Underwater Inspection of Bridges—Overview of a Statewide Program

R. RICHARD AVENT AND MARSHALL D. WHITMER III

A comprehensive statewide underwater bridge inspection program was conducted for the state of Mississippi. A total of 229 bridges on the federal-aid system were inspected. An overview of the inspection program is presented. The average number of bents or piers inspected per bridge was four, excluding four long bridges that averaged 235 bents or piers each. The type of inspection equipment, inspection methodology, and evaluation process used are described. The inspections were conducted by two three-man commercial diving teams under the on-site direction of a professional engineer. Before the project, the divers were required to take a 1-week course on bridge inspections that included a field dive. The overall condition of the underwater portions of the bridges on the federal-aid system was good. Less than 10 bents or piers out of nearly 1,900 inspected needed immediate attention. Only 6 percent were found to require remedial action over the next several years. Although a few scour problems were found, none were serious enough to immediately threaten the integrity of a bridge. To assist agencies in preparing for underwater bridge inspections, a method of rating six important aspects is given. This system would allow an agency to estimate the success of a proposed inspection process in terms of effectiveness as compared with cost.

The highway department of the state of Mississippi initiated a comprehensive underwater bridge inspection program in the spring of 1988. The program called for the inspection of all underwater portions of bridges on the federal-aid system from waterline to mudline. A total of 229 bridges was included in the inspection. An overview of the program is provided.

The Mississippi highway department is divided into six districts in terms of bridge inspection, maintenance, and rehabilitation. Under the supervision of the Bridge Division of the Mississippi State Highway Department (MSHD), each district has its own inspection teams that inspect the above-water portions of bridges on a regular basis. Inspections occur in 2-year intervals unless conditions of damage require more frequent inspections. In addition, each district has crews capable of providing maintenance and repair for routine damage. However, damage beyond the district's capability is handled by contract.

The approach used by MSHD was to have each district provide a list of bridges to be inspected underwater. The selection criteria were based on whether the underwater portions of the bridge could be inspected by the district inspection crews. Any bridge that did not allow for a dry season or shallow-water inspection by the state was included in the program. From a practical viewpoint, all bridges with a low water depth greater than 3 to 4 ft were included. Hardly any of these bridges had ever been inspected underwater. Figure 1 shows a state map detailing the location of all bridges and districts. Characteristics of the rivers and bridges can also be observed from the map. District 1 is characterized by flat to rolling terrain with relatively small streams and rivers. One exception is the Tombigbee River that runs north to south through much of the district and is large enough for navigation in points. However, several years ago the Tennessee-Tombigbee Waterway was built, connecting the Tombigbee River to the Tennessee River through a canal with a series of locks and dams to create a navigable waterway from Tennessee to the Gulf of Mexico. The flow patterns and water levels of this river have changed significantly since completion of the waterway. Forty-seven bridges were inspected in this district. District 2 consists of terrain ranging from flat near the Mississippi River to rolling terrain over the majority of the district. There are few large rivers and, consequently, relatively few bridges with underwater bents or piers. Only 20 bridges were inspected in this district.

District 3 includes much of the flatlands of the Mississippi delta. Several large rivers run through the district as well as a number of smaller streams. Forty-one bridges were inspected in this district. There is no District 4. District 5 consists of rolling terrain with some major rivers. Of particular interest is the Pearl River that flows south and eventually into the Gulf. The river serves a large drainage basin in the district and is known for its heavy flows and flooding. Twenty-eight bridges were inspected in this district. District 6 includes a number of large rivers and the entire Mississippi Gulf Coast. It has the longest and largest number of bridges. A total of 78 bridges were inspected including 4 that had more than 100 bents. District 7 has few rivers and streams and only five bridges were inspected in this district. However, one bridge is worth noting—the bridge at Natchez across the Mississippi River.

The inspections began on May 16, 1988; all inspections were completed by October 16, 1988. The state had district representatives at the site during all inspections.

DIVING PROCEDURES

The diving inspection teams were headed by a registered professional engineer who was also a trained diver. This engineer was present at the site during inspections. The engineer generally dove personally to inspect any serious problems encountered. However, most of his time was spent monitoring the inspections from the surface.

Two dive teams were used simultaneously. Each team consisted of two divers and a tender. One diver performed the

R. R. Avent, Civil Engineering Department, Louisiana State University, Baton Rouge, La. 70808. M. D. Whitmer III, Diving Services International, Inc., Hammond, La. 70804.

