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THE CIVIL ENGINEERING MIND — NATURE AND NURTURE

by
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Civil engineering is not an intellectual exercise although it has intellectual content. The civil engineer is action-oriented. He creates bridges to cross rivers; he collects, transports, purifies, and delivers water to drink and renders our waste products harmless. He creates facilities for moving people and goods — highways, subways, railways, airports and pipelines. He makes society as we know it possible. Increasingly he is recognized as the man to save the environment, not by stopping civilization but by accommodating it to nature.

Sam Mathis was such a man, a man of action. He created facilities to bring us energy from the oil fields of Venezuela and the gas fields of Libya. It is most fitting to name this lectureship in his memory and I am honored indeed to be chosen to bring you this first Sam Mathis Lecture. I hope my comments would have met with his approval.

Increasingly, we hear that the civil engineer should have more to say about government policy at all levels, that he should be heard, that he should not passively carry out technical assignments but should actively promote and support specific causes and courses of action. He should be advocate, politician, humanitarian. He should be in the forefront, fighting battles for the consumer, for conservation, for environment, and against pollution. He should, in short, make his influence felt.

I should like now to look at the engineer, man or woman, consider how he can best be trained, how he can best make his contributions, what responsibilities he should or can take, and how he can best serve society.

Ralph H. Burke

To set the stage, I should like to look at the accomplishments of one engineer with whom it was my good fortune to work for many of my younger years. This man quite possibly contributed more to the physical well-being of Chicagoans than any other engineer and perhaps as much as any person regardless of his profession. I doubt if you would know his name; it was not widely recognized by most Chicagoans even in his life-

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time. Ralph H. Burke died in 1956. I bring him to you as an example of what the civil engineer can accomplish in public service, both as a public employee and in private practice. He was a man of great technical ability, innovative, never satisfied with the past, a skilled negotiator, not a politician but one who had remarkable influence among politicians, a man to whom, indeed, politicians turned to solve many of their city's most pressing problems.*

Accomplishments

In 1934 he became Chief Engineer of the Chicago Park District, concerned with recreational facilities for Chicago's many neighborhoods. At the urgent request of Mayor Kelly in 1938 he was made available, while still holding that position, to serve as the Chief Engineer of Subways and Traction for the City of Chicago during the period of construction of the Initial System of Chicago Subways. The idea of subways for Chicago was not new; there had been many tentative plans for at least a generation, but no plan ever came to action. Suddenly the Public Works Administration, created to reduce unemployment during the Great Depression, approved an application by the City of Chicago for a grant to build its subways, but with the provision that construction be started within an incredibly short period of a few weeks. There were no plans, no specifications, not even an agreed-upon route. Little wonder that Mayor Kelly felt the urgency. Ralph Burke accepted the assignment, persuaded many disparate parties to agree on the subway routes, assembled a staff for design, surveying and construction, issued contract drawings and specifications for the first section of the subway, and had the work under contract within the deadline.

As we shall see, he was no stranger to tunneling, and he recognized the dangers and dislocations associated with tunneling in the soft clays beneath downtown Chicago. When he attended a meeting of the Western Society of Engineers at which Karl Terzaghi spoke on that subject, he engaged Terzaghi forthwith and agreed to Terzaghi's requirements of a laboratory staffed by suitable personnel under the direction of a man of Terzaghi's choosing. I was fortunate enough to be that choice.

Within a week of Mr. Burke's engaging Terzaghi, I arrived in Mr. Burke's office where he was impatiently awaiting me. As I had been told to come to the office immediately on reaching town, Mrs. Peck and I turned up on Friday morning directly from the railroad station. Mr. Burke graciously introduced himself to both of us and promptly dispatched me to the site of the first construction contract, where test borings were being made by a special crew under the supervision of a foreman imported from Boston

*I am indebted to J. L. Donoghue, President, Ralph H. Burke, Inc. for furnishing a number of the details about Mr. Burke's career.

because he knew how to take 2-in. Shelby tube samples. The problem seemed to be that Chicago clays did not want to stay in the Shelby tubes if treated by the procedures that were successful in Boston. Mrs. Peck waited while I dashed out to see the foreman, who certainly knew more about making Shelby tube borings than I did. Happily, he and I were able to work out some tricks that increased the recovery, and Mrs. Peck and I were granted the remainder of the weekend to rent an apartment and settle down.

