Evaluation of Seven Aluminum Highway Bridges After Two to Three Decades of Service

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ABSTRACT

Between 1948 and 1963 six aluminum highway bridges were erected in the United States and one was erected in Canada for highway overpasses and river crossings on Interstates and state highways. Girder types used vary from conventional built-up I and box to more radical triangular cross sections. Either riveting or welding was used depending on the structure. Recent reports from several owners and designers indicate that the performance of these bridges, particularly their corrosion resistance, is outstanding. This fact, coupled with the awesome number of obsolete bridges on the nation's roads and the impetus given to the Bridge Replacement Program by the Surface Transportation Assistance Act of 1982, resulted in a survey of the seven aluminum bridges in 1983. The results of this survey--based on inspection data provided by state highway officials--illustrate how the corrosion resistance of the alloys selected and how the design, details, test, construction, and erection methods employed are being verified by excellent performance in the field. Aluminum provides the bridge engineer and owner with a proven construction material for bridges where light weight and a long maintenance-free life are required.

There are an estimated 250,000 bridges in the United States in need of major repair or replacement. In 1982 the U.S. Congress passed the Surface Transportation Assistance Act that allocated $97.7 billion over a 5-year period for rebuilding the American infrastructure, including bridges. The following year the Aluminum Association, with the responsible state officials, surveyed seven aluminum highway bridges, erected between 1948 and 1963 in the United States and Canada for overpass and river crossings on Interstate and state highway systems, to determine their condition. Data were gathered on a variety of factors affecting performance such as traffic volume; environment; and the condition of superstructure, substructure, and approaches.

BACKGROUND

Before elaborating on the results of this examination, it might be useful to go back and review the reasons that justified the use of aluminum and the designs that were chosen. The potential of aluminum as a structural material has been amply demonstrated in its use for airframes since the 1930s. The first use of aluminum as a material for bridges was, appropriately enough, in Pittsburgh where the Smithfield Street Bridge was redecked in 1933 with a lightweight aluminum deck (plate plus stringers). Aluminum permitted the existing structure to sustain higher traffic loadings. In 1946 the possibility of using aluminum in railroad bridges was investigated by the Aluminum Company of America on a line serving a company aluminum smelter at Massena, New York. A riveted plate girder bridge was erected to span the Grassi River at the plant site. This was the first totally aluminum bridge built in North America.

Following this, the Aluminum Company of Canada erected a 504-ft riveted bridge over the Saguenay River in Québec in 1950 to demonstrate the practicability of aluminum for constructing highway bridges. The bridge is located near a generating station that supplies power to Alcan's Arvida works, the largest aluminum smelter in the world.

The Interstate Highway Program was the impetus for the next major thrust. This resulted in the first welded aluminum highway bridge in the United States being erected in Des Moines, Iowa, in 1958. Since the completion of the riveted Arvida bridge in 1950 a wealth of new technology had been developed on specifications, equipment, and procedures for welding aluminum. At the same time, stronger, more weldable, corrosion resistant alloys had become available. Because welding is normally a faster process than riveting and had become the standard joining method for steel bridges, the decision was made to weld the Iowa plate girder bridge. The aluminum structure was designed to work compositely with the reinforced concrete deck through shear lugs. Expansion joints were also aluminum.

The stimulus for building the next group of aluminum bridges in 1960 was the desire of Robert Moses to specify an alternate material to steel and concrete in order to improve delivery and erection schedules. The firm of Andrews and Clark, Consulting Engineers, New York City, was commissioned to design two overpass bridges on the Long Island Expressway. These were conventional riveted plate girder structures. During the planning phase the performance of the Arvida bridge was carefully studied to determine if there was any excessive cracking in the concrete deck as a result of differential expansion between the concrete deck and the aluminum structure. It was concluded that not only was there little or no cracking but that the contraction of the aluminum structure in the winter had the potentially beneficial effect of preventing the ingress of moisture and road salt into the deck. Of the bridges reviewed in this paper these Long Island Expressway bridges are the most important in proving the feasibility of aluminum because of the high traffic density they sustain.

The next step in the evolution of the aluminum bridge was an attempt to drastically reduce weight and initial cost. The first embodiment of this concept was the Fairchild Bridge, a semimonocoque, riveted girder consisting of a series of triangular boxes. Each box is made from stiffened aluminum sheet, with the sheets connected via longitudinal extrusions. With this construction, the weight of the aluminum structure was reduced substantially (one-quarter to one-fifth the weight of a steel structure) without sacrificing performance. Full-scale fatigue tests at Lehigh University suggested that a life of over 100 years could be anticipated. No failure occurred during the test period. Four bridges of this type were erected between 1960 and 1963.

