TESTING FORUM

ASTM D18 News

ASTM Committee D-18's Nominating Committee has selected the following slate of Officers and Members-at-Large for a two-year term beginning Jan. 1988. Acceptance of their nomination has been obtained from these nominees.

- Chairman: Woodland G. Shockley
- First Vice Chairman: Richard E. Gray
- Vice Chairman: Robert C. Deen
- Vice Chairman: Richard S. Ladd
- Vice Chairman: Howard J. Pincus
- Vice Chairman: James R. Talbot
- Secretary: Robert J. Stephenson
- Membership Secretary: Jorgen F. Christiansen
- Members at Large: Robert T. Donaghe
Vincent P. Drnevich
Helmar F. Hanson
Terry S. Hawk
C. William Lovell
Charles H. McElroy

Environmental News

Subcommittee D18.21 on Ground-Water Monitoring held a seminar and workshop on ground-water monitoring standards development on 22–24 Jan. 1987 in Tampa, FL. Nearly 200 attendees participated in the events.

Subcommittee D18.21 on Ground-Water Monitoring had follow-up workshops on standards development on 22–23 June in Cincinnati and 17–18 Sept. in Minneapolis, MN, both of these workshops being cosponsored by EPA. A number of draft standards are already under review.

The Ground-Water Standards Coordinating Committee of ASTM held meetings on 21 Jan. 1987 at Tampa, FL and on 22 June in Cincinnati, OH. A list of all ASTM standards related to ground-water supply and ground-water contamination studies has been prepared, and ASTM staff are developing ways by which ASTM standards and publications can be developed into a brochure for communication with the need-to-know public sector.

As a result of an earlier symposium on applications of remote sensing and remote data transmission and the need for geophysical standards for ground-water and other environmental studies, ASTM Subcommittee D18.01 on Surface and Subsurface Reconnaissance organized new sections during their June 1987 meeting in Cincinnati, OH. The new sections are as follows: 18.01.02 on Geophysical Exploration, 18.01.03 on Remote Sensing, and 18.01.04 on Remote Data Transmission. A workshop on remote sensing and on remote data transmission was held during the section meetings, and participation in a joint symposium on remote sensing will be held in conjunction with AEG during their annual meeting. During the June workshop a tour was held of the Corps of Engineers Data Center, which uses satellite remote data transmission to collect real time data needed to manage flows on the Ohio River.

The Committee D18-D19 sponsored symposium on Ground-Water Contamination Field Methods had its proceedings published as ASTM Special Technical Publication 963 in early 1988. A symposium on monitoring environmental factors from space is being published by ASTM as Special Technical Publication 967, entitled *Geotechnical Applications of Remote Sensing and Remote Data Transmission.*

International Symposium on Artificial Recharge of Ground-Water

The Task Committee on Guidelines for Artificial Recharge of Ground-Water, American Society of Civil Engineers (ASCE), is sponsoring an International Symposium on Artificial Recharge of Ground-Water. The symposium papers, oral and poster, will be presented at the Inn-at-the-Park (near Disney Land) in Anaheim, CA from 23 to 27 Aug. 1988.

Because of the world-wide interest in artificial recharge and the need to develop efficient recharge facilities, this symposium will bring together an interdisciplinary group of scientists and engineers to provide (1) a forum for many professional disciplines to exchange experiences and findings related to various types of artificial recharge, (2) learn from both successful and unsuccessful case histories, (3) promote technology transfer between the various disciplines, (4) provide an education resource for communication with those who are not water scientists, such as planners, lawyers, regulators, and the public in general, and (5) indicate directions by which cities or other entities can save funds by having reasonable technical guidelines for implementation of a recharge project. A proceedings of accepted oral and poster papers will be published. An exhibit of ground-water related equipment and books is contemplated.

Mid-way through the symposium, a one-day tour will visit well-injection barrier projects as well as surface recharge areas, and water reuse projects. On 22 Aug. plans are being made to offer an optional one-day continuing-education course on artificial recharge theory and practice.

