Consultants, Clients & Contractors

This timeless article, reprinted from the January 1958 issue of the BSCE Journal and written by a pioneer in soil mechanics, shows what it truly takes to excel at engineering practice.

KARL TERZAGHI

In this paper the writer describes some of his experiences as a consultant to engineering organizations on five continents, on projects involving large earthwork operations. Special emphasis is given to the factors which may lead to partial or complete failure of a project in spite of sound advice rendered by the consultant.

Introduction

A consultant is a person who is supposed to know more about a subject under consideration than his client. Once an engineer has acquired a reputation for superior knowledge and discovers that there is a demand for his services, his future career depends upon what he expects to get out of life. If he longs for financial success and social prestige, he will find that his aims can hardly be satisfied without the assistance of an engineering organization. Once the organization exists he becomes a slave to it. His income increases, but so do his worries. Sometimes he has sleepless nights because he does not know how to handle all the orders which have rained into his lap, and at other times, because his overhead charges begin to exceed his income. In any event, the Tax Collector sees to it that his income does not assume staggering proportions. He may still believe that he is a consultant, but in reality he has turned into a business man and executive equipped with all the prerequisites for stomach ulcers.

On the other hand, if he derives his principal satisfaction from practicing the art of engineering, he will desist from establishing an organization and concentrate all his efforts on broadening his knowledge in the field of his choice. In order to be successful in this pursuit he must be not only willing but eager to spend at least half of his time on unprofitable occupations such as research or the digest of his observational data. Therefore, his money-making capacity remains limited, but in exchange he has fewer worries and retains his freedom of action. That is the type of occupation which turned out to agree with my disposition.

Initiation Into the Consulting Fraternity

I never felt tempted to make a blueprint for my professional career, except inasmuch as I always considered the performance of work for the mere sake of earning money a waste of time and acted accordingly, quite often on the spur of the moment. Therefore, I did not join the consulting fraternity deliberately. I was dragged into it by accident and discovered afterwards that it was amazingly congenial. This happened about thirty-five years ago.

I was then forty years old and I was teaching applied mechanics and related subjects at the American Robert College in Istanbul. However, I spent most of my time on research concerning the physical properties of sedimentary deposits such as sand and clay. My interest in this field had been acquired in earlier years, while I was still engaged in the practice of earthwork engineering. During those years I became more and more impressed by our incapacity to predict the performance of soils under field conditions, and my affiliation with Robert College gave me a welcome opportunity to search for a remedy.

My research activities had no relation to my duties as a teacher, and they yielded no financial compensation. Yet I felt perfectly happy because I earned enough to live on and my venture into the unknown was so exhilarating that I felt no desire to exchange it for a more profitable occupation.

At the time referred to, I was engaged in digesting the results of my investigations concerning the consolidation of clay strata. In connection with this occupation I visited an industrial plant located at the head of the drowned portion of a valley in the proximity of Istanbul, because I was told that an open excavation was being made at the site of the plant. From the general geology of the region I knew that the subsoil of the plant consists of a deposit of soft silt and clay, with a maximum depth of several hundred feet, and I wanted to collect some specimens to be tested in my make-shift laboratory.

When I arrived at the site, I found, in addition to the excavation, a heap of precast reinforced concrete piles and the setup for a pile loading test. This fact aroused my interest, because I knew that the predecessors to the new structure rested on mat foundations. Therefore, I called on the general manager of the plant, whom I had met socially, and asked him to explain the project to me.

According to the construction drawings which I was shown, one-half of the proposed structure would have rested on point-bearing piles and the other half on friction piles embedded in soft clay. I was shocked and explained to the manager that the piles would do more harm than good. The portion resting on point-bearing piles is rigidly supported, whereas the portion on friction piles would settle at least several inches, whereupon the pile-supported foundation would fail like an overloaded cantilever beam by bending. Therefore, I suggested that the Company should sell the piles or throw them into the Bosporus.

After lengthy discussions, the manager began to realize the weight of my arguments but, he added, he would never succeed in inducing the design department of his organization, with headquarters in France, to accept my unconventional proposal. Therefore, he invited me to make a trip to France and try it myself. At the headquarters of the organization I, an obscure teacher, faced engineers with well established reputations, full of confidence in the soundness of their judgment. My arguments were received with utmost skepticism. The pile loading test had already shown that the settlement of the friction piles under the design load was negligible and, as a consequence, my pessimistic settlement forecast was considered to be wrong. Nevertheless, the mere existence of arguments in favor of the gloomy prediction made the designers of the foundation somewhat uneasy. Therefore, a compromise solution was proposed and accepted. The piles were retained as part of the foundation, but the site of the building was shifted away from the slope, whereupon all the piles assumed the function of friction piles.

