Pittsburgh ENGINEER

SUMMER 2008

Quarterly Publication of the Engineers' Society of Western Pennsylvania

A Special 25th Anniversary IBC Edition

CONTENTS

SUMMER 2008

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA
Pittsburgh Engineers' Building
337 Fourth Avenue
Pittsburgh, PA 15222
Tel: 412-261-0710 • Fax: 412-261-1606
e-mail: eswp@eswp.com

Pittsburgh ENGINEER is the quarterly publication of the Engineers' Society of Western Pennsylvania (ESWP). The ideas and opinions expressed within *Pittsburgh ENGINEER* are those of the writers and not necessarily the members, officers or directors of ESWP. *Pittsburgh ENGINEER* is provided free to ESWP members and members of our subscribing affiliated technical societies. Regular subscriptions are available for $10 per year.

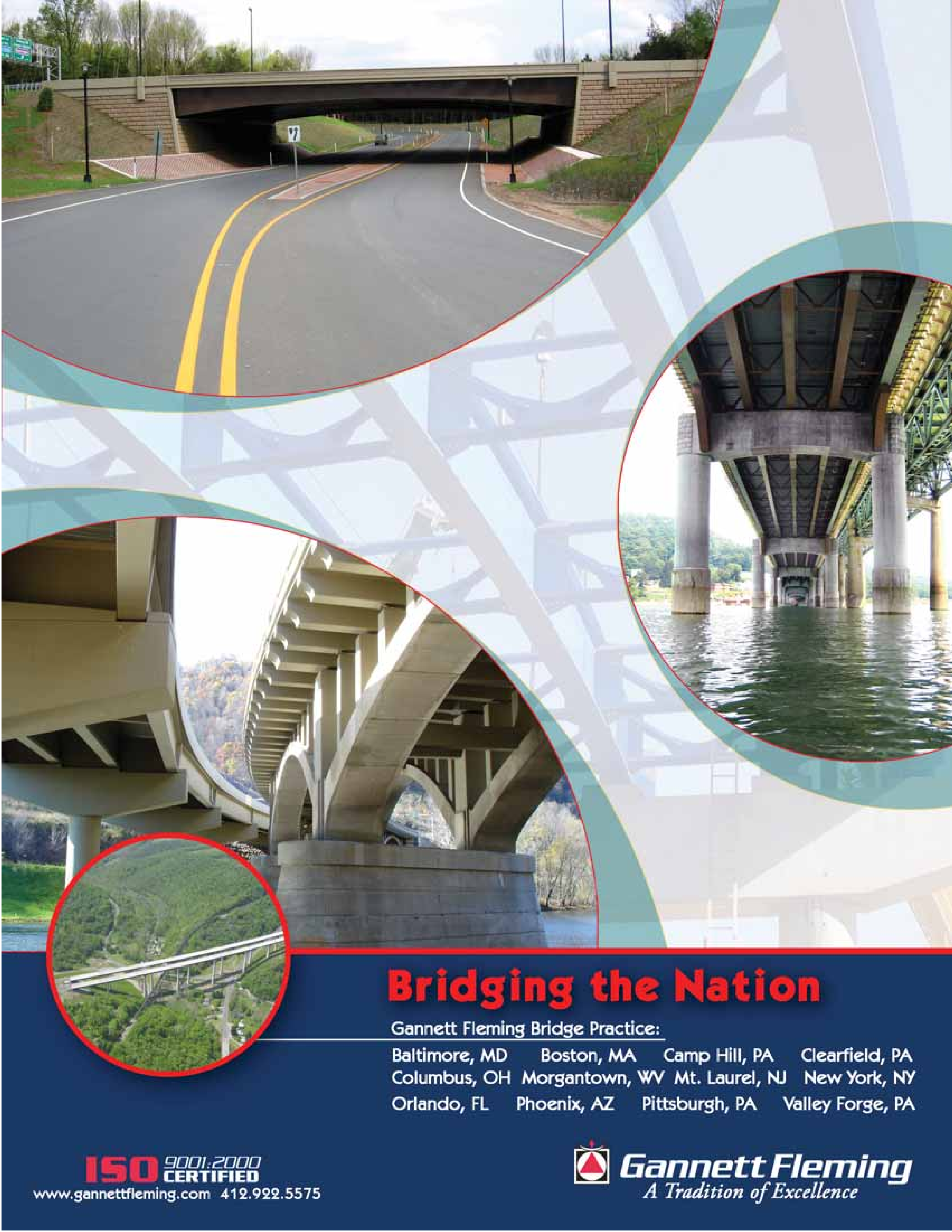
PUBLICATIONS COMMITTEE
The ESWP produces a range of publications as a service to our members and affiliated technical societies. ESWP Publications are supported by an all-volunteer Publications Committee.
Guest Editor: Thomas G. Leech, P.E., S.E., Gannett Fleming, Inc.

Chair: Daniel J. Tis, Siemens Environmental Systems & Services

Editor-in-Chief: David A. Teorsky, ESWP

Art Direction & Layout: David A. Teorsky, ESWP

Layout & Design: Christy Kaufman, Gannett-Fleming, Inc.


Bridging the Nation
Gannett Fleming Bridge Practice:
Baltimore, MD Boston, MA Camp Hill, PA Clearfield, PA
Columbus, OH Morgantown, WV Mt. Laurel, NJ New York, NY
Orlando, FL Phoenix, AZ Pittsburgh, PA Valley Forge, PA
ISO 9001:2000 CERTIFIED
www.gannettfleming.com 412.922.5575
Gannett Fleming
A Tradition of Excellence

HOW FAR HAVE WE COME? HOW FAR WILL WE GO?

This edition of the Pittsburgh Engineer celebrates the success of the International Bridge Conference and the spirit of bridge building from the inception of modern civilization. In recognition of the 25th anniversary milestone of the International Bridge Conference, we have assembled an eclectic array of technical articles, introduced a “bridge quiz”, conducted a round table discussion, developed a signature fold-out and have included several “shorts”, all, with the specific purpose of asking two important questions:

HOW FAR HAVE WE COME?

How far have we, as engineers, come within our profession? How far have we, the Engineers Society of Western Pennsylvania, come? How far have we, the International Bridge Conference, come within our 25 years of existence?

HOW FAR WILL WE GO?

Not just how far can we go, but more importantly how far will we go? What is over the horizon … for the engineering profession, … for the Engineers Society of Western Pennsylvania, … for the International Bridge Conference … and for the society that we as engineers serve?

This special edition answers these questions in a variety of ways and means.

The first half of this special edition is dedicated to the history of the engineering, and specifically the bridge engineering profession. We will ask some thought provoking questions and then provide some answers to: What makes an ideal engineer? How have expectations changed with time? How long should a bridge last? Is bridge building a trade, … an art, … a science? What/who do we build bridges for – railroads, … highways, … transit? Who planted the seed that became the International Bridge Conference? What has been the role of the International Bridge Conference over the past 25 years? Who is the FHWA, … how do they influence us daily? What has history … and what has forensics taught us?

The second half of this special edition dares to peek over the horizon and imagines what is in our immediate future for bridge engineering and construction, … what will be there 25 years from now … and what can we expect through the close of and beyond the 21st century. To gather some glimpse of what lies over the horizon we have called upon two groups of researchers to share their thoughts and visions. The first group, the FHWA will present a well defined mission; and will describe its implementation of stronger, faster, more cost effective strategies which is well underway. The second group, university researchers, will open up a world quite foreign to most of us, … a world of fiber reinforced polymers, sensors, ambient energy, scanners, damage detection, diagnosis, smart materials, self-healing materials, and analytical tools encompassing the mesoscale and macroscale.

To answer how far have we come, we will look to celebrate the success of bridge engineers from antiquity, from the birth of our country, from the beginnings of the industrial revolution, through the present. We will take an introspective look at our International Bridge Conference and those persons who have made this conference a success for the past 25 years.

To answer how far will we go, we will give you a peek beyond the immediate horizon. We will envision an International Bridge Conference, twenty five years from now. And we will invite you to use your imagination, your knowledge, and your skills to help shape a very bright future for bridge engineering and the International Bridge Conference!

Thomas G. Leech, P.E., S.E.
Guest Editor
Vice President and
National Bridge Practice Leader
Gannett Fleming, Inc.

What is it? – a bridge quiz for the 19th century

The year is 1832. Imagine that you are a young bridge engineer applying for work as an apprentice to Timothy Palmer. He gives you the following quiz. Passing (5 out of 6 correct) means you get your first job as an engineer. How well will you do? Answers are in the back of the magazine. (Do not peek.)

Just who is Timothy Palmer? – see the next article. – Ed.

Q1. What is the name of the wood joint shown?
[a] Lap splice [b] Wedge Scarf
[c] Joggle [d] Mortise & Tendon

Q2. What is the name of the wood joint shown?
[a] Lap splice [b] Wedge Scarf
[c] Joggle [d] Mortise & Tendon

Q3. What is the name of the wood joint shown?
[a] Lap splice [b] Wedge Scarf
[c] Joggle [d] Mortise & Tendon

Q4. What is the name of the washer shown?
[a] Round [b] Beveled
[c] Ogee [d] Flat

Q5. What is the name for the pin holding these structural wood members together?
[a] Tree-Nail [b] Trunnel
[c] Dowel [d] All of the above

Q6. What state has the most covered bridges?
[a] Ohio [b] Vermont
[c] Indiana [d] Pennsylvania

The bridge quiz was submitted by Justin Peaslee, Structural Engineer, Gannett Fleming, Inc.

Quotes for the Ages ...

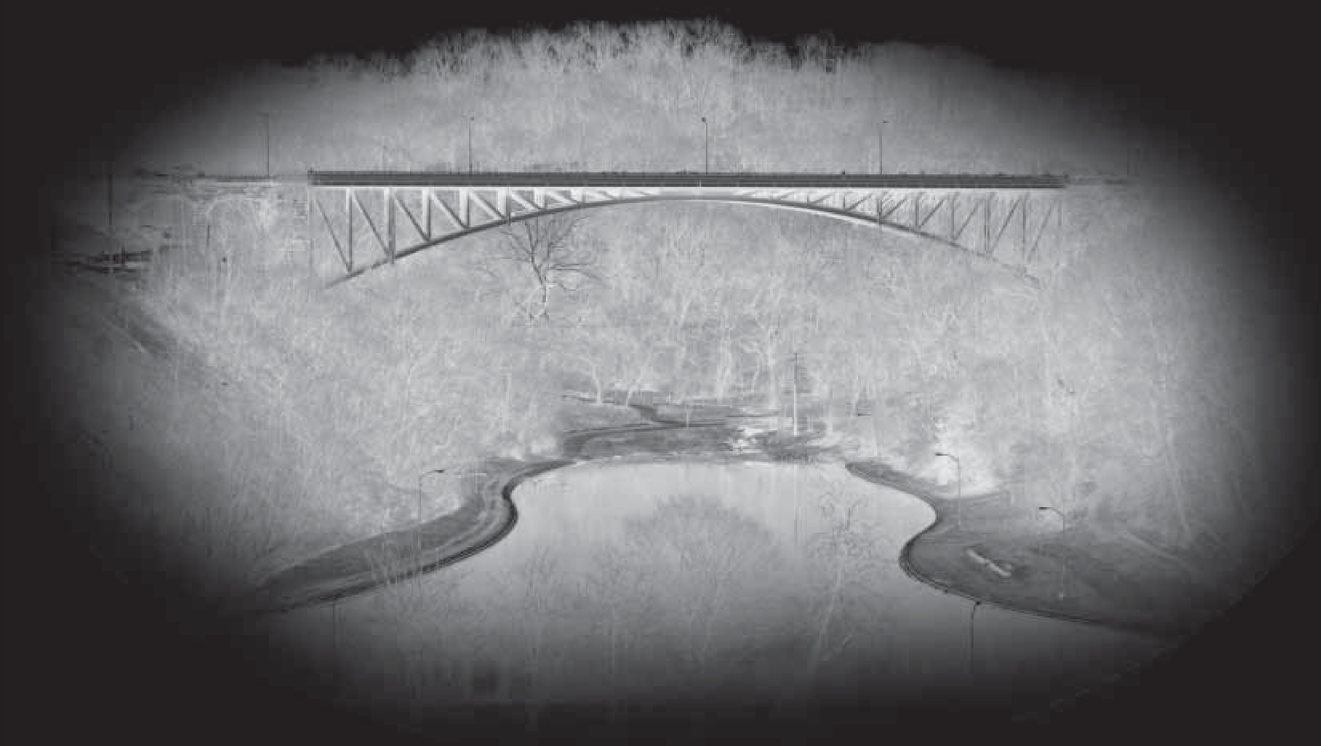
An assembly of ten of the greatest engineering quotes from antiquity to the present - Editor

The (ideal) engineer should be ...“ a man of letters, a skilled draftsman, a mathematician, familiar with historical studies, a diligent student of philosophy, acquainted with music, not ignorant of medicine, learned in the responses of jurisconsults, familiar with astronomy and astronomical calculations.”

Marcus Vitruvius, c. 40 BCE, Roman Army Engineer; his written masterpiece, De architectura (The Ten Books on Architecture), dedicated to the emperor Augustus, is the only surviving major book on engineering (architecture) from classical antiquity.

“I am an advocate for weatherboarding and roofing…not withstanding I am determined to give my opinion as it appears to be right. It is sincerely my opinion that the Schuylkill Bridge will last 30 and perhaps 40 years if well covered. I think it would be sporting with property, to suffer this beautiful piece of architecture…which has been built with expense and danger, to fall to ruin in ten to twelve years.”

Timothy Palmer, 1806 upon completion of the “Permanent Bridge”, a wooden arch railroad bridge spanning the Schuykill River, in Philadelphia, PA.



“...please...”

Edward Manning Bigelow, 1889, “father of Pittsburgh’s parks” [to Mary Schenley who he persuaded, via a race across the Atlantic in advance of opportunistic land developers, to donate 300 acres of land for a major city park – the bridge on this page is the signature bridge element within this park (Schenley Park).]

I …“ decree that the San Francisco Bay be bridged immediately.”

Norton I, (celebrated citizen of San Francisco and self proclaimed) Emperor of North America and Protector of Mexico, 1872. [The San Francisco-Oakland Bay Bridge was opened to traffic on Nov. 12, 1936.]

“Strauss will never build his bridge; no one can bridge the Golden Gate because of insurmountable difficulties which are apparent to all who give thought to the idea.”

Conventional wisdom, c. 1930 [The Golden Gate Bridge was opened May 27, 1937, one year before Joseph Baerman Strauss’ death.]

“We will build you a bridge a thousand feet high …
… if you’ll provide the money.”

Adolphus Bonzano, 1881 (to Thomas Kane contemplating the design of the 301’ tall Kinzua Viaduct, tallest structure in the word at that time.) The iron viaduct, when completed in 1882 vibrated so intensely with the passage of trains that it was replaced in less than 20 years with a more rigid steel structure.

I … “agree [with critics of my design] with regard to [reuse of] the old [wrought iron] anchor bolts… strong[er] bolts should have been used with superior details…”

C.R. Grimm, 1901, designer of the second Kinzua Viaduct (ASCE Transactions). [The Second Kinzua Viaduct catastrophically collapsed on July 21, 2003 during a tornado. Investigators determined that the collapse was a result of a hidden cracking within the anchor bolt system.]

“Today, bridge building is truly a science; only three decades back it was hardly worthy to be termed an art; while seventy five years ago, in our own country at least, it was no better than a trade.”

J. A. L. Waddell, 1916 [introductory chapter of his two volume treatise on “Bridge Engineering” dedicated to the Emperor of Japan.]

“It is refreshing to read something not buried in a mass of intricate calculations that are known only to the author.”

E.K. Morris, 1932, Member of the Water & Power Resources Board of PA, Pittsburgh, PA [ASCE Transactions] .

“If Ralph Modjeski had chosen a career in music instead of engineering, the world might have gained a famous concert-pianist but would have lost one of its finest bridge designers.”

William Shank, 1966 [Historical Bridges of PA

LOOKING BACK
on the Last 250 Years of Bridge Engineering

By
Brian Brenner, P.E.,
Fay Spofford &
Thorndike
and
David Lattanzi,
Gannett Fleming, Inc.

The Firth of Forth Rail Bridge, Scotland

Milestone anniversaries such as the 25th International Bridge Conference and the 250th anniversary of the founding of the host city, Pittsburgh allow us a chance to reflect on the history of bridge engineering. The last 250 years have played host to an explosion of dramatic new bridge forms and infrastructure demands. But where were we before 1758? Civil engineering hadn't changed much for 2000 years or so. For the most part, structures were designed using a trial and error or empirical approach. Put another way, structures that lasted were the blueprint for future designs even if we did not understand why they lasted. Timber and masonry dominated as easily accessible, yet uncontrollable, construction materials. On top of all this, the world had yet to see the impacts of the Industrial Revolution and most societies were still heavily agrarian.

