Standing Committee on Steel Bridges (AFF20)
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100 Years of TRB Steel Bridge Research

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YESTERDAY

History and Background of the Committee

The origins of TRB's Standing Committee on Steel Bridges can be traced back to the original Highway Research Board's (HRB's) Committee on Bridges, which was formed in 1949 and first met on May 2 and 3, 1950 in Washington, DC (*1*).

Under the leadership of Glenn S. Paxson, Bridge Engineer of the Oregon State Highway Commission, the Committee on Bridges worked on its own under the Department of Highway Design of the Highway Research Board for four years, from 1949 to 1953. In 1954, the HRB reorganized and the Department of Highway Design became the Department of Design, again overseeing the Committee on Bridges until 1962, when the Committee was renamed Committee D-8 -- Bridges, with a half dozen subcommittees, including the Subcommittee on Steel Research, D-8(3); this marked the inception of a continuously active organization dedicated to steel bridge research extending to the present day.

In 1964, another reorganization created the Bridge Division under the HRB's Department of Design, with a half dozen subordinate Committees, including Steel Superstructures, D-C2. This structure remained in place until 1970, when another reorganization created the Design and Construction of Transportation Facilities, Group 2 Council / A2C00, with Section C dedicated to Bridges, and with Committee A2C02 dedicated to Steel Superstructures. A2C02's name was changed from Steel Superstructures to Steel Bridges on June 19, 1973; the members at that time were Arthur Elliott, Gerard Fox, Wayne Henneberger, and William Kline. This organizational setup continued until 2003, when another reorganization resulted in a new numbering system for groups, sections, and committees, whereupon the current structure emerged; under the umbrella of the Design and Construction Group, AF000, is the Structures Section, AFF00, supported by eight standing committees, including the Standing Committee on Steel Bridges, AFF20. Table 1 lists the committee numbers, committee names, and chairpersons of the various incarnations of HRB's and TRB's committees related to steel bridge research from 1954 to the present.

History of Steel Bridge Research

Steel has been used in bridges for well over 100 years, beginning with the construction of Eads Bridge in St. Louis, MO in 1874, the first steel bridge in the world. Widespread use of steel in railroad and highway bridges spread rapidly due to the material's high strength and light weight compared with other construction materials. Discussion of steel bridges in research papers of the HRB date as far back as 1928 (*2*). The first paper focused primarily on steel highway bridges appeared in the HRB proceedings in 1932 (*3*). A variety of topics related to steel bridges have taken center stage over the years, including welding, fatigue, fracture, weathering steel, corrosion resistance, coatings, low alloy steels, high strength steels, curved girders, stability, analysis methods, economy, maintenance and inspection

TABLE 1 TRB Steel Bridge Committee Chairpersons

Committee No.	Committee Name	Chairperson	Term of Service
D-8 (3)	Steel Research	I.M. Viest	1962-1963
D-C2	Steel Superstructures	M.N. Quade	1964-1966
		Arthur L. Elliott	1967-1969
A2C02	Steel Superstructures	Gerald F. Fox	1970-1972
A2C02	Steel Bridges	Gerald F. Fox	1973-1974
		John W. Fisher	1975-1980
		Frank D. Sears	1981-1983
		Albert D.M. Lewis	1984-1989
		Charles W. Roeder	1990-1995
		Robert A.P. Sweeney	1996-2002
AFF20	Steel Bridges	Mark L. Reno	2003-2008
		Kenneth Price	2009-2011
		Barney T. Martin	2012-2014
		Domenic A. Coletti	2015-2020

Sources: Viest and Seiss (*1*) and current TRB database information.