An optional two-day field trip from Anaheim to San Francisco will be available on 27–28 Aug. to observe artificial recharge and land subsidence sites, as well as points of hydrologic, geologic, and historic interest along the tour route. The continuing-education course and the two-day field trip will cost extra over the regular registration fee.

For further information contact Ivan Johnson, Chairman, ISAR Organizing Committee, A. Ivan Johnson, Inc., 7474 Upham Court, Arvada, CO 80003.

Subcommittee Spotlight

Subcommittee Officer Changes

- D18.03 on Texture, Plasticity and Density: Ray Horz resigned as chairman to pursue advanced schooling. Terry Hawk has been appointed to the chairmanship.

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- D18.06 on Physio Chemical Properties: Keith Hoddinott is the new chairman.
- D18.94 on Education and Training: John Antrim was appointed chairman; Norbert Schmidt will be vice chairman.
- D18.99 on Quality Control: Peter Spellerberg was appointed chairman; James Forbes will be vice chairman.
- D18.21 on Ground-Water Monitoring (see the following news release).
- D18.93 formerly Soil and Rock Nomenclature: Changed Title and Scope of subcommittee to be more in line with ASTM Committee on Terminology regulations. The new title and scope are as follows:

(1) *Title:* Subcommittee D18.93 on Terminology for Soil, Rock, and Contained Fluids.
(2) *Scope:* "It shall be the responsibility of Subcommittee D18.93 to act for Committee D18 in the selection and approval of acceptable terms, symbols, units, and definitions pertaining to soil and rock, and the fluids contained therein in either the saturated or unsaturated subsurface zones; to review proposed standards or revisions to existing standards for compliance with accepted ASTM terminology and rules and terminology of other national and international organizations involving the disciplines related to D18 standards activities; and to maintain up to date Committee D18's terminology standard D 653."

New ASTM Subcommittee Formed to Develop Standards for Ground-Water Monitoring Investigations

The Executive Subcommittee of ASTM Committee D-18 on Soil and Rock voted at its June 21 meeting in Cincinnati, Ohio to elevate Section D18.01.01 to Subcommittee status. The new group, Subcommittee D18.21 on Ground-Water Monitoring, will be chaired by David M. Nielsen, Senior Hydrogeologist with IEP, Inc.; vice-chairman is A. Ivan Johnson of A. Ivan Johnson, Inc., and secretary is Joseph D. Ritchey of Keck Consulting Services, Inc.

The new Subcommittee has been charged with the responsibility of developing standards for methods and materials used in the conduct of ground-water and vadose zone monitoring investigations. Sections within the Subcommittee have been formed to address a variety of narrower subject areas, including:

- Surface and Borehole Geophysics, Wayne Saunders, chairman;
- Vadose Zone Monitoring, Lorne Everett, chairman;
- Monitoring Well Drilling and Soil Sampling Practices, Robert Pendergast, chairman;
- Determination of Hydrogeologic Parameters, Darrell Leap, chairman;
- Monitoring Well Design and Construction, Martin Sara, chairman;
- Monitoring Well Maintenance, Rehabilitation and Abandonment, Steven Nacht, chairman;
- Ground-Water Sample Collection, Handling and Field Analysis, Beth Martin, chairperson;
- Design and Analysis of Hydrogeologic Data Systems, Roger Henning, chairman; and
- Special Problems of Monitoring in Karst Terrains, James Quinlan, chairman.

Each of the Section chairpersons has identified standards or guidelines that apply to the subject areas of his/her individual group and identified areas in which the development of new standards or guidelines will be pursued. A summary of this work and a series of topical discussions on controversial issues in the field of ground-water monitoring requiring resolution will be presented at a Workshop on Ground-Water Monitoring Standards Development scheduled for 17-18 Sept. in Minneapolis, MN.

Membership in ASTM Subcommittee D18.21 and attendance at the workshop is open to any person interested in ground-water monitoring. For additional information, write to ASTM Subcommittee D18.21 Chairman David M. Nielsen: 771 Brooksedge Plaza Drive, Westerville, OH 43081.

