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WATER RESOURCES DEVELOPMENT, A VITAL RESPONSIBILITY OF THE CIVIL ENGINEER

PRESIDENTIAL ADDRESS BY ARTHUR T. IPPEN*

(Presented at the annual meeting of the Boston Society of Civil Engineers, held on March 16, 1961.)

"A people that is alive, will build for its future."
Inscription on memorial on the closure dike of the Zuider Zee, Netherlands

INTRODUCTION

THE advancement of a better human environment for all nations requires the creative and rational organization of human and of natural resources. Who can deny that this nation has been particularly blessed with both kinds of resources and that this has enabled us to reach a height of living standards and of opportunities for human growth still unmatched in the world. With this rise of national stature we have also inevitably achieved power and we have thus become involved in responsibilities of a scope and complexity, which we only gradually begin to comprehend. In this emerging conception of our world-wide obligations the achievement of an unassailable protective and defensive position for ourselves and our friends had first priority. We have accepted this burden and have carried it without sacrifice of our essential political beliefs in human dignity and freedom.

However, this, at best, has only bought us a limited time to carry out equally essential tasks which have arisen from the forward march of practically all humanity towards a better life, which as yet remains undefined in all its aspirations and complexities. But the prime components of future progress in the building of a free society every-

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where, whether in highly industrialized or in under developed countries, are inherent in the basic desire of all for a better human environment. It is in this area that our profession has found traditionally its major justification for its distinctive service and in which it must assume in the future expanded responsibilities for the effective control and the creative forming of human environment involving the fundamental resources of air, water, and land. The great problems in this area, both present and extrapolated to the future, are undoubtedly associated with new developments in the following fields:

1. Properly integrated use of land for purposes of the individual, the community, the industry
2. Transportation and physical communication systems
3. Conservation and development of water resources

Before dealing with the last of these in more detail a few remarks are in order on the general characteristics of these problem areas in relation to our profession. However diverse the technical problems may be in the areas listed they all have in common an increasing dependence on policy decided by large private and public agencies. This is by reason of the increasing magnitude and scope of many of the projects, where important economic and social factors and the commitment of major portions of the public income often outweigh the technical questions.

By contrast, the civil engineer has too often abdicated his responsibility in this area and has looked for professional rewards from the purely technical side of solutions. He has overlooked, however, that often thereby the very conception of the system or of the structures in question becomes narrowed down or frozen by other influences and that he has little part in the broad creative aspects of the structures he designs. Thus the public also has come to see in him increasingly the technician only, to whom certain tasks may be assigned, but it does not depend on him any more for originating and stimulating new aspects of its environment. This trend must be reversed if civil engineering wants to lay continued claims on being a profession; professional stature comes from exercise of responsibility, knowledge and insight in all the forces shaping major engineering works. The civil engineering profession must recapture a sense of mission with a look to the future and this involves a conscious effort to define its future tasks, to keep educating itself, to promote the advance of knowledge through research and the free exchange of ideas, to take seriously the education of its younger members to professional attitudes and requirements.

In an attempt to focus attention on the future tasks before the profession, I have tried in the following to outline briefly only that field with which I can claim some acquaitance. I am sure that the others mentioned above offer similar opportunities for reflection on the present role of civil engineering and for a view of what we might strive for in the future. This area, to which I must restrict myself by leaning and by experience is much in the news today both in the national and in the international scene and is comprised by the commonly accepted term of Water Resources Development.

Water Resources—General Remarks

That water is needed for almost all forms of human activity is saying the obvious. It is also obvious apparently to most that it is always available at relatively little cost. What has not been obvious to most of the public, however, is that in the future the available supplies will greatly and rapidly shrink in relation to the growing needs of the economy and of the population. It is only in recent times that experts have pointed to this trend in alarm and that in more recent months the representatives of the people under Senator R. S. Kerr of Oklahoma have assembled a wealth of information on the future critical needs for water for our own nation. In many foreign countries these needs are now the most pressing, and great investments are made to expand opportunities for growth through sometimes giant development schemes. Indeed in recent years we have witnessed serious political repercussions in our relationships with other nations as a consequence of our unwillingness to cooperate in such schemes. It may be surmised that our technical assessment of such needs is often inadequate in this area as well as our political appreciation for the vital aspirations of these countries.

It is apparent that water resources development is not only a technical problem area, but that it involves a wide array of economic, social and political questions as well.

What Are Water Resources?

The water resources of a continent, country, or region comprise potentially all sources of water, whether available as moisture in the atmosphere, as rain appearing on the surface, as water available by access to shore lines of inland bodies of water or of the seas, as groundwater in subsurface storage basins or subterranean streams. Thus the sciences involved in the study of water in these forms are the geophysical sciences of meteorolgy, geography, geodesy, hydrology, geology, coastal oceanography, or some of their many branches.

What Water Resources Are Available?

Only a small portion of the potential water sources is readily available, much of the water is lost by transpiration and evaporation, by seepage and by discharge into salt water basins. Immediately problems of water conservation arise for agricultural, sanitary, and hydraulic engineers, through ponding and stream regulation works, detention in major reservoirs, control of plant cover, as far as the water yield is concerned.

Water Quality and Reclamation

Scientists and engineers have been waging an ever intensified struggle to produce or to reestablish the water qualities desirable for various human pursuits. Contaminants are inherent in the natural as well as in the human environment; sediments must be removed, human and industrial wastes must be reduced to acceptable levels including particularly wastes from nuclear plants. Water must be processed by chemical and biological means for prime or secondary use by industrial plants and again before it is released into natural drainage systems.

Specific Water Use and Control

The major portion of normal runoff is controlled by means of retention basins and is put to multi-purpose use. The most important phases of utilization in addition to water supply for human and industrial consumption are power, irrigation, and navigation. Additionally major benefits are attained with respect to flood control, recreation, and the preservation of wild life.

Engineering of Water Resources

The provision of adequate water supplies of desirable quality for all the uses listed has been traditionally the field of sanitary and of hydraulic engineers with various degrees of specialization; in basic research concerned with the water cycle and with the flow phenomena in all types of hydraulic structures; in the application of the various sciences to water control in quantity and quality; in the design and construction of all structures and finally in the operational, administrative, and overall planning phases of the water economy. Needless to say with the ever increasing demands, engineering processes, and evaluations have become increasingly complex and require an ever broadening base in practically all the pertinent sciences.

FUTURE OUTLOOK

While in our country the present use of water is estimated at not more than 10% of the average rainfall, the use in percentages of readily available supply with all of our conservation and control measures is over 50% and the estimated use will exceed this available and fixed supply by 1980. In figures quoted by the U.S.G.S. the present rate of use of 300 billion gallons will double by 1980, as compared to a readily available supply of slightly over 500 billion gallons.

It is apparent that extraordinary efforts will be called for within our lifetime and that these efforts must include the application of new scientific ideas and technical measures, as well as new attitudes in the economic and social spheres of water resources development. While in other countries of comparative population density and industrial growth, the problems are similar, the nature of the water problem in the so-called under-developed countries varies all the way from more critical conditions to requirements of more effective control and utilization of abundant supplies. The potential benefits from comprehensive plans for a wide complex of problems such as these are unquestionably most substantial for all countries.

RESEARCH FRONTIERS IN WATER RESOURCES

The Report of the Select Committee on National Water Resources of the U. S. Senate estimates that up to 54 billion dollars will have to be spent in the U. S. alone on just two facets of the water problem in the next 20 years, provision of adequate quantity through storage and of acceptable quality by human and industrial waste collection and treatment. This does not include and provide for watershed protection, flood control, navigation, hydro-power, irrigation, plant and wild life conservation, and recreational use. This report also puts major emphasis on river basin planning by the states with the help of the U. S. Government and on the importance of research and development for new sources and for optimum and economic use of existing sources. It also calls attention to research coordination and better mobilization of public opinion in support of water resources activities. There can be no doubt, that a serious and concerted attack on this problem is imminent in view of the detailed and urgent needs set forth in this report. It is not intended to elaborate here greatly on this phase, but it will rather be attempted to list a few of the new developments in the field to illustrate the scope of new ideas and the activities needed in various fields to develop new technologies.

WATER AND THE ATMOSPHERE

In this area might be listed the development and the appraisal of methods to increase the precipitation rates particularly in more arid regions. This includes hydro-meteorologic forecasting and weather modifications. The control of water losses to the atmosphere is another phase of conservation including measures to reduce evaporation from surfaces of reservoirs by chemicals or shielding, the change of vegetative covers near reservoirs and streams and over other land areas from water wasting to water conserving types, the protection of exposed ground surfaces against evaporation by proper shaping or by application of artificial mulches. The possibility may also be considered of extracting water directly from the moisture of the air through use of excess heat power.

SURFACE WATER CONTROL

Once water is available on the ground, problems arise with either direct retention or proper channeling or drainage to further use. Flood control should embody both phases and raises questions on forecasting, sediment transport and avoidance of erosion, maintenance of water quality before and after human use, reduction or promotion of seepage into the ground. For example, the interruption of river flow through a succession of reservoirs causes sediment deposition in these basins with gradual reduction of the capacity, excessive erosion and "digging in" of the intermediate channel sections, conversion of water quality with respect to oxygen content and temperature, consequences with regard to survival of wild life, such as of the salmon in the Columbia River. Inherent, therefore, in all these problems are basic studies not only of hydrology, but of soil physics, chemistry and biology in relation to hydraulic conservation measures and structures. New problems arise with respect to water supply, waste disposal, waste water salvage in relation to the modified flow regime, as well as through the tremendous increase in the recreational use of ponded waters.

Irrigation waters have become essential to food production, but have in turn raised many problems for efficient channeling, maintenance, excessive seepage and evaporation. Chemicals are being developed to promote the precipitation of suspended sediments, to seal the channel walls and to restrict the growth of weeds. As an example of one consequence of irrigation practice with which our laboratory has come into contact, the propagation of schistosomiasis, a wide spread tropical and subtropical disease, is traceable to various types of snails as carriers of the parasitic worms. A study of the possible hydraulic factors detrimental to snail survival is therefore underway.

GROUNDWATER RESOURCES

Groundwater has been tapped since time immemorial as a ready source of supply, yet our knowledge with respect to availability, quality and flow behavior is still quite inadequate. In addition to studies correlating the properties of soil and of granular materials to the flow of water, quantitative determinations of groundwater basins and of their supply are needed to assess its potential for use. Techniques for recharging of groundwater basins with treated waste water or excess surface water during floods are in need of further development. Closely related to this problem is the prevention of salt water intrusion into coastal aquifers and the study of the diffusion of salt water into fresh water basins as the result of excessive pumping.

OCEAN WATER RESOURCES

The asset of ocean beaches and shore lines is a vital one to the economy of many states. Many beaches have been irreparably damaged by ill-advised structures and artificial inlets and expensive measures are necessary to preserve others. Most of these consequences stem from the difficulty of predicting the interrelation of wave characteristics and littoral sediment transport. Suitable structures are yet to be developed to cause the minimum damage to the natural equilibrium or to enhance the marginal value of some coastal areas. Physical oceanography in the shallow coastal areas is, therefore, an important field of research in order that offshore zones as well as shore lines and tidal estuaries may be made to serve their important role economically in the human environment. The awareness of efforts needed in this field as a part of the large research effort contemplated and recommended to the nation in oceanography generally must be promoted.

Major emphasis is given to publicly supported research efforts in desalting of ocean waters and of brackish waters. With major population centers along tidal shores and the rapidly decreasing fresh water supplies, this emphasis is fully justified. New methods are still desired and present methods are still subject to major changes in the applied technology. Scientific and economic factors are closely related and the impact of a major breakthrough in this area on the entire complex of water resources remains without engineering evaluation.

Finally, with improved technology, the use of tidal energy and of wave energy may be mentioned. Several projects of tidal power development have been carried to the point of detailed design and at least one of these is under construction in France. Wave power remains as yet unexploited, except for recently reported experiments in Russia.

WATER UTILIZATION

While many of the basic problems related to water resources development were discussed in the preceding sections in reference to the needs for water, an independent complex of problems arises as the result of the multiple use made of water after its supply has been provided and improved. Only a small portion of the water resources is developed for a single purpose such as for a water supply for human and industrial use, for hydro-power or for navigation. The norm for future development will be increasingly the multi-purpose development of entire watershed areas and river basins. While this problem has been with us for some time, it is believed that major contributions to further progress are now possible through the vast potential of modern methods of data collection and processing, of systems analysis by high speed computers, and thus of ready exploration of many complex situations for optimum overall function.

This applies also to the operational phases of the large systems of reservoirs such as exist in the Tennessee Valley, along the Missouri and the Columbia Rivers, which are to be adjusted continuously in accordance with the various demands of navigation, flood control, irrigation, and hydro-power. Hydro-power is the form most flexible and almost instantaneously responsive with respect to demand and load rejection in an electric power network. It is increasingly being used also for energy storage through pump-storage arrangements, thus increasing the overall efficiency of heat power—water power systems. Thus new techniques will certainly be under development in the future in new machinery as well as in new methods of integration of heat and water power.

New methods of water measurements may finally be mentioned here, by ultrasonic and electromagnetic means as well as by diffusion of radioactive materials; instrumentation based on novel applications of the physics of sound, electromagnetism, heat and radioactivity will certainly provide more convenient means of analysis and control and will make possible research in areas of fluid flow so far not accessible with conventional methods.

The Impact of Radioactive Materials

A special section is justified here in view of the increasing use of atomic power and of the large production of atomic fission and fusion materials, which have already had a major impact on water resources use and planning. The importance of the proper disposal of waste materials resulting from the atomic industry is already indicated by the extensive research activities in the Sanitary Engineering field. This area is the most critical one with respect to the further development of atomic plants since serious problems have already been encountered with the retention and eventual diffusion of contaminated waters into surface streams and subterranean aquifers. Disposal methods depending on the coastal zones of the oceans also are open to question in the future. Thus the area of engineering research in atomic waste treatment is constantly expanding and carries a major responsibility for the maintenance of proper human environment.

On the favorable side of the atomic products with regard to the water resources must be mentioned, however, the new perspective added to research in this field by use of these products as tracer materials. Studies of sediment transport with such tracers are still in an initial state of development, but already the important potential has been proved for such methods. Diffusion rates under complex natural conditions have been determined in estuary flow, the transport of silt has been followed in coastal areas as well as the movement of sand along shore lines under wave attack. Quantitative techniques remain to be investigated in addition to the established qualitative approaches. Subterranean aquifers may be explored with respect to flow characteristics and sources, seepage and permeability may be defined on a major scale, the mechanics of erosion and of sediment deposition may be unraveled on land surfaces, in natural streams and in large bodies of water. The employment of radioactive tracers for water measurement will certainly increase with new techniques acceptable to technical personnel and public alike, as the need for more quantitative knowledge develops for more effective planning and the more sophisticated use of water resources.

ECONOMIC AND SOCIAL PROBLEMS

Economic and social problems raised through availability and development of water resources are of such wide scope and have so many direct and indirect consequences that it is obviously impossible to touch upon more than just a few examples for the purpose of this discussion. Thus complex areas and situations picked at random must serve here for illustration with only their overall significance being mentioned rather than their detailed structure. It is hoped that the background of these major problems is familiar enough to permit the immediate phrasing of some questions in this area of the discussion without further reference to technical problems.

NATIONAL ASPECTS OF WATER RESOURCES RESEARCH

The economic justification of project development has always received primary attention of the planning engineer. His analysis in this area, however, must necessarily be focused an extrapolation of readily foreseeable economic and social consequences rather than the intangibles of the future environment he helps to create. Many questions arise in this area of planning with respect to the latter aspects and as to whether it is possible to establish by research on the economic and social history of major projects certain guide lines for future planning.

What were the detailed effects, for example, of the TVA multipurpose development on the economy and the social patterns of the specific area it serves, as well as the benefits or disadvantages accruing to other areas of the country from this development? Were the costs properly allocated to the various advantages derived, such as navigation, flood control, power and general reclamation and conservation? Opinions on this vary as widely as the initial commitment of the experts to either private or public interest. What are the answers on the basis of objective evaluation by social scientists and economists in the light of regional as well as of national aspirations for future reference?

California has just voted a large commitment of its income to the large scale provision of water for multiple purposes to cope with its future economic and population growth. In the past, the development of the Imperial Valley and of the metropolitan area around Los Angeles were possible only through water from the Colorado River. Controversies, still partly unresolved, arose over the rights of other states to this portion of the river flow. Have these developments been the most beneficial from hindsight as compared to original anticipated results? What economic lessons may be derived for future developments? What will be the economic impact of the new water plan, conceived on a gigantic scale, on the community both local and national? What general principles with respect to suitable water rights and water law have been derived?

Many legal and economic questions arise with the development of almost any major water resource. A new Delaware River water compact has just been concluded after more than 20 years of separate ways by the four riparian states. Does this give a pattern of organization of more general interest and what were the political and economic factors involved in the final arrangement?

Finally what will be the eventual modes and rights of water utilization by individuals, communities, states, and federal agencies? What restrictions must be imposed in the future on water use and how can the public be reeducated to accept them? This includes also the planning of land use in major flood plains, and along river banks where in many cases today effective engineering measures taken to protect the public against major floods have been obviated by land development contrary to the requirements of the flood control schemes.

INTERNATIONAL ASPECTS OF WATER RESOURCES DEVELOPMENT

There is little question that water resources development is one of the primary keys to the expanding economies of the under developed countries and continents. Major projects in this area have caught the imagination of the peoples and have come to be accepted as the focal points of their hopes for a better life. The United States has traditionally almost contributed to the planning of such projects through its private and public technical agencies and to the education of technical scientific personnel in its own universities and governmental organizations. This effort will undoubtedly be expanded. While so far, however, this type of intellectual export was based primarily on the experiences with our own resources program and on the personnel which grew with it, our contributions in this area will have to be based on knowledge of foreign conditions and water resources and are to be measured increasingly against performance in the foreign field. Hence an effective "feedback" of experiences and a primary acquaintance with foreign water resources in relation to economic and social factors must be built into training and technical aid programs. Factors of universal validity and those restricted to specific conditions must be discerned to arrive at suitable solutions on projects for specific environments. Needless to say, accepted principles of economic analysis of projects valid in the U. S. with certain predictable technical performance criteria may have to be modified materially in conformance to different social and economic standards.

This discussion would not be complete without referring also to the political problems involved, when the water resources schemes contemplated involve the interests of several nations. In this connection may be mentioned the water dispute between India and Pakistan, the Columbia River Compact between the U. S. and Canada as well as the St. Lawrence Waterway and Power Development, the Colorado River Agreement between Mexico and the U. S., the conflict of interest between Egypt and the Sudan over the Assuan project, the Israel-Jordan dispute over the water of the Jordan. Many other such problems are still in the offing, which can either be resolved in a friendly "give and take" based on indisputable technical facts or be dragged out interminably to the detriment of the economies on either side.

Many international agreements on joint exploitation of water resources have a long history of successful operation. The Rhine is a recognized international waterway of benefit to all riparian nations. The Suez and the Panama Canals, while administered by single nations, are open to international transit and exist only through the mutual interest of all maritime nations. The Kiel Canal and the Bosporus are other examples.

International law is still in development, however, with respect to the exploitation of offshore resources, as witness the various fishery disputes in the Gulf of Mexico, Alaska, off Iceland, Chile and in waters near Russian possessions in the Pacific. As technology develops for the exploitation of mineral resources farther offshore additional problems will certainly arise, in which previous international agreements may provide helpful precedents. This is true also with respect to the problem already imminent of atomic waste disposal in the deep parts of the oceans.

In the next decades many of the arid regions around the ocean shores will certainly call on salt water conversion for the development of agricultural production. Should not some attention be given now with respect to the most economical use of such waters, the available power sources and the population trends. What will be the economic impact and the social consequences of a major breakthrough in this area of research, particularly for the nations presently incapable of economic expansion for lack of water. Perhaps this may seem farfetched at present but it certainly challenges the imagination and upon detailed investigation may not appear as impractical as it now seems. Rapid implementation of suitable technologies in this area would certainly be a major contribution to the promotion of a better environment for many nations, with favorable political consequences.

CONCLUSION

This broad sweep of problems in water resources development through education, research, and planning shows that new and even fascinating demands upon our professional competences are ahead of us. I am sure that an equal challenge may be outlined in other fields, in urban redevelopment and in the planning of new communities, in new structural concepts and use of new materials, in transportation in urban and wider regions, in short, in conceiving and providing new dimensions to the future human environment.

There is no crisis in civil engineering as far as problems are concerned. The question of today is, does our profession have the internal strength to rise to these great opportunities and to assume the imaginative leadership, which the public rightfully expects from a profession. The question is not, does the public fail to recognize us as civil engineers, but rather, do the civil engineers provide the professional service the public must have for the betterment of its physical environment. We must be willing to accelerate our pace in advancing new knowledge, in adapting to practice the modern developments of our times. We must do better in encouraging and stimulating the young in our lines and in furthering their careers. We must build for the future with renewed determination.

Let me close with the words of a great engineer, who always thought of the future and thus had a great part in shaping it, Charles F. Kettering (of General Motors Corporation):

> *"Nothing ever built arose to touch the skies unless some man dreamed that it should, some man believed that it could, and some man willed that it must."*

ENGINEERING GEOLOGY ON THE JOB AND IN THE CLASSROOM

By KARL TERZAGHI,* *Honorary Member*

INTRODUCTION

In this paper the term "engineering geology" is applied exclusively to that small fraction of the sum total of geological knowledge which the civil engineer engaged in design and construction of subsurface structures such as foundations and tunnels must possess in order to practice his profession competently. Until a few decades ago the civil engineer knew enough about geology if he was thoroughly familiar with the meaning of the terms which are used by professional geologists in their reports on the results of their site explorations. At that stage every elementary course in general geology served this purpose, although at some institutions the course was given the name "Engineering Geology."

