



**PROBLEMS ASSOCIATED WITH NONDESTRUCTIVE
EVALUATION OF BRIDGES**

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Problems associated with nondestructive evaluation of bridges

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ABSTRACT

The U.S. has 542,000 bridges that consume billions of dollars per year in construction, rehabilitation and maintenance funds and which are the lifelines of U.S. commerce. The 1992 ISTEA (Intermodal Surface Transportation Efficiency Act) mandates the implementation of a quantitative computerized bridge management system by 1996. A prime need of such a system are quantitative bridge inspection methods to feed accurate reliable condition information to the huge database of bridges. Nondestructive evaluation (NDE) will fill a critical need in the implementation of effective bridge management. However, many serious barriers exist to the widespread routine application of this technology to bridges. This paper provides an overview of the typical problems associated with applying NDE to bridges.

1. BACKGROUND

In a good year, sufficient resources (\$5 billion) are available to improve about 10,000 bridges. Unfortunately, about 10,000 more become newly deficient in the same period. For the past few years, the U.S. has just been holding its own - improving just enough bridges to stay even. J.J. Ahlskog¹ states that recent FHWA studies show that the average life span of highway bridges is about 70 years and typically, significant rehabilitation is needed when the average bridge reaches mid-life. He goes on to say that this information coupled with the fact that the majority of bridges currently in use were built after 1945 leads to unhappy conclusions for the future.

- A full 40 percent of the total square footage of existing bridges falls in the 15 to 35 year old category
- If historic bridge life spans continue, 40 percent of our existing bridges will require replacement or rehabilitation in the next decade.
- Due to environmental and health regulations bridge rehabilitation costs are escalating at rates significantly higher than the inflation rate.

A key factor in the development of a life extension/replacement strategy for highway bridge structures (within the extreme budgetary constraints that are, and will remain a reality), is an effective bridge management system (BMS). A key component of the BMS is a means of monitoring or determining the condition of the existing structures in the management system. All of the elements that directly affect performance of the bridge including the footing, sub-structure, deck, and superstructure must be monitored. Current condition monitoring is based almost entirely on the use of visual inspection. Thus we see that the primary inputs to the bridge management system are data that by their very nature are subjective. Nondestructive evaluation (NDE) is a tool that, in actuality, is little used on bridges, but could eliminate much of the subjectivity of the input data for the bridge management system.

The potential penalties for ineffective inspection of bridges can be very severe. Instances of major bridge collapse are very rare, but the results are truly catastrophic. The collapse of the famous Silver Bridge at Point Pleasant, Ohio in 1967 resulted in loss of 47 lives. The cost of this disaster was 175 million dollars. This occurrence was well before the runaway litigation atmosphere that is reality today. If we assume a doubling of the cost every 5 to 7 years, we arrive at an estimate of between 2.1 and 5.6 billion dollars for the same occurrence today. Furthermore, these cost figures do not take into account factors such as loss of business resulting from loss of access or detours, the cost resulting from blockage of a major river shipping channel, and potential environmental damage due to hazardous materials being transported over the bridge at the time of collapse.

The consequences of ineffective bridge inspection are usually not as severe as the Silver Bridge. However, repair and retrofit costs on bridges represent a very significant portion of a state's transportation budget. In the future, replacement of a bridge will become an increasingly unattractive alternative. Construction cost growth, increased losses due to disruption of traffic during a total replacement, and the public's fierce resistance to new construction in conjunction with continuing tight budgets for the state DOT's will force life extension to be the only viable alternative for our aging bridges. This strategy will absolutely require increased use of NDE in a coordinated effort to obtain reliability assurance for these structures.