Things are a lot different today. Mathematical methods dominate our design methodologies although there is still an empirical element to most of our design codes. Engineered materials such as steel and concrete are our building blocks of choice. The urban landscape expands exponentially with each passing day, rapidly eroding rural lifestyles. The last 250 years of civil engineering are the direct result of revolutions in mathematical analysis, construction materials, and societal demands. These changes are imprinted on the modern bridge, creating an exceptional lens on bridge engineering history.

MATHEMATICAL MODELING

The ways in which we analyze bridges have changed almost beyond recognition. Granted, some engineers view the slide rule as archaeological artifact but the changes go far beyond computational methods. For millennia, bridges were designed either by trial & error or by empirical methods. We either observed what worked and what did not (trial & error) or we tried to apply naturally occurring systems to man-made structures (empirical design). These design methods dramatically limited our ability to innovate and develop more efficient structural forms. Not only that, the inherent risk of a design was unknowable. The offshoot is that bridge building was considered to be a far different profession than it is today. Bridge building was considered a trade learned through practical experience. While that practical experience is a crucial aspect of modern bridge engineering, the analytical methods developed over the last 250 years have transformed bridge design from a trade into a technical profession.

Around 1750—the actual date is unclear—Euler and Daniel Bernoulli developed classical beam theory, one of the cornerstones of modern bridge engineering. Euler and Bernoulli applied Hooke's Law and the newly developed Calculus to cantilever beams. The result was the ability to relate the response of loads on a beam to deflections, strains, and stresses. Beam theory is still to this day the foundation for our understanding of the strength of materials and of structural analysis. The Bernoulli family (eight mathematicians!) and Euler would continue their contributions to the field of engineering with the development of virtual work principles and Euler buckling theory.

The 19th century saw an explosion in truss design and analysis, rooted in the beam theory developed during the 18th century. Many truss designs were developed based on approximating a truss as a simple beam and then applying beam theory. Squire Whipple and Dmitri Jourawski are largely credited with the development of truss analysis techniques. These two engineers independently developed the "method of joints" in 1847 (Whipple) and 1850 (Jourawski). August Ritter published his "method of sections" in 1862. These analysis methods are still frequently used today.

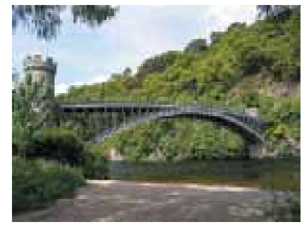
Countless engineers patented their own trusses. Thomas and Caleb Pratt developed the Pratt truss in 1844. This system of tension diagonals with compression verticals was useful for both timber and iron bridges. The Pratt truss is one of the most significant truss systems ever designed and many other well-known truss systems are based on the Pratt. Squire Whipple patented the Whipple Truss in 1847. Based on the Pratt, it was used primarily for long-span railroads. The Parker Truss, also based on the Pratt, would spawn the Camelback and Pennsylvania trusses. Many examples of these truss systems have lasted to this day.

While innovations in analysis techniques continued into the 20th Century, the next breakthrough occurred around 1940. Using techniques created by several earlier mathematicians, Alexander Hrennikoff and Richard Courant developed what is widely known as the Finite Element Method. It would not be known by that name, however, until 1956 when Turner, Clough, Martin, and Topp published their paper on the topic. Along with innovations in computing, the Finite Element Method has drastically changed the landscape of the engineering world. Today we use the finite element method for everything from simple girder bridge designs to bridge rehabilitation studies to complex dynamic analyses of our largest bridges. In many cases, the Finite Element Method is used alongside the classical analysis techniques developed over the past 250 years.

INNOVATIONS IN MATERIALS

Concurrent with the development of new analysis techniques, the last 250 years has also seen changes in the building materials used in bridge design. In essence, engineers have shifted away from naturally occurring materials such as timber and stone to man-made materials that we can easily manipulate.

Cast iron had been used in China since the 6th century BC but the industrial revolution in Europe increased the prevalence of cast iron as a building material. Its first use in a bridge was by Abraham Darby III. A third generation ironmaster, Darby used cast iron in his now famous Iron Bridge at Coalbrookdale in 1779. The bridge inspired the career of Thomas Telford, who would become a master of the cast iron bridge. His works would eventually include the Craigellachie Bridge in 1814. The Craigellachie Bridge is not only an aesthetic masterpiece but a technical triumph as well; Telford specified performance criteria for the cast iron used in the bridge, improving the cast iron's behavior in tension. Bridge builders were rapidly gaining control over materials.



The Craigellachie Bridge, Scotland

Cast iron would be used in many of the great bridges of the 19th century, including some of the trusses mentioned previously. Eventually, several well-known cast iron bridges would collapse in part due to the brittle nature of the material. The Tay Bridge Disaster of 1879 and the Norwood Junction Rail Disaster of 1891 forced builders to consider other materials.

Another material that owed its popularity to the Industrial Revolution is steel. Steel dates back to 1400 B.C. Africa, but

Henry Bessemer's invention of the Bessemer Process in 1858 made steel cost effective as a building material. The Bessemer Process also allowed the steelmaker to control the behavior of the finished product.

Countless bridges have used steel as the primary material. The first major steel bridge was The Eads Bridge in St. Louis, built in 1874. The bridge was innovative in many ways but the use of steel set the stage for modern bridge building. The Forth Bridge, built in 1890, was in part designed as a response to the Tay Bridge Disaster. The use of steel and the famously robust shape of the bridge allayed the many rail passengers fearful of crossing the Forth Bridge.

Perhaps the most important recent innovation in steel has been the research into fatigue behavior. Developed throughout the course of the 19th century, fatigue analysis for bridge design has become highly refined in recent decades. This is in large part due to the work of Dr. Fisher who is largely responsible for our understanding of "fatigue prone" steel details. Dr. Fisher presented some of his findings at the first International Bridge Conference in 1984.

Concurrent with the developments in steel were those in concrete. Concrete had been used as a building material for over 7000 years but Portland cement concrete as we know it today was patented in 1824. The significance of Portland cement is that it is a controllable, man-made cement and has allowed engineers to specify concrete for a variety of applications. Previously used naturally occurring limes were stable but difficult to manipulate.

Today, most bridge engineers think of reinforced concrete when they are talking about concrete. Beyond the ability to specify different cement and aggregate mixtures, reinforced concrete allows the engineer to resist forces in countless ways. Joseph Monier is typically considered the inventor of reinforced concrete in his attempts to make a stronger flowerpot. Monier would gain several bridge patents but was legally unable to build the bridges himself. He sold his patents to contractors such as Wayss, Freitag, and Schuster. This firm would eventually compete with Francois Hennebique to build reinforced concrete bridges. Hennebique was the first engineer to develop a building system using reinforced concrete. His first reinforced concrete bridge was built in 1894 in Switzerland.

Eugene Freyssinet, born 1879, is often credited as the inventor of prestressed concrete, but this is not so. Prestressing had been used in various applications since at least at 1888, when Freyssinet was only eleven years old. Freyssinet's contributions were focused primarily around the use of high-strength wire as well as developing an understanding of concrete creep behavior. Probably his most famous bridge, Pont Le Veurdre, was built in 1911. Originally a hinged arch bridge, Freyssinet's observation of significant deflection at midspan compelled him to jack the bridge up and fill the hinge with concrete. The additional jacking forced the arch of the bridge into a permanent state of compression and was Freyssinet's first attempt at prestressing. The bridge was destroyed in 1944.

Most material innovations in the past century have been improvements to the processes of making building materials. Computer controlled steel fabrication and precast concrete plants have made materials more durable and more reliable—not to mention more cost effective. Today, most of our bridges are a combination of steel and concrete. Composite plate girder bridges dot the highway landscape and cable stay bridges define skylines. The modern engineer typically looks at concrete and steel, trying to optimize the best aspects of each material.

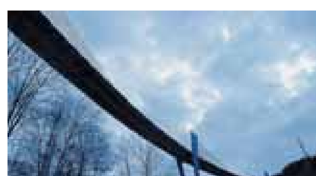
SOCIETAL DEMANDS

All of the aforementioned innovations occurred in large part due to the Industrial Revolution. Whether it was an entirely new bridge form or an improvement to a manufacturing process like the Bessemer Process, the bridges of today are a reflection of the rapid changes that produced the modern world.

The industrial boom that occurred in the 18th century gave birth to the Rail Age. Railroads became a critical aspect of modern infrastructure, transporting newly manufactured goods to expanding cities and new developments. These railroads had a distinct influence on the bridges of the day. Rail car loads are heavy, dynamic loads. They naturally require heavy, sturdy bridges to support them. The stiff, sturdy truss was a popular solution, as mentioned previously. This bridge engineering truism was as apparent 250 years ago as it is today.

The Hot Metal Bridge in Pittsburgh was originally designed for railroad use

Urban expansion increased the number of bridges within cities. As cities expanded, land became scarcer and more valuable and this led to a need for access to new land. The bridges of New York are an excellent example. As the need for growth increased, bridges were built to better interconnect Manhattan and the other Boroughs. A similar situation is occurring across China today. Incredible innovations in bridge design there are a direct response to urban expansion, whether to create supply lines or residential developments.



The Sunniberg Bridge in Switzerland was designed for automotive use. Photo courtesy of Jürg Mathis and Structurae.net

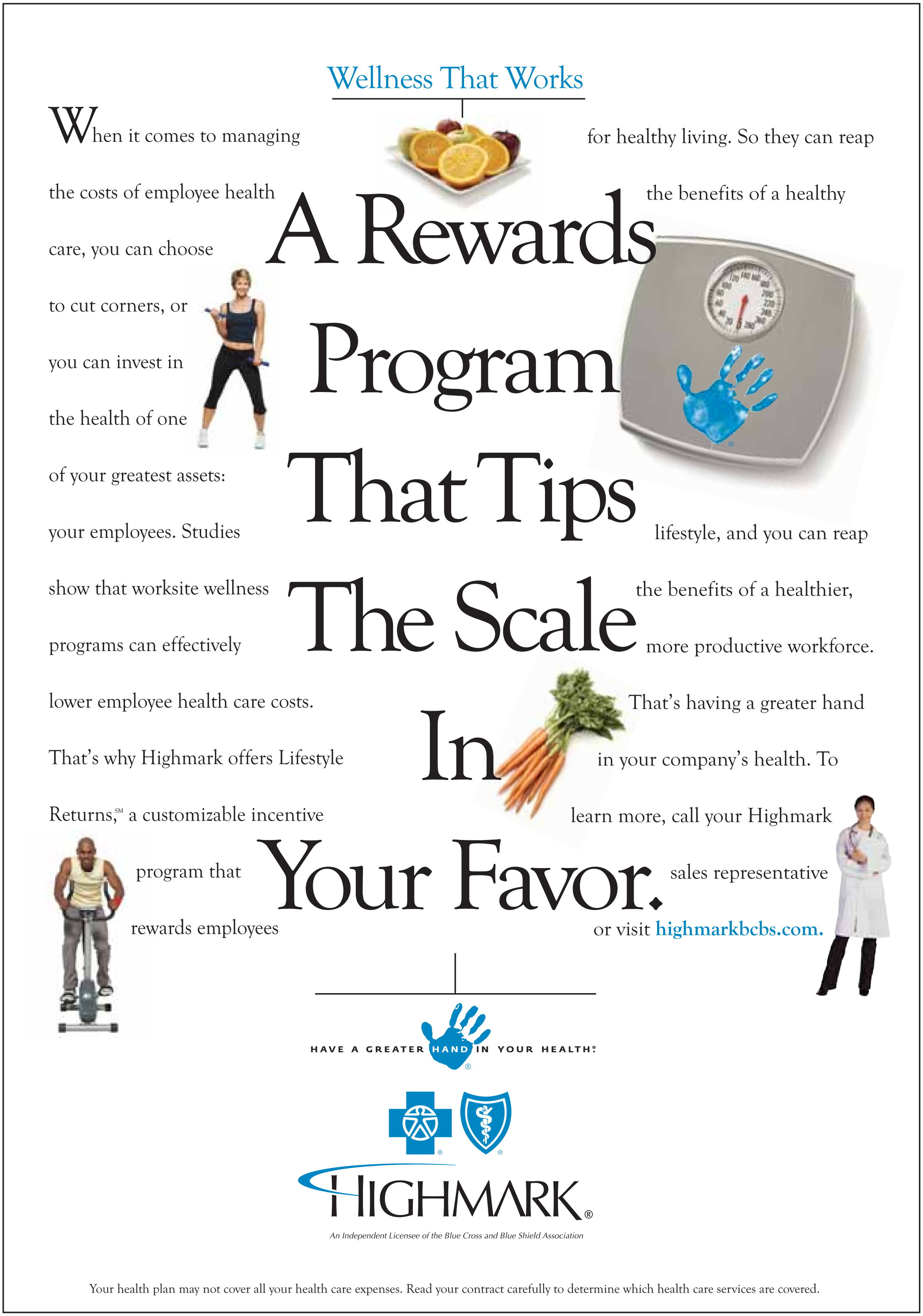
The birth of the automotive age has sculpted the modern bridge in much the same way that the rail age sculpted the bridges of the 19th century. Automotive loads tend to be smaller and more frequent. This leads to lighter bridges and concerns over fatigue failures and traffic capacity limitations. The automotive bridge boom also led to the death of the ferry system.

Public transportation in the urban environment has also put its stamp on bridges. The elevated rail system in Chicago is a unique signature of the city. First put into service in 1892, the "L" minimizes urban land impacts and is a masterwork of steel construction. Today it remains one of the busiest public transportation systems in the world and is in an almost constant state of growth.

CONCLUSIONS AND PREDICTIONS

Clearly bridges, and infrastructure in general, have responded to striking changes in analysis techniques, material innovations, and societal needs over the last 250 years. But can we use this perspective to shine light on the changes to come?

The societal pressures of today are likely to continue well into



Wellness That Works
A Rewards Program That Tips The Scale In Your Favor.
When it comes to managing the costs of employee health care, you can choose to cut corners, or you can invest in the health of one of your greatest assets: your employees. Studies show that worksite wellness programs can effectively lower employee health care costs. That's why Highmark offers Lifestyle Returns,SM a customizable incentive program that rewards employees for healthy living. So they can reap the benefits of a healthy lifestyle, and you can reap the benefits of a healthier, more productive workforce. That's having a greater hand in your company's health. To learn more, call your Highmark sales representative or visit highmarkbcbs.com.
HAVE A GREATER HAND IN YOUR HEALTH®
HIGHMARK®
An Independent Licensee of the Blue Cross and Blue Shield Association
Your health plan may not cover all your health care expenses. Read your contract carefully to determine which health care services are covered.

the next century. There is an increase in the demand for public transportation worldwide and urbanization maintains its breakneck pace. The United Nations reports that, for the first time in human history, more than half the world's population will live in an urban environment by the end of 2008. This expansion is projected to continue for at least the next thirty years, if not longer. The constant need for land and urban access will drive the practice of bridge engineering.

New materials are on the horizon. Fiber reinforced composites are becoming more common and so-called "smart" materials are being tested in laboratories across the globe. Many of our fabrication processes are computer controlled and almost certainly more will be in the future. And as research progresses so does our understanding of the materials we use. All of these innovations promise better performance and better control over the engineered materials of the future.

Computers will obviously be a part of our design methods for the foreseeable future and our design codes are already changing to make better use of this tool. Risk based analysis is beginning to shape our codes as well. As we better understand the materials we use, design methods will reflect that understanding.

> "Engineering is the art of modeling materials we do not wholly understand, into shapes we cannot precisely analyse so as to withstand forces we cannot properly assess, in such a way that the public has no reason to suspect the extent of our ignorance."

Yet at its core, bridge engineering will always remain the same. Dr. A.R. Dykes succinctly summarized the profession in 1946; "Engineering is the art of modeling materials we do not wholly understand, into shapes we cannot precisely analyse so as to withstand forces we cannot properly assess, in such a way that the public has no reason to suspect the extent of our ignorance." No matter what materials we use or how well we understand them, no matter what design techniques we use, no matter how society changes, this adage will hold likely true.

This article is based on an excerpt from the upcoming textbook "Introduction to Civil Engineering" by Brian Brenner, Chris Swan, and David Lattanzi - Editor.

REFERENCES

1. Billington, David P., (1983). *The Tower and the Bridge*. Princeton.
2. www.structurae.net, Retrieved March 2008
3. Timoshenko, S., (1953) *History of The Strength of Materials*. McGraw-Hill
4. United Nations Fund for Population Activities, *State of World Population 2007: Unleashing Urban Growth*. New York, 2007.
5. www.wikipedia.org. Retrieved March 2008.