At the present time a course in engineering geology also has the important function of focusing the attention of the engineer on the nature and importance of the uncertainties involved in the design of foundations and tunnel supports on the basis of test results and computation. This new requirement grew out of the development of soil mechanics and calls for increased emphasis on the engineering properties of sediments and the engineering significance of patterns of stratification. The need for such emphasis is not yet recognized by many teachers of the subject and the consequences become apparent in what the writer has called misuse of soil mechanics (Terzaghi 1961).

The statements contained in this paper are based on the writer's personal experience covering a period of more than half a century. His experience record includes the practice of engineering geology on four continents and the teaching of engineering geology at four different institutions of higher learning in Europe and the United States. These activities have given him manifold opportunities to become acquainted with the essential requirements to be satisfied by the gelogical training of candidates for subsurface engineering and with the consequences of the deficiencies of current methods of teaching engineering geology.

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THE "MISSING LINK" IN ENGINEERING GEOLOGY

At the turn of the century design of foundations and earthworks was based almost entirely on empirical rules and equations. The numerical values in the empirical equations contained constants which depended only on the type of material underlying the site. On routine jobs the classification of the materials was performed by the engineer or the boring foreman, and on important projects the services of a professional geologist were retained.

After graduation in 1906 the writer joined a contracting firm in the capacity of a junior engineer. During the following five years he had unusual opportunities to find out that the empirical rules then in use in the field of subsurface engineering were appallingly unreliable. Detrimental settlements and the failure of foundations, though common, always came as a surprise and no rational explanations were available.

Since the performance of a foundation obviously depends on the properties of the materials supporting the foundation, the writer arrived at what appeared to be the logical conclusion that our incapacity to predict the performance of foundations grows out of inadequate knowledge of the relationship between the data furnished by the geologist and the subsequent performance. Therefore, starting in 1912, he concentrated for several years on an attempt to discover these relationships by correlating observed unsatisfactory performances with the data contained in the geological reports describing the site. Some of these reports were as complete as one could wish. Yet no relationships of general validity could be discovered.

Not until 1918 did the writer begin to realize that his quest was doomed to failure, because the materials encountered at the investigated sites were designated by both geologists and engineers by terms which, from an engineering point of view, have no well-defined meaning. For instance, sand was described in both the geological and technical reports as course, medium or fine. However the engineering properties of each one of these three categories of sand can be extremely different depending on whether the sand is loose or dense, and this essential property commonly received no attention. In order to correlate the performance of a foundation with the geological characteristics of a site it is necessary to describe the materials underlying the foundation on the basis of their significant engineering properties and not of their visual characteristics.

The significant engineering properties of soils, such as compressibility and permeability, can be determined only by tests and the required experimental procedures did not yet exist. Therefore, in 1918 the writer decided to develop them himself. As his knowledge of the performance of soils in the laboratory increased, he supplemented his experimental investigations by theoretical ones. These were intended to disclose the relationship between the performance of the soils in the laboratory, such as the gradual consolidation of clay samples under constant load, and the consolidation of clay strata in the field acted upon by the weight of superimposed structures. A summary of all the findings, published in 1925 (Terzaghi 1925), initiated the subsequent development of soil mechanics.

AIM AND SCOPE OF INSTRUCTION IN ENGINEERING GEOLOGY

As a result of the development of soil mechanics many of the problems of foundation, earthwork and tunnel engineering can now be solved by mathematical procedures. However, the computations are inevitably based on more or less radically simplifying assumptions concerning the mechanical properties of the natural ground and the importance of the errors involved in these assumptions depends almost entirely on geological factors. The consequences of ignoring or underestimating the importance of these errors can be serious indeed. Therefore a course in engineering geology with adequate emphasis on these aspects of the subject is as essential for students who intend to practice in subsurface engineering as a course in applied mathematics is essential for all future civil engineers. Aim and scope of courses of both categories are determined by similar professional considerations. These are as follows:

In the field of applied mathematics every civil engineer should know enough to be able to solve most of the problems he is likely to encounter in structural design without any assistance. The required mathematical knowledge is very elementary compared to that of a professional mathematician. Nevertheless it serves its purpose, because it enables the engineer to formulate his problems in mathematical terms and to get, in exceptional cases, the solution of his equations from a professional mathematician without any engineering training.

In the realm of subsurface engineering, every practitioner should know enough about geology to recognize at an early stage of subsurface exploration at a given site those aspects of the subsurface conditions, such as the pattern of stratification of sediments or shear zones in rock, which require consideration from a geological point of view, and to determine their significant characteristics without any assistance. He should also be able to recognize those geological features at a given site which can adequately be investigated only by a professional geologist. These sites include for instance those of long rock tunnels. When dealing with such sites he should know enough about geology to be able to formulate his questions in such a manner that they can be answered by a geologist without any engineering training and he should be able to take full advantage of the information he gets.

The problems of river hydraulics, sedimentation in reservoirs, coastal erosion and public water supply can be solved competently only by engineers who have specialized in these fields. Therefore the geological information required for practicing in these fields is beyond the scope of a course in engineering geology for civil engineers who wish to prepare themselves for foundation, earthwork and tunnel engineering. Under the following headings the present status of the role of geology in subsurface engineering will be described.

ROLE OF ENGINEERING GEOLOGY IN EARTHWORK ENGINEERING

The theoretical methods of soil mechanics combined with the improved techniques of subsoil exploration promised at the outset to eliminate the necessity for depending on geological information in the realm of earthwork engineering. It appeared that it was only a question of time until all the problems in this field, like those in steel and concrete design, could be solved by theoretical methods using constants the value of which can be determined by laboratory tests. Hence for several years the writer maintained his contacts with geology only on account of his deep interest in this science. However, as his experience in the practical application of soil mechanics broadened, he realized more and more the inevitable uncertainties associated with the results of even the most conscientious subsurface explorations. The nature and importance of these uncertainties depend entirely on the geological characteristics of the sites. Therefore, geology returned to the orbit of the writer's professional interests, but this time primarily as a source of information concerning those geological details of the subsoil, such as the pattern of stratification, which are not disclosed by the boring records but may have an important influence on the degree of reliability of the performance forecast. Consequently as the years went by, he developed the following general procedure in dealing with the problems of earthwork engineering.

The first step in the investigation of a new site always consists in collecting all the information regarding the geological characteristics of the site from resident geologists and from publications, supplemented by a painstaking personal examination of the site. The interpretation of the findings is based on his previously acquired knowledge of the engineering properties of the products of the various geological processes such as glaciation or stream action. The knowledge was obtained with the assistance of soil mechanics by correlating the processes with the information obtained by experimental determination of the engineering properties of their products and with the pattern of stratification of the resulting deposits.

The results of the geological inquiry combined with the general layout for the project determine the maximum depth at which the seat of potential trouble may be located. Depending on the nature of the project this seat may consist of one or more strata with high compressibility, of an aquifer containing water under high artesian pressure, of avenues for the escape of water out of a reservoir to be formed by a dam, and the like.

The next step is to estimate the position of the horizontal and vertical boundaries of the seat of potential trouble by means of exploratory borings and the pattern of stratification of the deposits involved. If the seat of potential difficulties is relatively homogeneous, an elaborate subsoil exploration involving the testing of numerous undisturbed samples may be justified. On the basis of the results of the laboratory tests, a settlement or stability computation can be made. On the other hand, if the much commoner condition of nonhomogeneity is encountered, very little can be gained by accumulating test data in addition to those which disclosed the absence of homogeneity. In this case the third step is an evaluation of the inevitable uncertainties involved in the interpretation of the results of the subsoil exploration. Design has then to be based on the most unfavorable possibilities compatible with the known features of the subsoil conditions. However if the project permits modification of the design during construction, this uneconomical method can be avoided by adopting an observational procedure which requires that the gaps in the initial knowledge of the significant properties of the subsoil be closed by observations during construction. A more detailed description of the procedure supplemented by typical case records can be found in the writer's paper on "Past and Future of Applied Soil Mechanics," contained in this issue of the JOURNAL. (Terzaghi 1961)

ROLE OF ENGINEERING GEOLOGY IN ROCK ENGINEERING

In the field of rock engineering the most important and difficult problems are those encountered in connection with the selection of the alignment of long rock tunnels and the design of the tunnel supports. In the nineteenth century this information was obtained exclusively by extrapolation from the results of a conventional geological survey, by coreborings along those sections of the tunnel which were located at a relatively shallow depth and by observations in the pilot tunnels during construction. These investigations were invariably carried out by experienced geologists. However it was taken for granted by almost everybody that the findings of the geologist leave a wide margin for interpretation. Occasionally, the lack of more reliable information led to serious catastrophes involving the loss of many human lives and of important capital investments.

In the twentieth century increasingly extensive use has been made of geophysical methods of rock exploration, with spectacular successes in the fields of mining and petroleum engineering. Therefore during the last decades these methods were also introduced into the field of civil engineering. Experience shows that the most promising methods are the electrical and the seismic method. So far, the commonest application of these methods has been the topographic survey of buried rock surfaces. In 1928 the writer witnessed a remarkably successful operation of this kind in New England. Since then he has missed no opportunity to recommend the procedure to his clients as a supplement to the site exploration by borings, and he used it at damsites in Sweden, Italy, Canada and California. In every instance the survey was performed by the most experienced specialist in the region and the choice of method was left to him. Nevertheless, none of these surveys produced any useful results. The attempt to determine location and dimensions of cavities in limestone terranes by geophysical methods was also unsuccessful. Therefore the prospects of getting adequate information regarding rock defects by geophysical methods are rather remote.

During the last decade attempts have been made to provide a rational basis for rock engineering. The results are known as rock mechanics. In order to visualize the possible effects of these developments on the functions of engineering geology the nature of the seats of potential trouble in rock engineering must be considered.

Perfectly sound rock of any kind is commonly as homogeneous a material from an engineering point of view as artificial construction materials such as concrete. Its significant properties can be determined by laboratory tests. Engineering difficulties are encountered only in defective rock such as jointed rock, in shear zones or in zones of rock which is weakened by chemical alterations. Rock defects are commonly local defects. This condition excludes the application of rock mechanics to the design of tunnel supports in long and deep-seated rock tunnels unless a pilot tunnel is driven in advance of the main heading. However the information which can be obtained at the heading of a pilot tunnel concerning the strength characteristics of the rock is far less conclusive than the results of laboratory tests on undisturbed samples of a cohesive soil. Therefore it is doubtful whether anything could be gained by a refinement of the existing crude and semi-empirical rules for estimating the rock load on tunnel supports (Terzaghi 1946).

The seat of rock defects can be located in advance of construction only within the depth to which the rock can be explored by boring at a tolerable expense. Therefore the field for the potential practical application of theoretical procedures in rock mechanics is limited primarily to the investigation of the site for concrete gravity or arch dams, underground powerhouses and the evaluation of the degree of stability of high slopes on rock.

The borings disclose the location of the defective portions of the rock, but defective rocks from which undisturbed samples can be recovered are very rare. This fact eliminates the most important source of information on which the performance forecast in the realm of earthwork engineering is based. Between the borings the degree of continuity of the defective portions of the rock is unknown.

If the defective rock is located downstream from a storage dam failure may occur on account of the seepage pressures exerted by the percolating water on the walls of the open joints on its path from the reservoir towards the exposed rock surface. Recently the Malpasset Dam in France failed on account of such pressures in the rock supporting the left abutment. However, the intensity and the mechanical consequences of these pressures in the rock underlying the exposed rock surface depend entirely on the variations of the permeability of the jointed rock in the direction of the flow of the water between the reservoir and the potential surface of failure and these variations cannot be ascertained by any practicable means. (Terzaghi 1929). The evaluation of the hazards resulting from these uncertainties belongs in the domain of the engineer.

These facts lead to the following conclusions. In foundation and earthwork engineering the radical change in the function of engineering geology grew out of the development of procedures which permitted the determination of the engineering properties of potentially troublesome subsurface materials by laboratory tests and their definition by numerical values. In rock engineering this cannot yet be done. Therefore in this domain the function of engineering geology remains for the time being the same as it was in the nineteenth century. It consists in providing the engineer with a detailed description of the rock defects in the terms used by the geologist, and the hazards involved in the design on the basis of this inadequate information cannot be significantly reduced. It is then the duty of the engineer to recognize the most unfavorable possibilities compatible with this information and to adapt his decisions to his findings. In order to reduce the expenditure involved in this uneconomical procedure, observational methods should be used wherever conditions permit. This has been done ever since the first tunnel was driven through badly defective rock.

The legitimate use of theoretical procedures in rock engineering is still limited to those rare instances in which the rock strata can be considered without serious error to consist of statistically homogeneous materials. These instances include the computation of the stresses above large cavities in perfectly sound rock (Terzaghi and Richart 1952), the evaluation of the factor of safety of high slopes on closely and uniformly jointed rock and, under favorable conditions, the estimate of the magnitude and distribution of the surface subsidence above mine workings and brine fields. In connection with all the other problems of rock engineering significant new contributions to our knowledge can at the present time be expected only from well-documented case records containing the results of observations concerning the time-rate of the increase of the pressure of defective rock and the gradual deformation of rock at constant stress under field conditions. Data of this kind would considerably increase our capacity to interpret geological information in engineering terms.

ENGINEERING GEOLOGY AS A PROFESSION

During the last decade the writer has repeatedly been asked what training he would recommend to a student who wants to become an engineering geologist. In order to answer this question it is necessary to consider the services which are expected from members of this profession. In this connection distinction must be made between rock- and earthwork engineering.

The engineer engaged in rock engineering requests a painstaking geological survey of the site and a description in geological terms of the defective rock encountered in the drillholes and later on during construction. Both services were flawlessly rendered in the second half of the nineteenth century by the geologists who were attached to the construction organizations engaged in driving the first long railroad tunnels in the Alps such as the St. Gotthard tunnel. Most of the geological information they possessed can be found in any good textbook on geology published at the beginning of our century, although such a text would be utterly obsolete from the geologist's point of view. Hence all the important discoveries in the realm of rock geology which have been made since that time add very little to what the engineering geologist can use. However, the application of the elementary knowledge to the location and mapping of the essential geological features of a rock formation in the field requires years of training under the guidance of an experienced field geologist. Therefore, satisfactory results can be expected only from experienced professional geologists.

In earthwork engineering the principal function of engineering geology consists in providing the engineer with the geological information required to estimate the degree of uncertainty associated with the results of subsoil exploration by boring and testing. To make such an estimate calls for the mastery[1] of the mechanics and hydraulics of the processes which determine the performance of the subsoil. The geological knowledge required for making the estimate can be acquired by the civil engineer in the classroom, supplemented by reading and field observations later in life. On the other hand

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[1] In connection with the term "mastery" attention is called to the following fact. In every field of training the student passes in succession through two stages. In the first stage he "knows" his subject. He can apply the rules which he has learned but he does not notice it if he makes a mistake. In the second stage he "masters" his subject. Once he has arrived at that stage he can ask somebody else to apply the rules, but he sees at a glance whether or not the results are correct. In engineering mere knowledge can be dangerous.

the geologist may know the mechanics and hydraulics of subsurface processes, but he is not likely to have an opportunity to master these subjects. Hence in the realm of earthwork engineering the instances are rare in which an engineering problem requires the services of an engineering geologist, provided the civil engineer is adequately trained.

Considering these facts it appears that the principal requirements for performing the services of an engineering geologist are mastery of the techniques of geological mapping and a sound knowledge of those rather elementary geological facts which are needed for expertly practicing these techniques. He should also take a course in engineering geology for civil engineers in order to learn to distinguish between those geological facts which are significant from an engineer's point of view and those which are irrelevant. As long as the geological training of civil engineers is as inadequate as it is at the present time, an elementary knowledge of foundation engineering and soil mechanics is also desirable.

The role of engineering in the practice of engineering geology has been described by one of the most distinguished members of this profession (Berkey 1929) as follows:

"The position of a geologist is analogous to that of an advisor to the court. He may formulate the opinion but never render the final decision. . . . It is his duty to discover, warn, explain, without assuming the particular responsibility of the engineer who has to design the structure and determine how to meet all the conditions presented and stand forth as the man responsible for the project."

This statement is still as valid as it was when it was made, thirty years ago. The more an engineering geologist knows about engineering the better he is qualified to detect the weak spots in a project resulting from geological conditions which had escaped the attention of the engineer. He will also be in a better position to find out where significant additional information could be obtained by supplementary borings. However, under no circumstances should he try, or be asked, to tell the engineer how to proceed.

The function of the engineering geologist in large organizations has been aptly described by Burwell and Roberts (1950) and by Banks (1961).

PEDAGOGICAL ASPECTS OF ENGINEERING GEOLOGY

It has been stated at the outset of this article that one of the principal functions of a course in engineering geology consist in focusing the attention of the student on the difference between the mechanical and hydraulic properties of the natural ground and those which he assigns to them on the basis of the results of subsoil exploration before he starts making his estimates and performance forecasts. This difference can be insignificant, considerable or very important, depending on the geological characteristics of the site. However, in order to be of any practical value, the knowledge of this difference must be combined with the capacity to adapt procedures and decisions to the possible consequence of the prevailing uncertainties. Unfortunately this capacity, like that for creative writing, cannot be developed by systematic training. It can only be stimulated by representative examples and some students may never acquire it. On account of this fact, combined with the educational background of the civil engineer, the teaching of the subject involves considerable pedagogical difficulties.

In practically every one of his courses the student in civil engineering is supplied with information, such as the equations required for computing the stresses in the members of framed structures, which can be applied to the solution of practical problems almost without any original thinking on his part. By contrast, in engineering geology no such direct application of the information supplied to the student is practicable. Therefore the writer was not surprised to find that most courses in engineering geology fail to make any lasting impression on the students. As soon as the student has left his alma mater he again becomes blissfully unaware of the uncertainties involved in the assumptions on which his computations in subsurface engineering are based, and the consequences are deplorable indeed. (Terzaghi 1961).

On account of these conditions a course in engineering geology should include not only an account of the influence of geological factors on the uncertainties associated with the interpretation of the results of subsurface exploration. The students should also be informed on the influence of these factors on the program of subsoil exploration and on design. In order to satisfy these requirements the teacher should have at least a reading acquaintance with applied soil mechanics and subsurface engineering, in addition to adequate geological training. Extensive practical experience can hardly be expected. Therefore some of the lectures should be given by visiting lecturers with suitable qualifications. These men should be asked to present case records illustrating the role of geological reasoning in the design of dams or foundations at sites where the geological conditions preclude a reliable performance forecast. Examples of such cases can be found in the writer's companion paper. (Terzaghi 1961).

If it is intended to cover the subject in a one-semester course, a course in elementary physical geology should be a pre-requisite. If practicable the course should be preceded by a lecture and laboratory course in soil mechanics. The Appendix to this paper can be used as a guide for preparing a layout of the course. It is based on the writer's experience in teaching the subject. In connection with this layout it should be considered that very few if any engineering curricula in the United States include a course on tunnel engineering. Yet the performance of soils and rocks in tunnels depends to a large extent on the method of tunnel driving. Therefore every course in engineering geology should include several lectures on tunneling.

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APPENDIX

LAYOUT FOR A ONE-SEMESTER COURSE (40 ONE-HOUR LECTURES) IN ENGINEERING GEOLOGY

The following layout is based on the results of many years of experimentation in the classroom. Because it is assumed that the students are already familiar with the elements of physical geology, the lectures are strictly devoted to the engineering aspects of the various geological facts. Nevertheless 40 lectures are barely enough to cover the topics assigned to the course. Furthermore for pedagogical reasons, the reading assignments should be strictly limited to publications which contain both reliable and significant information concerning the topics covered by the course and these are still very scarce. Therefore none of the lectures can satisfactorily be replaced by a reading period. However the course ought to be supplemented by occasional field trips to sites, preferably open excavations or tunnels, where the teacher has an opportunity to show the students geological details of engineering significance. It should also be supplemented by classroom instruction in the preparation of geological sections from geological maps.

A. ENGINEERING ASPECTS OF GEOLOGICAL TOPICS

(Numerals in parentheses indicate number of lecture hours.)

Igneous activities, sedimentary rocks, metamorphism and alteration (3)
Significant Physical Properties of Sound Rock (2)
Rock Defects (2)
Slow Crustal Movements (1)
Earthquakes (2)
Engineering Properties of Products of Rock Weathering and Sedimentation (2)
Engineering Aspects of Weathering (1)
Slope Movements (1)
River Erosion and River Deposits (3)
Glacial Deposits and Permafrost (2)
Windlaid Deposits (1)
Tidal phenomena, tidal gages and shore deposits (2)
Groundwater (2)
Karst Phenomena (1)
Regional Subsidence (2)

B. GEOLOGICAL ASPECTS OF ENGINEERING OPERATIONS

Subsurface Exploration (3)
Open Cuts in Rock and Rock Tunneling (2)
Soft Ground Tunneling (1)
Curing of Landslides (1)
Drainage Operations (2)
Grouting Operations (2)
Chemical problems—toxic gases, deleterious waters (2)

PAST AND FUTURE OF APPLIED SOIL MECHANICS

By Karl Terzaghi,* *Honorary Member*

(Presented at the annual convention of the ASCE, held in Boston at which Professor Terzaghi was presented the first copy of the book "From Theory to Practice in Soil Mechanics.")

INTRODUCTION

I MUST confess that I have already had a sneak preview of the volume and I was much impressed by the splendid organization of the contents and the esthetic qualities of the book. Hence I wish to express my gratitude to the editors as well as to the publishers, John Wiley and Sons, Inc., for their successful effort to present the essence of the fruits of my labors in a beautiful nutshell.

Once I have published a paper I hardly look at it again, because my thoughts and efforts are already concentrated on other subjects and these are scattered over a large area. Therefore perusing this volume was quite an experience for me. It revealed the history of my gropings through the dark to a clearer understanding of the essential requirements of practicing my chosen profession. Since every one of us has to pass through a painful period of trial and error before he becomes a master in his own house, the story of my own endeavors may be a source of encouragement to those who are still at the foot of the slope.

THE OLD CODE

When I began the ascent, at the beginning of this century, I was equipped with a set of axioms which were then believed, at least by those who taught them to a flock of eager students, to be gospel truth. These were the rules:

(a) At a given load per unit of area the settlement of a spread footing is independent of the area covered by the footing.