One of the most significant early research efforts in the United States was the AASHO (American Association of State Highway Officials, predecessor to AASHTO) Road Test, which was jointly conducted by AASHO, the Bureau of Public Roads (BPR, predecessor to the Federal Highway Administration, FHWA), and HRB, with the HRB responsible for administration and direction of the program (*4*). The AASHO Road Test facility was built between August 1956 and September 1958, in Ottawa, IL, along the future alignment of Interstate Highway I-80. Testing was conducted from October 1958 to November 1960, with special studies extending into the summer of 1961. The facility consisted of six two-lane test loops with bridge and pavement test sections, and cost $27 million. See Figure 1. Trucks were driven continuously around the test loops 24 hours a day for months at a time to simulate actual highway use and exposure conditions. The tests provided insight into the response of bridges due to repeated high stresses and the dynamic effects of moving vehicles (*5*).

The AASHO Road Test was not only significant for the research results it produced, but also for the researchers who "graduated" from the program and went on to highly influential careers in transportation research. The project director was W.B. McKendrick, Jr. of Delaware, and the Chief Engineer for Research was W.N. Carey, Jr. of the HRB (predecessor to TRB). Notable "graduates" of the AASHO Road Test included Dr. Paul Irick, who went on to a successful career in data processing and analysis at Purdue University, Dr. Ivan Viest, who became an influential bridge promoter of composite steel bridge research and innovations in steel bridges as sales engineer at the Bethlehem Steel Corporation, Dr. John Fisher, who became arguably the "father of bridge fatigue research" at Lehigh University, Charles Galambos (brother of Theodore Galambos) who went on to a long career as a structural research engineer with the FHWA, and Dr. Steve Fenves, who was one of the researchers responsible for development of the original STRUDL (STRUctural Design Language), one of the original finite element analysis software programming codes developed in the 1960s.

Significant research results of the AASHO Road Test included the revelation of inelastic deflections under repeated overloads; these observations prompted NCHRP Research projects 12-01 and 12-06 by Baldwin, which led to the development of serviceability limits for steel bridges, including the service overload provisions in the AASHTO Standard Specifications for Highway Bridges (Load Factor Design, LFD) and the Service Limit State in the AASHTO LRFD Bridge Design Specifications, still in use today. The AASHO Road Test also demonstrated that the behavior of composite steel bridges was clearly superior to that of the non-composite steel bridges, leading to the common modern practice of designing bridges with composite decks. The testing also led to an understanding of fatigue failures of steel beams with cover plates (along with fatigue failures of prestressed concrete beams) which led to subsequent laboratory fatigue tests at the University of Illinois by Stallmeyer, Hall, Sherman, and Munse, and fatigue studies conducted by Dr. John Fisher as part of NCHRP Research Project 12-07 at Lehigh University.


FIGURE 1 AASHO Road Test facility.

Fatigue and fracture were major topics of steel bridge research throughout the second half of the 20th century in the United States, as evidenced by a long series of NCHRP Research Projects focused on these topics, including:

- NCHRP 12-12, Variable Loading (Schilling, Klippstein) 1975
- NCHRP 12-14, Fracture (Barsom and Novak) 1975
- FHWA Fracture Studies, (Rolfe, Barsom, Roberts, Frank, Galambos, and Irwin) 1970's
- NCHRP 12-15, Follow on Details of Fatigue (Fisher, Mertz, Keating) 1986
- NCHRP 12-28, Prediction of Fatigue Performance (Moses and Schilling) 1987
- NCHRP 12-31, Notch Toughness Variability (Frank) Notch Toughness Variability 1993

Further to technological advances, the AASHO Road Test lives on through the standardization of field testing of bridges, having established practices, criteria, and standards which influenced all subsequent structural testing of bridges in the United States.

Another significant steel bridge research effort was the Consortium of University Research Teams (CURT) Project in the 1970s. This was a multi-state funded, federally-coordinated research program into the behavior and design of curved girder bridges involving universities in New York, California, Pennsylvania, Maryland, and Rhode Island. The project included laboratory and field testing by David Beale and Charles Culver, an understanding of load distribution and flange lateral bending in curved steel girders, the development of three-dimensional analysis programs for curved girder bridges, and eventually the creation of the first set of AASHTO curved steel bridge guide specifications by Dan Hall.