RESULTS OF 1983 SURVEY

How have these bridges performed? Are the designs and details used meeting the test of time? What about corrosion resistance--particularly to road salt? What about overall maintenance? Answers to these questions are summarized in Table 1.

Arvida Bridge

The Arvida, Quebec, bridge was the first all-aluminum highway bridge and the largest aluminum structure ever built at the time of its erection in 1950. Total length is 504 ft including approach spans. Length between skewbacks is 290 ft. Rise of the fixed arch is 47.5 ft. Width of roadway is 24 ft plus two 4-ft sidewalks. The arch shape was chosen for aesthetic reasons although it was realized that a truss structure would be lighter and more economical. Because only three aluminum bridges had been erected prior to 1950 (the Alcoa bridge at Massena, a bascule bridge at Sunderland, England, and a footbridge in Scotland), it was thought necessary to record the behavior of the Arvida bridge for a period of time after it was erected to compare its actual performance with assumed design values in such areas as stress levels, temperature effects, and corrosion behavior.

The bridge, located near the city of Jonquiere, was designed by C.J. Pimenoff, chief engineer, Dominion Bridge Company, Ltd., and fabricated by that company at their Lachine, Quebec, works. Dead loads were based on a unit weight of 175 lb per square foot. Arches were designed for a live load of 80 lb per square foot plus two 20-ton trucks abreast. The floor system and floor slab were designed for a live load of 100 lb per square foot plus two 20-ton trucks abreast. An alternate live load for arch, floor system, and floor slab design was a 50-ton electrical transformer on a 12-ton trailer pulled by an 18-ton tractor traveling at 10 mph. Wind loads included (a) a horizontal force of 30 lb per square foot on 1.5 times the projected area of the structure plus 200 lb per linear foot applied 7 ft above the roadway or (b) a uniform load of 50 lb per square foot on 1.5 times the projected area of the unloaded structure.

The structure was designed to resist stresses due to temperature variation of plus or minus 70°F from a normal temperature of plus 30°F (a range from plus 100°F to minus 40°F). Aluminum alloy 2014-T6 (clad) was used for plates and for extruded structural shapes (unclad). Rivet alloy was 2117-T4, bolt alloy 2024-T4. Unit axial tension stress used for alloy 2014-T6 (net section) was 21,000 lb per square inch. The maximum compression stress could not exceed this level. Values used for shear and bearing were 12,500 lb per square inch and 30,000 lb per square inch, respectively. These levels of stress are consistent with those currently specified by AASHTO for alloys of comparable strength to be used in aluminum bridge-type structures.

The Arvida bridge has performed well during its 34 years of service. The bridge has not been painted despite the original concern about the relatively low resistance of alloy 2014-T6 to corrosion. In fact, Alcan inspectors advise that the bridge is generally in good condition and the only cost of maintaining the structure to date has been $5,000 for repairs to the base plates in 1971. The asphalt wearing surface on the bridge deck has required only normal maintenance over the years and was replaced in 1983. It should be noted that although traffic density is relatively light on this bridge, road salt is used to melt snow during a 6-month winter period from November to the end of April.

Long Island Expressway Bridges

In 1959, A.A. Trinidad, Jr., of Andrews and Clark, Inc., Consulting Engineers, New York City, presented a paper to the New York State Association of Highway Engineers titled "Problems Involved in the Developing and Designing of the Aluminum Bridges for the Long Island Expressway" in which the following points were made.

After inspecting the Arvida aluminum bridge in 1957, one thing stood out to Andrews and Clark: Under critical inspection, the structural aluminum showed no signs of corrosion or distress after 7 years of continuous exposure to the elements and to varying traffic loads. It was therefore agreed that with good design and construction practice a safe, durable, corrosion-free structural aluminum bridge with a concrete deck was practical. Further, preventing corrosion of the aluminum alloy by concrete and providing for differential thermal expansion would not be problems.

Two bridges carry the Long Island Expressway over the divided lanes of the Jericho Turnpike and have single spans of approximately 77 feet on a skew of over 30 degrees and a width of over 110 feet (Figure 1). They are typical of many medium-span bridges where vertical clearances are critical and large skews are common. Designing the aluminum girders to act compositely with the concrete deck enabled girder depths of 4 instead of 5 ft to be used while meeting a live-load deflection requirement of 1/800 of the span. After this 1-ft reduction, girder depth is still one foot greater than that of a steel structure.