WWW.BENTLEY.COM/BrIM

BRIDGE INFORMATION MODELING

BrIM

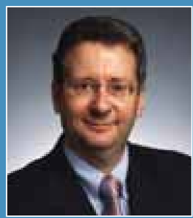
For lifecycle sustainability

Discover an innovative new approach to bridge engineering and project delivery

Bridge Information Modeling or BrIM is a practice that stands to revolutionize the way bridges are delivered and operated. It makes available a vast array of valuable bridge information for the many stakeholders involved in the bridge lifecycle, project conception to rehabilitation. With accurate, up-to-date information in hand at every step, the bridge community can reduce risk in project delivery and ensure well-maintained, safer bridges.

Incomplete information, tools and procedures result in a loss for everyone — the owner/operators, engineers, builders, even the public. BrIM puts an end to this confusion. It provides a clear path to bridge sustainability through data reuse, purpose-driven information delivery, and smooth interoperability. A win/win solution for all.

Join us for a Bentley-Sponsored Luncheon and Special Presentation by Bentley CEO, Greg Bentley at the International Bridge Conference (IBC)
Tuesday, June 3rd from 12:00 – 1:30 PM Westin Convention Center, Pittsburgh
(Across the skywalk from the David L. Lawrence Convention Center)



Bridge Information Modeling:
An innovative new approach to bridge project delivery

Visit Bentley Booth 401 at IBC
to see Bentley Bridge RM and Bentley LEAP Bridge software in action!

Bentley Bridge Solutions
The industry's most comprehensive bridge design and analysis software:

- Bentley® LEAP® Bridge
- Bentley® Bridge RM
- Bentley® BridgeModeler and Bentley® LARS
- Bentley® Rebar
- PowerRebar
- GEOPAK® Bridge
- InRoads® Bridge
- Bentley® CloudWorx
- STAAD®

BENTLEY®

A WALK THROUGH TIME - THE HISTORICAL

By Emory Kemp, Ph.D.

Lattice Truss over Connecticut River - NH, VT

THEMES

TENSION STRUCTURES

The use of rope and vines to fashion rudimentary suspension bridges dates before the Christian era with examples appearing in the high Himalayas in Tibet and independently in the hands of Incan builders in the Andes.

By the early modern era, the Chinese had fashioned impressive suspension bridges using wrought iron chain. Travelers such as Marco Polo and Kirscher introduced the Chinese suspension bridge design to Europe.

TIMBER, IRON AND STEEL FRAME STRUCTURES

Heavy timbers and even tree trunks were used from ancient time in structures, especially supporting roof structures.

Timber Framing was widely used in roof structures beginning in the early middles ages where the well known King Post Truss was hidden away in roofs throughout Europe.

The American Timber Covered Bridge is often assumed to have risen from American soil. As early as 1735, information on such bridges became available in Germany.

DOMESTIC AND COMMERCIAL FRAMED STRUCTURES

MASONRY AND CONCRETE

Stone masonry and brickwork dominated building in the ancient world including not only roads, bridges, and buildings, but also masonry drains and watercourses. Both the circular or 'true' arch and the corbelled or 'false' arch were developed in the Middle East.

It is believed that arcuated architecture was introduced to the Romans by the Etruscans. In the hands of the Roman engineers such as Vitruvius, arch bridges and domes for buildings were the hallmark of this new architecture. It represented the golden era of arcuated architecture.

The Romans also inherited and developed the use of concrete with waterproof properties, achieved by the use of lime-containing, argillaceous elements derived from the volcanic ash of Santorini and Vesuvius.

1500 BCE

TIME

Photographs, HAER Collection, *Courtesy of the Library of Congress*

DEVELOPMENT OF COMMON STRUCTURAL FORMS


King Post Truss - WI


Wheeling Suspension Bridge, WV

The suspension principle was employed sparingly in Europe. A notable pedestrian bridge was erected using an iron chain in 1741 in Britain. In 1801, an iron cable suspension bridge over Jacob's Creek appeared near Uniontown, PA.

Judge James Finley, considered the father of the American suspension bridges, is associated with a number of chain link structures until his death in 1828. Other notable 19th century examples include the Wheeling Suspension Bridge of 1849 and the Brooklyn Bridge of 1883.

Overseas bridges in Asia and Europe have overshadowed this American technology, best illustrated by the Golden Gate and San Francisco Bay bridges. Following World War II, German engineers developed a new type of tension structure which has been called the cable-stayed bridge. It has now become a dominant feature in multi-span bridges on a world-wide basis.

America took the idea of the covered bridge with alacrity. The earliest included the Permanent Bridge of 1806 and the Colossus of 1812, both over the Schuylkill.

In 1820, Itheil Town, independent of engineering theory, patented the Lattice Truss, claiming that his lattice truss could be built by the mile and cut off by the yard. In 1840, Elias Howe received a patent for a timber truss bridge featuring the use of wood, but replacing vertical tension members with wrought iron.

The introduction of wrought iron into the traditional building arts was a critical separation of architecture from civil engineering. In 1856 Sir Henry Bessemer developed a convertor which could reduce the carbon content of molten iron to produce mild steel on a very large scale, leading the transformation of the iron industry into steel. In the late 19th century, structural steel framing and the skyscraper allowed a totally new architecture to evolve.

While magnificent structures arose in the 19th and 20th century using iron and later steel, there is another whole tradition which is important in the built environment. A great number of heavy timber framed structures were built for residential and commercial purposes. Many mill buildings, barns and other structures of very significant size were erected across the country. The use of light structural members, studs, sills, and the use of modern techniques such as plywood and the increasing use adhesives are all part of this tradition.

The outstanding advances made by the Romans, with the use of concrete, were lost following the collapse of the Roman Empire c. 450 CE. It was not until the early stages of the Industrial Revolution that engineers turned their attention once again to concrete, when with a patent dated 1824, Joseph Aspdin established the manufacture of Portland cement.

Beginning in the latter half of the 19th century, French engineers and others sought a means to reinforce concrete to overcome its inherent weakness in tension. The prodigious growth of the use of reinforced, and later, pre-stressed concrete is a notable feature of the 20th century. Whole new systems for floors, monolithic frames , and bridge superstructures are hallmarks of this great revolution in building materials.

PRESENT

by Emory Kemp, Ph.D., Sr. Consultant to Gannett Fleming,Inc., retired professor and former head of Department of Civil Engineering, West Virginia University. Read Dr. Kemp's latest book entitled *American Bridge Patents: The First Century (1790-1890)*, West Virginia University Press, to learn more of the development of these common structural forms along an historical time line. - Editor.

MEET THE FEDERAL HIGHWAY ADMINISTRATION

By M. Myint Lwin, P.E., S.E.

The Federal Highway Administration (FHWA) is a major agency of the U.S. Department of Transportation (DOT). As a cabinet-level organization of the Executive Branch of the U.S. Government, the DOT is led by a presidential appointee-the Secretary of Transportation, Mary E. Peters. The top-level official at FHWA is the Administrator, James Ray (Acting), who reports directly to the Secretary of Transportation. FHWA is headquartered in Washington, DC, with field offices in every State, the District of Columbia, and Puerto Rico.

FHWA is charged with the broad responsibility of ensuring that America's roads and bridges continue to be the safest and most technologically up-to-date. Although State, local, and tribal governments own most of the Nation's highways, FHWA provides financial and technical support to State, local and tribal governments for constructing, improving, and preserving America's highway system. The annual budget of more than $30 billion is funded by fuel and motor vehicle excise taxes. The budget is primarily divided between two programs: Federal-aid funding to State and local governments; and Federal Lands Highways funding for national parks, national forests, Indian lands, and other land under Federal stewardship.

THE HIGHWAY PROGRAMS

FEDERAL-AID HIGHWAY PROGRAM

The Federal-aid Highway Program provides Federal financial resources and technical assistance to State and local governments for constructing, preserving, and improving the National Highway System, a 160,000-mile network that carries 40 percent of the Nation's highway traffic. The program also provides resources for one million additional miles of urban and rural roads that are not on the System, but that are eligible for Federal-aid.

FHWA's role is to oversee federal funds used for constructing and maintaining the National Highway System (primarily Interstate Highways, U.S. Routes and most State Routes). This funding mostly comes from the federal gasoline tax and mostly goes to State Departments of Transportation. FHWA oversees projects using these funds to ensure that federal requirements for project eligibility, contract administration and construction standards are adhered to.

FEDERAL LANDS HIGHWAY PROGRAM

The Federal Lands Highway (FLH) Program provides funding for public roads and highways within federally owned lands and tribal lands that are not a State or local government responsibility. Each year more than 900 million people visit National parks, forests, and wildlife refuges. Through the Federal Lands Highway program FHWA provides funding to maintain and improve access to these areas that include preparing plans, letting contracts, and supervising construction projects.

Under the Federal Lands Highway Program (sometimes called "direct fed"), FHWA provides highway design and construction services for various federal land-management agencies, such as the Forest Service and the National Park Service.

HIGHWAY RESEARCH PROGRAM

In addition to the Federal-aid programs, FHWA performs research in the areas of automobile safety, congestion, highway materials and construction methods. FHWA also publishes the Manual on Uniform Traffic Control Devices (MUTCD), which is used by most highway agencies in the United States.

A VERY BRIEF HISTORY

FHWA was created on October 15, 1966, however it has several predecessor organizations and a complicated history. For a more complete history of FHWA, see the article titled "A peaceful campaign of progress and reform: The Federal Highway Administration at 100" by Richard F. Weingroff. The article was published in the Public Roads Magazine, Autumn 1993, Volume 57, No. 2. The first predecessor was the Office of Road Inquiry (ORI) founded in 1893. In 1905 that organization's name was changed to the Office of Public Roads (OPR), and it became a division of the United States Department of Agriculture. The name was changed to Bureau of Public Roads (BPR) in 1915. In 1939 the name was changed to Public Roads Administration (PRA) and it was shifted to the Federal Works Agency (FWA). With the abolition of the FWA in 1949, its name was changed back to BPR and it was shifted to the Department of Commerce. In 1967 the BPR was transferred to the newly created FHWA, and was one of three original bureaus along with the Bureau of Motor Carrier Safety and the National Highway Safety Bureau (now known as NHTSA).

Federal-Aid Highway Acts enacted by Congress have changed and continue to change our driving experience. Two historic Acts are of significance in changing the highway systems. In 1914, the State highway officials joined together to form the American Association of State Highway Officials (AASHO). The objective of AASHO was to provide mutual cooperation and assistance to the Federal Government on legislative, economic and technical subjects related to highways. The AASHO-Federal cooperation contributed to the drafting and passing of the Federal Aid Road Act of 1916, entitled "An Act to provide that the United States shall aid the States in the construction of rural post roads, and for other purposes." The 1916 Act signified the beginning of the Federal-aid Highway Program. The 1916 Act apportioned a total of $75 million for Federal participation in the construction of rural post roads for the fiscal years 1917 through 1921. The Act also apportioned $10 million for construction of roads and trails within or partly within national forests for the fiscal years 1917 through 1926 at the rate of $1 million per year. The second historic Act was the Federal-Aid Highway Act of 1956, which President Eisenhower signed into law on June 29, 1956. The 1956 Act authorized a total of $25 billion for the fiscal years 1957 through 1969 to construct a 41,000-mile National System of Interstate and Defense Highways. The Federal share was set at 90%. The Act had a provision on vehicle weight and width limitations. The limits were essentially those of the policy of AASHO or those legally permitted in a State on July 1, 1956, whichever were greater.

THE VITAL FEW PRIORITIES

The Vital Few priorities are the focus areas that show the biggest performance gaps in the transportation system and present opportunities for FHWA to make the greatest difference. FHWA is committed to being successful in these focus areas.

SAFETY

Safety on our highways is FHWA's top priority. More than 42,000 people are killed annually in traffic crashes in this country. That equates to about 115 fatalities a day. FHWA is aggressively

advancing the activities and projects that prevent crashes and that reduce fatalities and serious injuries when crashes do happen. FHWA is focusing its safety program on addressing three crash types that relate most highly to fatalities: roadway departures, intersections, and pedestrians. FHWA also partners with others in DOT to increase the use of safety belts, as thousands of lives could be saved if every vehicle occupant would simply buckle-up.

CONGESTION MITIGATION

Congestion mitigation is another one of our top priorities. Demand for highway travel continues to grow as population increases. Between 1980 and 1999, miles of highways increased 1.5 percent while vehicle miles of travel increased 76 percent. FHWA is working with regional partnerships to address all aspects of congestion, including two of the most prevalent causes of traffic congestion; work zones and traffic incidents. FHWA is providing substantial assistance to State and local transportation agencies as they develop projects to increase capacity and remove bottlenecks.

As an interesting item of note, in July 2000, FHWA and DOT coordinated with the Federal Communications Commission to reserve the numbers "511" to enable travelers nationwide to access travel and traffic information across any area of the Nation.

ENVIRONMENTAL STEWARDSHIP AND STREAMLINING

FHWA is committed to protecting and preserving the environment through stewardship and timely reviews. In recent years, FHWA and our partners have made substantial contributions to the environment and to communities, through planning and programs that support wetland banking, habitat restoration, historic preservation, air quality improvements, bicycle and pedestrian facilities, context-sensitive solutions, wildlife crossings, public and tribal government involvement, and more.

FHWA will continue to support these programs while it also works with State, local, and Federal partners to conduct sound environmental reviews in a timely way. The environment is everybody's concern and at FHWA, it assumes a particular importance - one that touches virtually every aspect of highway planning, design, and construction.

THE ORGANIZATION

HEADQUARTERS

The headquarters, located in Washington D.C. provides policy and overall program direction to the Agency. The Headquarters organization is comprised of fourteen offices ranging in responsibility from administration, to research, to planning to technology and innovation to public affairs.

FIELD OFFICES

The field organization delivers program services to the FHWA's partners and customers. This organization consists of a Resource Center, State-level Federal-aid division offices, and Federal Lands Highway divisions.

Resource Center

The FHWA Resource Center supports the State-level Federal-aid division offices throughout the country, in the Division Offices' primary role of program delivery to FHWA's partners and customers. The FHWA Resource Center has offices in five locations: Atlanta, Georgia; Baltimore, Maryland; Lakewood, Colorado; Olympia Fields, Illinois; and San Francisco, California. The Resource Center has 12 virtual Technical Service Teams (TST) with repsonsiblities ranging from safety to operatons to planning to engineering to financing .

Federal-aid Division Offices

Federal-aid division offices, each headed by a Division Administrator, provide front line Federal-aid program delivery and assistance to partners and customers in highway transportation and safety services, including but not limited to, planning and research, preliminary engineering services, technology transfer, real property acquisition and management, bridge expertise, highway safety, traffic operations, environmental support, design, construction, asset management, and civil rights. The FHWA operates, jointly with the Federal Transit Administration, four metropolitan offices which are extensions of the respective division offices. These offices provide assistance, guidance, and information regarding Federal transportation programs to local, State, and other Federal agencies in these metropolitan areas.

Federal Lands Highway Divisions

The Federal Lands Highway (FLH) divisions, which report to the Headquarters Office of Federal Lands Highway, administer FLH programs (Forest Highways, Park Roads, and Parkways, Public Lands, Refuge Roads, and Indian Reservation Roads); the Defense Access Roads Program; and the Emergency Relief Program on Federally Owned Roads; provide engineering-related services to other Federal agencies, FHWA offices, and foreign countries as directed; and carry out technology and training activities related to FLH projects. There are three FLH divisions (Eastern, Central, and Western) located in Sterling, Virginia; Lakewood, Colorado; and Vancouver, Washington; respectively. The Division Engineer for the Federal Lands Highway Central Division is appointed as the Regional Emergency Transportation Coordinator for Region VII.

THE OFFICE OF INFRASTRUCTURE

The Office of Infrastructure, one of the fourteen FHWA offices located at Headquarters in Washington, D.C., ensures that the highway infrastructure supports the Nation's mobility needs by providing national leadership and technical expertise; advancing state-of-the-art technologies and innovations; and serving as stewards for the Federal-aid Highway Program in the following areas: program delivery and oversight, engineering policies and standards, pavements, materials, bridges, tunnels, geotechnical and hydraulic structures, contract administration, highway design, construction quality, maintenance and system preservation, and asset management.

The head of the Office of Infrastructure is the Associate Administrator for Infrastructure, King W. Gee. He provides executive direction over the activities of five organizational units including:

HIGHWAYS FOR LIFE TEAM

The mission of Highways for LIFE program is to advance Long lasting highways using Innovative technologies and practices to accomplishment Fast construction of Efficient and safe pavements and bridges with the overall goal of improving the driving experience for America.

