A survey on the status of use, problems, and costs associated with Integral Abutment Bridges

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Abstract: Integral abutment bridges provide an excellent alternative to conventional bridges built with bearings and expansion joints. Integral abutment bridges incur lower construction and maintenance costs compared to conventional bridges. In addition, they have a longer service life and a superior seismic performance compared to conventional bridges. Because of their advantages over conventional bridges, forty-one states are now using integral abutment bridges. However, despite their wide acceptance by state transportation agencies and the engineering community in general, use of integral abutment bridges for long bridges and in situations that involve complex structural and soil conditions is still limited. This paper presents the findings of a survey conducted in 2009 by the University of Maryland at College Park that focused on state integral abutment bridge practices. The paper summarizes the responses received from the states with regard to the status of use, problems, and costs associated with the use of integral abutment bridges in their states.

CE Database subject headings: Bridges; Bridge abutments; Bridge design; Bridge decks; Joints; Cracking; Construction costs; Maintenance costs.

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Introduction

Early bridge structures were designed as a series of simply supported structures. With the introduction of the Moment Distribution Method in 1930, structural engineers began to design bridges as continuous structures. As a result, it became possible to construct longer bridges. Problem is, concrete bridge decks experience expansion and contraction as a result of exposure to the environment and the imposition of loads. Consequently, there’s a need to provide deck joints in order to accommodate deck expansion and contraction without compromising the structural integrity of the bridge.

Unfortunately, the introduction of deck joints creates many problems to bridge owners. Joints are expensive to buy, install, maintain, and repair. Repair costs are high. Besides, joints leak over time, allowing deicing chemicals to attack the girder ends, bearings, and supporting reinforced concrete substructures. The result is corrosion and deterioration of girders, bearings, and substructure. Bearings are also expensive to buy and install and more costly to replace. Over time steel bearings tip over and seize up due to loss of lubrication or buildup of corrosion. Elastomeric bearings can split and rupture due to unanticipated movements. Because of these problems, it is necessary to continuously inspect, maintain, and periodically replace the joints. In a nutshell, use of expansion joints and bearings to accommodate thermal movement does not alleviate maintenance problems.

Integral abutments eliminate the need to provide deck joints. In addition, they can save bridge owners a considerable amount of money, time and inconvenience compared to conventional abutments. Because of these reasons, states began building integral abutments. Colorado was the first state to build integral abutments in 1920. Massachusetts, Kansas, Ohio, Oregon, Pennsylvania, and South Dakota followed in the 1930s and 1940s (Kunin and Alampalli 1999), Burke (1990). California, New Mexico, and Wyoming built integral abutment bridges in the 1950s. With the National Interstate Highway System construction boom in the late 1950s and mid-1960s, Minnesota, Tennessee, North Dakota, Iowa, Wisconsin, and Washington began moving toward continuous bridges with integral abutments, as standard construction practice. A testament of their excellent performance over the years is the fact that the current policy of the vast majority of states is to build integral abutment bridges whenever possible. This is confirmed by the results of this survey, which indicates that forty-one states are now using integral abutment bridges. The use of integral abutment bridges over the years is illustrated in Fig. 1.

