Education to Preserve Bridges and Dams as Capstones of Our Engineering Legacy

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This article suggests methods of educating preservationists to be confident and knowledgeable in evaluating engineering structures. Such structures confront preservationists ever more frequently, but few are trained in engineering or in the history of technology. They therefore run the risk of evaluating the work of engineers by inappropriate or inadequate criteria. The result may be a faulty understanding of the relative significance (or lack of significance) of an engineering resource, leaving it without the safeguards intended by law.

Our longstanding emphasis as a society on preserving buildings and neighborhoods has broadened and deepened over the years, with the recognition of new values and the perception of new threats. The preservation movement today, at least as it is practiced by those whose efforts are directed by the National Historic Preservation Act (NHPA) of 1966, takes cognizance of many types of cultural resources. Reviews that are mandated by the NHPA commonly identify not only buildings, landscapes, and archaeological resources but also engineering structures. Villages that are affected by federally funded projects, for example, will often be found to owe their origins to the presence of water power at a natural fall in a stream, to a historic bridge crossing that drew traffic to the site, or to the arrival of the railroad. Such communities must be surveyed and evaluated under federal law, yet a full evaluation requires understanding and describing the engineering technology that gave birth to the entire associated cultural landscape.

The energy with which the United States builds and rebuilds its highway system guarantees that historic bridges will figure in reviews under the

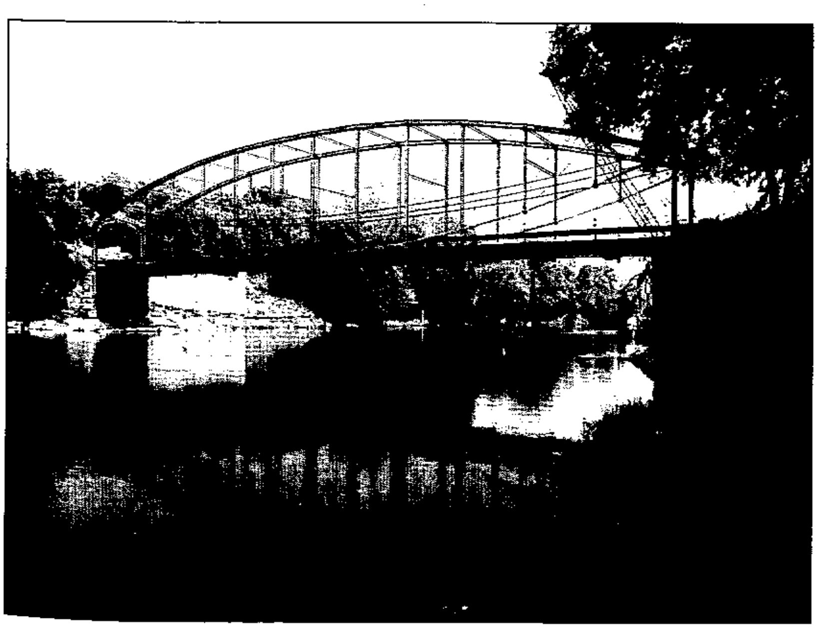

Fig. 1. Boardman's Lenticular Truss Bridge, Boardman's Road, New Milford, Connecticut, 1888, Berlin Iron Bridge Company, designer (Library of Congress, Prints and Photographs Division, Historic American Engineering Record, HAER CONN, 3-NEMI, 1-5).

NHPA and its kindred law, the Department of Transportation Act of 1966 (Fig. 1). Recent initiatives at "river restoration," aimed at returning streams to conditions of natural flow for the benefit of fluvial wildlife and recreational users of waterways, ensures that historic dams will be encountered frequently in future preservation reviews (Fig. 2). Publicly funded projects affect many other kinds of engineering resources, including roadbeds, rail corridors, utility lines, and manufacturing complexes, but bridges and dams confront preservationists with special frequency.

Bridges and dams are examples of the highest achievement of engineering analysis and constructive skill in any age. They impress us with their scale while defying us to understand their underlying science. When preservationists encounter an object of such obvious power, dynamism, and technical mystery as a bridge or dam, evaluating the structure objectively can be a challenge.

Guiding statutes require that the first step in evaluating a structure is to determine its eligibility for listing in the National Register of Historic Places. Instinct may suggest that the object embodies technological and social significance, yet the law mandates that its significance and integrity be described in precise language. The National Register of Historic Places requires that "a property must not only be shown to be significant under the National Register criteria, but it also must have integrity.... The retention of specific aspects of integrity is paramount for a property to convey its significance" (Andrus 1997, 44). The Register defines the seven aspects of integrity as location, design, setting, materials, workmanship, feeling, and association. The language necessary to describe a structure accurately and to assess its integrity, especially its integrity of design, materials, and workmanship, can only originate in a technical understanding of the object.

In trying to find this language, most preservationists are limited by a lack of training in the principles of engineering. Yet, engineers are often of little help in placing their work in context. Engineering education is rigorous, and the curriculum usually leaves scant time for coursework in engineering history or for detailed study of the evolution of any one type of structure. All too frequently, engineers are trained to equate old methods and materials with technical obsolescence or old designs with functional obsolescence (Fig. 3).[1] It is no accident that many engineering libraries have been purged of older textbooks.

Fig. 2. Pawtucket Dam and Gatehouse, Merrimack River, Lowell, Massachusetts, 1875, designer unknown (Library of Congress, Prints and Photographs Division, Historic American Engineering Record, HAER MASS, 9-LOW, 8A-12).