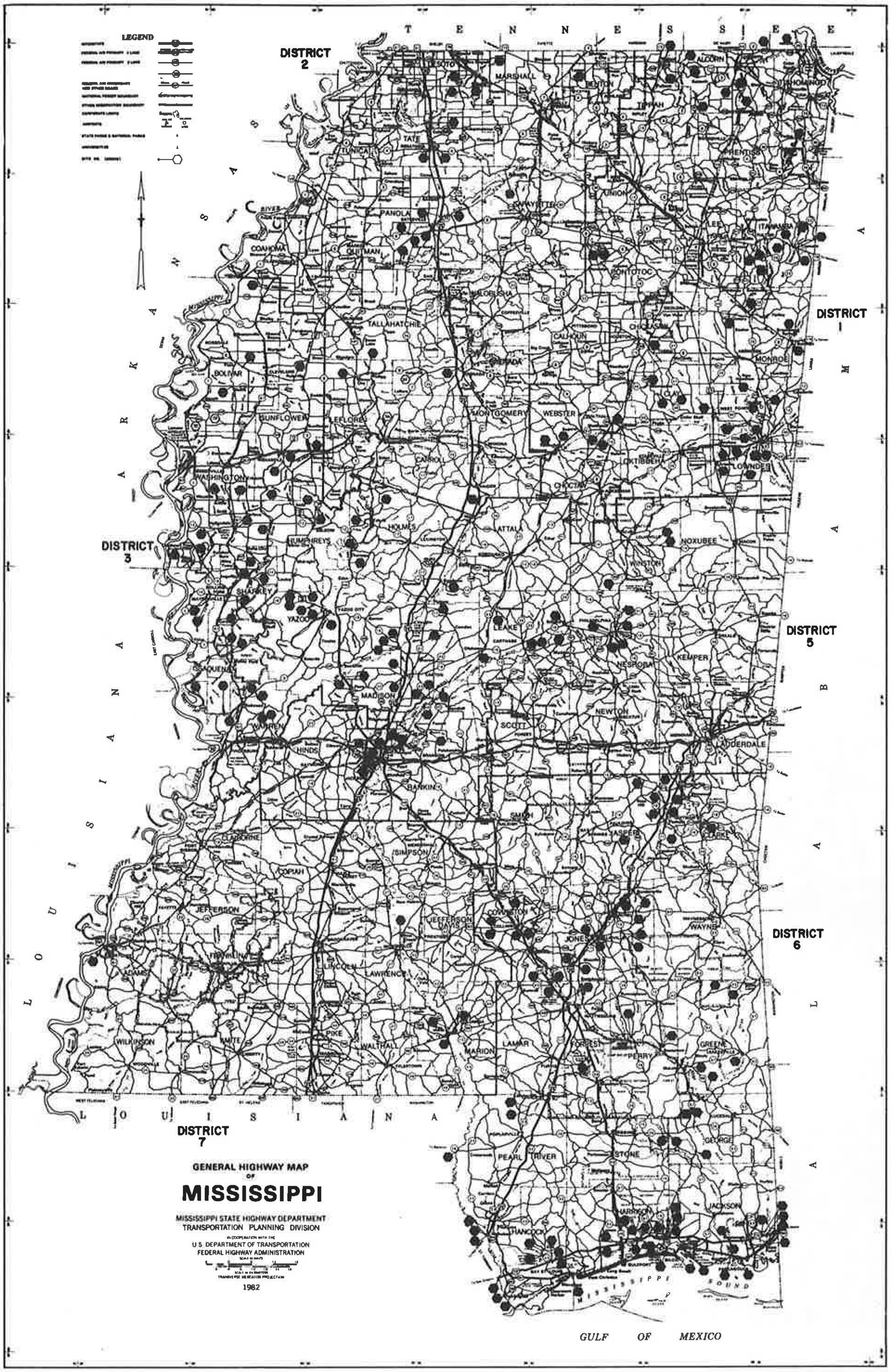

FIGURE 1 Location of bridges inspected.

actual inspection, while the other recorded the findings at the surface. The tender's responsibility was to maintain equipment and service the diver during a dive. The professional engineer alternated between the two dive teams as they moved from bridge to bridge.

The dive teams used commercial diving equipment. A compressor provided surface air to the diving hats. Two-way communication was maintained at all times through a communication line. A volume tank provided a reservoir of air and was connected with a pneumo tube that enabled the diver to measure water depths. The diver was equipped with various hand tools for inspection including a light, scraper, knife, calipers, incremental borer used for timber piles, and rule. In general, access to the bents or piers was from a motor launch. For some of the small streams, the access was from the shore. An outfitted diver and the launch equipment are shown in Figures 2 and 3.

The divers used for inspections were experienced commercial divers, particularly in offshore construction work, and also had some bridge inspection experience. In order to familiarize the divers with the requirements of the bridge inspection program, a two-part training program was developed. The program consisted of 18 hr of in-class instruction and a 1-day field dive for a bridge inspection. Also, during the course of actual inspections, a weekly review session was held to ensure continued consistency in the inspection approach.

FIGURE 2 Outfitted diver entering water.

