DILEMMAS FACING CONSTRUCTION EDUCATION AND RESEARCH IN 1990S

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ABSTRACT: Construction, seen as a discipline calling for higher education and research, is a relatively new phenomenon that has come into being largely since World War II. As such, it is having growing pains and, with them, differences in practices and opinions on the paths to be followed. Until 40 years ago, the managers directing the actual on-site construction were predominantly ambitious, hard-driving craftsmen who had come up through the trades. Their knowledge was gained by "doing." There was little university or industry interest in college-level education for construction managers, nor technical literature nor research to support it. Since that time, some 150 college-level educational programs for construction have evolved. Currently, these follow four tracks: two programs are undergraduate and one is graduate-level, based in civil engineering; the fourth track, primarily undergraduate, rests in numerous other university departments. Research is primarily found in schools following the graduate track. Each of these tracks has its own curriculum, constituency, and supporters among educators and in industry. The dilemma facing both the construction industry and the individual academic institutions is how to develop the interest and support necessary so that the universities can better serve both the construction industry and the owners for which it builds.

INTRODUCTION

I am greatly honored to receive the 1988 Peurifoy Construction Research Award of the Construction Research Council of ASCE, and accept it with humility and with full recognition that it is not for me alone. Rather, I am the "front man" for many, many others, many of them with past or present Stanford connections. High among them is John Fondahl, who joined me there in 1955, and several other past and present faculty colleagues, as well as a host of former students who have been involved with me in construction research.

Developing this presentation offered a problem, in that the award is given by the Construction Research Council. Even so, I decided to approach the topic by looking first at university education and its problems, since much of the research for construction in the United States will be done in educational institutions. Their problems, then, will be at the root of most of the dilemmas we are discussing and of solutions to them that can be proposed. Finally, the paper examines the past, present, and possibly future situation for university research for construction.

MANAGEMENT'S SHORT-RUN VIEWPOINT—ACHILLES HEEL OF ALL AMERICAN INDUSTRY

The dilemmas to be discussed here are not unique to construction. Rather, they stem largely from a viewpoint prevalent in all American industry. It is

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expressed well by Simon Ramo (1988), leading American industrialist, as follows:

> The structure of rewards to U.S. managers of industry fails to encourage long-term risk-taking, and this holds back investments in new technologies. The American pattern is to rate the performance of business management by a simple score: earnings for the period just ended, compared with the same period for the year before. Unfortunately, projects in advanced technology usually take longer to mature.

Ramo also points out that one of the consequences of this short-run viewpoint is that the United States is losing the technology race to countries that take a longer-range view of return on investments. In these countries, industry or industry and government working together plow far more resources into education and research. One measure of the results (Ramo, 1988) is:

> In 1987, the National Academy of Engineering examined thirty-four aspects of frontier engineering—and found Japan superior or at least equal to the United States in twenty-five, Germany in twenty-two, United Kingdom in twenty, France in fifteen, and Sweden in twelve.

Today, industry and government in the United States, concerned over this loss of leadership in education, research, and technology, are scrambling madly to catch up with the other countries, particularly Japan.

No segment of U.S. industry offers a more striking example of the consequences of this short-run viewpoint and its effects on education and research than construction. This highly fragmented industry has, at least until very recently, given only niggardly support to education, a precursor to research and to research itself. For example, the industry as a whole devoted less than 0.1% of its annual income to research, excluding that spent by private industry on its products. This contrasted with 3% or more for other industries. Outlays for research through the National Science Foundation, the Construction Industry Institute (both direct and indirect contributions), and others combined totaled about $13,000,000 [ENR 1988; Tucker 1988(a) and (b)]: this from an industry with a total volume of almost $400 billion.

Construction is Complex Industry—Meeting its Needs for Education and Research is Challenging

If we are to educate or do research for construction, we need to know what the industry is all about (Oglesby et al. 1989). Briefly, it is our largest and a most complex and fragmented one. It had an annual dollar volume (1987) of $389 billion. It involves owners (government, industry, private parties, and investors), designers and construction monitors (engineers and architects), constructors (usually but not always contractors), field managers and supervisors, and craftsmen. Furthermore, the product is usually "custom made," with almost every project a separate and unique entity, conceived, financed, designed, constructed, and operated separately.