Aluminum alloy 6061-T6 was chosen for both structurals and rivets because of its good strength, availability in a wide variety of product forms, high resistance to corrosion, and good fabricating qualities. Also, structural specifications for this alloy had been fully developed (American Society of Civil Engineers, Proceedings Paper 970). Recommended tensile design stress was 15,000 lb per square inch based on a specified ultimate strength of 42,000 lb per square inch and a yield strength of 35,000 lb per square inch.

Aluminum alloys work efficiently with concrete as a composite beam because of the relative closeness of the elastic moduli of the two materials. To reduce fabrication, two flange angles were developed that required special extrusion dies. These angles have an outstanding leg thicker, as well as longer, than the leg connected to the web plate. They were extruded for the full girder length to eliminate splices and cover plates. Top flanges were painted with zinc chromate to reduce attack on aluminum from the concrete. The steel shear connectors were hot-dip galvanized. A 7-in. reinforced concrete slab supports a 2.5-in. asphalt-concrete wearing surface.

The superstructure is designed for a standard HS-20 loading with 17 girders on the westbound bridge and 18 girders on the eastbound bridge. Girders are spaced 7 ft on center. Rivets are 3/4 in. in diameter, driven cold. These were the first riveted aluminum highway bridges built in the United States.

The total amount of aluminum used in the two bridges was approximately 270,000 pounds or about 14 pounds per square foot of bridge surface. This compares with an estimated 35 pounds per square foot for steel. The total cost of each bridge including abutments, wing walls, and deck was approximately $350,000 or an estimated 18 percent above the cost of a comparable steel structure. (In a recent 1984 study Andrews and Clark estimate that this premium could be reduced to around 5 percent). Plans and specifications were prepared by Andrews and Clark for the New York State Department of Public Works.

TABLE 1 Results of 1983 Survey of Aluminum Bridges

Location	L.I. Expressway over Jericho Tpke, Nassau County, NY (2 bridges)	Rte 36 over Appomattox R Chesterfield Co., VA.	Sykesville MD, Route 32 over River Rd.	Amityville, NY (2 bridge) Sunrise Hwy @ Rte 110 Sunrise Hwy @ Wellwood Av.	DesMoines, IA 86th St./I-80 overpass	Arvida P.Q. over Saguenay River
Date Completed	1960	1961	1963	1963	1958	1950
Designer	Andrews & Clark, NYC, NY	Hayes, Seay, Mattern & Mattern, Roanoke, VA	Maryland Hwy Admin. & Inter. Alum. Str. Inc.	Kaiser & N.Y.D.O.T.	Ned L. Ashton Iowa City, IA	C. J. Pimenoff
Owner	NY State D.O.T.	VA, DOT	Maryland Hwy Admin.	NY State D.O.T.	Iowa DOT	City of Jonquires P.Q.
Fabricator	Pullman Standard, Chicago, IL	Reynolds Metals Co. Sanford Constn. Co, Inc	International Alum. Str. Inc., & Globe Iron Construction Co., Inc.	Traveller Mfg. Co. Sub. Stanray Corp.	--	Dominion Brdg Co. Ltd., Lachine P.Q.
Type of Construction	Riveted pl. girder with extruded flange reinforced concrete deck.	Alum triangular girder. Gravity abutments on solid rock reinforced concrete deck.	Alum girder with concrete deck, abutments & piers. Riveted triangular box stiffened sheet girders, reinforced concrete deck with asphalt wear surface.	Riveted triangular Box Stiffened Sheet Girders, reinforced concrete deck.	Welded plate girder reinforced concrete deck.	Riveted aluminum arch, concrete deck, rock foundation
Span	76'-9"	100'-4"	93'-6", 94'-2", 105'-9"	30'-76'-76'-30'	41'-3", 68'-9",68'-9", 41'-3"	290' clear, 504' overall
Width	61'	28' clear roadway	30' roadway, 37' overall	96'-0"	24' roadway, 36' overall	24' roadway, 2-4 ft sidewalks
Girder Depth	4'-6"	4'-10"	5'-7"	6'-0"	3'-2"	4'x6'-2" deep box girders
Alloy:	6061-T6 pl. & ext'n 6061-7/8" Rivets	6061-T6 pl. & ext'n AN5 & AN10 bolts & rivets	6061-T6 pl. & ext'n girders field spliced	6061-T6 pl. & ext'n Al. plate type shear connectors	5083-H113 pl. 5183 weld wire	2014-T6 pl. 2117 rivets
Design Load	HS-20	H20 & HS15, wearing surface 20 psf, sidewalk live load 60 psf	HS-20	HS-20, future wearing surface 20 psf., sidewalk live load 60 psf.	HS-20+19 p.s.f.	50 ton transformer on 18 ton tractor and 12 ton trailer
Avg. No. Vehicles/Day /Year	140,000 50 million	8050 -	6100 -	7050/21,800 2,573,250/7,957,000 46,318,500/143,226,000 (18 years)	Less than typical, but rising	
Aluminum Superstructure						
a. Condition	Good-Excellent	good, slight pitting, bent stiffeners	good, some corrosion	good	Quite well, many 1/8"-2" long hairline cracks in welds connecting diaphram and stiffener to webs of beams.	Good-excellent
b. damage	none	longitudinal-stiffeners damaged by flood debris	none	minor-no repairs	Section loss in bottom flange beams 1-4 due to collision damage caused by high vehicle.	None reported
c. repair	none	none	none	none, will be difficult to jack structure to free frozen bearings.	Grinding to remove notch in flanges damaged.	Base plates repaired in 1971 at cost of $5,000
Bridge Deck	OK	fair-20ft^2 spalled	not visible	deck in good shape no unusual cracking	OK, random cracking, hair-line transverse crack,s a little leaching	OK
Condition of Roadway Surface	poor due to heavy vehicle traffic, asphalt wearing surface replaced.	OK	bitumen wearing surface patched at bridge joints otherwise good.	good, no problems	Fair	OK, resurfaced in 1983