The Highways for LIFE program aims at getting things done better, faster, safer, and more cost effective. The key to this is creating a culture within the highway community that invites innovation and rapidly adopts new practices, as well as effective technology transfer and improved ways for getting new technology to State highway agencies and practitioners faster. The program provides funding for demonstration construction projects, stakeholder input and involvement, technology transfer, technology partnerships, information dissemination, and monitoring and evaluation. The goals are to improve safety, reduce congestion due to construction, improve quality and improve customer satisfaction.

OFFICE OF PROGRAM ADMINISTRATION

The mission of the Office of Program Administration is to administer and provide program assistance on eligibility information, geometric design of Federal-aid highways, contract administration, and innovative contracting regarding the Federal-aid highway program

The Office of Program Administration develops national policies, standards, criteria, and guides on highway design, construction contract provisions, and national highway legislation. The Office provides technical assistance in using Federal-aid highway funds in interstate maintenance and rehabilitation, emergency relief for natural disasters and other catastrophic events, the Appalachian Development Highway System, ferry boat programs, and demonstration projects, VE studies, implementation of context sensitive solutions, major projects with total cost of more than $500 million, and other Federal-aid program related issues.

OFFICE OF PAVEMENT TECHNOLOGY

The mission of the Office of Pavement Technology is to administer engineering policies, develop standards and procedures, provide technical assistance, and lead innovative technology for the design and rehabilitation of highway pavements. The Office's focus areas are:

- Pavement Performance Optimization
- Advanced Quality Systems
- Pavement Surface Characteristics
- Environmental Stewardship

The Office of Pavement Technology provides national direction and guidance on overall pavement technology. The Office provides support and technical assistance in the development and deployment of innovative materials, processes, and technologies for the design, construction, and rehabilitation of pavements.

OFFICE OF BRIDGE TECHNOLOGY

The mission of the Office of Bridge Technology is to provide technical expertise for major and unusual bridges, tunnels, hydraulic/geotechnical structures and the Highway Bridge Program; provide policy direction and guidance for bridge inspection, replacement, and rehabilitation; compliance with NBIS, and promote innovation through technology delivery. The Office is dedicated to working together with AASHTO and our many partners and customers in State, local and tribal governments, industry, academia to provide the Nation with safe, secure, reliable, durable, and efficient highway bridges and tunnels.

The Office of Bridge Technology develops national policies, regulations, guidelines and advisories on highway bridge design, construction, inspection, preservation, rehabilitation and replacement, and other bridge relate issues. This Office provides leadership, stewardship, and technical assistance in delivering the Federal-aid program, which includes the National Bridge Inspection Program, the Highway Bridge Program (HBP) and the Innovative Bridge Research and Deployment Program. Some significant milestones of the Congressional Highway Acts follow:

Act and Year	Milestones
Federal-Aid Highway Act of 1971	**Established uniform national-level standards for bridge inspection and safety evaluation.**
Surface Transportation Act of 1978	**Established Highway Bridge Replacement and Rehabilitation Program.**
Surface Transportation and Uniform Relocation Assistance Act of 1987	**Added requirements for underwater inspection and fracture critical inspection.**
Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)	**Mandated use of bridge management systems. (Repealed mandate in 1995.) Established environmental standards.**
Transportation Equity Act for the 21st. Century (TEA-21)	**Established funds for activities that enhance the environment.**
Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005 (SAFETEA-LU)	**Established Special Rule for Systematic Preventive Maintenance. Increases funding for environmental programs. Established Highways for LIFE and Innovative Bridge Research and Deployment Programs.**

The Office of Bridge Technology works closely with the FHWA Office of Infrastructure Research and Development, and other research agencies in advancing bridge technologies through research, development, deployment, and education.

OFFICE OF ASSET MANAGEMENT

The mission of the Office of Asset Management is to provide leadership and expertise in managing high way infrastructure assets utilizing progressive policies and practices that facilitate transportation investment decisions regarding preservation, improvement, operation, and technology. The Office has three key responsibilities:

- To provide national leadership in asset management principles for highway program administration;
- To develop asset management policies for pavement, bridge, and system preservation; and
- To partner with the American Association of State Highway and Transportation Officials (AASHTO), other FHWA offices, and others to conduct nationwide programs.

In fulfilling these responsibilities, the Office of Asset Management serves as an advocate for asset management, system preservation, pavement management and analysis, bridge management and inspection, and construction and maintenance activities, as well as technology development, outreach, and partnering initiatives.

IN CONCLUSION

FHWA is committed to working with our customers and partners, to keep America moving safely, comfortably, economically, and without harm to our environment. In the years ahead, the staff of the FHWA Office of Infrastructure will be working cooperatively and collaboratively with members of AASHTO, professionals and managers from the highway industry, academia, other partners and customers, stakeholders and the public in meeting the challenges caused by an aging highway infrastructure, increasing congestion, natural disasters, security issues, the threat of global warming, limited funding, higher material costs, and the reduced pool of trained and experienced workforce.

To learn more about FHWA, please visit the FHWA exhibit area at the Exhibit Hall of the 2008 International Bridge Conference, June 2 – 4, 2008, in the new David L. Lawrence Convention Center in Pittsburgh, PA. FHWA, the 2008 IBC "Featured Agency", will be showcasing bridge technologies and innovations for meeting the highway infrastructure challenges of today and tomorrow. FHWA will also be making a series of presentations in the "Featured Agency" session on Monday, June 2, 2008, 1:30 p.m. to 5:00 p.m., to inform participants on the FHWA's Role in the National Bridge Program and the FHWA's commitment and dedication in working together with partners, and customers in advancing bridge technology for improving the condition, durability and performance of the Nation's bridges and tunnels. We, at the FHWA, look forward to seeing you in Pittsburgh, PA in the first week in June!

EDITOR'S NOTES:

1. For information on safety facts visit:http://safety.fhwa.dot.gov/facts/index.htp
2. For national traffic and road closure information, visit: http:/www.fhwa.dot.gov/trafficinfo/
3. For information on environmental streamlining, visit: http:/www.fhwa.dot.gov/environment/

M. Myint Lwin, P.E., S.E., is the Director of the Office of Bridge Technology for the Federal Highway Administration, U.S. Department of Transportation, and is based in Washington D.C.

Where are they now?

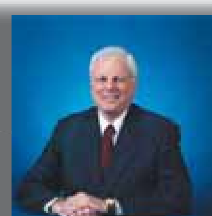
A brief look at some of the most influential IBC Chairs over the past 25 years - Editor.

YEAR		CHAIR
1984	IBC-1	William Vandemark
1985	IBC-2	John (Fred) Graham, Jr.
1986	IBC-3	Stephen Dake
1987	IBC-4	James Dwyer
1988	IBC-5	Peter Florian
1989	IBC-6	Herbert Mandel
1990	IBC-7	Carl Angeloff
1991	IBC-8	Victor Bertolina
1992	IBC-9	Reider Bjorhovde
1993	IBC-10	Lisle Williams
1994	IBC-11	Richard Connors
1995	IBC-12	Arthur Hedgren
1996	IBC-13	Eric Kline
1997	IBC-14	Chuck Schubert
1998	IBC-15	Gerald Pitzer
1999	IBC-16	Gary Runco
2000	IBC-17	Donald Killmeyer, Jr.
2001	IBC-18	James Cooper
2002	IBC-19	Donald Herbert
2003	IBC-20	Robert Wellner
2004	IBC-21	Thomas Leech
2005	IBC-22	Enrico Bruschi
2006	IBC-23	Kenneth Wright
2007	IBC-24	Myint Lwin
2008	IBC-25	Eric Kline

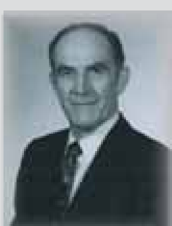
Consultant to OSMO-USA - retired former Chief Engineer of both Allegheny and PA Turnpike - was driving force in establishing the first International Bridge Conference under sponsorship of ESWP - member of first IBC executive board.

Consultant to STV - retired Executive with U. S. Steel, and the Port Authority of Allegheny County; active on national Transit and Rail subcommittees - former president of ESWP - member of first IBC executive board.

Head, BD Corrosion Manager, FAFTA Business Development Bayer MaterialScience, LLC - former District 11 Bridge Engineer - "father" of IBC Award's Program - member of first IBC executive board.



Deceased - former Director of FHWA Office of Bridge Technology - long time friend and mentor to the industry - IBC Student Award named in Jim's honor.



THOMAS D. LARSON

Educator, State Transportation Secretary, Strategic Planner and Pioneer - deceased 2007

Thomas D. Larson was sworn in as the Federal Highway Administrator on August 10, 1989. A native of Pennsylvania, Dr. Larson came to the FHWA after a distinguished career as a researcher, Professor of Civil Engineering, and administrator at the Pennsylvania State University; as Pennsylvania's Secretary of Transportation for eight years; and as an active leader in the American Association of State Highway and Transportation Officials and the Transportation Research Board.

Dr. Larson led the preparation of the National Transportation Policy in March 1990 and played a strong role in molding the landmark Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). To match this first major restructuring of the Federal-aid Highway Program and rethinking of the Agency's mission since the Interstate era began in 1956, Administrator Larson oversaw an FHWA reorganization and established the agency-wide strategic planning initiative (FHWA 2000) that prepared FHWA to better meet State and local needs in implementing ISTEA for the Nation's ever-increasing mobility needs.

Additional highlights during his tenure included a continuing decline in the highway fatality rate to an all-time low; a dramatic increase in the research, technology, and intelligent Vehicle Highway System programs; and continued support for university transportation centers. During his service, Dr. Larson also emphasized innovation and partnerships; renewed the commitment to environmental sensitivity as embodied in the FHWA Environmental Policy Statement of April 1990; reinvigorated motor carrier safety enforcement; and expanded diversity education and training for all employees.

In 1983, a conference of bridge engineers, sponsored by the Pennsylvania Department of Transportation, was held in Pittsburgh at the suggestion of Dr. Tom Larson. One year later, ESWP turned the success of what was a local bridge conference into an international conference and the International Bridge Conference was born - Ed.

IBC: THE FIRST 25 YEARS

Recollections of the Executive Committee – a Roundtable Discussion

In this issue, eight members of the 25th International Bridge Conference (IBC) Executive Committee tell readers how the International Bridge Conference came into being, give their recollections of the early struggles and then later successes, and finally take a long introspective look into the future of the Conference. Both Jim Dwyer (JD), past IBC chairman and Engineers Society of Western Pennsylvania (ESWP) President, and Lisle Williams (LW), past IBC chairman, were there at the beginning. Eric Kline (EK), current IBC chairman and active committee member has served the IBC for most of its 25 years of existence. Reidar Bjorhovde (RB) and Art Hedgren (AH), also past chairmen, who no longer actively serve on the committee, offer insights from the formative years and share their perspective for the future. While relatively new to the committee, Myint Lwin (ML), Kent Harries (KH) and Ken Wright (KW) offer other unique perspectives of the IBC and its future – Editor (Ed).

Ed: What was the seed that germinated to become the International Bridge Conference?

JD: In 1983, a conference of bridge engineers was held at the suggestion of Dr. Tom Larson (then Deputy Secretary for the Pennsylvania Department of Transportation PennDOT) and Dr. Roger Carrier, (then the local PennDOT, District Engineer). Pittsburgh with its rich bridge history was selected as the site for the conference. What a success it was, attended by greater than 300 bridge practitioners. The success of the bridge conference conducted by PennDOT in Pittsburgh proved the need for such a conference. Unfortunately PennDOT was not willing to sponsor a repeat conference. Others in Pittsburgh felt differently. They believed that the conference should be continued. They planted a seed.

> ... in 1984, the International Bridge Conference was born ...

Ed: Who planted that seed?

JD: Fred Graham, then Chief Engineer of the Allegheny County, Director of Engineering and Construction, took the lead by asking the Engineer' Society of Western Pennsylvania (ESWP) to sponsor and promote the conference. ESWP agreed and in 1984, the International Bridge Conference was born! Mary Jean Edgar, then Manager of ESWP, provided the leadership needed to organize and get the first ESWP sponsored conference underway by establishing a conference committee much in the format which is still used today.

Ed: What were the early conferences like? What was their focus?

Jim Dwyer

JD: In many ways it was very similar in format to that which we still use today, keynote session, technical papers, exhibitors, featured state...

LW: Our attendance grew and grew reaching in excess of 1000 participants within ten years. Our participant base grew quickly from simply the tri-state area in 1983 to the entire United States and many foreign countries.

Ed: How did the idea of a featured state develop?

JD: It was a natural follow up to the 1983 PennDOT conference; we looked to states with active bridge programs.

Ed: How did the conference change in its early years? Did the focus change as well?

Lisle Williams

LW: I have closely and personally watched "good ideas" incorporated into the program over the years that IBC has become one of the most prestigious bridge industry events in the world. Each year IBC gets "better than ever" with interesting and informative exhibits, unique programs, feature states/agencies/countries, local bridge tours, awards, keynote speakers, technical sessions, special interest presentations, a special theme each year, and the involvement of an ever-increasing number of colleagues and bridge experts

JD: I would say that our focus has never substantially changed. The conference committee noted that to be a successful conference, the quality of the papers presented must be of the highest caliber with practical values. This emphasis continues through the present day. Papers have never been allowed to become sales pitches.

Ed: What makes this conference different from any other "bridge" conference?

EK: This conference is built on "Content". The conference history is now a "tradition of pioneering excellence" in the bridge arena.

AH: I agree; however, a number of factors make the IBC different and I believe better than other bridge conferences. First and foremost is the quality of the papers presented. The program committee screens all the papers to make sure they are of a practical nature which are of value to practicing bridge engineers. Papers which are highly theoretical or are of only academic interest are not given as strong consideration. In addition the large number of suppliers of bridge products is quite valuable to practicing engineers. The educational seminars, special interest sessions, location and other factors all combine to make the IBC a preeminent conference.

Myint Lwin

ML: First and foremost, this conference is planned and organized by bridge engineers for bridge engineers in all aspects of bridge engineering – research, practice and training.

LW: The prospect of networking with peers from around the world and at all staff levels in one forum is truly amazing. The IBC offers a wonderful opportunity to meet and interact with colleagues and experts in your field, and inspires career development. Over the past 25 years, the growth and continued success of the International Bridge Conference can be attributed to the dedicated and cooperative effort of engineers working toward the same goal – promoting and recognizing the important role bridges play in today's world in moving goods and people.

RB: I would add that IBC focuses on usable information. Attendees can go home and apply a number of the things they hear about during the conference – immediately!

Ed: What were the technical presentations like in the early years? How have these presentations changed over time?

Art Hedgren

AH: The technical presentations in the early days were almost all slide presentations. The quality of the slides in numerous cases was quite poor. It was difficult to read slides which were photos of engineering drawings. As time went on the use of Powerpoint presentations became more common and now have become mandatory.

JD: It may seem strange to us now, but in the early years, there was quite an emphasis on CADD.

RB: The presentations have improved enormously over the years, both as a result of the IBC reputation and the visual aids facilities that are now available.

AH: I agree; the overall quality of the papers is now excellent with very good graphics. The one problem we occasionally have is with foreign speakers using the English language. We now are able to draw a lot more international papers than we did in the early days since the conference is recognized as a truly international bridge conference.

Roundtable Discussion Continues ...

Ed: The Award's program has been great. How did it get started? How were the names of the metals determined?

JD: The idea came about one night in the 20th floor lounge of the Hilton Hotel over drinks with Wes Shoup then of Roads and Bridge Magazine, Carl Angeloff and I discussing what could be done to improve the conference and enhance attendance. Out of this came the idea for the Robeling and Richardson Medals .

AH: In the early days the award's program was started with only two medals. The John Roebling award to honor an outstanding engineer who has devoted his life to the advancement of bridge engineering and the George S. Richardson award for a recent achievement in bridge which demonstrates technical advancement and economy. The awards were sponsored by Roads and Bridges Magazine and the ESWP respectively. As the years passed three additional awards were added to further recognize and publicize achievements in the field of bridge engineering. These were the Lindenthal, Figg and Hayden medals. All awards were named after famous engineers in the bridge field.

Ed: Who were some of the most notable award recipients? What strikes you about these individuals?

AH: All of the Roebling award recipients were notable and accomplished bridge engineers recognized by almost every-one in the bridge business. I particularly remember T.Y. Lin, John Fisher, Chuck Seim, and Jackson Durkee. All of the gentlemen were deeply honored and shared their recollections and feelings with us. In addition most of them brought their families, children and grandchildren to the award ceremony. It was always a touching moment when someone of this stature is so honored and reflects back on a career of exemplary accomplishment.

EK: Gene Figg was a giant. He was a very humble, self effacing man. He was the consummate professional.