Each of the groups that contribute directly or indirectly to construction is represented by individuals, organizations, or associations with diverse and often fragmented interests. For example, among the 450,000 contractors in

the United States, the largest has an annual volume in the $8 billion range, or 2% of the total; while, at the other extreme, the smallest does only a few hundred thousand dollars worth of work annually and employs about four people. Medium and small firms predominate, with the average number of employees about 10. The top 400 contractors carry out only one-third of the total work. There are at least 25 separate construction specialties, each offering unique problems and requiring special talents. Again, construction labor, which involves some 4.4 million workers, is represented, if at all, by some 15 craft unions. Twelve national trade groups, several with state or local affililates, represent the industry's political, labor relations, and other interests. All the other contributors, to the overall construction effort, including government representatives, planners, engineers, architects, bankers, bonding companies, material suppliers, lawyers, and accountants are equally diverse in their talents, interests, and ways of operating.

If we turn our attention to a single construction project, we find another set of complexities. It involves the entire life cycle of a physical facility from the "gleam in the eye" of an owner who is exploring the need for a facility until it is finally abandoned or dismantled. The steps in this life cycle are roughly as follows: (1) Conception; (2) authorizing and financing; (3) design; (4) administering construction for or by the owner; (5) actual construction, with all the off-site and on-site activities that this entails; (6) operating and maintaining for an owner or user; and (7) dismantling. Each has its peculiar set of problems and specialists to solve them.

Given all these voices and the variety of operations that make up the construction world, there is small wonder that even defining the educational needs and research topics and priorities, much less paying for them, baffles those who would improve it.

Evolution of Construction Management from Trade to Profession

Early Attitudes of Engineers, Architects, and Contractors toward Construction Education

From the beginning, architects and engineers have seen themselves as professional master builders who planned and designed projects and then supervised the actual construction, which was done by forces working under their direct supervision or by a contractor engaged primarily to provide and supervise the labor force. Design was seen as the key contribution of these professionals, essential to and a condition precedent for actual construction. Thus, from the beginning, design has been perceived as a separate discipline, with the status due a profession.

Education for design has a long history at the college and university level and has carried a substantial role in incorporating advances in materials and analytical procedures as they developed. For example, along with the progressive development of structural materials such as cast iron, wrought iron, steel, and reinforced concrete, education in design incorporated the new geometries, theoretical methods of analysis, and specifications that made it possible to utilize these new materials successfully and economically. Furthermore, these advances in design soon appeared in books and other publications suitable for teaching at the university level. Along with these advances, there developed organizations that dignified design as a profession,

while at the same time largely ignoring business and political matters. By the 1920s engineering and architectural design had full professional status. For example, professional registration for engineers began in the 1920s.

At least in the eyes of engineers and architects, the situation for construction was entirely different. The work and its supervision was left to constructors who were commonly craftsmen who had become contractors through hard work and enterprise. Technical and management knowledge was passed on to successors primarily through trade practices or by "word of mouth," since there were relatively few books or other publications from which construction management procedures and practices could be taught or otherwise learned in an organized manner. Also, contractors were entrepeneurs, with "making a profit" the primary motivator. Supporting organizations such as the Associated General Contractors focused primarily on labor relations, legislation, and other matters that affected financial well being. For reasons such as these, a large majority of design professionals and engineering educators viewed construction as a trade, conducted ruthlessly and sometimes dishonestly. Certainly construction was not seen by most engineers and architects as a profession and a proper subject for university education.

Contractors, looking at the other side of the coin, could see little in formal education either in design or in general to help them in running their businesses. Furthermore, in their view, engineers and architects were elitists who felt themselves to be too genteel to work with their hands or push others to do so, or to be concerned with money, business, and sometimes, political matters, which were the contractor's principal concerns.

Considering these circumstances, it is easy to see why education for construction at the university level was, until World War II, almost an orphan without a home, and, even today, is suspect in some engineering and architectural circles.

Environments that Led to Development of Educational Programs for Construction

Given the environment just described, it is easy to understand why only a small percentage of the engineering, architecture, and other schools that might have instituted programs in construction actually have done so. Also, as anyone familiar with the operation of colleges and universities could have predicted, there is a diversity in their details.

The developments leading to the founding and continuation of most of the construction programs have four elements in common.

1. A single faculty member or a group of faculty, often with earlier construction experience, who saw a need for and an opportunity to educate students for careers as professionals in construction management. This field, with few exceptions, was dominated by craftsmen turned entrepreneurs and offered unusual opportunities for college graduates.
2. A forward-looking faculty and administration that was willing to acknowledge that introductory courses in construction were a proper subject for professional education, and devoted effort, time, and financial resources to them. In the beginning, the construction courses were usually introduced as electives in the formal programs in civil engineering, architecture, and even management.
3. Contractors, and in some cases governmental agencies, that were ready and often eager to hire the graduates from such programs.

