontal component in the semi-plastic foundation soil greater than the shearing strength of that soil. Correction of the first type failure may be accomplished by breaking up and draining the sliding plane. Protective measures against the second type can be completed by adequate drainage by cut off trenches above the fill. Correct embankment slope design and proper fill compaction are both essential for preventing the third type failure. Correction of the fourth condition may require the removal of all unstable material or the construction of huge french drains at sufficient intervals to readily relieve the pore pressure by releasing the excess water squeezed out by the embankment load.

260. Proix-Noe, Marthe. "Etude d'un Glissement de Terrain du a ba Presence de Glauconie," Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences, 222:740-742, 1946, (in French).

At the end of the rainy season, landslides occur periodically in the region of Mustapha Superieur in Algeria. After a description of geologic section of the terrain in question, this article gives a physico-chemical study of the causes of the landslides and shows how they were due to the presence of glauconite which determines the geochemical action of water. As a result of base exchange, the groundwater becomes alkalinized. This causes peptization of colloidal material and hydroloyzes the alumino silicates so that the permeability increases. The glauconitic marl bed then gradually loses its rigidity and then slides. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

261. Putnam, W. C. "Landslides and Earthflows near Ventura, So. Calif." Geographical Review, 30:591-600, 1940.

The author describes slumps and earthflows which occur in loosely consolidated sediments and surficial debris of the Ventura area. The slides have a destructive effect upon oilfield structures in the area. Detailed measurements of movements in the oil fields are given. The dominant effect of the slides is on physiography. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

262. Raedschelders, H. "Improvement of the method of Calculation of the Equilibrium Along Sliding Circles," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 1:68-72, 1948.

Consideration of rotational equilibrium alone is insufficient, because each state of equilibrium is controlled by three conditions: The equilibrium of translation along two mutually perpendicular directions (for instance, a vertical and a horizontal direction), and the equilibrium of rotation. In the different methods of controlling the stability of slopes, one or two of the three conditions of equilibrium are often overlooked. In the case of a homogeneous soil mass a more rapid method taking into account the three conditions of equilibrium is suggested. The simplified method consists in the consideration of only one slice, and the inclusion of pore water pressures. The application and an example of the proposed method are included within the paper.

263. Rankine, W. J. M. "On the Stability of Loose Earth," Philosophical Transactions of the Royal Society, Series A, 147:9-27, 1857.

This paper is one of the first on the mathematical theory of the stability of loose earth. Many of the basic principles of soil mechanics still used today are derived in this article. The equations governing the horizontal and vertical forces acting on retaining walls or natural slopes are presented in pure mathematical form.

264. Rao, K. L. and M. I. Struct. "Stability of Slopes in Earth Dams and Foundation Excavations," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:691-695, 1961.

A study of the effect of time on slopes in ancient earth dams in India has been made by the authors in order to bring out particular features that may be usefully incorporated in modern designs. Examples of slope failures in two recently constructed earth dams are discussed. It was observed that if the outer part was made of freely draining gravelly soil and if the foundations were good, time had no effect on slopes. If the soil used on the outside was clayey, a tendency for sliding in the course of time could be expected.

265. Reiche, Parry. "The Toreva-Block, a Distinctive Landslide Type," Journal of Geology, 45:538-548, 1937.

In the southern part of the Colorado Plateau, landslide blocks which have fallen with a backward rotation towards the parent cliffs are common. These blocks are named "Toreva-blocks" because of typical development near Toreva, Arizona. The slip plane of the blocks is a curved plane, steeper in the upper part. The blocks are usually unbroken and in some places are as much as 1,000 feet long. The slide blocks are believed to be prehistoric because more humid climatic conditions would have favored their formation. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

266. Rettger, R. E. "Experiments on Soft Rock Deformation," American Association of Petroleum Geologists, Bulletin 19, pp. 271-292, 1935.

The article describes small scale laboratory experiments illustrating deformation of soft sediments produced by slump, differential movement, and differential loading. Materials used were fine sand and clay. The author could not reproduce all large scale phenomena. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

267. Reynolds, H. R. "Landslide Investigations in Russia," Civil Engineering (London), 56:608-610, 771-772, 1961.

Landslide investigations are carried out by special field stations located in region of slides. The special Russian terminology used in slide research and classification slides is given. The magnitude, direction, and rate of slide displacement are given. The Russian methods for calculation of critical equilibrium of soil are described. (Abstract taken from "Engineering Index").

268. Rhoades, R. "Geology in Civil Engineering: The Columbia Basin Landslides," Engineering, 163:377, 1947.

Along the Columbia River large prehistoric landslides occurred before Lake Roosevelt was filled, but new slides occurred after the lake was impounded, especially when the lake was drawn down from a high to a lower level. Permeabilities, angles of internal friction, apparent cohesions, pore pressures, and related properties have been determined in the area. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

269. Rice, G. S. "Some Problems in Ground Movement and Subsidence," Transactions, American Institute of Mining and Metallurgical Engineering, 69:374-393, 1923.

Subsidences due to mining and related landslides are described. The Frank, Alberta, Canada, slide is used as an example. The angle of slide of the unstable rock was the most important factor in subsidences. With loose material, this angle was only a few degrees steeper than the angle of repose. When rock formations are under load, "plane of stability" would be a better term. This plane would be a curved plane extending from the edge of the mine excavation to the most advanced surface break. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

270. Rio, M., Alejandro del, "Delslizamientos de Umbita Departamento de Boyaca," Servicio Geologico Nacional, Compilacion de los Estudios Geologicos Oficials en Colombia, 7:199-208, 1947, (in Spanish).

Landslides of Umbita, Boyaca department, Colombia, are described. The terrain where landslides occur is overlain by thick, poorly consolidated sandstone beds intercalated with calcareous shales. Their age is not certain, but probably Upper Cretaceous Guadalupe. Two types of slippage occur--slump, and earthflow or mudflow. The slides are due not only to the loose character of the sandstones, through which water penetrates easily to the slippery shale layers, but also to the general inclination of the beds in the direction of sliding. A drainage program was recommended to alleviate the condition. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

271. Rodgers, J. K. "Observations on Some Cincinnati Landslides," Ohio Journal of Science, 28:157, 1928.

Features observed in connection with several landslides indicate that the sliding has been confined to unconsolidated material on slopes of about 12 degrees. Concentric cracks appear at the upper limit of the slide, enechelon cracks at the lateral margin. Undercutting at the base of the slope and saturation below the surface of the clay or till are important contributing factors. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

272. Rodgers, J. K. "A Type of Landslide Common in Clay Terraces," Ohio Journal of Science, 29:167, 1929.

Clay terraces in the Hudson Valley Region and the Licking River are characterized by horizontally laminated clays undercut by lateral shifting of stream courses. First manifestation of instability is the bowing up at the toe of the slope. Sliding is rapid along the curved surface of the zone. There are three main divisions to the slide. They are: (1) down slipped block or series of blocks at head; (2) fissured and disrupted center area; and (3) anticlinal ridge or series of ridges in lower part. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

273. Rodgers, J. K. "A Type of Landslide Common in Clay Terraces," Proceedings, Ohio Academy of Science, 8:304, 1929.
Same article as Rodgers (272).