Future D-18 Committee Meetings and Approved Symposia

- Meeting: 24-28 Jan. 1988
  Albuquerque, NM
  Symposium on Ground-Water and Vadose Zone Monitoring and Sampling (3 days)
- Meeting: 26-30 June 1988
  Baltimore, MD
  D18.10/D04.39 Symposium on Non-Destructive Testing of Pavements (2 days)
- October 1988: Separate Symposium at AEG Meeting
  Kansas City, MO.
  D18.01 w/others: Remote Sensing for Geotechnical Engineering
- Meeting: 22-27 Jan. 1989
  Orlando, FL
  D18.13 Symposium on Geotechnical Aspects of Ocean Waste Disposal (2 days)
- Meeting: 25-29 June 1989
  St. Louis, MO
  D18.06 Symposium on Physico-Chemical Aspects of Soil, Rock and Related Materials
- Meeting: 21-26 Jan. 1990
  Las Vegas, NV

Other Meetings of Interest

- 21-22 Sept. 1987
  ASTM Headquarters, Philadelphia, PA
  1987 ASTM Officer's Conference
- 11-15 Jan. 1988
  Washington, DC
  67th Annual Meeting of TRB
  (Transportation Research Board)
- 22-28 Aug. 1988

Anaheim, CA
International Symposium on Artificial Recharge of Ground Water
- Dec 1988
New Delhi, India
International Symposium on Mining Subsidence (ISSMFE)
- 9-13 Jan. 1989
Washington, DC
68th Annual Meeting of TRB
- 10-19 May 1989
Baltimore, MD
IAHS 3rd Scientific Assembly (Includes International Symposia on (1) Ground Water Contamination and (2) Remote Sensing)

C. A. Hogentogler Award

The C. A. Hogentogler Award is given not more frequently than once a year to the author or authors of a paper of outstanding merit on soil and rock published by the Society. The purposes of the Award are to stimulate research, to encourage the extension of knowledge of soil and rock, and to recognize meritorious effort. The Award, established in 1953, is named in honor of the first Chairman of Committee D-18 on Soil and Rock and is financed through voluntary contributions by Committee D-18 members.

Rules Governing the Award

1. The C. A. Hogentogler Award is administered by an award subcommittee consisting of five members of Committee D-18, the chairman (the First Vice-Chairman of Committee D-18) and the other four members the most recent recipients of the award. If the winning paper is by two or more authors who are members of ASTM Committee D-18, only one will be appointed to the Hogentogler Subcommittee.
2. Papers eligible for the award shall have been accepted by the Society's Standing Committee on Publications for publication by the Society. These papers shall be the bona fide production of those who contribute them and shall not have been previously made public at any other than a Society meeting or in a Society publication.
3. In June of each year, the chairman of the Hogentogler Award Subcommittee solicits recommendations from D-18's Technical Subcommittees for papers eligible for the Hogentogler Award.
4. Between June 30 and Dec. 30 of a given year, the Hogentogler Award Subcommittee reviews the eligible papers, which have been published by the Society in the period from July 1 of the preceding year to June 30 of a given year. Preprints are not considered as publications.
5. The Hogentogler Award Subcommittee forwards nominations to the Chairman of Committee D-18 for approval by the Executive Subcommittee.
6. The Chairman of Committee D-18 notifies the winner or winners of the Hogentogler Award, and the award is made at the discretion of the chairman.
7. The Hogentogler Award consists of a walnut and bronze plaque. In the case of co-authors of an award paper, both authors will receive a plaque.

Obituaries

Rey S. Decker (1913-1987)

With the untimely death of Rey S. Decker, the members of ASTM Committee D-18 have suffered a great loss.