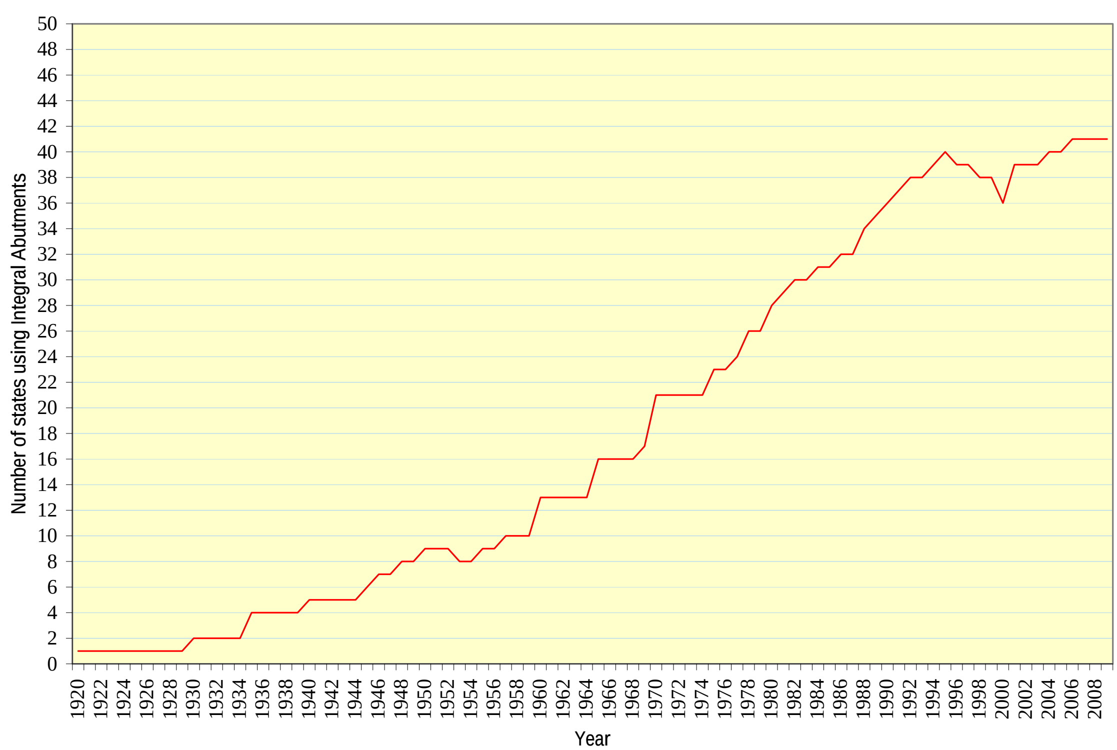

Fig. 1. Evolution of integral abutment bridges in the United States

However, problems with integral abutment bridges do exist; the severity and cause of problems differs from state to state. The state responses to the 2009 survey on integral abutment bridges conducted by the University of Maryland are shown in tables 1, 2, and 3. This paper focuses on the responses on the following three issues: (1) status of use of integral abutment bridges, (2) problems associated with integral abutment bridges, and (3) construction and maintenance costs of integral abutment bridges compared to conventional bridges. Forty-seven states responded to the survey; Montana, Rhode Island, and South Carolina didn't respond.

Status of use and problems associated with Integral Abutment Bridges

The 2009 survey on integral abutment bridges conducted by the University of Maryland indicates that forty-one states are now using integral abutment bridges. The state of Colorado pioneered the use of integral abutment bridges in 1920 followed by Massachusetts in 1930, and Kansas with Ohio in 1935. Nowadays, eight states; Missouri, Tennessee, California, Iowa, Illinois, Kansas, Washington, and Wyoming have more than 1,000 integral abutment bridges in their inventories. In fact, Missouri has over 4,000 integral abutment bridges and Tennessee over 2,000. Interestingly, the state of Washington having built more than 1,000 integral abutment bridges by the year 2000, they decided to switch to semi-integral abutments.

In addition to being the first state to build integral abutment bridges, the state of Colorado has the longest steel girder integral abutment bridge in the United States with a length of 318 m (1,044 ft) and the longest cast-in-place concrete integral abutment bridge with a length of 290 m (952 ft). The longest precast concrete integral abutment bridge in the United States is built in the state of Tennessee. It has a length of 358 m (1,175 ft).

Table 1 shows the state responses to the issues of (1) status of use of integral abutment bridges, and (2) problems associated with integral abutment bridges