The subway organization was still being created when I arrived. Mindful of his promise to Terzaghi, Mr. Burke enthusiastically assigned to the soil laboratory every inexperienced job applicant who had just received a Master's degree in civil engineering. We were truly an inexperienced group — all of us — but the nucleus of eight young men whom Mr. Burke selected worked together with great effectiveness. They went on, I am happy to say, in almost every instance to distinguished careers.

Although Mr. Burke liked to joke about his collection of inexperienced MS's, he was nevertheless entirely serious about the benefits to be obtained from soil mechanics as it began to develop before his eyes under Terzaghi's direction. When Terzaghi suggested a test section on one of the liner plate tunnel contracts, Mr. Burke instructed us to prepare a design on the basis of which he could negotiate with the contractor. Those of you who are familiar with Terzaghi's paper on Liner-Plate Tunnels on the Chicago Subway may recall the S-6 test section, the end result of Terzaghi's suggestion. In this day of expensive instrumentation, it is almost inconceivable that the added contract cost for the construction of the test section, not counting our own efforts, was about $6,000. Even at these bargain rates, the administrator of the federal funds, who was the overseer for the U. S. government on the project, refused to approve such an unprofitable expenditure. Nothing daunted, Mr. Burke persuaded the Chicago City Council that the test section would be a good investment, and the Council voted to finance it from City funds. That the investment paid off was demonstrated only a few years later when the lining of the Congress Street extension was designed to take advantage of the findings, at a substantial saving in cost.

After the first two years of subway construction, when the major problems had been faced and solved, Mr. Burke returned to the Chicago Park District in 1940. He stayed there as Chief Engineer until 1946, when at the age of 64 he left the Park District to establish a consulting engineering firm. One of his first assignments was the development of a major airport for the City of Chicago, the airport that today you all know as O'Hare. For many years it has been the busiest airport in the world and one of the most efficient. Mr. Burke had never had anything to do with airports before, but now he was responsible for what he felt would need to be the world's largest. He did not believe in thinking small. He considered a number of sites, including the possibility of one in Lake Michigan. After many comparisons and much discussion with all parties concerned, including the airlines, he settled on what was then known as the Chicago Orchard Site (did you ever wonder where the symbol ORD originated?), and developed a master plan that required the purchase of some 6,700 acres of property. At the time, jets had not yet entered civilian aviation in the United States. The jet age was on the horizon but nobody had any notion of its enormous impact on our ways of travel. Mr. Burke foresaw that the operation of great numbers of large jet-powered planes was inevitable within the lifetime of the proposed airport, and made his plans accordingly. Each time I visited him, for I was responsible for the initial soil studies of the area, I would see dozens of new master plans being laid out and evaluated. Many were unlike any yet in operation, but his imaginative mind led him to investigate all possibilities. The master plan of O'Hare field today is not Mr. Burke's, because he died in the early stages of its construction, but the preeminence and continued effectiveness of O'Hare can be attributed largely to his insistence on sound planning and the acquisition of enough property to permit the necessary development.

Mr. Burke was not only capable technically, but was also a patient and successful negotiator. At O'Hare, two major railroads crossed the site and a third skirted the edge. The two railroads on the site had, of course, to be relocated around the future airfield. Relocation of this sort is usually compensated by determining the increased length of trackage, by estimating future traffic, by determining the cost of the additional ton-miles associated with the relocation, and by capitalizing this cost. Such computation for the two railroads at O'Hare indicated a cost of several million dollars. Furthermore, the railroads were not overly cooperative in assisting the development of a competing form of transportation. Mr. Burke called in representatives of the two railroads and pointed out that air freight would become a major way of moving goods, that there would necessarily be an interface between air freight and rail freight, and that O'Hare would certainly become an air freight center. He foresaw additional business generated for the two railroads because of their favorable location and he declared that the city was willing to grant them an exclusive right for this traffic if they would be willing to be relocated without compensation. He went on to say that if they were unwilling to enter into such an agreement, the City would be inclined to give exclusive rights to the third railroad which merely skirted the property. The railroads wasted little time in accepting the proposal.