I left France with the conviction that the structure would settle as if the piles had not been driven, whereas my clients believed that the results of the settlement observations would demonstrate the absurdity of my settlement estimate. The preceding controversies were very instructive and suited my tastes to perfection. Thus I had discovered an interesting field for the practical application of the results of my research activities and I wished to get more assignments of a similar kind.

I did not have to wait very long, because as soon as the structure under consideration was completed, it started to settle approximately at the rate predicted by me, whereupon confidence in my judgment was established and the usefulness of my professional services was recognized.

A few months after I had returned to Istanbul, the manager of the plant showed me the settlement record of the older portion of the plant. The structures were at that time about twenty years old and all of them rested on reinforced concrete mats. According to the settlement forecast of the designers, based on the results of surface loading tests, the foundations should have settled by amounts not in excess of half an inch. In reality the settlement of the structures had reached a value of 16 inches. That was the reason why it was intended to establish the new building on a pile foundation. Yet the performance of the new structure showed that piles had practically no influence on the settlement of structures resting on the subsoil of the plant.

At the time when the new building was started the rate of settlement of the older ones had already become insignificant. However, while the new plant was under construction the rate of settlement of the existing structures increased again to several inches per year, and I was asked to investigate the causes of this surprising development. Upon inquiry, I found out that the rate of settlement of the old structures had started to increase at almost exactly the time when the sinking of a nearby caisson well was completed and pumping operations were started. The water was drawn from a gravel stratum located between the clay stratum and the surface of the underlying bedrock. At the time of the inquiry I already had a clear conception of the mechanics of the consolidation of clay strata and there was no doubt in my mind that the increase of the rate of settlement was due to the reduction of the porewater pressure in the gravel stratum, produced by the pumping operations. Therefore, I had no difficulty in persuading the management to plug the well. As soon as this was done, the rate of settlement again became inconsequential.

Immediately after the well was plugged, the foundation of the crane rail of a revolving derrick located at the waterfront of the plant site started to settle unequally, at an alarming rate, although the settlement of the rail had previously been too small to be noticed. The crane rail was mounted on a semi-circular platform, resting on untreated timber piles acting as friction piles embedded in soft clay. The space between the original ground surface, a few feet below low tide level, and the base of the platform, about seven feet above this level, consisted of an uncompacted cinder fill.

At the time the settlement started, the manager of the plant was already fully aware of the undesirable properties of the clay deposit underlying his plant. Therefore, he blamed the performance of the derrick foundation on the clay and asked me to remedy the situation by underpinning, or some other suitable procedure. However, the history of the settlement of the derrick foundation appeared to me to be incompatible with the consolidation characteristics of the clay. Therefore, I started my investigations at the platform. A single test pit excavated at the edge of the platform through the fill to the original ground surface sufficed to show that the clay was innocent, and the culprit was the teredo. Above low tide level, portions of the piles, with a diameter of 14 to 16 inches, were almost completely destroyed by the marine borers. After the fill was removed, some of the piles could even be knocked over by the laborers. Yet below the teredo-infested top section the piles were perfectly sound. Therefore, the reconstruction of the derrick foundation was performed by cutting the piles below low tide level and establishing the reinforced concrete rail support on the intact portion of the piles.

Important Consequences of Casual Observations

The assignments described under the preceding heading are typical of many others I had to handle during the following decades in various parts of Europe, the United States and North Africa. However, quite often the most essential services I rendered to my clients had no relationship to the original assignment. They grew out of casual observations I made while inspecting the site. The observations at the site of a multiple-arch dam are an example.

One of the buttresses of the dam had cracked and I was asked to make proposals for protecting it against further damage. At the time of my arrival at the site the reservoir was still empty. I found that the outer parts of the base of the buttress rested on sandstone and the middle part on shale. The cracks were produced by the compression of the shale and further damage could be prevented by a simple underpinning operation.

As a by-product of my visit to the site I noticed the following facts which had previously not received any attention. The shale bed responsible for the unequal settlement of the buttress formed part of a stratified formation composed of practically impervious layers of shale and intensely jointed beds of hard sandstone. The strike of the bedding planes intersected the direction of the crest of the dam at approximately right angles and the dip was approximately equal to that of the dip slope of the valley at the site of the dam.