(b) The settlement of a pile foundation is equal to the settlement of an individual pile under the same load per pile.

(c) The constants in Coulomb's equation for the shearing resistance of cohesive soils are independent of time.

(d) The earth pressure on lateral supports is independent of the amount of lateral yield of the support.

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(e) The influence of the presence of water on the shearing resistance of soils is caused by the lubricating effect of the water.

Design in earthwork engineering on the basis of these rules required practically no mental effort, but the results were often disappointing. This I found out at an early stage of my professional career, whereupon I started to worry. The following are a few of the incidents which attracted my attention.

In 1907, I designed my first footing foundation, using the rules and procedures which I had been taught; the walls of the structure cracked badly and the case was brought before the courts. Fortunately the misbehavior of the foundation was classified, also in accordance with the prevalent conceptions of those days, as an "Act of God."

In the same year my employer designed and built a low concrete diversion dam with concrete apron in a narrow rock valley in the eastern Alps. The dam was founded on a thick stratum of sand and gravel containing scattered boulders. The textbooks informed their readers that structures of this kind should be protected against piping failure by driving a row of sheetpiles along both the upstream and downstream edge of the base of the structure, but nothing was said about the required depth of penetration. Therefore the piles were simply driven to refusal which was met at some points at a rather shallow depth. When the reservoir was filled for the first time the structure failed by piping and the remnants were buried in sand and gravel. Fortunately this accident too was ascribed by the arbitrator to an "Act of God."

In 1913 the subsoil exploration for the design of the foundations of the new M.I.T. buildings in Cambridge, Mass., was started. According to a very competent geological report prepared by Prof. W. O. Crosby, the bedrock was encountered at a depth of 120 to 135 ft below the ground surface. The materials overlying the bedrock are in succession: boulder clay with a thickness of a few feet to 25 or 30 ft, blue clay with a normal thickness of 80 to 100 ft, glacial sand and gravel from zero to 35 ft, and loose overburden with a thickness of about 20 ft. It was decided to establish the foundations wherever possible on point-bearing piles driven to refusal into the glacial gravel overlying the clay. Where no such refusal could be obtained, the piles were driven through the gravel to a maximum of 50 ft into the clay.

In order to obtain what was expected to be a rational basis for the design of the pile foundation, 80 test piles were driven and on 38 of them complete pile loading tests were performed (Maine and Sawtelle, 1918). On the basis of the test results 13 rather elaborate rules were set up for the purpose of adapting the length of the piles to the variable subsoil conditions and the design load per pile was selected in such a manner that the anticipated settlement would nowhere exceed 1/16 inch.

At the time when these tests were performed, I was associated with the design and construction of pile foundations in Portland, Ore. I already had vague misgivings concerning the soundness of the current procedures regarding the design of such foundations, but I would still have been unable to raise any valid objections to the procedures which were used at the site of M.I.T. In 1925, when I gave the first lectures on soil mechanics on the American continent at M.I.T., the settlement of the library dome of the Institute had passed the 7-inch mark, and was still increasing at a rate of about ½ inch per year, but all I could do at that stage was to offer a rational explanation of what had happened.

Equally unsatisfactory were the conditions at the beginning of the twentieth century in the field of earth-dam design and construction. Earth dams with a height up to 70 ft had already been built in India before the beginning of the Christian Era. During the second half of the 19th century the record height of earth dams gradually increased to 125 ft, but there is hardly one volume of Engineering News or Engineering Record published in those days which does not contain an account of the failure of at least one of these structures. Therefore, as late as 1901 the Board of Consultants of the New York Water Supply arrived at the conclusion that the construction of an earth dam with a height of more than 70 ft cannot be considered advisable. This conclusion was fully justified because at the time when it was made there were not even any generally accepted empirical rules for the design and construction of earth dams. Some engineers believed that the upstream slope of homogeneous earth dams should be flatter than the downstream slope and others felt equally justified in making it steeper. Some engineers insisted on compacting the dam construction materials whereas others insisted that the material should be placed by dumping it into shallow pools to be maintained on the working surface.

The reason for the absence of agreement between engineers concerning the design and construction of earth dams is quite obvious. The relationship between water content, degree of compaction and shearing resistance was still unknown. Hence it was impossible to estimate the factor of safety of the slopes of earth dams with respect to sliding. As a consequence, if a dam failed, it was also impracticable to determine the cause of the failure and the failure was classified as an "Act of God."

One of the most impressive manifestations of the rudimentary state of our knowledge in this field in relatively recent times is a published account of the performance of three homogeneous earth dams in the former Netherlands Indies (Van Es, 1933). Two of the dams failed during construction, when the fill had attained a height of about 33 ft whereas the third one was successfully completed to its final height of 100 ft and has remained stable ever since. The difference between the performance of these dams was ascribed to a difference between the index properties of the construction materials and the placement water content did not receive any attention.

SOIL MECHANICS TAKES OVER

As I grew older, the number and size of our projects increased at an accelerated rate whereupon the shortcomings of the traditional procedures in the field of earthwork design became more and more conspicuous. Therefore, in different parts of the world, and almost simultaneously, attempts were made to discover and to eliminate the weak spots in the "Old Code" of the earthwork engineer. In January 1913 the American Society of Civil Engineers appointed a "Special Committee to Codify Present Practice on the Bearing Value of Soils", and in December of the same year the "Geotechnical Commission of the Swedish State Railways" started to develop procedures for determining the factor of safety with respect to sliding of the numerous slopes located along the railroads of southern Sweden. I remained unaware of these developments for a whole decade from 1914 to 1924, on account of the consequences of the first world war. In the meantime, in 1918, I embarked on a quest of my own at American Robert College near Istanbul in Turkey, where I was located at the end of the war. I started at what I considered the root of the evil, the absence of reliable information concerning the physical properties of soils.

I had neither research funds nor a laboratory at my disposal, no private practice, and a very modest salary. Therefore everything had to be improvised at minimum expense. My first earth-pressure apparatus was made out of empty cigar boxes and my loading devices consisted of empty oil cans filled with sand and attached to the ends of wooden beams with homemade knife-edge support (Fig. 1). The drying ovens (Fig. 2) were heated with kerosene lamps and if a lamp started to smoke during the night all the samples were spoiled. Many constituents of my equipment were picked up on the college dump. Hence the prospects for success were not very bright. However in the pioneering stage of any development an individual has very much better prospects for success than a committee because at that stage the development requires years of concentrated and undivided attention. Therefore, it is not surprising that the impetus for a radical revision of the basic principles of earthwork engineering

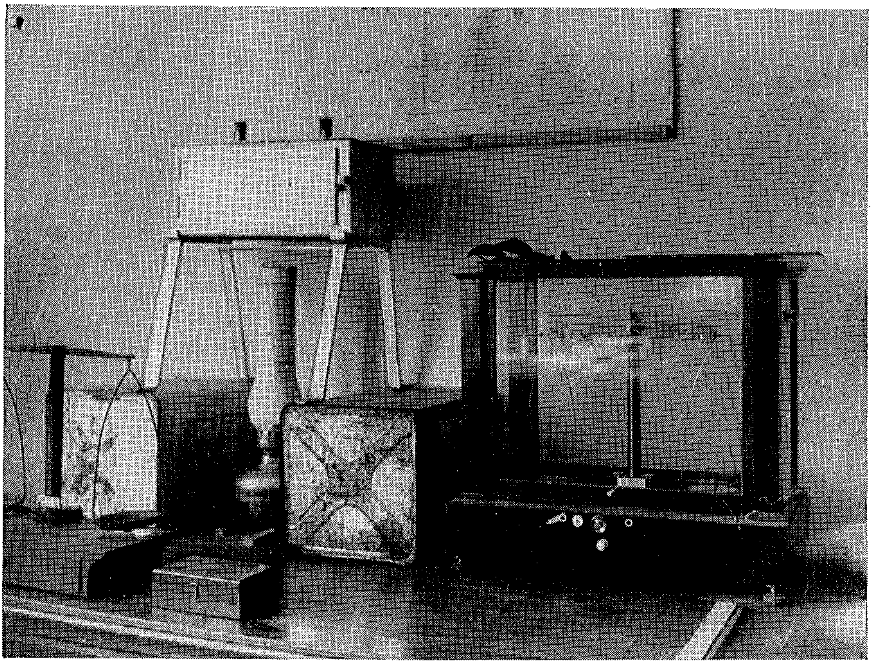

FIGURE 1.—THE AUTHOR'S DRYING OVEN IN HIS LABORATORY AT ROBERT COLLEGE (1918-1925).

was given by the publication of my single-handed findings in 1925 and not by that of committee reports.

The most important immediate effect of the publication of my test results was the formation of a vacuum created by the demonstration that the old rules for earthwork and foundation design were fallacious. In order to fill the vacancy it became necessary to develop new techniques for sampling and testing, and for measuring earth and pore-water pressures under field conditions. Simultaneously our knowledge of the physical properties of soils increased rapidly. The shearing resistance of cohesive soils is an impressive example. In 1910 it was believed by everybody, including myself, that the relationship between normal pressure and shearing resistance on plane sections through cohesive soils could be expressed adequately by Coulomb's equation which was derived in the eighteenth century. During recent years the same relationship constituted the sole topic of three important conferences, one of which was held in England and two in the United States. Yet our knowledge of this relationship is still in a state of development. The practical value of the results

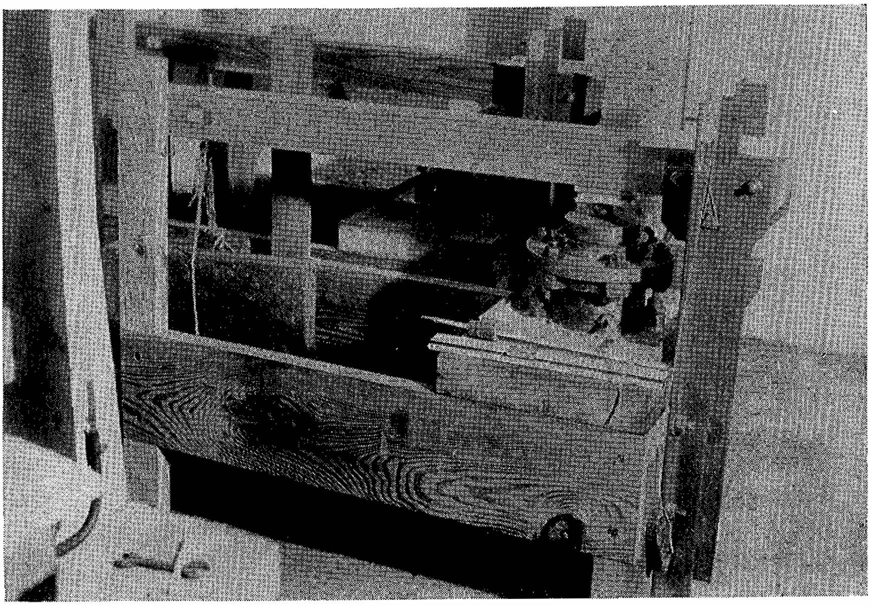

FIGURE 2.—THE AUTHOR'S CONSOLIDATION APPARATUS AT ROBERT COLLEGE (1920).

of some of the investigations concerning shearing resistance is not yet apparent, but once a practical problem requires relevant information it may be too late to get it. Hence, there is no doubt that the fruits of these patient efforts will some day serve a vital purpose.

SATISFACTORY PERFORMANCE FORECASTS

The practical application of soil mechanics started with attempts to compute the magnitude, distribution, and rate of settlement of structures located above homogeneous clay strata on the basis of the results of soil tests performed in the laboratory, and the results were very encouraging. Equally satisfactory were the forecasts of the performance of homogeneous fills made out of earth prepared and compacted in accordance with rigorous specifications. Earth dams with complete cutoffs, resting on a sand or gravel foundation, belong to this category.

As the years passed, the number of publications describing satisfactory performance forecasts increased steadily and left no more doubt that the fundamental principles of soil mechanics were sound. For this reason extensive subsoil exploration supplemented by soil testing is now compulsory in connection with all earthwork and foundation projects involving important capital investment, and every report dealing with the design of an earth dam is expected to contain a computation of the factor of safety of the slopes with respect to sliding. A departure from this practice is considered negligent. Nevertheless some engineers who have had the benefit of training in soil mechanics and take advantage of modern procedures of sampling and testing occasionally arrive at very erroneous conclusions concerning the future performance of the structures they design. In France, this fact has led to what a French engineer has described as "The Crisis of Confidence in Soil Mechanics (Lossier 1958)."

The examination of case records disclosing flagrant misjudgment in spite of apparently adequate subsoil exploration commonly leads to the following conclusions: Either the designer did not notice significant gaps in the information furnished by the subsurface exploration, or else the sampling and testing operations were carried out by inexperienced personnel. In both instances the structure was designed on the basis of faulty assumptions. Such a procedure can only be classified as a misuse of soil mechanics and leads inevitably to disappointing results. The psychological and technical circumstances responsible for such misuse are examined in the next section.

MISUSE OF SOIL MECHANICS

After the beginning of the 19th century, when applied mathematics successfully invaded the field of structural engineering, members of the engineering profession were taught, and even began to believe, that everything can be computed provided our knowledge of the strength of materials is far enough advanced. On the basis of this knowledge they were able to solve most of their problems without any guesswork, while sitting at their desks, and without being compelled to worry about the assumptions. Hence when soil mechanics came into existence it was expected that it would serve the same function in connection with earthwork engineering as applied mechanics does in bridge design.

These expectations were further encouraged by the fact that only successful performance forecasts in the field of earthwork engineering were considered worthy of publication, and in many articles no clear distinction was made between true forecast and forecast by hindsight. Case records of this category diverted attention from the important fact that there are many situations in which the geological conditions preclude the possibility of making an accurate performance forecast. Furthermore, many engineers do not yet realize the importance of the errors which may grow out of inadequate methods of testing. They believe that they have done their duty if they send their samples to the most conveniently located testing laboratory and accept the results at face value. Finally, many engineers do not yet realize that every boring record leaves a wide margin for interpretation unless the geological conditions are exceptionally simple.

Boring records and the report on the results of the soil tests are passed on to the designer, who constructs a physical soil profile on the basis of these data, replaces it by a simplified one, which may involve quite radical modifications, and starts to compute. In many instances the designer has not even seen the site and does not suspect that the constructed soil profile may have little resemblance to the real one. He may also consider it unnecessary to call on the testing laboratory and get first-hand information concerning the equipment which was used in making the soil tests and the qualifications of the technicians who made the tests. Hence it is not surprising that the application of soil mechanics to practical problems occasionally leads to very disappointing results.

When I published the book *Erdbaumechanik* I was not yet aware of the uncertainties associated with the interpretation of boring records and my methods of testing were still very primitive. Therefore I myself passed through a period during which my activities could be described as "misuse of soil mechanics." I am still shocked when I remember the bold conclusions which I drew in those days from the results of tests performed with primitive apparatus on an inadequate number of disturbed samples. However, this period was of short duration. It came to an end soon after 1926 when I settled in the United States. Here I had for the first time an opportunity to examine exposures of sedimentary deposits of very different origin and to secure closely spaced samples from individual drill holes. Through the results of the investigations of my disciples, foremost among them A. Casagrande, I also became acquainted with the importance of the influence of the methods of sampling and testing on the test results. Thus, as time went on and my consulting activities spread over larger and larger areas, I realized that sedimentary deposits which an erratic pattern of stratification are far more common than I had previously suspected and that these patterns preclude accurate performance forecasts.

At the outset these findings gave me a profound shock and I felt temporarily deeply discouraged. However, it did not take long to discover that the capacity for making reasonably accurate forecasts of the performance of structures resting on practically homogeneous strata with large horizontal dimensions is by no means the most important benefit which I derived from the results of my early investigations. Far more important, though much less spectacular are the practical consequences of the newly acquired insight into the mechanics of the processes of settlement and the influence of the porewater pressures on shearing resistance. Equipped with that insight I was now in a position to determine in advance of construction the type and location of potential sources of trouble in the subsoil and to proceed in accordance with the findings.

In order to take full advantage of this possibility, it is sufficient, first, to carry at least one exploratory boring at the site of each new structure to the maximum depth to which the proposed structure may have a significant influence on the stress conditions in the subsoil; and second, to determine the significant properties of the weak strata encountered in the borings by soil tests on representative samples or, in cohesionless strata, by penetration tests in the drill holes. If the subsoil exploration shows that the pattern of stratification of the troublesome strata is erratic, a reasonably accurate performance forecast is impracticable, but for many projects, also superfluous, because the design of a structure cannot be adapted to intricate details of the stratification of the subsoil. What counts under such circumstances are the variations of the average properties of the troublesome strata in horizontal directions. The following case records illustrate the procedure.

FOUNDATION DESIGN

Case 1. A tall and heavy office building was to be built on a thick stratum of sand and gravel, overlain by a 12-foot layer of loose, artificial fill. Along three lines crossing the site the building was located above very thick walls resting on the gravel, which were the remnants of an old fortress. The architects intended to establish the structure directly on the old walls and between them to support it on point-bearing concrete piles driven into the gravel. The settlement of the test piles under the service load assigned to them was 1/16 in. Since the architects had grown up under the influence of the "Old Code," they considered their foundation design satisfactory.

When I was requested to review the project I called attention to the fact that the settlement of the pile-supported portion of the structure would be many times greater than the settlement of the test pile, at equal load per pile, whereas the settlement of the old foundation walls would be negligible. Therefore I requested that the top part of the old walls should be replaced by a compressible cushion and bridged. After the structure was completed it was found that it had settled by amounts up to two inches. Hence, if part of the structure had rested on the old walls it would have been defaced by cracks. A quantitative performance forecast was neither practicable nor essential.

Case 2. On some projects, designers have been misled by the results of exploratory borings which were not deep enough. This possibility is illustrated by the following incident. During the second world war I was requested to review the project for an industrial development on the west coast of North America. The site was located at the shore of a drowned valley, a few feet below high-tide level. It had been explored by borings to a maximum depth of 80 ft. The boring records showed that the subsoil consists of sand, fine silty sand, and clay, resting at a depth of about 70 ft on dense sand and gravel. Therefore, it was intended to cover the site to an elevation of a few feet above high-tide level with a dredged fill and then to establish the factory buildings on point-bearing piles to be driven to refusal into the gravel stratum. (Terzaghi 1953)

Clay strata contained in drowned valley deposits are commonly normally consolidated and some of them are very compressible. On account of the large horizontal dimensions of the area to be covered by the hydraulic fill the weight of the fill alone can produce very important settlement due to the consolidation of clay strata of this kind located at a depth of far more than 80 ft. Therefore I requested that additional holes should be drilled to greater depth. At a depth of about 100 ft these new borings encountered a thick layer of highly compressible clay with a water content close to the liquid limit and an erratic pattern of stratification. A rough estimate based on the results of a few consolidation tests on representative samples showed that the combined weight of the fill and the superimposed loads would have produced unequal settlement of the pile-supported structures by more than one foot and the cost of carrying the foundation to a depth below the base of the newly discovered clay stratum would have been prohibitive. On account of these conditions the site had to be abandoned and the plant was built at another one located close to the outer boundary of the drowned valley deposits, although the new site was much less desirable from the manufacturer's point of view. At a later date an oil tank was erected on point-bearing piles close to the original site and it settled more than one foot.

Before soil mechanics came into existence, a loading test on a pile at the original site would have convinced the designer that the proposed foundation was satisfactory and the subsequent settlement of the structures would have been a surprise, as it was at the site of M.I.T.

Case 3. Another instructive example of the services rendered by soil mechanics without accurate performance forecast is the stabilization of a track with a length of about 1200 ft supporting one end of an ore bridge in a steel plant in eastern Ohio (Terzaghi and Peck, 1957). During the period 1933 to 1952 the cumulative outward movement of the track support was locally 4.5 ft, associated with a heave up to 3 ft (Fig. 3). At times the movement was so large and abrupt as to threaten the continuity of the operation of the plant. Borings showed that the track was underlain by the following strata, enumerated from top to bottom: (1) a 10-ft layer of very stiff clay, (2) a 10-ft layer of saturated, slightly plastic inorganic silt (rock flour), and (3) glacial till. Even between loading seasons the pore water in the silt stratum was locally under a moderate artesian pressure and during the loading seasons, the pore water pressure increased. The displacement of the track support was caused by inadequate shearing resistance of the subsoil along planes located in the silt.

FIGURE 3.—DISPLACEMENT OF ORE BRIDGE TRACK BY HEAVE AND LATERAL MOVEMENT.

It was originally intended to stabilize the track by a combination of vertical and batter piles. A simple computation showed that this procedure was impracticable because locally both sets of piles would have been lifted off their seat. However, the knowledge of the fact disclosed by soil mechanics that the shearing resistance of silt, like that of any other soil, depends on the effective and not on the total stress on the surface of sliding made it possible to stabilize the track without underpinning it. The desired result was accomplished by the installation of a 700-ft row of well points at 5-ft centers driven into the silt stratum. The header was attached to a vacuum pump which operates every year during the entire loading season. The quantity of water pumped out of the saturated silt stratum is not more than about 2 gal./min. Yet the movements have stopped.

USE OF FLOW NETS

If we face the problem of evaluating the degree of stability of the slopes of an earth dam resting on a permeable deposit, and not provided with a deep cut off, or of a slope on natural ground located downstream from a storage dam, it is necessary to determine the seepage pressures which act on the subsoil in the direction of the flow of the percolating water. This procedure requires the construction of a flow net. In order to construct the flow net the zone of seepage must be divided into several layers each of which is assumed to be perfectly homogeneous and it must be further assumed that the pattern of seepage on all vertical planes in the direction of the flow is identical.

This procedure is universally used, but quite often the constructed flow net has very little resemblance to the real pattern of seepage disclosed by the readings on observation wells after the reservoir is filled. Such discrepancies have even been encountered at the site of dams on strata which are fairly uniformly compressible throughout. Nevertheless I have found that the construction of flow nets can be of inestimable value even at sites where they cannot be expected to furnish any information concerning the real pattern of seepage. This statement is illustrated by Case 4.