4. Individual construction executives, companies, and trade groups that provided financial support for scholarships, research, or faculty positions. In numerous instances, also, these parties used their considerable influence to gain support from legislative bodies or college administrations.

Only where most, if not all, of these four elements were present at a given college or university did construction programs come into being and evolve and develop into the forms they have today.

Aims of Construction Education Today

The aim of construction education must be to give bright, alert, and hard-working individuals running starts toward a successful professional career operating in some phase of this highly complex industry. On the one hand, this education must offer enough preparation in some specialty that individuals can use it to "pay their way" immediately after leaving school, but at the same time provide the basic concepts, ways of thinking, and problem-solving tools needed later when they move toward management, which demands a broader range of knowledge and the "generalist" or "big picture" approach. Given these many demands for time in a curriculum, it becomes understandable why so many diversities in curricula and subject matter have developed. Similarly, one can see why university research interests for construction could range so widely.

Educational Programs for Construction—Past and Present

How Education for Construction Evolved

The evolution of construction education into its present forms is a fascinating story, but it can only be briefly summarized here. It is as follows:

- Before World War II: In the 1920s, a smattering of courses and a few largely informal programs in construction education were offered. In the 1930s, studies by engineering educators were made to determine the actual offerings in construction, and, based on these findings, an undergraduate construction program in civil engineering was proposed (Dietz and Little 1976; Ledbetter 1985).
- Between World War II and present: Four-year programs evolved in departments as diverse as civil engineering, architecture, and business and management. In addition, in civil engineering, some of these expanded into graduate programs.

There is some common subject matter among almost all the construction programs. From the beginning, estimating, accounting and cost accounting, and possibly contract law were included. To these many now add planning and scheduling. Textbooks are available in all of these areas. In addition, the computer is, today, a fundamental tool for students in all of these programs.

On the other hand, the programs have fundamental differences. The college- and university-level undergraduate construction programs that are based in engineering and architecture by necessity consider design to be fundamental. The little time that remains is given to a few courses in "actual construction." On the other hand, the "construction" programs, by playing

down design and the courses that support it, can devote somewhat more attention to courses in "actual construction," but they cannot also deal with many of the more complex problems and relationships. Only in graduate-level programs can more than passing attention be given to the broader range of concerns that make up the entire construction process, and are of particular concern to owners, top level personnel of the larger contractors, developers, financial interests, and governmental agencies. Highlights of and comparisons among the programs, as usually grouped, are:

Undergraduate Construction Option in Civil Engineering

This is a four-year Bachelor of Science degree that is viewed as an extension of civil engineering into construction; as such it is accredited by the Accrediting Board for Engineering and Technology (ABET). Professional affiliation is with ASCE; graduates are qualified for engineering registration. The relatively few elective units in the curriculum are devoted to courses in construction or others particularly relevant to it (Ledbetter 1985).

Undergraduate Engineering Technology Programs in Construction

These programs, accredited separately by ABET, are usually in civil engineering departments. They parallel the programs in civil engineering, but permit substitution of courses in construction or management for certain technical civil engineering subjects (Ledbetter 1985; Oglesby 1982).

Undergraduate Construction Programs

These programs are in departments of applied science, architecture, and business. As with the engineering schools, they devote something under a year to university requirements in general education, but are not bound by the requirements for engineering accreditation, which include advanced courses in mathematics and design as well as introductions to other engineering disciplines. These omissions have left time in the four-year curriculum for more attention to construction science and management and to business. Of the construction schools about 25 of the 75 are accredited by the American Council for Construction Education (ACCE); all are affiliated with the Associated Schools of Construction. Professional recognition of individuals is through the American Institute of Constructors (AIC) (Dietz and Little 1976; Dorsey 1987; Oglesby 1982).