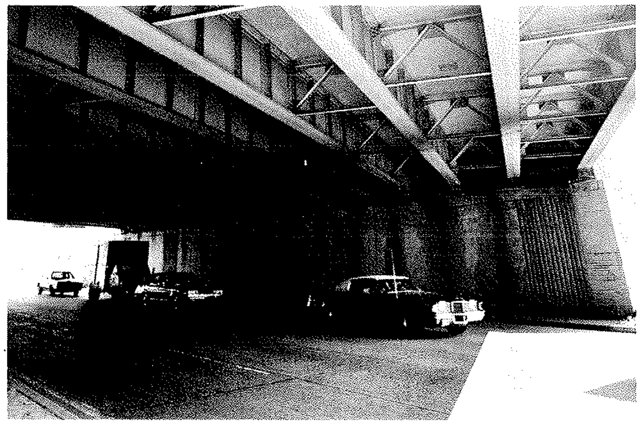

FIGURE 1 Aluminum superstructure of Long Island Expressway bridge.

This department supervised construction with its own engineering staff. Pullman Standard Car Manufacturing Company of Chicago was the fabricator, and the general contractor was Hendrickson Bros., Inc., Valley Stream, New York.

In the 1983 survey, New York State engineers reported that the aluminum structures were holding up very well. The engineers were particularly impressed with the speed of erection and suggested there might be a market for aluminum structures as replacement bridges on heavily used highways. Of the bridges surveyed, these Long Island bridges have by far the greatest traffic density. The estimated average daily traffic count is 140,000 vehicles; the yearly count is 50 million vehicles. This suggests that close to 1 billion vehicles have passed over these bridges since they were erected in 1960. Automobiles and light trucks accounted for 82 percent of the traffic with buses and heavy trucks (tractor-trailer) accounting for the remainder. Normal temperature range is 0°F to 100°F (58°F average). Road salt is used for more than 4 months per year.

The condition of the aluminum bridge structures was rated as good to excellent after an inspection of girder webs, flanges, stiffeners, diaphragms, and connector plates. There had been no structural damage. No corrosion was reported except of steel parts adjacent to the aluminum structure. The concrete deck is in good condition and has not required replacement. No water is leaching through the deck and there is no spalling concrete. Because of the traffic density the asphalt-concrete surface is rough and has some pot holes.

Iowa Bridge

The Iowa bridge is the only welded aluminum highway bridge in the United States. As noted earlier, welding was chosen over riveting to minimize weight and to gain experience with the type of construction being used on steel bridges. Erected in 1958, the Iowa bridge predates all the other highway bridges described in this paper except the Arvida bridge. The Iowa bridge was designed by Ned L. Ashton, Consulting Engineer, Iowa City, Iowa, for the Iowa State Highway Commission. The bridge is the 86th Street I-80 overpass and is located in the northwestern suburbs of Des Moines. It is a 220-ft-long x 30-ft-wide continuous aluminum girder bridge with a composite concrete deck. It has two 69-ft center spans and two 41-ft end spans.