Case 4. Fig. 4 is a vertical section across an erratically stratified glacial deposit through which water percolates out of a reservoir over the crest of a buried rock ridge towards a steep slope downstream from the left abutment of a concrete gravity dam. On account of the presence of gradual transitions between some of the strata, of sharp, steep boundaries between others, and of the difficulties involved in distinguishing between till with little cohesion and silty sand and gravel, an accurate interpretation of the results of the boring and sampling operations was impracticable and the constructed soil profile, Fig. 4, cannot be expected to disclose more than the salient features of the stratification. The details are unknown.

Many years before construction was started a large diameter watermain had been installed at mid-height of the slope between the valley floor and the reservoir level and the portion located downstream from the dam formed part of the new water-supply system. Because leakage from the reservoir would compromise the stability of the slope it was decided to intercept the seepage by means of a grout curtain established on or close to the crest of the rock ridge extending from the left abutment of the concrete dam to a distance of about 550 ft. from the abutment. (See Fig. 4). The grout holes with a depth up to 200 ft. below reservoir level were drilled along a single line and spaced 10 ft. Through the holes a quantity of about 1100 tons of cement was injected into the sediments.

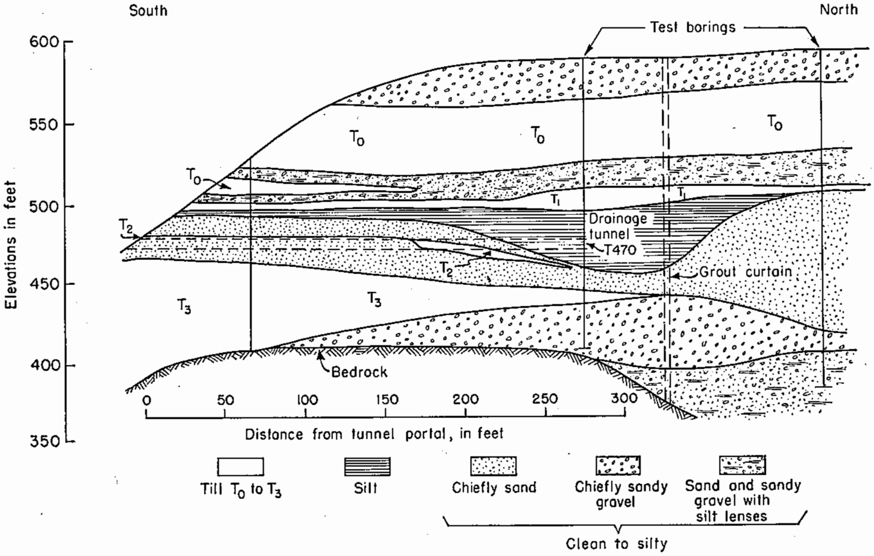

FIGURE 4.—GEOLOGICAL SECTION THROUGH GLACIAL AND FLUVIO-GLACIAL DEPOSITS. The deposits occupy the space between a grout cutoff and a steep slope downstream from left abutment of a concrete gravity dam.

While the reservoir was being filled for the first time, new springs came out of the slope and local subsidence was observed on the road located along the water main. Therefore, it was decided to supplement the grout curtain by drainage provisions in those portions of the slope which gave rise to concern. However, in order to design a drainage system it is necessary to know, at least in a general way, the variations in the permeability of the subsoil between the submerged area and the slope where the water comes out of the ground. At the site under consideration these variations could not even be roughly estimated, and it was not known whether or not the grout curtain served its purpose.

In order to fill the broad gaps in our knowledge 25 observation wells were installed within a distance of 1000 ft. from the left abutment. Some of these are located upstream from the grout curtain and most of them between the grout curtain and the slope where the springs came out. Several of these wells contain multiple piezometers, with perforated sections at different elevations. Observations on these wells showed that the piezometric elevation along vertical lines varies within wide limits. In order to use the observational data as a source of information concerning the variations in the permeability of the sediments acted upon by seepage pressures, the measured piezometric elevations were compared to the values which would have been obtained if the permeability of the subsoil did not change in the direction of the flow. These values can be determined by constructing an ideal flow net on adequate but radically simplifying assumptions.

The assumptions required for constructing the ideal flow net at the site illustrated by Fig. 4 were based on the following facts. The boring records have shown that the permeability of the subsoil below an elevation of about 470 is very low compared to the average permeability of the strata above it. Therefore it was assumed that the base of the ideal substitute for the real pervious layer is located at el. 470. The water in the reservoir does not rise to an elevation of more than about 80 ft. above this base. To a distance of about 700 ft. upstream from the left abutment the submerged outcrops of the pervious deposits are covered with a practically impervious blanket. Therefore the flow lines start upstream from that blanket and the average length of the path of percolation towards the area where the water comes out of the ground is about 1500 ft. Because this distance is very great compared to the vertical distance of 80 ft. between the base of the pervious layer and the water level in the reservoir it was further assumed that all the flow lines are located in horizontal planes. On these assumptions the flow net shown in Fig. 5*a* was obtained. However it was doubtful whether the grout

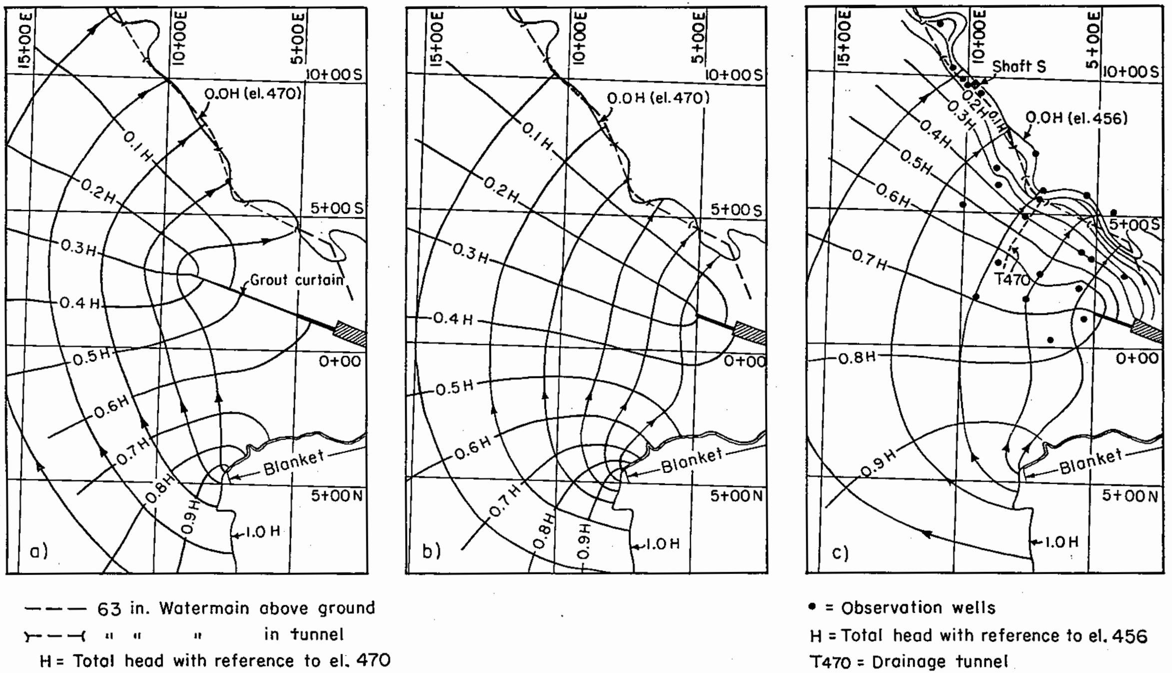

FIGURE 5.—FLOW NETS REPRESENTING PATTERN OF SEEPAGE FROM A RESERVOIR TOWARDS THE SLOPE SHOWN IN FIGURE 4.

(a) Theoretical flow net constructed on the assumption that the grout curtain is fully effective; (b) as before, but grout curtain entirely ineffective; (c) flow net constructed on the basis of the results of readings on observation wells before drains *T*470 and *S* were installed.

curtain shown in the diagram really served its purpose. Therefore a second flow net, Fig. 5*b*, was constructed on the assumption that the grout curtain does not exist. Fig. 5*c* represents approximately the real pattern of seepage. It was obtained by adapting the ideal flow nets to the results of the readings on the observation wells.

By comparing the real pattern of seepage with the ideal patterns it can be seen that the real flow lines cross the site occupied by the grout curtain as if the curtain did not exist. Thus the flow nets lead to the important conclusion that the grout curtain is entirely ineffective. On account of these conditions it became evident that the stability of the slope supporting the vulnerable water main can be assured only by adequate drainage.

The slope was drained by means of a tunnel, *T*470, at an elevation of about 470, at a distance of about 600 ft. downstream from the left abutment and a shaft *S* with collar elevation 470 at a distance of about 1200 ft. downstream from the left abutment, supplemented by horizontal pipe drains. The location of *T*470 and *S* is shown in Figs. 5 and 6 and that of *T*470 also appears in Fig. 4.

On account of the erratic pattern of stratification of the glacial deposit, the installation of the drains called for continuous experimentation in the field and there were various unanticipated incidents which required modification of the original design. Yet the final result was remarkably satisfactory. It is illustrated by Fig. 6. The plain curves are curves of equal lowering of the elevation of the total piezometric head *H* produced by drainage into shaft *S* and the dash curves represent the effect of drainage towards tunnel *T*470 with reference to the elevations which prevailed before the drains were installed. On account of successful drainage combined with local trimming operations the factor of safety of the slope is now higher than it was before the dam was built and the reservoir filled.

OBSERVATIONAL PROCEDURES

The case records presented under the heading "Foundation Design" showed that many problems of earthwork engineering can be solved without a detailed and accurate forecast of performance. Satisfactory solutions of such problems can be obtained on the basis of our knowledge of the fundamental principles of soil mechanics supplemented by a moderate amount of boring and testing. However there are others in which the geological conditions preclude the pos-

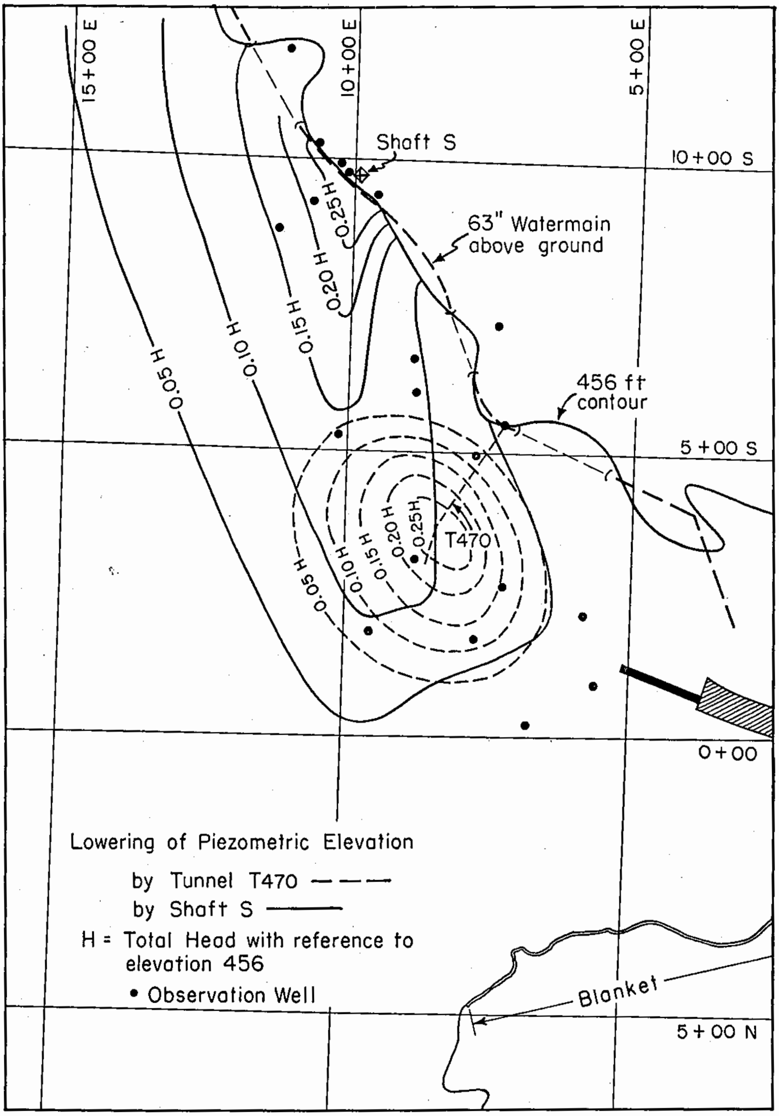

Figure 6.—Observed Lowering of the Piezometric Levels Produced by Drainage.

The figures, such as 0.2 H, inscribed in the contour lines indicate the decrease of the total head, *H,* produced by the drainage tunnels *T*470 and *S.*

sibility of securing in advance of construction all the essential information required for adequate design. If this condition prevails, sound engineering calls for design on the basis of the most unfavorable assumptions compatible with the results of the subsoil explorations. This rather uneconomical procedure can be avoided only on the condition that the project permits modifications in the design during or after construction in accordance with the results of significant observational data which are secured after construction is started. This can be called an "observational procedure."

Case 5. The observational procedure was used for the first time on a large scale in earthwork engineering between 1912 and 1922 by the administration of the Swedish State Railroads in connection with an investigation of the stability of slopes on glacial deposits, chiefly glacial clays, in railway cuts in southern Sweden, for the purpose of reducing the alarming frequency of catastrophic slides. Statens Järnvägars, 1922).

At an early stage of the investigations Petterson (1916) invented the graphical procedure known as the *Swedish circle method* by means of which the factor of safety of slopes with respect to sliding can be computed if the shearing resistance *s* of the slope-forming material is known. The Swedish investigators estimated the value *s* on the basis of the results of field penetration tests in bore holes, combined with cone pentration tests on remolded samples in the laboratory.

Using this procedure and refining the technique for determining the value *s*, the slopes subject to investigation were classified as safe, possibly dangerous, and obviously dangerous. The dangerous slopes were eliminated by relocation of the line or radical trimming of the slopes. The slopes of dubious stability were rather numerous and a cost estimate showed that the cost of adequately increasing their stability would be prohibitive. Therefore, in these cuts the railroad administration installed automatic devices which stopped oncoming trains at some distance from the ends of the cuts, as soon as the road bed started to move with reference to the firm base of the weak strata.

Case 6. As our knowledge of the significant properties of natural soil deposits increased with intensified subsoil exploration, the field of application of observational procedures expanded. I had for the first time an opportunity to use such a procedure in 1926 in connection with the water-supply reservoir formed by the Granville

Dam near Westfield, Mass. (Terzaghi, 1929). A wedge-shaped portion of the submerged slope adjacent to the right abutment of this homogeneous earth-dam is located on the outcrop of a fluvio-glacial deposit. This deposit occupies the entire space between the reservoir and an adjacent valley at a distance of about 3000 ft. from the reservoir. The surface of the deposit is dotted with kettle holes.

In order to get adequate information concerning the permeability of the strata exposed on the submerged portion of the slope I tested a great number of samples which were recovered from test shafts on profiles I to VIII, Fig. 7. The results of the permeability tests are represented in the figure by the horizontal dimension of the shaded blocks. It can be seen that the coefficient of permeability *k* of the materials exposed on the slope ranges between a value close to zero and 0.13 cm/sec. The corresponding variations of *k* in the direction of the flow lines between the submerged slope and their points of exit is unknown.

If it is assumed that *k* has the same value throughout the length of a flowline as it has at the submerged slope, a seepage computation shows that the loss of water from the reservoir would be excessive. It could be prevented only by covering the outcrops of the pervious strata on the reservoir slope shown in Fig. 7 with an impervious blanket. However, the geological origin of the sediments exposed on the slope suggested that the deposit had a lenticular pattern of stratification. On account of the discontinuity of the most pervious portions the real average permeability of such deposits may be very low. Therefore it was decided to postpone the decision concerning the construction of the blanket until the reservoir was filled for the first time and the loss of water from the reservoir could be measured. Observations after the reservoir had been filled showed clearly that the blanket was unnecessary.

If the estimate of the cost of the blanket had shown that the construction of the blanket would make the project economically unsound, I would have proposed the same procedure, but at the same time I would have notified the owners that the project involved calculated risk, and left it to them to decide whether or not they were willing to take it. Many lawsuits have grown out of the failure of the designers to recognize the existence of such risks or to notify their clients about them.

Case 7. Fig. 8 illustrates the application of observational pro-

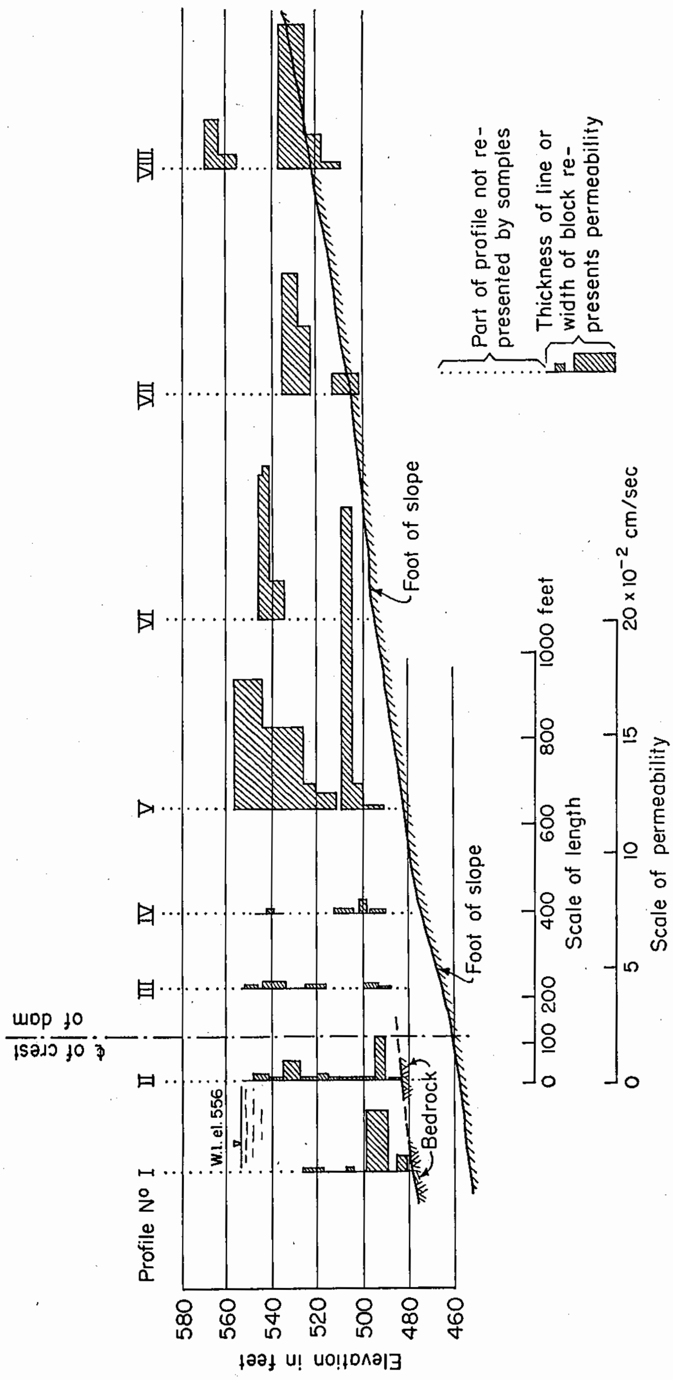

FIGURE 7.—FRONT ELEVATION OF SUBMERGED SLOPE IN WATER SUPPLY RESERVOIR.
The diagram shows the variations in the permeability of the fluvio-glacial sediments exposed on the slope.

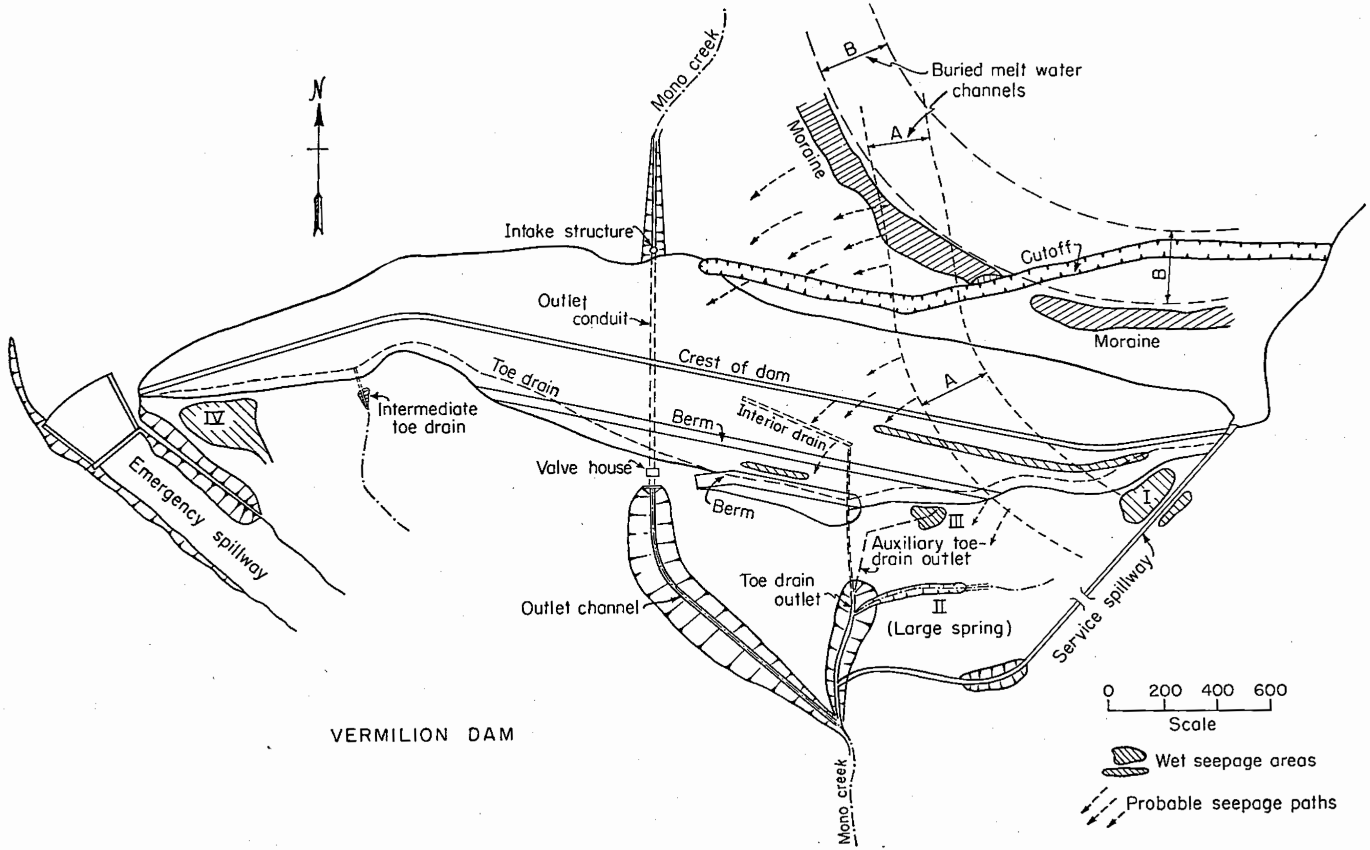

FIGURE 8.—PLAN OF VERMILION DAM.

