

# INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING



*This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:*

<https://www.issmge.org/publications/online-library>

*This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.*

## GENERAL REPORT ON THE ACTIVITIES OF THE CONFERENCE ON SOIL MECHANICS AND FOUNDATION ENGINEERING

For the information of those interested in the origin of this Conference, its preparatory organization, and the activities during the Conference week, the following report is written. At the same time it will serve as a permanent record of the most important events and of the chronological order of the meetings, which order could not be followed in the presentation of the papers and discussions in this volume. However, this report should not be considered as a complete record of all events that would be worthwhile recounting. It is only the setting, or frame, for a great many interesting happenings and personal contacts which will remain pleasant memories for those who have participated.

### Purpose of the Conference and its Organization

The need for such a Conference originated in the difficulty for engineers, as well as specialists in the field of soil mechanics, to keep abreast of the increasingly rapid developments of scientific methods for the analysis of problems in Earth and Foundation Engineering. The celebration of the three hundredth anniversary of the founding of Harvard University provided a welcome opportunity to suggest to the authorities of Harvard University that such a Conference be included in the program of the Tercentenary Celebration. The response was most gratifying. The University agreed not only to finance this undertaking but also to provide free living quarters and other conveniences for the Members of the Conference.

Considerable thought was given to the organization of the Conference in order that the following primary purposes might be accomplished in the most efficient way:

- (1) To make a survey of investigations in progress in the various Soil Mechanics Laboratories of the world.
- (2) To collect as much information as possible on the recent developments in Earth and Foundation Engineering and to make them available to all interested engineers.
- (3) To compare and coordinate experiences and the results of research.
- (4) To initiate closer cooperation for the purpose of advancing the scientific study of problems in Earth and Foundation Engineering.

No restrictions were placed on the number of contributions, provided they were within the scope of the Conference. However, to make it financially possible that all papers could be included in the Proceedings and that, in order to stimulate discussions, these papers would be available in printed form prior to the Conference, certain restrictions in regard to the length of the papers which could be included in the printed Proceedings had to be adopted. Of the entire number of 160 contributions which were accepted prior to the Conference, only 20 were submitted in such complete form that the entire paper could not be printed. A list of these papers, and the addresses from where they can be borrowed, are contained in the Foreword to Volume II of the Proceedings.

In addition to the discussions which were presented at the Conference, and the written discussions, numerous oral and written comments were received on the contents of the Proceedings. Among these there were many of sufficient general interest to suggest that they be included among the discussions. Requests that such comments be contributed in the form of a written discussion were not always fulfilled. Therefore, the Editorial Board took the liberty of including some of them in the form of brief statements among the discussions, without naming the authors.

The language requirement was admittedly a hardship to many Members. On the other hand the use of a single language made it possible for two volumes of the Proceedings to be printed prior to the Conference; and the fact that only one language was used in the meetings and discussions has apparently been one of the important factors which contributed to the success of the Conference.

All contributions were classified according to subject matter into the following 15 groups:

- A. Reports from Soil Mechanics Laboratories on Testing Apparatus, Technique of Testing and Investigation in Progress.
- B. Exploration of Soil Conditions and Sampling Operations.
- C. Regional Soil Studies for Engineering Purposes.
- D. Soil Properties (with particular attention to shearing resistance and consolidation characteristics).
- E. Stress Distribution in Soils.
- F. Settlement of Structures.
- G. Stability of Earth and Foundation Works and of Natural Slopes (including stability of dams and weirs).
- H. Bearing Capacity of Piles.
- I. Pile Loading Tests.
- J. Earth Pressure against Retaining Walls, Excavation Sheet piling, Tunnel Linings, etc.

- K. Ground Water Movement and Seepage.
- L. Soil Problems in Highway Engineering including Frost Action in Soils.
- M. Methods for Improving the Physical Properties of Soils for Engineering Purposes, including Recent Developments in Constructing and Compacting Earth Fills.
- N. Modern Methods of Design and Construction of Foundations.
- Z. Miscellaneous. (Contributions which could not readily be classified into one of the above divisions; or which for technical reasons could not be included in the respective division.)

Throughout the entire Proceedings the contributions were arranged in accordance with the above grouping. Within each group the contributions are numbered consecutively. This system of classification, together with the general index and the author index, has proven so satisfactory that all papers, and the discussions presented in the meetings of the Conference, were rearranged to follow the same system for this volume. However, since it appears desirable to keep on record the actual progress of the meetings and other events of the Conference, a corrected and supplemented program is included in this report.

#### General Notes on the Membership of the Conference

Prior to the Conference numerous inquiries were received from engineers interested in the aims of the Conference who desired to obtain the Proceedings but found themselves unable to attend in person. In order to embrace as large an interested group as possible, the Committee on Organization created the grade of Absentee Member. Organizations were permitted to join as Absentee Members.

Originally the membership fee was set at \$5.00 which included the Proceedings and free living accommodations and other privileges during the Conference. However, when the Committee on Organization realized that the number of papers submitted would be more than twice the estimated number and hence the printing costs more than doubled, it was decided that the membership fee should be ten dollars for those applying after May 15, 1936. The special rate of four dollars for libraries was also discontinued after that date.

A complete membership list arranged according to countries, is contained in the Appendix of this volume. The total membership consists of 206 Participating Members and of 181 Absentee Members.

#### Record of Meetings and other Events of the Conference

##### Friday Afternoon, June 19.

Members arriving at the Hotel Shelton in New York City were met and welcomed by the members of the New York Reception Committee, composed of distinguished American engineers. Members of the Conference were supplied with maps and printed information concerning outstanding engineering projects and other points of interest in New York and with the program for the official reception, to be held that evening, and for the excursions on the following days.

At 7:00 P.M. the company assembled in a private dining-room on the 64th floor of the R. C. A. Building, Rockefeller Center, where Members and their families were cordially welcomed by the members of the Reception Committee, other invited engineers from New York, and their wives. Cocktails and other refreshments were served and brief remarks of welcome were spoken by Mr. Robert Ridgway, President Karl von Terzaghi, and the Secretary. The company then moved up to the Rainbow Grill, on the 65th floor, where a section had been reserved for the dinner. The hearty welcome of the New York engineers and the excellent dinner created an atmosphere of mutual interest and goodfellowship which prevailed throughout the evening and extended to the meetings of the Conference.

##### Saturday, June 20. Excursion to West Point.

Busses carrying sixty-eight persons, including Members and their hosts and members of families, left the Shelton Hotel at 9:00 A. M. The route followed the famous Westchester County Parkways, passing the Kensico Dam and Croton Lake, crossing the Hudson River over the Bear Mountain Bridge to West Point, The United States Military Academy. After luncheon at the Thayer-West Point Inn, the grounds and various buildings of the Academy were visited. The return trip was made along the west side of the Hudson River to the George Washington Bridge; the bridge structure was inspected, and thence along Riverside Drive to the hotel.

##### Sunday, June 21. Excursion to New Jersey.

In the forenoon one group chartered a bus for a trip through the Holland Tunnel and over the New Jersey Elevated Highway to the Newark Airport. On the return trip a visit was paid to the top of the Rockefeller Tower from which a clear sky permitted a wonderful view of Manhattan and its surroundings. Other groups visited Museums, usually ending in a visit to the top of the Empire State Building or the Rockefeller Tower.

In the afternoon, at 3:00 P.M. the Members and some of their hosts who were planning to attend the Conference, left from Grand Central Station for Boston in a reserved, modern, air-conditioned car.

This ride to Boston was a pleasant interlude from the rather strenuous preceding days and it was only regretted that no arrangements had been made to serve tea. For here was a very friendly group of people, who though strangers two days before, were now attached to each other by many mutual interests.

Monday, June 22. First Meeting.

Forenoon

- 10.00 Opening of the Conference, Main Lecture Room in Pierce Hall, Graduate School of Engineering. Opening Remarks by A. Casagrande, presiding. (p. 11)
- 10.15 Address of Welcome by James Bryant Conant, President of Harvard University. (p. 11)
- 10.45 Address by President Karl von Terzaghi. (p. 13)
- 11.35 Address of Welcome by the Chairman of the American Committee, Vice-President Daniel E. Moran. (p. 18)

Second Meeting.

Afternoon - Ole Singstad, presiding

- 2.00-2.50 Lecture by Carlton S. Proctor (New York) on the Foundations of the San-Francisco-Oakland Bay Bridge. (N-10)
- 2.50-3.10 Opening Discussion by Lazarus White (New York) on Section N: Modern Methods of Design and Construction of Foundations. (N-14)
- 3.10-4.00 General Discussion: Jose A. Cuevas, Lazarus White, Karl v. Terzaghi. (N-15)
- 5.00 Reception by the President of Harvard University, at the President's House, for Members and their families. A delightful garden party which all members thoroughly enjoyed.
- 6.30 Weloome Dinner at the Harvard Union. Professor H. R. Mimno, Acting Dean, presiding. Members and their families were guests of the Faculty of Engineering. Address by Jerome D. Green, Director of the Harvard Tercentenary Celebration.
- 8.30 Visit to the Harvard University Museum (the famous Glass Flowers, the Harvard Forestry Exhibit, and other items of special interest).

Tuesday, June 23. Third Meeting.

Forenoon - Glennon Gilboy, presiding

- 9.00-9.40 Lecture by A. E. Bretting (Denmark) on the Foundations of Modern Bridges in Denmark. (N-11)
- 9.40-10.00 Motion Pictures on Soil Testing Procedures at the U. S. Army Engineers Soil Mechanics Laboratory, at Zanesville, Ohio. Comments by T. T. Knappen and R. R. Philippe. (U.S.A.)
- 10.00-10.20 Opening Discussions by D. W. Taylor (Cambridge, Mass.) on Section C: Regional Soil Studies for Engineering Purposes, and Section D: Soil Properties. (D-15)
- 10.20-12.00 General Discussion: H. F. Winterkorn, (D-16), D. M. Burmister (D-17), W. P. Kimball (D-18), G. Tschebotareff (D-19), P. Raes (N-16), C. A. Hogentogler (D-20), L. White (D-32), G. E. Ekblaw (D-21), L. F. Cooling (D-22).

Fourth Meeting

Afternoon - A. E. Cummings, presiding

- 2.00-2.40 Lecture by Jose A. Cuevas (Mexico) on Foundation Conditions in Mexico City. (N-17)
- 2.40-3.20 Lecture by W. S. Hanna and G. Tschebotareff (Egypt) on Settlement Observations in Cairo, Egypt. (F-1, Vol. I)
- 3.20-3.50 Opening Discussion by Karl von Terzaghi (Austria) on Section F: Settlement of Structures. (F-16)

3.50-5.00 General Discussion: D. M. Burmister (F-17), R. Tillman (F-18), W. Loos (F-20), K. v. Terzaghi (Z-22).

8.15 Pop Symphony Concert, Boston Symphony Hall. Members and their families were guests of Harvard University.

Wednesday, June 24. Fifth Meeting.

Forenoon - R. E. Bakenhus, presiding

9.00-9.50 Lecture by Prof. A. Agatz (Germany) on Experiences in the Construction of Harbor Works in Bremen and Bremerhaven. (N-12)

9.50-10.20 Opening Discussions by F. Kogler (Germany) on Section E: Stress Distribution in Soils (E-12); and by J. S. Crandall (Cambridge, Mass.) on Sections H and I: Bearing Capacity of Piles and Pile Loading Tests (H-7).