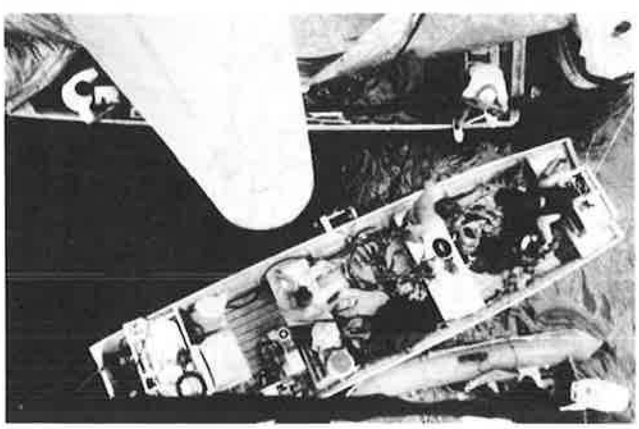

FIGURE 3 Aerial view of typical launch with three-man crew.

The specific items included in the inspection were

- inspection of steel, concrete, timber abutments, piers, pilings, fenders, and dolphins;
- identification of scour patterns in the stream bed adjacent to the foundation elements;
- identification and description of any cracks or erosion of concrete piers and abutments;
- identification and measurements of any voids beneath footings and abutments including a description of exposed piling;
- identification and description of any damage to the substructure that may have been caused by ship or barge collision or debris;
- description of piling on all pile-supported structures;
- identification and description of the condition of any pile protection, and
- identification of both location and description of condition of underwater power cables for any movable bridge.

A hands-on inspection was conducted of each bent or pier from waterline to mudline. For piles, each face was inspected from top to bottom in sequence. Visual inspections were not possible on many of the bridges because of muddy waters. So the inspection was done by feel. In addition to a hand inspection, a sharply pointed probe was also used to detect cracks, and dimensions were taken on all damaged sections found. Calipers were used to measure the flange thickness of steel piles, hammer soundings were used for concrete and timber piles, and a rule was used to measure damage to other types of bridge supports. Suspect timber piles were also cored with an incremental borer. For piers, the surface was inspected in 5-ft-wide vertical sections successfully moving around the perimeter of the pier.

In addition to the structural inspection, a bottom inspection was conducted to uncover evidence of scour. Depth elevations were taken at each pile of each bent. For piers, depths were taken around the perimeter. Depths were also taken 10 ft out from each bent or pier in each compass direction. If evidence of scour was found, additional depths were taken at 20 ft out. In cases where the scour could not easily be defined, a fathometer study was also conducted.

EVALUATION AND RATING

One of the key elements for reporting the inspection results was the bridge inspection and condition report form. A number of evaluations and rating schemes were reviewed for use in this project. The selected system is based on one used by the state of New York with some modifications. Each separate submerged structural element of the bridge was individually rated, as well as the overall unit. Elements typically identified were columns, footings, seals, piles, caps, and bracing. The overall unit was typically classified as pier, bent, or abutment. Fendering systems were classified as dolphins or bulkheads.

A numerical rating was used for the condition assessment with both the elements and the unit rated. The general rating scale was based on a 1 to 7 scale as follows.

1. Hazardous structure—The structure has lost practically all capacity to sustain the original design loads.
2. Potentially hazardous—Used to shade between a rating of 1 and 3.
3. Serious deterioration—The structure can no longer achieve its full original design capacity, while still maintaining the ability to react in a partially elastic manner retaining some degree of its original load-carrying capacity. However, extensive and serious material deterioration exists.
4. Major deterioration—Used to shade between ratings of 3 and 5.
5. Moderate deterioration—Isolated areas of light-to-moderate deterioration but not to the degree where there is any significant effect on the structure's ability to perform near the full original design capacity.
6. Minor deterioration—Used to shade between a rating of 5 and 7.
7. Undamaged—No evidence of decay or deterioration exists and the structure is performing at full design capacity.

These criteria were used for 26 rating categories under four headings: general, concrete and masonry, timber, and steel. A detailed summary of how the rating criteria were applied in each category is given in the Appendix.

The ratings were recorded on the bridge inspection and condition report form shown in Figure 4. Although the inspection divers gave a preliminary rating, the final rating was given by the professional engineer after reviewing the field reports.

The other key element for reporting the inspection results was the diving inspection report. This report consisted of a running account of the diver's description of each element inspected. A sketch showing both a plan and an elevation was made of each pier, bent, or abutment inspected. For cases in which significant damage was found, a tape recording of the dive was made. Additional elevations or detail sketches were made as needed. A file of typical pier and bent types was produced using a computer-aided drafting (CAD) system. The diving team used the CAD drawings as applicable and produced hand sketches for atypical cases.