Table 1. Status of use and problems associated with Integral Abutment Bridges

State	Currently Builds Integral Abutment Bridges	Year First Built Integral Abutment Bridges	Reason for Building Integral Abutment Bridges	Problems with Integral Abutment Bridges
Alabama	No	Never		
Alaska	No	1975	Discontinue in 2000 because the combination of a large thermal range in the state along with frozen ground conditions caused problems with their use	First, the thermal ranges can be quite extreme – in the interior regions of the state temperatures range from minus 60 degrees Fahrenheit in the winter to 90 degrees above zero in the summer. Second, foundation issues: Integral abutment bridges accommodate thermal expansion and contraction through the foundation piles rotating or bending in the

				soil. In Alaska, the soils are frozen in the winter, which prevents the piles from rotating. In addition, many of the bridge sites contain soils with boulder or prone to liquefaction. This requires the use of open-ended pipe piles, which tend to be much stiffer than H-piles.
Arizona	No	1975	Discontinue in 1996 because of problems with their use.	Having built 50 bridges, the state of Arizona has decided to discontinue the use of integral abutment bridges because longitudinal movements caused approach slab settlements. This condition required extensive and costly repairs.
Arkansas	Yes	2001	Eliminate deck joints	The state has limited experience with integral bridges with only 30 integral abutment bridges built as of this moment. Because of the small number of integral bridges in service, the state of Arkansas is unable to assess their performance at this point of time.
California	Yes	1950	(1) Lower construction and maintenance costs compared to conventional bridges (2) Better energy absorption for seismic forces.	(1) Need for continuous maintenance of approaches because of settlements at paving notch and along wingwalls. (2) Water intrusion between the abutments and the approaches that causes damages to the approach slab and pavement.
Colorado	Yes	1920	Lower construction and maintenance costs for integral abutment bridges	(1) A few integral abutments exhibit distress at the seat level (2) A few integral abutments exhibit distress at

			compared to conventional bridges.	the interface with the girder (3) A few integral abutment bridges exhibit distress at the connection of the wingwalls to the abutments, (4) Consistent problems with the approach fill when the approach slabs are long, that is, approach slabs having a length of 7.5 m to 10 m, (5) Consistent problems with the approach fill when there are no expansion joints at the ends of the approach slabs (6) Pavement distress at the ends of the approach slabs of longer structures when the approach slabs have no expansion joints at their ends (7) Pavement distress at the ends of the approach slabs caused by a combination of leaking expansion joints at their ends and general approach settlement.
Connecticut	Yes	1995	Savings in both construction and maintenance costs compared to conventional bridges.	The state has built only a few integral abutment bridges so far and reports no significant problems.
Delaware	No	Never		
Florida	No	1989	Discontinue in 1998 because there was no benefit with their use over conventional bridges.	Although the integral abutment eliminated the joint at the abutment, a joint was needed behind the approach slab. In addition, on several occasions, a double approach slab detail with a buried cap between the two slabs was required.
Georgia	Yes	1970	Use only when the situation warrants	No problems with integral abutment bridges.

Hawaii	Yes	2001	Lower construction cost compared to conventional bridges.	No problems with integral abutment bridges.
Idaho	Yes	1970	(1)Eliminate deck joints. (2) Lower construction and maintenance costs compared to conventional bridges.	No problems with integral abutment bridges.
Illinois	Yes	1986	(1)Eliminate deck joints. (2) Lower construction and maintenance costs compared to conventional bridges	No problems with integral abutment bridges.
Indiana	Yes	1978	(1)Eliminate the damage caused by leaking deck joints (2) Lower maintenance costs compared to conventional bridges.	Currently there are no problems with integral abutment bridges. However, in the past, cracking occurred in the deck when the contractor poured the bent and the deck in one pour. This practice is no longer allowed in the state of Indiana.
Iowa	Yes	1965	Lower construction and maintenance costs compared to conventional bridges.	No problems with integral abutment bridges.
Kansas	Yes	1935	(1)Eliminate deck joints and associated problems (2) Lower maintenance costs compared to conventional bridges.	The state reports that when integral abutments were combined in the past with Mechanically Stabilized Earth (MSE) walls, the moments caused the wall to distress. As a result, the Kansas Department of Transportation decided to