Comparison of Undergraduate Construction Programs

Robert Dorsey of the University of Cincinnati (Dorsey 1987), with whom this writer generally agrees, contrasts the orientations of undergraduate construction programs in civil engineering, architecture, and construction science and technology as follows:

- Programs with an engineering base tend to be: (1) More academically rigorous; (2) have better access to university resources; (3) have a graduate study/research orientation; (4) are exclusive in admissions (many students with good construction aptitude are not accepted); (5) have faculty with little on-the-job experience; and (6) have insufficient space in their curricula for many true construction subjects.
- Programs with an architectural base: (1) Tend to focus more attention on general education; (2) emphasize the design-construction progression; (3)

give an appreciation for contract documents; (4) are limited in scope to buildings (as compared to broader general construction); (5) have little research orientation; and (6) are lower in priority in their colleges compared with "pure" architectural studies.

- Construction programs: (1) Are less tradition-bound than the other two and are therefore more flexible in regard to curriculum and course work involving technical applications; (2) are more oriented to hands-on field practice; (3) are more responsive to the requests of industry; (4) have lesser priority in university budgets; (5) do little research; and (6) are staffed with faculty with lesser academic credentials.

Implied but not explicitly stated in Dorsey's comparisons of the three curricula is that graduates in the civil engineering "construction option" and in architecture, with the stronger emphasis on design, would have a better understanding of what the owner's intent in building the project is. This could be an asset later in the graduate's career. On the other hand, those from the applied science and technology curricula would have developed a greater knowledge in areas such as costs, planning, scheduling, and hands-on construction topics of more immediate use and value to an employer.

Graduate-Level Education for Construction

A group of approximately 40 construction engineers and management programs, all in civil engineering, enroll 500 or more equivalent full-time students. They focus primarily on graduate work, but require that students have taken or make up undergraduate construction courses (Oberlender 1987; Oglesby 1982). Professional affiliation is with ASCE; no mechanism for accreditation has been established. Among the early advocates of such graduate programs was W. A. Klinger (1955), a past president of the Associated General Contractors, and considered by many to be the construction industry's "grand old man" of construction education.

All these schools offer a Bachelor of Science degree in Civil Engineering, including a few construction-related courses for undergraduates. Some add a "construction option" designation to the Bachelor of Science degree for these students; others do not. The rationale for adding the fifth year, which leads to the Master of Science degree, is to offer a program credible in both engineering and construction and that also presents some of the advanced approaches that have been developed or are developing in construction technology and management. Requirements for admission at most schools are high, and graduates usually have very attractive opportunities for employment. Increasingly, students in these programs are mature, having returned to school from industry looking for advanced knowledge that is not otherwise available to them. Many of the schools with graduate programs have a strong research orientation, and their students provide both research assistants and prospective doctoral candidates (Oberlender 1984).

To date, the "construction" schools have been less active in graduate education. During 1985, eight of them gave post-graduate degrees to a total of 55 students, with two schools with very strong programs accounting for 43 in the total (Dorsey 1987). However, this condition cannot continue; the only question is the rate at which the number of graduate programs will develop. Affiliation is with the Associated Schools of Construction; there is no mechanism for accreditation.

Near-Term Future for Construction Education

More than 40 years have elapsed since construction education made its first few and rather feeble beginnings. Unless certain drastic adjustments, as discussed herein, occur, it will continue to grow and adjust to meet industry's demands, but slowly.

At present, the construction programs previously described and the curricula they follow seem to be quite well situated and accepted. They have established faculties, a flow of incoming students, contractors and others ready to employ their graduates, and, with a few exceptions, very modest financial support for the program, faculty, students, and research. Under these circumstances, one would not expect drastic changes in programs, curricula, or research efforts at most schools, except for the usual adjustments that normally accompany faculty reassignments or replacements. Neither does there appear to be a rush among other schools to develop construction programs, and it is questionable that many will do so unless, at particular schools, substantial outside financial support appears.

Why Expand University Educational Programs in Construction?

Observers of the construction industry have already seen far-reaching changes in present-day practices that impact almost all aspects of the construction process. Furthermore, these observers foresee many more advances to come as the result of past, present, and future innovation and research. The role of education is to make these concepts and practices known and usable.

Many of the advances made to date have already been presented in research reports, books, and other publications, most of them in forms suitable for teaching; and similar documents covering many later findings will follow. The issue becomes one of getting this new knowledge into the hands of construction students and practitioners so that it can be put to beneficial use.

Given that this body of knowledge in teachable form exists or will develop over time, a premise that might be advanced is: *A basic understanding of the principles and practices underlying any important construction or management procedure or practice for which a well-organized body of knowledge has been developed can best be learned in a full-time or in-service educational setting rather than through self-study or by hit-or-miss exposure on the job. Logically, then, this material should be incorporated into some form of organized educational program.*

This subject matter can be presented either as a part of the regular university programs or through continuing education. Each approach is presented briefly.