A few hundred feet upstream from the left abutment, the left-hand slope of the valley cut across the sandstone strata, providing free communication between the water in the reservoir and the joint system in the sandstone, whereas downstream from the dam the uppermost sandstone stratum was covered by a shale bed. Hence, while the reservoir was being filled the hydrostatic pressure on the base of the sloping shale bed would increase, and before the reservoir was full, the shale bed would be lifted off its seat and the dam would fail.

As a result of this discovery, the settlement of the buttress became a minor issue and the center of gravity of the problem shifted to the hydrostatic pressure conditions prevailing in the joint system of the rock strata underlying the site. By similar casual observations during construction, which had no direct connection with my assignments, I also prevented the failure of three major dams of the earth and rock-fill type.

Design Assumptions & Field Conditions

The assignments referred to under the preceding headings have one essential feature in common. In each case an engineering organization was in serious trouble and therefore willing to accept the consultant's recommendations. If the consultant is invited to cooperate on a project before unanticipated difficulties have been encountered, conditions may be radically different. This is due to the fact that some engineering organizations are subdivided into three independent compartments — the survey, design, and construction departments — or else they assign the supervision of construction to inspectors who have neither the duty nor the qualifications to judge whether or not the design assumptions are compatible with the field conditions.

The survey department is in charge of the topographic survey and the subsoil exploration by borings. The results of their labors are represented in a set of drawings which are turned over to the design department. The engineer in charge of the design may have visited the site of the proposed structure a couple of times, but the principal source of his information concerning the subsoil conditions is the boring records. These are accepted at face value, sometimes even without any inquiries concerning the qualifications of the personnel engaged in the boring operations. The draftsmen who prepare the construction drawings have not even seen the site. After the drawings are completed, "checked" and approved, they are transmitted, together with a set of specifications, to the construction department, whereupon the association of the design department with the project is practically terminated. The construction department receives orders to erect the structure in accordance with drawings and specifications, and has no obligation to make any inquiries concerning the design. Similar conditions prevail if the functions of the construction department are assigned to a group of inspectors who have not been connected with the design of the project.

In connection with structural engineering this administrative set-up is perfectly satisfactory, provided the engineers in charge of design are reasonably familiar with the methods of construction. On the other hand, in the realm of earthwork and foundation engineering the absence of continuous and well organized contacts between the design department and the men in charge of the supervision of the construction operations is always objectionable and can even be disastrous. This is due to the fact that boring records always leave a wide margin for interpretation. If the site for a proposed structure is located on a deposit with an erratic pattern of stratification, such as a marginal glacial deposit, the boring records may not disclose a single one of the vital subsoil characteristics, and the real subsoil conditions may be radically different from what the designer believed them to be. Therefore, the design assumptions may be utterly at variance with reality.

The consequences of these conditions depend on the qualifications of the personnel engaged in the supervision of the construction operations. If the supervision is in the hands of a construction department it also depends to a large extent on whether or not design and construction departments are on friendly terms with each other. More often than not the two departments despise each other sincerely, because their members have different backgrounds and different mentalities. The construction men blame the design personnel for paying no attention to the construction angle of their projects, but they are blissfully unaware of their own shortcomings. The design engineers claim that the construction men have no conception of the reasoning behind their design, but they forget that the same end in design can be achieved by various means, some of which can be easily realized in the field, whereas others may be almost impracticable. If none of the men in charge of design has previously been engaged in construction, the design may be unnecessarily awkward from a construction point of view. In any event, the construction men have no incentive to find out whether or not the design assumptions are in accordance with what they experience in the field during construction, and serious discrepancies may pass unnoticed. If conditions are encountered which require local modifications of the original design, the construction engineer may make these changes in accordance with his own judgment, which he believes is sound, although it may be very poor. Important changes of this kind have even been made on the job without indicating the change on the field set of construction drawings.

Furthermore, the layout of temporary installations is commonly left to the discretion of the superintendent of construction. The drainage provisions for unwatering the site for an earth dam and those for the disposal of the water coming out of a wet tunnel belong to this category.