ML: The individual award recipients practiced and exemplified long term personal and global commitment to bridge engineering. Young bridge engineers can be inspired by the commitments and accomplishments of the award recipients.

Ed: What are some of your fondest conference recollections?

ML: I was a first time presenter at the IBC in the late 1990's. I was encouraged by the constructive comments received from the IBC Executive Committee Members, who made it a point to mingle with the participants during the conference. They made me so welcome that I have been back every year to learn and network.

AH: One of my fondest recollections was the Q & A period after hearing a bridge presentation when Jackson Durkee would approach the microphone to pose a question. In his strong deep voice Jackson would say "Jackson Durkee, Consulting Engineer, Bethlehem, PA". He would then go on to call the author to task with a question dealing with his long experience in practical bridge erection and construction. Unfortunately Jackson has passed on and is no longer with us. Somehow the conference doesn't quite seem the same!

Ed: How does the IBC keep such a great attendance record year after year?

LW: The list of IBC presenters and attendees reads like a Who's Who in bridge design, construction and maintenance…state bridge engineers, owners and principals of engineering firms, FHWA representatives, fabricators, researchers, academia, contractors, manufacturers, industry suppliers …

AH: I would say firstly and foremost, the great papers with value to practicing engineers. But also the conference has been able to grow, evolve and change over the years to bring more value to the attendees. Such things as keynote sessions, educational seminars, special interest sessions, suppliers, proprietary sessions, networking, featured agency and other items all create for attendees. The attendance would not continue to hold up and increase if the attendees did not find exceptional value in the conference.

ML: I would offer that firstly, it is through the generous contributions by the bridge engineers who submit abstracts for consideration by the IBC Executive Committee. The Committee is then able to screen and select papers that the broad spectrum of topics of current interest to the Bridge Community. Secondly, IBC is able to draw the support of exhibitors who bring the participants up to date on the latest products and services available to the participants.

KW: I certainly agree. I think that the continual high quality of the papers and seminars continues to draw attendees.

> ESWP has been absolutely essential to IBC and its success.

The combination of technical content and supplier exhibits provides outstanding information for all of the attendees.

Reidar Bjorhovde

Ed: The Engineer's Society of Western Pennsylvania, recently celebrating 125 years, is the second oldest technical society in the US. How has the ESWP sponsorship helped the conference?

RB: ESWP has been absolutely essential to IBC and its success.

KW: ESWP has provided stability to the conference, acting as an anchor even as the makeup of the IBC executive committee has changed. Having a paid staff whose job it is to follow through on many of the details of conference planning has allowed the executive committee to focus on the technical aspects of the conference, which is really the strength of the committee.

LW: I would sincerely add that none of this would have been possible without the support and commitment of The Engineers' Society of Western Pennsylvania and the ESWP professional staff members dedicated to the Conference. They have made the IBC Executive Committee roles and responsibilities very enjoyable over the past 25 years.

Ed: What has been the most striking presentation over the years?

KW: I think that the plenary session on the Messina Straits Bridge (between Italy and Sicily) was particularly striking, given the high level of presenters, the scope of the bridge and the scale model that they brought with them.

Ken Wright

ML: For me, the 2007 "Featured Country: China" Session has been the most impressive. The speakers described an unprecedented undertaking in modern bridge construction that has blossomed in China over the last 15 years. The presenters showcased record-setting girder bridges, arches, cable-stayed bridges, suspension bridges and some long span railway bridges.

Ed: The keynote sessions have had some very dramatic speakers. What keynote session(s) have been the most remarkable?

EK: We had the New York DOT Secretary, Mr. Joseph Boardman, several years ago. He gave the best Keynote address that I have ever heard. The subject was world trade and how it circulates in North America … fascinating stuff!

Eric Kline

Ed: Over the past years, the number of international papers, presentations and awards has increased dramatically. How has this happened?

KH: Bridge engineering, by its very nature is an international endeavor. Whether we consider the “International” and “Peace” Bridges linking the US to its largest trading partner, Canada, or we consider bridges that are truly studies in geopolitics such as in Mitrovica- Kosovo, bridges are as much a sociopolitical phenomena as they are engineered structures.

AH: The IBC Executive Committee has made direct efforts to reach out to the international bridge community to make the conference a truly international conference. These efforts have been successful and have brought information, papers and awards to the conference about some of the largest, most technically challenging bridge projects in the world.

KW: The increase in international visibility has not occurred accidentally. The diversity was pushed by a few members of the executive committee (most notably Carl Angeloff) that identified that, in order to be a truly international bridge conference, we needed to reach out to the international bridge community. I believe that we are well on our way to being truly ‘international’.

RB: The number of international presentations is still too small to really justify the I of IBC. But it has gotten much better, and last year’s feature of China was absolutely outstanding.

Ed: It was a bold step, featuring China as a featured Country in 2007. How long did the planning for this take?

KW: The planning for this event took at least three years. A critical step toward this was Jim Cooper’s reach to the far east in his position with FHWA that began to develop some of the relationships necessary for China to happen. Myint Lwin’s appointment to the executive committee after Jim retired from FHWA was the next key step, as he had developed many relationships in China through scanning tours and other technology exchanges. Myint was able to capitalize on these relationships to follow through with China as the first featured country during his year as the general chairman.

ML: It took many years and persistent efforts by members of the IBC Executive Committee through many discussions and debates at committee meetings. The time was right in 2007! It was a bold and visionary move with calculated risks and outstanding efforts on the part of China.

KH: In retrospect, inviting China was a no-brainer. China is building more bridges… more signature bridges now… right now. Innovation in engineering, construction and finance is flourishing.

Kent Harries

Ed: Never the less, there are obviously areas that we could strengthen within the conference. How come there are so few educators at IBC? Is it because the speakers don't talk about research? And the student award winners mostly seem fairly modest, with little real bridge engineering issues being discussed.

RB: This is a major problem not only for IBC but for the entire bridge industry. There are actually very few bridge engineering programs in the US and Canada, and even bridge design courses are few and far between. Bridge research in the US is focused at maybe 20 universities (at most) – this is also the reason there are so few students around. This is one area where IBC and the local universities can make a real contribution.

Ed: What is over the immediate horizon? What will we see at the IBC five years from now?

KW: There is a tremendous opportunity for growth. It will be critical for the committee to build on the strategic planning exercise we undertook in 2007. We must keep our eyes on the goals set there to benchmark whether our future actions support the strategic goals that were laid out. I think the goal of IBC becoming the "World of Bridges" is a realistic goal if we maintain our focus and steadily work toward those goals. However, change is never easy, and the changes that must occur to meet our goals will be uncomfortable.

KH: IBC needs to grow and expand its catchment in order to be vital. This will involve including a broader scope of interests/expertise reflecting the nature of bridge engineering today. Topics like long term monitoring and self-sensing/diagnosing and eventually healing structures will enter the vernacular and must enter the conference scope.

RB: We need and should see a much larger involvement and sponsorship from bridge industry groups.

ML: The success of the Featured Country – China has motivated IBC to consider other featured countries every three to four years. Five years from now we shall see more globalization in our presentations and outreach. We will be taking a lead in global "sustainability" effort and what the Bridge Community can contribute to "Green Bridges".

Ed: How can IBC and ESWP contribute to the sustainability of well qualified and experienced future bridge engineers?

ML: The two groups should intensify and lead efforts in contributing to the practical aspects of educators and students. For examples, both organizations can directly influence the engineering curricula in engineering universities and provide practical training opportunities to educators and students in engineering offices – private and public. The pool of trained and experienced bridge engineers is dwindling. We sense it when we recruit bridge engineers to fill vacant positions. The IBC Executive Committee can take the lead by forming a special committee to address the issue of shortage of qualified and experienced bridge engineers … now and in the future. I fully expect a 50th anniversary for this conference.

Ed: What is the future of the International Bridge Conference? Will there be a fiftieth anniversary?

EK: The world is changing very fast just now. Travel is expensive in time and cost. The Conference of the future may well be virtual rather than physical. It is true that people buy from people, not organizations, but information changes hands quickly over the world wide web. IBC 2033 may consist of presentations presented to a virtual audience who are all linked electronically but not physically in the same place. There has been little change in the way we deliver the content in 25 years. It is true that slides are now electronic and the Proceedings are on a CD, but the Conference is still the same. It is hard to see that it will still be done that way in 2033. Exhibits could be virtual as well.

> I fully expect a Fiftieth anniversary for this conference.

KH: Contrary to popular perception – engineers are "people" people – we want to meet our colleagues face to face. For this reason, conferences will persist. However the role of conferences will change. Technology transfer, however, will not likely be a driving force as it is today. As it is, many conference series are dying. Others are sprouting up to last a few years and then go to the great conference hall in the sky. Conference series must find a niche and a raison d'etre. While I do not have a clear vision of the IBC Fiftieth, I am sure it will be very different than it is today.

KW: I fully expect a fiftieth anniversary for this conference. Twenty six years ago, many folks thought that the conference sponsored by PENNDOT would be the last one. However, one person with great vision convinced several key local bridge leaders and the ESWP to try again and again. We are now approaching the twenty-fifth conference. The committee needs to seek out people of vision to allow the conference to thrive for another twenty-five years, but I certainly think that end is possible.

ML: As long as people are driving on the highways, there will be a demand for bridges, and the IBC will grow. At the rate IBC is going, and considering the continuing strategic planning efforts by members of the IBC Executive Committee, we should see and expect a more glamorous and exciting fiftieth Anniversary!

RB: I sure hope so!

Editor's notes:

1. This article is dedicated to the entire body of the executive committee of the IBC which has provided the inspiration and leadership for the International Bridge Conference over the past 25 years.
2. 25 years ago, the home for the Engineers' Society of Western PA was a small rented alcove of the William Penn Hotel.
3. To this day technical interest remains quite high within the IBC; only 1 out of 2.5 abstracts submitted are accepted for presentation and publication by the technical committee.
4. Mr. Joe Boardman is currently serving as the head of the Federal Railroad Administration for President Bush.
5. See the accompanying bio of Dr. Tom Larson – who provided the initial inspiration for a local "bridge conference" which quickly grew into the International Bridge Conference.

SUSTAINABILITY

Considerations in Bridge Design, Construction, and Maintenance

By M. Myint Lwin, P.E., S.E., FHWA, Office of Bridge Technology, Washington D.C.

The World Commission on Environment and Development, in their Report on Our Common Future (1987), defines sustainability as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This implies that the development of highway projects, including pavements and bridges, must consider the rights of future generations to raw materials and ecological support systems, such as the climatic, agriculture, economic, and cultural systems. When designing, building, and maintaining a safe, durable, and efficient highway system, we need to work together to coordinate and integrate environmental protection and enhancement activities in the decision making process. We need to consider recycling of old pavements and bridges, involving the communities in the selection of the best environmentally sensitive designs, protecting watersheds and natural habitats during construction, and conserving resources in the operation and maintenance of the facilities.

THE FHWA INITIATIVES

In 2002, the Federal Highway Administration (FHWA) designated environmental stewardship and streamlining as one of its three "vital few goals," along with safety and congestion mitigation. Subsequently, FHWA made substantial investments in improving the quality and efficiency of environmental decision-making through initiatives such as context sensitive solutions, the Eco-Logical approach, the Exemplary Ecosystem Initiatives program, the recently announced Human Environment Initiatives program, and efforts to link planning and the environment. Visit the FHWA website at www.fhwa.dot.gov/csd/index.cfm for more information on these and other initiatives.

Context sensitive solution is a collaborative, interdisciplinary approach that involves stakeholders in developing transportation facilities that complement their physical settings and preserve scenic, aesthetic, historic, and environmental resources while maintaining safety and mobility.

Through the Exemplary Ecosystem Initiatives program, FHWA recognizes best practices in environmental stewardship demonstrated at the state level. Since 2002, FHWA has highlighted more than 20 innovative and forward-thinking initiatives that employ ecosystem-based approaches.

FHWA has hosted more than 20 workshops across the country to promote the linkages between planning and the National Environmental Policy Act. Also, a planning work group, chaired by FHWA and established as part of Executive Order 13274, Environmental Stewardship and Transportation Infrastructure Project Reviews, aims to advance integrated planning by bringing together the necessary agencies and stakeholders early on.

To promote ecosystem approaches to transportation development, FHWA championed a multi-agency effort to develop a nonprescriptive approach to making infrastructure more sensitive to wildlife and ecosystems through greater agency cooperative conservation. The effort culminated in May 2006 with release of the publication Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects (FHWA-HEP-06-011).

SAFETEA-LU Section 1805 Use of Debris from Demolished Bridges and Overpasses stipulates that any state that demolishes a bridge or an overpass that is eligible for federal assistance under the highway bridge replacement and rehabilitation program under Section 144 of Title 23, United States Code, is directed to first make the debris from the demolition of such bridge or overpass available for beneficial use by a federal, state, or local government, unless such use obstructs navigation. The term "beneficial use" means the application of the debris for purposes of shore erosion control or stabilization, ecosystem restoration, and marine habitat creation.

GREEN HIGHWAYS

A new multidisciplinary partnership brings together the diverse initiatives and activities that contribute to the "greening" of U.S. highways. The Green Highways Partnership (Green Highways) is a voluntary, collaborative effort aimed at fostering partnerships to improve upon natural, built, social, and environmental conditions, while addressing the functional requirements of transportation infrastructure. Green Highways provides state departments of transportation (DOTs) with the opportunity to highlight the many good environmental practices already underway and encourages additional innovations.

FHWA is one of many partners that include federal and state transportation and regulatory agencies, contractors, industry groups, trade associations, academic institutions, and nongovernmental organizations focused on highways and resource management issues. The partnership engages practitioners who represent an array of disciplines, including engineering, environment, law, safety, operations, maintenance, and real estate.

Green Highways grew out of efforts by the U.S. Environmental Protection Agency's (EPA) Region 3, which consists of the mid-Atlantic States of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia and the District of Columbia. "The goal is to achieve transportation and environmental objectives so that both are 'better than before,'" says Hal Kassoff, Senior Vice President at Parsons Brinckerhoff Inc., a consultant involved in the initiative.

Through a combination of networking events and opportunities, public-private partnerships, and a new website clearinghouse (www.greenhighways.org), Green Highways proponents are pushing the boundaries of traditional highway building practices. "Whether one represents industry or government agency, everyone involved welcomes the opportunity to advance to a more sustainable country and world," says Robb Jolly, Senior Vice President of Market Development for the American Concrete Pavement Association (ACPA).

GREEN BRIDGES

The concepts of "Green Bridges" should logically follow the approaches, efforts, and partnerships established for "Green Highways." In "Green Bridges," the design, construction, and maintenance practices should give full consideration to at least the following areas:

- Attention to safety, durability, mobility, and efficiency
- Compliance with environmental and preservation laws and regulations
- Application of context sensitive solutions
- Sustainable site selection and planning
- Utilization of high performance materials and quality workmanship
- Safeguarding air and water quality and efficiency
- Conservation of materials and resources, and
- Avoidance of negative impacts on the ecosystems

A good example of a "Green Bridge" is the Green Bridge Project in Brisbane, Australia. It is Australia's first pedestrian, bicycle, and bus bridge. The bridge, now known as the Eleanor Schonell Bridge, is a cable-stayed structure with a 390-m (1280-ft) -long main span, and connects the University of Queensland's St. Lucia campus and Dutton Park (www.brisbane.qld.gov.au and search for "Eleanor Schonell"). The community was involved in the design of the Green Bridge. It has several environmental and cultural features included in the design:

- Bio-retention ponds that collect and filter water runoff from the bridge deck
- Interactive touch screens featuring bridge information
- A solar roof at the Dutton Park that is used to power digital signage and lighting on the bridge, and
- Poetry by local writers is permanently etched into the railings and concrete of the pedestrian walkway

The safety and mobility related benefits of this pedestrian, bicycle, and bus bridge are:

- Improved access to the university campus
- Enhanced public transportation services
- Encouragement of walking, bicycling, and other modes of green transportation
- Reduced congestion on local streets, and
- Reduced traffic going through the city

EDUCATION IN SUSTAINABILITY

At the 2007 PCI Convention and National Bridge Conference, Emily Lorenz, Editor-in-Chief of the PCI Journal, conducted an educational seminar on sustainability. The seminar provided an overview of sustainability and explained the importance to those who work in the construction industry.

In their 2007 Design Awards Program, PCI established a new award category: Best Sustainable Design. This award helps to heighten the awareness of the significance of sustainability and promotes the use of "Green Bridges" principles in the design of bridges. The inaugural award went to the 5th Street Pedestrian Plaza Bridge, owned jointly by the Georgia Department of Transportation and the Georgia Institute of Technology. The bridge deck included high planter walls that not only help to control noise and limit visibility of the traffic below but also serve as landscaping areas.

