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Designing Service Life Into a Bridge

Prise en considération de la durée de service d'un pont, lors du projet

Die Erhöhung der Lebensdauer von Brücken als Aufgabe der Projektierung

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SUMMARY
In the past, bridge engineers have attempted to develop designs with durable materials that require minimum maintenance but, with few exceptions, little effort has been made to record their results. This paper presents several ideas for designs which extend service life and suggests that the National Bridge Inventory and Inspection Program required in the United States could be used as a valuable learning tool for improvement of bridge designs.

RESUME
Les ingénieurs ont de tous temps essayé de réaliser des ponts avec des matériaux durables et d'un entretien minimum. Rares sont cependant les cas où le comportement réel a été mesuré et protocolé. L'article présente plusieurs idées devant permettre de prolonger la durée de service des ponts. Le Programme national d'inventaire et d'inspection des ponts, appliqué aux Etats-Unis, offre un instrument qui devrait contribuer à l'amélioration des projets de ponts.

ZUSAMMENFASSUNG
Seit jeher haben die Ingenieure versucht, Brückenprojekte aus beständigem Material und mit minimaler Unterhaltspflicht zu realisieren. Trotzdem sind die Fälle selten, wo das wirkliche Verhalten gemessen und protokolliert wurde. Der Artikel gibt mehrere Ratschläge für eine verlängerte Lebensdauer von Brücken. Das in den USA angewandte Brückenbestands- und Inspektionsprogramm bietet ein Dokument an, das zur Verbesserung der Brückenprojekte beiträgt.

1. INTRODUCTION

The service life of a bridge can be defined as that period of time over which a bridge can serve a useful purpose without excessive maintenance. Engineers would prefer the ideal condition of always building a bridge on a rock foundation, using materials that will last forever, and strong enough to withstand any natural force. The real life situation, however, is usually far less than ideal. Limited funding, availability of materials, mediocre workmanship, marginal designs and lack of or poor maintenance leave much to be desired. All of these shortcomings put severe limitations on what we can expect for the service life of a bridge.

It is not a general practice to plan obsolescence for a bridge. Usually a bridge is designed and built to accommodate a vehicular traffic demand and some expected flood conditions. It is then kept in service as long as possible because of the lack of replacement funds. The present long list of deficient bridges in the United States attest to the fact that we are losing ground on any well intentioned plans of maintaining our bridges to make them last forever. Improvements on present design practice to extend service life should be the single greatest present day challenge to bridge engineers.

2. INSPECTION PROGRAM

The nationwide bridge inspection program here in the United States is relatively new. It was started in the early 1970's and has served its initial purpose in locating deficiencies and prioritizing bridge replacement needs. Inspection teams were quickly assembled and after minor training were given inspection assignments. Professional expertise and reporting procedures were not consistent or uniform. Although the Federal Highway Administration has developed inspection training programs, a key area of concern today is the training and experience of the inspectors.

2.1 Lessons from the inspection program

This on-going bridge inventory and inspection program offers, however, a base for study of deficiencies and needed changes. Most bridge inspection reports give data on present structural conditions, safety features, and recommendations for needed maintenance, rehabilitation or replacement. With the help of a computer these reports can single out the magnitude of a problem. For instance, it was generally known that bridge decks were deteriorating at a rapid rate, but data from the inspection program told us the size and extent of this deficiency. An analysis of inspection data and existing designs can direct us to needed changes, not only in design, but also in inspection records and remedial action to be taken.

The State of Alaska assigns its design staff to inspection teams, which gives designers a chance to "see their designs in action" and hopefully improve the inspection effort, as well as correct design deficiencies. It is generally agreed that inspection data must be taken and recorded by knowledgeable individuals or its worth is questionable. Many believe that more professional engineers should be used for inspection. Our brief experience with the program tells us it can give good feed-back data for improving design and construction practices, as well as giving guidance for managing a maintenance program.