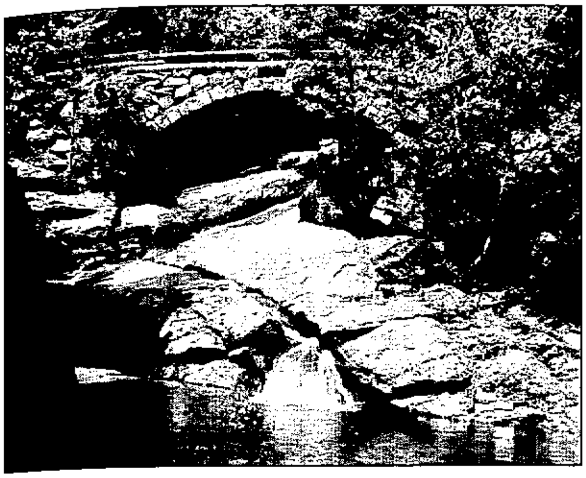

Fig. 3. Gleason Falls Dry-Laid Stone Arch Bridge, Beard Brook, Hillsborough, New Hampshire, mid-nineteenth century, designer unknown (Library of Congress, Prints and Photographs Division, Historic American Buildings Survey, HABS NH, 6-HILL.V, ID-2).

IMMINENT THREATS TO OUR ENGINEERING LEGACY

The inability of preservationists to treat the works of engineering with the same level of sophistication applied to buildings, neighborhoods, or archaeological resources has resulted in a great but poorly documented loss. Historic bridges are apparently the single category of engineering structure for which this loss can be measured with any degree of accuracy, because most states began to inventory their National Register-eligible bridges during the 1980s under directives from the Federal Highway Administration (FHWA). Using the baseline documentation provided by these state bridge surveys, a workshop on historic bridges, held in Washington, D. C., in December 2003, came to a dire conclusion:

> Since 1991, federal legislation has inspired an important transformation within the transportation community, broadening its mission from the traditional task of providing a safe and efficient highway system to acknowledging that these activities play a critical role in preserving our nation's natural and historical heritage. Despite this cultural shift, recent statistics suggest that half, if not more, of our Nation's historic bridges have been lost in the last twenty years—two decades in which transportation and preservation consciousness was at a high level. This is an alarming and sobering statistic (DeLony and Klein 2004, 1).

The "alarming" loss of historic American bridges is occurring despite the intent of Congress and the stated positions of several influential entities. Section 4(f) of the Department of Transportation Act of 1966 allows the federal Secretary of Transportation to approve a transportation project that requires the "use" of a historic resource *only if* (1) there is no feasible and prudent alternative to such "use," and (2) the project includes all possible planning to minimize harm to the historic resource resulting from such "use" (49U.S.C. 303 §771.135 Section 4(f)).[2]

The removal of historic bridges and other highway structures has been ongoing since the advent of the automobile more than a century ago. Losses have often been noticed and lamented, especially in the case of wooden covered bridges and other works of engineering that happen to evoke feelings of nostalgia (Fig. 4).[3] These covered bridges are among the few categories of engineering structures that have inspired preservation efforts since the early twentieth century.

By contrast, the planned removal of dams is mostly a phenomenon of the twenty-first century and is just beginning. Relatively few dams have been deliberately removed from American rivers, but the availability of federal funding for river restoration, combined with the frequent participation in proposed dam removals by private organizations like American Rivers, Trout Unlimited, FishAmerica Foundation, and various organizations devoted to recreational use of streams by "paddlers," will increasingly make

Fig. 4. Henniker Road Bridge, spanning Contoocook River, Hopkinton vicinity, New Hampshire, 1862, destroyed 1936, John Briggs, designer (Library of Congress, Prints and Photographs Division, Historic American Buildings Survey, HABS NH, 7-HOP.V, 2-1).

historic dams the subject of review under the National Historic Preservation Act. The availability of funding for dam removal is not currently counterbalanced by reliable sources of funding for dam repair.[4]

RESPONSES TO THE THREATS

The directive to the Federal Highway Administration to work toward bridge preservation was strengthened with the passage of the Surface Transportation and Uniform Relocation Assistance Act (STURAA) in 1987. This act created a historic bridge program that codified a Congressional finding that it is in the national interest to encourage the rehabilitation, reuse, and preservation of bridges that are significant in American history, architecture, engineering, and culture (23 U.S.C 144(o)).

The American Society of Civil Engineers (ASCE) has developed a policy on the rehabilitation of historic bridges for continued vehicular use when possible, noting that

> Historic bridges are important links in our past, serve as safe and vital transportation routes in the present, and can represent significant resources for the future.... Bridges are the single most visible icon of the civil engineer's art. By demonstrating interest in the rehabilitation and reuse of historic bridges, the civil engineering profession acknowledges concern with these resources and an awareness of the historic built environment (DeLony and Klein 2004, 25).

Perceiving the gap between these commitments and actual accomplishment in the field, the Standing Committee on the Environment of the American Association of State Highway and Transportation Officials (AASHTO) entered into an agreement with the National Cooperative Highway Research Program of the Transportation Research Board to produce general guidelines for bridge rehabilitation and replacement, hoping that such protocols might be adopted across the nation. The resulting report, *Guidelines for Historic Bridge Rehabilitation and Replacement* (March 2007), stated that

> while the National Historic Preservation Act of 1966 (amended) and Section 4(f) of the U. S. Department of Transportation Act of 1966 specify nationally applicable processes for considering preservation or replacement of historic bridges (defined as those that are listed in or have been determined eligible for inclusion in the National Register of Historic Places), there is no corresponding protocol

> that ensures a nationally consistent approach to determining when rehabilitation is the appropriate decision or when replacement is justified. State and local transportation agencies have developed a wide variety of approaches for managing historic bridges... but few of the processes are founded on written protocols or guidelines that ensure balanced decision making that spells out to all stakeholders when rehabilitation is the prudent alternative (Harshbarger et al. 2007, A-2).