				stop using MSE walls with integral abutments. Instead, MSE walls are now combined with semi-integral abutments with apparently no problems.
Kentucky	Yes	1970	Lower construction and maintenance costs compared to conventional bridges.	No problems with integral abutment bridges.
Louisiana	No	Never		
Maine	Yes	1988	Lower construction and maintenance costs compared to conventional bridges.	The state reports that sometimes the 1.75:1riprap slope in front of the abutment slumps over time. This results in only riprap covering the bottom of the abutment. Consequently, there’s a concern that air and water have direct path to the tops of the piles.
Maryland	Yes	1990	(1)Eliminate deck joints (2) Lower maintenance costs compared to conventional bridges.	No problems with integral abutment bridges.
Massachusetts	Yes	1930		No problems with integral abutment bridges.
Michigan	Yes	1991	(1)Eliminate deck joints on superstructure (2)Lower construction costs compared to conventional bridges.	The state reports some pavement distress and occasional substructure distress of integral abutment bridges
Minnesota	Yes	1960	Lower construction and maintenance costs compared to conventional bridges.	Currently there are no problems with integral abutment bridges. However, in the past, there were leakage problems when the approach panel was not

				anchored to the integral abutment.
Mississippi	No	1945	Discontinue in 1953 because of problems with their use.	Expansive soil problems on integral bridges.
Missouri	Yes	1969	(1)Keep open-deck joints to a minimum. (2)Lower construction and maintenance costs compared to conventional bridges.	There are problems in instances when the integral end bents are founded on rock; in this case the abutment beam/diaphragm is designed to slide on a concrete footing. In the likely case that the bridge gets too long and the fill is too rigid, movement is restricted. As a result, the beam/diaphragm may be cracked. In fact, the state of Missouri reports an occasion in which the beam/diaphragm developed cracks and warped as a result of the conditions just described.
Montana	Yes	1970		
Nebraska	Yes	1977		The state reports that when tie rods are not used between wingwalls, wingwalls pull away from abutment causing the fill behind the abutment to spill out.
Nevada	Yes	1978	Lower construction and maintenance costs compared to conventional bridges.	No problems with integral abutment bridges.
New Hampshire	Yes	1992	(1)Have joints away from bridge (2)Lower maintenance costs compared to conventional bridges.	No problems with integral abutment bridges. However, they have difficulty identifying locations that in their opinion are good candidates for integral abutment bridges.

New Jersey	Yes	1988	Eliminate deck joints and reduce construction and maintenance costs.	No problems with integral abutment bridges.
New Mexico	Yes	1955	(1) Proven good performance (2)Eliminate the joint in the deck at the abutments. (3)Lower construction and maintenance costs compared to conventional bridges	The state reports spalling of the abutment diaphragms at expansion bearings when the extruded polystyrene that separates the abutment diaphragm and the abutment cap is not present or is too thin to provide girder rotation. According to New Mexico Department of Transportation, the separation between the diaphragm and cap is needed at expansion abutments to allow girder rotation and prevent spalling of the cap or diaphragm.
New York	Yes	1980	(1)Eliminate deck joints and improve durability (2)Lower construction and maintenance costs compared to conventional bridges	The state reports very good performance. However they note three minor problems: (1) Moderate cracking of approach and deck slabs at the ends of the span. This has been improved by modifying the detail; eliminating reinforcing bars that run continuously through the approach and deck slabs, (2) Some twisting of bridges on high skews, and (3) Unequal deflections of stage-constructed integral bridges; this is taken care by introducing a closure pour in the abutments to allow the deflection from the slab pour in the second stage to be equal to the deflection in the stage-one beams.

North Carolina	Yes	2006	Eliminate deck joints and reduce maintenance	No problems with integral abutment bridges. However, they note a few constructability questions regarding placement of approach fill so that cranes can sit closer to the bridge when setting girders.
North Dakota	Yes	1960	(1)Eliminate deck joints (2)Lower construction and maintenance costs compared to conventional bridges	No problems with integral abutment bridges.
Ohio	Yes	1935	Lower construction and maintenance costs compared to conventional bridges.	No problems with integral abutment bridges.
Oklahoma	Yes	1980	Lower construction and maintenance costs compared to conventional bridges.	According to the state of Oklahoma the only problem with the use of integral abutments bridges is settlement of the approach slabs.
Oregon	Yes	1940	Lower construction and maintenance costs compared to conventional bridges.	No problems with integral abutment bridges.
Pennsylvania	Yes	1946	(1)Speed of construction 2)Eliminate deck joints (3)Lower construction and maintenance costs compared to conventional bridges	No problems with integral abutment bridges.
Rhode Island	Yes	2004		
South Carolina	Yes	2001		