Fatigue and corrosion will become increasingly important considerations as we go beyond the 75 year life expectancy and current visual inspection techniques will not suffice. Effective NDE applied to condition determination as part of a BMS can play a major factor in directing the proper use of the limited funds available and avoid the unnecessary waste of doing unneeded or premature repairs. Fisher² points out that any methodology used to repair fatigue damaged details is case specific and is dependent on the size and location of the crack. Generally, the earlier the crack is detected, the easier becomes the repair. Clearly then, it is critical that the condition monitoring method used for bridges must be capable of detecting small growing cracks and accurately locating the crack tip so as to minimize repair costs. The current common practice of relying on visual inspection cannot reliably achieve the desired degree of early defect detection. This shortcoming is recognized and a remedy is to require frequent inspection of all fracture critical structures. A disturbing anecdote is that most major cracking problems in bridges in recent years have been found by the public, not the bridge inspector. Effective application of improved NDE will more reliably determine the condition of these structures and eliminate the need for frequent re-inspection of the structures in the inventory that have a clean bill of health. This in turn will allow the states to concentrate their efforts on the structures that need close watching. Thus we see that increased application of improved NDE can favorably impact both repair/rehabilitation costs and eliminate unneeded inspection and repair.

Before NDE can be implemented in a systematic manner to provide a more quantitative assessment of the condition of critical elements of the structure, major barriers must be overcome. In the following sections we will show specific examples of some of the problems that have to be dealt with if NDE is to be effectively applied to bridges.

2. ACCESSIBILITY

Bridges are large civil structures that can be as much as one mile in length or more and usually traverse both difficult terrain and water. Their height can range from 20 feet to several hundred feet or more. Common practice, particularly in older structures was to provide little if any access to critical elements of the bridge that need to be examined. The inspector in these cases is forced to scale high steel or use devices such as a man-lift to gain access. Access difficulties can place the inspector in life threatening situations where one slip can leave him dangling from his safety harness, or worse. These conditions both contribute to very low productivity, and tend to reduce the reliability of the tests being performed. It is difficult for a trained inspector to apply careful judgment and sophisticated expertise to performance of the test, when he thinks that he may be about to make an unplanned attempt at a new high diving record.

Bridges that have no provisions for access (i.e. ladders and catwalks) are typically inspected using various forms of the man-lift. In Figure 1 we see an example of this type of bridge. The bridge is a through truss built in 1950. It carries eastbound I-94 over the St. Croix river at Hudson WI.

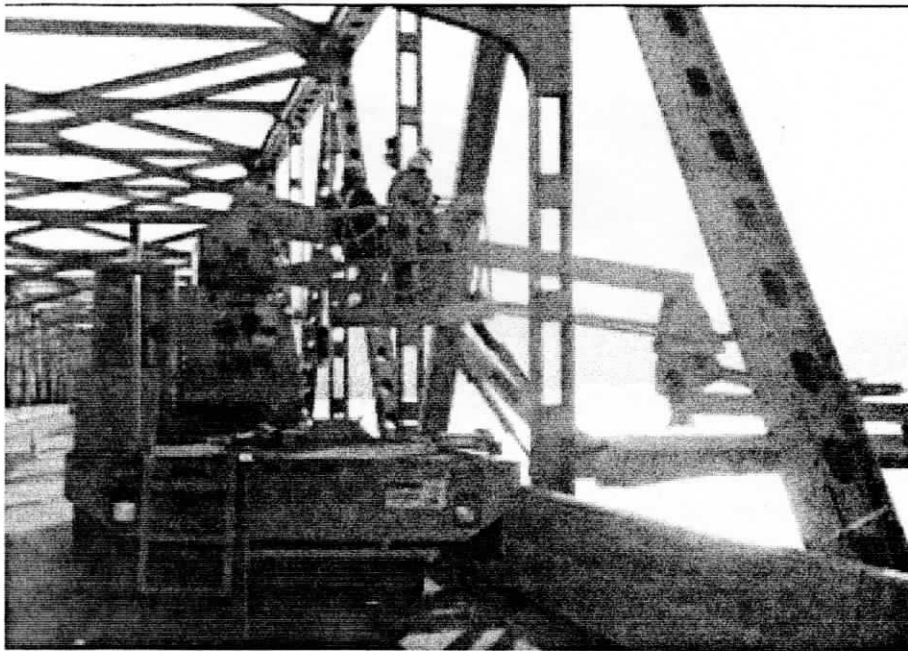


Figure 1. I-94 bridge over St. Croix River

In this figure we see a typical man-lift type device used for achieving access to bridges like the Hudson bridge. This approach is quite effective for providing access to accomplish close visual inspection and some ultrasonic testing or surface NDE but as can be seen in the figure, space is quite limited in the "bucket" so that large pieces of equipment would be impractical. This type of access equipment typically provides power for equipment that needs it. The use of this approach does require closing of one traffic lane on the bridge and necessary associated traffic control. Furthermore, the presence of heavy truck traffic causes the bridge to move and the movement is amplified by the lever arm of the reach-all. The motion is easily sufficient to induce motion sickness in most people which further reduces productivity.