Rey was a native of Fort Lupton, CO. He graduated from Colorado State University in 1936 and began his distinguished career with the Soil Conservation Service in 1938 as a Soil Technologist in CO. Because of his expertise in soil physics and soil chemistry, he was selected to serve as Head of the first soil testing laboratory in Albuquerque, NM in 1943 in association with the Saline Waters Study. Rey established the National Soil Mechanics Laboratory for the Soil Conservation Service (SCS) in Lincoln, NB in 1956 and served as its Head until 1967. He then served as the principal Soil Mechanics Engineer for the SCS and was headquartered in Lincoln until his retirement in 1974. Upon retirement from SCS, he joined the firm of Hoskins-Western-Sonderegger, Inc., Lincoln, NB as a geotechnical consultant until the fall of 1986. Rey was a recognized expert in the design and construction of earth and earth-rock dams and pioneered the identification, testing, and treatment of dispersive clays.

Rey's professional affiliations included the American Society for Testing and Materials (ASTM), the American Society of Civil Engineers (ASCE), The International Society of Soil Mechanics and Foundation Engineers, and the National Society of Professional Engineers. Rey joined ASTM in 1967 and actively participated in the activities of Committee D-18 on Soil and Rock. From 1971 until 1974 he was Chairman of Subcommittee D18.07 on Soil Classification; from 1974 to 1976 he was Secretary of the D-18 Committee. During 1973-1975 he was a member of the D18.97 Subcommittee on Special Awards, and other ASTM activities included work on technical Subcommittees D18.02, 03, 04, 05, 06, and 08. In 1976 Rey was Co-Chairman and Co-Editor of the ASTM Symposium on Dispersive Clays, Related Piping, and Erosion in Geotechnical Projects that produced ASTM's Special Technical Publication (STP) 623. For this symposium he received a Special Services Award from ASTM.

Rey was a consultant on overseas assignments and a guest lecturer at many seminars and conferences. He was the author of several important technical publications, and in 1973 he was awarded ASCE's Wellington Prize for his paper, "Piping in Earth Dams of Dispersive Clays." Another paper, "The Development and Use of the SCS Dispersion Test" won the ASTM Hogentogler Award in 1978.

Thomas Hampton Thornburn (1916-1986)

Tom Thornburn was born 29 June 1916, in Urbana, IL, and graduated from Evanston (Illinois) High School. His B.S. (1938)

from the University of Illinois in Chemistry was with highest honors; his Ph.D. (1941) was from Michigan State in Soil Science. During World War II he was an Army Air Force pilot and flew bomber missions over Sicily, Italy, and the Balkans. In 1945 he joined the staff of the University of Illinois at Urbana-Champaign, becoming Professor Emeritus of Civil Engineering on 1 Sept. 1975.

Professor Thornburn was a fellow of both ASCE and GSA, a member of ASTM, TRB, American Society of Photogrammetry, ASEE, NSPE, and a registered P.E. in Illinois. He joined Committee D-18 in 1961 and was Chairman of Subcommittee D18.07 for ten years (1961-71). In 1964 he chaired an ad hoc committee that recommended the creation of Subcommittee D18.12 on Rock Mechanics, was member-at-large on the Executive Committee from 1968-1976, and helped in preparation of ASTM Practice Description of Frozen Soils (D 4083). Committee D-18 presented him with a Special Service Award in 1977.

Dr. Thornburn's principal research interests were soil engineering for transportation facilities and planning; classification of soils; correlation of engineering properties of soil deposits with pedologic, geologic, airphoto information, and land forms; and the use of county soil reports and maps for engineering purposes. He was co-author with Ralph B. Peck and Walter E. Hanson of one of the most widely used introductory texts in geotechnical engineering, *Foundation Engineering.*

On 3 Aug. 1986, Professor Thornburn died in Las Vegas, NV. He is survived by his wife Mary, four sons, and one grandson.

Correction of Strength for Membrane Effects in the Triaxial Test

by Willard DeGroff,[1] Robert Donaghe,[2] Poul Lade,[3] and Pierre La Rochelle[4]

Dr. Vincent P. Drnevich, Technical Editor of the *Geotechnical Testing Journal* posed a number of questions dealing with membrane corrections in an editorial in the Sept. 1986 (Vol. 9, No. 3) issue of the Journal. There were six responses: Suzanne Lacasse of Norwegian Geotechnical Institute (NGI), John Peters of U.S. Army Engineers, Waterways Experiment Station (WES), Poul Lade of University of California, Los Angeles (UCLA), Fumio Tatsuoka of University of Tokyo, Stein Sture of University of Colorado and Steve Poulos of Geotechnical Engineers, Inc., Winchester, MA.