Key factors were recorded on the drawings or in accompanying notes. Specific items noted were bridge deck surface-to-waterline distance; depth from waterline to mudline at all piles, around piers and abutments, and 10 ft to each side of all elements; location, size, and depth of spalls and holes in

Date: ______________ Year Built: ______________ Bridge ID No: ______________

Feature Crossed: ______________ Feature Carried: ______________

												General											Concrete/Masonry								Timber				Steel		
BENT/PIER/ABUTMENT			UNIT NUMBER			UNIT DESCRIPTION						VOIDS	HOLES	IMPACT DAMAGE	LOSS OF SECTION	DISPLACEMENT	MISSING ELEMENTS	PREVIOUS REPAIRS	SCOUR/EROSION	LOSS OF FILL	MARINE GROWTH	DEBRIS	CRACKS	SPALLS	EXPOSED REINFORCING	LAITNT CONCRETE	SULPHATE ATTACK	HONEYCOMBING	RUST SPOTS	GROUT LOSS IN MASONRY	SPLITTING	MARINE BORERS	ROT	FASTENERS	DETERIORATION	CONNECTIONS	UNIT RECOMMENDATIONS
20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57

Remarks:

REVIEWED BY: ______________
TITLE: ______________
DATE: ______________

FIGURE 4 Underwater bridge inspection rating form.

concrete and steel; location, length, width, and depth of all cracks or breaks in concrete, steel, or timber; degree of section loss in corroded steel elements; degree of scaling on concrete surfaces; degree of checking on timber surfaces; level of decay (including core samples if necessary) for timber elements; misalignments or displacements; missing elements; details of previous repairs; description of scour or erosion around elements; level of marine growth; degree of drift and debris buildup; location of exposed reinforcing; location of laitent concrete; location and degree of honeycombing; type and degree of marine borer damage; and fastener deterioration.

These field reports were used by the professional engineer to prepare a final inspection report. A separate report was then prepared for each bridge that included CAD-generated drawings detailing all damage, condition rating forms, evaluation of the seriousness of damage found, and recommended repair alternatives.

SUMMARY OF BRIDGE TYPES INSPECTED

The dominant structural elements inspected were concrete pile bents. However, a variety of different structural systems were also inspected. A summary of the number and type of both bents and piers inspected is shown in Table 1. The largest number of bents were the concrete pile type. However, four long bridges on the Gulf Coast included half of all these bents.

OBSERVATIONS AND RECOMMENDATIONS

Condition Assessment of Mississippi System

The Mississippi system is in good condition overall. A summary of the inspection results is given in Table 1. Fewer than 1 percent of the bents and piers had what can be classified as major damage. Major structural damage refers to damage requiring significant structural repair within 1 year. Examples included timber piles that had completely rotted, buckled steel piling, and fractured concrete piles. In two cases, lane closures were initiated to reduce live loads with repairs immediately following.

Six percent of the bents had moderate damage. These defects require repair over the next several years but do not significantly reduce the structural integrity of the bent. Typical examples include spalls and cracks exposing reinforcing, corrosion of steel elements, and small areas of decay in timber elements.

Two percent of the bents and piers had scour or erosion to the extent that 5 ft or more of the element had become exposed since construction. Scour was not found to immediately threaten the integrity of any structure. However, additional multifrequency fathometer studies have been recommended to further evaluate a few of the more serious cases.

The final assessment given in Table 1 is recommendations for the frequency of future inspections. A recommendation is that an underwater inspection for most bridges be conducted

TABLE 1 SUMMARY OF BENT, PIER, AND ABUTMENT TYPES INSPECTED AND EVALUATION RESULTS

Type	Number of Bents/Piers/Abutments				
	Total Inspected	Repairs Required for Major Structural Damage	Repairs Required for Moderate Structural Damage	Significant Scour	Early Re-inspection Recommended
Bents					
Concrete Pile	1,330 (71%)	0	11 (0.8%)	5 (0.4%)	51 (3.8%)
Timber Pile	193 (10%)	8 (4.1%)	47 (24%)	0	40 (21%)
Steel or Concrete Encased Steel Pile	142 (7.5%)	0	27 (19%)	1 (0.7%)	15 (11%)
Column	58 (3.1%)	3 (5.1%)	10 (17.2%)	14 (24%)	2 (3.4%)
Pier					
Dumbbell	95 (5.1%)	1 (1.1%)	13 (14%)	9 (9.5%)	7 (7.4%)
Hammerhead	19 (1.0%)	0	0	2 (11%)	0
Wall/Solid	36 (1.9%)	0	1 (2.8%)	7(19%)	10 (28%)
Abutments					
Concrete	4 (0.2%)	0	0	0	0
Timber	3 (0.2%)	0	2 (67%)	0	0
Steel	1 (0.05%)	0	0	0	0
Total	1,881	12 (0.6%)	111 (5.9%)	38 (2.0%)	125 (6.6%)

every 5 years. Depending on the age and degree of deterioration, more frequent inspections should be made. On the basis of these considerations, it was recommended that 7 percent of the bent or piers be reinspected at 1- or 2-year intervals. These reinspections, when compared with the initial inspection, will provide improved guidelines for determining the best frequency for future inspections.