South Dakota	Yes	1948	(1)Eliminate joints in the deck (2)Lower construction and maintenance costs compared to conventional bridges	Currently no problems with the use of integral abutment bridges. However, in the past they had a small bit of spalling at the abutments around girders in some of the early skewed integral abutments with prestressed girders. The problem was eliminated by using some perform around the girders.
Tennessee	Yes	1965	(1)Improve structure efficiency and service life (2)Lower construction and maintenance costs compared to conventional bridges	No problems with integral abutment bridges.
Texas	No	1994	Discontinued because the state of Texas gained no economic or performance advantage over its conventional practice	According to Texas Department of Transportation "The soil conditions in most of Texas are such that drilled shafts or prestressed concrete piling are required. Very few structures, less than 10 percent, have conditions where steel piling and therefore integral abutments could be used. Steel piling is seldom used in Texas due to its cost when compared to prestressed concrete piling. This makes integral abutments uncompetitive from a cost standpoint in Texas geotechnical and bidding environments." However, integral abutment bridges were built on rare occasions in Texas in instances where the site-specifics allowed the use of

				steel H-piling on sandy soil. Although the integral bridges performed well, the state gained no economic or performance advantage with their use over its conventional practice.
Utah	Yes	1984	(1)Improve seismic performance (2)Eliminate deck joints (3)Lower maintenance costs compared to conventional bridges	The state reports that integral abutment bridges are “mostly working really well.” However, they report some pulling away from the backwall of prestressed concrete girder integral abutment bridges. They don’t observe any pulling away from the backwall of steel girder integral abutment bridges. In addition, they observe deck cracking in the vicinity of the integral abutments.
Vermont	Yes	1981	(1)Eliminate deck joints and bearings (2)Lower construction and maintenance costs compared to conventional bridges	No problems with integral abutment bridges.
Virginia	Yes	1982	(1)Eliminate deck joints (2)Lower construction and maintenance costs compared to conventional bridges	Currently there are no problems with integral abutment bridges because the state was able to successfully solve a number of problems with their integral abutment bridges (1) Rotations of skewed integral abutment bridges induced by soil-structure interactions; the rotations are now resisted by providing a “buttress force” in a variety of ways, and (2) Cracking of the approach

				slab; the problem was dealt by changing the approach slab connection detail. The original connection consisted of straight bars that extended from the deck into the approach slab in the plane of the top mat of reinforcement. When settlements occurred (as would be expected when an approach slab is used), the approach slab acted as a cantilever and cracking occurred at the ends of the connection bars. The connection detail was changed so that the reinforcing bars pass through the point of rotation, thereby allowing the rotation of the approach slab, while maintaining the connection.
Washington	No	1965	Discontinue in 2000 and switch to semi-integral abutment bridges In their view, semi-integral abutments are more economical than integral abutments. They also allow the structure to move during a seismic event, which results in reduction of seismic forces.	
West Virginia	Yes	1994	(1)Eliminate abutment joints and associated problems when joints leak	Shortly after construction, many West Virginia integral abutment bridges exhibit cracking at the ends of their approach slabs when

			(2)Lower construction and long-term maintenance costs compared to conventional bridges	nominal thresholds are exceeded.
Wisconsin	Yes	1960	(1)Avoid deck joints, which may leak and damage the substructure (2)Lower construction and maintenance costs compared to conventional bridges	No problems with integral abutment bridges.
Wyoming	Yes	1957	(1)Eliminate deck joints (2)Lower construction and maintenance costs compared to conventional bridges	No problems with integral abutment bridges.

Costs associated with Integral Abutment Bridges

The 2009 survey on integral abutment bridges conducted by the University of Maryland also addresses the issue of costs associated with the use of integral abutment bridges. Tables 2 and 3 show the state responses to the issues of construction and maintenance costs of integral abutment bridges compared to the costs of construction and maintenance of conventional bridges.