In areas I to IV, water came out of the ground while the reservoir was being filled for the first time.

cedures to the design of the Vermilion Dam in Southern California with a height of about 150 ft. (Terzaghi and Leps, 1959). The dam shown in the figure rests on thick fluvio-glacial deposits with an erratic pattern of stratification. The deposit was laid down between crescent-shaped terminal moraines and rests on granite at a depth up to 200 ft.

The cost of a cutoff extending down to bedrock would have been prohibitive and a reliable forecast of the pattern of seepage through the fluvio-glacial deposits was impracticable. Yet this pattern has a decisive influence on the factor of safety of the downstream slope with respect to sliding and on the layout of the drainage system required to eliminate the danger of piping. On the other hand, during construction and the first filling of the reservoir, it was possible to detect significant differences between design assumptions and reality, before it was too late to prevent detrimental consequences. Owing to this circumstance, the original design could be based on what appeared to be the most probable, and not the most unfavorable, assumptions compatible with the results of the subsoil exploration. The observational devices required for checking on the original design assumptions were installed as construction proceeded.

The original project included an incomplete cutoff to a maximum depth of 20 ft. on the bottom of the reservoir as shown in Fig. 8, an impervious blanket covering the area between the cutoff and the base of the impervious core of the dam (not shown in the figure), and the installation of a row of bleeder wells (not shown in the figure) with a maximum depth of 100 ft., located along the center-line of the bottom of the toe drain. While the dam was being built all the observation wells were installed which were needed to get a clearer picture of the real pattern of seepage, as in Case 4 illustrated by Figs. 4 to 6. Furthermore filter material was stockpiled on the valley floor downstream from the dam. As the reservoir was being filled it was found that the piezometric elevations were almost everywhere below the elevations which were assumed to prevail when the stability computation for the downstream slope was made. At the one spot where they were slightly higher some additional fill material was added to the slope. It was further found that the bleeder wells located in the proximity of one abutment served no useful purpose. However, water came out of the natural slope in the areas indicated by shading and labeled I to IV in Fig. 8, at distances up to 300 ft.

from the downstream toe of the dam. The danger of piping by subsurface erosion starting from these areas was eliminated at a very moderate expense by covering them with inverted graded filter.

Case 8. An unusual opportunity for the application of the observational procedure was encountered in connection with design and construction of submerged shipways on the Atlantic Coast (FitzHugh, Miller and Terzaghi, 1945). These shipways differ from the conventional type inasmuch as the side walls consist of cellular cofferdams surrounding a thin, but pile-supported concrete floor (Fig. 9). The side walls were acted upon by the lateral pressure exerted by a hydraulic back-fill consisting of marl chunks, and the piles supporting the floor were driven through a layer of marl with a thickness of 20 ft. into an underlying aquifer consisting of silty sand. The side walls had to satisfy the condition that they should remain practically vertical at every stage of operation of the shipways, and the sum of the weight of the shipway floor and of the underlying marl stratum should be at least 1.5 times the hydrostatic uplift on the base of the marl stratum when the shipways were empty. However, a reliable forecast of the lateral deflection of the side walls was impracticable and the hydrostatic conditions which would prevail in the aquifer during operation of the shipways were unknown. Therefore, the following procedure was adopted.

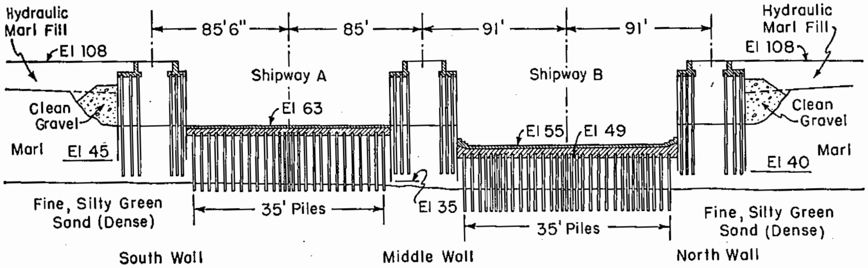

FIGURE 9.—CROSS SECTION THROUGH TWO SUBMERGED SHIPWAYS.

The gravel pockets on both sides of the shipways were placed in dredged cuts after the side walls were built and backfilled, to reduce lateral pressure on the walls.

During the back-filling operations the increase of the lateral deflection of the side walls was measured. When it was found, by extrapolation from the observational data, that the lateral deflection of the side walls would be excessive, a wedge-shaped portion of the hydraulically placed marl fill was removed by dredging in the area adjacent to the outer face of the cellular sidewalls of the shipways. This material was replaced by gravel communicating with the shipways through pipes across the side walls. Thus the lateral pressure on the side walls was reduced to a nominal value.

In order to get information concerning the hydrostatic pressure conditions in the aquifer underlying the shipway floors, piezometric tubes were installed with their open ends located in the aquifer. While the shipways were being pumped out for the first time, the piezometric elevations were measured. When it was found that the factor of safety of the shipway floors was locally smaller than 1.5 the uplift pressure was reduced within these areas by the installation of relief wells. The cost of the modifications of the design during construction, amounting to about $250,000, were very small compared to the savings realized by the radical departure from the conventional design of submerged shipways.

The preceding case records are representative of the manifold practical applications of observational procedures in earthwork engineering. In every case the procedure was used to compensate for the inevitable uncertainties involved in the interpretation of the results of the subsoil exploration.

There are no case records which demonstrate more impressively the existence of these uncertainties, and the means for coping with them, than those describing the successful use of observational procedures. Yet there are still many engineers engaged in earthwork design who are not yet fully aware of the existence and the importance of these uncertainties. Therefore the publication of such case records serves a vital educational purpose, by counterbalancing the psychological effect of the records of reasonably accurate performance forecasts which can be expected only under exceptionally favorable conditions.

ROLE OF GEOLOGICAL CONSIDERATIONS IN EARTHWORK ENGINEERING

The nature and importance of the uncertainties involved in the interpretation of the results of subsoil exploration are essentially determined by the geological history of the site. Therefore I have acquired the habit of starting the investigation of a new site by collecting information regarding the geological characteristics of the site from resident geologists and from published sources, supplemented by a painstaking examination of the site. The interpretation of the findings is based on my previously acquired empirical knowledge of the engineering properties of the products of the different geological processes such as glaciation or stream action. The knowledge was obtained with the assistance of soil mechanics by correlating the processes with the information obtained by experimental determination of the engineering properties of their products and with the pattern of stratification of the resulting deposits.

The results of the geological inquiry combined with the general layout for the project determine the maximum depth at which the seat of potential trouble may be located. Depending on the nature of the project the seat may consist of one or more strata with high compressibility, of an aquifer containing water under high artesian pressure, avenues for the escape of water from a reservoir and the like. This procedure for estimating the maximum depth for the first exploratory drillholes was illustrated by case 2 under the heading "Foundation Design."

The next step is to determine the horizontal and vertical boundaries of the seat of potential trouble by means of exploratory borings and the pattern of stratification of the deposits involved. In some instances this pattern can be predicted on the basis of the results of the geological reconnaissance. Varved clay deposits in an undisturbed state are always practically homogeneous in horizontal directions because they were deposited in still water. On the other hand the index properties of clay located at the base of drowned-valley deposits are likely to vary over short distances in both vertical and horizontal directions, because the currents responsible for their transport prior to sedimentation shifted throughout the year. In doubtful cases information concerning the degree of homogeneity of a seat of potential trouble can be obtained by a moderate amount of testing of samples recovered from the exploratory borings. The degree of homogeneity determines subsequent procedures.

If the seat of potential difficulties is relatively homogeneous, an elaborate subsoil exploration involving the testing of numerous undisturbed samples may be justified. On the basis of the results of the investigations, a settlement or stability computation can be made.[1] The prerequisites for the success of such operations are satisfied

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[1] Quite recently I encountered a deposit of glacial lake clay which proved to be far more compressible than the consolidation tests on undisturbed samples indicated, but this deposit is unique in my experience.

throughout large portions of the coastal plains, or on lake deposits such as those underlying some of the plains northwest of the Great Lakes Region or the valley of Mexico. On the other hand, if the much more common condition of nonhomogeneity is encountered, very little can be gained by accumulating test data in addition to those which disclosed the absence of homogeneity. In this case the third step is an evaluation of the inevitable uncertainties involved in the interpretation of the results of the subsoil exploration. Design has then to be based on the most unfavorable possibilities compatible with the known features of the subsoil conditions. However, if the project permits modification of the design during construction, this uneconomical method can be avoided by using the observational procedure described in the preceding section of this paper (Case 5 to 8).

If this general procedure is followed, developments conspicuously at variance with what is anticipated can be due only to significant geological details located between drillholes or between the points where samples were recovered. The possibility of such developments came to my attention shortly after I published the book *Erdbaumechanik* (1925) when I was asked to review the design for the substructure of a steam power station. The site for the station covered an area of about 200 by 100 ft. and it was explored by borings spaced 50 ft. both ways, to a depth of 60 ft. below the ground surface. The borings showed that the site was located on a stratum of waterbearing sand and gravel with a thickness of 15 ft. resting on a remarkably homogeneous deposit of stiff clay. The station was to be provided with a sub basement on a heavily reinforced concrete mat, resting at a depth of about 20 ft. on the stiff clay.

Prior to starting the excavation the site for the subbasement was surrounded by a row of steel sheet piles driven to a depth of about two feet into the stiff clay. After the excavation was completed no water entered the pit except for the water which leaked out of the sand through the interlocks of the sheetpiles.

When I visited the site on the evening of the day when the excavation was completed and the laborers had left, the night watchman informed us that a "blow" had occurred in the pit, a few minutes earlier. When we arrived at the pit we saw a jet of water shooting out of the clay close to the center of the pit. The point of emergence of the jet was buried beneath a cone-shaped and rapidly growing accumulation of clean sand.

To stop the flow of sand we replaced the cone-shaped sand deposit by an empty cement barrel and filled the barrel with concrete aggregate to act as a filter. As soon as this operation was completed a second blow occurred at some distance from the first one, which was then treated in the same manner. During the next few hours a whole string of barrels was installed above springs on a meandering line which did not approach any of the points where test-borings had been made. Subsequent investigations showed that the springs came out of a narrow belt of clean, waterbearing sand located at a depth of a few feet below the bottom of the excavation. Before the reinforcement for the concrete floor of the subbasement was placed, the cavities formed by the discharge of sand from the belt were plugged by grouting.

Buildings on spread footings may be—and have been—severely damaged on account of a few footings resting on exceptionally compressible material contained in pockets located entirely between the points where test borings had been made. Slopes of earth dikes or dams on stiff clay have failed on account of the clay containing a few thin layers of exceptionally weak material such as bentonite located between the elevations at which samples were recovered from the bore holes. Fortunately such incidents are rare, but inevitable.

Under normal conditions the general procedure described in this paper protects the engineer in charge of an earthwork project against the serious danger of underestimating the uncertainties involved in the results of his subsoil exploration. However no hard-and-fast rules can be established concerning the details of practicing the procedure, because at every new site the designer is likely to encounter some conditions which are without any precedent in his own experience or in published case records. This fact points to an important difference between structural engineering and applied soil mechanics.

Many problems of structural engineering can be solved solely on the basis of information contained in textbooks, and the designer can start using this information as soon as he has formulated his problem. By contrast, in applied soil mechanics a large amount of original brain work has to be performed before the procedures described in the textbooks can safely be used. If the engineer in charge of earthwork design does not have the required geological training, imagination and common sense, his knowledge of soil mechanics may do more harm than good. Instead of using soil mechanics he will abuse it.

CONCLUSIONS AND OUTLOOK

In 1936, when the First International Conference on Soil Mechanics and Foundation Engineering convened at Harvard, I no longer had any illusions concerning the limits nature has set to the degree of accuracy which can be achieved in the prediction of performance in the realm of earthwork engineering. Hence at that time I started to promote comparison between forecasts and observed performance and correlation between case records and the geological characteristics of the site. I expected that once practicing engineers had learned to evaluate the inevitable uncertainties associated with performance forecasts at given sites, the misuse of soil mechanics would automatically stop. This, however, turned out to be a wish-dream.

We are now living in the year 1960. The generation of engineers which still believes that the settlement of a pile-supported structure can be predicted from the results of a loading test on a single pile is gradually dying out. However, the misuse of soil mechanics is still practiced all over the globe, because the members of our profession are spoiled almost beyond recovery by the success of applied mathematics in other fields of civil engineering. Once an engineer has left his alma mater his mind is likely to become dogmatic. Therefore he must be warned against the misuse of soil mechanics at an early date.

Most of the obstacles to a rigorous treatment of the problems of earthwork engineering grow out of the geological history of the soil deposits underlying our sites. Therefore, I used to call the course in engineering geology I gave at Harvard an antidote to "Theoretical Soil Mechanics" and I taught it in this spirit. However, so far very few courses in engineering geology accomplish their vital mission because in most of them the subject is still presented as an accumulation of facts leaving it to the student to discover that these facts are essential ingredients in engineering reasoning and the basis for observational procedures. That discovery rarely ensues. Therefore the misuse of soil mechanics will continue unless the center of gravity of the courses in engineering geology is shifted from the geological facts to their engineering consequences. Among the most important of these are the limits which nature has set to the degree of reliability of the information which can be obtained by presently available means for subsurface exploration. (Terzaghi, 1961).

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BETTER CONCRETE THROUGH CHEMISTRY

By M. E. Prior*

(Presented at a meeting of the Structural Section, B.S.C.E., held on January 11, 1961.)

Concrete is one of our most versatile building tools and at the same time one of the most abused materials of construction. Despite this abuse, however, it does an outstanding job for the construction engineer.

Steel is manufactured in mills according to exacting specifications and can be checked by the various new techniques available as to its composition and strength before it is shipped to the job. In other words, it is a finished product before it is put in place. Concrete, on the other hand, is put in place as a mixture of ingredients and the end product, the hardened concrete, is developed on the job.

Concrete is made up of four basic materials; portland cement, sand, coarse aggregate and water. Individually, these materials have to meet certain specifications in order to insure that the resultant concrete will, when properly proportioned, develop the designed strength.

The American Society for Testing Materials has set up limiting specifications for the various types of portland cement. The manufacturers adhere to these requirements and furnish plant certifications to the effect that the cement will meet the specifications. Producers of coarse and fine aggregate will furnish these materials to meet the grading requirements, and minimum silt and organic contents as set forth in ASTM specifications. The purity of the water used is not generally a problem because water suitable for drinking purposes is considered satisfactory for use in producing concrete and is available in practically all areas.

The proper proportioning of these materials is important. Nationally recognized organizations, such as the American Concrete Institute and the Portland Cement Association, furnish tables and design information which can be used by the engineer to obtain the desired concrete strengths.

All of this is not enough, however, because it is impractical

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* Technical Service Manager, Construction Chemicals, Dewey and Almy Chemical Division, W. R. Grace & Co.

to control the hardening of the concrete in the field. Facilities are not available as they are in a steel mill for laboratory control of the mixture, and more important, the subsequent handling of the material as it becomes the finished product.

Concrete develops its strength by the hydration of the portland cement. It is a complex reaction which develops products that bind the mix together in a solid mass. No attempt will be made in this presentation to explain this reaction, but suffice it to say at this time that it is a chemical reaction which starts as soon as the cement and water come in contact. Once this reaction is started there is no turning back and starting over again. The rate at which the concrete stiffens and hardens is governed primarily by time and temperature as is the case of most chemical reactions. Hence, the person responsible for placing the concrete must get it in the proper location before the reaction has proceeded to the point where the concrete becomes too stiff to move or handle. Often, unavoidable delays occur and, as a result, it will become necessary to reject the batch or add more water to the concrete in order to get it in place. Any addition of water automatically changes the mix design specified by the design enginer, and, as a result, lower-than-calculated strengths will be obtained. This fact is based on the work done by Duff Abrams some forty years ago and since substantiated beyond a doubt by many other investigators (1)(2)(3). Mr. Abrams showed that the strength of the concrete in the plastic range varied inversely with the water cement ratio. The higher this ratio, the lower the strength.

More than enough water to hydrate the portland cement is added to every concrete mix for the practical purpose of making it possible to place it. The practical man on the job has to place this concrete in many difficult locations and under adverse conditions. He may have a network of heavy reinforcing steel to get it by and around. He may have breakdowns of equipment or forms which delay the placing. He may be working in below zero weather or with temperatures running around 100° F. Hence, it is obvious that any steps that can be taken to reduce the water/cement ratio of a given mix while at the same time maintaining plasticity will improve the strength. Chemistry has played an important part in making possible the use of minimum water/cement ratios.

Over twenty-five years ago, several manufacturers interested in the production of cement and concrete started investigating the possibility of applying their knowledge of dispersing techniques to portland cement. One of the first applications was a highway in the state of Massachusetts where a dark, concrete pavement was desired. Up to this time, the use of materials such as carbon black to produce dark concrete had met with little success because the color was not uniform and the strengths suffered due to a large increase in water requirement. It was found, in the course of investigations, that certain materials such as lignosulfonic acids and their salts had a pronounced effect on the fluidity or plasticity of portland cement pastes, mortars and concrete, plus the fact that they were good dispersants for carbon black. In other words, less water was required, as much as 15-20% less, to produce an equivalent plasticity to that of a nontreated mixture, and in turn less carbon black was required for a given degree of color. In accordance with Abrams' water/cement ratio law, this resulted in higher concrete strengths for the same cement content. There was, however, another factor introduced by the use of these materials. They increased the setting time of the portland cement. A concrete which normally obtained its initial set in four to five hours was found to require six to seven hours for initial set. This was a mixed blessing. For example, this delay could be of inestimable value on the job where difficult placing problems existed or high atmospheric temperatures prevailed. On the other hand, it proved to be a distinct disadvantage under low temperature conditions or where early form removal was desirable.

This was a challenge to the chemists and they went to work on the development of two types of admixtures. One suitable for use in controlling the delay in the intial set of the concrete and one that would not alter the setting time from that of the non-admixtured concrete; both materials to have the desired water reducing, plasticizing properties. As a result of research by the leading manufacturers in this field, we now have available these two types of materials which are becoming widely used in the concrete field. Both fall into two basic types of chemicals; lignosulfonic acids and their salts and hydroxylated carboxylic acids and their salts. At the Third Pacific Area national meeting of the American Society for Testing Materials, a very complete symposium was held on water reducing and initial set retarding admixtures of these types (4). Data and opinions were presented by specifiers, consumers, concrete producers and admixture producers which indicated these types of admixtures to be a definite factor in the production of quality concrete.

The fact that these materials reduce the basic water requirements of the concrete mix means that the consumer is getting an increase in the design factor of safety if no change is made in the mix design. On the other hand, the proper redesign of the concrete mix will result in economies in construction. Since the design engineer is primarily interested in the concrete developing a certain strength, it is generally accepted practice to specify a minimum strength requirement at twenty-eight days. It is true that some engineers still specify mix proportions which include a minimum cement factor and maximum water content, but this does not necessarily insure the proper strength. Despite the fact that the materials used in concrete meet certain specifications, it is a well-known fact that the strength produced from materials of different sources may vary as much as 100%. Hence, it is best that the designer specify strength and leave the mix proportions to the concrete engineer, who is better qualified to take advantage of the available materials to produce quality concrete.

If the job requires retardation, the concrete engineer can use the proper admixture addition rate to obtain the desired setting time. He not only has his own experience to draw on, but also that of the admixture manufacturers and their research laboratories.

Initial retardation of the concrete generally means extending the time of initial set at least two hours beyond that normally found in the same concrete under identical conditions, but with no retarding admixture present. This time of intial set is determined by means of a Proctor Penetration apparatus in accordance with ASTM Designation C 403 (Fig. I). Initial set is considered to have taken place when the concrete will resist a pressure of 500 pounds per square inch as applied by the penetrometer. At this point it is considered impossible to move or further consolidate the concrete by vibration, and it is also often referred to as the "vibration limit."

The length of time of initial retardation can be varied to suit the job requirements by adjusting the addition rate of the admixture. (Fig. II). The admixtures are generally supplied by the manufaturers in a liquid, ready-to-use form, thus making it simple for the concrete producer to satisfy the needs of the engineer.