CLOSING REMARKS

Sustainability is about cleaner air and water, greener earth, and healthier living for the present and future generations. Let's continue to design sustainable concrete bridges!

In the next few editions of ASPIRE™ we will continue to discuss the social, economic, and ecological benefits of sustainable concrete bridges. The author invites readers to share ideas and suggestions, facts and figures, case studies, etc. on these topics by writing to him at myint.lwin@ dot.gov.

Reprinted with permission from the Executive Editor of ASPIRE Winter 2008 Edition, the Concrete Bridge Magazine

Research Directions in Bridge Engineering for the 21st Century

By Kent A. Harries, Ph.D., FACI, P.Eng., University of Pittsburgh,
James H. Garrett, Ph.D., and Irving Oppenheim, Ph.D., P.E., Carnegie Mellon University, and
Dennis R. Mertz, Ph.D., P.E., University of Delaware

In recognition of the 25th anniversary milestone of the International Bridge Conference®, this edition of Pittsburgh Engineer is looking back over our achievements as a profession. This article looks forward, or rather, imagines what we will be looking back upon for the 75th milestone. Bridge engineering is a science, technology and art. Progress in at least two of three of these endeavors is affected by research. This article describes some current and proposed research activities that we feel will contribute to bridge engineering by the middle of the 21st century.

Bridges in the mid-21st century will most likely not appear much different than they do today. This should come as no surprise; the majority of bridges in service in, say 2050, probably exist today. What will change is the relationship and interaction between the physical infrastructure – the bridge – and its operational environment. Bridges, along with other components of the Nation's infrastructure, will be imparted with self-monitoring, self-diagnosing, self-evaluating, and eventually even self-healing capabilities. The foundations for these "smart bridges" are being laid down in today's university and government research labs. This article briefly describes some of the more promising enabling technologies for smart bridges.

The primary challenge into the foreseeable future of bridge engineering is maintaining the safety and serviceability of a neglected and deteriorating system. This requires technologies that will extend the useful service life of bridges – in many cases far beyond their 75-year design life. To accomplish this, we must develop a new branch of infrastructure engineering: "deterioration science", to study the effects of and synergies between the stressors affecting our bridges. The fundamental relationship we need to address is the relationship between distress to the system and performance of the system. In its simplest form, we consider the relationship between physical damage to a bridge and its rating or load-carrying capacity; however, the relationships affecting performance go much deeper than this.

SENSOR TECHNOLOGY

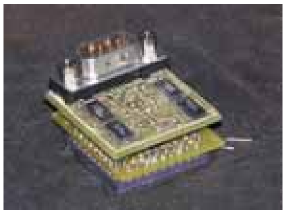
All manner of phenomena affect bridges and there is likely a sensor suitable for detecting most phenomena of interest. The challenge for bridge engineers is the sheer scope of the problem of selecting and locating an array of sensors in a rational and useful manner on a structure as large and complex as a bridge. Sensors for such purposes must be robust and long-lived. Sensors will be arrayed in self-assembling, self-aware and self-repairing networks. To be effective, they will be powered by their environment through energy harvesting and be wireless. Researchers at the University of Pittsburgh, Los Alamos National Labs and elsewhere are exploring the various forms of ambient energy (e.g., radiowaves, light, thermal, airflow, vibrations, etc) that can be harvested to power the sensor networks on infrastructure systems. Wireless inductive coupling, where the sensor is integrated with a receiving coil and is actuated when in proximity with a handheld scanner (probe) coil, is also being explored to power and query bridge sensors. Sensors will also multi-task: assembling their network in different formats to allow different queries of the structure. Sensor and sensor network technology is the most mature of the enabling technologies for smart bridges.

Fiber optic sensors, monitoring position and strain, have been brought from the research lab into field application with numerous installations in Europe and a growing number of demonstrations in the United States. Accelerometers have been used to monitor vibration characteristics of structures, and more recently researchers at Stanford University, University of California at Berkeley, the University of Michigan and Carnegie Mellon University have developed platforms for data collection and management, and wireless transmission of sensed data.

"Active" sensing is exemplified by ultrasonic inspection methods. Conventional ultrasonic inspection is performed manually, but sensor researchers at many institutions (including the University of Pittsburgh and Carnegie Mellon University) have been studying the behavior of piezoceramic wafers permanently mounted on steel plate girders functioning as active transducers. Related to this, research into the behavior of "guided" waves that can travel for relatively long distances in linear components such as girders, rails, and pipes will extend the application of active sensing methods in bridge structures.

Installing acoustic emission sensors, Victoria Bridge, Montreal (NSF project, collaboration between Lehigh University and Carnegie Mellon University)

Passive sensing is exemplified by acoustic emission testing, in which sensors are monitored to detect ultrasonic stress waves that are emitted when damage occurs under test loadings or ambient excitation. Field applications include the monitoring of suspension bridge cables in New York City, the testing of a railroad bridge in Montreal and the forensic examination of the December 2005 failure of the Lake View Drive Bridge in Washington PA [fig A]. Related research activities



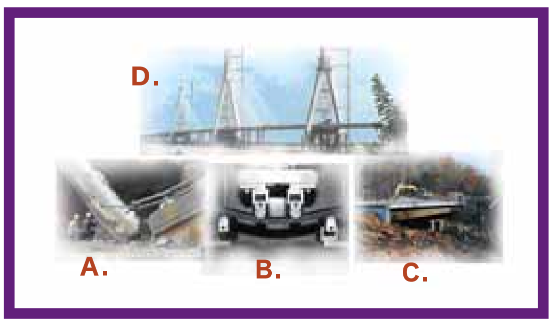
MEMS 4-channel acoustic emission sensor system, 1 inch (25 mm) on a side (NSF project, collaboration between Lehigh University and Carnegie Mellon University).

include the development of MEMS (microelectromechanical systems) devices to act as acoustic emission sensor systems that combine multiple sensors, with different frequencies, in a small volume.

In addition to the research being done on point sensors, research is also being carried out at Carnegie Mellon University, the University of Texas in Austin, Iowa State University, and elsewhere, with wide area sensors, such as laser scanning technology. Laser scanners are able to capture millions of points on the surfaces of a bridge being constructed or in operation, such that a very detailed survey of the three-dimensional geometry is captured .

DATA MINING, DAMAGE DETECTION, AND DIAGNOSIS

Sensor networks produce data – a significant amount of data. Methods are required to distill this data into useful information that tells us something of interest about the structure. Bridges vibrate, distort and emit all manner of noises. Only a very few of these emanations are indicators of concern, although their aggregate may tell us a great deal about the performance or performance trends of a structure. Researchers at Carnegie Mellon University have been exploring Knowledge Discovery from Data (KDD) techniques and creating frameworks whereby KDD techniques can more easily and consistently be applied to the large amount of data collected in infrastructure sensing applications Using these techniques, it will be possible to detect anomalies in the patterns of data collected, determine if the sensors or the system is generating the anomaly and determine what the likely causes of the anomaly are.



Advances in algorithms for damage detection are of value for bridge applications. Developments and demonstrations related to bridges have been contributed by the research group at Los Alamos National Laboratory, as exemplified by methods to recognize changes in signals received by active sensors that correspond to structural damage. The leading edge of damage detection research is the attempt to use active sensors without reliance on baseline measurements, termed "reference-free" damage detection, for which research has been centered at Carnegie Mellon University and at the Korean Advanced Institute for Science and Technology (KAIST).

The critical link for smart bridges is that between sensing and the decision or action taken based on collected data. Defining the fundamental relationship between distress to the system and performance of the system is conventionally based on model-driven evaluation schemes; these will become more robust and sophisticated as the density of data increases. The increased density of data will additionally allow for more data-driven models of behavior to be derived absent of underlying physical models. Finally, as proposed by researchers at the Swiss Federal Institute Lausanne (EPFL), data will be used to reason over all of the many models that might explain the existing data and point to where more data might be acquired so as to resolve which model is actually the best fit to reality.

NEW MATERIALS – SMART MATERIALS

Materials science plays a key role in developing smart bridges. Materials and coatings which, themselves behave as sensors or sensor arrays will be more robust and damage tolerant than discrete sensors. High strength and other high-performance materials are already reshaping bridge infrastructure and providing opportunities to significantly increase the life of structures. Fiber reinforced polymer (FRP) [fig B] and fiber reinforced cementitious (FRC) materials are already moving from the realm of research to practice.

Self-healing materials take a variety of forms and are often designed to mimic the behavior of living systems. Microsphere embedment is used to affect the autonomic healing of polymers and some non-ferrous metals. Upon the formation of damage, microspheres break, their contents interacting with the available catalyst in the surrounding polymer matrix forming new polymerization. Similar applications have been proposed for cementitious matrices where embedded microspheres may be used to affect pore water PH and thereby maintain corrosion resistance through passivation. Tube (rather than sphere) embedment has been shown to be more efficient for the self-repair of discrete cracks. Engineered cementitious composites (ECC) use hollow, high performance fiber reinforcement in relatively small volumes [fig C]. In addition to the strength imparted by the fibers themselves, the fibers are filled with a polymer resin ("superglue") which is released and "heals" the ECC as the fibers experience distress.

A number of materials exhibit self-healing properties when subject to a controlled stressor such as applied heat or current. Shape memory alloys (SMA) can recover permanent strains through the application of heat or magnetic fields [fig D]. SMAs can also be used for actuation since large forces can be generated in returning the material to its original state. Electroactive materials are similar to SMAs only using current rather than heat to affect actuation. Many common sensors are based on the principles of electroactivity. Applications of electroactivity have recently been proposed for prestressing/post-tensioning unidirectional fiber materials for structural repair. Electrohydrodynamics utilizes current in plastic materials to redistribute the material itself, causing particle coagulation at damage sites.

MULTISCALE COMPUTATIONAL MODELS OF ENGINEERING MATERIALS

To design and use the new materials described, and others providing targeted functionality, such as high-strength and high-ductility, as in bulk metallic glasses or advanced high performance steels (HPS), an understanding of the mechanics of these materials is extremely important. This requires a fundamental understanding of the mechanisms of stressing and deformation of the involved materials and structures at appropriate length and time scales not possible to acquire from experimentation alone. At the scale of angstroms and femtoseconds, all materials of interest can be described by quite reliable physical theories (molecular dynamics/quantum mechanics) whose solutions, in principle, can be computed at arbitrarily larger length and time scales. However, all of the applications of interest occur at length and time scales that are simply not computable even with the most powerful computers that may be expected to emerge in the next decades. Researchers at Carnegie Mellon University are developing and applying predictive multiscale materials modeling tools to the mechanics of crystalline, granular, and amorphous materials. These tools encompass modeling ranging from atomistic and molecular dynamics simulation to field models of mesoscale and macroscale response developed through coarse-graining theory or other approaches.

CONCLUDING REMARKS

This brief article has touched on only some of the many advances that will take place in the coming years improving the way in which our profession will maintain and operate bridge systems in the future. These include: robust, wireless and ubiquitous sensor systems, computation support for sifting through the mountains of data collected by these systems, and high fidelity computational models of our bridge materials, components and systems that better model and help predict material and system performance and degradation. More and more, the public and our leaders are asking for greater investment in our infrastructure. It is important to remember that in addition to encouraging governments to invest in the renewal of our vital bridge infrastructure, resources must also be invested in research, such as that described in this article, which allows us to make the best use of that money spent for infrastructure renewal.

FIGURE REFERENCES

A. Lake View Drive Bridge – forensic study involved array of acoustic emission sensors (Pittsburgh Post Gazette).
B. 60 foot long bridge highway bridge with all-glass FRP deck (Harries).
C. ECC specimen tested under bending load showing ductile behavior (ECC Technology Network).
D. The Dong Ting Lake Bridge in China is equipped with magnetorheological motion dampers to counteract gusts of wind (Lord Corporation).

FHWA – Advancing Technologies for Longer Lasting Bridges

By Sheila Rimal Duwadi, P.E. Team Leader, Bridge Safety, Reliability & Security and
Ian M. Friedland, P.E. Technical Director, Bridge & Structures R&D

To meet the demands for the 21st century transportation network, and in anticipation of the current multi-year highway legislation, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the Federal Highway Administration (FHWA), in 2002, embarked on a research and development (R&D) strategy for a robust and aggressive program to preserve the nation's aging and deteriorating bridge infrastructure and advance new technologies for designing stronger, longer lasting bridges. A summary of this program was published as a three part series in 2003 in 'Roads and Bridges' (Ref 1, 2, & 3). To the extent made possible by the SAFETEA-LU legislation this strategy is currently being implemented. This paper summarizes the strategy that was developed and the current research effort. SAFETEA-LU allowed FHWA to close the gaps in some critical areas while other areas are currently unfunded or are being conducted with limited resources.

In formulating its R&D agenda, the FHWA realized that essential to the success of meeting these challenges required breakthrough developments in understanding the processes and mechanisms resulting in the physical deterioration of bridge materials and elements; improvements in technology for inspecting and quantifying the condition of bridges and bridge elements, including nondestructive testing, remote sensing techniques and global monitoring; breakthroughs in the area of materials and methods to counter deterioration processes in new structures; and breakthroughs in technology to mitigate damage from natural and human induced events including rapid repair technologies. Driving this process was a clear recognition of improvements in data collection which provide for quality, accurate and precise information on the condition of our bridges.

BACKGROUND

The importance of our highway network to the country's economy, for day to day mobility and for mobilization in times of emergency, cannot be overstated. Our highways play a vital role both during normal and in emergency situations linking critical nodes and destinations. Bridges represent an important aspect of this network, and today the condition of our bridges is of increasing concern. If the U.S. Government and hence the FHWA is to deliver on the challenges facing our infrastructure to meeting the Nation's present and future needs, research has to be conducted and the results effectively deployed. The challenges include eliminating deficiencies in the bridge population, and providing for rapid repair and construction. These become critical especially when safety, congestion and mobility become the driving issues.

The 2007 National Bridge Inventory (NBI) database shows that the nation's public highways include around 600,000 bridges. Most of these were built during the 1960's and 1970's during construction of the Interstate Highway system. That the bridge infrastructure in the United States is aging should not be 'breaking news' today, but that they are not only aging but deteriorating at a faster rate than can be repaired or replaced should be of concern. The average age of a bridge today is 44 years, with a quarter of the bridge population classified as being deficient. Around 3,000 more bridges become deficient each year, however more importantly, approximately 1 billion crossings of these deficient bridges occur every day. Unless new technologies and practices are deployed, the new bridges under construction today will deteriorate at about the same rate as those that were constructed 20 years ago. Nationally, highway agencies build, replace and rehabilitate about 10,000 bridges per year. (Ref 2)

Bridges deteriorate for many reasons. The application of deicing salts to clear roadways of snow and ice is a major factor leading to corrosion of reinforcing steel in concrete decks and corrosion of bridges built of steel components. Poor details including leaking joints are another factor that can lead to bridge component deterioration. Salt air and industrial environments also drive corrosion of steels. All of this can eventually compromise safety.

R&D PROGRAM THRUST AREAS

To meet the challenges and deliver technologies and methodologies for improving our bridge inventory and enhancing design and construction the FHWA envisioned and proposed the "Bridges for the 21st Century" program as part of the surface transportation legislation authorizing the highway and bridge programs for fiscal years 2004 through 2009.

The program includes three major thrust areas. The first centers on stewardship and management of the existing bridge inventory to ensure safe, continuing service at the lowest cost. The initiative calls for reliable and timely data and information, improved decision-support tools and the development of quantitative, relevant and useful measures of performance. The second centers on developing a new generation of cost-effective, high-performance and low-maintenance bridges, thereby developing a new paradigm in design and construction that results in bridges that are built faster and cheaper, yet provide a minimum 100-year life span and require little or no maintenance. The initiative calls for use of enhanced materials, structural systems, technologies and specifications for improved structural performance. The third thrust area involves ensuring the safety and reliability of bridges by eliminating or minimizing the impact of natural hazards like floods and earthquakes, and minimizing the damage from human induced stresses, such as overloads, vessel or vehicular impact or intentional damage from terrorist activities.

Current FHWA bridge and structures R&D program is focused in these three thrust areas conducted by researchers working within the following three respective interdisciplinary teams.

- Infrastructure Inspection & Management
- Bridge Design & Construction
- Safety, Reliability & Security

Turner Fairbank Highway Research Center

The Turner Fairbank Highway Research Center (TFHRC) located in McLean, Virginia is the hub of FHWA's highway research activity where much of the research is conducted in house in its many laboratories. To complement the work at TFHRC work is also carried at universities and at other research institutions nationwide and internationally.