10.30-12.00 General Discussion: J. G. Mason (H-8), R. Pietkowski (H-9), R. D. Mindlin (E-13), D. M. Burmister (E-14), D. P. Krynine (E-15), L. White (H-10), P. Raes, (H-11), G. Tsohebotareff (H-12), C. S. Proctor (H-13), K. Hauge (H-14), B. K. Hough (E-16), A. E. Cummings (H-11).

Sixth Meeting.

Afternoon - F. A. Marston, presiding

2.00-2.40 Lecture by G. Rodio (Italy) on the Foundation of the Building "La Basilese Vita" in Lugano, a Description of Modern Methods of Deep Foundation Construction. (N-13)

2.40-3.10 Lecture by W. Loos (Germany) on Comparative Studies of the Effectiveness of Different Methods for Compacting Cohesionless Soils. (M-5)

3.10-3.40 Motion Pictures on Modern Methods of Earth Dam Construction, with explanatory comments by T. T. Knappen and R. R. Philippe (Zanesville, Ohio).

3.40-3.50 Opening Discussions by H. A. Mohr (Cambridge, Mass.), on Section B: Exploration of Soil Conditions and Sampling Operations (B-9); and by Karl von Terzaghi (Austria) on Section M: Methods for Improving the Physical Properties of Soils for Engineering Purposes (M-6).

4.00-5.00 General Discussion: Daniel E. Moran (read by W. P. Kimball) (B-10), E. W. Vaughan (B-15), W. S. Housel (F-24), E. F. Bennett (B-11), H. E. Russell (B-13), D. M. Burmister (B-12), S. J. Buchanan (B-14), C. S. Proctor (Proposal for continuation of the work of the Conference see p. 5 ).

6.30 Committee on Bearing Value of Pile Foundations of the American Society of Civil Engineers. Dinner Meeting. (H-18)

8.00-10.30 For Members and their families: Group visits to the Soil Mechanics Laboratories of the Massachusetts Institute of Technology and of Harvard University, with demonstrations.

Thursday, June 25. Seventh Meeting.

Forenoon - L. F. Harza, presiding

9.00-9.40 Lecture by K. R. Kennison and S. M. Dore (Boston, Mass.) on the Quabbin Project of the Metropolitan District Water Supply Commission, with special emphasis on those features which were to be inspected by the members on the following day.

10.00-10.20 Motion Pictures on the Construction of the Largest Hydraulic Fill Dam in the World, at Fort Peck, Montana, with explanatory comments by G. A. Hathaway and T. A. Middlebrooks.

10.20-11.00 Opening Discussions by J. D. Justin (Philadelphia) on Section K: Ground Water Movement and seepage (K-5); and by F. A. Marston and Glennon Gilboy (Cambridge, Mass.) on Section G: Stability of Earth and Foundation Works and of Natural Slopes. (G-10 & 11)

11.00-12.00 General Discussion: D. W. Taylor (G-16), O. Stevens (K-9), J. Ehrenberg (G-14), T. T. Knappen (G-12), W. P. Craeger (K-6), T. A. Middlebrooks (G-15), D. M. Burmister (K-7).

### Eighth Meeting

Afternoon - John R. Nichols, presiding

- 2.00-2.40 Lecture by G. Beskow (Sweden) on Frost Action in Soils and Its Relation to Highway Engineering. (L-13)
- 2.40-3.20 Motion Pictures on Irrigation in Mexico, with explanatory comments by F. Gomez-Perez.
- 3.20-3.50 Opening Discussions by A. Casagrande on Section J: Earth Pressure, (J-7); and by C. A. Hogentogler on Section L: Problems in Highway Engineering, (L-9).
- 3.50-5.00 General Discussion: K. v. Terzaghi (J-8), H. F. Winterkorn (L-10), R. D. Mindlin (J-9), E. F. Bennett (L-11), J. E. B. Jennings (J-10), D. M. Burmister (G-13), R. Tillmann (F-19), W. P. Kimball (F-22).
- 5.00-6.00 Special Meeting and Report of the Resolution Committee - C. R. Young, presiding. (see pp. 6-7)
- 8.00-10.30 For Members and their families: Group visits to the Soil Mechanics Laboratories of the Massachusetts Institute of Technology and of Harvard University, with demonstrations.

### Friday, June 26. Excursion to the Quabbin Project of the Metropolitan District Water Supply Commission.

This trip was arranged as a joint excursion with the Boston Society of Civil Engineers. Over one hundred Members of the Conference enjoyed the excursion which was favored by pleasant weather conditions. While all construction details and the finished parts of the project were very interesting, particular attention was paid by the Members to the modern methods of earth transportation, the construction of rolled embankments, and all the details of the hydraulic sluicing process which is used for the construction of the major portion of the dams. (see Papers No. Z-14 and Z-15)

### 6.30 P.M. Farewell Dinner in the Banquet Hall of the historic Longfellow's Wayside Inn at Sudbury, Mass.

Other Members of the Conference and the Ladies had arrived at the Inn during the afternoon and visited the antiques which Henry Ford has collected to preserve the character of early American culture. In spite of the fact that Henry Ford does not permit alcoholic beverages in the Wayside Inn (which was not learned until all arrangements for the farewell dinner were complete) there prevailed a gay spirit throughout the evening. Frank E. Winsor presided during the after dinner addresses by F. E. Schmitt (p. 19), A. Agatz (p. 21), and K. v. Terzaghi (p. 22). When the President of the Conference ended his address wishing "many happy returns to the Conference", enthusiastic applause reflected the thoughts of all present.

### Saturday, June 27.

Joint Meeting of the Committee on Foundations and Soil Mechanics of the Society for the Promotion of Engineering Education, and of the Committee on Standardization of Symbols and Conventions. (see report on p. 258).

### Sunday, June 28 to Tuesday, June 30.

A group of twelve Members, mostly from European countries, visited projects of the New Hampshire State Highway Department. The visitors were particularly impressed by the excellent riding qualities and the durability of the tar-surface treated gravel roads which represent a large percentage of the state highways. The construction of such roads was inspected in all its details. During this excursion the visitors had ample opportunity to admire the scenic beauty of the White Mountains.

### Suggestions for the Continuation of the Work of the Conference and Report by the Committee on Resolutions

At numerous informal occasions during the Conference one heard the desire expressed that the valuable work of the Conference and the splendid spirit of cooperation of its Members should be continued in form of an International Organization and that plans be made for a second Conference to meet a few years hence.

The following proposal regarding the continuation of the work of the Conference was presented by Mr. Carlton S. Proctor (New York) at the end of the sixth meeting, on June 24:

"It seems to me that this is the time to give some thought to the continuance of this International Conference. This grows out of a good deal of discussion which was had today at noon, by various members of the Conference, and rather than bring the idea up at the last moment when hasty action might be necessary, it seemed to a number of us that it would be wiser to start the ball rolling at this time to permit the opportunity for mature consideration and judgment.

I personally feel that this International Conference marks a milestone in the history of engineering, that the papers that have been presented here, the cooperative spirit, the attitude of engineer and research expert in giving to the engineering world such data and statistics as they have available, and in contributing toward the development of this new science, is such that we certainly must continue

this effort. A great opportunity will be lost if the Conference is not continued.

It seems to me that there are various suggestions that might be put into action. One is that the President appoint a committee to consider the whole matter of the continuation of the Conference. Another suggestion was that a permanent international society be formed. In any event, there seems to be a unanimity of opinion that some such international conference of this kind should be held again within a period not exceeding two years, and that a great deal of additional data will be available within that time. The thought is that we are accumulating data and accumulating records more rapidly and more accurately than ever before, and that with the accumulation of such data a permanent organization might be set in motion which would make available to the members of the Conference such papers and reports as are received, in the form, say, of one of these volumes of Proceedings, issued about once a year.

It has been thought that because of the very excellent work being done, and because of the central location, a conference of this kind might be held within a period of not exceeding two years in Holland, if Holland desires to invite the Conference. That is certainly an ideal location and there is certainly a great deal of excellent work being done there, as evidenced by the splendid papers presented here from Holland.

In any event, Mr. President, I would like to move at this time that consideration be given to the continuance of the Conference, and that you appoint a committee to consider this matter and report to the Conference, between now and the close of the Conference, and that thereafter by action of this group, the Conference be continued on a basis either as an international society or as an informal group. I would suggest that representative Chairmen of the various countries be appointed to the Committee and to discuss the matter with other members of the Conference and report before we adjourn. I so move."

The enthusiastic response to these remarks by Mr. Proctor led to the organization of a Committee on Resolutions under the chairmanship of Admiral R. E. Bakenhus. In this Committee were represented the National Committees of most of the countries which participated in the Conference. At the close of the last meeting, on June 25, a business meeting was called to order under the chairmanship of Professor C. R. Young in which Admiral R. E. Bakenhus read the following three resolutions which the Committee on Resolutions had prepared:

#### Resolution No. 1

Whereas the International Conference on Soil Mechanics and Foundation Engineering came into being and conducted its sessions as a result of the initiative and generosity of Harvard University as a part of its Tercentenary Celebration, and

Whereas the members of the Conference received unusual courtesies at the hands of Harvard University and enjoyed its hospitality, and

Whereas the facilities of Harvard University were made available to the sessions of the Conference, and the Conference now having demonstrated its value as an important forward step in the progress of Engineering

Be it resolved by the Conference assembled in meeting this 25th day of June 1936 that the Conference express its thanks and deepest appreciation to Harvard University and that the Secretary be authorized and directed to send a copy hereof duly signed by the President of the Conference and attested by the Secretary, to President Conant of Harvard University.

#### Resolution No. 2

Having in view the unqualified success of the International Conference on Soil Mechanics and Foundation Engineering, culminating in the meetings at Harvard University June 22 to June 26, 1936, as the first Conference of the Tercentenary Celebration of Harvard University, and, having further in view, the unusual initiative and labor upon which the preliminary organization and conduct of the Conference in session were dependent, be it resolved:

That the thanks of this Conference in meeting assembled this 25th day of June 1936 be extended

To: The Committee on Organization of which Dean Harry E. Clifford of the Graduate School of Engineering of Harvard University was Chairman and without whose support and guidance the Conference could not have been held.

To: The President of this Conference, Dr. Karl von Terzaghi, professor at Technische Hochschule in Vienna and visiting professor at Harvard University, in recognition of his wisdom and guidance of the affairs of the Conference, and particularly as he has given freely to the Conference and to the profession from his wide knowledge and experience such that he has been instrumental in the founding of the new science of Soil Mechanics.