The development of approximate live load distribution factors is another interesting topic of research through the history of bridge design in the United States. The origin of this topic can be traced back to seminal work by Newmark and Siess in 1942 (*6*), which developed simplified equations which were widely used for over 50 years. Interestingly, in 1968 Sander (*7*) proposed adding one term to the Newmark equations; this proposal was rejected by AASHO as being "too complicated," but later in 1993 AASHTO adopted significantly more complicated equations proposed by Imbsen in NCHRP Research Project 12-26, Distribution of Wheel Loads on Highway Bridges (*8*). Puckett tried to simplify the approach to live load distribution in NCHRP Research Project 12-62 in 2006 (*9*), but AASHTO rejected this proposal.

Figure 2 shows a bar chart of steel bridge-related papers published by the HRB and TRB since the 1950s, taken from the Transport Research International Documentation (TRID) database. (Only three papers predating 1950 are included in the database.) The horizontal axis in the top graph shows time, with papers grouped in five year intervals to more clearly show general trends. "Spikes" in research can be identified as following significant events in the history of the United States' bridge inventory. The surge of papers in the interval between 1972 and 1975 includes a number of papers on the topic of steel fracture, in the wake of the collapse of the Silver Bridge across the Ohio River between Point Pleasant, WV and Gallipolis, OH on December 15, 1967, which resulted from fracture of that suspension bridge's steel eye-bar chains. The findings of the research initiated after this collapse eventually led the creation of the National Bridge Inspection Standards (NBIS) a significant step forward for the safety of bridges in the United States. The surge of fatigue and fracture papers in the interval between 1977 and 1980 followed the 1977 fracture of Interstate I-79 Neville Island Bridge over the Ohio River, near Pittsburgh, PA. This research advanced the state of knowledge of fatigue and welding of steel bridges and led to the development of the AASHTO Fracture Control Plan. The surge of fatigue and fracture papers in in the interval between 1985 and 1991 was a result of the proliferation of fatigue cracking found on high traffic volume steel bridges throughout the United States. In fact, a significant amount of research into the topics of fatigue and fracture, in large part performed through the National Cooperative Highway Research Program (NCHRP) have resulted in significant advances in the safety and reliability of steel bridges. The widespread phenomenon of fatigue cracking in the 20th century has essentially ceased as research proven designs and details have become the norm.