THE INFRASTRUCTURE INSPECTION & MANAGEMENT TEAM

The Infrastructure Inspection & Management team is focused on the thrust area of stewardship and management, with an overarching mission of infrastructure durability. The team is comprised of specialists with expertise in bridge inspection methods, tools, and data analysis; bridge and asset management systems and data mining; corrosion and corrosion protection; and structural rehabilitation. The research conducted is supported by the Nondestructive Evaluation (NDE) Center, a Paint and Coatings laboratory for metallic structures and systems, and the Bridge Management Information Systems laboratory at TFHRC.

In the past, many bridge owners neglected bridges until they were beyond rehabilitation and in need of replacement. One primary objective of FHWA's stewardship and management focus is to encourage bridge owners to provide more emphasis on system preservation based on state-of-the-art preventive maintenance and rehabilitation techniques.

The Long Term Bridge Performance (LTBP) program is a major research component proposed under the Bridges for the 21st Century program and authorized by SAFETEA-LU. The LTBP program, down the road, will provide data to support improved tools, methods and programs for bridge preservation and management. This 20-year program will conduct detailed period assessments of selected bridges representing a cross section of the infrastructure in order to identify and collect research-quality data on the most important factors that influence deterioration and affect performance. This type of quantitative data, collected for hundreds of bridges over at least a 20 year period will, when properly analyzed, lead to significant advancements in the knowledge of bridge performance. These studies will lead to better understanding of the causes of deterioration, and help develop and deploy proven preventive maintenance and rehabilitation techniques. This will also make it possible to develop improved models for assessing future deterioration and deficiencies so transportation agencies can develop and implement cost-effective strategies for bridge preservation. All aspects of stewardship and management rely heavily on sound, quantitative data on bridge conditions and comprehensive information that documents the factors that influence performance and deterioration. Currently that type and level of information is either not available in a format useful for analysis or not available at all, and the LTBP program will be able to provide answers to these questions.

The Non Destructive Evaluation R&D program conducted through the NDE Center provides state highway agencies with independent evaluation and validation of NDE technologies, develops new NDE technologies, and provides technical assistance to states exploring the use of these advanced technologies. Among the studies currently underway are those associated with evaluation and assessment of imaging systems for bridge components; steel weldment fatigue assessment and characterization technologies; and development of advanced bridge deck evaluation methods and tools. SAFETEA-LU designated a new program on Steel Bridge Testing developing NDE technology for the detection of growing fatigue cracks in steel bridges.

In the areas of metallic coatings for structural steels, work is currently being completed on the assessment of improved 2-coat shop and field applied systems, and the development of a long-lasting yet cost effective single-coat shop applied coating system.

THE BRIDGE DESIGN & CONSTRUCTION TEAM

The Bridge Design & Construction team is helping to address the thrust area of cost-effective, high-performance and low-maintenance bridges by developing next generation materials and systems for both new and replacement construction. The team is comprised of specialists in structural engineering with expertise in traditional and innovative/high-performance highway structure materials, geotechnical applications and foundation design/construction, and long term durability of structural materials. The team also has expertise in full scale structural testing, instrumentation, failure analysis, and advanced analytical modeling techniques. The research conducted by the Bridge Design & Construction team is supported by the structures laboratory, geotechnical laboratory, and the materials testing and characterization laboratory at the TFHRC.

To evaluate the market potential for the Bridges for the 21st Century program and focus its research, the FHWA conducted a detailed analysis of new bridges constructed between 1996 and 2000. The goal was to define the most promising system to pursue and develop in the initial years. During that five-year period, states and communities built 33,823 new bridges in the United States. Further analysis of statistics on length and span revealed that the majority have maximum span lengths of 100 ft or less. These findings lead to the conclusion that existing market conditions support a strategic focus on researching a few standard bridge types, simple spans (less than 100 ft), and bridge systems that incorporate standardization and hence can be manufactured in significant numbers. (Ref 2)

The program performance goals were therefore set to include achieving a service life that is no longer controlled by corrosion and involves little or no structural maintenance; reducing construction time significantly; designing bridges that can be widened easily or adapted to new traffic demands; reducing life-cycle costs significantly; elevating resistance to attack or minimizing damage resulting from flooding, earthquake, fire, wind, fracture, corrosion, overloads and collisions; integrating the design and construction of the substructure and superstructure; and eliminating vertical and lateral clearance problems.

The High Performance Concrete (HPC) program funded by SAFETEA-LU is focused on improving technology related to high performance concrete (HPC) bridges. The FY06-09 plan contains research issues that fall into three categories: material testing, structural testing, and systems testing, with a focus on lightweight concrete and deck design and construction.

The High Performance Steel (HPS) program also authorized by SAFETEA-LU is focused on improving technology related to high-performing steel in the construction and rehabilitation of bridges. Highlights of the FY06-09 plan contain research that addresses optimized welding processes and procedures for automated bridge fabrication; improvement in HPS steel grade with enhanced corrosion resistance; long term performance of weathering steel bridges; testing and evaluation of modular, rapid construction bridge concepts; and high performance fabrication and erection.

SAFETEA-LU designated Ultra-High Performance Concrete (UHPC) program is focused on improving technology related to ultra-high performance concrete (also known as reactive powder concrete). Areas of research include precast bridge deck panels; prestressed I-girders and bulb-tees; Pi-girder performance; tensile fatigue; guide specifications and design tools; fabrication solutions for precast UHPC components; deck durability under simulated truck loadings; and fundamental and computer modeling of the structural behavior.

The geotechnical research program did not receive dedicated funding in SAFETEA-LU, but because of the importance of this area it is supported by the FHWA from a number of sources. Highlights of the studies in its FY2006-09 program include the design and performance of Geosynthetic Reinforced Soil (GRS) for walls and abutments; MSE/shoring wall performance; shallow foundation technology; development of a systems design methodology for approach/abutment /backwall integration; application of advanced materials to bridge foundations; structural health monitoring systems for substructures and foundations; and reliability-based design for soil and rock properties.

THE SAFETY, RELIABILITY, & SECURITY TEAM

The Safety, Reliability & Security team is focused on the bridge safety, reliability, and security' thrust area. This involves research on protection of new and existing bridges and highway structures from the damaging impacts resulting from both normal day-to-day and extreme events, including natural and man-made hazards like earthquakes, floods, hurricane-force winds, and terrorism. The team has significant expertise and knowledge regarding the phenomena associated with these extreme events, and in providing engineering solutions that provide a high level of resilience to resist them. This team is also charged with leading the research agenda for issues associated with bridge security. The research conducted by the Safety, Reliability & Security team is supported by the hydraulics laboratory and the aerodynamics laboratory at the TFHRC.

The team's current focus is to deliver the knowledge and technologies that will help ensure that the nation's highway bridge infrastructure continues to function safely and reliably during and after extreme or infrequent catastrophic events. Aside from a seismic R&D program, SAFETEA-LU did not provide any dedicated funding to cover research that addresses the goals of this thrust area. However, because of the importance of these issues, limited research is continuing, funded through support from the State Highway Agencies and other infrastructure owners and through other FHWA programs.

Natural disasters like earthquakes and floods have a high probability of affecting large land areas and a high number of highway structures simultaneously, significantly disrupting regional mobility, emergency response and regional economies. The Seismic R&D Program at FHWA developed and continues to refine guidance for retrofitting bridges to make them less likely to fail during earthquakes, explore new design concepts and advance the understanding of seismic effects on structures and develop solutions. The program as authorized in SAFETEA-LU directs funding to the University of Nevada, Reno and the University of Buffalo for fiscal years 2005 through 2009. Highlights of the program include continued refinement of the highway network seismic risk analysis program, known as REDARS, previously developed with FHWA funding; design guidelines and fragility functions; accelerated bridge construction in high seismic areas; innovative seismic protective devices; multi-hazard dynamic testing on highway bridge piers and foundations; developing pushover-analysis tools on bridge seismic design and retrofitting; and development of seismic ground motion and fragility curves for bridge types in the Central United States.

Floods and scour cause more bridge failures in the United States than all other causes combined. Approximately 85% of the structures contained within NBI are over water. Since the late 1980s, state highway agencies have undertaken a nationwide effort to evaluate these bridges to identify those that are scour critical. Highlights of the FY06-09 program include a study on bottomless culverts; drainage system junction loss experiments; quantification of lift and drag forces on bridge decks due to inundation and wave action; optimum bridge deck shapes to minimize pressure flow scour and pressure flow scour for live bed conditions; pier scour countermeasures using fluidic devices; development of an in-situ scour potential testing device using a vertical jet; and advanced physical/numerical modeling.

Wind and wind loadings can have a significant effect on the design, safety and performance of structures. Since the dramatic collapse of the original Tacoma Narrows bridge in 1940, there has not been a major collapse of a bridge due to wind loadings, however, even mild wind speeds especially combined with light rain can cause large amplitude vibrations. This has become an issue on long span cable supported structures as in the Fred Hartman Bridge in Houston, Texas, the Burlington Bridge in Burlington, Iowa, and the Cochrane Bridge in Mobile, Alabama. As there are currently no provisions in the AASHTO bridge design specifications for aerodynamic design of new structures, the focus of this program is to develop comprehensive guidelines for the design of long-span bridges; specifications for assessing the aerodynamics of new designs; a rational method for wind-climate analyses; guidelines to retrofit bridges that have aerodynamic problems; and development of appropriate countermeasures.

The Nation's vulnerability to terrorism became a concern after the events of Sept. 11, 2001. The FHWA has been partnering with the defense community to draw on that body of knowledge and experience, and then synthesizing and transferring applicable technologies to secure the transportation infrastructure. To protect the Nation's infrastructure, a more complete understanding is needed of the threats, ways to identify specific vulnerabilities, methodologies to eliminate or protect against these vulnerabilities, and a framework for translating this knowledge into standards and specifications for new and existing bridges and tunnels which is not currently available. To support this, the FHWA created a multiyear R&D program plan (Ref 4). To develop a resilient physical infrastructure that can withstand acts of terror, FHWA proposed developing new design systems, analysis techniques, better materials, methodologies for assessing the safety and residual capacity of structures after an incident, and new techniques for rapidly repairing and restoring bridge infrastructure. Through support from bridge owners and with limited FHWA funds, the current research effort has included assessing steel bridge towers for vulnerability to blast loadings and developing mitigation measures for these towers; identifying surveillance and security technologies; and developing a computer analysis program for characterizing blast loadings on bridge components.

IN SUMMARY

The FHWA has a robust and aggressive R&D program aimed at preserving the Nation's aging and deteriorating bridge infrastructure and advancing new technologies for constructing stronger and longer lasting bridges. With the help of a range of stakeholders, gaps and needs were identified and a program set in place. The current surface transportation highway authorization, SAFETEA-LU, has provided funding in specific designated program areas, allowing the FHWA to conduct research to close the gaps in some critical areas. However, much more is yet to be accomplished. The importance of highways to the Nation cannot be overstated and bridges, being critical links, are of significant concern. The programs and projects underway in the three R&D thrust areas at the FHWA should get us closer in the understanding of infrastructure deterioration processes; development of better inspection and condition assessment technologies; formulation of new and more cost-effective and durable design systems; and in rapid repair technologies. As SAFETEA-LU expires in 2009, there is much anticipation on what the future holds for the continuation of existing research and development, and initiation of new programs that will lead to breakthrough technologies and processes to meet the challenges of improving the performance of our Nation's highway bridges and structures.

REFERENCES

1. Hooks, John M. (June 2003) Holding it together: FHWA Bridge Plan Part I. *Roads & Bridges*, Volume: 41 Number: 6, Scranton Gillette Communications.
2. Chase, Steven B. (July 2003) The bridge of the future: FHWA Bridge Plan Part II. *Roads & Bridges*, Volume: 41 Number: 7, Scranton Gillette Communications.
3. Duwadi, Sheila Rimal, (August 2003) Ready for the any day event: FHWA Bridge Plan Part III. *Roads & Bridges*, Vol: 41 Num: 8, Scranton Gillette Communications.
4. Duwadi, Sheila Rimal; and Steven B. Chase; Multiyear Plan for Bridge and Tunnel Security Research, Development and Deployment, FHWA-HRT-06-072, Federal Highway Administration, McLean, VA 22101, March, 2006.

New FRONTIERS IN BRIDGE DESIGN & CONSTRUCTION

By Hota V. S. GangaRao, Ph.D., P.E., Professor, West Virginia University, Morgantown, WV
Samer H. Petro, P.E., Manager- WV Operations, Gannett Fleming, Inc, Morgantown, WV

Bridges are iconic and their design, construction and maintenance have changed a great deal in the past 100 years and will change even more dramatically in the next 25 years. Advanced delivery methods such as design-build bridge systems have increased steadily with the use of innovative materials such as high performance steel and concrete. In addition, filed implementation of glass or carbon fiber reinforced polymer (FRP) composites have been steadily gaining notoriety because of their high strength and stiffness to weight ratio, good durability including non-corrosiveness and excellent resistance to fatigue and blast. FRP composite materials also lend themselves well to prefabricated bridge construction leading to minimized traffic delays and enhancing on site safety of construction workers.

FRP Composites have been used for superstructures and substructures of bridges; and are ideally suited for use in unique bridges such as floating or movable bridges. In addition, composite systems can be manufactured to utilize smart materials to report damage, self heal and even self clean the structure. Composite applications are not limited to new structures, as composites can be utilized to rehabilitate or upgrade existing bridges.

This paper will discuss the vision and future challenges of bridge design + construction using FRP composite materials.

SUPERSTRUCTURES

Bridge system design and construction are intriguing because generic structural responses can be combined in innovative manners to arrive at durable and economical structures. Some of the generic responses are: beam bending, membrane action through arching which converts bending forces primarily into compressive axial effects, cable and/or suspension systems which help efficiently transfer vertical loads to the ground while providing adequate stiffness through superstructural elements such as decks, longitudinal beams and diaphragms. All of these structural elements provide adequate stiffness to limit displacements, vibrations and fatigue while helping to maintain structural durability and longevity. One of the fascinating structural systems being advanced to its maximum span limits is the suspension/stay cable system with steel or concrete superstructure. Many of these suspension/stay cable systems vary in terms of strand configuration as well as cable arrays. These systems are even coupled with arch systems to enhance load transfer efficiencies of the superstructure. However, the single clear span lengths are currently limited to approximately 6,400 feet because of self weight constraints, which are playing a major role with reference to conventional materials.

For example the Akashi-Kaikyo Bridge built in 1998 consumed 91% of the design stresses towards dead loads while the remaining 9% of the stress resists live load stresses. Another example of a suspension bridge is the Kanmonkyo Bridge, built in 1973, whose span is 2335 feet where the dead load induced stress was about 75% of the total design stresses. These bridges have conventional decking and deck stiffening systems ranging around 300-400 pounds per square foot of the deck area.

Figure 1: Externally Applied Glass (GFRP) Composite Materials - Phoenix, AZ

Figure 2: Externally Applied Carbon (CFRP) Composite Materials - Phoenix, AZ

However, the use of high strength polymer composite decking and possibly even carbon composite deck stiffening systems can reduce the percentage of self weight induced stresses in a bridge structure and also provide higher (design) resisting stresses for live loads and other loads in relation to conventional materials. Figures 1 and 2 show examples of FRP components incorporated in more recent bridges.

Recognizing the influence of high strength and stiffness to weight ratio, the future of bridge superstructure span limits can be pushed beyond the conventional wisdom of around 9,000 - 12,000 feet.

SUBSTRUCTURES

Composites can be used for piers and abutments in an efficient manner. For example, double-walled cylindrical shells made of glass composites are pultruded up to 24 inches in diameter. The failure strengths of these shells can be around 40,000-50,000 psi. Similarly, carbon composites can be manufactured to sustain 100,000-150,000 psi. Another novel approach to mass produce and erect large size piers on site is an infusion process where curvilinear panels up to 8-10 feet in diameter segments with a length of 100 feet can be constructed.

FRP composite elements have also been used as earth retaining structures including abutment walls in an economical manner. Durability of these systems is found to be excellent. The soil retaining structural designs can take advantage of the non-corrosive nature of the material as well as its strength to build durable retaining walls reaching a height of 40-50 feet.

UNIQUE BRIDGES

Bridges made of FRP composites can be floating bridges, underwater bridges and even those that would be folding and unfolding as the service demands. Similarly a number of exotic movable bridges can be developed because of low self-weight (10 lbs/ft^2). However, these bridges have to be anchored to the sea bed where the shapes must be streamlined like an airfoil. Composite materials would be ideally suited to be used as anchor cables, as glass composites are non-corrosive. In addition, a wide range of movable and portable bridges have been developed and field implemented by Johannson, Hota, and others.