The drainage provisions for unwatering the site for an earth dam prior to the beginning of the filling operations may introduce an element of serious weakness into the structure without the superintendent of construction suspecting it. In one instance the box drains leading to the sumps at the site for an earth dam were laid out in such a manner that the completed structure would have failed by piping through the drains. When I arrived at the site the drains were already buried beneath fill material and no record was kept of the location of the drains. Fortunately, the thickness of the layer of fill located above the drains was still moderate. After I reconstructed the layout of the drains on the basis of the results of cross-examination, it was not yet too late to eliminate the sources of weakness represented by the drains.

On another project the excavation for a powerhouse was being made at the foot of a forest-covered talus slope. The talus consisted of a mixture of rubble and the sandy and silty products of rock weathering. The slope rose at the angle of repose of the talus material to the exit of a wet tunnel at an elevation of about one thousand feet. The water coming out of the tunnel was allowed to flow into the uppermost portion of the accumulation of talus, where most of it disappeared into the voids of the material. When the quantity of discharge reached a value of about 3 cfs a talus slide occurred. The slide removed the forest cover of the slope, killed two men who were working in the excavation and filled the excavation with a mixture of rocks and trees. Subsequent investigation showed that neither the resident engineer representing the construction department, nor the contractor's superintendent of construction had suspected that the flow of water into the uppermost part of the talus slope could have disastrous consequences.

Such can be the qualification of the men who are placed in responsible charge of erecting a structure "in accordance with drawings and specifications." If the field conditions are radically different from the design assumptions they may not even notice it. The following example illustrates the possible consequences of the failure of a field inspector to pay any attention to the design assumptions. The project involved the construction of a tall reinforced-concrete structure. The site was located above a steep rock slope which was subsequently buried in succession under a blanket of gravel, a layer of soft clay, a peat deposit and artificial fill. The site was explored by borings spaced 50 feet both ways. According to the soil profile which was constructed on the basis of the boring records, the surface of contact between the gravel structure and the overlying soft and highly compressible sediments was well defined and fairly even. Therefore, the design department decided to establish the structure on spread footings supported to point-bearing piles to be driven through the soft sediments to refusal in the gravel blanket.

When the piles were driven, the total depth of penetration varied within each cluster by amounts up to 16 feet. Yet the superintendent did not notice that this fact is incompatible with the design assumption. After all the piles were driven and the structure almost completed, the structure started to settle unequally by amounts up to one inch per month. It was not until then that the abnormal performance of the piles was brought to the attention of the design department. Subsequent investigation showed that the thickness of the gravel stratum was very much greater than the original borings indicated and that it contained thick lenses of soft clay. The bearing capacity of the individual piles was much greater than the design load, and the settlement was exclusively due to the consolidation of clay lenses. Some of the piles had met refusal in the gravel above a clay lens and others went through several clay lenses into the lower portion of the gravel stratum. This was the reason for the erratic variation in the total depth of penetration of the piles. If this variation had been brought to the attention of the design department as soon as it was observed, the causes would have been investigated and the pile-driving procedure modified in such a manner that all the piles could be driven to bedrock.

Performance by the Contractor

If a job is carried out on a contract basis, one more element of uncertainty enters into the operation. It is the attitude of the contractor towards his work. The contractor cannot be expected to be interested, or even aware of, the reasoning behind the design. His sole aim is to perform the work covered by the contract at a minimum expense. (Occasional discrete departures from the specifications reduce the cost quite considerably.) The inspectors, too, may be inclined to consider uncomfortable items in the specifications as superfluous refinements, conceived in the hothouse atmosphere of the design department. Such an attitude is not conducive to rigorous inspection. Therefore, a consultant can never be sure how a structure was built unless he maintains continuous contact with the construction operations. To illustrate this statement the writer adds an account of some observations he made during the construction of a dam resting on decomposed rock.

The dam was a clay dam with internal drainage supplemented by a row of filter wells which were drilled through the decomposed rock into sound, jointed rock at a depth ranging between 40 and 90 feet. In order to coordinate the construction operations with the time schedule, the upstream portion of the embankment was constructed before the filling operations on the downstream side of the base of the dam were started.

The dam was built by a contractor with considerable experience in the field of earth dam construction. Yet every one of the memoranda I wrote describing my findings at the site after returning from my inspection trips contained passages like the following:

> "At the site of the dam, the cutoff trench was already backfilled. Along the west slope of the first installment of the fill, the new fill was placed against older, dried out and uncompacted material. The gradient of the surface of the new fill was such that the next rainstorm will produce a pool in the northeast corner of the new fill. The pumping equipment is inadequate. Although the job calls for a large amount of hand tamping, the contractor has made no provisions for tamping equipment. On the upper level, in the upstream portion of the dam, filling operations should be discontinued because the water content of the borrow pit material is at

present too low and the contractor has made no provisions for sprinkling.