To: Dr. Arthur Casagrande, Assistant Professor in the Graduate School of Engineering of Harvard University, Secretary of the Conference, in recognition of his leadership and initiative, of the herculean task performed in the preparation for and in the conduct of the meetings, of the editing of the technical papers for publication, of the management of the business and routine affairs of the Conference, and further through him to his able assistants, Mr. Philip C. Rutledge, Instructor in the Graduate School of Engineering of Harvard University, Treasurer of the Conference, and to Mr. John D. Watson, Research Assistant in the Graduate School of Engineering of Harvard University, who have loyally supported him in the heavy labors, and be it further resolved:

That copies of this resolution be forwarded by the Chairman of the Resolutions Committee through the President of Harvard University to

Dean Harry E. Clifford  
Dr. Karl von Terzaghi  
Dr. Arthur Casagrande  
Mr. Philip C. Rutledge  
Mr. John D. Watson

---

Resolution No. 3

In order that the International Conference on Soil Mechanics and Foundation Engineering may continue as a permanent organization, be it resolved

- a) That Dr. Karl von Terzaghi continue in office as President of the permanent organization;
- b) That Dr. Arthur Casagrande continue in office as Secretary and also fill the office of Vice-President;
- c) That all who are members of the present Conference be entitled to membership in the permanent organization; that additional members be admitted under requirements established by the International Committee;
- d) That the President take steps for the formation of an International Committee. Such a Committee would be elected by National Committees where such Committees exist, and where no such Committees exist, the President would appoint provisional members, and such members would be urged to take appropriate steps within their own countries to organize local National Committees in cooperation with existing societies or organizations, or otherwise to advise the President what steps, if any, are suggested for him to take to encourage the formation of such National Committees.
- e) That the President appoint an Executive Committee of which the President and the Secretary shall be members, consisting of a total membership of five, and whose headquarters shall, for the time being, be in Boston (Cambridge) Mass., or New York, N. Y., and that the Executive Committee shall be responsible for the conduct of the business of the Conference until a Constitution is adopted or the Conference shall direct otherwise.
- f) That the second meeting of the International Conference on Soil Mechanics and Foundation Engineering be called to meet at a time and place to be selected by the President with the advice of the International Committee.
- g) That each member pay annual dues to be fixed by the International Committee. That provision be made for membership in the Conference of organized bodies with dues as fixed by the International Committee.
- h) That the President be authorized to accept contributions for the support of the Conference in addition to dues of members.
- i) That the Secretary have custody of the funds of the Conference, to be expended for the purposes of the Conference as authorized by the President or by the Executive Committee until a permanent Constitution may provide otherwise.
- j) That at the next meeting of the International Conference the International Committee, or a sub-committee thereof as the President may appoint, present for the consideration of the Conference a Constitution and By-laws for the permanent organization and government of the Conference.
- k) That conflicting clauses and cases not covered by the foregoing clauses be left to the initiative of the Executive Committee with the approval of the International Committee for decision.

---

Resolutions No. 1 and 2 were adopted with hearty applause. Some discussion developed regarding Resolution No. 3. It was suggested that the activities of the American Society of Civil Engineers in the field of Soil Mechanics would make the existence of an independent National Committee unnecessary. Finally, Resolution No. 3 was voted upon, and with only one opposing vote, it was adopted.

In Resolution No. 3 are contained all essential elements to insure the continuation of the work of the Conference. At present, the principal efforts are directed toward the organization of the International Committee which, in cooperation with the Executive Committee and the National Committees, shall have the duty to organize future Conferences, to assist in the organization of new National Committees, and to expand and coordinate all activities into an International Society at such future time as may become advisable to do so.

It is proposed that each country shall be represented on the International Committee by not more than three members who shall be nominated by the respective National Committee and where no such Committee exists, three provisional members shall be appointed by existing engineering societies or organizations. It is further proposed that the Executive Committee with the approval of the International Committee, shall have the right to nominate one additional member without consulting the respective National Committee.

The members of the International Committee shall communicate by correspondence, and decisions and other matters of general importance will be made available through the National Committees to all persons interested in the activities of the International Organization.

### Acknowledgement

The writer wishes to fulfill his pleasant duty of thanking all who participated in the Conference. Its splendid success was due primarily to the intense interest and hearty cooperation of all Members of the Conference.

To President James B. Conant of Harvard University, to Dean H. E. Clifford of the Harvard Graduate School of Engineering and Mr. Jerome D. Green, Director of the Harvard Tercentenary Celebration, are due the sincere thanks of the civil engineering profession for fulfilling an urgent and important service by opening the doors of Harvard University to this Conference and for making this undertaking financially possible.

The success of the Conference is in a large measure due to the invaluable work of its President, Professor Terzaghi, who has not only contributed to the Proceedings the most outstanding papers on Soil Mechanics which have appeared for many years, but who has aided also in the organization of the Conference and actively assisted the Editorial Board in its difficult task. During the meetings of the Conference Professor Terzaghi succeeded brilliantly in stimulating interest in the discussions. His own discussions, contained in this volume, will be an unfailing guide for those students of soil mechanics who find themselves bewildered by the quantity of material and the differences of opinion contained in the many papers.

The thanks of the Committee on Organization are extended to the New York sections of the American Society of Civil Engineers and of the Harvard Engineering Society, who were the hosts at a delightful reception and dinner and interesting and instructive excursions prior to the Conference for those members, particularly from foreign countries, who arrived first in New York. In particular Mr. Robert Ridgway (New York), Chairman of the Reception Committee, and Mr. Thomas Crimmins (New York) deserve high praise for their thorough planning of these events.

Through the kind cooperation of Mr. Frank E. Winsor, Chief Engineer of the Metropolitan District Water Supply Commission of Greater Boston, and of his Associates, the interesting and appropriate excursion to the Quabbin project of the Commission was made possible.

Mr. F. E. Everett, Highway Commissioner of the State of New Hampshire, and his engineers, L. F. Johnson and J. O. Morton, provided the opportunity for a pleasant and an instructive inspection trip through that State.

The following members of the Faculty of the Harvard Graduate School of Engineering, C. H. Berry, F. R. Ellis, G. M. Fair, A. Haertlein and R. P. Siskind, have rendered valuable assistance in the organization and technical arrangements for the Conference.

And last but not least the writer wishes to express his gratitude to his immediate associates, P. C. Rutledge and J. D. Watson, who have worked tirelessly on the innumerable tasks and the large amount of routine work which preceded the Conference. Particularly the preparation of the Proceedings and their successful completion in so short a time would not have been possible without their admirable devotion to the cause and their intelligent planning.

The Proceedings were printed by the Spaulding Moss Co. of Boston, using the Planograph process. Considering the unusually short time which was available for the printing of the first two volumes, their appearance has been very satisfactory to the Editorial Board.

Cambridge, Mass.  
October 1, 1936

Arthur Casagrande  
Secretary to the Conference

### TREASURER'S REPORT

#### Summary of Expenses of the Conference.

Publication of Proceedings of the Conference in three volumes, totaling 992 pages	\$5044.62
Publicity prior to the Conference	\$ 536.40
Meetings and Entertainments during Conference	\$1447.75
	Total cost of the Conference \$7028.77

Note: This total cost does not include stenographic service under the item "Publicity" above, furnished by the Graduate School of Engineering, Harvard University; living accommodations and service provided for approximately 230 persons (Members and families) by Harvard University through the Tercentenary Celebration Office; the reception tendered to the Members and their families by the President of Harvard University; the reception and dinner in New York at which the New York sections of the American Society of Civil Engineers and the Harvard Engineering Society were hosts.

Income of the Conference.

From 206 Participating Members, 181 Absentee Members and the sale of the remaining sets of Proceedings to make a total of five hundred sets.

Cash Received as of November 20, 1936	\$3122.15
Accounts Payable as of November 20, 1936	\$ 74.00
	<hr/>
Total Receipts	\$3196.15

Note: Registration fees in the Conference, including the Proceedings, were \$5.00 from Dec. 2, 1935 to May 15, 1936, with a special rate of \$4.00 to engineering libraries. After May 15, 1936 the rate for registration in the Conference or purchase of the Proceedings was \$10.00. All Absentee Members have been assessed a shipping charge of \$1.00 per set of three volumes.

Net Deficit	\$3832.62
-------------	-----------

This deficit has been met by Harvard University, the host to the Conference.

Itemized Expenses of the Conference.Proceedings

Volume I	Stenographic Salaries	\$ 372.13
	Editorial Salaries	122.00
	Office Equipment Rental and Supplies	89.46
	Printing, Binding, Etc.	1082.57
	Shipping Costs	100.11
		<hr/>
	Total Volume I	\$1766.27
Volume II	Stenographic Salaries	\$ 312.65
	Editorial Salaries	92.00
	Office Equipment Rental and Supplies	64.50
	Reprints included in Volume II	20.39
	Printing, Binding, etc.	1133.71
	Shipping Costs	99.60
		<hr/>
	Total Volume II	\$1722.85
Volume III	Stenographic Salaries	\$ 229.60
	Editorial Salaries	150.00
	Office Equipment Rental and Supplies	52.40
	Printing List of Members for Volume III	29.50
	Estimated Printing, Binding, etc.	946.00
	Estimated Shipping Costs	148.00
		<hr/>
	Total Volume III	\$1555.50
Totals for Volumes I, II, and III		
	Stenographic and Editorial Salaries	\$1278.38
	Office Equipment Rental and Supplies	206.36
	Reprints and Misc. Printing	49.89
	Printing, Binding, etc.	3162.28
	Shipping Costs	347.71
		<hr/>
	Total Volumes I, II, and III	\$5044.62

Note: For five hundred sets of Proceedings this is equal to a cost of \$10.09 per set of three volumes.

Publicity Prior to the Conference.

Printing Announcements, Stationary, etc.	\$ 310.78
Mailing Publicity Items	75.55
Office Equipment and Supplies	49.50
Miscellaneous Expenses	100.57
	<hr/>
Total	\$ 536.40

Note: All stenographic service under this account was furnished by the Graduate School of Engineering, Harvard University.

Meetings and Entertainments during the Conference.

Preparation of Buildings and Exhibits	\$ 259.23
Printing Programs and Lists of Members	121.75
Badges for Members	27.00
New York Excursions Saturday and Sunday, June 20 and 21	243.98
Note: All expenses of the reception and dinner in New York on the evening of Friday, June 19, were paid by the New York sections of the American Society of Civil Engineers and the Harvard Engineering Society.	
Welcome Dinner, Monday, June 22	253.75
Pop Symphony Concert, Tuesday, June 23, including bus transportation to and from Symphony Hall	275.50
Stenographic Report of the Conference Meetings	134.04
Projection of Slides and Moving Pictures	21.50
Excursion and Farewell Dinner, Friday, June 26	
Receipts from sale of tickets	\$489.00
Expenses: Bus transportation	\$295.50
Lunohes	69.00
Dinners	220.50
Total	\$585.00
Net Deficit for Excursion and Dinner	96.00
Deficit on Excursions for Ladies	15.00
	<hr/>
Total	\$1447.75

Cambridge, Mass.  
November 20, 1936

Philip C. Rutledge  
Treasurer to the Conference

## ADDRESSES

### OPENING REMARKS

Arthur Casagrande, Secretary to the Conference

In the absence of the Chairman of the Committee on Organization, Dean Clifford, I have the honor to open the first International Conference on Soil Mechanics and Foundation Engineering. On behalf of those who have conceived and planned this Conference, I extend to you our most cordial welcome.

The unusual significance of this day in the development of the oldest of engineering fields will be shown later by Professor Terzaghi, the President of this Conference, in his opening address.