Table 2. Comparison of construction costs between integral abutment bridges and conventional bridges

Construction Cost	State	Number of States
Integral abutment bridge construction costs lower compared to conventional bridges	California, Colorado, Connecticut, Hawaii, Idaho, Illinois, Iowa, Kentucky, Maine, Michigan, Minnesota, Missouri, Nevada, New Mexico, New York, North Dakota, Ohio, Oklahoma,	27

	Oregon, Pennsylvania, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, Wyoming	
Integral abutment bridge construction costs higher compared to conventional bridges	Arkansas, Georgia, Maryland, Nebraska, Utah	5
Integral abutment bridge same construction cost as conventional bridges	Indiana, Kansas, New Hampshire	3
No response to the question or survey	Massachusetts, Montana, New Jersey, North Carolina, Rhode Island, South Carolina	6
Do not use integral abutment bridges	Alabama, Alaska, Arizona, Delaware, Florida, Louisiana, Mississippi, Texas, Washington	9

Table 3. Comparison of maintenance costs between integral abutment bridges and conventional bridges

Maintenance Cost	State	Number of States
Integral abutment bridge maintenance costs lower compared to conventional bridges	Arkansas, California, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Minnesota, Missouri, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Utah, Vermont, Virginia, West Virginia, Wisconsin, Wyoming	32
Integral abutment bridge maintenance costs higher compared to conventional bridges		0
Integral abutment bridge same maintenance cost as conventional Bridges	Georgia, Hawaii, Nebraska	3

No response to the question or survey	Massachusetts, Michigan, Montana, North Carolina, Rhode Island, South Carolina	6
Do not use integral abutment bridges	Alabama, Alaska, Arizona, Delaware, Florida, Louisiana, Mississippi, Texas, Washington	9

Summary of Responses

The responses to the survey indicate that forty-one states are using integral abutment bridges and nine states don't use integral abutment bridges. Out of the nine states that do not use integral abutment bridges, three states (Alabama, Delaware, and Louisiana) never used integral abutments, three states (Alaska, Arizona, and Mississippi) discontinued their use due to serious problems, and three states (Florida, Texas, Washington) discontinued their use either because they realized no performance advantage over their conventional practice (Florida, Texas) or they concluded that semi-integral abutments offer more advantages compared to integral abutments (Washington). The status of use of integral abutment bridges is illustrated in Fig. 2