[1]Brainard-Kilman, 10531 S. Wilcrest, Suite 200, Houston, TX 77099 (Member of GTJ Editorial Board).

[2]U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS 39180 (Chairman of D18.05 on Structural Properties).

[3]Professor, School of Engineering and Applied Science, University of California at Los Angeles, Los Angeles, CA 90024 (Member of the GTJ Editorial Board).

[4]Professor, Faculté des Sciences, Université Laval, Quebec, P.Q. G1K 7P4, Canada.

The authors of this report were selected as a panel, with Willard DeGroff as chairman, by Dr. Drnevich to take the input and prepare this report, which includes the recommendations of the panel. The material submitted was taken and organized in the same order of questions asked in the editorial. In addition to incorporating the opinions expressed in the responses, views of the reporting panel also are included.

In the triaxial test, a flexible membrane (usually latex) encases the soil specimen so confining stress can be applied to the specimen without allowing the confining fluid to penetrate into the soil pore space. The diameter and thickness of the membrane usually are chosen so their effect on measurements of soil properties is insignificant. If, for example, the diameter of the membrane is too small, lateral stresses exerted on the specimen by the membrane may produce specimen disturbance and also affect the magnitude of the confining pressure on the specimen during the test. In the case of membrane thickness, a significant portion of the measured strength of the soil may be caused by the strength of the membrane, which is a function of membrane thickness. In cases where it is impossible to select a membrane that will avoid significant effects on strength measurement, that is, for tests on very soft soils or where suitable membranes are not available, corrections are generally applied to test results for membrane effects. As was pointed out in the editorial, the procedure for placing the membrane around the specimen may result in the application of some axial and lateral confinement to the specimen, which may influence results.

Question 1.: What specification should be placed on the unstretched diameter of a membrane relative to the initial diameter of the specimen?

Commentary: The unstretched diameter of the membrane should be slightly less than that of the specimen when caps and bases have approximately the same diameter as the specimen. This, along with the use of O-rings, aids sealing the membrane to the cap and base. Guidance in ASTM Unconsolidated-Undrained Compressive Strength of Cohesive Soils in Triaxial Compression (D 2850) calls for the unstretched membrane diameter to be between 75 and 90% of that of the specimen. For most soils this specification will meet the requirement that the membrane not apply a radial stress to the specimen exceeding 5% of the expected shear strength.

Responses: Three responses were received for this question: (1) membrane-to-specimen-diameter ratio should be less than 1.02 (no lower limit given); (2) the membranes should have diameters up to about 3% less than that of the specimen; and (3) the relaxed/unloaded diameter of the membrane should not be less than 90% of the diameter of the specimen if the test is to be conducted at a confining pressure less than 35 kPa (5 psi), and that the membrane diameter could be as low as 70% of the specimen for confining pressures of 140 kPa (20 psi) and more.

Recommendation: The panel recommends the specification be changed to require the unstretched membrane diameter be between 90 and 95% of the specimen diameter.

Question 2: What should be the allowed maximum thickness of membrane relative to the diameter of the specimen?

Commentary: The choice of membrane thickness primarily should be a function of the estimated strength of the soil and the permeability of the membrane material relative to the time of testing. However, the choice also may depend on whether the soil contains particles that may puncture the membrane. In considering permeability, it should be remembered that air will pass through a membrane more easily than other fluids and that since most liquids used for chamber fluids contain air, the permeability relative to air should be a major consideration. Problems with air can be avoided if deaired water is used for the chamber fluid and air-water interfaces are eliminated or located at the end of a long length of tubing connecting to the chamber. Guidance given in ASTM D 2850 requires the membrane thickness to not exceed 1% of the diameter of the specimen.