274. Rodriguez, A. R. "Analysis of Slope Stability," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:709-716, 1961.
The author sets forth the elastic-plastic conditions which must be satisfied by the stresses on a plane of failure in a cohesive material. He has studied the equilibrium of a sliding mass in accordance with the Swedish method, assuming the usual boundary conditions. He determines the equilibrium of a mass of soil for various angles of slope. Finally, he suggests certain modifications of the boundary conditions which are necessary to reduce errors.

275. Root, A. W. "California Experience in Correction of Landslides and Slipouts," Proceedings, American Society of Civil Engineers, 79:No. 235, August, 1953.
Same article as Root (277).

276. Root, A. W. "California Experience in Correction of Landslides and Slipouts," Proceedings, American Society of Civil Engineers, 79: Separate No. 235, Aug. 1953.
Gives examples of solutions to various types of landslides caused by various factors.

277. Root, Arthur W. "Correction of Landslides and Slipouts," Transactions, American Society of Civil Engineers, 120:281-289, 1955.
Discussion of the correction of landslides and slipouts in highway construction and maintenance in California. The author presents measures for the corrective treatment of landslides which have been found to be successful in California.

278. Root, A. W. "Horizontal Drilling--New California Approach In Landslide Control," Roads and Streets, 98:54-6, September, 1955.
Interception and removal of subsurface water is often an effective method of preventing or controlling landslides, especially the "slump" type. One method of subdrainage used extensively in California consists of installation of horizontal drains, which are 2-inch perforated pipes placed in drill holes bored into a slope. One of the principal advantages of the horizontal drain method controlling landslides is the relatively low cost compared to other methods of stabilization. Improved methods and drilling equipment have made possible the economical installation of horizontal drains in all but the most difficult formations.

279. Root, A. W. "Control of Slides by Underdrainage," Paper presented at the Annual Meeting of the American Society of Agricultural Engineers, Santa Barbara, California, June 23-26, 1958.
In the majority of landslides, especially the slump type, ground water is a major factor causing the slide movement.

Several different types of subdrainage have been used successfully for correcting and preventing landslides. It is emphasized that subdrainage is not always the most exonomical or most effective method of controlling a landslide. The most appropriate method of treatment, can be designed only after a careful exploration, analysis, and evaluation.

280. Rowe, P. W. "A Stress-Strain Theory for Cohesionless Soil With Applications to Earth Pressures at Rest and Moving Walls," Geotechnique, 4:70-88, 1954.

Experiments with cohesionless soils in the shear-box and triaxial-compression machines are described in which the influences of sample thickness, soil type, length of slip line, type of test, confining pressure, soil density, direction of loading, and strain history of the soil have been studied. The results substantiate the hypothesis that the degree of mobilization of internal friction depends upon the degree of granular interlocking, which is a function of the movement of the grains per unit length of the slip line. A new type of confined-compression test is described, the results being used to predict the variation of the at-rest earth pressure coefficient with depth. (Abstract taken from "Highway Research Abstracts").

281. Ruedy, R. Bibliography on Soil Mechanics, 1940-1944. National Research Council of Canada, No. 1291, Ottawa, Canada, May, 1945.

A collection of the more important references on Soil Mechanics from the Purdue Conference on "Soil Mechanics and Its Applications," 1940.

282. Rufenacht, A. "Pore Pressure Assumptions for Stability Studies of Earth Dams," Proceedings Second International Conference on Soil Mechanics and Foundation Engineering, 3:230-33, 1948.

By use of some wide assumptions, the Terzaghi consolidation theory can be used to determine in a simple way the pattern of pore pressure distribution due to consolidation of an earth dam. This pattern takes account of all the main factors affecting the building of pore pressures, such as soil characteristics, time of construction, shape of the structure and relative distribution of earth and rockfill. The method leads to conservative values, mainly on account of the assumption of the drainage being restricted to a vertically upward direction. If the pore pressures thus obtained are excessive, a reduction could be effected by judgement, taking the shape of the structure into consideration, particularly as regards possibilities of lateral drainage.

283. Russell, I. C. "A Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington," U. S. Geological Survey, 20th Annual Report, Part 2, pp. 193-204, 1898-1899.

Landslides in northern Washington leave characteristic topography: steep escarpments and fissures adjacent to the escarpments, grading into a series of basins formed by backward tilting of slide blocks, and finally to gently rolling old age landslide topography. Thousands of slides have occurred where the Columbia lava overlies soft lacustrine beds; these slides are

also favored by vertical jointing of the lava, undercutting of the escarpment by streams, and saturation of rocks with water. Snow avalanches grading to mudflows are common in the winter, and slides of gravel terraces underlain by clay beds occur. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

284. Saada, A. S. "A Rheological Analysis of the Shear and Consolidation of Saturated Clays," Paper presented at the 41st Annual Meeting of the Highway Research Board held in Washington, D. C., Jan. 8-12, 1962.

This report deals with the material "Saturated clay" characterized by its dry density and moisture content. A change in the moisture content gives another material with other properties. Five series of tests showed that in saturated clay the directions of maximum shear stresses and strains coincide and are independent of the stress at failure. The independence of the shear behavior from the pore pressures is demonstrated. The tests also showed that the material has no true yield limit and that the curvature of the stress-strain diagram is influenced by the rate of strain at all stress levels. Finally, the creep tests showed that the rate of strain at the steady stage was dependent only on the value of the stress and independent of the load path. The above results lead to the conclusion that a saturated clay is a visco elastic material, and that in its steady state of creep the laws of the theory of elasticity regarding the distribution of stresses are applicable. (Abstract taken from "Highway Research Abstracts").

285. Saito, M. and H. Uezawa. "Failure of Soil Due to Creep," Proceedings Fifth International Conference on Soil Mechanics and Foundation Engineering, 1:315-318, 1961.

The authors suggest that by measuring the surface strain of slopes it is possible to forecast slope failure. A close relationship between strain rate and rupture due to creep was established with the aid of simple compression and triaxial compression tests in the laboratory. It is represented by a straight line on log-log paper, or simply expressed by the fact that creep-rupture life is inversely proportional to the strain rate. It is independent of the kind of soil or testing methods used, and is valid for test results carried out in foreign countries and for the measured values derived from full-scale experiments of slope failure. This relationship may be used to forecast the occurrence of slope failure or landslides.

286. Sall, G. W. "Strip Land Reclamation at Little Sister," Mining Congress Journal, 40:26-28, 71, July, 1954.

The rehabilitation program of land disturbed by strip mining near St. David, Fulton County, Illinois is presented. Grading of the spoil banks is performed behind mining. The fertility of the land increased after stripping and reclamation. (Abstract taken from "Engineering Index").