3. DESIGN FEATURES FOR EXTENDING BRIDGE LIFE

Our objective here is to discuss ways of designing service life into our bridges. In the past our experience, and oftentimes our intuition, has helped us to make decisions to "save our bridge," by using the right design, materials, or protection. Often bridge performance history has been of great assistance. To better illustrate this point, let us discuss several specific design features or considerations that could extend the life of a bridge.

3.1 Design for natural disasters

We have made progress by reacting to catastrophic failures. Bridge failures caused by floods, earthquakes and wind, have brought about changes, both in design specifications and the requirement of model performance testing.

Because of the concentration of many earthquakes in California, the State has been a leader in rewriting seismic design specifications, as well as retrofitting existing bridges to withstand future occurrences. Bridge failures due to flooding, on the other hand, have not received as much attention, primarily because of the scattered nature of occurrences in time and location. Probably more bridges are destroyed by floods than any other single cause, but how many are destroyed annually is unknown. Analysis of bridge failures and historical flood data could give valuable guidance on providing protection to existing bridges, as well as some direction in future decisions. Information on how bridges fail during floods can give us important data for the design to resist pier scour, uplift, and drag forces.

In the past, some bridges destroyed by floods, wind, or earthquake have been replaced without learning from the failure. Today we are trying to study our failures and use these unfortunate occurrences to improve our designs. The replacement of the Tacoma Narrows Bridge and the new Hood Canal Bridge are good examples of using failures for extensive studies to improve the replacement structure.

3.2 Consider man-made disasters

Nature can wreak havoc to improperly designed bridges, but modern day traffic can also present hazards to bridge structures. Gasoline tanker trucks have burned under a structure causing its superstructure to sag and fail. Out-of-control heavy trucks have demolished vertical columns, and oversized loads have crushed structural members, both resulting in loss of service of a bridge.

Design planning for proper clearances and protection of vulnerable parts from the impact of errant vehicles are essential for the safety of a bridge structure, as well as the public using it.

Fortunately this type of disaster happens infrequently. However, a judiciously placed barrier or additional vertical clearance may reduce the chance of these occurrences without much additional cost.

3.3 Avoid obsolescence

Predicting future traffic needs is sometimes difficult, especially in developing areas. Selecting a bridge type that can be widened easily to provide for additional capacity may avoid complete bridge replacement. Many through truss bridges in good service condition are obsolete because of narrow roadways, which cannot be easily widened.

3.4 Plan for future rehabilitation

Long life for concrete bridge decks has not yet been proven. Protective measures have been researched and applied in the field and will offer an excellent data base for incorporation into the inspection program. As the years of experience accumulate on these systems, analyses of performance could be very informative. However, today many bridge engineers feel that after providing a deck protective system, the design of the bridge should allow the deck to be removed and replaced.

Conventional girder bridges usually allow the deck to be removed and replaced. But one area of concern is the future problem of deck reconstruction on segmental prestressed concrete box bridges. In this type of construction, the roadway deck is an integral part of the load-carrying superstructure, which cannot be conveniently removed during replacement. Some designers have suggested that extra tendon ducts be installed for future use if additional prestressing is needed while replacing the deck. Another viable solution for new bridges of this type is to add a secondary deck on an impervious membrane to prevent chloride penetration into the top flange of the main superstructure. This deck can be monitored and replaced when necessary, but without supporting or destroying the main superstructure. Initial studies indicate the cost of this secondary deck to be in the order of 5 percent of the capital investment. The benefit/cost ratio for such a system can be very high indeed for this type of bridge.

3.5 Adequate maintenance

Much bridge deterioration and attendant reduction in service life are due to poor maintenance. Commonly, bridge maintenance is performed only when an emergency occurs. This lack of maintenance is caused by several reasons: (1) insufficient or marginal funding, (2) lack of trained personnel and (3) designs too difficult to inspect or maintain.

Timely repairs cannot be made if troubled areas are not found or reported. Often such repairs will not be made if they are too complicated and expensive. Hence, it is important to design for ease of inspection and simplicity of maintenance and repair.