In these introductory remarks, I should like to point out that the organization of this Conference was an adventure, or an equation with many unknowns. Those relatively few among the members who are engaged in soil mechanics research have never doubted the urgent need for such a Conference. However, it was evident that its success would depend essentially on the participation of engineers actively engaged in foundation and earth work engineering. The biggest doubt in our minds was the number of practicing engineers who would be interested in attending.

Today, in the presence of this distinguished membership, which exceeds in every respect our boldest expectations, I feel almost ashamed of my original lack of confidence. It is indeed a most encouraging sign of the appreciation of the importance of this field and of the necessity of its advancement that we have with us as members of the Conference a group of executive engineers who apparently feel that it is not sufficient to leave decisions in this difficult field entirely to their subordinate engineers, and therefore have come here to inform themselves of the viewpoints of the specialist in Soil Mechanics and Foundation Engineering.

With the opening of the Conference, the Committee on Organization has fulfilled its function and the Conference becomes, so to speak, the property of its members. I carry out this transfer from the Committee on Organization to the members with the hope that these meetings are only the beginning of an organization which will continue to function in some form or other during future years.

In its essential features, this Conference may already be called successful. I need only to refer to the cooperation of the contributors to the Conference and to the resulting first two volumes of the Proceedings which contain the fruits of their labors. These volumes contain a greater wealth of the most advanced knowledge in the fields of Soil Mechanics and Foundation Engineering than can be found in any engineering library. If we succeed in evaluating these contributions and in bringing out the supplementary information in the discussions, which we all so much desire, then we must say that this Conference has fulfilled its function well.

In closing I wish to express on behalf of the Committee on Organization, our thanks to the members of this Conference for their splendid cooperation in its organization, and I wish particularly to thank President Conant of Harvard University for making it possible for the Conference to meet here. The elaborate arrangements which you, Mr. President, have provided to make the members feel at home in this, the oldest and most renowned University in the United States, are gratefully accepted. In addition, I wish to express my personal thanks for all that the University has done during the past four years to promote the advancement of Soil Mechanics.

It gives me the most sincere pleasure to present the President of Harvard University: Dr. James Bryant Conant.

### ADDRESS OF WELCOME

James B. Conant, President of Harvard University

Editorial Note: In his address President Conant welcomed the members of the Conference most cordially, expressing his hope that these meetings might be very successful and that the members might enjoy their visit to Harvard University. He went on further to review in brief the history and development of Harvard University during the three hundred years since its founding. His presentation is summarized in the following sketch.

Foundation and Government. Harvard College was founded by a vote of the General Court of the Colony of Massachusetts Bay on October 28, 1636.

On November 15, 1637, the College was "ordered to bee at Newetowne," and five days later the General Court appointed the first Board of Overseers, consisting of Governor Winthrop, Deputy-Governor Dudley, four other magistrates and six ministers "to take order for a colledge at Newetowne". At some time before the end of the year the Overseers acquired an acre and an eighth of land, the nucleus of the College Yard, together with a dwelling house in which the College was opened during the summer of 1638. On May 2, 1638, the name of Newtown was changed to Cambridge, in recognition of the English university at which most of the Overseers, and many other leading colonists, had been educated.

On September 14, 1638, John Harvard, a puritan minister and Master of Arts of Emmanuel College, Cambridge, died at Charlestown in his thirty-first year. Half his estate and his library of over four hundred volumes were left to the College. Consequently the General Court, on March 13, 1639, voted "that the colledge agreed upon formerly to bee built at Cambridg shalbee called Harvard Colledge".

Under Henry Dunster, a Cambridge graduate, who was appointed President in August, 1640, the College began to flourish. A course of study was established in the liberal arts similar to the course for the baccalaureate in the English universities. A new building was erected, and the first class graduated in 1642. The degree of Bachelor of Arts was conferred after four years' study; the Master's degree after three years' post-graduate study, either in the College or elsewhere.

In order to give the College a corporate character and a less cumbrous government, President Dunster, who served from 1640 to 1654, petitioned the General Court for a charter. The original document, signed by Governor Dudley on May 31, 1650, is preserved in the University Archives. The President and Fellows of Harvard College - consisting of the President, the Treasurer and five Fellows, and commonly called the Corporation - were given perpetual succession by this Charter.

The Growth of the University. Although the sum of £ 779 17s 2d bequeathed in 1638 by John Harvard was spent rather than invested, by 1700 the gifts and income-bearing funds of Harvard University exceeded its revenue from the State. In 1833 Harvard received its last grant from any public body, and today is supported entirely by gifts and by invested funds totalling (June 30, 1935) over \$128,000,000.

In keeping with this physical growth, Harvard University has enlarged its aims. The College was founded to provide a liberal education for ambitious young men growing up in the New World, as well as to train a learned ministry. The election of John Leverett as President in 1707 - the first President who was not a clergyman - was a triumph for liberalism, and a step in the direction of intellectual independence which Harvard has followed ever since. Before 1736 Harvard had sent forth 1,248 graduates to Massachusetts Bay, other colonies and the mother country.

In its second century, 1736-1836, a period during which American culture began to assume a definite character, Harvard acquired the name "University" and established separate schools of medicine, law and divinity. The presidency of John Thornton Kirkland (1810-1828) is often called "The Augustan Age of Harvard," and in 1820 twenty-seven per cent of the entering Freshmen were from outside New England.

In the third century of its existence, Harvard University gathered momentum in scholarship and further widened its intellectual horizon. Teachers such as Henry Wadsworth Longfellow, James Russell Lowell and Louis Agassiz brought from Europe a fresh outlook which contributed to the growing idea of liberal education in America. During this period Presidents Josiah Quincy, Edward Everett, Jared Sparks, James Walker and Cornelius Conway Felton presided over the institution. President Thomas Hill (1862-1868) saw that the function of a university was to add to knowledge as well as to disseminate it. President Charles William Eliot (1869-1909), recognizing a growing demand of the community, brought to full flower the intellectual tendencies which had been gradually developing. He expanded elective courses (which had begun in 1825) into a system embracing a wide range of subjects and at the same time developed the nationwide service of the University. President Abbott Lawrence Lowell (1909-1933) continued this widening and deepening of studies through modification of the elective system, the introduction of the Tutorial System, the establishment of the Freshman dormitories and the inauguration of the House Plan; and stood firmly even in times of great stress for a free and vigorous intellectual atmosphere.

RELATION BETWEEN SOIL MECHANICS AND FOUNDATION ENGINEERING  
 Presidential Address  
 Karl von Terzaghi  
 Professor at the Technische Hochschule in Vienna, Austria

The opening of this Conference is an event of unusual significance. It represents the first international council in the perpetual war of the civil engineer against the treacherous forces of nature concealed in the earth. Due to scattered and world-wide efforts extending over a period of 25 years, new and efficient weapons have been forged and the prime purpose of our meeting consists in discussing the means of exploiting the advantages thus secured. For the sake of brevity these recent developments have been given the name of soil mechanics. The transition from the classical theories of the pre-war generation to soil mechanics is synonymous with a transition from a purely abstract treatment of the problems of soil behavior to one based on an intimate knowledge of the manifold and complex properties of the different types of earth. The validity of the older theories of earth pressure and earth resistance was limited to ideal materials whose properties can be described in five lines. However, in order to describe the practically important properties of earth such as nature has produced, one needs a good-sized book. As a consequence, the older theories failed in a great number of cases of outstanding practical importance. This, in a nutshell, was the reason for the necessity of a radical departure from past practice.

Our meeting coincides in time and space with the Tercentenary Celebration of the oldest and most eminent institution of higher learning in the United States. Owing to the hospitality of Harvard University, represented by its president, Dr. Conant, the retrospect over the glorious and scholarly past of this University combines with the official inauguration of a new and important field of applied science.

Origin of Soil Mechanics. Ten years ago the investigations which led to this Conference still had the character of a professional adventure with rather uncertain prospects for success. This adventure began a short time before the war, simultaneously in the U.S.A., in Sweden, and in Germany. It was forced upon us by the rapid widening of the gap between the requirements of canal and foundation design and our inadequate mental grasp of the essentials involved.

In the United States, the catastrophic descent of the slopes of the deepest cut on the Panama Canal issued a warning that we were overstepping the limits of our ability to predict the consequences of our actions. The columns on dam-failures in the engineering magazines never ceased to maintain a feeling of uneasiness among those engaged in harnessing the rivers of the country, and the visible effects of the settlement of heavy public buildings founded on materials other than bed rock demonstrated also to the layman the existence of alarming gaps in our knowledge of so-called *terra firma*. To close these gaps, the American Society of Civil Engineers in 1913 appointed a Committee to investigate the situation. The outstanding achievement of this Committee, with Mr. R. A. Cummings as chairman, consisted in a realization of the importance of expressing the properties of soils by numerical values. We cannot possibly utilize our practical experience to full advantage, unless the soils to which our experience refers can be recognized unmistakably in other localities. However, the final answer to this problem of identification still remains to be found, although the progress in this direction is very encouraging.

In Sweden intensified activities in soil research were induced by a series of unexpected and catastrophic slides in the cuts of the Swedish State Railways, which took a heavy toll of lives and of capital. In order to eliminate the danger of the recurrence of similar events, the Swedish State Railways appointed in 1913 a Geotechnical Commission to investigate the degree of safety of the slopes along the existing lines. During the ten years of its existence the Commission, headed by Prof. Fellenius in Stockholm, developed some of the most important fundamental principles for our present methods of stability computations.

In Germany the construction of the Kiel Canal between the North and the Baltic Seas brought more than one surprise to the engineers who built it. Prominent among the accidents was the energetic outward movement of a heavy quay wall, solidly supported by a forest of wooden piles. The piles were strong enough to support the wall, but the clay was not strong enough to support the piles. Therefore the wall and the piles moved out as a unit. The rapid growth of German harbors brought additional variety into the stately collection of unsolved problems. Hence it was more than a mere accident that the research was started in the hydraulic laboratories of that country. The director of the Prussian hydraulic laboratories in Berlin, Mr. Krey, improved the existing methods for the computation of the pressure and the resistance of the earth in connection with retaining walls and bulkheads. He succeeded in developing a rational procedure for computing the forces which act on bulkheads, and furnished important contributions to our knowledge of the shearing resistance of soils.

I myself, prior to 1912, worked as a superintendent of construction. Year after year, in the Austrian Alps, in Transsylvania, and in Russia, I had ample opportunity to witness the striking contrast between what we expected when digging into the earth or loading it, and what really happened. Deeply impressed by the fundamental futility of pertinent theoretical knowledge, I came to the United States and hoped to discover the philosopher's stone by accumulating and coordinating geological information in the construction camps of the U.S. Reclamation Service. It took me two years of strenuous work to discover that geological information must be supplemented by numerical data which can only be obtained by physical tests carried out in a laboratory. The observations which I made during these

years crystallized into a program for physical soil investigations which looked as if it could easily be carried out in one year. In reality the research activities extended over a period of eight years.