Possible Ways to Expand University Offerings in Construction

Given that important construction subject matter can best be taught and should be taught in classroom settings, how can this be accomplished? Currently, the educational system for construction is neither organized nor financed to expand its coverage to fully incorporate already-developed knowl-

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edge, much less to add that which will be developed in the future.

Some aspects of the problem associated with expanding programs and possible ways of coping with it are:

Lengthening Four-Year Curriculum

There is no chance, given the crowded curricula of any of the four-year programs, to make substantial additions to them. Simply put, one can say that "To introduce new areas of study into the curriculum or to treat already-covered areas in greater depth in any of the four-year programs is not feasible." To cope with this problem there seems to be no alternative but to extend the curriculum to incorporate a fifth year of study, largely devoted to courses but possibly incorporating some electives when they can be made available, just as the five-year programs do now.

Strengthening Five-Year Programs

The current graduate construction programs already incorporate some of the newly developed knowledge in their curricula. However, they also will be forced to make adjustments to accommodate new knowledge as it develops. If the staff is sufficiently large, courses might be taught by a faculty member. Sometimes a specialist might be imported for the purpose.

Staffing in Areas Where Expertise Has and Will be Needed

At the schools having four-year programs, faculty teaching and administrative loads are already heavy, so that time will not be available to develop and teach new subject matter. At the five-year schools, although teaching loads are generally lighter, pressures on the faculty to obtain financing for and do research consumes much of their remaining time, so that developing this added expertise will be difficult for them also.

Even if funding is available, finding talented faculty to replace attrition, much less to expand current offerings can be a serious obstacle to expanding the subject matter to be taught. Although the satisfactions can be great, teaching does not appear to offer a highly attractive career for most of the ambitious young students interested in construction. Compared to industry, the pay and other rewards can be relatively unattractive. There are the ever-tightening demands for the degree of Doctor of Philosophy; and, once the person is hired, there is the scramble and trauma associated with obtaining tenure.

Staffing is probably the biggest obstacle to getting or augmenting a construction program. To establish a new faculty position, particularly if it involves tenure, will take several years. The required steps are: (1) Assuring funds to finance the position; (2) advertising the position; (3) going through the selection process to appraise the candidates and recommend one; (4) negotiating the conditions of employment; and (5) getting the person on board and established.

Developing In-Service Education

Given their present level of staffing, the universities are ill equipped to present even a fraction of the newly developed or developing materials to large numbers from the industry. However, to date, staffing in-service courses has not been a problem since industry interest in such programs is almost nonexistent (as described herein).

Role that Research Can Play in Improving Educational Programs

Sponsored research can do much to broaden and strengthen a university's educational program in construction. It provides funds to pay for released time for faculty, which can lead to an expanded teaching staff. Departments and individuals who bring in and do the research will gain stature, and this is a plus to the university, its program, and to the individuals when decisions on salary or tenure are made. Often, research contracts or grants provide the financing needed to support graduate students, particularly those at the doctorate level. Also, in most instances, universities levy a substantial overhead charge on research projects for overall administration and for the use and maintenance of its facilities. All in all, the impacts of these and other ripple effects explain, at least in part, why universities urge and sometimes insist that their faculty seek out research support.

Funding University's Expanded Role in Construction Education

Most leaders in the construction industry, owners, designers, and contractors alike, being action oriented and accustomed to seeing things happen rapidly, are not tuned in to the characteristics of universities and how they operate. They do not understand the time and cost problems to be faced in restructuring academic programs in construction or any other discipline, or what is involved in adding faculty or courses. It is common to hear complaints such as "Your graduates do not know anything about managing people," or "Why don't you have a course in heating and ventilating?" But many construction executives tend to resent or shrug off questions, vital from the university's point of view, such as "Who can teach these courses" or "Who will pay their salaries?" Somehow, such questions are interpreted as "money grabbing," and not as ones that any manager must ask if an enterprise is to be successful.

Contractors, in particular, feel that they are getting a "bum rap" when they are accused of failure to support university education and research. They point out that owners are the ultimate beneficiaries of any industry-wide improvements and cost reductions that university activities bring. They further complain that the tight-fisted practices of owners, both public and private, in awarding and administering contracts, force them to shave profit margins so slim that they can barely stay in business, much less support educational activities. They point out the contrast with Japan, where governmental policy makes it financially attractive for contractors to afford large in-house research activities.