Even in structures that have ladders and catwalks, accessibility to the test site can be a challenge. Figure 2 below shows an overall view of the I-680 bridge over the Sacramento near Benicia CA. This bridge is a deck truss with an overall length of 1.18 miles. It was built in 1960 and the main truss members are

fabricated from T-1 high strength steel. Cover plates were fillet welded to the bottom H section at the point of connection with the vertical truss member. Cracks developed in these welds which were subsequently ground out and bolted doubler plates were added for redundancy. This structure requires periodic re-inspection because of the fracture critical nature of the connections in question. Access to the truss is gained by means of a ladder from a road passing beneath the bridge. This ladder connects with a 976 foot catwalk to the end of the first truss span at which point a descent of a 50 foot ladder leads to the truss catwalk.

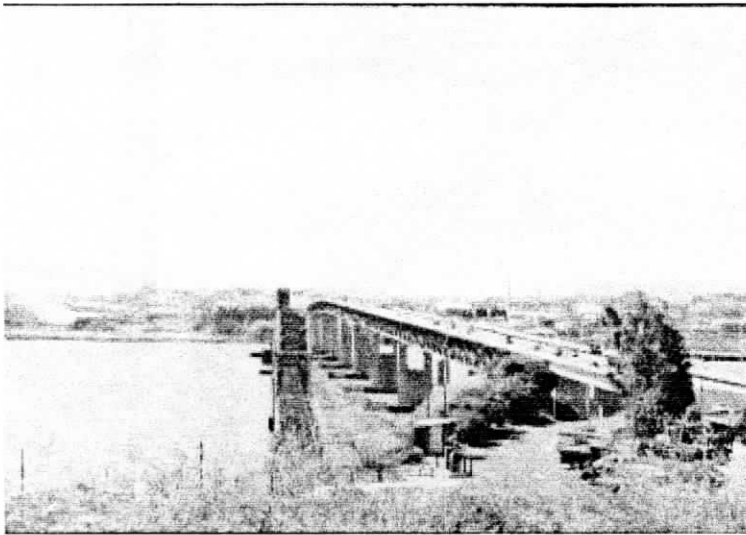


Figure 2. Overall View of I-680 bridge near Benicia CA

A view of this catwalk is shown in Figure 3. This catwalk extends the length of the truss portion of the structure and is the path over which any inspection equipment must be carried to reach the critical truss members. Additional access to the top and bottom truss chords is provided by a side traveler constructed by CALTRANS to allow both inspection and painting. A view of the side traveler is shown in Figure 4.