The early strength, sometimes up to one day, is lower for initially retarded concrete than for regular concrete of the same cement factor, plasticity and under identical conditions. After two days of

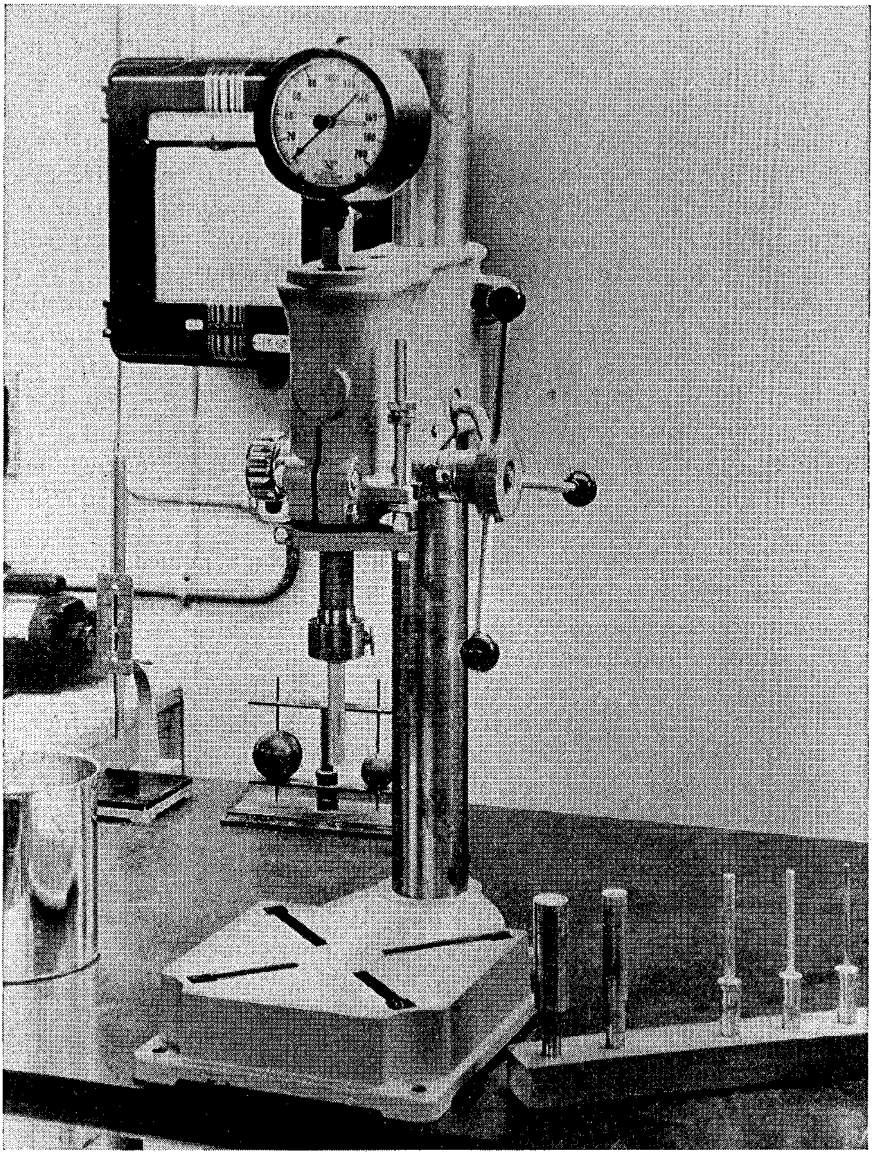

FIGURE I.—PROCTOR PENETROMETER.

curing, however, the strength of the initially retarded concrete surpasses that of the plain concrete, and maintains this advantage at all later ages. This strength increase generally amounts to 10-18%, depending on mix design and other related factors.

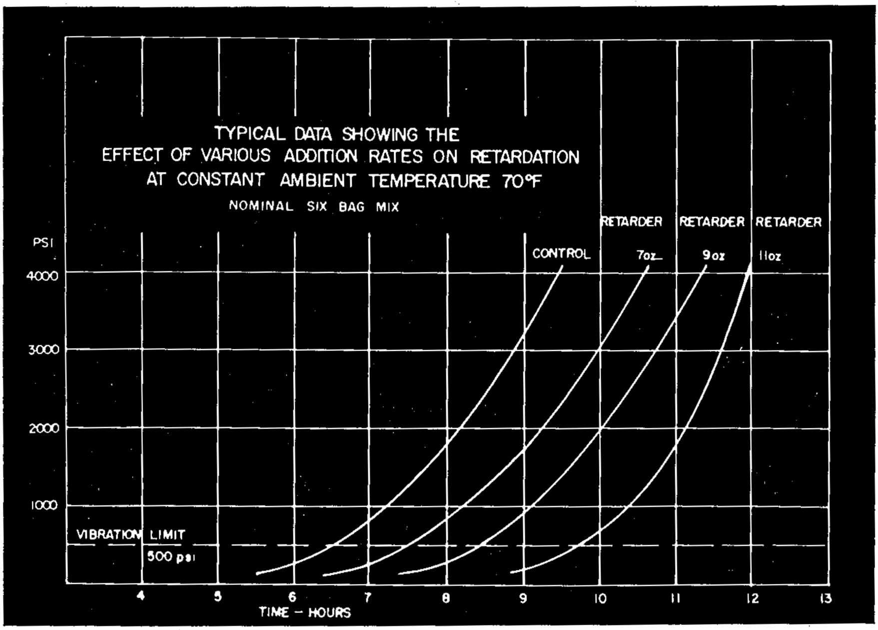

FIGURE II.—TIME OF SET-ASTM DESIGNATION C 403 VARIABLE ADDITION RATE OF RETARDER.

Initial retardation enables the contractor to properly place concrete under conditions which would otherwise seriously affect the quality of the job. High temperatures cause rapid setting of the concrete and interfere with the proper finishing. Also, too rapid a rate of hardening may cause cracking as in the case of bridge decks. In such an instance it is important that the concrete remain plastic until all of the concrete is in place and there will be no more deflection due to loading the supporting members. Another instance where rapid setting can cause trouble is in prestressed beams. It is essential that the concrete remain plastic during the period of vibration so that it will not be broken away from the stressed steel and lose the very important bond to steel that must be developed.

The water reducing type of admixture is basically the same as the initial retarding admixture except that it has been modified chemically to eliminate the retarding influence. A fixed addition rate is generally recommended and is based on the cement factor.

Both types of admixtures have many common factors. They increase the plasticity of the mix by reducing the interparticle attraction of the cement, thus in effect lubricating the mix. This action reduces the water requirement of the mix anywhere from 10-20%, depending on the mix design and materials used. As has been pointed out, this reduction in water is reflected in increased compression strength. The over-all quality of concrete is indicated by compressive strength and, therefore, better bond strength, greater flexural strength, higher durability, increased abrasion resistance, less bleeding, and lower permeability are some of the benefits that may be derived from the use of these materials.

Perhaps the best known admixture for concrete is that which introduces air in the mix. This type of admixture is relatively new compared to the water reducing materials, but its use has grown rapidly because of the spectacular results obtained. About 1940 it was discovered that concrete containing entrained air had superior resistance to the deterioration due to freezing and thawing cycles. This immediately started researchers on the road to finding out the optimum quantity of air, the size of the bubble, the spacing, and the methods of introducing the air. It was found that the air produced by either of two chemicals, a sulfonated hydrocarbon containing a catalyst and a wood rosin by-product, was the most effective. Other chemicals introduced air in the desired percentages, but they invariably seriously affected the resultant strength and/or did not increase the durability. Further research on this problem, principally by members of the U. S. Bureau of Reclamation staff, has turned up the fact that these two materials are unique in the size of the bubble produced, the angle of contact, and the surface film. In normal concrete there are approximately four million of these bubbles per cubic inch and they average less than 100 microns in diameter. Other types of air of larger bubble diameter, lower contact angle, or lower film strength are not satisfactory. At the same total air content, there may be only about 400,000 bubbles per cubic inch (5).

Air entrainment is not limited to climates where freezing and thawing cyles are prevalent. Research has shown that definite advantages may be obtained where the concrete is in contact with alkali salts (6). The salts that enter the concrete under these conditions are destructive. The growth of such crystals in the concrete exerts a terrific pressure just the same as the freezing of water. Concrete being a rigid material will break when this pressure exceeds its inherent strength, but if there are the tiny air voids interconnected by capillaries as in air entrained concrete to absorb some of this pressure, the concrete has several hundred per cent greater chance of surviving.

In addition to the benefits which air entrainment imparts to the durability of concrete, there are other important factors to consider. Air entrainment lubricates the concrete mix by providing ball bearings for the aggregate to roll on (Fig. III). Hence, the water/cement ratio of the mix can be and should be reduced to maintain designed plasticity. This reduction in water generally compensates for any strength loss that may be introduced by substituting air for solid material in mixes containing 6 sacks of cement or less. One manu-

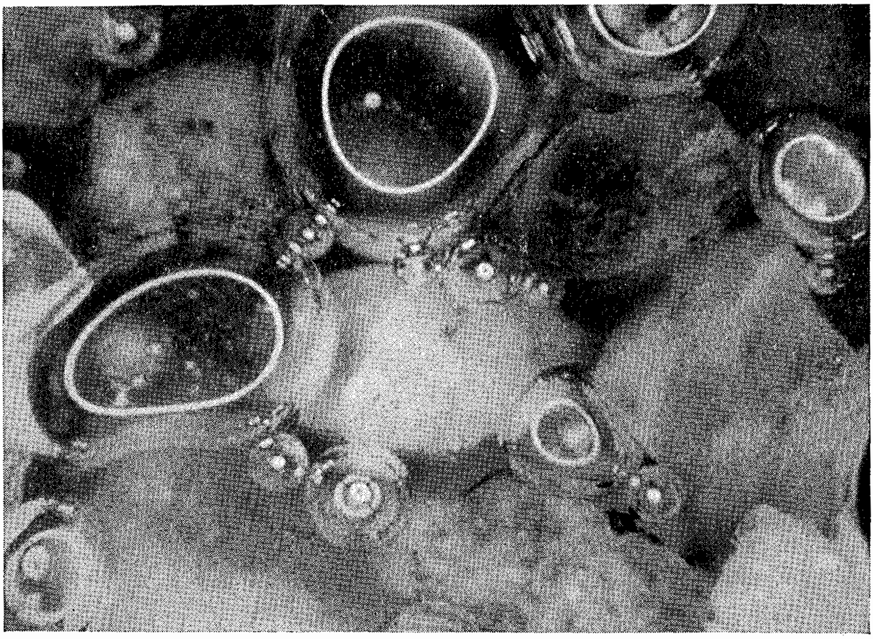

FIGURE III.—ENTRAINED AIR IN SAND MIX (65× MAGNIFICATION).

facturer provides an agent containing a catalyst which further reduces any tendency toward strength loss. It should also be noted that when making comparisons between non-air entrained concrete and air entrained concrete, it is essential that the actual cement factor be maintained. Since air is, in a sense, a fifth ingredient of the concrete mix, it is necessary to reduce the quantity of one of the other ingredients to compensate for this addition. This is generally done by reducing the sand volume an amount equivalent to the approximate air content minus the water reduction (7).

Other uses of chemicals in concrete include materials to accelerate the setting of the cement. Such materials have particular application in cold weather work because as with all chemical reactions temperature plays an important role in the rate of the hydration of the cement. In cold weather this reaction is slowed down considerably unless suitable precautions are exercised. The use of warm aggregates and mixing water plus heated or insulated forms helps this situation, but it is often desirable to add an accelerator to insure proper setting. The most widely used material for this purpose is calcium chloride. It is important, however, that such material be used with discretion since excessive quantities can cause too fast a reaction. Normally the addition rate is limited to 2% by weight of the cement except in rare cases, and often 1% is sufficient with heated materials (8).

Recently materials have been developed by the chemists which greatly aid in the repair of concrete. There are two general types of these materials. One is a synthetic latex type emulsion which can be mixed with portland cement, aggregate and water to provide a mix that will bond to practically any material and has the same properties and appearance as concrete. The material can be featheredged and used to repair either thin or deep surfaces as well as broken sections. It is a "ready-to-use" product which will generally re-emulsify if exposed to water, but is also available in a composition that will not reemulsify or soften in the presence of water. This latter type is particularly recommended for use in areas exposed to weathering.

The other bonding or repair material is a two component mixture which is generally applied as a glue to bond the newly placed concrete to the old or as a surfacing material. It is basically expoxy resin which is relatively expensive and difficult to apply, but these disadvantages may well be justified where the protection of the concrete from such deleterious materials as acids and alkalies is of prime importance. It is a very strong bonding agent, far exceeding the strength of concrete, and must be properly plasticized to avoid excessive strains.

Many times reference is made to concrete produced by the Romans in making their aquaducts. This is used as an illustration as to how much more lasting this concrete seems to be than our present day material. We could produce this type of concrete, but because of our present day concepts no one would accept it. The reason is that the Romans were not in a hurry. The concrete they made was not put into service for a long time, possibly several years, after it was placed. It had plenty of time to adequately cure and develop strength. The cementitious material was a slow hydrating type and gained strength very slowly compared to our standards. We, on the other hand, demand that the concrete be ready to take the full designed load almost as soon as it is placed. In order to meet these requirements the cement chemists have adjusted chemical compositions and fineness, admixture chemists have provided hydration aids and water reducing materials, but despite all of this we still haven't been able to duplicate the effect of time. We are making progress, but the old adage to the effect that the longer it takes to produce a material the longer it will last, still holds true to a certain extent.

The cement and concrete chemists are never idle. New ideas are being investigated daily. The future of the application of chemical admixtures in portland cement concrete is unlimited. Our research people are continually finding new types of admixtures which, although perhaps not as glamorous as those we read about for cosmetics, are of vital importance to the concrete consumer. Every concrete structure is in a sense a monument, and it must be built to last.

Then next few years will bring completely new chemical admixtures to make portland cement concrete even more versatile and efficient than it is at the present time.

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OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

FEBRUARY 15, 1961.—A Joint Meeting of the Boston Society of Civil Engineers with the Northeastern University Student Section was held this evening at Northeastern University, 360 Huntington Avenue, Boston, Mass.

The Student Section were hosts to the Boston Society of Civil Engineers and the meeting was called to order at 7:00 P.M., by President James McDonough of the Student Section. On welcoming members and guests attending he turned the meeting over to President Arthur T. Ippen of the Boston Society of Civil Engineers to conduct any necessary business.

President Ippen stated that the reading of the Minutes of the previous meeting January 25, 1961 would be published in a forthcoming issue of the Journal and that the reading of those minutes would be waived unless there was objection.

The Secretary announced the names of applicants for membership and that the following had been elected to membership February 13, 1961:—

Grade of Member—Richard W. Amon*, Joseph R. Assenzo*, William H. Combs, Robert L. Fuller*, Harry M. Horn, Robert S. Johnson, Charles C. Ladd*, John L. Lowe, Joseph J. Macaione, Frederick J. O'Connell, Jr., Charles W. Roy.

President Ippen requested the Secretary to present recommendations of the Board of Government to the Society for action. The President stated that this matter was before the Society in accordance with the provisions of the By-Laws and that notice of such action was published in ESNE Journal dated February 13, 1961.

The Secretary presented the following recommendation of the Board of Government for action to be taken at this meeting.

> MOTION "to recommend to the Society that the Board of Government be authorized to transfer an amount not to exceed $2500 from the Principal of the Permanent Fund to the Current Fund for current expenditures."

On MOTION duly made and seconded it was VOTED "that the Board of Government be authorized to transfer an amount not to exceed $2500 from the Principal of the Permanent Fund to the Current Fund for current expenditures."

President Ippen stated that this was the final action to be taken on this matter.

President Ippen made announcement of coming meetings of the BSCE and then turned the meeting back to President McDonough who then introduced the guest speaker of the evening, Dr. Asa S. Knowles, President of Northeastern University who gave a most interesting talk on "Northeastern University—Child of Destiny."

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* Transfer from Grade of Junior.

Sixty-nine members and guests attended the dinner and meeting.

The meeting adjourned at 8:30 P.M.

CHARLES O. BAIRD, JR., *Secretary*

MARCH 16, 1961.—The 113th Annual Meeting of the Boston Society of Civil Engineers was held today at the M.I.T. Faculty Club, Cambridge, Mass., and was called to order at 4:15 P.M., by President Arthur T. Ippen.

President Ippen announced that the reading of the Minutes of the Society Meetings had been omitted during the year. The Minutes of the January and February 1961 meetings would be published in a forthcoming issue of the Journal. The Minutes of the April, May, September, October, November and December 1960 meetings to be declared approved as published.

It was VOTED "to approve the Minutes as published."

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership on March 13, 1961:—

Grade of Member—Michael A. Donnelly, John M. Rufo, David B. Weiner*.

Grade of Junior—Joseph P. Yamello.

The Annual Reports of the Board of Government, Treasurer, Secretary and Auditors were presented. Reports were also made by the following committees —Hospitality, Library, John R. Freeman, Public Relations, Advertising, Subsoils of Boston and Joint Legislative Committee.

It was VOTED "that these reports be placed on file."

The Annual Reports of the various Sections were read and it was VOTED "that the Annual Reports of the various Sections be placed on file."

President Ippen stated that all foregoing reports would be published in the April, 1961 issue of the Journal.

The Report of the Tellers of Election, John C. Adams, Jr., and Marcello Guarino was presented and in accordance therewith the President declared the following had been elected Officers for the ensuing year:—

President	James F. Brittain
Vice-President (for two years)	George G. Bogren
Secretary (for one year)	Charles O. Baird, Jr.
Treasurer (for one year)	Paul A. Dunkerley
Directors (for two years)	Alexander J. Bone Harry L. Kinsel
Nominating Committee (for two years)	John S. Bethel, Jr. Elliot F. Childs George M. Reece

The retiring President Arthur T. Ippen then gave his address entitled "A People that is alive, will build for its future."

Thirty-five members and guests attended the business meeting.

The Meeting adjourned at 5:45 P.M. to re-assemble at 8:00 P.M., the Annual Dinner being held in the interim.

The President called the meeting to order at 8:45 P.M.

Following general remarks and the introduction of the newly elected President James F. Brittain, and other guests at the head table President Ippen announced that a Trust Fund for the Boston Society of Civil Engineers had been set up by Karl R. Kennison, a Past President of the Society. A standing ovation was given to Mr. and Mrs. Kennison.

President Ippen stated that a number of prizes were awarded annually for worthy papers presented at the Society and Section meetings and also Scholarship Awards. President Ippen read the names of recipients and asked them to come forward and presented the following Awards and Scholarships:—

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* Transfer from Grade of Junior.

Award	*Recipient*	*Paper*
Desmond FitzGerald Award	Edward C. Keane	"Problems of Boston, The Central City of a Metropolitan Area."
Clemens Herschel Award	Brig. Gen. Alden K. Sibley	"Engineering and the Basic Sciences: The Challenge of the 60's."
Sanitary Section Award	John S. Bethel, Jr. Clair N. Sawyer Charles Y. Hitchcock, Jr.	"Copper and Brass Tube Mill Wastes Treatment."
Desmond FitzGerald Scholarship	Joseph H. Metelski	Northeastern University.
William P. Morse Scholarship	John C. LeFevre	Tufts University.

President Ippen introduced the guest speaker of the evening, Dr. Harold E. Edgerton, Professor of Electrical Engineering, M.I.T. who gave a most interesting illustrated talk on "Adventures with Camera Stroboscope."

At the conclusion of the talk President Ippen on behalf of the Society thanked Dr. Edgerton for a most enjoyable talk and then turned the meeting over to President elect James F. Brittain.

President Brittain presented retiring President Arthur T. Ippen with a certificate of appreciation for services rendered.

The meeting adjourned at 10:15 P.M.

CHARLES O. BAIRD, JR., *Secretary*

STRUCTURAL SECTION

JANUARY 11, 1961.—The meeting of the Structural Section was held on this date in the Society Room. Chairman Paul S. Crandall called for election of a committee to nominate officers for the coming year. The following were proposed and unanimously elected to the Nominating Committee: Casimir J. Kray, Richard W. Albrecht, and William A. Henderson.

In the technical session, Melville E. Prior, Technical Service Manager of Dewey & Almy Chemical Division, W. R. Grace & Company, spoke on "Better Concrete through Chemistry." He said that mixing water for concrete is coming under closer scrutiny. For one thing, he said, sometimes the air content of concrete is adversely increased by detergents which get into the mix water from a polluted ground water supply. Mr. Prior described the discovery of cement dispersing materials which considerably reduce the required amount of mix water and thereby increase the strength, bond and watertightness of concrete. Setting time for concrete is varied by use of accelerators and retarders, he said, noting the various advantages of these properties. Mr. Prior described also the uses and benefits of air entraining compounds, pozzolons, fly ash, latex emulsions and epoxy resins.

Following a discussion period, the meeting adjourned at 9:20 P.M.

Attendance, 62.

E. N. SMITH, *Clerk*

MARCH 8, 1961.—A Joint Meeting with the Hydraulics Section, BSCE and the American Society of Civil Engineers, Massachusetts Section, was held on this date at the United Community Services Building.

At the business session, Mr. William A. Henderson, Chairman of the Section's Nominating Committee, reported that committee's nominations for officers for the coming year. There being no additional nominations from the floor, Structural Section Chairman, Paul S. Crandall, declared the proposed slate elected. The new officers are:

Chairman	Myle J. Holley, Jr.
Vice Chairman	Edward N. Smith
Clerk	Percival S. Rice
Executive Committee	Harl P. Aldrich Max D. Sorota Mark M. Kiley

The speaker of the evening was Mr. J. B. Schijf, Chief Engineer of Design and Planning for Coastal Flood Protection and Reclamation Projects for the Netherlands Government. Mr. Schijf's subject, "Wresting New Lands from the Sea," covered the history of need, the development of design and the construction of two of the Netherlands' most famous "dikes," the Zuider Zee and the Delta projects.

The meeting was adjourned at 8:30 P.M. Attendance, 90.

E. N. SMITH, *Clerk*

ANNUAL REPORTS

REPORT OF THE BOARD OF GOVERNMENT

1960-1961

Boston, Mass., March 16, 1961

To the Boston Society of Civil Engineers:

Pursuant to the requirements of the By-Laws the Board of Government presents its report for the year ending March 16, 1961.