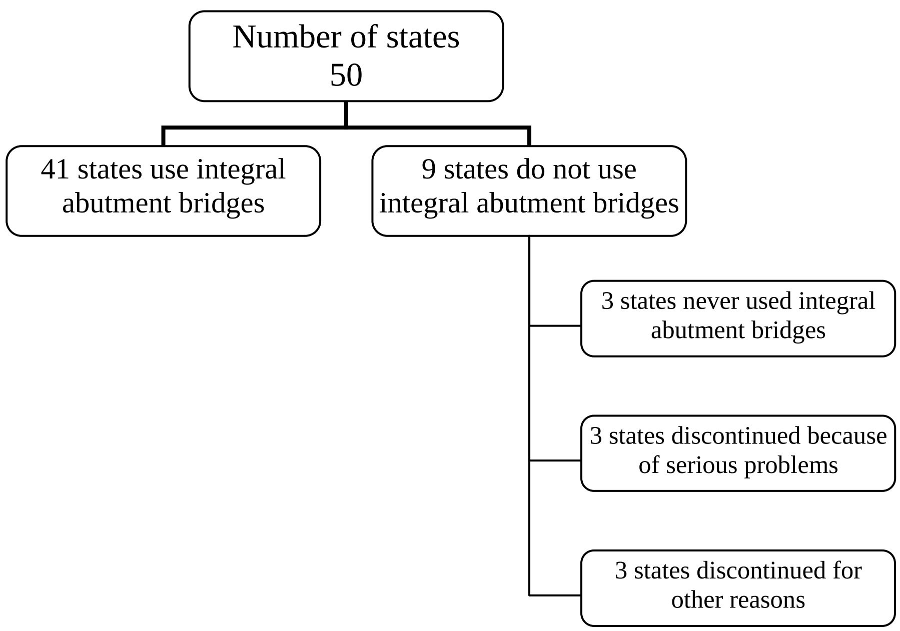

Fig. 2. Status of use of integral abutment bridges

The responses also indicate that twenty-five states have no problems with the use of integral abutment bridges. In addition, twelve states (California, Colorado, Maine, Michigan, Missouri, Nebraska, New Mexico, New York, North Carolina, Oklahoma, Utah, West Virginia) report either minor or moderate problems with the use of integral abutment bridges. Four states (Indiana, Kansas, South Dakota, Virginia) had moderate problems with integral abutment bridges in the past; they found a solution to their problems and report no problems at this moment. However, three states (Alaska, Arizona, and Mississippi) had serious problems with integral abutment bridges; as a result, discontinued their use. The status of problems with integral abutment bridges is illustrated in Fig. 3.

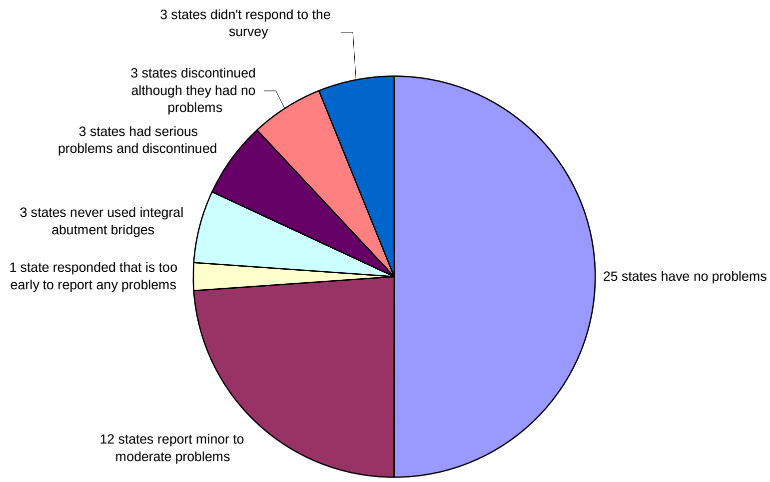

Fig. 3. Status of problems with integral abutment bridges

The responses with regard to the issue of construction costs of integral abutment bridges compared to conventional bridges indicate a lower construction cost in twenty-seven states, higher construction cost in five states (Arkansas, Georgia, Maryland, Nebraska, Utah), and same construction cost in three states (Indiana, Kansas, New Hampshire). The status of comparative construction costs of integral abutment bridges and conventional bridges is illustrated in Fig. 4.

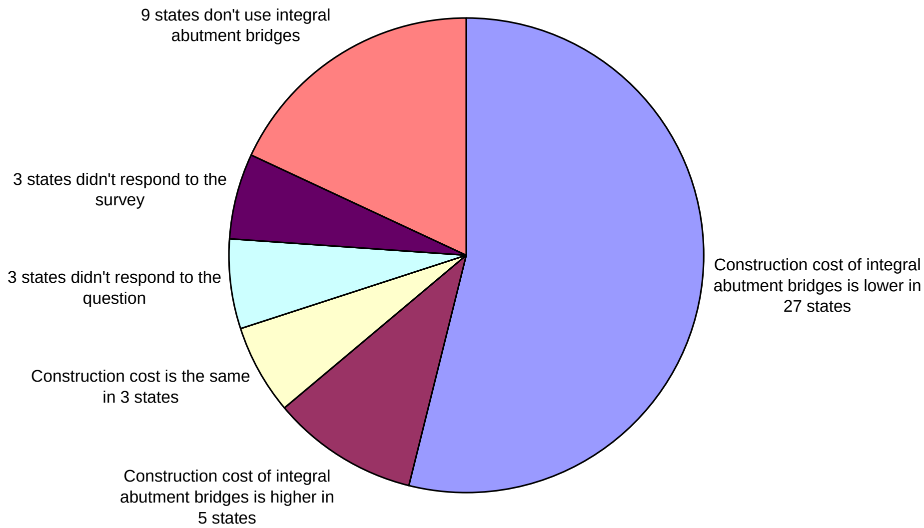

Fig. 4. Status of comparative construction costs of integral abutment and conventional bridges