The most important ramification of this statewide inspection was the establishment of a benchmark for the state system's underwater bridge components. Early stages of deterioration were discovered in a number of cases, allowing the opportunity for repair, rehabilitation, and preventive maintenance at a cost-effective stage.

Levels of Inspection

Although above-water bridge inspection procedures are now well established, underwater techniques are not nearly as well defined. The basic problem is visibility. A great deal of underwater bridge inspection is performed in zero or near-zero visibility. Cracks, defects, and misalignments that might be readily apparent above water are often difficult to detect in murky water. Maintaining diver orientation is also difficult. As a partial compensation, the underwater portions of most bridges are simple elements compared with superstructure design. The question arises as to how thorough an underwater inspection should be.

On the basis of experience, significant differences can exist in inspection programs. Some of these differences may be unavoidable, but many are a result of not considering the components that go into an inspection. In addition, an agency may desire to balance inspection costs and level of inspection. To provide some guidance in qualitatively evaluating the level of inspection, six basic underwater inspection characteristics are presented in Table 2. Basic characteristics are inspector qualifications, inspection thoroughness, inspection equipment used, level of record keeping, personnel preparing the final report and evaluation, and diving equipment. Associated with each of these characteristics are three levels of competence or quality. By evaluating the inspection characteristics to be used for a given bridge inspection, a numerical score can be obtained ranging from 18 to 6. The particular weightings assigned here are inessential, but this approach can be used as a general guide in evaluating the overall quality of the inspection. An overall rating of the quality of inspection could be classified as follows:

Inspection Quality Level	*Sum of Numerical Rating from Table 2*
0	5–7
1	8–11
2	12–14
3	15–18

TABLE 2 QUALITY RATING OF UNDERWATER INSPECTIONS

Inspection Characteristics	Numerical Rating		
	3	2	1
Inspector Qualifications	Engineer	Inspector trained diver with engineer at surface	Inspector trained diver
Inspection Thoroughness	Direct visible inspection of all elements	Limited visibility with hands-on inspection of all elements	Visible or hands-on spot sampling
Equipment Used	NDT	Coring/probes	Surface scrapers or hands only
Level of Record Keeping	Detailed sketches, field notes and rating sheets	Limited field notes and rating sheets	Overall rating only
Personnel Preparing Final Report and Evaluation	Engineer	Technician/Draftsman	Secretarial staff
Diving Equipment	Surface supplied air with communication line to surface and video equipment	Surface supplied air and communication line to surface	Scuba

Although subjective, this system allows an agency to evaluate the quality of an underwater inspection proposal. An agency may opt for a lower quality inspection based on such extenuating circumstances as age of bridge, track record of the specific bridge type, usage of bridge, and funds available. However, as the quality level of the inspection is reduced, the risk of missing damage may increase dramatically. To place the Mississippi inspection in perspective, the sum of the numerical ratings from Table 2 range from 14 to 17 placing the quality level at a high 2 to 3. This range occurred because judgment was used at the site by the professional engineer to decide which level of inspection was required. For example, although an engineer trained as a diver was present at the site, he only performed inspections when indications of damage were found. Thus, a rating of either 2 or 3 could be placed for inspector qualifications. Also, limited visibility required hands-on inspection approximately 50 percent of the time, giving a rating of 2 or 3 for inspection thoroughness. Video equipment was also available at the site but was only used when damage was found, given a rating of 2 or 3 on diving equipment.

Of particular attention is the differentiation of diving equipment between surface-supplied air and scuba. Actually, it is not just the equipment, but the training associated with use of the equipment that has prompted this delineation. The training and experience associated with commercial diving is generally greater than that required by scuba. The implication is not that there are not qualified scuba divers, but rather, there is a higher probability that a scuba diver will have less training and experience.

Considerations when Planning Inspections

Several additional aspects should be considered when setting up an underwater inspection program.

1. Drift removal should be an expected expense in many rivers. For the Mississippi job, a separate diving crew preceded the inspection team to remove drift and debris.
2. The need to remove marine growth should be evaluated and included as a cost item in coastal areas. This removal can be quite expensive and must be balanced against the inspection level desired.
3. The qualifications and training of the divers are of primary importance for a competent inspection. Both their training as divers and as inspectors carry equal weight. However, few have training in both. To use commercial divers trained to be bridge inspectors would be more effective than to train bridge inspectors or professional engineers to be divers. Commercial divers are required to have extensive training in all aspects of underwater operations. In addition, much of their experience is related to investigating damage. The additional training as a bridge inspector represents a relatively small step. However, diver training is a major undertaking requiring not just training but significant experience and physical conditioning to be qualified.
4. The time and cost of a bridge inspection will be affected by many aspects, which include the number of bridges to be inspected, cleaning (if necessary), level of inspection, structural type, number of underwater components per bridge, water depth, water current, and drift removal required. The cost of the Mississippi inspection program averaged $1,750 per bridge.