Responses: There are two responses to this question (1) gave criteria based on the magnitude of corrections to shear stress failure and (2) suggested that a lower limiting thickness of about 0.1 mm was necessary because of problems with leakage. Both said they use a thickness of 0.2 to 0.3 mm (0.008 to 0.012 in.) for routine testing.

Recommendation: The panel recommends ASTM D 2850 be changed to limit membrane thickness to 0.5% of the diameter of the specimen. Since the choice of membrane thickness is a function of permeability and testing time, it should be pointed out that membranes used for unconsolidated-undrained triaxial tests may be thinner than those required for longer tests such as the consolidated-undrained triaxial test.

Question 3.: Should common prophylactics be acceptable as membranes for testing 36 to 38- mm (1.4 to 1.5-in.) diameter specimens according to the answers given to Questions 1 and 2?

Recommendation: For specimens of 36 to 38 mm (1.4 to 1.5 in.) diameter, the prophylactic membranes are excellent because of the low to negligible corrections required and low leakage. (In fact, the lowest rate of leakage measured by Leroueil et al. (1986) was obtained with a prophylactic membrane). The prophylactic is the best choice for tests on soft soil and is acceptable for performing unconsolidated-undrained tests according to ASTM D 2850.

Question 4.: For soft cohesive soils, a membrane expander is usually used to assist in placing the membrane over the specimen. What techniques should be written into the procedures to minimize both disturbance and preloading of the specimen?

Commentary: Those of us who test soft soils can remember many cases of speeding up the process of placing membrances over specimens on the verge of slumping so that the support of the membrane (even a thin one having a diameter close to that of the specimen) could arrest the process. Although the problem is important in testing sensitive soils, the point could be made that in routine testing, most soils susceptible to significant disturbance by this problem are probably so disturbed by the time they reach this point, a little more disturbance will not matter.

Responses: There were three responses to this question: (1) radial stress on the specimen just after mounting should not exceed 5% of the expected shear strength; (2) marks placed on the unstretched membrane should be used to ensure no axial strain in the membrane; and (3) the problem is of importance in testing sensitive clays but that there is insufficient information concerning the problem to develop corrections.

Recommendation: Guidance for selecting a membrane and a warning concerning the possibility of disturbing the specimen when placing the membrane over the specimen should suffice.

Question 5.: What corrections to account for membrane effects should be applied, if any, to account for:

(a) diameter differences between specimen and unstretched membrane?

(b) diameter and length changes caused by consolidation (or swell) of the specimen during the saturation and consolidation phases of tests that include these phases?

(c) increased (decreased) lateral confinement caused by lateral strains caused by axial loading (unloading)?

(d) axial load carried by the membrane?

Responses: There were three responses to these questions: (1) derived equations for correcting axial and radial stresses for membrane effects; (2) referred to equations given in Berre's suggested international code for triaxial testing; and (3) there should be corrections for each factor.

Recommendations: The panel's recommendations on corrections for membrane effects are shown in Table 1. La Rochelle expressed his opinion on strength corrections in view of the conditions of the membrane as influenced by the soil behavior. This opinion is presented in Appendix A.

Commentary: The panel has not tackled the problem of corrections for the shear plane failure case, neither did the Editorial raise this question. Hence, it may be considered to be outside the scope of the present survey. However, given the complexity of the phenomenon, a semi empirical approach based on observation and measurement, as proposed by La Rochelle et al. (1986), may be used to obtain membrane and area corrections at large strains in a triaxial specimen failing along a shear plane.

Question 6.: How should the properties of the membrane material be determined?

Responses: There were three responses to this question. (1) Poisson's ratio for rubber be assumed to be 0.5 and use a typical value for Young's modulus for rubber of 1400 kPa (200 psi); (2) there are two ways to determine Young's modulus with the more correct method giving a 37% larger value of 20% strain (in tension) and (3) various latex rubbers have very different moduli even for the same thickness. Results of a study for NASA concerning properties of natural rubber were provided to support this statement.