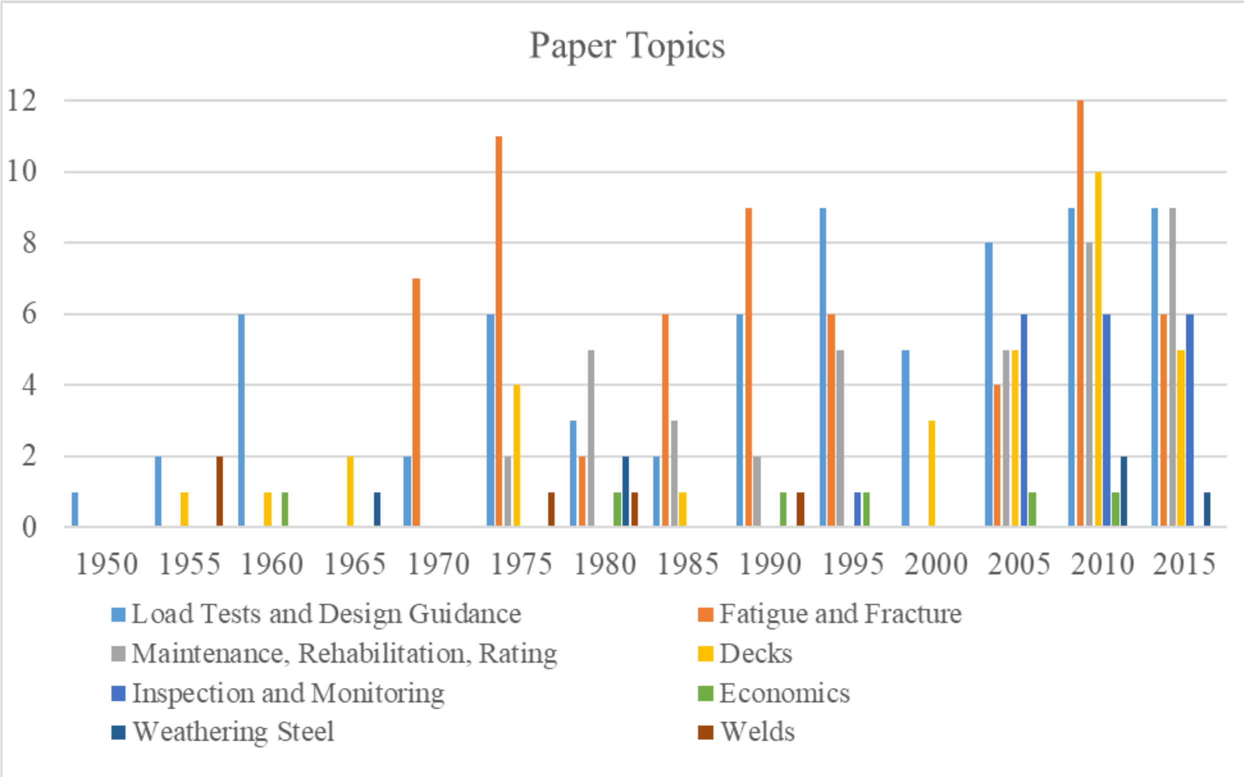

FIGURE 2 HRB and TRB steel bridge-related papers, grouped by topic and year of publication.

Since 2000, there has been a further surge in research on the topic of decks for steel girder bridges. This trend is fueled primarily by recent interest in steel orthotropic deck panels. Another recent trend is growing interest in inspection and monitoring research. Most recent research papers in this category focus on automated, long-term structural monitoring, which can be used to supplement bridge inspection. Other topics of significant research interest related to steel bridges include welding of steel bridges, low-alloy steels, high strength steels, weathering steel and other corrosion-resistant steel bridge technologies, maintenance and composite concrete decks for steel girder bridges. In most cases, the research performed and published through the HRB and TRB have led quickly to implementation of new design provisions, analysis methods, fabrication methods, inspection techniques, etc. In fact, practicality and immediate application are a consistent features of steel bridge research in the US, particularly as promulgated through the HRB and TRB.

The history of advancement in the engineering of steel bridges is inextricably tied to the history of advancement in engineering of other steel transportation structures; research in one area influences, aids, and relies on advancements in other areas. For example, use of welds as a form of structural connection was originally developed in the late 1800s. The first use of welding in a bridge in the United States was in 1928, when the Westinghouse Electric and Manufacturing Company built a railway bridge in Turtle Creek, PA (*10*). Searching the TRID database for the term "weld" instead of "steel bridges" reveals papers dated as early as 1940 related to rail welding; from 1946 to about 1953, the majority of the papers focus on ship welding, largely a byproduct of research into welding of ship hulls following notable fracture failures of Liberty ship hulls during World War II, and address metallurgical quality, fatigue tests, improved materials and methods, etc. *(11)* The first paper in the TRID addressing welding of steel bridges dates from 1953, "Torsion of Plate Girders", by Chang and Johnston, covering research at Lehigh University which investigated bolted, riveted and welded plate girders subjected to twisting moment and developed equations for design (*12*).

Research for steel bridges continues today as we address the ever-changing landscape of bridges in the United States. Topics recently completed or under consideration include redundancy, advanced computer analysis methods, service life modeling and continued enhancements to the AASHTO LRFD Bridge Design Specifications.