The bridge is designed for AASHTO HS20-HS16 live loads plus 19 lb per square foot. The aluminum alloy specified for the structure was 5083-H113 welded with 5183 welding wire. The shielded inert gas metal arc welding process was specified to meet welding qualifications of Section IX of the ASME Boiler and Pressure Vessel Code. Fabrication conformed to ASCE Paper 970-ST3. Estimated weight of structural aluminum was about 75,000 pounds or approximately 12 pounds per square foot of bridge surface. Aluminum main beams weighed an estimated 53,144 pounds, diaphragms 17,288 pounds, and expansion joints about 4,000 pounds.

Traffic over the Iowa bridge, although less than typical, has increased in the past 2 years and is expected to continue rising. According to the Iowa Department of Transportation, the bridge has needed little maintenance and most of this was due to structural damage caused in 1978 by a vehicle exceeding the maximum height limits colliding with the superstructure. This overheight load struck the right exterior beam of span 3 causing a 2-in.-deep notch in the bottom flange. This notch was smoothed out by grinding to prevent it being the point of origin for a crack. In addition, weld cracks were observed between the ends of diaphragms 2, 3, and 4 and the web of beam 3. These cracks are being monitored and in a 1981 inspection were reported as numerous, fine, 1/8 to 2 inch cracks in the welds connecting diaphragms and stiffeners to the web of beams. The cracking is thought to be due to the welder pulling away when ending a weld. These cracks continue to be monitored.

The remaining four aluminum bridges in the survey represented attempts to substantially reduce metal content and cost by applying aircraft design principles to reduce weight and to use the production facilities of a number of fabricators supplying riveted aluminum structures to the transportation industry.

Amityville, New York, Bridges

In 1965 the New York State Department of Public Works (NYSDPW) let contracts for two aluminum bridges with riveted triangular box stiffened sheet girders. These structures were designed by Kaiser Aluminum & Chemical Corp. and NYSDPW. Both are located near Amityville, N.Y., one on Route 110 and Sunrise Highway, the other at Wellwood Avenue and Sunrise Highway. The bridges are 212 ft long and 96 ft wide and have two center spans of 76 ft and end spans of 30 ft (Figure 2). Loading was AASHTO HS-20

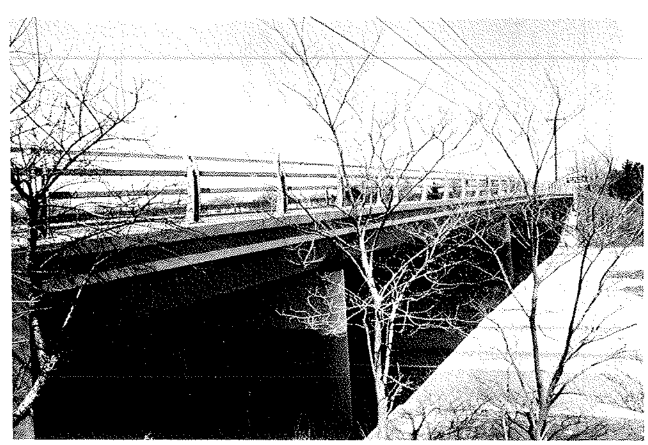

FIGURE 2 Amityville bridge.

with a 20 lb per square foot provision for a future wearing surface.

Sidewalk live load is 60 lb per square foot. Specifications called for an approved semimonocoque design for the superstructure with the skin braced by stiffeners or diaphragms for additional strength. The girders work compositely with the concrete slab. Individual inverted triangular beams made of alloy 6061-T6 support the concrete deck. They measure 10 ft wide x 6 ft deep overall and have 0.081-in.-thick side sheets and a 0.032-in.-thick corrugated top sheet. A bottom sheet, 0.102 in. thick, bridges the apices of the triangles. These sheets are riveted to specially designed longitudinal extruded sections and to lateral extruded bulb angle stiffener beams.

Falsework was eliminated by casting the concrete slabs directly on the corrugated top sheets that run longitudinally on top of the beams. A layer of 2.5 in. of asphaltic concrete covers the slabs. In designing the bridges as composite beams, stresses created by the difference in thermal expansion between aluminum and concrete are reacted to by thermal beams that run the full width of the structure near bulkheads. The aluminum superstructure of each of the Amityville bridges weighs 356,000 lb or about 17.5 lb per square foot.