Period of Transition. All these early efforts which were started before the war and carried on by isolated groups or by individuals had one important feature in common. They were still guided by the intention to establish a science of soil behavior comparable to the science of bridge design. The major part of the college training of civil engineers consists in the absorption of the laws and rules which apply to relatively simple and well-defined materials, such as steel or concrete. This type of education breeds the illusion that everything connected with engineering should and can be computed on the basis of a priori assumptions. As a consequence, engineers imagined that the future science of foundations would consist in carrying out the following program: Drill a hole into the ground. Send the soil samples obtained from the hole through a laboratory with standardized apparatus served by conscientious human automata. Collect the figures, introduce them into the equations, and compute the result. Since the thinking was already done by the man who derived the equation, the brains are merely required to secure the contract and to invest the money. The last remnants of this period of unwarranted optimism are still found in attempts to prescribe simple formulas for computing the settlement of buildings or of the safety factor of dams against piping. No such formulas can possibly be obtained except by ignoring a considerable number of vital factors.

Unfortunately, soils are made by nature and not by man, and the products of nature are always complex. After a decade of mental and physical experimentation in the newly developed field, it became obvious that the method of approach must be radically changed. The design of bridges and of other purely artificial structures requires only a knowledge of mechanics. Theory governs the field and experience is a matter of secondary importance except for that acquired over the drafting board. The theoretical results can be depended upon, because the equations contain no important element of uncertainty. However, as soon as we pass from steel and concrete to earth, the omnipotence of theory ceases to exist. In the first place, the earth in its natural stage is never uniform. Second, its properties are too complicated for rigorous theoretical treatment. Finally, even an approximate mathematical solution of some of the most common problems is extremely difficult. Owing to these three factors, the possibilities for successful mathematical treatment of problems involving soils are very limited. In bridge design, the theory provides us with certainties and eliminates the necessity for observations on full-sized structures. In soil mechanics the accuracy of computed results never exceeds that of a crude estimate, and the principal function of theory consists in teaching us what and how to observe in the field. Whenever we explore the natural soil by drilling a hole or by extracting a sample, we alter its state even before the direct contact between the soil and the tool is established, and the effect of this change on the results of our tests can only be learned by experience. The theories which we apply in order to make the step from the test results to a numerical estimate of the effect of our engineering operations are bound to be based on radically simplified assumptions. The importance of the difference between theory and reality can again be learned only by experience. It depends to a large extent on the type of soil. The Proceedings of this Conference contain a great number of instructive examples. Finally, a natural soil is never homogeneous. Its properties change from point to point, while our knowledge of these properties is limited to those few spots at which the samples have been collected. To get information on the importance of the error produced by our inadequate knowledge of the deposits, we are compelled to compare the results of our forecast to those of direct measurement in a great number of cases. Owing to these facts, successful work in soil mechanics and foundation engineering requires not only a thorough grounding in theory combined with an open eye for the possible sources of error, but also an amount of observation and of measurement in the field far in excess of anything attempted by the preceding generations of engineers. Hence the center of gravity of research has shifted from the study and the laboratory into the construction camp where it will remain. The first fruits of this revised and essentially empirical attitude towards the problems of earthwork engineering are assembled in the Proceedings of our Conference.

Progress Achieved. After I read these volumes, I could not help remembering an episode which occurred some eighteen years ago. At that time I spent several months in a systematic effort to make an inventory of what we knew or believed we knew about the interaction between structure and earth. For that purpose I went through all the volumes of the leading English, German, and French engineering periodicals which had been published since 1850 and through all the textbooks which I could secure, abstracting all the articles and chapters relating to the subject of my investigations. This occupation was far from being as profitable as I had hoped. The abstract which covered a period of more than half a century contained less positive information than the two volumes of our Proceedings. Nevertheless, my efforts were fully compensated by an illuminating bird's-eye view of the situation which prevailed in the field of foundation engineering prior to the world war. Comparing this situation with that created by the recent developments of soil mechanics, I notice the following changes: a vast improvement in the quality and quantity of observation on full-sized structures, a rapid elimination of the time-honored antagonism between theory and practice, and the replacement of blind faith in rules and prescriptions by a refreshing demand for adequate evidence. I shall now try to present to you the salient features of these recent developments and their practical consequences.

The Conflict between Theory and Reality. One of the outstanding impressions which I got while preparing the abstracts of pre-war publications was that of a steady decline of the capacity for careful observation after the eighteen-eighties. Prior to about 1880 a surprisingly great number of stimulating field observations were published by engineers. A few examples may suffice. The oldest editions

of the English textbook by F. W. Simms on practical tunneling are full of valuable data drawn from actual experience in the early days of tunnel construction through English clays. Some of the French papers on the slides which occurred during the construction of the railroad line from Paris to Lyon are masterpieces in the line of keen observation, and the description of the discouraging experiences during the construction of the first German and Austrian railroads across regions of unstable subsoil are still an inexhaustible source of information after half a century. However, after the eighties, the interest in observing and describing the whimsical manifestations of the forces of nature seemed to fade out. I am inclined to explain this decline by a growing confidence, produced by the inertia of the human mind, in the theories concerning the behavior of earth. At the time when the theories originated, their authors were still keenly aware of the bold approximations involved, and nobody thought of accepting them at face value. As the years passed by, these theories were incorporated into the stock of knowledge to be imparted to students during the years of their college training, whereupon they assumed the character of a gospel. Once a theory appears on the question sheet of a college examination, it turns into something to be feared and believed, and many of the engineers who were benefited by a college education applied the theories without even suspecting the narrow limits of their validity. If the structures designed on the basis of these sacred theories stood up, their behavior was considered to be normal and not worth mentioning. If they failed, it was an act of God, which should be concealed from the eyes of mortals, who might believe that the designer was poorly grounded in theory. This uncritical attitude toward the problems of earth behavior induced a growing resentment of those who had eyes to see against the theoretical textbook wisdom. Among the documents of this justified resentment, I wish to mention a paper published in 1908 by the experienced subway expert, J. C. Meem, on the bracing of tunnels and trenches, in the Transactions of the American Society of Civil Engineers. The contents of this paper and of the numerous discussions which followed left no doubt concerning what the authors thought about the college attitude toward earth pressure problems. It was not very complimentary.

However, the feeling of resentment against unwarranted generalization does not suffice to transform an accumulation of haphazard professional experience into a store of knowledge and of general usefulness. In order to accomplish such a transformation, three conditions must be satisfied. First of all, there must be a generally accepted method for describing the soils to which the individual experiences refer. Conventional terms such as "fine, water-bearing sand" may mean almost anything between a loose accumulation of small grains, incapable of sustaining an appreciable load, and a stratum which is almost as hard as rock. The terminology must be based on numerical values of some soil. Otherwise it is worthless. Second, the observation methods must be reliable; otherwise there is too wide a margin for interpretation. If an observer claims that a building did not show any signs of settlement, the structure may have settled through a distance of one-tenth of an inch to four inches, provided the settlement was uniform and the distance to the neighboring structure was appreciable. Finally, the report on the observation must be accompanied by a statement of all the vital factors which were likely to have influenced the object of the observation. Otherwise the observation cannot be used as a basis for a valid conclusion. In order to satisfy this third requirement, the observer must be familiar with the physics and mechanics of the observed phenomenon. Thus, for instance, no valid conclusion can be derived from the results of a settlement observation on a building covering an area of 100 by 100 feet unless we have at least reliable geological information concerning the nature of the subsoil to a depth of at least 150 feet. In one of the cases which I had under observation, a building settled more than one foot owing to the compression of a layer of clay located between a depth of 100 and 130 feet below the surface of the ground.

Rationalized Observation. Practically none of the above requirements were satisfied by the observations of the pre-war engineers, because the knowledge of the physical properties of the soils and of the forces exerted or transmitted by the water in the soil was by far too inadequate. Therefore the ignorance of the practical engineers differed from that of the faithful textbook believers merely in kind but not in profundity. A single example may suffice to explain what I mean. During my professional career, I met a great number of practical engineers and of experienced contractors who honestly believed that the settlement of a pile foundation involving a load of 20 tons per pile should approximately be equal to the settlement of an individual pile during a loading test under 20 tons. Important decisions were based on this simple assumption. Yet, if we really measure the settlements - and I have done it very often - we find that the settlement of the pile foundation may range anywhere between five and five hundred times that of the individual pile. The failure of experienced engineers to know this commonplace fact can only be due to an idiosyncrasy against measurements, combined with a habit of mistaking the absence of any visible signs of settlement with the absence of settlement.

Owing to the failure of the practical engineers to produce a reliable code for the design of foundations out of their own resources, the antagonism between dogmatic theory and inadequate experience merely led to a state of stagnation which reached its climax in the first decade of our century. However, the subsequent development of soil mechanics eliminated this state of stagnation in a radical fashion. The act of elimination started with an attack on time-honored and sacred institutions such as the classical earth pressure theories, the pile formulas, and the tables of safe bearing values of soils. The attack left a heap of ruins with very little to replace them. Intensified experimentation with soils led to the discovery of a whole series of physical factors of vital importance which escaped the attention of the investigators of the previous generations. Foremost among these factors are those which determine the gradual increase of settlements at a constant load. The knowledge of the existence of these new factors made it necessary to rebuild the theories in accordance with our increased knowledge of the properties of the material. While building a theory one is painfully conscious of the

approximations involved and of the gaps which it leaves after it is finished. In order to make these theories applicable to actual cases, it became necessary to observe the performance of full-sized engineering structures far more carefully than it was ever done before. Thus the spirit of conscientious observation characteristic of the middle of the nineteenth century experienced a revival on a very much higher plane. The visual inspection was supplemented by systematic and precise measurements, and the danger of fatal omissions was reduced by a superior knowledge of the physical nature of the processes involved. This inauguration of a new era of direct and intimate contact between the engineer and his structures alone would suffice to justify the time and labor invested in soil mechanics during the brief period of its existence. Our theories will be superseded by better ones, but the results of conscientious observations in the field will remain as a permanent asset of inestimable value to our profession. Whoever peruses the Proceedings of this Conference cannot fail to be impressed by the new spirit disclosed by the text and the diagrams of these volumes. The days of abstract foundation philosophy are gone forever. And so are the days of unwarranted generalizations based on inadequate evidence.

Truth and Fiction in Textbook Engineering. The second outstanding impression which I received while abstracting the engineering periodicals, eighteen years ago, was produced by my discovery of the complete absence of what is commonly called adequate evidence. As the years passed, one formula after another appeared, and one rule after the other was advertised, but when I attempted to locate the empirical evidence on which the claims were based, I found there was none or almost none. This paradoxical fact leads us to one of the most important tasks to be performed if our professional standard is to be elevated. It consists in revising our attitude toward evidence.

In pure science a very sharp distinction is made between hypotheses, theories, and laws. The difference between these three categories resides exclusively in the weight of sustaining evidence. On the other hand, in foundation and earthwork engineering, everything is called a theory after it appears in print, and if the theory finds its way into a textbook, many readers are inclined to consider it a law. In order to find out to what extent a theory deserves its name, it suffices to dissolve it into its principal components and to examine each one individually.