"At the southeast corner the contractor has blocked the exit for the accumulating rainwater by a pile of waste material. Originally the lowest point of the saddle southeast of the site was 505. Now it is already 508.5 and the diversion of the rainwater towards the southeast will require a substantial amount of excavation which could have been avoided by intelligent planning.

"In my last memorandum I requested that the north end of the cutoff trench should be excavated down to decomposed rock. The inspector assured me that he has passed this request on to the contractors. Nevertheless, I found that the fill was placed against the pocket of very permeable alluvial materials.

"If the contractors continue to disregard the elementary rules for the construction of earth dams and to ignore the instructions of the inspector wherever they can, the resulting structure will be unsafe in spite of conservative design."

Consultants or Scapegoats

Conditions like those described under the preceding heading prevailed on many of the projects with which I was associated in the course of my professional career. In some instances they were considerably worse. Hence it is evident that the success of large-scale earthwork operations depends on many factors other than the adequacy of the original design. This fact introduces serious complications into the relationship between the client and a consultant who is retained in an advisory capacity in the design stage of a project.

The incentive for retaining a consultant commonly grows out of the fact that the functions of most engineering organizations cover a very broad field, including earthwork, structural, hydraulic, mechanical, and electrical engineering. Few, if any, of the members of such an organization have the time and the opportunity to specialize. Hence, if a new project assigned to such an organization involves design problems of an unusual character, a consultant is retained who is expected to cooperate in the solution of the problems.

In engineering organizations with a watertight partition between designers and the personnel engaged in construction, the consultant is quite obviously placed at the disposal of the design department. After the design is completed his service period on the project, like that of the design department, is considered terminated. He has no control over what the inspectors and the contractor chose to make out of the drawings and specifications, and he cannot even know whether or not the men on the job are competent enough to notice significant differences between design assumptions and field conditions. If the engineering firm does not maintain a construction department, or if the owner reserves the right to supervise construction, conditions may be even worse. The consequences depend on the type of service the consultant was asked to render, as shown by the following examples:

(a) The client requests the consultant to participate in the design of a structure and in the drafting of the specifications. He has the sincere intention of acting in accordance with the consultant's recommendations, but the service period of the consultant ends as soon as construction starts. The consultant's advice cannot be sounder than his knowledge of the subsoil conditions at the time when the advice was rendered. If these conditions are radically different from what the boring records indicated — which is by no means uncommon — the structure may fail in spite of conscientious adherence to the consultant's advice.

(b) The client invites the consultant to make proposals concerning design and construction, but he reserves — or assumes — the right to deviate from the recommendations as he deems fit, without informing the consultant about the final decision concerning the design. If this decision is the result of misjudgment or ignorance, the consultant is unable to prevent its consequences.

(c) The consultant gets the assignment of participating in the design of a small portion of a large unit; *e.g.*, the design of the core for an earth dam which has been designed by others. If the structure fails on account of conditions which have no bearing on the

performance of the portion investigated by the consultant, this portion goes with it, and after failure it may be impracticable to find out which part failed first.

(d) The consultant is asked to express an opinion concerning the design of a structure without being given an opportunity to make a thorough investigation of all those field conditions which determine the performance and safety of the structure. The consultant's opinion may be sound or unwarranted, depending on circumstances unknown to all the parties involved.

(e) An engineering firm requests a consultant to participate in the preliminary stage of a large project merely for the purpose of using his name as window dressing. If and when the firm gets the job, the consultant is shelved and remains in his state of retirement unless something goes wrong. After the shortcomings of the design have become noticeable it may be too late to correct the mistakes.

In each one of these five cases the name of the consultant remains permanently associated with the project. Proceeding from case *(a)* to case *(e)* the hazards to the good reputation of the consultant increase. In any event, if the project ends in disaster the consultant will find himself in the front row of scapegoats, because he was introduced to the owner as the foremost authority among the persons who participated in the design.