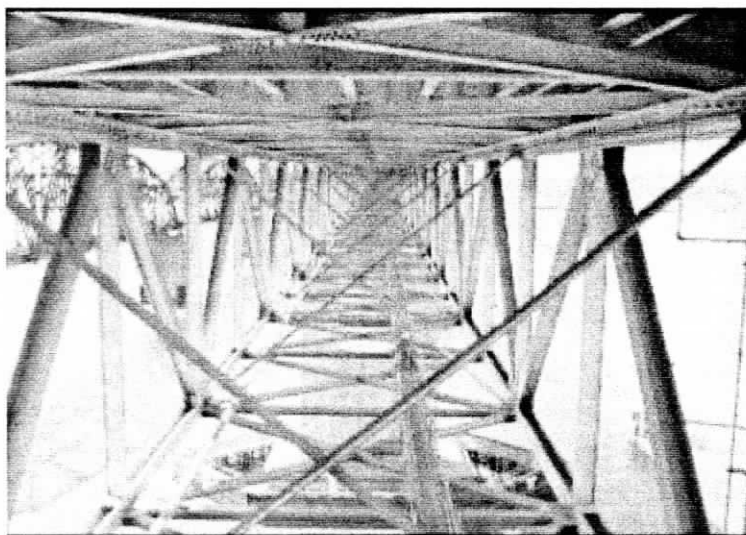


Figure 3. A view of the center catwalk on the I-680 Bridge

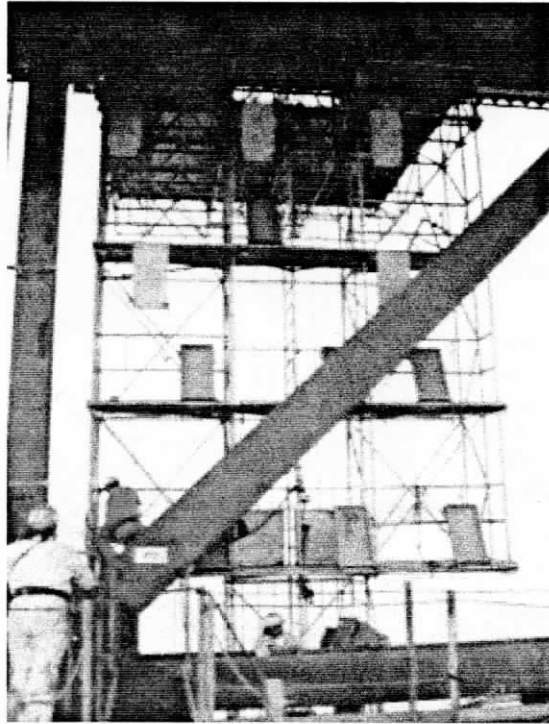


Figure 4. The CALTRANS side traveler.

The I-680 bridge is an excellent example of what can be done to provide access to the critical portions of a structure. This approach is unfortunately, very rare. Even with an approach like that used on the I-680 bridge, one can clearly see the advantages to be gained by developing small lightweight NDE equipment. A box weighing 10 pounds or more will become a serious problem if it has to be carried and lifted over the range of distances that are encountered on this type of structure.

3. ENVIRONMENT

The bridge environment provides its own set of challenges to the application of NDE. Besides the typical hazards provided by the local weather of temperature extremes, precipitation, and winds, the bridge itself adds the challenge of vibration and noise. Any test procedure that requires either partial or total closure of the bridge to traffic causes major problems that include:

- Added cost for traffic control.
- Restricted working hours (i.e. late at night).
- Scheduling problems and delays.

The bridge surfaces that must be inspected will typically be covered with rust and dirt. Figure 5 and 6 show examples of the typical surface conditions encountered on a bridge.