Every theory consists of three parts, a set of assumptions, a process of reasoning, and a final result. Since the validity of the reasoning can easily be verified, it suffices to concentrate our attention on the first and last parts. Each of these may be dissolved into words expressed by symbols and figures. The first requirement for an acceptable theory should be that the words have a definite meaning. Many of the terms which are used in textbooks on foundation engineering have a very vague one, if any. In this connection, the term "safe bearing value of piles" may be mentioned. Some eight years ago a very expensive factory was established on a whole forest of piles, between 60 and 80 feet long. The machinery erected in this factory was extremely sensitive to unequal settlement. The bearing capacity of the individual piles was most satisfactory. According to all the textbooks and manuals relating to this subject, the load on the piles was equal to or smaller than one-half of the safe bearing value. Yet the owner of the factory refused to share this opinion, because some parts of his factory settled through a distance of one foot. In western Austria stands a post-office building with continuous footings on a very compact bed of sand and gravel, 23 feet thick. The building exerts a pressure of 2.5 tons per square foot on the ground. I do not know of any building code or of any textbook which does not contain a very much higher figure for the safe bearing value of such a stratum. Nevertheless, the settlement of the building ranged between two and three feet. The same books which inform the patient reader on the safe bearing values also contain instructive tables with the values of the coefficient of internal friction of fat and of lean clays and loams. Yet with some skill and experience in laboratory procedure, one can get almost any specified friction value for a given clay. A score of other examples could easily be added.

Considering these unpleasant facts, one of the first requirements for a clean-up in the field of foundation engineering is insistence on a satisfactory explanation of the meaning of the terms. If a theory claims to furnish a safe bearing value, or if it operates with the coefficient of internal friction of clay, one may as well stop reading, unless the author explains in detail what he means by these terms.

The second requirement for an acceptable theory consists in the presence of adequate evidence for the assumptions. If these assumptions were obtained by a radical simplification of reality, which is the rule in connection with theories pertaining to soils, the evidence for the results must be presented. Whatever evidence is available can be classed into one of the following five categories:

- (a) No evidence whatsoever;
- (b) Evidence obtained by distorting the facts;
- (c) Unbalanced evidence; that is, evidence obtained by eliminating all those facts which do not sustain the claim;
- (d) Inadequate evidence, covering the entire range of present knowledge, yet insufficient to exclude the possibility of a subsequent discovery of contradictory facts; and
- (e) Adequate evidence.

No honest business man and no self-respecting scientist can be expected to put forth a new scheme or a new theory as a "working proposition" unless it is sustained by at least fairly adequate evidence. In any case, we expect him to inform us on the uncertainties involved. Therefore it is surprising to find upon closer scrutiny that many of the accepted rules of foundation engineering are based either on no evidence whatsoever, or on unbalanced evidence, and that the textbooks do not mention this serious

failing. These rules seem to pass from one generation of textbooks into the next one by a process of diffusion, whereby the scruples regarding the inadequacy of the evidence disappear.

One of the popular assumptions for which there is no evidence whatsoever is the claim that the coefficient of internal friction of fine moist sand or of clay soils is identical with the tangent of the angle of repose, which again is supposed to be identical with the slope obtained by dumping the material from a low trestle or out of a box. In spite of repeated and convincing proofs of the invalidity of this assumption, it continues to appear in textbooks and to mislead unsuspecting engineers. Another case of a dogma sustained by no evidence whatsoever is the assumption that the hydrostatic uplift exerted by the water in a concrete or in a clay acts over not more than one-third or one-half of the area subject to uplift. This assumption is based exclusively on personal opinion and maintained by majority vote. Yet it has a decisive influence on the design of important and very extensive structures, including the highest storage dams. As soon as we attempt to verify this opinion by physical experiments, such as those described in a paper in the second volume of the Proceedings, we find that it is grossly erroneous. A third dogma supported by no evidence is the assumption of a definite relation between the angle formed by the planes of shear in a cohesive soil and the angle of internal friction in Coulomb's equation for the shearing resistance of such soils. The fallacy involved in this dogma is analyzed in an article of the first volume of the Proceedings. It invalidates the so-called accurate theories of the stability of slopes which are based on this fallacy.

As a classical example of a prescription which is in part based on unbalanced evidence, and in part on none at all, the Engineering News Formula may be mentioned. This formula is supposed to represent the relation between the weight and the drop of the hammer, the penetration produced by the blow, and the safe bearing value for the pile. The real meaning of the term "safe bearing value" is nowhere defined. The numerical results furnished by the formula can only be defended by wilfully suppressing at least one-half of the existing evidence. In the form which is intended to apply to piles which are driven by a steam-hammer, the denominator contains a constant, 0.1, which originated in pure imagination. If we discover that a commercial advertisement is based on such evidence, we call it bluff and reject it. However, in the field of foundation engineering the critics are far more lenient. The formula has been published over and over in texts and manuals without any warning to the reader, and it continues to represent an integral part of the majority of building codes and of government regulations. Another example of a conception artificially maintained by means of unbalanced evidence is the theory that the lateral pressure of the earth on the back of a supporting structure should increase, like a hydrostatic pressure, in direct proportion to the depth below the surface. This theory originated some 150 years ago. Under certain conditions, specified in one of the papers of the first volume of the Proceedings, the hydrostatic pressure distribution really exists. However, under other conditions of great practical importance, such as those which exist on both sides of a timbered cut, the distribution of the lateral pressure may be very different from that required by theory. Nevertheless, year after year, the dogma of the hydrostatic pressure distribution is handed out as gospel, and contradictory evidence is consistently ignored.

Grossly unbalanced is also the evidence offered in support of the claim that the settlement of a building can be predicted from the results of one or of several small-scale loading tests performed at the level of the base of the future foundation. For each case of evidence for this claim which has thus far come to my attention, I can quote at least two cases out of my own experience which contradict it. Considering these facts, the academic merits of the underlying theory are utterly irrelevant, because the empirical arguments suffice to invalidate the claim.

In most cases the unbalanced character of the evidence is due merely to our inadequate knowledge. Into this class belongs the assumption that the results of properly conducted shearing tests on so-called undisturbed samples of clay are always identical with the shearing resistance of the untouched clay deposit. For many years I accepted this assumption until I came across several cases which contradict it. This experience makes it necessary to find out, by future observations, the limits of the validity of the original assumption.

I do not doubt that the majority of engineers adopt the suggested attitude toward evidence in all their business transactions. In case they should decide to introduce it also into their professional relations to mother earth, radical changes in their attitude toward accepted rules could not fail to ensue.

**Outlook.** The skeptical attitude towards our conceptions, and the readiness to modify them in accordance with increasing knowledge of the material, must be considered the second outstanding achievement of soil mechanics. By patient observation we have learned to discriminate between what we really know and what we merely believed. The amount of knowledge sustained by adequate evidence is appallingly modest, and the number of factors with a decisive influence on soil behavior is very much greater than was expected twenty-five years ago. The successful analysis of the reaction of the earth to changes produced by loading or by excavation was paid for by a heavy sacrifice of simplicity. Moreover, the severe restrictions on further progress along purely theoretical lines have become obvious. One of the most instructive examples of these limitations is to be found in the theory of arching in soils behind the timbering of cuts. The theory demonstrates that arching develops. It discloses the mechanics of arching, and reveals the limits between which the distribution of the lateral pressure of the earth may range. At the same time it leaves no doubt that the real distribution of the pressure depends on the method of constructing the timbering. Since we are not in a position to evaluate this influence on the basis of abstract reasoning, we are obliged to secure the required information by direct measurement of the pressures in full-sized cuts. We face a similar situation in almost every other field of soil mechanics. Our advanced knowledge of the mechanics and physics of soils makes it pos-

sible to grasp most of the essential factors which govern the stress and strain and the equilibrium of real earth. It has brought to us a realization of the extremely narrow limits of the validity of the older theories, and informs us of the existence of sources of danger which previously were hardly suspected. Nevertheless, in order to make the step from the qualitative appreciation of what is going to occur to a quantitative forecast requires accurate and systematic observations on full-sized structures.

Foremost among the sources of error requiring thorough investigation is the difference between the soil in its original state, and after it is delivered in the laboratory. In some cases the correction for the errors produced by the effect of sampling and handling can be made by computing the deformation of the subsoil for earlier stages of construction, and subsequently comparing the results with those of direct measurement. The first volume of the Proceedings contains a very instructive example for a successful operation of this kind.

Since we have achieved a reasonably clear conception of the possibilities and limitations of future research, the function of this Conference is simple. It consists essentially in establishing personal contacts between those who are interested in the subject from a theoretical or a practical point of view, and in stimulating exchange of experience. Though it originated not more than twenty-five years ago, soil mechanics is already old enough to have acquired the modesty which springs from experience. We know today that nothing worth while can be accomplished in this discipline without the intelligent and patient cooperation of the practicing engineer in the field. Some of the most valuable contributions to the Proceedings are a direct result of such cooperation. For this reason, we are very happy to welcome among the guests of the Conference a great number of outstanding executives and experienced construction engineers. Since these men owe their success and their professional standing to a keen discrimination between reality and fiction, I am sure they will appreciate our feelings against half-baked textbook wisdom, and assist us in getting down to tangible facts.

#### ADDRESS BY DANIEL E. MORAN

Vice President of the Conference and Chairman of its American Committee

As Chairman of the American Committee I can add but little to the eloquent addresses of welcome you have just listened to. The Committee and the Officers of the Convention cannot but feel gratified by the world-wide response to the invitations issued in the name of the great University whose guests we are. These responses have come from engineers and scientists from all parts of the world, from our good neighbors Canada and Mexico, from Cuba and the Republics of South America, from Great Britain, and ten of the principal countries of Continental Europe, from Africa, Asia and Australia, as well as from the United States of America.

Without specific authority I may say that we as "members" and guests are greatly honored by having been bidden to this conference sponsored by the oldest and greatest of American Universities, now celebrating the 300th Anniversary of her founding. For you, Mr. President, we wish long and happy years of service, for Harvard itself we hope and pray that she may continue in the future as in the past, free, unbidden and unafraid, holding high the torch of enlightenment and leading men and women in the paths of wisdom and knowledge.

The wide-spread and remarkable interest in this Conference can be readily understood when the importance and vital necessity of the subject is appreciated. For years, Engineers and Scientists have studied, classified and tested structural materials of all kinds. But all structures depend for stability on contact with some stress resisting solid material, a part of the Earth's Crust. The material may be any one, or a combination of several of an indefinite number or kinds of material. The difficulties in the way of evaluating these different kinds of material, in determining the laws governing their behavior, and in coordinating results, seemed so insurmountable that until recent years no real attempt, no practical start was made. True, some physicists, mathematicians, and engineers evolved theories generally based on arbitrary, sometimes erroneous assumptions, but the results were of questionable value in guiding engineers. Until a few years ago little had been done, and even now little is generally known of the facts which have been developed by your efforts. As a simple example; well-known text books, treating foundation design, now in common use define clay as "A general name for cohesive soils" and purport to give its physical, chemical and geological properties, (Hool & Kinne Pg. 361-2--Foundation Abutments and Footings, 1923) but say no more about its structural properties than Baker in 1889, who stated that "damp clay will squeeze out in every direction when a moderately heavy pressure is brought upon it" (Baker Pg. 190--A Treatise of Masonry Construction, 1889). Furthermore, these books recommend "as essential to the proper design of foundations the accurate determination of local conditions--the character of the underlying strata--and the making of excavations or borings" (Jacoby & Davis--Foundations of Bridges and Buildings,--Page 585, 1925) and then fall back on the recommendations of Baker to determine the bearing capacity "by direct experiment, good judgment and experience" (Page 138); never a word about soil mechanics or what may be done with a boring sample or the dangers of basing designs on inadequate or improper borings.

