INTERNATIONAL ENGINEERING HISTORY AND HERITAGE

Improving Bridges to ASCE's 150th Anniversary

PROCEEDINGS OF THE THIRD NATIONAL CONGRESS ON CIVIL ENGINEERING HISTORY AND HERITAGE

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Abstract: These Proceedings of the International Engineering History and Heritage Congress contain papers prepared for delivery as part of the American Society of Civil Engineers National Convention in Houston, Texas, from October 10 to 13, 2001. The papers included provide information on civil engineering history and heritage programs in the United States, Canada, Mexico, and Great Britain and on preservation, restoration, and education activities carried out on individual historic civil engineering projects in these nations.

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Foreword

These Proceedings are dedicated to our mothers (who passed away in the last few years), Barbara Strobel Fredrich and Stella Hovezak Rogers, who supported our civil engineering education and careers.

The third National Congress on Civil Engineering History and Heritage has been expanded to include international engineering speakers and topics. With an emphasis on civil engineering history teaching/learning, restoration of historic bridges, and the American Society of Civil Engineers' 150th Anniversary, we have adopted a sub-theme: "Improving Bridges to ASCE's 150th Anniversary." Our co-sponsors include the ASCE Committee on History and Heritage, the Institution of Civil Engineers Panel for Historical Engineering Works, the ASCE International Activities Committee, the National Park Service, the Texas Section, ASCE and Branch History Committees/Directors, and the hosts: Houston Branch, ASCE and the University of Houston. Session organizers include Frank Griggs, Jr., Eric DeLony (who provided several international contacts), Robie Lange, Augustine J. Fredrich, and Jerry R. Rogers with young members, students, and Section/Branch Officers invited to co-sponsor sessions and attend. We especially thank the 2001 Congress speakers and authors of scholarly papers that will make these ASCE Proceedings so valuable.

The first ASCE Engineering History Conference was held in Washington, D.C. in 1996 with an ASCE Proceedings: *Civil Engineering History: Engineers Make History* (ISBN 0-7844-0209-4). The second Congress was held in Boston in 1998 at the 150th Anniversary of the Boston Society of Civil Engineers with an ASCE Proceedings: *Engineering History and Heritage* (ISBN 0-7844-0394-5). With ASCE's *Sons of Martha: Readings in Civil Engineering Literature* by Augustine J. Fredrich and this third ASCE Engineering History and Heritage Proceedings, there are ample civil engineering papers to utilize in courses in teaching/learning civil engineering history in university classrooms and for students grades 4 through 12.

The Importance of Engineering History

Henry Petroski

Introduction

Every profession has a history, and the degree to which that history is known, remembered, preserved, honored, and used determines to a great extent the degree to which the profession knows and understands itself and is acknowledged and respected as a profession outside the confines of its own practice. The profession of engineering has a long, rich, and important history, but many technically astute engineers are dismissive of that history. They emphasize the state-of-the-art, current trends, and the future of their specialist technology to the exclusion of its history. As a result, the history of engineering has not been especially prominent in most professional discussions or technical meetings. History would seem to have the reputation among many engineers of being frivolous, irrelevant, and distracting from the development of the ever-changing state-of-the-art and the pursuit of the future.

This is, at the least, a short-sighted view for the several reasons discussed in this brief paper. First, by understanding and promoting engineering history, engineers will reinforce their profession and its standing. Second, by being well-versed in and careful in their use of engineering history, engineers will avoid being labeled as technicians who are not only not liberally educated but also ignorant of even their own heritage. Third, engineering history is also engineering. The history of engineering, from the details of specialized fields to the sweeping narratives of great projects, provides essential information and caveats about what was once the state of the art and hence what should be recognized as being fundamental rather than irrelevant to the latest state of the art.

Professional History

Historians often mark the beginnings of a profession by such tangible events as the establishment of societies and the publication of proceedings. By such

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criteria, the profession of engineering in America begins with the founding of the American Society of Civil Engineers in 1852, a milestone that we begin to celebrate formally at this annual meeting.