These guidelines are a recent offering so far unsupported by any mandate or initiative from AASHTO. They have probably had little impact on individual states and certainly have not yet had the anticipated effect of standardizing the treatment and preservation of historic bridges across the nation.

As for dam preservation, Federal agencies such as the U. S. Army Corps of Engineers and the National Oceanic and Atmospheric Administration (NOAA) will soon be required by the National Historic Preservation Act to lead reviews on historic dams.[5] The question of National Register eligibility of dams, alone or in districts, will increasingly become the subject of survey and study by these federal agencies, by preservation consultants, and by State Historic Preservation Offices.[6]

THE DIFFICULTY OF EVALUATING NATIONAL REGISTER ELIGIBILITY

In the interest of ensuring adequate historical perspective, the National Park Service states that a property that has attained significance within the last fifty years is normally not eligible for listing in the National Register of Historic Places. But such properties may be eligible if they are integral parts of Register-eligible districts or if they possess "exceptional" significance (Sherfy and Luce 1998). Some engineering structures will possess exceptional significance and will have attained National Register eligibility before reaching the usual age requirement of fifty years and yet will not be recognized as eligible by untrained reviewers.

In the case of engineering structures, exceptional significance may not be evident to the untrained eye (Fig. 5). Structures possessing such significance have certainly been demolished without the review required under the National Historic Preservation Act because they were less than fifty years old and their exceptional qualities were undetected.

A structure of this type may have been designed through the application of a sophisticated analytical method, the incorporation of innovative materials or

Fig. 5. Luten Bridge, County Road 228, spanning Pine Log Creek, Cash vicinity, Georgia, 1920, Daniel B. Luten Bridge Company, designer. The simple appearance of this concrete arch hides the fact that Luten was a pioneering innovator in reinforced concrete design (Library of Congress, Prints and Photographs Division, Historic American Engineering Record, HAER GA, 65-CASH.V, 1-1).

engineering principles, or the use of an advanced fabrication technique. If such a structure can be shown to have set important precedents, it may indeed embody exceptional significance. When evaluated from the vantage point of the early twenty-first century, for example, certain steel bridges that employed arc-welding techniques during the 1960s may well be found to possess exceptional significance even when they are not yet fifty years old.

Despite their current visibility as potentially threatened structures, dams are less easily studied and documented than bridges. Dams are also rendered more complicated in a technical and sociological sense because most of them are components in a larger complex, such as an industrial plant or a hydroelectric station. In the northern United States, most nineteenth-century dams were built of timber (Fig. 6). Because such structures must be repaired or rebuilt from time to time and are often covered with concrete as a replacement for their plank aprons, timber dams require special understanding and scrutiny when their integrity is evaluated.

The problem for most evaluators is that the exceptional nature of such structures is not evident absent a familiarity with recent and old engineering textbooks, methods, and materials of the recent past.

RECENT SOURCES

How do we educate preservationists to be confident and competent in evaluating engineering structures? How do practitioners in the field attain such competence, especially when they may lack technical training? How do faculty instill such competence in students who may have found their way to the study of historic preservation from non-technical fields such as history, art history, or sociology?

A few good sources are readily available and are already familiar to most preservationists. Other reliable sources may be out of print but available in libraries. Still others, among the most valuable for a deeper understanding of the history of engineering, are long out of print but often available in the second-hand book market and, increasingly, online—particularly engineering textbooks from past eras.

The crisis in bridge preservation, which has seen the loss of half or more of the nation's historic bridges since the 1980s, has stimulated the recent creation of several valuable sources. In 1985, Ohio State University held the first in a series of intermittent but important historic bridge conferences. Succeeding conferences have contributed many valuable insights, techniques, and case studies in bridge preservation. A new publication *Historic Bridges:*

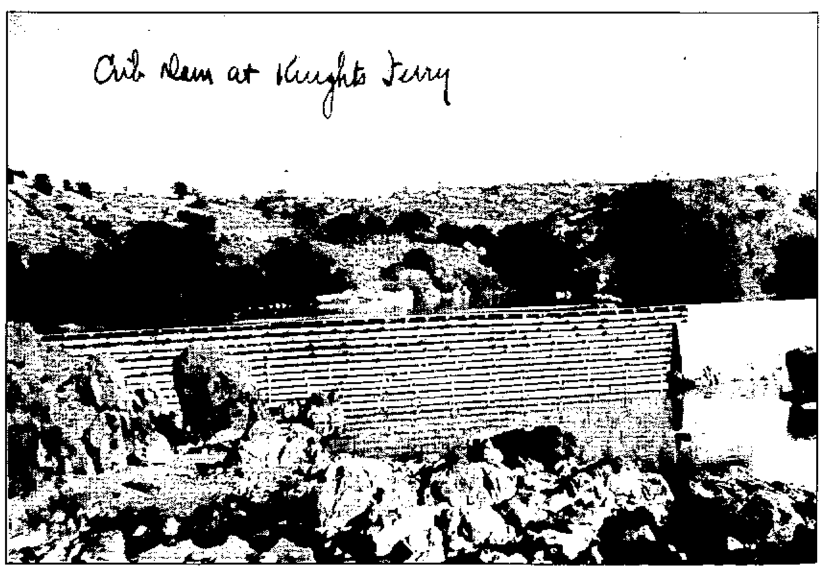

Fig. 6. Timber crib dam at Tulloch Mill, Knights Ferry, Stanislaus River, Stanislaus County, California, 1862, date of destruction unknown, designer unknown (Library of Congress, Prints and Photographs Division, Historic American Buildings Survey, HABS CAL, 50-KNITF, 2B-1).

