A2F04: Committee on Construction of Bridges and Structures
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Bridge Construction

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In the 20th century, bridge construction technology evolved and was fueled by the Industrial Revolution. At the turn of the century, steel bridges were riveted together, not bolted; concrete bridges were cast in place, not precast; and large bridge members were built from lacing bars and smaller sections, not rolled in one piece. Plastic had not yet been invented. Construction techniques such as post-tensioning, slurry walls, soil freezing, and reinforced earth walls had not yet been conceived. Surveying was performed mechanically since infrared, optical technology was still 75 years away.

Bridge construction is changing as the new millennium begins. New construction techniques and new materials are emerging. There are also new issues facing the bridge building industry relative to the research needs associated with these new techniques and materials.

LONG-SPAN BRIDGES

Suspension Bridges

While suspension bridge building was conducted at a modest pace throughout the 20th century, an unprecedented number of spans of remarkable record lengths were built in the Far East and Denmark. Both the Akashi Kaikyo Bridge in Japan and the Great Belt Bridge in Denmark were completed in 1998. The Akashi Kaikyo Bridge is the largest suspension bridge in the world, with a span of 1991 m, and the Great Belt Bridge is the second largest, with a span of 1624 m.

While spans lengths have increased nearly fivefold during the course of this century, they may have reached their physical limits with today's materials. Research will be necessary to develop the new, ultra-high-strength steel wire or carbon fiber wire required to build the longer main suspension cables that will make it possible to increase span lengths to beyond 2000 m.

As we enter the new millennium, rehabilitation and ongoing maintenance of the existing suspension bridges must continue as well. Recent rehabilitation measures for the main cables and suspension systems of these bridges have uncovered degradation through corrosion and hydrogen embrittlement. Research is needed to determine the remaining useful service life of suspension bridge cables and what measures can be taken to slow or halt the degradation process.

Other components of long-span bridges, existing and new, are being revolutionized as technology moves forward. Advances in deck technology are producing stronger, lighter decks. Orthotropic and exodermic decks are becoming increasingly popular on long-span structures as a means of reducing dead load. Bearings, joint systems, and seismic retrofitting components are becoming increasingly efficient as more large-scale testing facilities are built.

Cable-Stayed Bridges

Cable-stayed bridges are a phenomenon of the latter half of this century, and have become more efficient and longer in span as a result of advances in computer technology during the 1980s and 1990s. Cable-stayed bridges represent an efficient alternative to suspension bridges, particularly when spans are in the 300 to 500 m range. However, record spans, such as the Tatara crossing in Japan, are now in the 900 m range.

Perhaps one of the greatest areas of concern and debate with regard to cable-stayed bridge construction is protection measures for the stay tendons. The debate is focused on the use of epoxy versus grout, encased or nonencased stay cables, and a variety of issues regarding the protection of these key bridge elements. There has been a modest amount of research to date on this topic, but more research will be essential as these unique structures age. Other stay cable research topics should include the effects of wind-induced vibrations, anchorage details, and determination of in-service stay tensions.

SHORT- AND MEDIUM-SPAN BRIDGES

Changes can be expected as well for short- and medium-span bridges, which represent the vast majority of bridges to be built. To meet public demand for minimal traffic disruption, construction times for these bridges will have to decrease, and traffic flow will need to be maintained during construction, often within a few feet of workers and equipment. Consequently, public agencies and contractors will seek new materials and methods that enable shorter construction times without compromising safety. The need to make work conditions safer and more efficient will also continue to be emphasized.

There will be advances in the construction of these bridges in many areas. New technology will enable better quality control of the positioning of bridges and members. The design–build approach, which takes into account actual soil and environmental conditions, will also become more widely accepted. Problems in construction will be dealt with immediately to keep the work moving. More experienced people that know how to approach problems and devise solutions will be involved.

The Global Positioning System (GPS) will be used to locate bridge working points more accurately and quickly with fewer people. Each succeeding unit of segmental structures will be located by GPS, and adjustments to elevation and plan locations will be made instantly. Construction equipment will be run by computers that are directed by GPS. One person will monitor multiple units from a remote location via video cameras and computers.

Precast foundation, abutment, pier, and superstructure units will eliminate costly field formwork. Quality control of plant-cast units will minimize variations in size and strength, as well as extend seasonal construction time into fall and spring. Delivery systems will grow in number and size to handle complex units. Labor economies will help drive the development and use of segmental production craftsmen directed by a few highly skilled individuals. Precast arch-like structures, such as Bebo Arch, will continue to gain acceptance. Use of these structures will result in an aesthetically pleasing bridge without the associated deterioration of exposed concrete decks.