The relocated railroads had to cross a peat bog with a depth up to about twenty-five feet for a distance of about one-half mile. The agreement with the railroads required all unstable material beneath the right-of-way to be removed and replaced. Unfortunately, removal of the peat for the two-hundred-foot right-of-way would have been very expensive, and extremely flat slopes would have been required adjacent to the excavation for stability. The flat slopes would have encroached on a major highway and a high pressure gas line. We concluded that the peat could be stabilized by a combination of sand drains and surcharging, a procedure that up to that time had been used only to a very limited extent. The railroads, who had anticipated that the peat would be removed, raised objections. Mr. Burke blandly pointed out that upon completion of the stabilization there would be no unstable material beneath the track and, therefore, there would be nothing according to the agreement that needed to be removed. Although the consolidation due to the surcharging took about a year longer than planned, the operation was nevertheless successful. I smile every time I land at O'Hare and look out at the parallel railroad tracks on the peat bog.

Somewhat later he undertook the Grant Park Underground Garage, on its completion the largest parking garage in the world. Quite typically, Mr. Burke had never before designed a parking structure. Anxious as always to keep costs to a minimum, Mr. Burke inquired whether the two-level garage could be floated without any deep foundation although its base would rest on the softest part of the Chicago clays. The entire structure, a single floating raft three hundred by twelve hundred feet in plan, has served its purpose admirably. It was so successful that the Park District at a later time built a similar underground structure with three levels beneath Grant Park and Michigan Avenue several blocks to the south. It, too is supported by a floating foundation.

I have told you only some of Ralph Burke's major accomplishments, but I think they will demonstrate to you that this one engineer left his mark on many aspects of the City of Chicago. He was indeed an indispensable man. Notwithstanding that he was a lifelong Republican and a resident of Evanston, while Chicago was controlled by the Democratic party and while one of the requirements for employment by the City of Chicago was residency within the city itself, three successive Democratic mayors turned to him as the man to do the hard jobs.

Training

What were his background and training? For fourteen years he was employed by the Sanitary District of Chicago, where he advanced to principal construction engineer. The Sanitary District had an enviable reputation as a progressive engineering organization and, among other activities, pioneered tunnel construction in the soft Chicago clays. For another fourteen years he was chief engineer and general superintendent of a major contractor doing heavy construction in the Chicago area. Many of us might think that twenty-eight years constitute a full career, but for Mr. Burke it was a training period after which he embarked on and carried out his major engineering works. His education? He studied liberal arts at Northwestern University to please his father, although he wanted to be an engineer.

Thereafter, he attended MIT, from which he was graduated in 1906. Thus, Ralph Burke is one of your own most distinguished graduates, and it is partly for this reason that I have chosen to tell his story on this occasion. After MIT, he continued part-time studies at the Kent College of Law in Chicago, again to please his father. Although he did not receive a law degree, his legal education gave him a valuable background that had much to do with his ability to deal with contractors and to negotiate. Thus, we can say that he not only had the best technical education possible in his day, but an unusually broad, general education as well.

Experience

I have mentioned Mr. Burke's long period of practice as an engineer and a contractor while he learned the details of his profession from all sides. There is a feeling today that the young engineer who wishes to leave his mark should and can vault immediately into a position of authority where he can make major decisions and influence development without thorough broad education, technical training and apprenticeship. A few engineers have succeeded in doing so, but most who have tried to advance too rapidly, who have been too impatient, who have felt that the years of learning as apprentices are too costly, have experienced the frustration of failing to meet their goals and ambitions. They have been forced to make decisions without adequate knowledge. They have been forced to accept the opinions of too many others without being able to apply the test of their own experience. They have found themselves listening to equally persuasive but contradictory arguments and unable to reach a rational decision of their own. In short, they have lacked full preparation. I would not argue that 28 years are needed. The time could be much shorter, but the experience is invaluable.

Engineering Education

A successful and influential civil engineer like Ralph Burke has many backgrounds to draw upon but, in my view, he is fundamentally a technical man. Without technical competence, no matter what his other attributes, he is not an engineer. There is no substitute for decisions based on dispassionate, rational thinking grounded in experience. Hence, I am quite convinced that the engineer's education must, therefore, be primarily technical. It should not be narrow; it should not overlook communication with others; it should not avoid studying social values; but it must above all be technical. It should not be divorced from practice but pointed toward practice.