Other than lack of periodic painting of steel bridges, drainage and debris cause most problems in structural deterioration and traffic hazards. Salt water from clogged or broken drains and leaking expansion joints falls onto underlying supports causing discolorization and spalling of concrete and corrosion of supporting hardware. Minimizing the use of drains and providing adequate clean-out access of pipes and leak-proof expansion joints will make maintenance easier and help to extend service life.

To reduce the maintenance cost of painting, weathering steel has been used in recent years, but its performance has now been questioned. Apparently, it may not develop its proper "patina" when subjected to salt water, salt air or salt spray, and thus it could revert to the ordinary corrosion process. In the proper environment it should provide a long service life, but field studies on its performance are in progress.

3.6 Select appropriate bridge type

Maintenance and operation costs should be considered when selecting a bridge type. Some bridges have unusually high maintenance and operational costs. Movable highway bridges, constructed primarily to reduce profile grade and provide increased navigational clearances for water traffic are good examples of high costs, both to construct and maintain. A bridge of this type should be selected only as a last resort. Through trusses are vulnerable to oversized loads and constant maintenance is required to straighten and replace members.

Material selection is often related to or determines bridge types. The availability, cost and durability of a structural material must be considered with the environmental conditions at the location. Coastal regions, in particular, require increased maintenance for steel bridges and careful design precautions for concrete construction.

3.7 Minimize catastrophic failures

One of the primary reasons for establishing the National Bridge Inspection Program in the United States was to reduce the chance of another catastrophic bridge failure as experienced with the West Virginia Silver Bridge in 1967. Periodic inspection of critical load carrying elements of a bridge is believed essential for bridge safety, long service life, and to avoid a catastrophic collapse.

Steel fractures have closed at least three steel tied-arch bridges recently and several others are being watched closely for the appearance of cracks. This type of bridge generally possesses a non-redundant tie which is fracture critical; i.e., if it fractures completely the bridge will likely collapse. Fortunately, in the problem cases, only partial fractures have occurred before discovery and remedial action was taken.

Confidence in analysis, materials, and workmanship are commendable attributes, but practices that give repeated trouble should be changed. Designing bridges with fracture critical members should be severely scrutinized as to the savings realized and the margin of safety provided. In the tied-arch case, it is suggested that the use of stressed cables, as used in prestressed concrete, offers a viable alternate. Such cables, in combination with plate steel, would make the arch tie more redundant, thus helping to avoid complete collapse of a bridge.

When fracture critical members are present in a bridge structure to be inspected, special instructions and highly qualified personnel are needed. The seriousness and importance of this inspection cannot be overemphasized, and the reporting of any unusual findings is essential. Beyond the emphasis given to the finding of and reporting a deficiency, a great responsibility rests on supervisors to see that quick action is taken or failure may occur causing loss of life.

3.8 Minimize local failures

Cracking of a local area from either fatigue or brittleness usually does not gain the spectacular attention of a major failure. Nonetheless, these cracks are serious and reduce the service life of the bridge, if not repaired. Recent research has proposed a better understanding of these phenomena and suggests methods of avoid future problems.

Fatigue cracking usually results from a poor design detail or from a fabrication flaw. Both sometimes occur at the same point. Cracking is a function of the stress range and joint configuration, both of which can be controlled by the designer. Flaws serious enough to cause trouble must be controlled by a quality assurance program and detected by proper inspection during the fabrication and erection of the structure.

Similarily, brittle cracking is now understood to be a function of material toughness, temperature, and the stress intensity at a flaw. By specifying toughness for the lowest operational temperature at the bridge site, and relying on a good quality assurance and inspection program, the incidence of brittle fracture can be greatly reduced.

4. CONCLUSIONS

Providing long service life for our bridges requires following proven principles of design, fabrication and inspection. Selecting the appropriate type, keeping the details simple, and being aware of the unusual happening that can occur are important considerations. An adequate maintenance program properly funded will help perpetuate the quality built into the structure. And finally, to further emphasize the objective of this presenation a comprehensive and continuing inspection program will provide useful information for maintenance repairs and also serve as a learning tool to provide the necessary feedback to develop and improve our bridge technology of the future.

5. REFERENCES

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