Recommendations: The panel recommends assuming a Poisson's ratio of 0.5. For Young's modulus, which varies with differ-

TABLE 1—*Equations for membrane corrections.*

Item	Equations	Definitions
Case a: correction for diameter difference between specimen and unstretched membrane	$\Delta\sigma_{r\,corr} = 2E_i \dfrac{d_o - d_m}{d_m d_o}$	
Case b: diameter and length change during saturation and consolidation	$\Delta\sigma_{a\,corr} = -4E_m \dfrac{t_o}{d_i}\left(\epsilon_a + \dfrac{1}{3}\epsilon_v\right)$ $\Delta\sigma_{r\,corr} = \dfrac{-4\,E_m \epsilon_v t_o}{3\,d_i(1-\epsilon)}$ assuming $(1 - \epsilon_v) \approx 1$, $\Delta\sigma_{r\,corr} = \dfrac{-4\,t_o}{3\,d_i} E_m \epsilon_v$	E_i = tangent modulus of material (at 1% strain)
Case c: for unconsolidated-undrained triaxial test	$\Delta\sigma_{a\,corr} = -4E_m \dfrac{t_o}{d_i}\epsilon_a$	d_o = diameter of specimen at time of correction d_m = initial diameter of membrane
consolidated-undrained and consolidated drained triaxial test	$\Delta\sigma_{a\,corr} = \dfrac{-4t_o E_m}{d_i}\left(\epsilon_a + \dfrac{\epsilon_v}{3}\right)$ $\Delta\sigma_{r\,corr} = \dfrac{-4\,E_m t_o}{3\,d_i}\epsilon_v$	E_m = modulus of elasticity at 10% extension ϵ_a = axial strain of the specimen
for all of the above tests in Case c when uniform spaced horizontal wrinkles develop	$\Delta\sigma_{r\,corr} = -2E_m \epsilon_r \dfrac{t_o}{d_o}$	ϵ_v = volumetric strain of the specimen
corrected axial and radial stresses in triaxial test	$\sigma_{a\,corr} = \sigma_a + \Delta\sigma_{a\,corr}$ $\sigma_{r\,corr} = \sigma_r + \Delta\sigma_{r\,corr}$	d_i = initial diameter of specimen t_o = initial thickness of rubber membrane

ent factors (type of rubber, age, alteration, previous uses, and amount of strain), it is recommended that the modulus be measured with the setup proposed by Henkel and Gilbert, which is illustrated in the book by Bishop and Henkel. In the case where it is not possible to make such measurements the value of 1400 kPa (200 psi) can be used.

Commentary: It is La Rochelle's opinion that the modulus of extension or the modulus of elasticity needs to be determined and that the setup proposed by Henkel and Gilbert is found to give satisfactory results and to be quite simple. The main problem is that the modulus varies with strain, being higher at small strain. This variation seems to be more important for thicker membranes. It was found to be appreciably less for prophylactic membranes, or membranes thinner than 0.1 mm. For thicker membranes two moduli should be used: one measured at low strains of 0 to 1% to calculate the initial confining stresses (Eq 4 of La Rochelle et al. 1986), and another value given by the average between 1 and 20% of extension (or the secant modulus at 10% extension) for the corrections to be applied during the compression test.

Question 7.: Do membrane properties change significantly by contact with chamber or pore fluids or both?

Responses: There was only one response to this question: (1) membranes swell with time when submerged in water. Where membrane effects are important, it is suggested that membranes be soaked several days before use and that membrane properties be measured before and after the test.

Commentary: The following statement probably best summarizes the response to this question: This is a case where there is not enough information about the significance of this effect on results to discuss it in a routine procedure.

Question 8.: For high shear strengths, membrane corrections are inconsequential. Below that level of shear strength should membrane corrections be required?

Responses: There were two responses to this question: Response (1) did not make a recommendation for level of shear strength above which no correction is required. Instead a criteria was recommended for the allowable membrane correction for different levels of shear stress at failure. The membrane correction is controlled by selecting the appropriate membrane thickness. The criteria proposed for membrane correction is as shown in Table 2.