Evaluation, Preservation, and Management (Adeli 2008) includes fifteen essays from the eighth *Historic Bridge* Conference of April 2008.

Eric DeLony and Terry H. Klein's *Historic Bridges: A Heritage at Risk* identifies and quantifies the problem by publishing the proceedings of the first workshop on the preservation and management of historic bridges, convened in Washington, D.C., in December 2003 (DeLony and Klein 2004).

Another publication, fulfilling an initiative that arose from that first conference, is *A Context for Common Historic Bridge Types* (2005), sponsored by AASHTO in cooperation with the Federal Highway Administration and prepared by a team of consultants for the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Research Council (Parsons Brinckerhoff 2005). This 239-page report provides a context for bridge development in the United States, discusses the most commonly encountered bridge types, and provides guidance in evaluating the significance of historic bridges and assessing their individual eligibility for the National Register.

Guidelines for Historic Bridge Rehabilitation and Replacement (Harshbarger et al. 2007), mentioned above, was compiled in the hope of providing a widely applicable "protocol for defining when rehabilitation of historic bridges can be considered prudent and feasible." This publication, too, fulfilled an objective that was defined during the first workshop on the preservation and management of historic bridges in 2003. All three resources following the 2003 conference can be found online.

Among the sources still in print are several that were created under the auspices of the National Trust for Historic Preservation. These include the popular *Great American Bridges and Dams* (Jackson 1988) and the twenty-eight-page publication in the Trust's Information series, *Preserving Historic Bridges* (Snyder 1995).

Other popular books, intended to inspire broad admiration and solicitude for historic bridges, include Eric DeLony's *Landmark American Bridges* (1993) and, for an international perspective, David Bennett's *The Creation of Bridges* (1999) or Charles S. Whitney's *Bridges: Their Art, Science, and Evolution* (1983).

The Surface Transportation and Uniform Relocation Assistance Act (STURAA) of 1987 required all states to inventory and determine National Register eligibility for their highway bridges. Many states have published books based on the bridge surveys that resulted from this mandate. Some of these books are straightforward listings and illustrations of eligible bridges; some were written by consulting specialists and discuss bridge design and technology in considerable detail. Some are handsomely designed and are calculated to instill general interest and solicitude for historic bridges: the Maryland and Nebraska bridge books are examples of such publications (Legler and Highsmith 2002; Potter and Puschendorf 1999). One of the more recent of these state bridge books, *Crossings: A History of Vermont Bridges*, goes beyond most such volumes, examining the place of the bridge in art, photography, cultural landscape, and in the identity of place, as well as its role in transportation and engineering (McCullough 2005).

Bridges, dams, canals, and other engineering works cannot be understood without a broader context. A somewhat more inclusive perspective on the history of civil engineering is offered by Anthony E. Neville's *Bridges, Canals and Tunnels* (1968).

Carl Condit of Northwestern University provided the first comprehensive summary of the technology and materials from which engineering works are created. His *American Building Art: The Nineteenth Century* and *American Building Art: The Twentieth Century*, published in the early 1960s and now out of print, were landmarks in explaining the origins and evolution of American civil engineering in non-technical terms (1960; 1961).

OLDER SOURCES

Textbooks are the most authoritative sources of engineering information in any period. It is regrettable that they are often considered obsolete once new technologies are introduced or newer texts are written. To the historian, no book is ever obsolete; each is an authentic document of the age in which it was

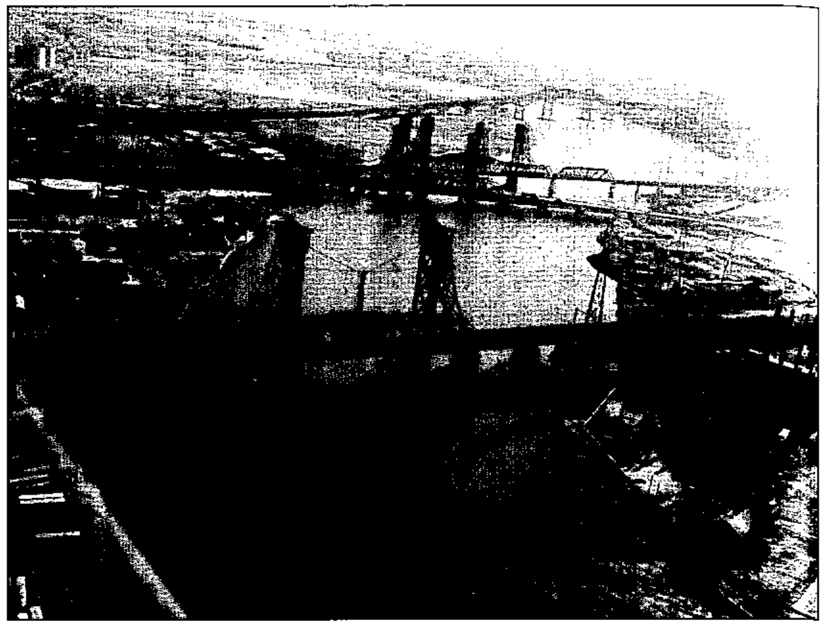

Fig. 7. Vertical lift bridges, Hackensack River, Kearny, New Jersey, early twentieth century, John Alexander Low Waddell, designer (Library of Congress, Prints and Photographs Division, Historic American Engineering Record, HAER NJ, 9-KEAR, 2-3).

written and is the best possible portal to the realities of that age. But because engineering is a forward-looking profession, it generally has limited use for the textbooks of earlier generations. Engineers tend to look to early books only for specific information, not for a general understanding of technology that appears obsolete from a present-day perspective. For this reason, many engineering libraries retain few textbooks from fifty or one hundred years ago.