As of 1982, the traffic count on the Route 110 and Sunrise Highway bridges was 7,050 vehicles per day, 2,573,000 vehicles per year. The estimated 18-year total was 46,318,500 vehicles. The equivalent figures for the Wellwood Avenue bridge are 21,800 (daily), 7,957,000 (yearly), and 143,226,000 (18 years).

These bridges are located in a light industrial seacoast region with minimum and maximum temperatures of 0°F and 100°F, respectively. Humidity varies between 50 and 100 percent. Road salt is used over a 4-month winter period. Annual snowfall is relatively light at 12+ inches.

Structural damage to the bridges has been minor and has required no repair. A major potential maintenance problem will be servicing rusted steel bearings. The problem is caused by the difficulty of jacking up the triangular beams due to lack of clearance and a fear of overstressing the structure locally at supports. (Shortly after erection the webs of both the Amityville and Sykesville bridges required reinforcement to resist the high shear loads at supports.) It was suggested, however, that the maintenance problems with the bearings could have been eliminated if aluminum or elastomeric bearings had been used initially. Other observations included the presumed difficulty in making repairs if a truck should hit the bridge, possible problems in obtaining a new triangular box girder, close placement of girders during construction that affects expansion and contraction, and difficulty in obtaining proper camber and correct beam length during fabrication. The bridge decks of both Amityville bridges were reported to be in excellent condition and have not been repaired or patched in 18 years. No maintenance of the aluminum superstructure has been required.

Sykesville, Maryland, Bridge

The Sykesville, Md., bridge (Figure 3) is similar to the Amityville bridges in design and construction. It was designed by the Maryland State Highway Administration and International Aluminum Structures, Inc., in 1963. It is located on Maryland Route 32 (Sykesville bypass). It spans River Road, the South Branch of the Patapsco River, and the B&O Railroad. There are three spans of 93 ft 6 in., 94 ft 2 in., and 105 ft 9 in. Depth of the triangular girders is 5 ft 7 in. (Figure 4). Overall width of the structure is 37 ft (30 ft clear roadway). AASHTO design loading is HS-20.

FIGURE 3 Sykesville bridge.

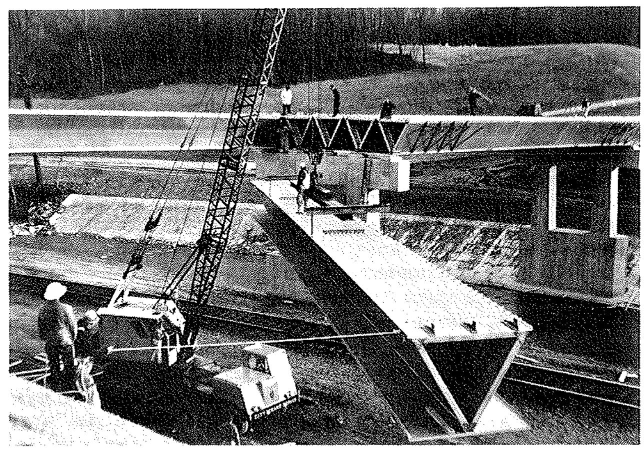

FIGURE 4 Erection of cell beam on Sykesville bridge.

The estimated traffic count in 1983 was 6,100 vehicles per day, up from 4,800 vehicles per day in 1980. The region is rural; average annual temperatures vary from plus 100°F to minus 5°F. Road salt is used over a 3-month winter period to handle an average snowfall of 22.5 in.

The aluminum beams were reported to be in good condition with no repairs necessary although there is some visible corrosion including discoloration at the longitudinal joints connecting the bottom plates. Steel bearings are rusted. The slab is constructed of lightweight concrete with a bituminous wearing surface that has been patched at the joints. Spot repairs to the concrete deck are anticipated. The effect of road salt leaching through the deck awaits coring data to determine if there has been any effect on the aluminum.

Appomattox, Virginia, Bridge

The Appomattox bridge also employs semimonocoque triangular beam girders, but its details are worth studying because they differ somewhat from those used in the triangular beam bridges in Maryland and New York (Figure 5). Located on Route 36 over the Appomatox River in Chesterfield County, Virginia, the bridge has a single span of 100 ft 4 in. and, due to clearance restrictions, a depth of 4 ft 10

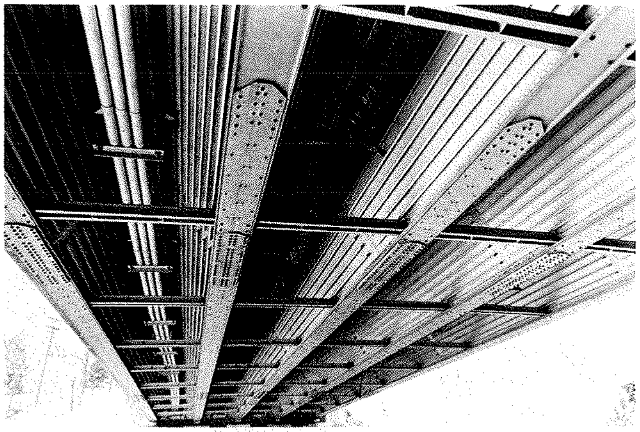

FIGURE 5 Aluminum superstructure of Appomattox River bridge.