As significant as the founding of a society is, engineers themselves should not accept such a narrow definition of their profession, and they should insist that their profession has roots as old and deep as any. The very beginnings of civilization and of engineering are coeval. Indeed, civilization as we know it would not have developed were it not for the practice of engineering, which provides infrastructure and other tangible things that contribute to making us civilized.

The medical profession never even hints that it is only as old as the American Medical Association, founded in 1847. Rather, physicians emphasize their roots in antiquity by taking the Hippocratic oath, a declaration of medical ethics as familiar to laypersons as a doctor's bill. Though some national customs, such as the Canadian Iron Ring Ceremony, promote engineering as a calling, the profession in the United States unfortunately has no widely recognized single symbol of its roots and its integrity.

The legal profession does not mark its beginning with the founding of the American Bar Association. Roman law and English common law are frequently cited as being still relevant to understanding the nature of our judicial system. Though the engineering literature has it roots in ancient texts such as Vitruvius, this heritage is seldom acknowledged as significant or relevant to modern engineering. Yet it is.

The practice of engineering is no less ancient than that of medicine and the law, and engineers do themselves a disservice when they look only to their parochial interests in marking the beginnings of their profession. The American Society of Civil Engineers was indisputably our first significant national society, but the subsequent fragmenting of the profession into mechanical, electrical, chemical, and a host of other specialized societies has left us without a single American Engineering Society that could give the profession an identity akin to that of the AMA and ABA and the historical and professional unity that such associations connote.

Granted, the qualifier "civil" included all non-military engineering in the middle of the nineteenth century, but the ASCE's lack of responsiveness to those civil engineers dealing more with dynamic than static structures drove them to form their own society, the American Society of Mechanical Engineers, in 1880. The establishment of other specialized societies followed, and engineering has acquired in the public mind a reputation for being an amorphous mass of specialists with no overarching identity.

Today, there is an American Association of Engineering Societies, but its very name points to the fact that it is engineering organizations that are being served by it rather than the profession of engineering itself or its practitioners. An individual engineer cannot even join the AAES.

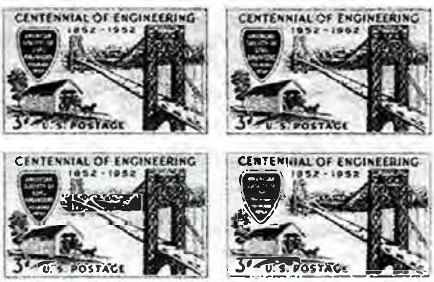
Specialized engineering societies certainly have a role to play in serving their members and promoting the profession, but the unqualified profession of engineering is often ill served by their competition for members. And much of the public remains confused about exactly what or who is an engineer.

Rather than stressing differences, the engineering societies might be better served by emphasizing the profession's common history and heritage, which is long and rich. The first engineer known by name is generally said to be the Egyptian pyramid builder Imhotep. *Ten Books on Architecture* is considered the oldest book on engineering extant, and in it Vitruvius discusses such matters as building walls, moving construction materials, and designing siege machines. The surviving work of another ancient Roman, Frontinus, deals with the water supply of the city of Rome. Knowing our ancient professional forebears and reading the classics of the profession today should leave little doubt in anyone's mind that the practice of engineering was already well established in ancient times.

Roman aqueducts remain today monuments to the achievements of the ancient engineers, and the profession should celebrate such public manifestations of its roots. These structures show engineers not only to have been essential for the development of the infrastructure of ancient civilizations but also to have been capable of building structures that to this day are considered model achievements of art and beauty. These are the images of engineers that we should all want to see promulgated.

Gaining Respect by Respecting History

The centennial of the ASCE was marked in 1952 with the issuance of a commemorative postage stamp bearing the legend, "Centennial of Engineering," an arrogance that must have piqued those who do not call themselves civil engineers. Even those civil engineers not engaged in bridge building may have found the stamp odd, in that its main images were a pair of bridges, each of which had at most a forced relevance to the years 1852 and 1952.