Key Roles of the Steel Bridge Committee

The ideas for much of the research described above originated in the HRB/TRB steel bridge committee. One of the main functions of the committee throughout its history has been the development and sharing of Research Needs Statements (RNSs). Over the years the process has become more structured, leading to a very effective approach to developing high-value RNSs. In fact the Standing Committee on Steel Bridges was recognized as a Blue Ribbon Committee by TRB in 2018 for its success in advancing research. RNSs from TRB standing committees in general, and from AFF20 in particular, form the outline and basis of NCHRP research projects, which often produce findings and recommendations that contribute directly to advancements of the AASHTO bridge design and construction specifications.

Another significant role of the HRB/TRB steel bridge committee is the dissemination of research results. The steel bridge committee fosters the sharing of research results on a wide scale through many venues, whether it be through podium sessions held at the TRB Annual Meeting (and accompanying companion papers), publication of steel bridge research in the *Transportation Research Record*, or special conferences or publications. The steel bridge committee has worked hard to spread knowledge of advances in steel bridge engineering throughout the United States and the world. Also, the Committee has strengthened its relationship with many other organizations in the steel bridge community to further facilitate implementation through them.

Major Accomplishments of the Steel Bridge Committee

Over the years the HRB/TRB steel bridges committee has contributed to major advancements in the state of knowledge of steel bridge engineering, helping to develop, review, and disseminate results of research in welding of steel bridges, low-alloy steels, high strength steels, weathering steel and other corrosion-resistant steel bridge technologies, fatigue and fracture of steel bridges, analysis of steel bridges, design of various parts of steel bridges, etc. Recent examples include:

- NCHRP Research Project 12-79, Guidelines for Analytical Methods and Erection Engineering of Curved and Skewed Steel Girder Bridges.
- NCHRP Research Project 20-07, Task 355, Guidelines for Reliable Fit-up of Steel Girder Bridges
- NCHRP Research Project 12-113, Cross-Frame Analysis and Design Improvements
- NCHRP Synthesis 20-05, Task 48-03, Corrosion Protection for Extending Steel Bridge Service Life

One of the strengths of the steel bridge committee in successfully developing and sharing research is its well-developed networking with the steel bridge industry. For many years the membership of the committee has represented a broad cross-section of the steel bridge industry, including academic researchers, owners, consulting designers, fabricators, and others. For example, the TRB steel bridge committee maintains consistent and close ties to the AASHTO

Committee on Bridges and Structures (CBS) Technical Committee on Steel Design (T-14), sharing prioritized research idea lists and striving to develop RNSs which address the needs of steel bridge owners throughout the nation and actively striving to have at least several people serving simultaneously on both committees. The TRB steel bridge committee has also maintained a long-standing and close relationship with the American Institute of Steel Construction (AISC) and their branch organization, the National Steel Bridge Alliance (NSBA), again consistently keeping an AISC/NSBA representative as a Member of the committee, and consistently having that Member provide a "state of the steel bridge industry" report at the Committee Meeting each year. Overall, the committee has successful striven for balance in its Membership; the official TRB review and ratings of AFF20's 2017 Triennial Strategic Plan included comments such as: "Membership is very good and well balanced both geographically and by affiliation;" and "The committee membership represents a very good diversity." The committee also recently initiated a formal Liaison protocol, identifying committee Members and Friends to formally coordinate with over two dozen related TRB committees and other industry organizations.

TODAY

The Committee has identified the following emerging, critical, and cross-cutting issues as being among the most significant issues in transportation today:

- **Changes to Design Technology and Workforce**: Design technology continues to evolve at an exponential pace, while the workforce continues to become younger. Computerized analysis and design methods are universally used, and become more powerful, more sophisticated, and more complicated each year. Building Information Modeling for Bridges and Structures (BIM for Bridges and Structures) is poised to completely revolutionize the entire design-detailing-fabrication-construction-asset management process. The "Interstate Generation" of engineers has left the industry for all practical purposes, while reduced hiring of new engineering graduates during the economic downturns of the 1970s-1990s has left today's bridge engineering community populated by a large number of relatively inexperienced engineers supervised by a disproportionately small number of more experienced engineers. This younger generation also embraces different learning and research methods and modes (e.g., online video-based learning and online research using Google, Wikipedia, etc.). As a result, research must adapt to these trends to best provide modern engineers with quantified, appropriately-vetted answers to the challenging questions associated with how to implement these new technologies. Furthermore, mentoring, best practices, quality control procedures, and other means of leveraging knowledge and experience will be critical in transitioning to an increasingly paperless work environment and a younger pool of engineers.
- **Emphasis on Durability, Maintainability, and Inspectability:** Steel bridges must be durable, simple and economical to maintain, and allow for easy inspection. Owners' steel bridge inventories are both growing and aging, but the funding available for maintaining these inventories is not growing commensurately. Further, owners desire to minimize traffic disruptions associated with repairs and rehabilitation. Older steel bridges are subject to problems and issues with corrosion, deterioration, fatigue and fracture, difficult and/or costly maintenance, and the need for frequent, sometimes expensive, inspections. New steel bridge designs must balance the competing goals of having low initial cost and low life-cycle cost, including consideration of user costs associated with interruptions to, or limitations on, traffic and usage. As a result, a wide-ranging, holistic research program is

needed for steel bridges, addressing innovative systems, innovative materials and coatings, constructable designs, robust construction practices, effective construction quality control practices, effective maintenance practices, economical retrofits and repairs, and design details which enhance durability, maintainability, and inspectability,

- **Changes to Traffic:** The era of "one driver in one car" is rapidly coming to an end. Revitalization of urban centers and cultural changes among the Millennial and Gen-Z/iGen generations are leading to increased interest in shared ride services (such as Uber and Lyft) increased use of mass transit (particularly light rail and high speed rail), and the influences of "smart" technology and social media applications which distribute traffic more uniformly across the infrastructure system. The development of autonomous vehicle technology may further fuel these changes in transportation demographics, not only among passenger vehicles but also with regard to commercial trucking, as evidenced by increased interest in "truck platooning" technology. As a result, the steel bridge community may need to develop safe, economical responses to the increased stress on infrastructure resulting from the denser traffic patterns associated with autonomous vehicles. Like the rest of the transportation industry, the steel bridge community will need to be prepared to deliver effective, consistent designs for high speed rail and light rail transit systems. The exact makeup of the future transportation network is not known at this time as these technologies rapidly advance; however the known fact is that things will change dramatically over the next 50 years.
- **Impacts of Construction and Maintenance Activities on Highway Users: "**Get in, get out, and stay out," is more than a slogan in the transportation industry; it is an increasingly nonnegotiable expectation of the traveling public. The traveling public is increasingly dependent on uninterrupted access to the full capacity of the transportation network in the US. Road closures and lane closures, result in significant negative impacts on traffic, safety, and the economy. To minimize such impacts, the demand for accelerated bridge construction techniques and bridges requiring fewer, less intrusive maintenance and inspection activities will increase. The price of these innovations need to be measured and evaluated as costs which could be offset with higher initial cost construction. The Steel Bridge Committee must partner with other committees to share expertise and help guide research in these areas.
- **Changes to Procurement Methods:** Alternative delivery methods such as design-build, design-build-operate-maintain, construction manager/general contractor (CM/GC), and construction management at risk are becoming more prevalent in the transportation industry. The assignment of responsibilities between designer, builder, owner, and maintainer is less clear than in traditional design-bid-build procurement. Design codes, standards, and specifications developed for the traditional design-bid-build delivery model may not be completely appropriate for alternative delivery models. As a result, owners are faced with the challenge of establishing procurement requirements which ensure strength, serviceability, maintainability, and inspectability requirements are achieved, without adversely stifling innovation or limiting the potential for cost and time savings, when alternative delivery methods are used.