As skilled technicians who can monitor bridge construction become less available, local governments will increasingly turn to the use of wood-panel and similar types of bridges. Components that are easily assembled and inspected will gain favor because they are viewable, and do not require inspectors with extensive experience and skills in such areas as the performance of concrete air and slump tests.

A recent development is a resurgence in the construction of post-tensioned concrete box girder bridges built on placed and compacted fills. Traffic is maintained on bypasses, and fill from the bridge construction is reused to build the bridge approaches. This type of construction allows forms and workers to operate efficiently at grade, instead of being suspended above the ground and traffic. Contractors that are equipped to move fill material will take advantage of this method.

New materials, such as plastics, polymer concretes, and high-performance concretes, will be used for the construction and rehabilitation of bridges. As bonded fiber-reinforced composites become temperature tolerant, they will increasingly be used to rehabilitate bridges and make them capable of carrying the latest truck loads. To bring deteriorated concrete beams and other components up to capacity, carbon reinforcement bars will be used to keep the existing uncoated and epoxy-coated bars from developing corrosion hot spots. High-strength polymers and concretes may be used to extend span lengths through reductions in dead loads. Use of larger-sized steel strands in tensioned members, along with higher-strength concretes, will become common practice.

Full acceptance of plastic chairs and form ties will keep corrosion from progressing through the steel to the concrete. Plastic and aluminum stay-in-place forms will be used to reduce form weights and costs. The ability to leave a form in place will reduce removal as well as placement costs.

Before the 1970s, most bridge designs had deck expansion joints combined with fixed and expansion support bearings. The idea was to allow the structure to expand and contract. However, expansion joints tend to fill with dirt and debris, and bearings deteriorate over time. Thus, the structure stiffens with age, and maintenance needs increase more rapidly with time.

In the early 1970s, bridge engineers investigated ways of minimizing this problem. The solution found was to eliminate costly expansion devices and support bearings. The result was the development of the jointless bridge. A jointless bridge is built on a flexible substructure so the structure can expand and contract with minimal distress. This type of structure becomes more flexible as it ages.

Today jointless structures have become a viable alternative for short- and medium-span bridges. However, many questions remain unanswered. For example, should there be a span length limitation for this type of structure? Should length limitations be different for steel and concrete bridges? Are thermal stresses more important to these bridges than to conventional bridges? What are the most effective methods for connecting abutments to the superstructure? Research on such issues will be required to support the use of jointless bridges for short- and medium-span crossings.

Short- and medium-span bridges using the new load and resistance factor design (LRFD) codes will benefit from the safety factors related to dead load. However, this benefit will be offset to some degree by heavier truck loads and associated safety concerns.

The LRFD codes represent an attempt to keep live-load conditions and values in line with load factor design. This may be a rather moot point, however, as final LRFD moment and shear values are comparable to existing load factor design values.

Challenges in the construction and repair of new short- and medium-span bridges will become more complex, but can be met through better planning and equipment. Designers must learn to adapt to changing conditions and technology to provide a better product for the public.

VISION FOR THE FUTURE

In the 21st century, new technology will meet changing needs and provide alternatives that will lead to new standards in engineering and construction worldwide. The future economic impact of bridge construction will revolve around ways of implementing simple design and construction solutions through innovative thinking. Improved interaction among bridge design, construction, maintenance, and field performance will be essential in providing the most economical infrastructure.

Cutting-edge research in new enhanced materials, advanced smart sensing, and life-cycle management will provide the technology needed to construct more durable, maintenance-free structures, and to rejuvenate and extend the life of older structures. Nondestructive evaluation techniques suitable for in-field construction, quality control, and structural integrity assessment of large structures will be developed.

Reliable, inexpensive, rapid, automated inspection techniques will emerge as well. To optimize the safe operation of civil structures with a minimum of expense, it will be necessary to develop innovative, built-in remote monitoring systems for highway bridges using state-of-the-art sensors, telemetry, recorders, and analyzers. Such systems will yield complementary data on anomalies, bridge traffic, and project-life estimation, as well as management and maintenance planning for the structure. The data will be read out remotely on demand and transmitted to a central monitoring station.

Advanced composites made of resin-impregnated strong fibers [fiber-reinforced plastic (FRP)] could become prominent construction materials in the 21st century. This class of light, durable materials could provide sizable benefits to the global infrastructure. The speed and ease of installation of composites as compared with conventional materials will make use of FRP particularly competitive with respect to construction costs. FRP composites can be used as stand-alone structural members, as reinforcement for prestressed and nonprestressed concrete, or in combination with other structural materials for new construction or repair and rehabilitation. Composite bridges made with new materials will afford the opportunity to use embedded sensors and actuators.

Finally, education and training programs in bridge inspection, evaluation, and design incorporating cutting-edge technology and promoting lifelong learning are likely to be created. These programs will link universities, industry, and departments of transportation worldwide using satellite television and the World Wide Web.