CONCLUSIONS

An underwater bridge inspection program has been described in which 229 bridges were inspected. A summary of the inspection results was presented, indicating that the overall condition of these federal system bridges was quite good. A guide to subjectively rating the quality of an underwater bridge inspection proposal was also given to aid agencies contemplating bridge inspections.

ACKNOWLEDGMENTS

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APPENDIX
Rating Criteria for Underwater Inspection of Bridges

The criteria for rating the conditions of the underwater portions of bridges for the Mississippi bridge inspection program were based on a rating system developed by the highway department of New York State. Each separate bent, pier, abutment, fendering system, or dolphin of the submerged substructure was identified and rated on 26 conditions as shown in the rating form (see Figure 4). In addition, these units were subdivided into individual structural elements (e.g., columns, footings, and piles), and each subunit was also rated.

The overall rating system has been previously outlined in this paper and is based on a numerical scale of 1 to 7 with 7 indicating excellent condition. The purpose of this appendix is to explain how the rating system was applied to specific categories of potential damage. For each category, the criteria are given for numerical ratings of 1, 3, 5, and 7. The even numbers between these ratings are used to shade between the odd-numbered ratings. Rated items are keyed to the rating form numbering as shown in Figure 4 and are classified under four headings: general, concrete and masonry, timber, and steel.

Item 32—Voids

Rating	*Criteria*
1	Given for a condition of massive voids that seriously jeopardize the stability of the unit. Included would be major loss of cross-sectional area, loss of masonry blocks or material, collapse, or settlement due to void-caused failure of a unit support.

Rating	*Criteria*
3	Given for a condition of serious voids that are beginning to threaten the stability of the unit, that are serious enough to warrant repair within the next 2 years, or that reduce the structural capacity of the unit, though not threatening to cause an immediate collapse or a sudden failure.
5	Voids are present, but are relatively minor, with either one major void or several small ones. These voids would not pose a major reduction in cross-sectional area of the unit but could develop into a problem in the future.
7	No voids present.

Item 33—Holes

1	Either a massive hole or many major holes in a unit that seriously jeopardize the integrity of the unit. Collapse of the unit may be possible because of the holes.
3	Major holes in the unit that are either in large enough numbers or large enough in size to significantly reduce structural capacity. The condition would merit monitoring and a probable repair within the next 2 years.
5	Holes are major enough or frequent in occurrence to warrant concern (such as smaller holes with minor loss of fill and no displacement or loss of members), although they do not pose a major threat to the structures.
7	No holes present.

Item 34—Impact Damage

1	Major impact damage with settlement of portions of the unit. The unit does not function as designed. If a fender system, the piles are cracked through or severed and would not protect the structural unit. If a structural unit, major damage exists with possible settlement and failure of the structural unit.
3	Significant impact damage that limits the effectiveness of the unit. In a fender system, this may reflect some cracked and broken piles but no settlement, and protection is still available to the structural unit. In a structural unit, loss of material or fallen blocks may exist, with an obvious condition that would warrant monitoring and possible repair within the next 2 years.
5	Impact damage is present and one or two members have signs of damage, but the unit is not significantly affected. A splintered fender system or cracked members on structural units are examples of this rating.
7	No impact damage present.

Item 35—Loss of Section

1	Extensive loss of section on supporting members of the unit or the substructure of the unit, possibly with signs of collapse or settlement that would require immediate repair. Loss of section may be a combination of several other conditions, but rating under this item should be limited to the actual loss of section condition in the range of 80 to 100 percent.
3	Significant loss of section, possibly allowing some settlement in the next 5 years if uncorrected. The section loss would be between 40 and 60 percent.
5	Minor to moderate loss of section. The unit is not in structural danger, but loss is present and continues. The section loss ranges from 10 to 20 percent.
7	No loss of original cross-sectional area.

Item 36—Displacement

1	Displacement of members of the unit, or the entire unit, that allows continued movement and potential collapse of the unit (e.g., downward crushing of supports due to loss of cross section).
3	Displacement of the unit, or parts of it, that is moderate and does not appear to be capable of continuing.
5	Minor displacement of the unit or portions of the unit that does not appear to be changing and does not pose a serious threat to the stability of the unit.
7	No displacement has occurred.