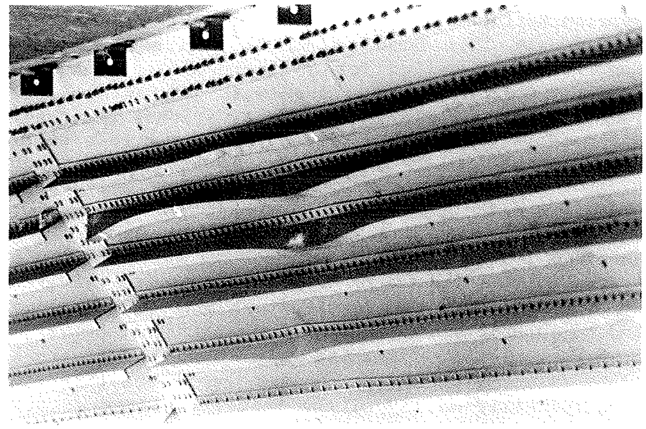

FIGURE 6 Appomattox River bridge: stiffeners damaged by flood debris.

in. This provides a span-to-depth ratio of 20.7 to 1, which is somewhat higher than that of most other bridges in this survey and results in minor vibrations when a heavy vehicle crosses the structure. Clear width of the roadway is 28 ft. AASHTO design load is H20 and HS15. Alloy 6061-T6 was used for all sheets, plates, extrusions, and rivets; connectors include aluminum AN5 and AN10 bolts and rivets. The bridge was designed by Hayes, Seay, Mattern & Mattern, Roanoke, Va., fabricated by the Reynolds Metals Company, and erected by the Sanford Construction Company in 1961.

Unlike the other triangular bridges, there are no continuous lower plates so the girders are open on their underside. Exterior longitudinal stiffeners reinforce the side sheets of the triangular beams; there are also interior stiffeners. There is provision for jacking the bridge to service bearings.

The estimated average number of vehicles per day is 8,050; 95 percent of these vehicles are automobiles and light trucks and the remainder are heavy vehicles. The bridge is located in an industrial region. Road salt is used, as required, over a 5-month period each year.

The structure is reported to be in good condition. The condition of individual aluminum components such as flange extrusions, side sheets, diaphragms, stiffeners, and connector plates is reported to be good but with slight pitting. The aluminum has taken on a typical rough granitelike appearance. Cadmium plated steel bolts and nuts are rusted and steel bearing plates and rocker assemblies need painting.

The longitudinal stiffeners of the upstream fascia girder have been bent by pounding from large timbers, power poles, and other large flood debris (Figure 6), but no structural repair has been required. There has been no adverse reaction between the aluminum structure and the concrete deck. The condition of the roadway surface is classed as fair with about 20 square feet spalled.

SPECIFICATIONS, DESIGN DATA

Current aluminum specifications available to bridge designers include aluminum chapters in both AASHTO Standard Specifications for Highway Bridges and AASHTO Standard Specifications for Support for Highway Signs, Luminaires and Traffic Signals. The Aluminum Association's Specification for Aluminum Structures or Specifications for Aluminum Bridge and Other Highway Structures are referenced in both cases. In 1983 the American Welding Society (AWS) published the first edition of AWS D1.2 Structural Welding Code--Aluminum. This code was approved by AASHTO in 1983.

Aluminum Standards and Data provides detailed information on nomenclature, product forms, mechanical and physical properties, fabricability, dimensional tolerances, and so forth for a wide variety of alloys. Additional design information is also available in Commentary on Specification for Aluminum Structures. These publications are available from the Aluminum Association, Inc., Washington, D.C.

SUMMARY

This 1983 inspection revealed that no painting or other major maintenance has been required for the aluminum superstructure of the seven bridges studied. Fascia girders of two of the bridges have been hit but the only repair required was grinding out a notch on the flange of one beam. The satisfactory performance of concrete decks and aluminum superstructures continues to verify the validity of the design principles, specifications, details, fabrication, and erection practices used initially. No fatigue cracking was reported for any of the riveted structures, and the type of fatigue cracking found in the one welded aluminum structure could be avoided in future bridges by modifications in fabrication and design.