287. Savage, C. N. "Earthflow Associated with Strip Mining," Mining Engineering, 187:337-9, March, 1950.

Examination of subsurface materials and determination of the bearing strength of these materials is one of the first steps in determining the stability of spoil bank slopes. Water plays two important roles in the stability of spoil bank slopes: (1) as a lubricant, aiding failure and (2) as an increased load on spoil banks with steep slopes which also aids failure. The usual strip mining procedure forms a broad, ditch-like catchment area which intersects surface runoff and the ground water table, in some cases. This water can then seep down through the spoil bank. The weight of the subsurface runoff increases the force-bearing tangent to the slope, water and suspended clay lubricate the spoil bank materials, and gravity movement begins.

288. Sawyer, L. E. "Mined Area Restoration in Indiana," Journal of Soil and Water Conservation, 17:65-67, 76, 1962.

An analysis of the problem of restoring spoil from open-cut coal mining and the progress being made in Indiana are presented. The article points out that research results have shown that grading spoil banks decreases the capability of the spoil material to absorb water. This condition caused increased erosion and a decrease in vegetation growth and survival. Graded spoil banks also hindered tree seedling plantings.

289. Scheffel, E. R. "Slides in the Conemaugh Formation near Morgantown, West Virginia," Journal of Geology, 28:340-355, 1920.

Slides are described in the area in and near Morgantown, West Virginia. The Conemaugh formation is composed of alternating beds of shales, sandstones, coals, and limestones. The three types of slides, primary, fluid, and dry, are defined and discussed. Reduction of slope above the road, growth of vegetation, well planned drainage, and heavy retaining walls are suggested remedies. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

290. Scheidegger, A. D. "Theory of Rock Movement on Scree Slopes," Alberta Society of Petroleum Geologists, 9:131-138, 140, 1961.

The physical theory of dry rock movement on scree slopes is presented. The basic assumption is that the volume expansion and contraction due to daily and seasonal temperature fluctuations causes the movement. (Abstract taken from Engineering Index).

291. Schrero, "Bibliography of Physical Properties and Bearing Value of Soils," Proceedings, American Society of Civil Engineers, 57: 871-921, 1931.

Entire bibliography contains about 800 references. The material is confined to that found in the Technology Department of the Carnegie Library of Pittsburgh. The bibliography covers literature up to 1928. The topics are divided into ten sections one of which is slides, slips, and subsidences.

292. Schultz, and B. Cleaves. Geology in Engineering. New York: John Wiley and Sons, pp. 280-305, 1955.

Classifies and describes soil mass movements. The types of mass movement are divided into: (1) slow flowage, (2) rapid flowage, (3) slides, and (4) subsidence.

The mass movements classified as slow flowage, rapid flowage, and slides are subdivided and each is described in detail. The causes of the slow flowage, rapid flowage, and landslides are discussed. The prevention of landslides is also considered.

293. Seifert, R. "Stability Investigations of Dams," V. D. I. Zeitschrift 77:361-365, 1933, (in German).

294. Sevaldson, R. E. Slide at Lodalen. Norwegian Geotechnical Institute, Publication 19, 1956, (in Norwegian).

The paper describes a slide in a clay slope near a marshalling yard in Oslo, Norway. Stability calculations based on the s_u-analysis, using values of the undrained shear strength which could be expected to exist in the slope immediately before the slide, give a reliable but somewhat uncertain basis for estimating the stability. However, it is not possible to use this method for estimating the long-term stability. Stability, analyses using Bishop's method, including effective stresses based on the apparent cohesion and the apparent angle of friction, give approximately correct results. This method also can be used for estimating the long-term stability of the slope. (Abstract taken from "Highway Research Abstracts").

295. Shannon, W. L. "Measurements of Lateral Movements in Soil," Proceedings of the Ninth Canadian Soil Mechanics Conference, December 15-16, 1955, published by The National Research Council of Canada, Ottawa.

296. Sharpe, C. F. S. Landslides and Related Phenomena. New York: Columbia University Press, 125 pp. 1938.

Landslides are classified on the bases of (1) kind of movement and its relative rate; (2) relative water content of the moving mass; and (3) kind of material. The three main types of slips defined and discussed are slow flowage, rapid flowage, and landslide. The various methods of prevention and correction of landslides are discussed. The causes of landslides are tabulated under "basic or passive condition favoring landslides" and "active or initiating causes of landslides". Subsidence is also included in a separate chapter. An extensive bibliography accompanies the text.

297. Sharpe, C. F. S. and E. F. Desch. "Relations of Soil Creep to Earthflow in the Appalachian Plateau," Journal of Geomorphology, 5:312-324, 1942.

A study of earthflows in the Appalachian Plateau region has indicated the significance of soil creep in the localization of earthflows and slumps. The bedrock consists of alternating shales, sandstones, limestones, clays, and coals, essentially horizontal. The outcrop of clay and coal layers, on a hillside, thins and bends downhill under the soil layer, due to creep. These impervious layers of clay or coal on the slope interfere with the downward percolation of surface and ground water.

The overlying soil layer becomes saturated and earthflow results. Earthflows are commonly aligned at or close below the elevation of clay and coal layers. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

298. Shepard, C. H., N. E. Mason, and D. J. Ray. "A Problem in Highway Slope Stability," Highway Research Board, Bulletin 309, pp. 116-130, 1962.

During construction of a highway cut through clays, silts, and sands of glacial outwash origin, the cut slope became very unstable. Extensive sloughing and erosion, with some slope movement, developed as excavation of the cut proceeded. A heavy flow of ground-water seepage developed in the cut slope. Drainage methods used to control this seepage are described.

After excavation of the cut area was complete, further slow movement of the slope face was observed. Successive cross-sections showing rate and nature of movement are presented. Additional field explorations employing continuous sampling techniques were made to determine cause of movement. Methods of sampling and testing are described. Investigation revealed slickensides, resulting in low-strength zones, in a soil mass that had general high-shear strength. Also, a zone of soft low-strength elastic clay was disclosed at a critical location below subgrade.

Observations indicated movement on a failure plane approaching the shape of a circular arc. Analyses by the Swedish circular arc method and the critical height of slope method are discussed. Results of further study to determine the slope section required to attain stability are presented. Corrective treatments used in this solution that are considered to have general application to similar problems are summarized.

299. Skempton, A. W. "A Slip in the West Bank of the Eau Brink Cut", Journal, Institution of Civil Engineers, 24:267-287, 1945.

The slip in the cut was probably initiated by erosion. Slope stability was analyzed by two simple methods using shear characteristics of the material. Both methods gave correct estimates of the factor of safety, but in neither case did the calculated critical slip circle coincide with the actual slip surface. These results are discussed briefly in relation to other published data and it is concluded that more information on slips in natural cohesive strata must be presented before a complete understanding of the factors involved is possible. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10).

300. Skempton, A. W. "The $\emptyset$ = 0 Analysis of Stability and Its Theorectical Basis," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 1:72-77, 1948.