The reality is that, in general, construction education and research, along with other academic programs, is supported from a university's budget, which draws primarily on endowments, alumni and other private support, government appropriations, and student fees. There are a few exceptions, such as modest support for construction from individual firms; or occasionally a "chair" may be established at an individual university. But in most instances, established programs in a university grow slowly when reliance is on existing university sources of funds. For a school to start a new discipline or to significantly expand an ongoing program requires substantial and continuing financing to sustain faculty and staff, provide additional student support, and, possibly, permit a research effort. In the case of public universities,

some of this financing might come from private sources, but usually the bulk of it is through appropriations of public funds pushed through by representatives of the affected industry. Private schools usually look to nongovernmental sources, although they may seek out governmental funds for special purposes, including support for research. One can dream about expanding university offerings in construction, but the reality is that the rate at which this happens rests in the hands of industry leaders, owners, designers, and contractors alike, not with university faculty and administrators. As noted earlier, their response to date has not been enthusiastic.

Dilemmas Facing In-Service Education

Given the large body of more-advanced knowledge that is accumulating on construction techniques and practices, one might expect that the construction industry would be clamoring both for intensive courses to introduce the various new techniques and methods and for workshops on specific topics. But this is not the case. Around the country there are a few programs in construction management conducted by consultants, occasional short sessions organized by construction-user groups sponsored by the Business Roundtable or the Construction Industry Institute, and a scattering of short courses on specific topics such as productivity improvement or constructibility. But, stated frankly, organized in-service education for construction managers is almost nonexistent and there appears to be little demand for it. It is worth noting that the situation in Japan is entirely different. There, the industry does not rely on the universities at all. Rather, in-service education is an integral part of employee development in each of the large construction companies.

A reverse form of continuing education, very valuable to the member firms of the Construction Industry Institute and associated academics, has developed recently. Participants in its task forces sometimes take home the knowledge they have gained and apply it with excellent results. In one instance, by employing constructibility concepts developed through CII research, the company saved 5% in costs and 13% in time; the ratio of savings to expenditures to apply the concepts was 32:1. In another case, a firm applying the findings of the cost-of-quality studies, reduced the cost of errors and omissions from 6.3 to 1.5% (ENR 1988). It can be hoped that others, learning of such successes and with the procedures to be used readily available in the publications of the Institute, will undertake some form of in-service education to reap similar gains.

Sad as it may seem, the bright star for in-service construction education is in the area of "claims." Workshops in this area are widely advertised. Their aim is, after things have gone wrong on a project, to place the blame on the other party. These workshops have almost nothing to say about doing it right the first time, which is the positive approach to education.

The level of university participation in continuing education for construction is particularly distressing. Occasionally, faculty members participate in workshops such as those previously mentioned. Two programs for on-campus higher level construction education have been undertaken; one, at Stanford, has been discontinued for the present; the other at Texas A and M University is continuing, with a growing enrollment that, in 1988 totaled 31 students (G. Stukhart, personal communication, Oct., 1988).

Among the explanations for the construction industry's apparent indifference to continuing education, as seen by an educator, are:

- A highly fragmented industry, with interests dispersed among many specific problem areas. It becomes difficult for management, which is driven by many demands on its time and energies, to learn about, see the need for, or release personnel to attend in-service programs that fit their needs.
- A failure on the part of buyers and contractors alike to appreciate the demonstrated payoffs that in-service education can bring. In contrast, Japanese contractors, who recognize its value, have strong in-house training centers for their employees.
- Management complacency. Management has a high level of confidence in its ability to do its job properly, using known techniques and methods. Neither is it threatened by new approaches, since competitors seldom know of them either.
- As mentioned earlier, a short-run, profit-oriented approach to expenditures, which looks for an early payoff rather than for long-range benefits. The usual management opinion is that in-service courses do not meet this criterion.
- A suspicion of and prejudice against educators. Managers often envision them as theoretical, impractical, and self serving, and therefore unable to offer much of value.

The potential demand for such in-service training could be tremendous, once the gains it offers are known. If one in 10 of the 450,000 contractors were to propose a single candidate for even a single course, educational institutions would be overwhelmed. However, no major unified, nation-wide effort either from academia or the construction industry appears to be under way.

In sum, it must be said that at present in the United States, little formal in-service education exists. Rather, knowledge, if gained at all, results from informal contacts or by self-study from books or other publications.