One thing is certain; the rapid rate of change in the modern world makes paramount the need to communicate and coordinate across disciplines and specialties. As a result, in recent years the TRB Standing Committee on Steel Bridges has initiated many efforts to collaborate with related TRB committees and other industry organizations, both formally and informally. "Diversity" in terms of the membership of the Committee has extended beyond the traditional definitions of male/female, minorities, and international members; another key characteristic of diversity today is a broad representation of the industry, including academic researchers, owners, consulting design engineers, fabricators, and industry advocacy group representation. The Committee has also instituted a formal liaison program, where individual Members or Friends of the Committee are identified to communicate with other TRB committees and industry organizations to share information about the Committee's activities and to report back on the activities of these other related organizations. In particular, the Committee maintains very close ties with AASHTO's Steel Design technical committee, T-14, as well as TRB's Standing Committees on the Fabrication and Inspection of Metal Structures (AFH70), Construction of Bridges and Structures (AFH40), Structures Maintenance (AHD30), Bridge Preservation (AHD37), and Corrosion (AHD45).

TOMORROW

Looking to the future, the Committee has several goals.

- **Maintain a Diverse Membership:** AFF20 already boasts a diverse committee membership, with participation from academia, federal and state transportation owner-agencies, industry, and consulting engineers with a good mix of younger and more seasoned members, and male and female members. This broad cross-section of the steel bridge field brings the benefits of multiple perspectives on any topic. Over the next several years, the Committee will encourage continued participation of a broad range of individuals through a continued commitment to maintaining a diverse committee membership, active use of the Friends of the Committee, and proactive methods of mentoring and coaching younger engineers to aid in the passing of knowledge now that the "Interstate Generation" of engineers has largely retired.
- **Encourage Committee Involvement**: Participation of all members is needed to fully achieve the potential of the diverse nature of the AFF20 membership. In this way, all members will feel valued and will be more likely to participate and contribute to the Committee's activities. Over the next several years, the Committee will encourage more active participation of all members through the continued promotion of our formal program where individual Committee Members are identified as representatives of the Committee to foster interaction and technology transfer with other TRB committees, as well as with other industry organizations (e.g., NSBA, AASHTO CBS, AASHTO T-14, etc.) and the organizing committees of national and international bridge conferences (e.g., International Bridge Conference, World Steel Bridge Symposium, etc.). Committee Members will be encouraged to actively participate with these other committees and organizations, and to report back to AFF20 during Committee Meetings.
- **Embrace Cross-Cutting Issues:** The committee has identified a number of key cross-cutting issues which are expected to be of importance in future years, including:
  - Changes to Design Technology:
    - Design best practices
    - Quality control procedures
    - Mentoring and other means of transferring knowledge
    - BIM for Bridges and Structures
  - Emphasis on Durability, Maintainability, and Inspectability:

    - Innovative designs (including integral abutment bridges)
    - Proper detailing as it relates to service life
    - Materials (including high strength steel, stainless steel, etc.)
    - Coatings (including galvanizing, metalizing, weathering steel, etc.)
    - Construction methods that enhance maintainability
    - Best practice maintenance actions that lengthen service life
    - Effective bridge inspection policies, practices, and techniques
  - Changes to Traffic
    - Effects of Truck Platooning on design and fatigue loading
    - Appropriate design criteria for LRT and HSR bridges
  - Impacts of Construction and Maintenance Activities on Highway Users
    - Accelerated bridge construction
    - Prefabricated bridge elements
    - Innovative bridge construction, maintenance, and inspection techniques
  - Changes to Procurement Methods
    - Procurement specifications and criteria which provide appropriate standards for serviceability, maintainability, and inspectability in addition to basic structural performance.

- **Research:** The primary goal of AFF20 is to help guide steel bridge research in the US through the development of Research Needs Statements which can generate high-value research products. One of the most important aspects of the development of Research Needs Statements is how well they respond to the needs of bridge owners and specification writers. To this end, AFF20 will continue to communicate regularly with the AASHTO Technical Committee on Steel Design, T-14, including assisting T-14 with annually updating their research priorities list. The Committee will also initiate a more regular dialog with other AASHTO Technical Committees such as T-4 (Construction), T-11 (Research), T-19 (Computers), T-17 (Metal Fabrication), along with FHWA, AWS, and AISC, and other related organizations.

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