A summary of the methods of $\emptyset$ = 0 analysis for calculation of active and passive pressure and bearing capacity of clays and the calculation of factors of safety in clay slopes is given. The $\emptyset$ = 0 assumption applies only where there is no water content change. The limitations of this method and cases where it is not applicable are described.

301. Skempton, A. W. and A. W. Bishop. "The Measurement of the Shear Strength of Soils," Geotechnique, 2:90-108, 1950.

Tests are described for determining the shear strength parameters involving, c, apparent cohesion, and $\emptyset$, angle of shearing resistance, of the principal soil types under controlled conditions of pore pressure dissipation. The significance of the results is discussed in terms of their application in stability analyses.

302. Skempton, A. W. and J. D. Brown. "A Landslide in Boulder Clay at Selset, Yorkshire," Geotechnique, 11:280-293, 1961.

An analysis was made of a long-term slip in a valley slope of the river Lune, near Middleton-in-Teesdale. The slip was entirely within a deposit of heavily overconsolidated intact boulder clay. Although a complete picture of the groundwater flow net was not obtained, sufficient information was nevertheless available to show that the field value of the cohesion intercept was approximately equal to the laboratory value measured in drained triaxial tests. This is in marked contrast to the results found from long-term slips in overconsolidated fissured clays.

303. Skempton, A. W. and F. A. DeLory. "Stability of Natural Slopes in London Clay," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 2:378-381, 1957.

In several areas of the London clay north of the Thames the natural hillsides are not yet in final equilibrium. Where the ground water level reaches the surface in winter, slips can occur on 10 degree slopes, but all slopes flatter than 10 degrees are stable, although subject to soil creep. This critical slope is in agreement with an analysis of stability based upon the laboratory value for the angle of shearing resistance, provided the cohesion intercept is taken as zero.

304. Skempton, A. W. and H. Q. Golder. "Practical Examples of the $\emptyset = 0$ Analysis of Stability of Clays," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 2:63-70, 1948.

Examples of the use of $\emptyset = 0$ stability analysis in determining ultimate bearing capacity, critical height of a clay face, and the possibility of slips in clay bank are presented. The conclusions are that the cumulative evidence is ample to substantiate the application of the $\emptyset = 0$ analysis, to stability problems in clays, providing the limitations of the method are kept in mind. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

305. Smith, E. C. "Soil Mechanics: Factor of Safety of Clay Banks," Institution of Civil Engineers, Journal, 18:293-6, June, 1942.

Graphical solution of the Swedish circle method to locate the failure surface which has the lowest safety factor. Coulomb's formula for determining the shearing stress of the soil us used.

306. Southwest Builder and Contractor. "Report on Santa Monica Palisades Slides," Southwest Builder and Contractor, 135: No. 7, 37-43, February 12, 1962.

There have been precedents for landslide studies involving single large slides, or multiple small slides of like character in a compact area, but none approached the extent and complexity of the Palisades (bordering the Pacific Ocean between Santa Monica and Malibu) study. There have been hundreds of slides, many exceeding 100,000 cu. yd. of displacement, scattered over 15 mi. of ocean frontage, and widely varied in character. Some were sudden falls from steep cliffs and others gradually creeping on gentle slopes. Some were wet and more active in wet weather, others dry and unpredictable.

The consulting engineers investigated many factors believed to cause or to contribute to the cause of landslides, and listed 34 slides, for each of which 2 to 5 factors are alleged to have contributed. Most frequently listed factors were: high ground water, concentrated runoff entering slide, perched water from rain, perched water from irrigation, septic tank or leaking sewer, continuous perched water, street and highway cuts, stream erosion at toe, fill at top of slide, tension cracks at top of bluff, slipping along faults, earthquake, bedding attitude, and removal of slide talus. (Abstract from Highway Research Abstracts.)

307. Sowers, G. B. and G. F. Sowers. Introductory Soil Mechanics and Foundations. Second Edition, New York: The MacMillan Company, pp. 317-329 and 338-343, 1961.

A thorough coverage of the basic principles of stability of earth masses rather than step-by-step rules for design are given. Some of the topics which are discussed include the circular arc analysis with example calculation, the method of slices, cracking at the top of a slope and the effect of submergence and seepage. Slopes in homogeneous soils which are composed of either soft clay, a cohesive soil, or a cohesionless soil are also included in this book. Earth movements in nature are covered along such lines as classification, creep, landslides and subsidence. The topic of landslides is further discussed with regard to flow slides, linear shear slides, rotational slides and correcting of landslides.

308. Spangler, M. G. Soil Engineering. Second Edition, Scranton, Pennsylvania: International Textbook Company, pp. 288-301, 1960.

The stability of slopes is discussed in this chapter. Some of the specific topics covered include forces acting along an infinite slope, normal and shearing forces on inclined surface, analysis of mass resting on inclined layer of clayey soil and an analysis of homogeneous soil. Other topics of interest include an outline of a graphic analysis of the stability of a slope, details of the method of slices, and a discussion of the phenomenon of creep.

309. Spanos, N. M. "Core Drilling," Proceedings, Coal Mining Institute of America, 73:66-73, 1959.

The author reports on the core drilling procedure for locating and mapping various types of rock strata. The use of the core drillings is discussed. The author also points out that few coal mining companies are taking advantage of the information which can be obtained from core drillings.

310. Speedie, M. G. "Selection of Design Values from Shear Test Results," New Zealand Engineering, 10:377-8, 1955.

311. Stanton, Thomas E. "Stabilizing Earth Slopes by Boring Horizontal Drains," Public Works, 79:20-22, February, 1948.

The presence of ground water is the most important factor influencing the development of slides and embankment slipouts. Subsurface water reduces the stability of cut slopes and foundations under embankments through saturation of the soil, thereby diminishing the shear resistance. The weight of the ground mass constitutes a driving force tending to cause slide movements, particularly where hydrostatic pressures are induced in impounded ground water, thereby adding to the driving force.

The California Division of Highways undertook to correct such conditions through the installation of perforated metal pipe drains in horizontal or slightly inclined holes. "Hydrauger" equipment was adopted for drilling the holes and is still being used, although numerous improvements have been developed in both the procedure and equipment. In general, the tentative locations, lengths, and required number of drains are determined by a preliminary investigation consisting of vertical test borings and a geological survey. The final locations and lengths of drains are determined by conditions encountered during the installation.

312. Stanton, Thomas E. "California Experience in Stabilizing Earth Slopes Through the Installation of Horizontal Drains by the Hydrauger Method," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:256-260, 1948.

Same article as Stanton (311).

313. Steinbrenner, W. "The Stability of Earth Slopes Under the Influence of the Ground Water Flow Produced by Severe Rain," Bauingenieur, 19:164-168, 1938, (in German).

314. Stout, W., R. T. Stull, W. J. McCaughey, and D. J. Demorest. "Coal Formation Clays of Ohio," Geological Survey of Ohio, Fourth Series, Bulletin 26, Columbus, 1923.