Much has been said about the need to include socio-humanistic subjects in the engineering curriculum. I would not disagree in principle, and Ralph Burke's broad background illustrates their value, but I submit that every person learns best what he is most interested in, at the time when his interest is greatest. A prospective engineer as a student is most interested in the practice of engineering. His courses, then, should be slanted in this direction. Even the basic courses should contain practical examples from which the student can get glimpses of the essential nature of his subject.

I do not mean that all courses, or even many courses, should be case-history studies. There is far too much to learn to permit the luxury of many such cases or courses. Yet, if the instructor has the desire and the background, practice can be brought into the most basic course. For a good many years I have taught two courses, the beginning course in foundation engineering for undergraduates, and the finishing course in foundation engineering for graduate students. The latter is strictly a case history course, and I find it challenging. Nevertheless, the beginning course for undergraduates is even more challenging. The young men and women meeting this subject are just beginning to glimpse what their profession is like. They have been injected with large doses of mathematics, physics, chemistry and mechanics, but they have seen very little of what engineering does with these fundamentals. We try to assign our best and most experienced teachers to that first undergraduate foundations course, because they can bring into it the brief first-hand glimpses of the profession that make the difference between action-oriented engineering and academia.

Moreover, even the most practical-minded student, the one most technically oriented, may be highly receptive to instruction in public speaking and in good writing if he realizes that his professional advancement depends on his ability to communicate his ideas. He may be receptive to psychology if he realizes that he will become a member of a team consisting of people of many disciplines and walks of life — architects, planners, politicians, financiers, interested citizens — and that if he is to make his contribution he must be persuasive, understanding, and perceptive. What better place to develop and insist on good English than in every engineering report? The English and rhetoric departments cannot go it alone; without the follow-through in the technical classroom, the future civil engineer will all too readily conclude that real engineers don't need such extravagances. But give him the incentive and he may learn the pleasure of good craftsmanship in writing and speaking.

I hasten to add that a surprisingly large number of civil engineering students have broad interests and take pains to cultivate them. I hope our curricula allow such students to follow their interests without unnecessary academic restrictions.

Research and Teaching

Research is essential in the development of civil engineering and of civil engineering teachers. Yet research in civil engineering is not civil engineering, and the two should not be confused. Unless civil engineering research arises out of practice, as it should, it is likely to lead to a false conception of what civil engineering is actually about. On the other hand, research closely and clearly related to practice is invaluable to a student participant at all levels, and essential at the highest graduate levels. It may be complex and sophisticated, but if the student (and his research supervisor) have a clear view of how it may fit into the advancement of practice, it can serve as an effective vehicle for education. If it does not arise out of practice, if the researcher must attempt to find some practical area in which his esoteric results might possibly find an application, it is a supremely poor educational experience.

Who teaches our civil engineers? Often their professors are not really civil engineers at all. They are researchers, theoreticians, analysts. They are working in areas essential to civil engineering, they often make contributions to civil engineering, but they are not in fact civil engineers and they cannot give undergraduate students a realistic picture of civil engineering. Worse still, they may attract graduate students to follow in their own footsteps, to become still more refined and still further removed from the profession. Although there are some happy exceptions among both professors and institutions, I fear that civil engineering education and civil engineering are drifting apart, and that someday our most highly rated schools may find themselves playing a secondary role in the education of civil engineers. I fear, too, that the accreditation of our engineering schools, to which we in academia pay so much attention, is akin to the self-ratings of members of an exclusive club.

How can we avoid this apparent divergence of civil engineering teaching from civil engineering practice? Not, as might seem obvious, by converting retired practitioners into professors because, with a few shining exceptions, these men have been separated from the academic world for so long that they fail to realize the legitimate demands on the time of students for the engineering fundamentals that must be taught. I believe it can be accomplished at least partly by three major steps, which I shall enumerate rather than attempt to develop in detail.