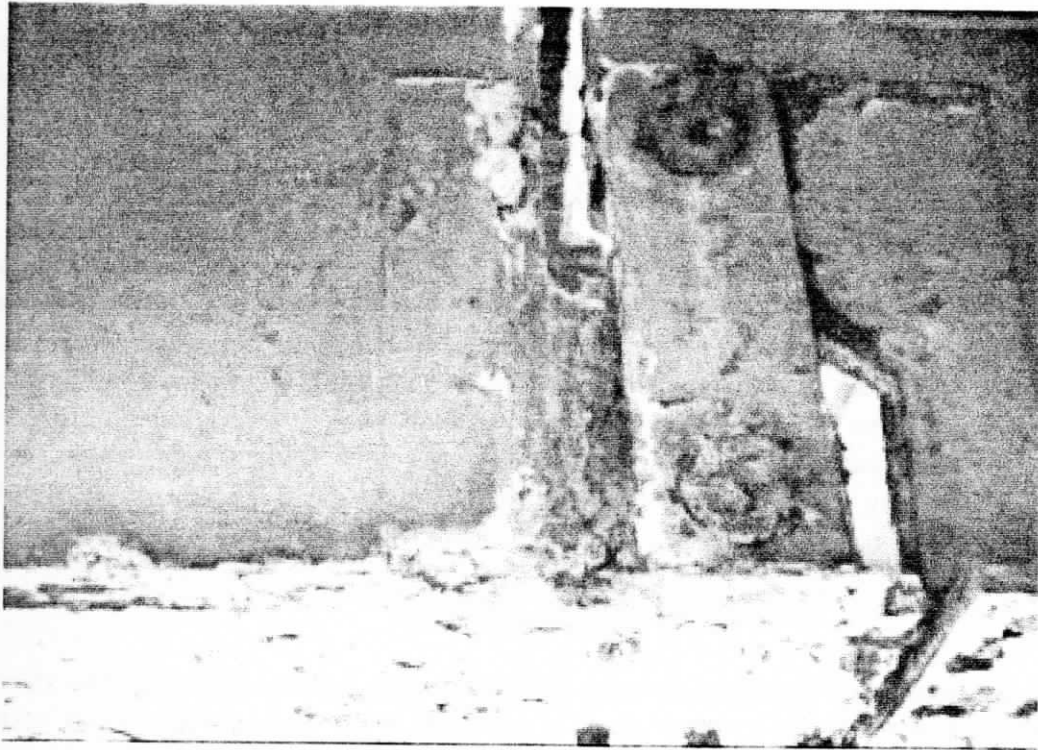


Figure 5. Close-up of pin and hanger detail

Figure 5 shows a close-up of a typical pin and hanger detail on an elevated portion of I-94 located in southern Wisconsin. The pin and hanger is located in an expansion joint area and is subject to run-off of water from the deck that has dissolved deicing salts. This detail is a major inspection problem in parts of the country where heavy use of deicing salts are encountered. Figure 6 shows a close-up of the bascule girder on an old rolling bascule lift bridge. This surface has both the rust and dirt problem in addition to limited access because of the multitude of fasteners.

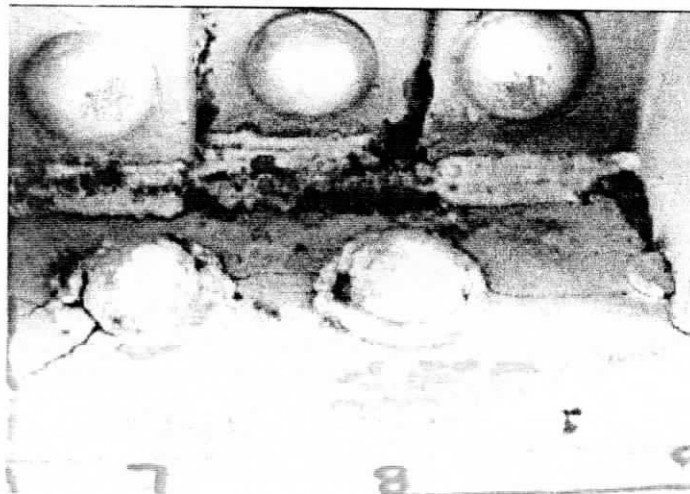


Figure 6. Close-up of Bascule girder

Paint thickness on older bridges may become excessive and severely hamper the application of many NDE methods. Lead based paint, which is common on older structures, must be dealt with carefully. If paint must be removed, proper safety procedures must be followed to prevent damage to the environment and potential health problems for the inspector. The latter becomes a serious consideration when the inspection must be accomplished in confined spaces such as inside box girders.

4. OPERATOR SKILLS

Common practice in state highway departments in recent times has been to reduce the work force to comply with budget cutting measures. Many experienced bridge inspection personnel have been given early retirement and either have not been replaced, or have been replaced by entry level personnel with minimal experience and training. This situation will probably continue in the foreseeable future. This steadily worsening situation places a great deal of emphasis on the need for easy to use equipment that produces clear unambiguous results. This situation also points out the growing need for application of expert systems to the bridge NDE problem. This latter need will become increasingly acute as we continue to lose expertise in this field.

5. CONCLUSIONS

The development of bridge management systems (BMS) requires improved techniques for determination of the condition of critical elements of a structure if these systems are to provide reliable decision support. NDE will play a critical role in this process. The developers of NDE equipment and techniques for application to the bridge inspection problem need to pay heed to the severe conditions that exist in the bridge inspection environment. The equipment must be lightweight, portable and easy to apply and the results must be easy to interpret. Above all, the researchers who are attempting to address these problems need to experience first hand the field situation. They must also work hand-in-hand with the practitioners to constantly insure that they are pursuing a cost effective solution to a real bridge inspection need.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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