The life of a typical bridge is expected to be at least 50 years although there are obvious exceptions. Based on an estimated total traffic count of 1 billion vehicles, an average of 114,000 vehicles have traveled across the aluminum Long Island, N.Y., bridges each day since they were opened to the traffic in 1960. This billion-vehicle performance represents a life expectancy of at least 50 years for similar aluminum bridges if the lifetime average daily traffic count is 55,000 vehicles rather than the 140,000 carried by the Long Island superstructures.

In addition, the premium for aluminum bridges appears to be narrowing according to studies made by Andrews and Clark Consulting Engineers in 1960 and in 1984. In 1972, in a paper entitled "Aluminum Bridges--An Evaluation," presented to a combined meeting of the American Society of Civil Engineers and the Engineering Institute of Canada, John Clark of Alcoa concluded: "In the main, it has been shown that aluminum in bridges give trouble-free, maintenance-free service--up to 28 years in the examples cited."

Ten years later, the 1983 survey of these same bridges leads to a similar conclusion. On the basis of engineering applicability, aluminum is now a proven material for bridge construction. Any initial cost premium is more than justified by low maintenance and long life.

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Finite-Element Load Distribution Factors for Multi-T-Beam Bridges

PATRICK R. REISNOUR and FAHIM A. BATLA

ABSTRACT

In this paper the determination of the lateral distribution of wheel loads on multi-T-beam bridges using the finite-element method is presented. The results are compared with existing applicable AASHTO specifications and other methods found in the literature. The evaluation of lateral wheel load distribution is of importance because of the significance of the localized effects of wheel loads on stresses and deflections of individual T-beams and must be determined with sufficient accuracy. It is found that significant differences exist in wheel load distributions determined using applicable specifications and other methods compared with distributions determined using the finite-element method of structural analysis.

The use of precast concrete components for the construction of multi-T-beam bridge superstructures with short to medium span lengths is increasing because of the ease of construction and relative economy associated with this type of superstructure. Because of the complexity of the behavior of multi-T-beam superstructures, the bridge engineer must often rely on design aids to avoid the complicated mathematical procedures of a rigorous analysis. These design aids should be simple to use yet lead to sufficiently accurate designs.

For bridges with short to medium spans, considerable emphasis must be placed on the calculation of stresses and deflections due to wheel loads. This emphasis is necessary because the local effects of these loads are of considerable significance in comparison with those effects caused by the other loads on the superstructure that are better distributed both longitudinally and transversely. Therefore the lateral distribution of wheel loads on multi-T-beam superstructures must by determined with a considerable degree of accuracy.

In this paper a comparison of factors used for the lateral distribution of wheel loads on nonskewed multi-T-beam superstructures obtained by several methods is presented. The load distribution factors that are based on existing design aids and other methods are compared with distribution factors determined using modern techniques of structural analysis based on the finite-element method. In the finite-element method, T-beam-type or similar structural systems are represented as an assemblage of plate finite elements and the overall behavior of the structure is then represented by the interaction of in-plane and out-of-plane plate deformations of the plate elements.

A multi-T-beam bridge superstructure is constructed by placing single-, double-, or multiple-stem T-beams side by side on the supports (Figure 1). In this investigation the flanges of adjacent T-beams are assumed to be connected throughout the length of the superstructure in a manner that provides full transfer of transverse shear and bending moments between the beams. The behavior of a multi-T-beam superstructure can be represented as the interaction of the longitudinal bending, transverse bending, and torsional behaviors of the superstructure (Figure 2). These individual aspects of the overall behavior of the structure are in turn dependent on structural parameters such as span lengths and thickness of the flanges and stems. The distance between the stems, width of the superstructure, depth of the stems, and position of wheel loads also affect the behavior of the superstructure. The parameters, which influence the distribution of wheel loads, that are varied in this study include

1. Span length,
2. Width of the superstructure,
3. Depth of the superstructure,

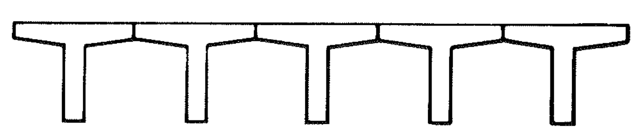

FIGURE 1 Cross section of multi-T-beam superstructure.