Earlier Research Activities for Construction

Research for construction, defined broadly, might be divided into two categories. The first of these, which has been and is doing well in the United States, focuses on new developments with specific applications; for example, studies and experiments involving materials, machinery, or equipment. In each of these and similar areas, individual firms or trade organizations, on their own or under contracts with universities, generate ideas and carry out research that promises a profit or competitive advantage to its sponsors. The motivation is clear: demonstrated profits resulting from earlier research will continue with continuing research.

The second broad area of research for construction deals with new or better approaches to the many problems of the individual parties involved in construction. Its targets are in broadly diffused areas that could affect management practices or construction techniques or methods. Without a central focus in a firm or a specific industry group, and with little assurance of short-term gains, research in these areas has found little industry support and has generally languished. Fortunately, governmental agencies have sometimes

adopted the longer view. A personal instance is the research at Stanford sponsored by the (then) Bureau of Yards and Docks of the U.S. Navy. It pioneered advances in planning and scheduling, methods improvement, and safety. Other schools also have done outstanding research, often without outside support of any kind. More recently, the Structures and Building Systems Program in the Division of Mechanics, Structures, and Materials Engineering of the National Science Foundation has provided modest support for fundamental research in construction. Beginning about five years ago, the Construction Industry Institute entered the scene (see herein). Unfortunately, to date the potential for research by the faculties of the 150 or more schools that teach construction has been sadly underutilized.

Current and Future Trends in University Research in Construction

It has already been pointed out in the discussion of in-service education that firms applying the results of recent research carried out in American universities can generate substantial savings. But the pace of gains from additional research will be slowed unless the industry itself sees the need, puts up the money, and applies its findings to its problems. Past attitudes that demand short-run payoffs and ignore longer-range benefits must change before this can happen.

There is evidence that the construction industry is becoming more receptive to the concept of university research for construction. Probably the best example began five years ago when, as an outgrowth of the Business Roundtable Cost Effectiveness Study, the Construction Industry Institute, based at the University of Texas, Austin, was formed. Today, each of its 70 members, about equally divided between large owners and contractors, contributes $25,000 per year directly to the institute and possibly five times that amount in indirect support through participation of key personnel in the institute's activities (ENR 1988; Tucker 1988b). These, together, total about $10,000,000. Adding other direct research support, which might be in the range of $3,000,000 (Tucker 1988a), gives a grand total of $13,000,000. This is an encouraging beginning, but only a beginning.

Seen from other viewpoints, however, this investment in research becomes trivial. Considering contractors alone, it amounts to an average annual contribution from each of the 450,000 of possibly $30, or less than two hour's pay for a craftsman; if only the top 400 contractors and no owners participated, this would be $3,000 from each, or something like 20 man days pay. This is about 0.3% of their annual volume. In contrast, Japan, our chief competitor in the worldwide and even the domestic construction markets, does far better. Through a team effort of contractors and government, some $400,000,000 per year goes to construction research to serve a market half the size of that in the United States (Tucker 1988a; Paulson 1980). Given the results that these investments have produced, it is easy to understand why we in the United States are frantically trying to pick Japan's brains.

Without question, there is a vast array of research talent in American universities eager to do meaningful research for the construction industry. But, as with construction education, the pace at which research moves ahead will rest with the industry, augmented in a small way by grants from government.

Conclusions

This paper represents a look back and a look forward at construction education and research from one who is passing from the scene. It indicates that real strides have been made in education since World War II, but argues for a great expansion of its scope to make the now-existing body of organized subject matter available as a part of formal education. It proposes that, to make this possible, the construction industry greatly increase financial support for the universities, and that it become seriously involved in continuing education to carry this knowledge to those already in practice.

The paper also argues that the industry has done little to date to foster new research or to use the findings of that already done, although the payoff from using its findings have been shown to be substantial. Only now is the industry barely beginning to gear up to launch universities into a substantial research effort.

All in all, this paper argues that there is a great opportunity for colleges and universities to become more effective in their teaching and research for the construction industry, but is pessimistic about the prospects of these happening rapidly because of the difficulties of convincing a fragmented industry to support their efforts wholeheartedly. The dilemmas in construction education and research in the 1990s rest not so much with the ability of the schools to meet the needs of the industry as with the industry's short-run viewpoint and fragmentation, both of which inhibit its ability to organize financial support and more active participation.

Appendix. References

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