Historians of technology, by contrast, can derive invaluable information from words and ideas that were fresh when a now-historic structure was new. Yet, preservationists tend to turn to old textbooks infrequently. One reason, noted above, is that such books are not easily found in libraries. Another is that the engineering text is intimidating to the non-technical user; filled with formulas, equations, and incomprehensible diagrams, such a book may appear to be written in code. It is evident on quick perusal that the full value of such a book is denied to anyone who lacks fairly advanced education in mathematics, strength of materials, and structural analysis.

What is often not evident is that even the most technical textbook will contain much plain language. Teachers of engineering need to engage their students through language, pictures and diagrams, and mathematical formulas or graphics. With some effort, the lay reader can usually derive benefit from the language and the diagrams, if not always from the mathematics.

American engineering education in the early twentieth century was dominated by a number of accomplished and prolific authors. Several engineers in the field of bridge design wrote texts that summarized the practice of their time. One of the most significant of these was Canadian-born John Alexander Low Waddell, a practicing engineer who, among many other accomplishments, perfected the vertical lift bridge (Fig. 7).[7] Waddell's first slim book, *De Pontibus: A Pocket-Book for Bridge Engineers* (1898), was supplanted by his gigantic two-volume *Bridge Engineering* (1916), supposedly drafted on long steamboat and train journeys from job to job. Both books are now rare and expensive, though still commonly found in university libraries and bridge engineers' offices. These books feature voluminous clear text and few formulas. The more than two thousand pages in *Bridge Engineering* provide information on almost every aspect of American bridge design as it was practiced in the early twentieth century.

Waddell's books were directed toward fellow practicing designers more than to students. Other, smaller books were written as classroom texts. These books tend to be more technical, yet they explain and illustrate almost every detail that the preservationist is likely to encounter in the field.

Among the more prolific writers of the early twentieth century was Mansfield Merriman, professor of civil engineering at Lehigh University. Together with Henry S. Jacoby, professor of bridge engineering at Cornell, Merriman published the long-popular *A Text-Book on Roofs and Bridges* in four "parts" or volumes. *Part III, Bridge Design*, first appeared in 1894 and passed through many editions. The book is a standard reference for steel bridge design and fabrication in the early twentieth century (Fig. 8).

Jacoby also published an important work on timber design, *Structural Details, or Elements of Design in Heavy Framing* (1909, with later printings). In collaboration with Roland P. Davis, professor of structural and hydraulic engineering at West Virginia University, Jacoby revised this reference many years later under the title *Timber Design and Construction* (1930).

Jacoby and Davis also wrote an important reference in another field, often overlooked in the description and assessment of engineering structures: *Foundations of Bridges and Buildings* (1914, with later editions). The same important subject of foundations and substructures was also treated in a comprehensive work by another important author, Ira O. Baker, professor of civil engineering at the University of Illinois. Baker's *A Treatise on Masonry Construction* (1889, with later editions) remains the single best source on the subject of stone masonry as used in footings, foundations, abutments, arches, and dams (Fig. 9).

The introduction of Portland cement into American construction at the end of the nineteenth century, together with the increasing use of steel to reinforce concrete, compelled Baker to revise his *Treatise on Masonry Construction* in later editions (1899 and 1909). Encouragement was given to American users of reinforced concrete when a Joint Committee on Concrete and Reinforced Concrete was created in 1903 to study all aspects of this new material. Composed of representatives from the American Society for Testing Materials, the American Society of Civil Engineers, the Association of American Portland Cement Manufacturers, and others, the committee carried out seven years of laboratory tests followed by five years of field testing. Its findings, released between 1909 and 1917, gave American engineers ever-increasing confidence in the reliability of reinforced concrete and of the formulas and specifications used in its design. J. A. L. Waddell devoted a full chapter of his monumental *Bridge Engineering* (1916) to reinforced concrete bridges, and several other authors wrote contemporary textbooks that were devoted entirely to the subject.

Among the more prolific of those authors was George A. Hool, professor of structural engineering at the University of Wisconsin. In 1912, Hool published