The older bridge depicted was a covered bridge. Though covered bridges did not originate in nineteenth-century America--the Grubermann brothers having built some of considerable span in Switzerland in the eighteenth century--the form does have a special association with America. But there is no special reason to associate them with the year 1852 or to use them to symbolize American engineering at mid-century. Already at that time significant suspension bridges, such as the one across the Ohio River at Wheeling, had exceeded 1000 feet in span.

The second span on the centennial stamp was the George Washington Bridge, a defensible but confusing choice in retrospect. Though it did set the tone for suspension-bridge building through 1940, when the Tacoma Narrows bridge collapsed, the George Washington itself dated from 1931, more than two decades before the centennial was celebrated. The Golden Gate Bridge was a more recent example and the one that would no doubt be chosen today to symbolize engineering in such a public context as on a commemorative postage stamp. Also, the technically more complex San Francisco-Oakland Bay Bridge, completed in 1936, had been heralded as the greatest bridge project ever undertaken in the country. Indeed, a survey of the seven wonders of U.S. Civil Engineering conducted by ASCE in the wake of the Centennial identified the Bay Bridge as the only notable bridge. (It was, however, displaced by the Golden Gate Bridge in an updated survey conducted four decades later, suggesting that engineers are no less susceptible to fashion and style than are lay tourists.)

Only the history of the circumstances surrounding the promotion and design of the centennial stamp, which has yet to be fully written, can explain why the centennial of engineering was celebrated with the image of a two-decades-old bridge. Was it politics, rather than objective history, that celebrated on the stamp a bridge that was arguably the structural and aesthetic model that led to perhaps the most infamous bridge collapse in the history of engineering?

It is certainly appropriate for any society to celebrate its centennial or its sesquicentennial, but such occasions for reflection should never be taken as opportunities for misrepresentation. There are a lot of liberally educated members of the public who, unfortunately, appear to know much more about the history of engineering than do many members of the profession. Such a situation can only promote the stereotype of the engineer as an uncultured technician and, hence, of the profession as an upstart.

History Is Relevant to Practice

For all of its value to raising the status of the profession, the history of engineering should not be viewed as a mere cultural adjunct to the real (technical) work of engineers. Rather, the history of engineering provides an invaluable collection of case studies for understanding better the nature of engineering itself and for providing invaluable models, lessons, and caveats for its practice.

Engineers know that there are limits of practice, and that to work too casually beyond the state of the art is to invite disaster. The limits of practice are naturally defined relative to past experience, and in this regard they are set by history, albeit usually recent history. Still, very remote history can also be extremely relevant to engineering today and tomorrow. In fact, engineers ignore the history of their field at their peril. Engineering, being the design and making of things, is not a uniquely modern concept, and it is presumptuous to treat it as such.

The Brooklyn Bridge pushed the envelope of suspension bridge design when it was proposed by John Roebling in the late 1860s. The main span of the bridge, which was completed in 1883, was about 45 percent longer than the next longest suspension bridge, and this significant leap in size in a structure that captured the imagination of engineers and lay persons alike, emboldened bridge engineers to propose, design, and build even longer spans.

Before the decade was out, Gustav Lindenthal had proposed between New York and New Jersey a suspension bridge with a 3500-foot main span, more than double that of the Brooklyn Bridge. Early in the twentieth century, Leon Moisseiff, who would have a major role in the design of virtually every major suspension bridge built in America through the 1930s, was applying more sophisticated theories of analysis to the design of suspension bridges, thus enabling them to be made longer, lighter, and more sleek in appearance. The Manhattan Bridge, completed in 1909, was a masterpiece in steel.