The following is a statement of the status of membership in the Society:

Honorary	7
Members	982
Associates	6
Juniors	66
Students	4
Total	1065
Student Chapters	2

Summary of Additions

New Members	28
New Juniors	9
New Students	1

Reinstatements

Members	2

Summary of Transfers

Junior to Member	13

Summary of Loss of Members

Deaths	17
Resignations	12
Dropped for non-payment of dues	27
Dropped for failure to transfer	13

Life Members	98
Members becoming eligible today for Life Membership	6
Remission of dues	0
Applications pending on March 16, 1961	9

Honorary Membership is as follows:

Frank M. Gunby, elected, February 15, 1950
Karl R. Kennison, elected, February 7, 1951
Frank A. Marston, elected, February 15, 1960
Charles M. Spofford, elected, December 19, 1945
Karl Terzaghi, elected, March 3, 1952
Howard M. Turner, elected, February 18, 1952
William F. Uhl, elected, February 7, 1955

The following members have been lost through death:

Robert W. Anderson, October 4, 1960
J. Richard Braks, April 9, 1960
Armand W. Benoit, May 15, 1960
Walter A. Ford, November 19, 1959
Edward I. Gardiner, April, 1960
J. Arthur Garrod, March 24, 1960
Benjamin W. Guppy, July 10, 1960
Albert Haertlein, June 6, 1960
Carl C. Harris, April 4, 1960
Kenneth M. Kelley, September 22, 1960
John G. W. Thomas, March 17, 1960
George R. Standberg, March 16, 1960
William F. Swift, January 22, 1960
Walter C. Voss, November 2, 1960
Walter E. Wheeler, January 17, 1961
Russell H. Whiting, January 25, 1961
John O. Harmaala, May 5, 1960

Meetings of the Society

March 16, 1960. Address of the retiring President Edward C. Keane. "Problems of Boston, Central City of a Metropolitan Area."

April 25, 1960. Joint Meeting with the Massachusetts Section, American Society of Civil Engineers. "Engineering and the Basic Sciences—The Challenge of the 60's. Brig. General Alden K. Sibley.

May 18, 1960. Joint Meeting with Surveying & Mapping Section, BSCE. "Modern Trends in Surveying." Mr. George MacDonald, Vice President, Lockwood, Kessler & Bartlett, Soysset, New York.

September 28, 1960. Joint Meeting with the Transportation Section, BSCE. "M.T.A. and Boston Transportation Problems." Thomas J. McLernon, General Manager, Metropolitan Transit Authority.

October 10, 1960. Dinner Meeting of BSCE in connection with National Convention of ASCE. "Rebuilding a City," Honorable John F. Collins, Mayor of City of Boston.

November 16, 1960. "Publish or Perish—The Survival of Civil Engineering." Gordon M. Fair, Abbot and James Lawrence Professor of Engineering and Gordon McKay Professor of Sanitary Engineering, Harvard University.

December 14, 1960. Joint Meeting with the Structural Section, BSCE. "A City Planner Looks at the Urban Explosion." Prof. Roland S. Greeley, Prof. of City Planning, M.I.T.

January 25, 1961. "Multi-Purpose Uses of the Connecticut River at Holyoke Since 1792." Robert E. Barrett, Jr., President, Holyoke Water Power Company.

February 15, 1961. Joint Dinner Meeting with Northeastern University Civil Engineering Society. "Northeastern—Child of Destiny," Dr. Asa S. Knowles, President of Northeastern University.

Attendance at Meetings

Date	*Place*	*Meeting*	*Dinner*
March 16, 1960	Hotel Vendome	27	120
April 25, 1960	Hotel Lenox	35	35
May 18, 1960	United Community Services Bldg.	53	47
September 28, 1960	United Community Services Bldg.	90	58
October 10, 1960	Statler Hotel	170	170
November 16, 1960	United Community Services Bldg.	70	32
December 14, 1960	United Community Services Bldg.	14	—
January 25, 1961	United Community Services Bldg.	35	—
February 15, 1961	Northeastern University	69	69

Average Attendance

Sections

Twenty-one meetings were held by the Sections of the Society during the year. These meetings of the Sections offering opportunity for more detailed discussions continue to demonstrate their value to their members and to the Society. A wide variety of subjects were presented. The Annual Report of the various Sections will be presented at the Annual Meeting and will be published.

*Funds of the Society**

Permanent Fund. The Permanent Fund of the Society has a present value of . The Board of Government authorized the use of as much as necessary of the current income of this fund in payment of current expenses. By vote of the Society (as prescribed by the By-Laws) at the January 25, 1961 and February 15, 1961 meetings, the Board of Government was authorized to transfer an amount not to exceed $2500 from the Principal of the Permanent Fund for current expenditures. The amount necessary to transfer from the Principal of Permanent Fund for current expenditures was $420.48.

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* Details regarding the values and income of these funds are given in the Treasurer's report.

John R. Freeman Fund. In 1955 the late John R. Freeman, a Past President and Honorary Member of the Society, made a gift to the Society of securities which was established as the John R. Freeman Fund. The income from this fund is to be particularly devoted to the encouragement of young engineers. Mr. Freeman suggested several uses, such as the payment of expenses for experiments and compilations to be reported before the Society; for underwriting meritorious books or publications pertaining to hydraulic science or art; or a portion to be devoted to a yearly prize for the most useful paper relating to hydraulics contributed to this Society; or establishing a traveling scholarship every third year open to members of the Society for visiting engineering works, a report of which would be presented to the Society.

Edmund K. Turner Fund. In 1916 the Society received 1,105 books from the library of the late Edmund K. Turner, and a bequest of $1,000, "the income of which is to be used for library purposes." The Board voted to use $100 of the income for the purchase of books for the Library. The expenditure from this fund during the year was $80.

Alexis H. French Fund. The Alexis H. French Fund, a bequest amounting to $1,000 was received in 1931, from the late Alexis H. French of Brookline, a former Past President of the Society. The income of the fund is "to be devoted to the Library of the Society." The Board voted to use $100 of the available income for the purchase of books for the Library. The expenditure from this fund during the year was $80.25.

Tinkham Memorial Fund. The "Samuel E. Tinkham Fund," established in 1921 at Massachusetts Institute of Technology by the Society, "to assist some worthy student of high standing to continue his studies in Civil Engineers, had a value of $2,338.18 on June 30, 1960. Denis F. Healy of Brockton, Mass., a student in Civil Engineering, class of 1961 was awarded this Scholarship of $200 for year 1960-61.

Desmond FitzGerald Fund. The Desmond FitzGerald Fund established in 1910 as a bequest from the late Desmond FitzGerald, a Past President and Honorary Member of the Society, provided that the income from this fund shall "be used for charitable and educational purposes." The Board voted on April 11, 1960 to appropriate from the income of this fund the sum of $100 to be known as the Boston Society of Civil Engineers Scholarship in Memory of Desmond FitzGerald and to be given to a student at Northeastern University. It was voted on January 15, 1960 "to adopt the recommendation of the Committee at Northeastern University, namely, a $100 Scholarship be given to Bernard X. Ohnemus. Presentation made at the Annual Meeting of the Society March 16, 1960.

Clemens Herschel Fund. This fund was established in 1931, by a bequest of $1,000 from the late Clemens Herschel, a former Past President and Honorary Member of the Society. The income from this fund is "to be used for presentation of prizes for papers which have been particularly useful and commendable and worthy of grateful acknowledgment." The Board of Government voted on April 11, 1960, that no appropriation be made from this fund for this year.

Edward W. Howe Fund. This fund, a bequest of $1,000 was received in 1933 from the late Edward W. Howe, a former Past President of the Society. No restrictions were placed upon the use of this money, but the recommendation of the Board of Government was that the fund be kept intact, and that the income be used "For the benefit of the Society or its members." The Board voted April 11, 1960 that the payment of the Herschel Prize Award and Section Prize Awards be appropriated from the income of this fund. The expenditure made during the year from the income of this fund was $164.70.

William P. Morse Fund. This fund, a bequest of $2,000 was received in 1949 from the late William P. Morse, a former member of the Society. No restrictions were placed upon the use of this money, but the recommendation of the Board of Government was "that this fund be kept intact and that the income be used for the benefit of the Society or its Members." Upon recommendation of a committee appointed by the President, the Board voted on April 5, 1954 "to appropriate from the income of this fund the sum of $100 to be known as the Boston Society of Civil Engineers Scholarship in Memory of William P. Morse, and be given to a Civil Engineering student at Tufts University." It was voted January 25, 1960 "to adopt the recommendations of the Committee at Tufts University, namely, that a $100 Scholarship be given to Michael A. Covell. Presentation was made at the Annual Meeting of the Society March 16, 1960.

Prizes

Award	*Recipient*	*Paper*
Desmond FitzGerald Medal	Edward C. Keane	"Problems of Boston. The Central City of a Metropolitan Area."
Clemens Herschel Award	Brig. Gen. Alden K. Sibley	"Engineering and the Basic Sciences: The Challenge of the 60's."
Sanitary Section Award	John S. Bethel, Jr. Clair N. Sawyer Charles Y. Hitchcock, Jr.	"Copper and Brass Tube Mill Wastes Treatment."

Library

The report of the Library Committee contains a complete account of the Library Committee activities during the past year.

Committees

The usual special committees dealing with the activities and conduct of the Society were appointed. The membership of these committees is published in the Journal and the reports of the committees will be presented at the Annual Meeting.

Your Board in conclusion, wishes to express its appreciation of the excellent work done by the Officers of the Sections and by the Committees of the Society.

Arthur T. Ippen, *President*

REPORT OF THE TREASURER

Boston, Massachusetts
March 16, 1961

To the Boston Society of Civil Engineers,

This report is for the fiscal year beginning March 1, 1960 and ending at the close of business on March 1, 1961.

The Boston Safe Deposit and Trust Company is the custodian of our securities and serves as our investment counsel. All transactions of securities indicated in this report have been made upon the recommendation of the Boston Safe Deposit and Trust Company with a vote of approval by the Board of Government of the Boston Society of Civil Engineers. The Boston Safe Deposit and Trust Company audits the account at the close of the fiscal year and furnishes the Treasurer of the Boston Society of Civil Engineers with a certified copy of the audit.

Six of the tables accompanying this report summarize the financial standing of the Society as of March 1, 1961.

These six tables are:

Table I	Comparison of Book Values and Market Values of Stocks, Bonds, Co-op Bank, and Investment Cash.
Table II	Comparison of our Fund's Book and Market Value.
Table III	Distribution of Funds—Receipts and Expenditures.
Table IV	Record of Investments—Bonds.
Table V	Record of Investments—Stocks.
Table VI	Record of Investments—Co-operative Bank.

Two tables have been prepared to compare the Book Value and Market Value of our holdings during the past five years. These tables are as follows:

Table VII	Five Year Comparison of Book Values.
Table VIII	Five Year Comparison of Market Values.

The attention of the membership is directed to the fact that the Market Value of our holdings is in excess of $200,000.00. The Acts of Incorporation dated 1861 as amended by the Acts of 1902 state as follows: "The said corporation may hold real and personal estate, not exceeding in amount two hundred thousand dollars, and the funds or property thereof shall not be used for any other purpose than those declared in the first section of this act." Early in the fiscal year, in anticipation of the fact, the President with the approval of the Board of Government appointed a special committee and authorized the expenditure of funds to determine the legal standing of the Society in the matter of its financial holdings.

The services of a renowned attorney were engaged to investigate the law in the matter. Quoting in part from a four-page typewritten report to the Board of Government the attorney stated:

"It is my opinion that the Society does not need to petition the Legislature to amend its charter, and that it may hold 'real and personal estate to an amount not exceeding five million dollars' ". Again, after considerable discussion of the various laws which have been enacted dealing with the financial holdings of such societies as this, he stated: "It is my opinion that it does so successfully, and that it recognizes the trend which is apparent in the above discussion, namely that past, present, or future charitable corporations, however organized, whether by special act of the Legislature or under the general laws, may hold up to $5,000,000.00 irrespective of any wording to the contrary in their charter."

On the basis of this legal opinion the Board of Government concluded that no further action would be necessary.

The following security changes were accomplished by the Boston Safe Deposit and Trust Company during the fiscal year:

Union Pacific Railroad
    Sold 220 shares

General Motors Corp.
    Purchased 126 shares

South California Edison
    Received 2-20/100 shares common stock dividend on common stock
    Received 1-60/100 shares common stock dividend on preferred stock
    Purchased 20/100 shares common stock
    Total increase 4 shares of common stock

Texaco, Inc.
    Received 1 share stock held for consolidation in 1960
    Received 4-18/50 shares stock dividend
    Sold 18/50 shares
    Total increase 5 shares

Hartford Insurance Co.
    Received 26 shares in stock split
    Received 52 shares stock dividend
    Total increase 78 shares

During the fiscal year the amounts of money accumulated in the Publications Fund from the sale of Volume II became sufficient to repay the interest on the loan initially made from the Permanent Fund. The Board of Government, therefore, voted to close the Publication Fund and transfer the sum of $756.11 to the Permanent Fund.

During the year the Transportation Section felt that a series of lectures on Highway Transportation and Design would be of value to the membership of our Society and to the Profession in general. Since the only funds available to the Section were those needed for their routine business, the Board of Government voted to transfer $125.00 from the Desmond FitzGerald Fund and $125.00 from the William P. Morse Fund. The $250.00 transferred was used to establish the Transportation Lecture Fund upon which the Section could draw for its various expenses involved in the lecture series.

The income in interest and dividends to the Permanent Fund less the expenses charged to the Permanent Fund was $3,830.76. This sum was transferred to the Current Fund to defray the fiscal expenses. There was, however, a remaining deficit of $420.48 in fiscal expenses. The principal of the Permanent Fund was reduced by this amount and the sum transferred to the Current Fund.

A total of $360.00 in entrance fees was added to the Permanent Fund.

It is interesting to note that of the total expenditures of the Society approximately 21% came from the income to the various funds. Without this income it would be necessary to increase the dues by 20% more or less or curtail some of the many benefits to the membership.

Of the cash funds on hand indicated in the following tables, $295.65 is held in escrow for Federal Withholding Tax payments, Massachusetts Income Tax, and Social Security.

PAUL A. DUNKERLEY, *Treasurer*

TABLE I
COMPARISON OF BOOK VALUES AND MARKET VALUES OF STOCKS, BONDS, CO-OP BANK, AND INVESTMENT CASH

	BOOK VALUE 3/1/61	MARKET VALUE 3/1/61
Bonds	$ 51,942.25	$ 47,112.52
Stocks	55,193.47	150,583.26
Co-op Bank	4,442.74	4,442.74
Available for Investment	3,091.79	3,091.79
Total 1961	$114,670.25	$205,230.31
Total 1960	109,067.54	183,665.14
Increase	$ 5,602.71	$ 21,565.17

TABLE II
COMPARISON OF BOOK AND MARKET VALUES OF FUNDS

	BOOK VALUE 3/1/61	MARKET VALUE 3/1/61
Permanent	$ 66,254.40	$118,578.37
John R. Freeman	35,454.25	63,454.00
Edmund K. Turner	1,327.32	2,375.56
Desmond FitzGerald	2,478.74	4,436.31
Alexis H. French	1,331.91	2,383.78
Clemens Herschel	1,167.17	2,088.93
Edward W. Howe	1,196.10	2,140.71
William P. Morse	2,476.96	4,433.12
Surveying Lectures	513.53	919.09
Structural Lectures	370.85	663.73
Boring Data	1,000.00	1,789.74
Volume I	863.57	1,545.57
Transportation Lectures	235.45	421.40
	$114,670.25	$205,230.31

TABLE III

DISTRIBUTION OF FUNDS—RECEIPTS AND EXPENDITURES

BOSTON SOCIETY OF CIVIL ENGINEERS

REPORT OF TREASURER—MARCH 1, 1961

	DISTRIBUTION OF FUNDS			NET PROFIT OR LOSS AT SALE OR MATURITY		TRANSFER OF FUNDS		BOOK VALUE 3/1/61
	BOOK VALUE 3/1/60	INTEREST AND DIVIDENDS				PURCHASED	SOLD	
		CASH	CREDIT	+	—	+	—	
	1	2	3	4	5	6	7	8
Bonds	$ 51,942.25	$1,922.50						$ 51,942.25
Co-op Bank	4,291.23		$151.51					4,442.74
Stocks	52,108.32	5,028.66		$3,104.15		$5,590.67	$2,505.52	55,193.47
Available for Investment	725.74					2,366.05		3,091.79
Total	$109,067.54	$6,951.16	$151.51	$3,104.15		$7,956.72	$2,505.52	$114,670.25

Columns 1 + 3 + 6 — 7 = 8

TABLE III—*Continued*

		ALLOCATION OF INCOME—PROFIT AND LOSS				
FUNDS	BOOK VALUE 3/1/60	INCOME COL. 2 & 3	NET PROFIT COL. 4 & 5	RECEIVED	EXPENDED	BOOK VALUE 3/1/61
Permanent	$ 63,711.33	$ 4,227.15	+$1,847.44	$ 1,116.11	$ 4,647.63*	$ 66,254.40
John R. Freeman	32,623.26	2,164.50	+ 945.97		279.48	35,454.25
Edmund K. Turner	1,296.75	86.04	+ 37.60		93.07	1,327.32
Desmond FitzGerald	2,502.46	166.03	+ 72.56		262.31	2,478.74
Alexis H. French	1,292.01	85.72	+ 37.46		83.28	1,331.91
Clemens Herschel	1,083.13	71.86	+ 31.41		19.23	1,167.17
Edward W. Howe	1,249.44	82.90	+ 36.23		172.47	1,196.10
William P. Morse	2,480.86	164.60	+ 71.94		240.44	2,476.96
Surveying Lectures	471.51	31.28	+ 13.67		2.93	513.53
Structural Lectures	340.51	22.69	+ 9.87		2.12	370.85
Boring Data	1,000.00					1,000.00
Vol. I	388.42			535.15	60.00	863.57
Transportation Lectures	0.00			430.00	194.55	235.45
	$108,439.68	$ 7,102.67	+$3,104.15	$ 2,081.26	$ 6,057.51	$114,670.25
Current	1,500.00	3,830.76**	+	17,738.85	21,569.61	1,500.00
Totals	$109,939.68	$10,933.43	+$3,104.15	$19,820.11	$27,627.12	$116,170.25

Secretary's change fund of $30.00 should be added to show total cash

Cash Balance	Investment Fund	$3,091.79	$4,251.74	* Transferred from Permanent Fund
	Current Fund	1,500.00	3,830.76**	** Transferred from Income to Permanent Fund
	Total Cash	$4,591.79	$ 420.48	Transferred from Principal of Permanent Fund

Table IV—Record of Investments—Bonds
March 1, 1960 to March 1, 1961

BONDS	DATE OF MATURITY	INTEREST RATE	INTEREST RECEIVED	PAR VALUE	BOOK VALUE 3/1/61	MARKET VALUE 3/1/61
Aluminum Company of America	Apr. 1, 1983	3⅞%	$ 193.75	$ 5,000.00	$ 5,037.50	$ 4,781.25
Associates Investment Co. Deb.	Aug. 1, 1979	5⅛%	307.50	6,000.00	6,000.00	6,157.50
Columbia Gas System Inc., Deb., Series D	July 1, 1979	3½%	70.00	2,000.00	2,066.17	1,815.00
Consumers Power Co. 1st Mortgage	Sept. 1, 1975	2⅞%	86.25	3,000.00	3,140.35	2,583.75
Florida Power Co., 1st Mortgage	July 1, 1984	3⅛%	31.25	1,000.00	1,017.50	802.50
Florida Power Co., 1st Mortgage	July 1, 1986	3⅞%	193.75	5,000.00	5,037.59	4,400.00
General Motors Acceptance Corp.	Sept. 1, 1975	3⅝%	181.25	5,000.00	5,101.80	4,606.25
Georgia Power Co., 1st Mortgage	Dec. 1, 1977	3⅜%	168.75	5,000.00	5,162.50	4,400.00
Province of Ontario	Sept. 1, 1972	3¼%	97.50	3,000.00	2,936.25	2,692.50
Public Service Electric and Gas Co.	June 1, 1979	2⅞%	115.00	4,000.00	4,097.50	3,267.52
Scott Paper Co. Conv. Deb.	Mar. 1, 1971	3.0%	30.00	1,000.00	1,123.79	1,357.50
So. Pacific 1st Series A Oregon Lines	Mar. 1, 1977	4½%	180.00	4,000.00	4,191.30	3,785.00
Superior Oil Co. Deb.	July 1, 1981	3¾%	150.00	4,000.00	4,000.00	3,740.00
Tidewater Oil Co. Deb.	Apr. 1, 1986	3½%	70.00	2,000.00	2,032.50	1,685.00
U.S.A. Treasury Notes Series A	May 15, 1964	4¾%	47.50	1,000.00	997.50	1,038.75
Totals			$1,922.50	$51,000.00	$51,942.25	$47,112.52

Table V—Record of Investments—Stocks
March 1, 1960 to March 1, 1961

STOCKS	CLASSIFICATION	NO. OF SHARES	DIVIDEND RECEIVED	BOOK VALUE 3/1/61	MARKET VALUE 3/1/61
American Telephone & Telegraph Co.	Common	207	$ 683.12	$ 7,729.00	$ 23,779.13
Consolidated Edison of New York Inc.	Common	50	150.00	2,494.03	3,593.75
Continental Insurance Co.	Common	150	307.50	3,506.71	8,887.50
General Electric Co.	Common	150	300.00	2,341.47	9,862.50
Hartford Fire Insurance Co.	Common	104	114.40	1,472.75	7,007.00
General Motors Corp.[2]	Common	126	63.00	5,576.32	5,670.00
Jewel Tea Co., Inc.	Common	62	108.50	1,467.10	3,177.50
National Dairy Products Corp.	Common	100	200.00	1,154.74	6,412.50
New England Electric System	Common	198	213.84	3,075.89	4,554.00
Pacific Gas and Electric Co.	Common	105	273.00	3,625.34	8,531.25
Scott Paper Co.	Common	75	165.00	4,860.86	7,875.00
Southern California Edison Co.	Common	59	143.00	1,932.99	4,314.38
Standard Oil of New Jersey	Common	324	729.00	3,260.66	14,256.00
Texaco, Inc.	Common	222	621.30	3,034.49	21,534.00
Union Carbide Corp.	Common	100	360.00	2,958.44	12,450.00
Union Pacific Railroad[1]	Common	220	198.00	0.00	0.00
Pacific Gas and Electric Co.	Preferred	100	150.00	2,704.89	3,150.00
Radio Corporation of America	Preferred	20	70.00	1,720.75	1,442.50
Southern California Edison Co. Ltd.	Preferred	40	104.00	1,140.24	2,680.00
Southern Railway Co.	Preferred	75	75.00	1,136.80	1,406.25
Totals			$5,028.66	$55,193.47	$150,583.26

[1] Sold 220 shares of Union Pacific Railroad September 16, 1960.