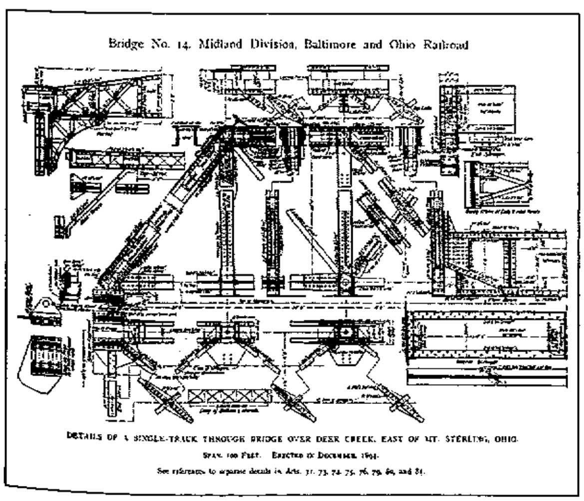

Fig. 8. Pin-connected railroad bridge over Deer Creek, east of Mount Sterling, Ohio, 1894, Baltimore and Ohio Railroad, designer (Mansfield Merriman and Henry S. Jacoby, A Text-Book on Roofs and Bridges, Part III, Bridge Design, *4th ed. New York: John Wiley and Sons, 1905, Plate III).*

his three-volume *Reinforced Concrete Construction,* treating fundamental design principles, retaining walls, concrete buildings, and concrete bridges and culverts. Later, in collaboration with his Wisconsin colleague W. S. Kinne, Hool edited an important series of engineering texts that provided a virtual engineering library; this set remained a standard reference until well after World War II. Hool and Kinne's series included *Reinforced Concrete and Masonry Structures* (1924); *Foundations, Abutments, and Footings* (1923); *Structural Members and Connections* (1923); *Stresses in Framed Structures* (1923); *Steel and Timber Structures* (1924); and *Movable and Long-Span Bridges* (1923). So important was this series that it was revised and republished in 1942-1944, during the war. These second editions contain new text and illustrations that document the advances in American engineering from the 1920s to the 1940s. All these textbooks are out of print.[8]

Two important but rare books on dam construction are Edward Wegmann's *Construction of Masonry Dams*, published in 1888, a standard nineteenth-century text; its second edition (and subsequent editions) included earth, rock-fill, and timber dams (Fig. 10). The second book, mentioned previously, is Mansfield Merriman's *A Text Book on Retaining Walls and Masonry Dams*, published in 1892. A more readily available book is Ira O. Baker's *A Treatise on Masonry Construction*, which has a good chapter on dams.

Fortunately, one of the best nineteenth-century books on dam-building has been reprinted. Leffel's *Construction of Dams* and Bookwalter's *Millwright and Mechanic,* originally published in 1881 in Springfield, Ohio, by the James Leffel Company, manufacturers of water turbines, is currently available as a reprint. It is especially strong in describing the varieties of timber dams.

The early twenty-first century has also countered the purge of "obsolete" books from technical libraries with the internet. Google Book Search and the Internet Archive have already made hundreds of out-of-copyright textbooks available at no charge. These services also allow word searches within the texts and list second-hand book services that may offer copies for sale. Any preservation studies program would do well to ensure that its library resources retain or acquire such textbooks or at least that students are made aware of key titles and of their availability on the internet.

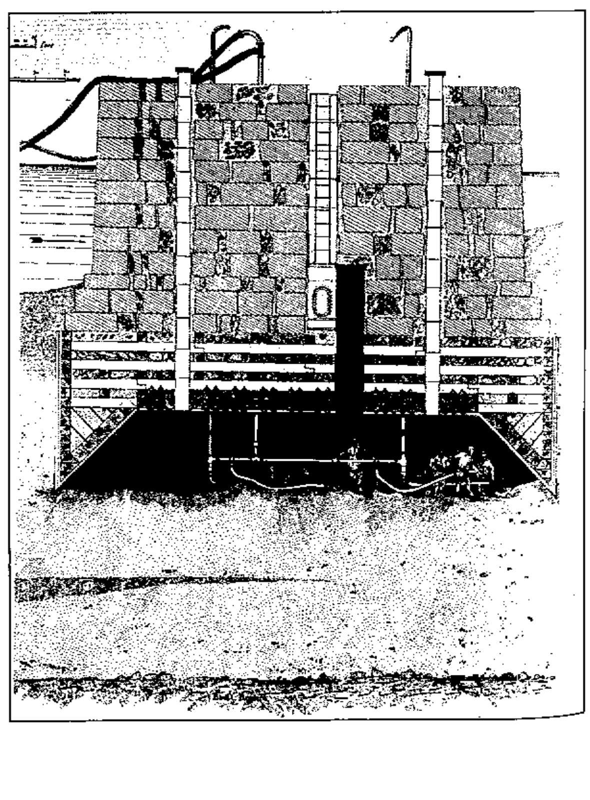

Fig. 9. Pneumatic bridge caisson, Blair Crossing Bridge over the Missouri River near Blair, Nebraska, c. 1883, George S. Morison, designer (George S. Morison, The Blair Crossing Bridge, *1886, as reproduced in Ira O. Baker,* A Treatise on Masonry Construction, *8th ed. New York: John Wiley and Sons, 1897. Library of Congress, Prints and Photographs Division, Historic American Engineering Record, HAER NEB, 89-BLAIR.V, 1-4).*