SMART MATERIALS FOR BRIDGES

Typical challenges are to identify proper material systems and processes that are conducive to: 1) self assessing and self healing materials under a wide range of load actions, 2) coatings or constituents in resinsthat can be used as sensors and 3) self cleaning and de-polluting structural elements inbridges. Bridge decks typically sustain deterioration under environmental attacks as well as repetitive loads. As stated previously composites are relatively inert to salts and have excellent fatigue resistance; hence increasing the service life of a composite bridge deck could save not only large sums of money but reduce traffic disruption. Recent developments in the use of carbon fibers to sense and heal the damage through liquid polymers filled in carbon nano-tubes is a good example. Composites are being used to top both new and existing bridge decks. Coatings consisting of nano-tubes can also be used as sensors to detect micro-cracks, fire and hazardous chemicals. For example, electrically conductive coatings in cooperation with wireless networks are being developed to detect fire and other structural hazards. Inorganic coatings are available for self cleaning and cleaning some of the exhaust deposits from traffic vehicles. The self cleaning properties improve durability by oxidizing pollutants that can potentially cause serious deterioration. These inorganic polymer coatings can be used on bridges and barriers to partially clean the atmosphere.

REHABILITATION AND UPGRADE OF STRUCTURES WITH FRP COMPOSITES

Many of the nations' bridges are failing more frequently than before due to age and excessive loads and frequency of traffic thus resulting in costly repairs. Similarly many other structures that were not designed to carry contemporary axle loads or those that were not designed to resist earthquake and blast forces can be well protected and/or structurally upgraded with composites.

Externally applied glass (GFRP) or carbon (CFRP) composite materials can significantly enhance the structural performance of many of these bridges and improve their load carrying capacities at a fraction of the cost of total replacement and at a fraction of the time.

CONTINUOUS MONITORING

To evaluate the performance of the FRP strengthening systems, a continuous monitoring program can be installed to measure strains in real-time making a bridge "a smart structure." The bridge is typically instrumented and tested before retrofit and shortly after installation of the strengthening system. The initial tests establish a number of critical benchmark responses of the bridge; while the other tests provide information regarding the participation of the FRP system. The monitoring system can be powered with a solar array and data can be uploaded wirelessly to a Web site which can be easily accessed by the owner for continuous monitoring (Figure 3).

CONCLUDING REMARKS

It has been shown that FRP composites have the potential to revolutionize the design and construction of bridge structures reaching new frontiers in the 21st century and beyond. The merits were highlighted herein for using FRP composite materials such as strength and stiffness, durability, load capacity, geometric optimization, self healing, and others. This is especially true for future implementations. With a projected service life of up to 100 years, FRP composites have advantages that simply cannot be overlooked.

Figure 3: Bridge with Solar-Array Powered Continuous Monitoring System - Phoenix, AZ (2008)

Dr. GangaRao's latest initiative involves the future development of a National Science Foundation Center for the Integration of Composites into the Infrastructure. Gannett Fleming is proud to support and be a part of this new joint venture - Editor.

IBC 2008 Bridge Awards Program

By Carl Angeloff, P.E.
Bayer Materials Science

The International Bridge Conference in conjunction with Roads and Bridges Magazine, Bayer Corporation and Bridge design and engineering Magazine, annually awards five metals and one student award to recognize individuals and projects of distinction. The metals are named in honor of the distinguished engineers who have significantly impacted the bridge engineering profession worldwide. The student award is named in honor of a former IBC General Chairman, champion of the student award's program and friend to the bridge community at large.

John A. Roebling Medal

The John A. Roebling Metal recognizes an individual for lifetime achievement in bridge engineering. We, at IBC, are pleased to recognize Leonardo Fernandez Troyano as the 2008 recipient. As a co-founder of Carlos Fernandez Casado S.A. Project Consultancy Firm, Dr. Fernández is widely recognized as one of the world's leading bridge engineers for his designs beautiful and elegant contemporary bridges. As he approaches his 70th year, he maintains his passion for historic bridges and their preservation. Dr. Fernandez is recognized for his many published technical articles and books including a monumental treatise, entitled Bridge Engineering published in 2003.

George S. Richardson Medal

The George S. Richardson Medal, presented for a single, recent outstanding achievement in bridge engineering, is awarded to Nangtong City, Jiangsu Province, China for the Sutong Bridge. As part of a $1.5 billion crossing of the Yangtzee River, the structure features a seven span cable-stayed unit with a main span in excess of 3,400 feet, the world's record for cable-stayed crossings.

James C. Cooper Student Award

The James D. Cooper Student Award recognizes undergraduate and graduate students who demonstrate an interest and passion for bridge engineering. The award is presented to winners of a student competition for technical writing and engineering insight. For 2008, the graduate award is presented to Woo Soek Kim, a graduate student in the Department of Civil and Environmental Engineering at the Pennsylvania State University for his paper entitled: Simplified Nonlinear Numerical Method for Integral Abutment Bridges. This paper reports the development of a numerical model to simulate integral abutment bridge behavior and provides the basis for long-term and/or probabilistic numerical simulation of such structures. For 2008, the undergraduate award is presented to Heidi Clayville, Theresa Howell and Kristen Erickson of Washington University in St. Louis for their paper entitled: The New Daniel Boone Bridge Project: US Route 40/I-64 Across the Missouri River.

Gustav Lindenthal Medal

The Gustav Lindentahl Metal, awarded for an outstanding structure that is also aesthetically and environmentally pleasing, recognizes the Route 50 Bridge over the Ohio River and Blennerhassett Island, Parkersburg, West Virginia. The distinctive 878-foot long network tied arch with inclined hangers using stay-cable-technology gives the structure its signature element.

Eugene C. Figg Jr. Medal

The Eugene C. Figg Jr. Medal for Signature Bridges, recognizing a single recent outstanding achievement in bridge engineering which is considered an icon to the community for which it is designed. For 2008, we recognize the High-Main Street Bridge, Hamilton, Ohio. Its location within the City's monumental core adjoining the Neo-Baroque War Memorial and Art Deco City Hall resulted in a Memorandum of Understanding between the City, SHPO and the funding agencies that dictated the aesthetic guidelines consistent within the context of the historic district wherein it lies.

Arthur G. Hayden Medal

The Arthur G. Hayden Medal, recognizing a single recent outstanding achievement in bridge engineering demonstrating vision and innovation in special use bridges, will be presented to recognize the Tri-Countries Bridge, Weil Amrhein, Germany. This delicate, simple yet expressive pedestrian bridge, spanning the Rhine River with a main span in excess of 750 feet, connects Germany and France immediately adjacent to the Swiss border.

LIST OF ADVERTISERS

A special thanks to all of you who support the Pittsburgh ENGINEER magazine!

Don't Miss the Fall 2008 Issue of the Pittsburgh ENGINEER with a featured focus on ENERGY. Advertising closing date: August 15, 2008. Visit www.eswp.com/publications for advertising information.

Chairman's Message

By Eric Kline, KTA-Tator, Inc.

As this year's chairman, I am pleased to welcome all of you to the 25th Annual International Bridge Conference. The Executive Committee of the International Bridge Conference®, has been planning for 18 months in anticipation of the IBC2008. There are many major changes which will dramatically increase the value of the IBC 2008 for everyone involved with the Conference: Presenters, Committee meeting attendees, Exhibitors, and Conference attendees and spouses.

For those of you who are attending the IBC for the first time, we trust that you will find the Conference a rewarding and exciting educational experience. For those who have attended IBC previously, we eagerly anticipate your return to Pittsburgh. Come, celebrate our 25th anniversary, learn about the latest technical developments and take full advantage of the many networking opportunities afforded by our Conference.

We are proud to announce the following major features and events at the 25th Anniversary IBC:

OUTSTANDING KEYNOTE SESSION

Our Keynote session will feature nationally known leaders Ms. Mary Peters, U.S. Secretary of Transportation (invited), Dr. T. Peter Ruane, President & CEO of ARTBA, Mr. John Horsley, Executive Director of AASHTO, and Mr. Malcolm T. Kerley.

A SUPERB FEATURED AGENCY – A FIRST FOR IBC – THE FEDERAL HIGHWAY ADMINISTRATION

As the Featured Agency, the IBC Executive Committee sought to invite the single agency that represents all of us, which funds much of the infrastructure development in the US and provides leadership worldwide – the Federal Highway Administration (FHWA). FHWA accepted our invitation and has developed an exciting, landmark program featuring a host of presentations dealing with the Federal-aid highway program itself, as well as major projects and substantial issues reflective of the challenging times we all face.

BRAND NEW LOCATION

The IBC-2008 will be located at Pittsburgh's new David L. Lawrence Convention Center (DLCC). The conference hotel headquarters will be the Westin Convention Center Hotel. The relocation of the Conference has allowed for major changes in the Exhibit Hall, a major feature of the Conference.

EXPANDED TRADE SHOW

There are over 155 exhibitors at IBC 2008 (an all time high). They are all providers of goods and services to the bridge industry. IBC has traditionally had a long list of exhibiting firms who see the value in IBC and return year after year. They are joined by some 35 additional firms. We heartily welcome both those returning as well as the first time exhibitors.

EXPANDED TECHNICAL PROGRAM

The Conference also features a substantial expansion in our Technical Program. The additional meeting space and presentation rooms at the David Lawrence Convention Center allows IBC to offer over 80 technical presentations from well qualified authors.

NEW WORKSHOPS

The Conference will include workshops sponsored by: BPF, SHRP2, NSBA, BCW, , TRB, AASHTO TIG, FHWA-HSR, FHWA-LRFD, SSPC, AREMA, ADSC, ACMA, AGA , Panel, FHWA-ABC, WPA-TRF, PennDOT .

FOUR MAJOR COMMITTEE MEETINGS

TRB – TRB Subcommittee AFF10 (2) Bridge Aesthetics, mid year meeting This groups function is, "To educate the profession on how to improve the appearance of bridges and other structures during design, construction and operation."

AASHTO/NSBA - The AASHTO/NSBA Steel Bridge Collaboration develops, publishes, and maintains standards for steel bridge design, fabrication, and erection. These standards are intended to improve steel bridge economy and value.

APC - The Associated Pennsylvania Constructors' Bridge Committee meets quarterly in Harrisburg with Penn DOT to discuss Pennsylvania's bridge concerns in detail. We open the meeting to all attendees to demonstrate our approach to problem solving.

SCEF/PCEF - The Mid-Atlantic States' Committees for Economic Steel and Prestressed Concrete fabrication (SCEF and PCEF) will be meeting during the course of this year's IBC. The committees were formed out of the recognized need to improve quality and economy of steel and concrete bridge structures through achieving uniformity and standardization of design and fabrication details, procedures and practices.

SPECIAL ACTIVITIES FOR SPOUSES

This year, we will be introducing a new program for spouses and guests of conference attendees. While you are attending one of the technical functions of the conference, your spouse will be able to enjoy one of the many attractions of the Pittsburgh area. Some of the potential activities are listed in the conference program. Please contact the conference office for more details.

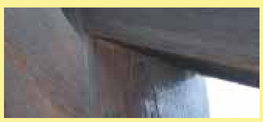
A SPECIAL CELEBRATION FOR THE 25TH ANNIVERSARY

Come join us Tuesday Evening at the Senator John Heinz History Center, a short walk from the Convention Center. From 5:00 to 7:00, on Tuesday Night, June 3, join us in a special celebration of IBC's 25th anniversary and a celebration of Pittsburgh's History. Come mingle and network with colleagues; meet the Executive Committee and make new and life-lasting friends.

Answers to the *Quiz* From Page 6

Q1. [c] Joggle Joint is the correct answer; joggle joints were used mainly as a tension joint in covered bridges located in the bottom chord.

Q2. [d] Mortise & Tendon is the correct answer; mortise and tendon joints were used in covered bridges to connect wind bracing, knee braces, and transom beams.

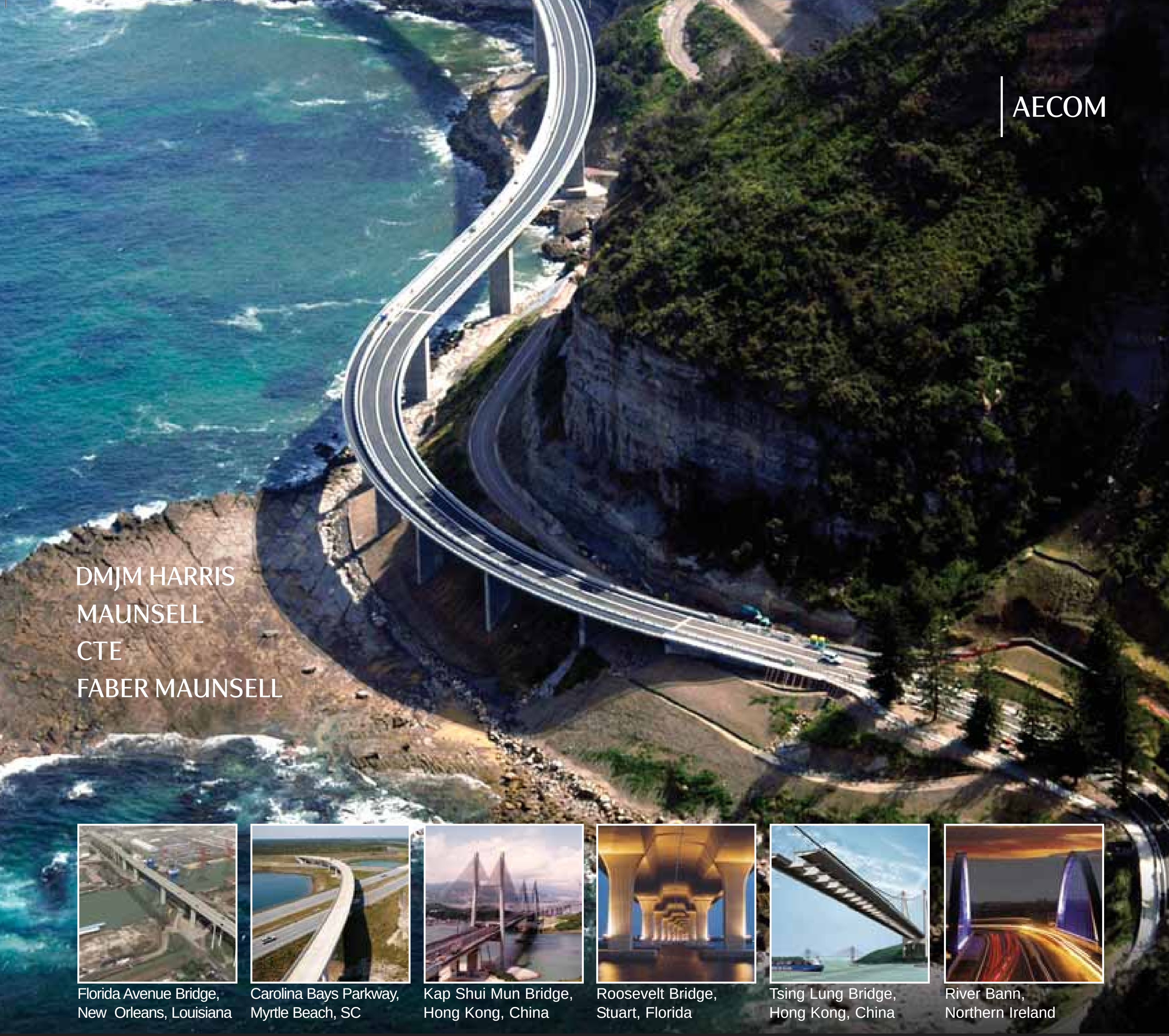


Q3. [a] Lap splice is the correct answer; lap splice joints were mainly used in covered bridges in the top chords.

Q4. [c] Ogee is the correct answer; ogee washers were commonly used on historic covered bridges.

Q5. [d] All of the above are the correct names for the wooden pin that holds a mortise and tendon joint together.

Q6. [d] Pennsylvania is the correct answer; Pennsylvania has the most covered bridges totaling 221 in number.



Florida Avenue Bridge, New Orleans, Louisiana

Carolina Bays Parkway, Myrtle Beach, SC

Kap Shui Mun Bridge, Hong Kong, China

Roosevelt Bridge, Stuart, Florida

Tsing Lung Bridge, Hong Kong, China

River Bann, Northern Ireland

Background photo: Lawrence Hargrave Drive, New South Wales, Australia

Spanning the globe

For nine decades AECOM and its operating companies have been contributing to the success of bridge engineering projects around the world. Our skilled professionals have provided, and continue to provide, the full range of services necessary for project development—feasibility studies, scheme development, financing/procurement, detailed design, project management, site supervision, quality audits, independent checking, and design-build and construction engineering. Our clients include government institutions, financiers and some of the very best bridge contractors in the world.

No matter how large the project, we have the experience, the knowledge, the resources of AECOM and—most importantly—the people to get it done.

Visit us at Exhibit Booth 210

www.aecom.com