Item 37—Missing Elements

1	Many missing elements or members or a single missing element or member in a critical location that results in a serious loss of ability to support the unit as initially designed as well as possible settlement and shifting of the unit.
3	Moderate loss of elements or members that does not cause a major effect on the

Rating	Criteria
	structural unit (e.g., the loss of a member of a multimembered fender system).
5	Minor loss of elements or loss of a minor member that does not have a significant effect on the unit's ability to function as designed.
7	No missing elements.

Item 38—Previous Repairs

1	Reflects total failure of the repair to achieve the desired result, allowing the initial deficient condition to continue and increase (e.g., a concrete patch used to stop the undermining of an abutment falls out resulting in a serious and potentially hazardous condition).
3	Reflects partial failure of the repair, but the original condition is partially protected and is not increasing.
5	Repair is deteriorated but is still in place and protecting the original condition.
7	Either the repairs made to the original construction are in excellent condition or no repairs have been made.

Item 39—Scour/Erosion

1	Denotes a major loss of material with the footing exposed and undermined and with pilings, if present, exposed. The diver should be able to reach under the footing and locate piles.
3	Denotes a significant loss of material around the unit, although the pilings are not exposed. The difference in elevations between one end and the other, or between the channel and the unit, is within 4 to 5 ft.
5	Reflects that scour is minor and does not appear to pose a threat to the stability of the unit.
7	No scour activity at the unit.

Item 40—Loss of Fill

1	Major loss of fill resulting in collapse of the ground behind the unit being inspected leading to major settlement to the roadway. Loss of material from the areas is continuing and threatening the unit if not stopped quickly.
3	Significant loss of fill that does not immediately threaten the unit, although there is collapse of soil in the area. Repair suggested within the next few years to avoid future problems.
5	Minor loss of fill without signs of collapse of soil behind the unit being inspected. Probings reveal no major cavities due to missing material.
7	No loss of fill at the unit.

Item 41—Marine Growth

1	Heavy marine growth, with thick growth of 4 to 6 in. or more in the tidal zone and below. Small voids could not be noted in the unit without cleaning the surface.
3	Moderate marine growth, with 2 to 4 in. of barnacles, and so forth, in the tidal zone and below. Small voids could be seen without cleaning, but exposed rebar or major cracks might be difficult to detect.
5	Minor growth, with only minimal cleaning actually needed to inspect the tidal zone and cleaning not needed on other areas of the unit.
7	No marine growth on the unit.

Item 42—Debris

1	Extensive amount of debris covers the bottom of the waterway in the area of the unit. Debris in the surrounding area would hinder attempts to excavate for forms, should repairs be needed, and hinders the stream flow.
3	Significant debris located near the unit. Only part of the unit's area has debris.
5	Minor amount of debris around the unit. Much of the debris will be capable of being moved by the diver.
7	No debris around the unit.

Item 43—Cracks

1	Major, deep cracks through the unit, usually combined with displacement of the sections, that cause major concern for structural integrity of the unit.
3	Significant set of cracks, possibly extensive or deep, that do not jeopardize the integrity of the unit to the point of possible failure. Damage may consist of many minor cracks

Rating	*Criteria*
	or a few major cracks that would not be in a critical location.
5	Minor set of cracks that are wide enough and deep enough to note but do not compromise structural integrity. Cracks rated 5 should be larger than hairline cracks.
7	No cracks present in concrete and masonry unit.

Item 44—Spalls

1	Extensive loss of material around reinforcing or at the corner of the unit. Spalling continues around reinforcing allowing the reinforcing to be totally exposed.
3	Loss of concrete at reinforcing bars or at corners. Exposed reinforcing in spalls, possibly with some loss of section. Loss of concrete is structurally significant but does not threaten integrity of the unit to the point of potential failure.
5	Spalling to the extent that reinforcing is exposed but not deteriorated. Loss of material is not yet structurally significant.
7	No spalling present.

Item 45—Exposed Reinforcing

1	Ten or more reinforcing bars exposed, with over 50 percent of each bar exposed. Possibly several bars that are totally exposed for some of the length.
3	Five to nine bars either exposed less than 50 percent or fewer bars that are exposed more than 50 percent, but not for long distances.
5	One to four reinforcing bars exposed with significant exposures or some minor exposure where the bar is just visible for an inch or so.
7	No reinforcing bars exposed.

Item 46—Laitent Concrete

1	The unit consists of over 50 percent laitent concrete, with probings over 1 ft into the material and the strength of the concrete seriously less than the original specifications. Possibly large voids in the material where erosion has occurred. A condition of imminent failure existing because of the unknown quality of the material.
3	The unit has distinct areas of laitent concrete, readily defined and probed back to solid material. The laitent concrete pockets do not pose an immediate threat to the structure, although the condition of the concrete is serious enough to warrant future inspection consideration or remedial work.
5	The unit has a few small pockets of laitent concrete or there is a small layer of laitent concrete on the top of the substructure where a cold joint exists. The unit is not under any structural danger, but the condition does exist.
7	No laitent concrete in unit.