Practice

The first is to inject young staff members into practice. This can be done in many ways, and it reflects quickly in their teaching. Secondly, there should be administrative enthusiasm rather than administrative disdain for practice. When promotions are considered, significant practice should be recognized not only as being equal to the preparation and publication of research, but as being more desirable than publication or research. Undoubtedly, I am bucking the present trend with this statement, but I feel it strongly. I can't help asking what we are trying to do with our emphasis on publication and research: advertise our universities, or train engineers? Thirdly, we can use innovative techniques in teaching. I am convinced that case histories, properly used, can teach engineering judgment to a substantial degree. I was greatly pleased and favorably impressed by the report written on the Mangla Dam project by Professor Lambe's students a few years ago. This project was innovative to a high degree, and I am sure it left its mark on every student as well as every staff member who participated. I was intrigued not only by the interest of the students in Mangla Dam, but also by their great interest and considerable enthusiasm for the Tarbela Project, which they visited somewhat incidentally to Mangla. The reason for the enthusiasm and for the difference in attitude was that Tarbela was under construction, a going concern, whereas Mangla was essentially completed. Here, I think, is the key to good civil engineering education. The students are interested in the action of their profession. They should see their profession in action, and they will derive from these insights the motivation to learn whatever is necessary to engage actively in their profession. They can even be persuaded that economics, English, or law are worth their attention.

Engineering Judgment

Should the engineer be a partisan or advocate of one side in matters of consumer interest, of the environment, of all the issues that we encounter so frequently today? Only, I feel, if he has considered and fairly evaluated all the evidence that he can obtain. Partisanship based on suppressing part of the evidence, based on emphasizing the desirable aspects associated with one point of view and the undesirable aspects associated with the other, this partisanship tarnishes the public's view of the engineer who, in reality, has nothing to offer if it is not a balanced judgment derived from a dispassionate study. Biased partisanship, which makes the point but suppresses part of the facts, is not for the civil engineer. The civil engineer need not and should not be disinterested, but he should be fair. That his views may not be spectacular enough to sway the public at the height of a controversy is an unfortunate reflection on public opinion and how it is formed, but it preserves the integrity of the profession.

There is no room, in my opinion, for Ralph Naders in civil engineering. Such people undoubtedly have effectively and dramatically called our attention to faults and shortcomings in engineering practice and have brought to pass many desirable changes. Yet, their tactics have been to highlight one side of a picture and to underplay the valid arguments that almost always exist on the other. The tactics are those of advocates, of lawyers, but not of engineers.

In our part of the country a highly controversial reservoir project is being designed by the Corps of Engineers. The project has its advantages and disadvantages, its positive and negative impacts. One of the leaders of the opposition is an engineer and an academician. He advances sound technical reasons for his objections, but never admits the possibility that there may be compelling arguments in favor of the project. He is an engineer-hero in the eyes of the opponents and is often quoted in the press. If the press reports are accurate, he characterizes the Corps of Engineers as an incompetent, biased, self-serving organization. To be sure, the Corps has made its share of mistakes, but it is by no means incompetent and it is composed of many dedicated people including engineers. Partisanship by engineers leads to exaggerated statements that discredit engineers and engineering, and in the long run can only be destructive.

There is room, of course, for honest differences of opinion among engineers. There is every reason why engineers should debate the differences, even in public. In the now prevalent violent swings of public opinion and public reaction, a partisan proponent may see his view rise and fall, to be displaced by another. Even the public recognizes that the extreme views cannot be the ultimate and best solution, and eventually, if not as soon as might be desired, comes to a more reasoned middle-ground solution toward which it can be helped by the activities of the public-minded, unbiased, experienced engineer. After violent swings of public opinion, there is often a return to sanity. It would be my hope that the engineer will be found already occupying that position of sanity, and will have had a hand in bringing the public to that ultimate point of view.

In one sense, all civil engineers are in the public service, because their works are either used directly by the public or make available something the public needs or wants. For a quarter of a century, Sam Mathis was associated with one company, a private enterprise. The odds are high that the gasoline you and I have used in our cars at one time or another has passed through some facility he constructed. From the subsiding swamps and shorelines of Lake Maracaibo to the deserts of Libya, he built his share of the physical facilities that make possible society as we know it, and without which our enormous mass of humanity could no longer survive. We may debate, with good reason, how to order our priorities in growth of population and use of resources, but whatever the decisions, there will be need for the constructive action of civil engineers like Sam Mathis and for nurturing the civil engineering mind.