This bulletin begins with a chapter on the history of the Clay Industry in Ohio, which is followed by a chapter concerning coal formation clays in Ohio. The testing of clays, influence of minerals and mineral components in clays and the mineralogical examination of coal formation clays are further topics of concern that are discussed. The final two chapters include the chemical analysis of clays and the theory of the origin of coal formation clays as their focal points for discussion.

315. Stroganov, A. S. "Visco-Plastic Flow of Soils," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:721-726, 1961.

The author gives the invariable characteristics of the mechanical properties and mechanical equations of state of the visco-plastic flow of soils based on the generalization of the Hencky and Bingham conception. The solutions of problems on visco-plastic flow of a soil layer along a rough inclined plane and between two rough surfaces which have practical significance

in an estimate of the stability of certain types of landslides and slopes are given. In addition, the principal equations concerning the plane problem of visco-plastic flow of soils are given.

Suklje, L. "A Landslide Due to Long Term Creep," Proceedings, Fifth International Conference on Soil Mechanics and Foundation Engineering, 2:727-735, 1961.

A landslide which occurred along the Gradot ridge in Macedonia, Yugoslavia, in 1936, when about 20 million cubic meters of silt and sand, covered by a volcanic deposit, slipped and filled the valley of the torrential Vatasha River to a depth of 70 meters is described. The landslide lasted for only a few minutes, occurring along a plane of soft clay as the culmination of a creep over a considerable period of time. Owing to unequal creep deformation of the underlying cohesive strata, the cohesion of the sandstone, conglomerate, and volcanic overburden was overcome decades or even centuries before the slide took place. Later the shear strength of the over-consolidated cohesive lower strata was overcome by creep which occurred over a long period. Dynamic earthquake effects contributed towards cracking of rigid strata and also helped to sustain the creep of the cohesive soil.

317. Swedish Landslide, Engineering News Record, 145:31, 1950.

Houses slid as far as 420 feet in a landslide at Surte, in Sweden. The soil consists of a top layer of dense clay, underlain by sandy clay and fine sand. Heavy rains saturated the pervious strata under the clay, eventually building up artesian pressures that "floated" the relatively impervious clay stratum. The whole sliding phenomenon took place in a few minutes.

318. Takata, A. and S-1 Kambara. "Problems Concerning Stability Calculation of Earth Dam on Movement and Action of Infiltrating Water," Transactions, Second Congress on Large Dams, 4:415-429, 1936.

In this paper a study has been made of the effect of water seeping through a dam on stability. It was found that the resultant of the buoyant force of the water and the seepage force, on any small element of the dam, acts in the direction perpendicular to the lines of equal pore pressure. The direction of lines of equal pressure can be determined conveniently either from model studies or by the construction of a flow net. Attention is called to the effect of capillarity on the location of the lines of equal pore pressure.

319. Tan, Ek-Khoo. "Stability of Soil Slopes," Transactions, American Society of Civil Engineers, 113:139-158, 1947.

All cohesionless soils assume an angle of repose. On the other hand, when the soil possesses some cohesion the natural slope can be made steeper. A study of the phenomena and mechanics involved in the failure of earth slopes is reported in this paper. In the model studies of sand slopes used to investigate the slide phenomena, the angle of repose of cohesionless soil was found to be an entirely superficial phenomenon and independent of the height of the slope. However, the inclination and the height of

a bank of cohesive soil were found to depend upon cohesion.

An approximate mathematical solution of the slope problem based on the theory of plasticity was developed to determine the possible position of the sliding curve and the stress conditions leading to failure. The theory shows the slip lines to be arcs of circles. A sliding failure is imminent whenever the height and inclination of slope, and the shearing properties of soil, bear such a relation to each other that a plastic region develops and tends to enlarge progressively.

320. Tan, Ek-Khoo. "Stability of Soil Slopes," Proceedings, American Society of Civil Engineers, 73:19-38, 1947.
Same article as Tan (319).

321. Taylor, D. W. "Stability of Earth Slopes," Journal of the Boston Society of Civil Engineers, 24:197-246, 1937.
The author presents a review of several methods proposed for analyzing the stability of earth slopes with comparison of results furnished. Complete mathematical solutions are obtained by the two most reliable methods and are tabulated. Homogeneity of the soil is an important simplifying assumption. Measurements of the constants which describe shearing strength are briefly discussed. Values for unit weight and their applicability are discussed. The effect of seeping water is analyzed and a procedure is recommended which does not require determination of a flow net. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

322. Taylor, D. W. "The Stability Analysis of a Foundation Failure," Proceedings, Highway Research Board, 18:93, 1938.

323. Taylor, Donald W. Fundamentals of Soil Mechanics. New York: J. Wiley and Sons, 700 pp., 1948.
Chapter 16 is devoted to the stability of slopes. Various methods of slope stability analysis are presented. The factors which cause slope failures are presented and discussed. The methods of measuring shear strength along with the shearing characteristics of sands are given in Chapter 14. Chapter 15 presents the shearing strength of cohesive soils.

324. Tchurinov, M. V. "Modifications par Alteration dans la Composition, la Structure, et les Proprietes des Argiles du Cretace Inferieur," Comptes Rendus (Doklady) de l'Academie des sciences de l'URSS, 49:364-368, 1945, (in Russian).
The author discusses modifications of lower Cretaceous clays by alteration in the composition, structure, and properties. The localization of landslides near Ulyanovsk, Volga region, USSR, is related to the intense alteration of the clays of the area. The changes in their chemical and physical properties are set forth in detail and tabulated.

325. Tennessee Valley Authority. An Appraisal of Coal Strip Mining. Knoxville, Tennessee: Tennessee Valley Authority, February, 1963.
General facts concerning strip mines as compared to underground mines are presented. Strip mining is studied in detail

in the areas of extent of stripping, major coal buyers, stripping methods, and the type of land stripped. The effects of stripping on stream pollution, soil erosion, and land value are discussed. The methods of reclamation are presented along with the laws of various states which enforce and direct reclamation. Of particular interest is the legislation concerning the grading of spoil banks in different states.

326. Terzaghi, Charles. "Landslides", Proceedings, Highway Research Board, 7:122-127, 1927.

Landslides occur when the slope is greater than the angle of internal friction. The factor of safety can be computed if $\emptyset$, the angle of internal friction, and C, the cohesion, are known. The French or the Swedish method of computation may be used. The values of $\emptyset$ and C are difficult to estimate because of lack of uniformity of most soils and the fact that $\emptyset$ and C are apt to change with changes in hydraulic conditions or soil structure. Slides may be remedied by drainage; by maintaining a stable slope as computed by the Swedish method; and by placing obstacles such as piles in the path of the slide if the drop in consistency of the mass is small. Established facts and strong indications concerning the soil mechanics of slides are listed, research in progress is noted, and further research is suggested. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

327. Terzaghi, Karl. "The Mechanics of Shear Failure on Clay Slopes and the Creep of Retaining Walls," Public Roads, 10: No. 10, December, 1929.