Item 47—Sulphate Attack

1	Extensive sulphate attack has reduced the section of the unit and is actively continuing in the deterioration of the unit.
3	Active sulphate attack with only minor loss of section and the depth of the softer concrete is not more than 1 in.
5	Signs of sulphate attack, although the depth and overall extent of the attack is minor.
7	No sulphate attack of unit.

Item 48—Honeycombing

1	Extensive honeycombing with voids that have loose material and can be excavated by hand. Usually a combination of honeycomb, void, and laitent concrete, with potentially large void that would jeopardize the unit structurally.
3	Honeycombing exists in more than one location or at one major location, although the void caused by honeycombing is not structurally critical.
5	Minor honeycombing exists, although the aggregate is solid in the void with good cement bonding, or the size of the void is very small.
7	No honeycombing of unit.

Item 49—Rust Spots

1	Unit has more than 20 major rust spots.
3	Unit has between 10 and 20 major rust spots.
5	Unit has less than 10 major rust spots or many very minor rust spots that are only a discoloration of the surface.

Rating	Criteria
7	No rust spots on unit.

Item 50—Grout Loss in Masonry

Rating	Criteria
1	Extensive loss of grout in joints, or granite blocks have fallen because of loss of grout between rows of blocks. Several sections have lost more than 50 percent of grout. Possibility of granite blocks falling from the unit because of the lack of binding grout.
3	Loss of grout in many locations, although the depth of the loss is less than 50 percent of the depth of the block or the loss is limited to a narrow bank, such as the lower tidal zone, possibly in only one horizontal joint.
5	Loss of grout noted in several locations, but extent of loss is minor, with shallow-depth sand and overall linear footage limited.
7	No loss of grout in masonry unit.

Item 51—Splitting

Rating	Criteria
1	Severe splitting of the pile or timber that causes the members to carry either no load or just a small fraction of their design load. Timber planking in a bulkhead that no longer retains fill due to splitting. Fender pile that has split at a fastener and no longer retains the fender system.
3	Splitting condition that affects the performance of the member but does not reduce the area by more than 30 percent or does not rule fasteners ineffective.
5	Minor splitting in the tidal zone due to ice action. Possibly minor impact damage on a fender system. The condition does not jeopardize the effectiveness of the unit at this time, but the condition does exist and is noteworthy.
7	No splitting of timber members in unit.

Item 52—Marine Borers

Rating	Criteria
1	Severe borer attack in the tidal zone with loss of section of the timber member that affects the ability of the member to operate as designed.
3	Several signs of marine borers in the tidal zone, or below, with some loss of section, but no major effect on the function of the members.
5	A few signs of marine borer activity, but no signs of major infestation and no significant loss of section at the tidal zone.
7	No signs of marine borers in timber members.

Item 53—Rot

Rating	Criteria
1	Severe rot of timber piles or planking that reduces the effective area of the members to less than 60 percent of the original member. Rot could be in the upper areas of the timber, caused by rain buildup, or in the tidal zone, caused by improper treatment or lack of treatment.
3	Significant rot noted in the members, with loss of section and reduction in the ability of the members to function as designed, although no structural problems. Not all members have rot, and not all members supporting a section of the unit have significant rot.
5	Some signs of rot in members, with no significant loss of the members' function. Usually just the outer inch of material is softer than a new pile, but still very solid.
7	No signs of rot in timber members.

Item 54—Fasteners

Rating	Criteria
1	Seriously deteriorated or missing fasteners that allow the timber members to carry little load.
3	Significant number of deteriorated or missing fasteners that reduce the capacity up to 50 percent.
5	Small number of deteriorated or missing fasteners with no significant loss of capacity.
7	No signs of fastener loss or deterioration.

Item 55—Deterioration

Rating	Criteria
1	Heavy corrosion with loss of section and possible signs of failure. Holes in the steel where the steel has been rusted through.
3	Moderate corrosion of the steel with heavy pitting, but no major holes. Only minor section loss.
5	Corrosion and oxidation on the steel surface, but only mild pitting, no holes, and no section loss.

Rating	*Criteria*
7	No corrosion or deterioration of steel members of unit.

Item 56—Connectors

Rating	*Criteria*
1	Missing or seriously deteriorated bolts or heavy section loss in welds. Effectiveness of the connector is seriously questioned. Splice welds in the piles would also be considered at this time.
3	Moderate deterioration of connectors or welds, with members still functioning, but capacity of the connector questioned.
5	Some minor rusting of bolts but no section loss. Welds show signs of rusting, but no section loss found.
7	No deterioration of connectors or welds.

Item 57—Recommendation

This item represents the overall rating of the element or unit considering all of the separate items previously listed.

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