Until Terzaghi's articles appeared in the Engineering News I know of no published explanation, in the English language, of the underlying reasons for the consolidation of clay under increased loads.

Twenty years ago the matter of foundation design was largely an art, the designers being guided by uncorrelated experiences, rules of thumb, prejudices, and wild guesses, all made in the name of "good practice". Today order and rational designs are slowly taking the place of ignorance and error.

The subject is of cardinal importance, it is a new field, virgin territory demanding that it be explored and mapped. You and your co-workers are the pioneers and to you the engineers of the future must look for guidance.

In conclusion, may I quote the benediction which appears at the end of the preface to the first translation into English of the Principles of Euclid. This was written 66 years before the founding of Harvard, by John Dee, astronomer, chemist, mathematician, student of white magic, one time Professor of Mathematics at the University of Oxford, and at one time standing trial for Witchcraft, who wrote, "So I commit you unto God's merciful direction, for the rest: hartely beseeching hym, to prosper your Studyes, and honest Intentes: to his Glory, and the Commodity of our Countrey. Amen".

#### SOIL STUDY AND ENGINEERING F. E. Schmitt, Editor, Engineering News-Record

It is my very pleasant duty to express to those of you who have come from abroad the gratitude of the American contingent for your coming here and giving us the benefit of your knowledge on the new subject of soil study and soil engineering. I know that all the members of the Conference from this country share my appreciation and are glad to have the privilege of meeting with investigators who in distant parts of the world are laboring to throw light on its obscurities.

Soil knowledge is entering very practically into engineering operations in this country. Today you saw a typical example, but it is only one of many, and if you could take time to see all that is being done within the United States in earth construction you would be impressed with the effort to place this art on a foundation of science. All that you have done in your own laboratories and field operations has been of help to us, and all your additional investigations will give further help. Needless to say, we hope that our own work will have similar value to you.

The Conference that closes tonight is a unique occasion. Few branches of science or technology ever grew to strength and practical value so rapidly, and I am sure that none was able at such an early age to assemble its leading workers from all parts of the world or to show equal accomplishment. These results, which grew out of the enthusiastic cooperation of soil study and engineering, give assurance that continued cooperation will bring still further progress.

We are meeting in the atmosphere of a celebration of the growth of knowledge through study and science, the Harvard tercentenary. Thus my mind naturally turns to the unusual joining of scientific and engineering study that is embodied in our new soil knowledge. And it is well worth noting that the scientific and technical advance which you are helping to create deals with the oldest construction material known to man. Earth has been in his hands and at the point of his working tools longer than any other material of the constructive arts, yet none is so little known. Quite new materials, such as steel, mineral oil, rubber and concrete, have been studied to highly useful effect; but earth, though it is so old that pick and spade have come to be the very symbols of labor, still remains the subject of empiricism.

And yet few things are more important to engineer and builder, for the largest share of the world's investment in construction is expended on earth. This commonest and cheapest of all materials consumes the continuous labor of millions of men, and the expenditure of thousands of millions of dollars a year. May we not reasonably expect that better knowledge of its behavior, obtained through scientific study, will benefit mankind? Experience in other fields shows that we can predict this effect with confidence. It tells us that economy and efficiency will be gained through knowledge of the physical laws of soil action.

On the face of the matter, nothing seems more poorly adapted to scientific study than earth, commonly known as dirt. We deal with it in excavation and embankment building, in foundation work, and wherever the stability of the ground affects us, whether on level plain, on hillside or on river bottoms. Engineers have to consider the flow of water through and over the soil; they are concerned with changes of soil structure by consolidation, flow, compaction and loosening of texture, as well as with the effects of weather and structural earth disturbance. We should be able to profit from scientific study in every one of our dealings with earth. We know that if we can learn how to cut, or loosen, or move earth more easily, human toil will be lessened and much wasted expenditure will be saved.

Knowledge of the physical laws of earth action and the promise of fuller knowledge has stimulated study in remarkable degree. But it is only a beginning; we have a long distance yet to go. Today we know little more than that soil is ever changing and that its changes in state are significant to the engineer. Sometimes a very minor change may have important consequences, as in the soil under a roadway slab or a building foundation. We are beginning to observe and measure such changes, and are looking forward to learning how to control them. Until much more precise knowledge is obtained, however, we must content ourselves with the empirical judgment that normally the changes are of limited range and that construction expedients can provide for their effects, more or less successfully.

Perhaps I am taking too much time to emphasize the simple and obvious fact that scientific study of soil engineering is important. But it should be useful to reflect on why this study has been neglected in the past, because this reflection may help to give better guidance for the future. We remember, of course, that virtually every structural material has been subjected to physical measurement of its properties and their relation to service; but that whenever these processes of measurement were applied to soil the result was a failure.

It is because of this fact, no doubt, that the early study of the mechanics of soil made use of mathematical fictions. Set up to express what was believed to be the behavior of the material, these fictions never acquired more than academic status, however, and engineers declined to accept them fully. As experience failed to verify the teachings of these artificial mechanics they ignored it in their practical work.

The bulky but unimportant literature on pile driving is a demonstration of how thoroughly the academic attack failed. Nevertheless, by their mere persistence the fictions and the academic analyses won a place in the treatises of engineering that they still hold tenaciously. I can recall many hours spent in reading books on retaining walls that covered hundreds of pages with geometrical diagrams and formulas but mentioned only two physical facts (and these were not facts!), namely the identity of angle of friction with angle of repose and the plane form of the surface of rupture. Such books, which have stood as cornerstones of our engineering libraries for many decades, held back the birth of a true soil science.

Let me mention an interesting memory. Some time ago, when an important tunneling enterprise was being developed, certain calculations of ground pressure and strength of lining were based on the classic doctrines of angle of repose and Rankine pressure, and it was concluded that the tunnel would be most stable in exceedingly soft soil, a semi-liquid mud, but that if the soil should prove to be stiff the tunnel would inevitably collapse. This was the strange mathematical conclusion; but the fact of course is that the engineers did not really believe this deduction: they used it to support an argument, but did not use it as the basis of their design. They were too sensible to do that. They designed and built an excellent tunnel, which has never collapsed and is not in the slightest danger of collapsing. But this is so only because practical engineers know that our alleged science of earth is false, and in important questions do not allow it to mislead them. Unfortunately they do often allow it to mislead them in minor questions, as may be seen from the number of retaining walls, abutments and wing walls that are out of plumb and badly cracked. The earth back of the walls likes to ignore the mathematical fictions of the schoolroom.

Why is it, we are bound to ask, that the scientific treatment of soil as an engineering material has remained so defective? Probably the chief reason is that the material is extraordinarily complex. Because of this complexity, quantitative soil study in its modern phase made little progress until true scientific method was applied, about two decades ago. Your president did the decisive pioneering. Working patiently and painstakingly, with simple home-made equipment of almost toy dimensions, he singled out certain elementary properties, studied to isolate them from other variables, devised methods for their measurement, and scrutinized these methods as carefully as physicist or astronomer, to eliminate errors and attain the desired degree of precision.

He soon found that old views and dogmas had to be discarded almost in their entirety. At the very beginning he saw that soils fall into two large classes, the predominantly granular soils and the predominantly cohesive and plastic soils, and so he worked with pure, uniform sand and pure clay as simple arch-types. He saw that their behavior--for example, as to compressibility--is essentially different, and he recognized that this implies wholly distinct properties and experimental practices.

The striking success that attended his efforts is known to the world. Even at that time he recognized that his simple types occur in nature but rarely, and that most soils are intricately complex and composite; but leaving these to the future, he laid a secure foundation of purpose and procedure for the development of a knowledge of simple soils. Today we have before us the fruits of the movement which he initiated and which quickly drew world-wide interest and vitalized the prior thoughts and work of a number of others. Measurement of the mechanical properties of simple soil types has progressed far, and in addition the methods have been applied to practical work in many composite soils, though in general scientific study has not yet entered this field.

So much for what has been accomplished up to the present; now a moment's thought as to what lies ahead. We know that soil as a construction material is a problem not only to the engineer but also to the scientific researcher, and that to both of these workers it is an exceptionally complex and difficult problem. If we will take a moment to consider the difficulties that confront them we may better understand the nature of their coming tasks.

Examination of any soil samples from different locations reveals at once an extraordinary variation in character. Soil is seen to be a multi-phase material, one that comprises solids, colloid gels, liquids and gases in infinite range of variation. Up to now it has escaped classification; it may always do so. Again, up to now we cannot say which of its properties are significant; we have hardly grasped, or even listed, the fixed data that determine its behavior. Its qualities depend much on its consistency--and this term is quite as elusive when applied to soil as when applied to mortars and concretes. It exhibits such effects as stickiness, slipperiness, susceptibility to sudden change--as in melting or caking, or in failure of cohesion. Its changes of state are as important as its properties in any one state; in fact little use can be made of data on its characteristics in only a single state.

The modifying influences that affect the behavior of soil include mechanical, chemical, thermal and doubtless also electric treatment. Weather affects soil greatly. Tidal influence appears to be important in some cases; at least we have the suggestive observation that the subsoil of the Hudson River carries the embedded tunnels up and down by a minute amount during the tidal cycle. Tectonic, seismic and other extraneous forces may disturb it, as well as the action of vegetation, of time, and of various forms of life, from burrowing muskrat to microorganism. Finally, various changes may be brought about by intent, as by compaction, loosening, addition or subtraction of moisture, incorporation of bituminous or chemical binders, flocculation and dispersion, and doubtless other possible effects.

But most of all we are confused by the infinite variation of soils as nature has made them. No one class or type of soil can be said to exist in two locations, and this is the principal reason why attempts to classify soils have failed except for limited uses. Indeed, the definition of soil must probably always remain statistical in its nature, and we may have to reconcile ourselves to expressing soil character by broadly approximate statement of averages. Of course the erratic variation represented in stratification, lens structure, and morainal or delta-deposit heterogeneity, lies beyond even such form of expression.

I think you will agree with me that under such circumstances we can never hope to see the application of scientific results to engineering accomplished by formula. It cannot be an exact procedure. Soil study may furnish some broadly generalized conclusions, but beyond this the practical use of soil knowledge is bound to remain an engineering operation. The developed art, in short, will differ fundamentally from the precise methods of design and precalculation which we have been able to follow in other engineering practice. Dr. Terzaghi's opening address aptly characterized the futility of attack on the engineering problems of earth by formula. And this suggests that there is a sharp division of function between the soil scientist and the engineer, and that while the two should cooperate they will in the main have separate fields of action.

It has been said that soil research has moved from the scientific laboratory to the construction camp. The statement picturesquely characterizes the current activity in soil engineering, but actually it is true only in a limited sense. There is a vast amount of basic scientific work remaining to be done on soils, and this is wholly the responsibility of the scientist's laboratory.

Consider what it is that we will demand of the scientist. We will expect him to study simple, defined soil types; to identify their properties and devise measurements for them. We will look to him for a classification of soils, based first on laboratory behavior alone, then if possible also on field facts. He will have to study soil behavior and the factors influencing it; assist in developing methods of field sampling, test and verification; establish laws of soil constitution, soil properties and their modification, progressively bringing these laws if possible to apply to all defined soil types. The scientist will be concerned with the statics, the dynamics, the physical chemistry of soils, and perhaps also their electrical reactions. Still greater problems may be revealed as his work goes forward.