A digest of the published data concerning friction and cohesion of clay soils discloses the fact that the angle of internal friction of such soils is exceedingly small as compared with the slopes of cuts and fills. Hence, the stability of clay fills and clay cuts depends essentially on cohesion. Due to this fundamental fact, the factor of safety of slopes with a given inclination rapidly decreases beyond the critical height at which the soil can stand with a vertical face. Hence, a stable fill of a certain height and consisting of a certain clay soil is no indication of stability in a fill of twice that height, with the same slope and consisting of the same material. In computing the factor of safety of a cut or fill, the curvature of the sliding surface must be taken into account, else the results of the computation may be very misleading. The graphical procedure presented in this paper furnishes the means of making stability computations within a few hours.

328. Terzaghi, Karl. "Earth Slips and Subsidences from Underground Erosion," Engineering News-Record, 107:90-92, 1931.

Two examples of how underground erosion caused slips and subsidences are discussed.

329. Terzaghi, Karl. "Stability of Slopes on Natural Clay," Proceedings, First International Conference on Soil Mechanics and Foundation Engineering, 1:161-165, 1936.

An investigation of the shearing resistance of undisturbed clay. Clays were classified into the following types: (1) soft intact clays, free from joints and fissures; (2) stiff intact clays, and (3) stiff fissured clays. Calculated values of the shearing resistance of type (1) are compared with those obtained by general experience. For type (1) the computation of the stability of slopes involve a vital element of uncertainity. Type (2) is rare. Type (3) represents failure along a zone of local weakening within a very deep zone of potential disintegration. The stabilization of slides in type (1) clay can be made by reducing the slope. Type (3) clay can be stabilized by injecting cement grout. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

330. Terzaghi, Karl. "Critical Height and Factor of Safety of Slopes Against Sliding," Proceedings, First International Conference on Soil Mechanics and Foundation Engineering, 1:156-161, 1936.

The deformation of an earth fill under the influence of its own weight occurs by expansion of the upper and compression of the lower part of the slope. The equations defining the failure plane derived from various theories are discussed. Assumptions of both circular and noncircular sliding planes are presented. The author also discusses the stability of fills acted upon by percolating water.

331. Terzaghi, Karl. Theoretical Soil Mechanics. New York: John Wiley and Sons, 510 pp., 1943.

Chapter nine of this textbook has been devoted to the stability of slopes. The equations for the critical height of a vertical bank is derived. The theoretical equations are given for determining the stability factor and critical circle when the angle of shearing resistance is zero or greater than zero. The correction in stability computations for tension cracks is also given. Composite surfaces of sliding and the shearing stresses at the base of cohesionless fills are discussed.

332. Terzaghi, Karl. "Mechanism of Landslides," Chapter 4 in Application of Geology to Engineering Practice, Geological Society of America, Berkey Volume, p. 83-123, 1950.

This article is a general review of the mechanisms, preventions, and corrections of landslides. The causes of landslides are given with the aid of illustrations. Many examples of various types of slides are shown and described. Methods of preventing and correcting slides are suggested. The article is written so that a nonengineer can understand the terminology and theory involved in describing a landslide.

333. Terzaghi, Karl and R. B. Peck. Soil Mechanics in Engineering Practice. New York: John Wiley and Sons, 566 pp., 1948.

The stability of slopes is discussed in chapter eight of this book along with retaining walls. The types of slides which commonly occur in various types of soil are presented. The stability

of the base of embankments is discussed for various soil types and the procedures for stabilizing the base are presented.

334. Terzaghi, Karl and R. B. Peck. "Stabilization of an Ore Pile by Drainage," Proceedings, American Society of Civil Engineers, Journal of Soil Mechanics and Foundation Division, 83: No. SM1, January, 1957.

Instability of the track supporting one end of an ore bridge in a steel plant was caused by excess porewater pressure in a layer of silt. A successful permanent system of vacuum well points was installed after preliminary field tests demonstrated the feasibility of draining the silt in this manner.

335. Thompson, D. M. "Strip Coal Mining Design Systems," an unpublished M.S. Thesis, College of Mineral Industries, The Pennsylvania State University, 1953.

Various major topics dealt with in this paper include prospecting, stripping machines, techniques of stripping, and blast hole drilling of overburden. Explosives used in surface mining, principles of haulage, and developments in auger mining are still other areas discussed. Chapter eight of this thesis concerns the reclamation of stripped land. Three methods are discussed: (1) reforestation, (2) seeding for pasture, and (3) the replacement of the topsoil. These lands may also be easily converted into recreational areas with fresh water lakes and all kinds of wild life. Because spoil banks lack valuable nitrate which are essential for plant growth, a legume is used in the initial plantings to raise the available nitrogen level in the soil and thus allows more profitable species to be planted later. The last two chapters are concerned with power facilities for strip mines and factors in the design of strip mines.

336. Tompkin, J. M. and S. H. Britt, "Landslides--A Selected Annotated Bibliography," Highway Research Board Bibliography No. 10, 1951.

The bibliography is a selected list of references believed to be helpful to engineers, geologists, and others concerned with landslide problems. The list is subdivided into sections following Sharpe's classification. The annotations emphasize those factors that may be most helpful in solving or clarifying other similar problems.

337. Toms, A. H. "The Effect of Vegetation on the Stabilization of Artifical Slopes," Proceedings, Conference on Biology and Civil Engineering, Inst. Civil Engineers, 1949.

338. Toms, A. H. "Recent Research into the Coastal Landslides at Folkestone, Warren, Kent, England," Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, 2:288-293, 1953.

Research in 1938-39 showed that the subsidiary landslips on the sea side of the railway on the Kent coast between Folkestone and Dover were due to deep shear failure in the Gault clay resting on the lower levels in the back of the slip area, and calculations have been made to assess the relative factors of safety

against further movements which would be provided by groundwater lowering or toe-loading of the slips.

339. Trollope, D. H. "The Systematic Arching Theory Applied to the Stability Analysis of Embankments," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 2:382, 1957.

A new theory describing the detailed stress distributions developed in wedges of granular materials resting on foundations of varying stiffness is briefly outlined. The application of this theory to the design of earth and rock fill dams is discussed in the light of available evidence concerning pressure measurements made on model and full size embankments. The evidence presented indicates that the theoretical predictions are substantiated by a wide range of field experience. Two-dimensional stability analysis is then considered in terms of: (a) collapse along an assumed surface of failure; (b) a point-to-point stress analysis. Finally the implications of the theoretical analyses as they affect the design and construction of embankments are discussed.