The responses with regard to the issue of maintenance costs of integral abutment bridges compared to conventional bridges indicate a lower maintenance cost in thirty-two states, and same maintenance cost in three states (Georgia, Hawaii, and Nebraska). Not surprisingly, no state reports a higher maintenance cost with the use of integral abutment bridges. The status of comparative maintenance costs of integral abutment bridges and conventional bridges is illustrated in Fig. 5.

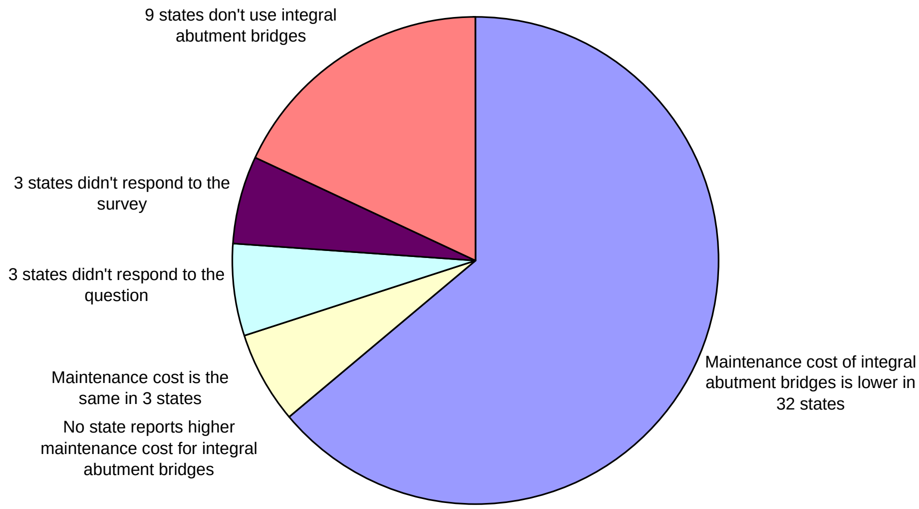

Fig. 5. Status of comparative maintenance costs of integral abutment and conventional bridges

Conclusions

The obvious conclusion coming out of the responses to this survey is that the vast majority of states use integral abutment bridges. In fact, forty-one states use integral abutment bridges. In addition, the number of integral abutment bridges, both statewide and nationwide, increased considerably in the last few decades. Eight states have more than 1,000 integral abutment bridges; among them, Missouri with more than 4,000 and Tennessee with more than 2,000 integral abutment bridges. The responses received from the state departments of transportation confirm the fact that use of integral abutment bridges almost always results in lower bridge maintenance costs compared to conventional bridges. The responses also confirm that in the vast majority of states, the construction cost of building integral abutment bridges is lower than the construction cost of building conventional bridges.

In addition, most states report no problems with integral abutment bridges; a limited number of states report minor to moderate problems with the use of integral abutment bridges. Interestingly, a number of states that previously had problems with integral abutment bridges were able to come out with a solution to these problems. As a result, they report no problems with the use of integral abutment bridges at this moment.

However, it is very important to recognize that many problems are avoided because integral abutment bridges are built within the limitations imposed by the design parameters outlined in each state's Bridge Design Manual. These design limitations prohibit the use of integral abutments for long bridges and in situations that involve complex structural and soil conditions. In addition, there are limitations on skew, curvature, and type of piles to name a few. Apparently, more research on integral abutments is needed in order to advance the use of integral abutment bridges. Research that predicts the behavior of integral bridges based on theory, rather than empirical evidence. In turn, this will lead to the introduction of national guidelines for integral abutment bridges, which will provide legitimacy to this cost-effective method of bridge construction. The current absence of such a document acts as a deterrent to the use and further advancement of integral abutment bridge construction.

Acknowledgments

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