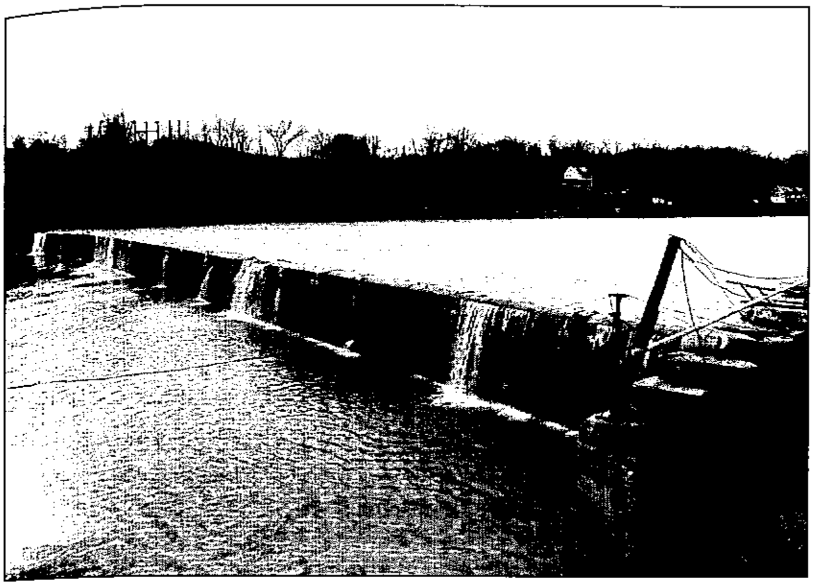

Fig. 10. Chesapeake and Ohio Canal, Dam 5, Williamsport vicinity, Maryland, c. 1860, designer unknown (Library of Congress, Prints and Photographs Division, Historic American Buildings Survey, HABS MD, 22-FOFR.V, 4-1).

TECHNICAL JOURNALS

Engineering literature in the United States has never been confined to textbooks. From the nineteenth century, engineering journals have been the vehicles through which theories, debates, technical advances, and structures of note have been made known to the profession. The field of engineering has generated a venerable and voluminous periodical literature. When accessible in local libraries, these professional journals are invaluable to the student, researcher, or preservation consultant. The American Society of Civil Engineers (ASCE) has been especially prolific and diligent in recording the evolution of engineering. ASCE's *Transactions* and *Proceedings* are an invaluable record of the state of American civil engineering since the nineteenth century. Other nineteenth-century periodicals include the *Journal of the Franklin Institute* and the *Journal of the Association of Engineering Societies*. The twentieth century saw the introduction of the *Journal of the American Concrete Institute*. More general professional journals also contain valuable documentation. These include *Engineering News*, *Engineering News-Record* and the ASCE's *Civil Engineering*. Runs of these periodicals may be found in larger university libraries, especially those that support engineering programs.

A number of currently active organizations publish periodicals that record valuable research in the history of engineering and technology. The Society for Industrial Archeology (SIA), founded in 1972, has published the journal *IA* since 1975. The SIA promotes the preservation of structures and equipment that are significant in the history of engineering, industry, and technology. The international Association for Preservation Technology/Association pour la préservation et ses techniques, organized in 1968, has published its *APT Bulletin* since 1969, frequently featuring articles dealing with aspects of engineering history, especially archaic materials and techniques and their preservation. The Construction History Society (CHS), an international organization based in England, has published its annual scholarly journal, *Construction History*, since 1985. CHS has also published multivolume proceedings of the first and second International Congresses on Construction History, held in Madrid (2003) and Cambridge, England (2006). In 2008, members of the CHS in the United States formed the Construction History Society of America.

Sources like those mentioned above are necessary for a basic education in the history of engineering. Whenever possible, such resources should be available to students during their formal training. But these and similar sources become absolutely indispensable when students, faculty, or consultants confront a bigger challenge: the compilation of National Register nominations, historic structure reports, or Historic American Engineering Record (HAER) documentation for works of engineering. These documents require the development of lucid context statements. To varying degrees, such documents also require physical examination, evaluation, and recordation. The value of this kind of field work is multiplied when accompanied by a familiarity with the design and fabrication practices that gave form to the structure. For the most part, that familiarity can be gained only through contemporary published sources, coupled with the physical examination of the object.

There is no substitute for field work in the study of the history of engineering. Some preservation programs have found ways to incorporate the physical inspection of engineering structures into the curriculum, just as most have found ways to incorporate the study of buildings or designed landscapes into student training. The University of Vermont, which has pioneered in the analysis and preservation of covered wooden bridges, has also offered historic bridge courses that have addressed a wider range of structures. Students in a number of preservation programs have gained invaluable knowledge by participating in recordation projects for the Historic American Engineering Record (HAER) since its inception in 1969.

RECOMMENDATIONS

As shown above, there are many available resources, both current and older, that can aid preservationists in understanding and evaluating engineering structures. To reverse current trends in engineering structure preservation, both educational and professional groups and programs should utilize these sources and might consider the following strategies:

- Assemble a collection of the classic books on engineering and engineering history in the library that serves the program. As noted, such books are often available on the internet, and copies can frequently be purchased at reasonable prices from dealers who list their stock on book services like Amazon.com Books, Abebooks, or Alibris.
- Encourage publishers or nonprofit sponsors to reprint a select collection of the most influential out-of-print textbooks. Certain classic textbooks such as Waddell's *Bridge Engineering* and Condit's *American Building Art* deserve to be reprinted.
- Encourage the compilation of contexts for categories of engineering structures comparable to *A Context for Common Historic Bridge Types* (2005), mentioned above, and the publication of similar books.
- Offer courses in "engineering for non-engineers," or similar means of instilling student confidence in describing and assessing the significance of engineering works. Many schools offer courses in the history of science or technology for non-specialist students. It should be possible to develop similar courses for non-engineering students. Such courses would explain the principles of structural behavior and the development and characteristics of various structural materials and would probably best be taught by trained engineers who are skilled in conveying engineering concepts by words or illustrations rather than by mathematical formulas. A clearly written and well illustrated textbook supporting such courses is much needed.