340. Turnbull, J. M. "Shear Resistance of Soils," The Commonwealth Engineer, 39:374-81, 418-26, 1952.

A comprehensive theory of the interpretation of tests for shearing resistance of soils and the solution of Coulomb's equation is presented. Six laws are stated which give the essential requirements for presentation of the test data in a form suitable for use in the design of structures, and examples of results of tests by direct shear are shown to confirm the theoretical treatment. Attention is drawn to defects in the usual presentation of the results of tests by means of direct shear and triaxial compression methods of obtaining the shearing resistance of soils.

341. U. S. Corps of Engineers. Stability Analysis Study. Waterways Experiment Station, Vicksburg, Mississippi, February, 1940.

342. U. S. Corps of Engineers. Soil Mechanics Design - Stability of Slopes and Foundations. Office of the Chief of Engineers, Department of the Army, Chapter 2, Part CXIX, February, 1952.

343. U. S. Geological Survey. "Landslides," U. S. Geological Survey, Highway Research Board, Bibliography No. 10, 53 pp., 1951.

A compilation of 291 annoted references covering the period from 1920 to 1950. Contains an index of authors and sources. The contents are subdivided into description, investigation, control, and prevention of landslides.

344. Valishev, N. T. "Remarks on Appraisal of Dynamical Stability of Sand in Subsoil and in Hydraulic Structures," Printed Summary of Master Thesis, Institute of Civil Engineering, Leningrad, 1958.

345. Van Burkalow, Anastasia. "Angle of Repose and Angle of Sliding Friction, an Experimental Study," Geological Society of America, Bulletin 56, 669-707, 1945.

This paper summarizes a controlled laboratory study to determine subaerial angles of repose of loose material. Results show that the angle of repose varies: (1) inversely with the size of fragments in perfectly sorted materials but directly in those imperfectly sorted; (2) inversely with the density of fragments; (3) directly with their angularity, roughness, and degree of compaction; (4) inversely with height of fall of material on free cones; and (5) directly with increase of moisture up to the saturation point but inversely beyond that. The angle of sliding friction varies inversely with size and density of fragments and directly with their surface roughness. For the same material the angle of sliding friction is definitely lower than the angle of repose. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

346. Vanden Berg, G. E. "Requirements for a Soil Mechanics," paper presented at the Annual Meeting of the American Society of Agricultural Engineers at Columbus, Ohio, June 1960.

The mathematical requirements necessary to define forces and deformations at a single point in a three dimensional soil mass based on the concept of a continuous medium are pointed out. None of the present-day concepts of relationships between stress and strain such as current plastic and elastic theories accurately describe observed phenomenon in the soil. Therefore, stress and strain must be simultaneously measured and a rigorous soil mechanics developed based on the resulting accurate stress-strain relationships.

347. Vanderwilt, J. W. "A Recent Rockslide near Durango, in La Plata County, Colorado," Journal of Geology, 42:163-173, 1934.

A rockslide on Carbon Mountain involving the Fruitland formation, which is largely shale, is discussed. Slope along direction of major movement has gradient of 40 per cent. The maximum recorded rate of movement was about 30 to 45 feet per day. The initiating cause was thought to be softening of shale by infiltration of water. The primary cause was the pull of gravity on a weak formation lying on a relatively steep slope. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

348. Varghese, P. C. "New Approach to Analysis of Stability of Slopes," Indian Roads Congress Journal, 19:23-43, April, 1955.

The author presents a slope stability analysis procedure for homogeneous clay slopes called resistance envelopes. The resistance envelope is evolved by assuming a number of circles of failure for a given slope. Results using the resistance envelope method agree with results obtained by the friction circle method. Abstract taken from "Engineering Index".

349. Vargus, M. and E. Pichler. "Residual Soil and Rock Slides in Santos (Brazil)," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, 2:394-398, 1957.

In 1928 a spectacular landslide occurred on the hills of the city of Santos, causing great damage and taking a heavy toll of life. Twenty-eight years later, in the same month of March, a great number of similar slides came down the hills nearly simultaneously, repeating the catastrophe of 1928. Most of the slides took place along the residual soil mantle that partially covers the underlying crystalline formation. An analysis of the causes, prolonged heavy rain being the main one, was made. The local geological conditions as well as those concerned with the soil properties were studied and an attempt was made to compare the shear characteristics of the residual soil in situ with that obtained in the laboratory.

350. Vine, W. A. "Slope Stability in Open Pit Mines," Mining Congress Journal, 44:78-81, August, 1958.

The author describes the material comprising pit walls as being solid, loose particles with some large, solid formations. Thus, he uses Coulomb's formula to predict the failure plane of slopes. The factors affecting cohesion are described as soil creep, saturation, ice, and drying. He concludes that the proper shape of a pit wall, when the material making up the wall has fairly consistent strength properties, is not a plane surface, but should be curved to somewhat follow the shape of an incipient surface of sliding.

351. Von Moos, Armin and R. F. Rutsch. "Uber einen durch Gefugestorung Verursockten Seenferebruch (Gorgensee, Kt. Berne)," Eclogae Geologicae Helvetia, 37:385-394, 1944, (in German).

The causes and mechanics of slumping in an area on the west shore of Gelzen Lake, Bern Canton, Switzerland, are discussed. The slumping occurred in a zone composed of loam,fresh water limestone,and peat. The stability of the upper part of the zone, which was frozen, was disturbed by the lowering of the lake. The falling of trees and fissuring of the ground by tree roots further disturbed equilibrium. Slipping took place in the limestone with consequent collapse of the overlying peat and soil layers. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

352. Walker, F. C. and W. W. Daehn. "Ten Years of Pore Pressure Measurements," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:245-250, 1948.

When pore pressure test apparatus is installed in the embankment and foundation of a large earth dam or a dam built on a critical foundation, a continual check can be maintained on the stability of the dam for uplift pressures and possible foundation piping. The accumulated data from these installations are used to observe the construction and operating characteristics of each embankment and, if necessary, the data are available for computing its stability against sliding. The observations from the piezometers now installed in five large earth dams have produced very interesting results. Certain general phenomena are characteristic of all the dams, but the magnitude

and location of high pore pressures can be fully explained only through additional observations and study. For example, in comparing the observations from Deer Creek, Green Mountain and Anderson Ranch Dams, large construction pressures were not observed in Deer Creek Dam although the other two dams showed high pressures during their construction.

The observations made on existing dams will prove invaluable in formulating new designs, especially since many of the new dams under consideration will have to be built on complex and poor foundations. To insure a check on the stability of these dams, pore pressure apparatus should be installed at critical locations. When such apparatus is properly installed, dangerous conditions will be indicated before failure takes place. If critical conditions are observed, the data will be available so that corrective measures can be applied.

353. Walker, F. C. and W. G. Holtz. "Control of Embankment Material by Laboratory Testing," Proceedings, American Society of Civil Engineers, 77: No. 108, December, 1951.

The theory of limiting moisture content as it applies to the stability of earth structures is discussed and it is related to the field control of moisture in embankments. The effect of pore pressure and rock content is analyzed, and several typical examples are cited. Laboratory testing of embankment material is correlated with field data for compaction, permeability, consolidation, and settlement tests. The apparatus and procedure for the triaxial shear test is also discussed.