Conclusions

On account of the hazards involved in the lack of contact between design and construction departments on jobs involving large earthwork operations, progressive and competent engineering organizations maintain a soil mechanics department. During the design period this department supervises the boring operations and performs the soil tests. During the subsequent construction period it has the function of testing intermittently the materials derived from the borrow pits, supervising the compaction procedure and adapting it to changes in the character of the borrow pit materials. It has the additional function of comparing the design assumption concerning subsoil conditions with the conditions encountered in the field and, if necessary, modifying the design in accordance with the findings, requesting the design department to make the required changes. The importance of the services of the soil mechanics department is particularly notable on projects involving the design and construction of earth dams, because most of the favorable dam sites have already been utilized and soil conditions at the remaining ones may be so complex that the design assumptions based on the results of the subsoil exploration preceding the design stage are utterly at variance with those encountered during construction.

If a consultant is retained by an engineering organization in which the soil mechanics department maintains a continuous and intimate contact between design department and the job during the construction period, the cooperation between consultant and client is commonly frictionless and satisfactory, provided the members of the soil mechanics department are well trained and competent. Furthermore, the consultant can render a maximum of service in a minimum amount of time, because the soil mechanics department keeps him informed on whatever differences between design assumptions and field conditions are detected during the construction operations, and the department can be expected to take care that his instructions will be carried out on the job.

However, in most engineering organizations, design and supervision of construction are still divorced, though this fact may be camouflaged by a small soil mechanics department with no function other than providing the design department with the basic data for design. If a consultant is invited by an engineering organization with such an administrative setup to cooperate on a project in the design stage, he should watch his step. First of all, he should turn down the assignment unless it involves the duty to remain in active contact with the project until the end of the period of construction, and to inspect the job whenever he considers it necessary. In order to be able to perform his duty he must get detailed weekly reports informing him of all those observational facts which have a significant bearing on the validity of the design assumptions. Such a report can be prepared only by a competent soils engineer, who stays on the job permanently. Second, if the consultant accepts the assignment, he should find out as soon as possible whether or not the inspection of the construction operations on the job is satisfactory. If he arrives at the conclusion that the inspection is inadequate and his efforts to ameliorate the condition are unsuccessful, he should submit his resignation, leaving no doubt concerning the reasons which compelled him to do so.

The subject of this paper is of vital interest to consultants as well as to their clients and to the persons who furnish the capital for realizing their projects. The need for expert advice on difficult projects is universally recognized. However, the cooperation of consultants of high standing on such projects creates an unwarranted feeling of security, unless full advantage is taken of the services they are able to render. A satisfactory formula for accomplishing this purpose has not yet been established.

The preceding suggestions are based on my personal experiences and observations, the scope of which is inevitably limited. Therefore, other consultants and engineering firms employing consultants could render a valuable service to the engineering profession by presenting in the discussions to this paper some of their experiences and opinions concerning the relationship between consultants and clients.

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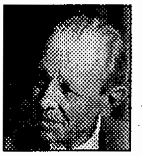
NOTE — *A reprint (photocopy) of the original facsimile paper and all of the discussions is available for $25.00 from BSCES, The Engineering Center, 1 Walnut St., Boston, MA 02108-3616, (617) 227-5551.*



KARL TERZAGHI, *founder of soil mechanics and a renowned civil engineer, was born in Austria in 1883. He received a conventional education at a military school in Hungary. In 1904, he received his engineering degree from the Technical University of Graz. Two years later, he returned to the university for another year of study, chiefly in geology. Terzaghi began practicing civil engineering as a superintendent of construction in various parts of the Austrian Empire and in czarist Russia. In January 1912, after receiving his doctorate from the Technical University in Graz, Terzaghi traveled to the United States in the hopes of obtaining insight into fundamental principles by means of a systematic study of the relation between foundation conditions. Returning to Austria in 1913, Terzaghi was convinced of the inadequacy of case studies, supported only by theoretical insight, into the behavior of soils under conditions imposed by civil engineering operations. He embarked on a program of experimental and theoretical research designed to provide the required fundamental knowledge. Five years later, the results were presented in a book,* Erdbaumechanik auf bodenphysikalischer Grundlage, *published in Vienna. In 1925, Terzaghi received an invitation to lecture at the Massachusetts Institute of Technology (MIT). In 1929, Terzaghi left MIT to accept a professorship at the Technical University of Vienna. Terzaghi returned to Cambridge in 1938 to accept a part-time lectureship at Harvard University, which appointed him Professor of the Practice of Civil Engineering in 1946. After retiring in 1956, he continued to lecture for several more years as a professor emeritus on engineering geology. During the last three years of his life, Terzaghi wrote six important papers, a large number of illuminating discussions, and several reports on projects with which he had been intimately and actively connected. He died in 1963.*