Neither the Manhattan nor any of the major suspension bridges that followed it contained the diagonal stay cables that were a signature of John Roebling's spans. The caveats regarding past failures of suspension bridges, which Roebling had written about over a half century earlier, were apparently forgotten by such great designers as Ammann, Steinman, and Modjeski who were following Lindenthal in his ambition and Moisseiff in his analysis. The sheer weight of the steel cables and decks of their structures were considered sufficient to steady them in the wind, and so the cable-stays of Roebling were dismissed.

Among leading bridge designers there was a growing confidence in increasingly sophisticated analysis, and so less and less conservative assumptions began to be made about traffic load. Wind was considered only as a static transverse load on the deck, in spite of the fact that aerodynamics was a growing field and aerodynamic instability was a well-known problem among aircraft designers. In spite of articles in the civil engineering literature drawing attention to the new field, bridge designers proceeded as if it did not exist. They were ignoring the future as well as the past.

By the 1930s, the state-of-the-art in long-span suspension bridge design seemed to be guided almost more by aesthetic than by structural considerations. Concern with the way bridges looked in profile became almost obsessive, with the small depth-to-span ratio of the single untrussed deck that the George Washington Bridge exhibited providing a model to be emulated and a goal to be surpassed.

The historical case studies of suspension bridge decks collapsing in the wind, rather than being studied as they were by Roebling, appeared to be ignored or forgotten--if they were ever studied--by twentieth-century bridge designers. The Menai Strait Suspension Bridge, which was infamous in Britain for the susceptibility of its deck to being destroyed in the wind, was held up in America as an aesthetic model, with no mention of the repeated failure of its deck. Whereas in Britain, the negative experience with the behavior of the Menai had altered the course of bridge design, making the suspension bridge an all but ostracized form there, in America it was held up as a thing of beauty.

As is well known, suspension bridges built in the late 1930s in America began to exhibit unexpected behavior in the wind. Beginning with the Golden Gate Bridge, and manifested even more so in the much narrower examples of Steinman's Thousand Islands Bridge and Ammann's Bronx-Whitestone, these bridges exhibited deck undulations that required retrofitting with cables to check the motion.

The culmination of bridges misbehaving in the wind came with the Tacoma Narrows Bridge, of course. Though a consulting engineer reviewing the design had questioned the unprecedentedly small width-to-span ratio of the bridge as designed by Moisseiff, he stood on the successful use of his theory in so many large suspension bridges, and his experience and reputation prevailed. The bridge was built to his specifications and, of course, its deck collapsed in a 42-mile-per-hour wind within four months of its completion.

In the wake of the colossal collapse, the century-long history of suspension bridges failing in the wind reappeared almost immediately in the engineering press. In these reports, rather than being held up as an aesthetic model alone, the Menai Strait Bridge was once again prominently discussed for its instability.

The case of the Tacoma Narrows Bridge is a classic example of the importance of engineering history in engineering design. It shows incontrovertibly that the history of the field was relevant to the state-of-the-art and that ignorance of that history left bridge engineers without an invaluable design tool—the identification of a critical failure mode.

Conclusion

History is not just a cultural frill, something that engineers might take up as a hobby after they retire from active practice. The history of engineering is a valuable adjunct to the technical tools that an engineer brings to a task, whether that task be the promotion of the profession or the design of a structure.

Engineering history provides us with a perspective on our profession so that we can place it properly in the context of the history of civilization and the world. By doing that, we gain a pride in our profession and convey to others that pride in an objective and effective way. In using and appealing to history to gain respect, however, we must always maintain a professional integrity and objectivity about it that does not allow historians to criticize our history as facile, frivolous, or false. We will not gain respect by disrespecting or misrepresenting our history.

The value of engineering history also goes beyond its being part of the liberal education of an engineer. Engineering history is useful, if not essential, to understanding the nature of engineering; it also assists in the practice of the profession. We gain perspective across fields of engineering by knowing their various and interrelated histories. A historical perspective assists engineers in identifying failure modes and catching errors in logic and design. Engineering history, in short, is engineering as well as history.