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ENDNOTES

1. Fig. 3 illustrates a stone bridge, which is regarded as obsolescent, and therefore endangered.
2. With reference to historic resources, "use" means either a "taking" or the adverse effect of a project upon the resource.
3. The preservation of covered wooden bridges was addressed by the establishment of the National Historic Covered Bridge Preservation (NHCBP) program, sponsored by Senator James Jeffords of Vermont as a component of the Transportation Equity Act for the 21st Century (TEA-21). The University of Vermont sponsored the First National Best Practices Conference for Covered Bridges in Burlington, Vermont, in 2003, there adopting the "Burlington Charter for the Preservation of Historic Covered Bridges." Some of the findings of this conference were eventually memorialized in Phillip C. Pierce, Robert L. Brungraber, Abba Lichtenstein, and Scott Sabol, *Covered Bridge Manual* (Washington, D.C.: Federal Highway Administration, Publication No. FHWA-HRT-04-098, 2005).
4. Bills that would have provided funding for dam repair were introduced in the 108th and 109th Congress but failed to pass. H.R. 3224, the "Dam Rehabilitation and Repair Act of 2007," is before the 110th Congress.
5. Because dam removal is sometimes integrated with highway projects, the AASHTO Standing Committee on the Environment commissioned an introductory study on the subject. See ICF Consulting, *A Summary of Existing Research on Low-Head Dam Removal Projects* (National Cooperative Highway Research Program, Transportation Research Board of the National Research Council, NCHRP Project 25-25, Task 14, September 2005).
6. Among the sources that have been published on the subject of dam removal are: American Rivers and Trout Unlimited, *Exploring Dam Removal: A Decision-Making Guide* (N.p.: American Rivers and Trout Unlimited, 2002) and *Dam Removal: Science and Decision Making* (Washington, D.C.: H. John Heinz III Center for Science, Economics and the Environment, 2002). A recent article describing the relationship between early deforestation, dams, and stream sedimentation is Robert C. Walter and Dorothy J. Merritts, "Natural Streams and the Legacy of Water-Powered Mills," *Science* 319 (January 18, 2008): 299-304.
7. Waddell was the inventor and patent holder of the first widely-used design for vertical lift bridges.
8. Those university and engineering libraries that hold a copy of these out-of-print rare books usually treat such holdings as "special collections" rather than as current references in the stacks. These works are also readily available in the second-hand book market, usually commanding only modest prices.

REFERENCES

Adeli, Hojjat. 2008. *Historic Bridges: Evaluation, Preservation, and Management*. Boca Raton, Florida: CRC Press.

Andrus, Patrick W. 1997. "How to Evaluate the Integrity of a Property," in *How to Apply the National Register Criteria for Evaluation (National Register Bulletin 15)*. Washington, D.C.: U.S. Department of the Interior, National Park Service.

Bennett, David. 1999. *The Creation of Bridges*. Edison, N.J.: Chartwell Books.

Condit, Carl W. 1960. *American Building Art: The Nineteenth Century*. New York: Oxford University Press.

Condit, Carl W. 1961. American Building Art: The Twentieth Century. New York: Oxford University Press.

Delony, Eric. 1993. *Landmark American Bridges*. New York: American Society of Civil Engineers.

Delony, Eric and Terry H. Klein. 2004. *Historic Bridges: A Heritage at Risk; A Report on a Workshop on the Preservation and Management of Historic Bridges, Washington, D.C., December 3-4, 2003*. Rio Rancho, New Mexico: SRI Foundation, Preservation Conference Series 1.

Harshbarger, J. Patrick, Mary E. McCahon, Joseph J. Pullaro, and Stephen A. Shaup. 2007. *Guidelines for Historic Bridge Rehabilitation and Replacement.* NCHRP Project 25-25, Task 19. Washington, D.C.: National Cooperative Highway Research Program of the Transportation Research Board for the American Association of State Highway and Transportation Officials.

Jackson, Donald C. 1988. *Great American Bridges and Dams.* Washington, D.C.: Preservation Press.

Leffel. 1881. *Leffel's Construction of Mill Dams and Bookwalter's Millwright and Mechanic* (reprint, n.d.). Newton, North Carolina: Society for the Preservation of Old Mills.

Legler, Dixie and Carol M. Highsmith. 2002. *Historic Bridges of Maryland*. Crownsville: Maryland Historic Trust Press.

McCullough, Robert. 2005. *Crossings: A History of Vermont Bridges*. Barre: Vermont Historical Society.

McVarish, Douglas C. 2008. *American Industrial Archaeology: A Field Guide*. Walnut Creek, California: Left Coast Press.

Neville, Anthony E. 1968. *Bridges, Canals and Tunnels.* New York: American Heritage Publishing Company.

Parsons Brinckerhoff with Engineering and Industrial Heritage. 2005. *A Context for Common Historic Bridge Types*. NCHRP Project 25-25, Task 15. Washington, D.C.: National Cooperative Highway Research Program of the Transportation Research Board of the National Research Council.

Potter, James E. and L. Robert Puschendorf. 1999. *Spans in Time: A History of Nebraska Bridges*. [Lincoln:] Nebraska State Historical Society.

Sherfy, Marcella and W. Ray Luce. 1998. *Guidelines for Evaluating and Nominating Properties that Have Achieved Significance Within the Last Fifty Years (National Register Bulletin 22)*. Washington, D.C.: U.S. Department of the Interior, National Park Service.

Snyder, John. 1995. *Preserving Historic Bridges*. Washington, D.C.: National Trust for Historic Preservation.

Whitney, Charles S. 1983. *Bridges: Their Art, Science, and Evolution*. New York: Greenwich House.

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