354. Ward, W. H. "The Stability of Natural Slopes," Geography Journal, 105:170-197, 1945.

This paper presents a general picture of the factors which control the movements of natural slopes, with particular reference to those examples which have been studied by the Building Research Station of the Department of Scientific and Industrial Research, at Garston, near Watford. The origin and causes of the failure of slopes for each type presented is discussed. A bibliography is included at the end of the paper. (Abstract taken from "Landslides" Highway Research Board Bibliography No. 10.)

355. Waters, J. M. and D. L. Bartlett. "A Direct Method for the Location of Slip Planes," Civil Engineering and Public Works Review, 51: 1956.

The method described consists of driving into an embankment a length of tubing of alkathene, which is a flexible corrosion-resistant plastic of great toughness and low weight. A deformation will occur in the alkathene tubing due to the shearing action at the slip plane. Its location is determined by lowering a short steel mandril attached to a length of cord down the center of the tubing. (Abstract taken from "Highway Research Abstracts.")

356. Watkins, G. L. "Stability of Colliery Soilbanks," Colliery Engineering, 36:493-497, November, 1959.

In this article the author outlines the various theories of soil mechanics applicable to a study of soil heap stability. The type of materials in the foundation and in the spoilbank is described. Equations for various soil properties, such as shear, cohesion, angle of internal friction, and angle of natural repose, which are needed to determine the factor of safety for the spoilbanks are given. The equations for the factor of safety from failure by landslip, spreading, piping, and sinking are defined. The factor of safety equation for the overall stability of a spoilbank against circular slip is presented.

357. Williams, P. J. "Direct Recording of Solifluction Movements," American Journal of Science, 255:705-715, 1957.

Probes made of spring steel strips with electrical resistance strain gages attached, are inserted into the soil to detect solifluction movements. Bending of the probe by soil movement can easily be determined at any time from strain gage readings. A new instrument is described which also gives some indication of the vertical velocity profile.

358. Williams, P. J. "Investigation into Processes Occurring in Solifluction," American Journal of Science, 257:481-490, 1959.

Mechanics of soliflucation downslope after a late snow were investigated using instrumental techniques for the determination of soil pore-water pressures, density, and movement. Substantial changes in water content and considerable sub-surface water occurred together with changes in state of stress during solifluca-tion. Low and sub-atmospheric pore-water pressures were observed also during soliflucation.

359. Wilson, Stanley D. "Detection of Landslides," a paper presented at the Eleventh Northwest Conference on Road Building, University of Washington, February 21, 1958.

This paper describes an instrument which has been developed for the purpose of measuring subsurface ground movements, and three examples are presented to show typical applications with respect to detection of landslides. The first typical application discussed was on the cut slope of a large open-pit mine in Utah. Another typical example was where the problem of surface creep was encountered. The third example presented was where a small excavation along the edge of the river triggered off a major landslide involving 10 million cubic yards of shale. In order to measure ground movements with this instrument, observation wells must first be installed. At its present stage of development this instrument (Slope Indicator) has a sensitivity of 1:1,000. This permits accurate determination of the ground deformation when it is as little as one inch in 100 feet of depth. The maximum tilt that the present instruments can operate in is about 8^{o} on either side of vertical.

360. Wilson, S. D. "Detection of Landslides," Proceedings, Eleventh Northwest Conference on Road Building, University of Washington, 1958.

361. Wilson, S. D. "Application of Soil Mechanics to Stability of Open Pit Mines," Colorado School Mines - Quarterly, 54:93-113, July, 1959.
Same article as Wilson (362).

362. Wilson, S. D. "Slope Stabilization in Open Pit Mining," Mining Congress Journal, 46:28-33, July, 1960.
In the field of soil mechanics it has been found that most earth slides or slope failures are the result of excess water pressure accumulating behind the slope face. Recent experiences by the author have led him to the same conclusion with regard to the stability of cut slopes in open pit mines, particularly in fractured and fissured rock. It follows, then, that slope stabilization in open pit mines may be reduced to the basic problem of relieving of subsurface drainage. Unfortunately, this is as difficult in practical application as it is simple in concept. First, it must be verified that excess water pressure is present; second, the unique combinations of topography, stratification and faulting which collected the water and concentrated the seepage paths leading to the cut slope must be detected and analyzed; and third, a feasible and economical method of relieving the excess pressure must be devised.

363. Wilson, S. D. and C. W. Hancock, Jr. "Horizontal Displacement of Clay Foundations," a paper presented at the First Panamerican Conference on Soil Mechanics and Foundation Engineering, Mexico City, September, 1959.
This paper describes an instrument which has been developed for the purpose of measuring subsurface ground movements, and describes the application of the instrument to four specific problems. First is described horizontal compression of soil under the foundation of a steam-electric generating plant located in an area of general subsidence. Next is presented an example of horizontal movements in a clay stratum underlying an earth dam; followed by a landslide problem. Finally movements along bentonite seams resulting from excavation in a shale formation are described. In order to measure ground movements with this instrument, observation wells must first be installed. The wells are lined with a plastic casing and at times the ground movement which results in the bending of this plastic casing may become great enough such that the instrument will not pass this slide zone.

364. Wood, R. F. and J. V. Thirgood. "Tree Planting on Colliery Spoil Heaps," Colliery Engineering, 32:512-516, December 1955 and 33:27-32, January, 1956.
Many colliery waste sites are capable of producing respectable crops; and many more are capable of bearing tree growth. Spoil heaps are usually potentially fertile, and can also provide sufficient moisture to support tree growth. Actual toxicity is probably rare, and when it occurs often

quite local in distribution. The choice of planting species is firstly governed by the local conditions, particularly by the smoke pollution factor, which may rule out all conifers. Special measures such as levelling and the importation of soil are not usually warranted; nor is the use of extra large stock, which may, in fact, give poorer results than smaller plants.

365. Wolf, W. H. and W. G. Holtz. "Slope Stability Studies for the Delta-Mendota Intake Canal," Proceedings, Second International Conference on Soil Mechanics and Foundation Engineering, 3:268-274, 1948.

Because of the complexity of the field conditions, the critical character of the materials involved and the unusual depth of the cut, the slope stability analysis for the Delta-Mendota Intake Canal was performed on the basis of data obtained by a detailed field investigation and laboratory testing program. The stability analysis was based upon the Swedish theory (slip circle) as developed by Petterson, Hultin, Fellenius, and others. Before applying the Swedish method to the study of the proposed slopes, the unit weight, cohesion, and internal friction values were determined on undisturbed soil samples in the Earth Materials Laboratory. The purpose of this paper is to present the general procedures followed for the systematic use of field investigations, sampling, and laboratory testing with a well known slope analysis method in obtaining a rational design of earth slopes.

366. Zeevaert, L. "Methods of Calculating the Stability of Earth Slopes," Ingenieria (Mexico), 15:261-270, 1941, (in Spanish).

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