[2] Purchased 126 shares of General Motors Corp. September 16, 1960.

Table VI—Record of Investments—Co-operative Bank

CO-OPERATIVE BANK	CLASSIFICATION	NO. OF SHARES	DIVIDEND RECEIVED	BOOK VALUE 3/1/61	MARKET VALUE 3/1/61
First Federal Savings and Loan Association of Boston, Acct. No. 1S-631	Savings Account		$151.51	$4,442.74	$4,442.74

TABLE VII—COMPARISON OF BOOK VALUES DURING LAST FIVE YEARS

YEAR	*1957*	*1958*	*1959*	*1960*	*1961*
Bonds	$ 51,907.25	$ 51,907.25	$ 52,944.75	$ 51,942.25	$ 51,942.25
Stocks	51,465.51	51,432.25	52,026.74	52,108.32	55,193.47
Co-op Bank	4,845.16	5,003.89	4,155.11	4,291.23	4,442.74
Available for Investment	4,388.24	1,212.35	1,208.18	725.74	3,091.79
Totals	$112,606.16	$109,555.74	$110,334.78	$109,067.54	$114,670.25

TABLE VIII—COMPARISON OF MARKET VALUES DURING LAST FIVE YEARS

YEAR	*1957*	*1958*	*1959*	*1960*	*1961*
Bonds	$ 48,531.24	$ 48,956.90	$ 47,671.60	$ 44,690.65	$ 47,112.52
Stocks	109,725.00	106,907.46	135,493.75	133,957.52	150,583.26
Co-op Bank	4,845.16	5,003.89	4,155.11	4,291.23	4,442.74
Available for Investment	4,388.24	1,212.35	1,208.18	725.74	3,091.79
Totals	$167,489.64	$162,080.60	$188,528.64	$183,665.14	$205,230.31

REPORT OF THE SECRETARY

Boston, Mass., March 16, 1961

To the Boston Society of Civil Engineers:

The following is a statement of cash received by the Secretary and of the expenditures approved by the President in accordance with the Budget adopted by the Board of Government.

FOR THE YEAR ENDING MARCH 16, 1961

	Expenditures	Receipts
Office		
Secretary, salary & expense	$ 689.25	
Treasurer's Honorarium	397.00	
Stationery, printing & postage	694.30	
Incidentals & Petty Cash	146.35	
Insurance & Treasurer's Bond	36.38	
Quarters, Rent, Tel.	3,955.50	
Office Secretary	4,800.00	
Social Security	191.20	
Meetings		
Rent of Halls, etc.	200.00	
Stationery, printing & postage	47.00	
Hospitality Committee	1,596.31	$ 1,512.01
Reporting & Projection	18.00	
Annual Meeting, March, 1960	687.50	491.50
Sections		
Sanitary Section	27.79	
Structural Section	45.55	
Transportation Section	15.00	
Hydraulics Section	19.40	
Construction Section	9.40	
Surveying & Mapping Section	8.00	
Journal		
Editor's salary & expense	723.50	
Printing & Postage	5,510.16	
Reprints	—	
Advertisement	—	1,548.45
Sale of Journals & Reprints	—	2,006.90
Library		
Periodicals	67.50	
Binding	93.50	
Forward	$19,978.59	$ 5,558.86

REPORT OF THE SECRETARY (Continued)

	Expenditures	Receipts
Brought Forward	$19,978.59	$ 5,558.86
Miscellaneous		
Binding Journals for Members	12.75	12.75
Badges	—	5.00
Bank Charges	8.18	
Miscellaneous	433.81	14.01
Engineering Societies Dues and charge for Journal space	1,071.84	
Public Relations Committee	64.44	
Membership Committee	—	
Dues from B.S.C.E. Members		11,727.75
Trans. Income Perm. Fund		3,830.76
Trans. Principal		420.48
	$21,569.61	$21,569.61

Entrance Fees to Permanent Fund $360.00

28 New Members; 9 New Junior Members; 1 New Student Member; 13 Juniors transferred to Member.

The above receipts have been paid to the Treasurer who's receipt the Secretary holds. The Secretary holds cash amounting to $30 included as payment under item 23 (Petty Cash) to be used as a fixed fund or cash on hand. $219.13 withholding tax and $76.52 Social Security which is payable to the Collector of Internal Revenue and State of Massachusetts in April, 1961 is not included in the above tabulation.

CHARLES O. BAIRD, JR., *Secretary*

REPORT OF THE AUDITING COMMITTEE

Boston, Mass., March 16, 1961

To the Boston Society of Civil Engineers:

We have reviewed the records and accounts of the Secretary and Treasurer of the Boston Society of Civil Engineers and we have compared the bank statement of securities held by the Boston Safe Deposit and Trust Company with the enumeration submitted by the Treasurer.

We have found them to be in order and to account accurately for the Society's Funds.

FRANK L. HEANEY
WILLIAM A. HENDERSON

REPORT OF THE EDITOR

Boston, Mass., March 13, 1961

To the Board of Government
Boston Society of Civil Engineers:

The Journal was issued quarterly, in the months of April, July, and October, 1960 and January, 1961, as authorized by the Board of Government on December 20, 1935.

During the year there have been published 12 papers presented at meetings of the Society and Sections.

The four issues of the Journal contained 373 pages of papers and proceedings, 7 pages of Index and 41 pages of advertising, a total of 421 pages. An average of 1,590 copies per issue were printed.

1,000 extra issues of the July, 1960 Journal at a cost of $310 were printed for distribution at the A.S.C.E. Convention.

The cost of printing the Journal was as follows:

Expenditures	
Composition and printing	$4,089.00
Cuts	766.81
Wrapping, mailing & postage	344.35
Editor	707.50
Copyright	16.00
1,000 Journals for ASCE Convention	310.00
	$6,233.66
Receipts	
Receipts from sale of Journal and reprints	$2,006.90
Receipts from Advertising	1,548.45
	$3,555.35
Net cost of Journal to be paid from Current Fund	$2,678.31

CHARLES E. KNOX, *Editor*

REPORT OF THE LIBRARY COMMITTEE

Boston, Mass., March 16, 1961

To the Boston Society of Civil Engineers:

The work of the Library Committee consisted of selecting new books to be purchased for the Library. In December letters were sent to the Chairmen of the various sections requesting recommendations of suitable books.

The Library Committee held two meetings, on January 24 and February 1, respectively, to discuss the recommendations that were received. Consideration was also given to available book reviews published in 1959 and 1960 relating to the subject of Civil Engineering. As a result of these discussions the following list of books was selected for purchase:—

Soil Mechanics, Foundations, and Earth Structures, Tshebotorioff, McGraw-Hill
Elasticity Fracture and Flow, Jaeger, Wiley
Creep of Engineering Material, Finnie and Heller, McGraw-Hill
Structural Design for Dynamic Loads, Norris et al., McGraw-Hill
Waste Treatment, edited by P. C. G. Isaac, Pergamon Press, N. Y.
Handbook of Corrosion, H. H. Uhlig, Wiley
Design of Small Dams, Supt. of Documents
Cumulative Index to ASCE Publications
Highway Engineering Handbook, McGraw-Hill
Theory of Plates and Shells, 2nd Ed., Timoshenko
Basic Geology for Science and Engineering, Dapples, Wiley
Aerial Photographic Interpretation, Lueder, McGraw-Hill

The following books were received as gifts from the authors:

Elementary Structural Analysis, C. H. Norris and J. B. Wilbur
Chemistry for Sanitary Engineers, Clair N. Sawyer.

THOMAS C. COLEMAN, *Chairman*

REPORT OF THE HOSPITALITY COMMITTEE

Boston, Mass., March 16, 1961

To the Boston Society of Civil Engineers:

The Hospitality Committee submits the following report for the year 1960-1961:

The Annual Dinner, a joint meeting with the American Society of Civil Engineers in conjunction with the Department of Civil Engineering, Northeastern University, a joint meeting with the Northeastern University Civil Engineering Society, a special dinner meeting in connection with the 1960 national convention of the American Society of Civil Engineers, and five regular meetings of the Society were held during the past year.

Catered dinners were served prior to all but two meetings of the Society.

The average attendance of members and guests for all nine meetings or dinners (using the larger attendance figure) was 73, as compared to last year's average of 110. The attendance at regular meetings of the Society was 52 persons per meeting. This was considerably below last year's average of 86. Heavy snowstorms and sub-zero temperatures during the months of December and January were largely responsible for the reduced attendance figures.

SUMMARY OF MEETINGS AND ATTENDANCE

Date	Place	Attendance Meeting	 Dinner
March 16, 1960	Hotel Vendome	27	120
April 25, 1960	Hotel Lenox	35	35
May 18, 1960	United Community Services Building	53	47
September 28, 1960	United Community Services Building	90	58
October 10, 1960	Statler Hotel	170	170
November 16, 1960	United Community Services Building	70	32
December 14, 1960	United Community Services Building	14	—
January 25, 1961	United Community Services Building	35	—
February 15, 1961	Northeastern University	69	69

CLEMENT D. ZAWODNIAK, *Chairman*

REPORT OF THE ADVERTISING COMMITTEE

Boston, Mass., March 16, 1961

To the Boston Society of Civil Engineers:

One meeting of the Advertising Committee was held during the past year. Mrs. Virginia Boudia again acted as advertising solicitor for the Journal; also, members of the Board of Government and chairmen of the various sections were asked to solicit for advertisements from those concerns with which each had some contact.

During the past year, $1,548.45 was collected from advertisers. This is a reduction of $260.25 from the previous year.

The following advertising has been carried in the Journal during the year:

	April	July	October	January (1961)
Professional Cards	36	37	37	37
¼ page	18	19	18	19
½ page	1	1	1	1
Full page	1	1	1	1
Inside Front Cover	1	1	1	1

It is recommended that consideration be given to using professional solicitors to obtain advertisements.

GEORGE M. REECE, *Chairman*

REPORT OF THE JOHN R. FREEMAN FUND COMMITTEE

Boston, Mass., March 1, 1961

To the Boston Society of Civil Engineers:

Mr. William F. Uhl resigned from the Committee this autumn. He has served as member of the Committee since 1942. The Board of Government appointed Mr. George R. Rich, of Charles T. Main, Inc., a member of the Committee to take Mr. Uhl's place.

The Committee has appropriated money to provide for the publication of the report of the Committee on Floods which will shortly be ready for editing for publication. The estimated requirements are $500 for preliminary work, and $1500 to $2000 for printing.

HOWARD M. TURNER, *Chairman*

REPORT OF LEGISLATIVE COMMITTEE

Boston, Mass., March 9, 1961

To the Boston Society of Civil Engineers:

Appearances were made by members of the Committee on several Bills during the 1960 registration session. The Bills related to classification of engineers in state departments and to regulations concerning contracts for Public Works.

There was little legislative action concerning registration of engineers during the 1960 session. A Bill House No. 2271 would have required an extension of the Grandfather Clause. Acting together with the Committee for Registration of Professional Engineers and of Land Surveyors, we obtained legislative counsel and were successful in preventing the passage of this legislation.

We also took part with this same Committee in the successful efforts to obtain favorable action on appointment of engineers recommended by the engineering societies to the Board of Registration of Professional Engineers and of Land Surveyors.

Members of our Committee have been present at legislative hearings during the 1960 session.

EDWARD WRIGHT, *Chairman*

REPORT OF THE PUBLIC RELATIONS COMMITTEE

Boston, Mass., March 16, 1961

To the Boston Society of Civil Engineers:

No formal meetings were held during the year by the Public Relations Committee as no subject matter was evidenced to warrant a meeting of the Committee.

The undersigned called upon representatives of the Boston daily newspapers at the Press Room, Boston City Hall, and requested their co-operation in publicizing the Society and Section meetings. Very little newspaper publicity resulted from this endeavor.

During the year, copies of notices of meetings were sent to approximately fifty members of the Society for posting at their various offices.

All Society members are requested to consider this problem of public relations and publicity, and submit their recommendations to the president for action by the Public Relations Committee.

JOHN F. FLAHERTY, *Chairman*

REPORT OF THE COMMMITEE ON SUBSOILS OF BOSTON

Boston, Mass., March 1, 1961

To the Boston Society of Civil Engineers:

Boring data from Greater Boston, prepared for publication by the Committee on Subsoils of Boston, appeared in six issues of the Journal from October 1949 to October 1956.

This data, consisting of 6,356 borings and 203 open-cut excavations to bedrock, has been reprinted and will be published by the Society in one volume in the near future.

The Committee is now working actively on the collection of recent boring data to supplement that already published in the Journal.

LAWRENCE G. ROPES, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION

Boston, Mass., March 16, 1961

To the Sanitary Section,

Boston Society of Civil Engineers:

Four meetings of the Sanitary Section were held during the year as follows:

June 4, 1960.—Joint Meeting with the Parent Society. This meeting was the Annual Sanitary Outing which took place at Derry, New Hampshire. The speaker at this meeting was Darrell A. Root. One of the highlights at this meeting was the inspection of a Sewage Oxidation Pond. Members and guests had luncheon at the Chanticleer Lodge in Derry, New Hampshire. Forty-one members and guests attended this meeting.

October 19, 1960.—Ariel A. Thomas presented a paper on "Starting up New Sewage Treatment Plants." Twenty-three members and guests attended this meeting.

December 7, 1960.—Gerald McDermott from the Taft Sanitary Engineering Center presented a paper on "Predicting a Pollution Effect Upon a River." Thirty-eight members and guests attended the meeting.

March 1, 1961.—Annual Meeting. The following officers and members of the Executive Committee were elected:

Robert H. Culver	Chairman
George W. Hankinson	Vice Chairman
Charles Y. Hitchcock, Jr.	Clerk
Francis T. Bergin	Committee
James M. Symons	
William C. Traquair	

A paper entitled "Small Sewage Treatment Plant," was ably presented by Richard M. Power. Fifty-four members and guests attended this meeting. Total attendance for the four meetings was 156. Average attendance was thirty-nine.

Four meetings of the Executive Committee were held during the year.

George W. Hankinson, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE STRUCTURAL SECTION

Boston, Mass., March 16, 1961

To the Structural Section,

Boston Society of Civil Engineers:

The following meetings of the Structural Section were held during the past year.

April 13, 1960.—Mr. Paul S. Crandall of Crandall Dry Dock Engineers, Inc. spoke on the subject "Reconstruction—Charles River Dam Lock Gates." Attendance 31.

May 11, 1960.—Mr. Morton H. Eligator of Weiskopf & Pickworth gave a talk on the Subject "Design & Construction of Chase Manhattan Bank's New Head Office Building." Attendance 60.

November 9, 1960. Mr. Albert G. H. Dietz, Professor of Structural Engineering at M.I.T., spoke and led a discussion on the "Draft for a Revision of Part 28—Structural Metals—of the Boston Building Code." Attendance 45.

December 14, 1960.—Joint Meeting with the Main Society. Mr. Roland S. Greeley, Associate Professor of City Planning at M.I.T., spoke on "A City Planner Looks at the Urban Explosion." Attendance—16—in spite of the fact that this was during the period of Boston's worst December blizzard in many years.

January 11, 1961.—Mr. Melville E. Prior of Dewey & Almy Division, W. R. Grace & Company, spoke on "Better Concrete through Chemistry." Attendance 62.

Total attendance at the five meetings was 214. Average 43.

Edward N. Smith, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SURVEYING AND MAPPING SECTION

Boston, Mass., February 24, 1961

To the Surveying and Mapping Section,

Boston Society of Civil Engineers:

Three meetings of the Surveying & Mapping Section were held during the past year as follows:

May 18, 1960.—Joint Meeting with the Boston Society of Civil Engineers. Mr. George MacDonald, Vice President of Lockwood, Kessler & Bartlett, spoke on "Modern Trends in Surveying." Attendance 45.

October 26, 1960.—Mr. Loring P. Jordan, Jr., a partner in the Law Firm of Rachemann, Sawyer & Brewster, gave an interesting talk on "Waterfront Property Lines." Attendance 15.

January 18, 1961.—Annual Meeting—The following Officers were elected for the coming year:

Roy L. Wooldridge	Chairman
Rudolf S. Slayter	Vice President
Richard D. Raskind	Clerk
Joseph A. Bodio	Executive Committee
Robert E. Cameron	
Alexander E. Manning	

Following the elections, Mr. Robert E. Cameron spoke on "The Geodimeter Base Line Survey, Kunhar River Valley, West Pakistan." Attendance 23.

Total attendance for the year was 83; average attendance 28.

ROY L. WOOLDRIDGE, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE CONSTRUCTION SECTION

Boston, Mass., March 16, 1961

To the Construction Section,

Boston Society of Civil Engineers:

The Construction Section was essentially reactivated during the current year. In order to increase interest in the activities of the Section, an unofficial advisory group of interested members was convened by the chairman and held three meetings during the year. These meetings were used to discuss a long range objective and program for the Section, as well as a program for the current year.

There was substantial agreement among the members participating in these discussions that it should be the general objective of the Section to provide a meeting grounds for that portion of the society membership which encompasses a wide range of engineers with a direct or indirect interest in construction. These members would represent widely differing points of view and areas of principal interest, and many of them would not be directly employed in the contracting business; however, all would be interested in the common area of interaction between engineering design, fabrication and construction.

Thus, it was felt that future programs should be of three types:

1. Programs in which a guest speaker discusses a specific subject of interest to the membership. Most such programs would deal with problems involving an interplay between engineering and construction aspects.
2. A series of interrelated lectures on a particular topic of the type mentioned above, but which had widespread interest to the membership and required a broader and more detailed presentation. Thus, members would be able to obtain more than a survey, or narrowly detailed, coverage of important new developments affecting engineered construction. An example of such a lecture series would be one on the applicability of precast and prestressed concrete to various types of construction in the future, including broad design considerations, requirements for feasibility, methods of manufacture, and construction problems frequently encountered.
3. Discussion meetings which permit discussion between members and guests, of widely varying specialized backgrounds of experience but with mutual interests, on the influence of engineering considerations on construction and visa versa. Such discussion meetings could take the form of a panel discussion between a limited number of invited participants in front of a general meeting, or of a meeting open only to members of the BSCE which would be an open discussion with only a single moderator to keep it orderly.

The section was assigned only one meeting date in the period between September 1, 1960 to March 1, 1961. The theme of this meeting was the rational use of precast and prestressed concrete in building construction. The speakers were Mr. Irwin Spire, principal engineer with the Freyssinet Company, New York City, and Mr. Robert Bierweiler, Vice President of New England Concrete Pipe Company. Attendance of 72 was close to the capacity of the meeting room and extremely encouraging for the success of the new program.

A third program, planned for April 12, is a joint presentation with the Structural division of a talk by Mr. William Mueser on the Design and Construction of the Bremerton Basin Dock.

New Officers of the section for 1961-62 are the following:

Robert A. Bierweiler	Chairman
James Archibald	Vice Chairman
John Cullinan	Clerk
Frank J. Heger	Executive Committee
Leonard Tucker	
Donald Goldberg	

FRANK J. HEGAR, *Chairman*

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AND
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The advertising pages of the JOURNAL aim to acquaint readers with Professional and Contracting Services and Sources of Various Supplies and Materials. You would find it of advantage to be represented here.

Volume 48 APRIL, 1961 Number 2

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

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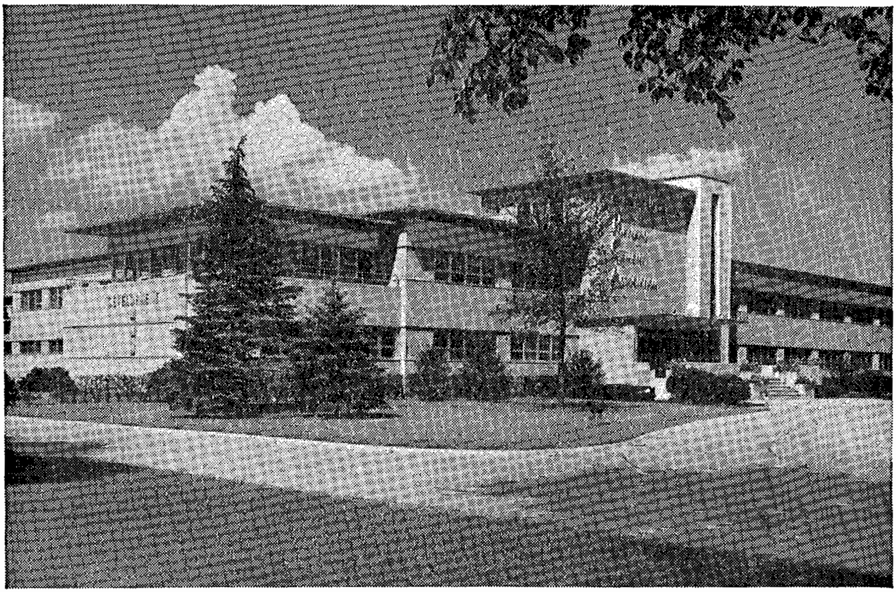

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