On the other hand the engineer has equally large tasks in the field of soils, as the experience of the last half dozen years reveals. It is his responsibility to utilize the scientist's facts and conclusions, modified and applied as the variation of practical factors dictates; to adapt scientific measurements to the cruder conditions of practice; to devise new means for utilizing or counteracting specific properties of earth and to improve the old ones by invention based on scientific principle; to adapt his tools and structures to the laws of dynamic behavior explored by the scientist in his laboratory. And finally, he has the associated responsibility of exploring the characteristics of soil, its variation and structure as found in nature, and reporting the phenomena that will be the raw material of further research. In short, his work if well done will from month to month establish a new starting point for scientific study. Of course he must also scrutinize his own work at every step, test his methods and construction procedure by the most advanced scientific understanding, and wherever possible support the efforts of the scientist by full-sized job experimentation.

Since these highly important but separate lines of work must be carried on, it is gratifying that scientists and engineers both have entered into soil study and that they have joined in this first Conference. Up to the present they have worked in close cooperation and used the same language, and this cooperation unquestionably will continue. For some time to come, also, we may expect that it will be as intimate as heretofore. But when the point is reached where soil science takes up the more fundamental aspects of its problem the two groups are certain to diverge in their activities--though, it may be hoped, without ceasing to cooperate.

In summary, then, I wish to express the conviction that as the work of the soil scientist departs from that of the engineer their continued cooperation and exchange of thought will become progressively more essential, for it is only by aid of such exchange that soil knowledge can advance as it should. It is to be hoped that this Conference will mark the beginning of organized interaction of the two workers, and that through the formation of active national groups concerned with soil mechanics and soils engineering an efficient means of cooperation and interchange may be created. With such a structure, centered from time to time in international conferences of the kind just concluded, the vigorous spirit of research and progress evidenced here is certain to have a new scientific art whose results will have large meaning to human progress.

#### FAREWELL ADDRESS

Dr. Ing. A. Agatz, ord. Professor. Technische Hochschule, Berlin

At the end of the First International Conference on Soil Mechanics and Foundation Engineering, I would like to ask your permission to say a few words to you in the name of all the foreign members:

We have followed the call of our President, Dr. Karl von Terzaghi, and we have come to your country from all over the world. The aim of this Conference was to lay a foundation stone for a future cooperative work in this field of Engineering, which I hope will be successful in all countries.

Already at New York we have been received by the American Society of Civil Engineers and by the Harvard Engineering Society and greeted in the friendliest manner. We were given then the opportunity to get an impression of the importance of the wonderful engineering structures of New York and of the

beauties of its charming surroundings.

The same cordial hospitality was extended to us in Cambridge. Some of us could feel younger and were reminded of our own student days, as we occupied the comfortable student quarters reserved for us at Harvard. During the many excursions and on all other occasions every possible friendly attention was shown to us. Everyone of us will return home strongly impressed by the American hospitality.

A good remark was made during yesterday's meeting by Mr. Cuperus, when he said that the interest of the foreign members in the Conference was in an inverse relation to their number. I believe that one could write a further equation: to obtain the interest of the foreign members in the Conference, one should multiply their number by the distance they had to travel.

After our last official meeting tonight some of us will remain for some time longer in other parts of your beautiful country with its wonderful engineering works. We shall then return to our homes, impressed by all that we have seen and bearing with us the most charming recollections.

We have the sincere desire to express now to you all our warmest thanks for your hospitality. We wish to you and to your country the best in everything that one could wish, and we hope that we will all meet again at the next Conference.

CLOSING ADDRESS OF THE PRESIDENT  
Dr. Karl von Terzaghi, Technische Hochschule, Vienna

In his stimulating address, Mr. F. E. Schmitt mentioned my own modest share in arousing the interest of the engineering profession in the subject of this Conference which terminates today as promisingly as it started a week ago. It was Mr. F. E. Schmitt who established some fourteen years ago the first contacts between my primitive laboratory in Constantinople and the American world of Engineering. About six years later he wrote me that he had tried hard to adapt my methods of presentation to the needs of the average engineer, but that his labor of love seemed to have been wasted. His appearance as a speaker at this table seems to indicate that he later changed his opinion. Otherwise we would not have the benefit of his stimulating company.

When Professor Casagrande informed me last summer of his intention to organize an International Conference on Soil Mechanics and Foundation Engineering, I felt very pessimistic about it and I know that Mr. Schmitt shared my gloomy premonitions. We both believed that the time was not yet ripe for such a daring adventure. However today, at the close of the Conference it is plain that Casagrande, in his youthful optimism, saw very much clearer than we.

First of all, the Conference gave us a bird's-eye view of the activities in the field of our endeavours, which could not possibly have been otherwise obtained. Although I never failed to keep in close contact with new developments, I was amazed at the wealth of useful information which had escaped my attention, and I am sure that all the other members feel the same way about it. The second outstanding achievement of the Conference is that it has given a powerful impetus to further observation and research.

This impetus is essentially due to the enthusiastic co-operation on the part of the delegates of twenty different countries scattered all over the globe. This joint effort represents one of the most inspiring manifestations of international co-operation I have ever experienced. Therefore I wish first of all to express to the delegates of the foreign countries my heartiest thanks and appreciation.

According to the classification proposed by Mr. Schmitt in his address, the members of the Conference can be divided into three groups. The first one includes those executives and practicing engineers who accepted our invitation for the purpose of surveying the field and for the purpose of learning something new and useful during the discussions. The second group consists of those who practice the methods of soil testing in the field in connection with individual, practical problems and the third one comprises the men engaged in laboratory research. On account of the divergence between the interests of these groups, I wish to say a few words to the members of each group separately.

The practicing engineers who attended our Conference witnessed not without discomfort the final destruction of many of their cherished illusions regarding the value of the methods of estimating bearing capacity of the earth and of piles. They could not fail to notice a growing scepticism against the application of simple and ready-made formulae to the design of foundations. Therefore they are entitled to ask what they are going to receive in exchange for the lost treasures. The answer is simple. Soil Science offers medical service based on sound though very fragmentary knowledge in exchange for the service of the medicine-man.

The Proceedings of the Conference contain a great number of examples of the type of medical service which Soil Science is able to offer. To illustrate this statement I select an example at random. It is the paper which was read by Professor Gilboy about the settlement of earth fills on a stratified subsoil. If the traditional medicine-man has been trusted with the investigation of the subsoil of one of the fills described by Dr. Gilboy, he would have made a loading test on an area of one square foot, neatly trimmed and prepared and forty-eight hours later he would have presented the prospective owner of the dam with a magic figure: The safe bearing value of the soil. Under this system there were two possibilities. Either the fill stood up to the satisfaction of the owner, whereupon the reputation of the medicine-man for achieving very useful results with surprisingly simple means still further increased. Or else the embankment failed. In this case the incident was, if possible, passed over in silence, because everybody felt guilty to some extent without being able to find out on which part of

the entire operation the failure should be blamed. In contrast to the medicine man, Gilboy and his associates labored for many weeks in an effort to solve their problem, and I feel sure that few among you failed to be impressed by the results of his work. He was able to predict not only the magnitude, but also the time rate of settlement over a period of many months with a striking degree of accuracy. Twelve years ago when I derived the fundamental equation for this procedure I would have considered such an achievement almost impossible owing to the technical difficulties involved. And many things which we consider impossible today, at the meeting of our first Conference, will be commonplace ten or twenty years hence.

However, in spite of our promising start, there is no doubt about the magnitude and the difficulty of the work which still needs to be accomplished. Foremost among the urgent investigations ranks the painstaking observation of full-sized structures the world over, and the comparison between the observed facts with what was predicted from the results of the soil investigations. In order to accumulate the knowledge required to handle successfully unusually difficult and novel problems, we must never cease to increase our skill and experience by a scientific analysis of what can be observed in connection with current engineering operations. In this as well as in many other respects we face the same situation as the physician does. Suppose a millionaire or a leading statesman falls seriously ill and wants to be cured of his ailment. All his money and all his influence would not suffice to restore his health unless the physician had previously acquired the necessary experience by conscientiously dealing with the diseases of countless humbler patients. In this analogy, the millionaire represents our unique and expensive engineering structures such as the construction of high dams on a compressible and permeable base or the foundations of buildings similar to that of the Soviet Palace in Moscow. The humbler patients correspond to the average run of building construction.

The data required to predict the performance of foundations and for a scientific analysis of observed phenomena must be provided by the labors of the members in the second group of Schmitt's classification. They are building the solid base for our science and nothing could be accomplished without their conscientious co-operation. To be successful in their work, they need first of all a thorough grounding in physics, and second, an inquisitive attitude towards the ultimate purpose of their tests. Otherwise investigation degenerates into a habit, comparable to the pious act of an old peasant woman who was found absorbed in prayer, while kneeling in front of a mile-stone on a mountain road. When a passing tourist asked her which saint this stone represented, she replied, "I don't know, but he is certainly good for something."

The answer to the question concerning the purpose of the soil tests can only be expected from the members of Schmitt's third group. Whatever progress we have achieved thus far originated in the laboratory. Yet living in an atmosphere of splendid isolation in their laboratories the members of this group are naturally inclined to underestimate the limitations of the validity of purely logical reasoning. Since I was for many years in a similar position, I wish to give them the following advice drawn from my personal experience. If they cannot resist the temptation of inventing a new theory they should conceal their product in their files until their conclusions are confirmed by ample evidence obtained from laboratory experience, because even then, with respect to practical application, their results can only be considered interesting possibilities, subject to subsequent confirmation by observations on full-sized structures. Premature publication of a theory may force its author to defend his thesis as the philosopher Hegel defended one of his physical deductions. When a physicist of the experimental type who attended the lecture dared to claim that Hegel's statements were in contradiction with the observed facts, the philosopher proudly retorted, "The worse for the facts." In the realm of pure science such an attitude can be considered good sport. However when applied to engineering the expenses involved in the sport are likely to be excessive.

The most efficient remedy against debauch in the line of theory consists in an intimate contact with the men in the field. In order to establish such a contact on a world-wide scale, our Conference was organized. For the benefit of those who are not familiar with such organizations I wish to say that each one consists of two parts.

One part is supposed to get its meals at regular hours, to be clean and shaved and to get a reasonable amount of sleep. When appearing before the audience this part of the organization is expected to produce the erroneous impression, that the show was staged without any serious effort. This impression should serve to encourage the calling in of another conference through the initiative of those present. This part of the organization is called the President.

The second one has the ominous title "Committee on Organization". Since I never served as a member of a Committee on Organization I can only tell you what I saw during the last six months. The unfortunate members of this Committee worked every day from 9 a.m. to 2 a.m., seven days per week. They sacrificed soul and body to what you experienced as organization, and they discarded the fact that they are human beings. During a period of six months they not only handled the crushing amount of routine work connected with the Conference, but in addition they developed the most successful plan for running the Conference which I have ever seen in operation. It is certainly astounding that they survived the ordeal. Through their personal sacrifice they have contributed more towards stimulating universal co-operation in our field of endeavour, than any amount of printed material could have accomplished. Therefore I cannot think of any more appropriate close for this address than to propose a rising vote of thanks to Casagrande and his associates.