Response (2) said it depends on the magnitude of membrane correction and its relationship to the stress strength.

Two responses to the editorial did not supply specific answers to the questions but instead either asked additional questions or made suggestions concerning whether corrections for membrane effects should be made in the triaxial test. (1) asked whether additional corrections should be made for specimens failing along a shear plane or for the case where the membrane wrinkles during the test or when enlarged low-friction caps and bases are used. He stated he thought no one correction can cover all cases encountered in practice. (2) on the other hand felt that it is inappropriate to apply membrane corrections since uncertainty in the shear strength used for stability analysis masks such small test errors. He felt some guidance should be given on how corrections should be made but that the proper perspective relative to the significance of the corrections should be given for the aid of both practicing engineers and researchers.

Recommendations: The membrane correction should be incorporated when it exceeds 10% of the value to which it is applied or an engineer determines that the correction should be applied for the test being performed. Recommended corrections are presented in Table 1.

Summary of Panel Recommendations

- The unstretched membrane diameter should be between 90 and 95% of that of the specimen.
- The membrane thickness should not exceed 0.5% of the diameter of the specimen for unconsolidated-undrained tests.
- Prophylactics are acceptable for performance of tests on specimen of 36 to 38 mm (1.4 to 1.5 in.) diameter.
- The membrane correction should be incorporated when it exceeds 10% of the value to which it is applied or an engineer determines that the correction should be applied for the test being performed. Recommended corrections are presented in Table 1.
- For use in membrane correction equations one can assume Poisson's ratio of 0.5 and a value for Young's Modulus can be determined by the method recommended by Bishop and Henkel (1957).

TABLE 2—*Criteria proposed for membrane correction.*

Maximum Shear Stress at Failure, τ_f		Membrane Correction,
kPa	psi	% of τ_f
12.5	≤2	≤15
12.5 to 25	2 to 4	≤10
>25	>4	<5

Appendix A

Bulging Failure

It should be realized that, although the right cylinder assumption may be close to the actual behavior of the membrane at small strains, the situation is quite different at large strains where bulging is evident. In such cases, the formulae based on experimental data might be preferable as suggested by La Rochelle et al. (1986) and others.

If no buckling occurs (no observable wrinkles), the axial stress must be reduced and even the correction proposed by Duncan and Seed (1967) underestimates the contribution of the membrane; if buckling occurs (with apparent wrinkles), the membrane cannot support axial load and the resulting correction is much smaller. These corrections are discussed in the paper by La Rochelle et al. (1986); the differences in the magnitude of the two corrections "with" and "without buckling" accentuates the need for visual observation during and after the test.

The formulae proposed by Berre (1982) give essentially the same results as those obtained by the solution of Duncan and Seed (1967) but have the merits of being simpler to apply. La Rochelle emphasizes that observations of what happens during the test are essential both for membrane and for area corrections, that is, corrections have to be chosen in the light of the actual behavior.

Shear Plane Failure

In many cases, such as in over consolidated clays and in dense sands, the failure of triaxial specimen occurs along a shear plane. The movement along a shear plane usually appears at the peak strength value or at a slightly larger strain, and quickly mobilizes the strength of the membrane as the soil wedges out of the side of the specimen with increasing strain. As discussed by La Rochelle et al. (1986), the phenomenon by which the membrane is mobilized in such a case in complex and is influenced by many factors such as the relative stiffness of the membrane and of the soil, the contact friction between the membrane and the soil, which depends on the confining effective pressure, the angle of inclination of the plane, and the overall geometry of the shear plane. It should further be emphasized that no two specimens will fail with exactly the same geometry.

Moreover, this type of failure introduces a variation in the cross-sectional area of the specimen, which often results in a correction as significant as, and even more significant than, the membrane correction. It is not always clear whether the cross-sectional area decreases or increases as the movement takes place along the plane combined with some amount of bulging. Measurements on the failed specimen may be required to ascertain this behavior. The method suggested by La Rochelle (1986) may be used to make these.

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