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Tech Brief

Corrugated Steel Culvert Pipe Deterioration

FHWA-NJ-2006-007

August 2009

SUMMARY

This research provides the basis for developing a comprehensive management plan for culverts including inspection, cleaning, condition assessment, prediction of remaining service and repair/rehabilitation. Inspection frequency guidelines were developed that rate corrugated steel culvert pipes (CSCP's) at three levels. A four condition state assessment system was developed based on quantifiable section losses, specific surface features, and a prescribed response associated with each condition state. A Markov deterioration model was used to predict the future condition state of new CSCP in urban and rural settings. The transition probabilities were developed based upon inspection data and corrosion studies. The model was extended to predict the future condition of new CSCP in both urban and rural settings for a 30-year design service life. In the next phase of this research project the Weibull distribution was used to predict the remaining service life of CSCP and other culverts. The Weibull distribution provided better agreement with pipe corrosion data that became available subsequent to the completion of this project.

A framework for inspection and rehabilitation/replacement of CSCPs was developed based on recent Governmental Accounting Standards Bureau (GASB) requirements. Benefits of the proposed system will include long-term savings that should accrue from adopting optimized preventive maintenance strategies. The condition states of CSCPs are used to express the extent of its deterioration. Different rehabilitation options were discussed and recommendations made for deteriorated CSCPs. These options were to be incorporated into the recommended culvert information management system (CIMS), which uses survival probabilities based on the condition state of CSCP.

The proposed CIMS is capable of analyzing decisions to inspect, rehabilitate/replace or do nothing at both project and network levels. The proposed CIMS can also be used to estimate the required annual budgetary allocation for a stipulated planning horizon and to maintain or improve the aggregate condition state of culverts in NJ. Phase I of the CIMS was implemented and it stores and retrieves the location and condition states of culverts.

INTRODUCTION/BACKGROUND

Corrugated steel culvert pipes serve as an inexpensive means for crossing streams and providing drainage along and across roadways, and thus are very important components of many transportation systems. They are cheaper, more easily transported, and more easily assembled than other culvert pipes. The design flexibility of CSCP and its predictable mechanical properties allow

the engineer to design a culvert, which will withstand heavy traffic loads and other site conditions that might occur during the life of the pipe.

NJDOT Maintenance has identified the deterioration of CSCP as a significant problem because many installed pipes are at or near the 30-year age mark. Most of these older culverts exhibit 80-90% section losses or in many cases 100% section losses at the inverts of the culvert. If this deterioration is not addressed within the next several years, many areas will exhibit soil transfer from under the pipe resulting in erosion and/or collapse. A pipe collapse may result in the above roadway settling, or itself collapsing, which would prove very costly in terms of traffic delays and roadway repair.

RESEARCH APPROACH

An extensive literature search was performed to find the best way to maintain CSCP's. This literature search and deductive reasoning was used to develop a scheme to inspect CSCP's. Then, based on inspection data, a methodology to estimate the condition state of CSCP's was developed. Knowing the condition state of a CSCP, a mathematical formulation was developed to estimate the remaining service life of inspected CSCP's. At NJIT a year long experiment was conducted to evaluate and document the effectiveness of Instrumented Cathodic Protection (ICP) in protecting culverts. An automated methodology based on intelligent image processing and learning techniques for simultaneous defect detection and condition state assessment of culverts was proposed to bridge the gap between image analyses used to identify internal defects in pipelines and culverts, and the subsequent condition state assessment analysis. A conceptual framework for recommending culvert inspection or rehabilitation/replacement needs and prioritizing them while adhering to budgetary allocations, and minimizing risks and costs associated with failure, was developed. At network scale, the allocation of funds is determined based upon an initial budget and the optimum sequential path in the annual decision making process.

FINDINGS

A Markov deterioration model was used to predict the future condition state of new CSCP in urban and rural settings. The transition probabilities were based upon inspection data and corrosion studies. The model was extended to predict the future condition of new CSCP in both settings over a 30-year design service life. In the next phase of this project, the Weibull distribution was used to predict the remaining service life of CSCP and other culverts because this distribution provided better agreement with pipe corrosion data that became available after the completion of this project. An automated methodology, based on intelligent image processing and learning techniques for simultaneous defect detection and condition state assessment of culverts, was found to be feasible. Instrumented Cathodic Protection (ICP) was found to be an effective and inexpensive way to protect CSCP's from corrosion. The development of a culvert information management system (CIMS) based on the condition state of the culvert and the estimated remaining service life was recommended. The proposed CIMS will determine and prioritize culvert inspection or rehabilitation and/or replacement needs, while adhering to budgetary allocations, and minimizing risks and costs associated with failure. At network scale, the allocation of funds will be determined based upon an initial budget and the optimum sequential path in the annual decision making process, which can be determined using a combination of operations research tools.

CONCLUSIONS

New inspection frequency guidelines for CSCP's in NJ were proposed, where the CSCP's are rated at three levels. The rating categories are based on corrosion and erosion, bed load, pH, and culvert size, age and importance, and are ranked according to increasing need; e.g., annual inspections are recommended for Category III (older pipes with reported problems).

A condition state assessment system, which defines four condition states of culverts, is recommended for use in NJ. The condition states should have quantifiable section losses, specific

surface features, and a prescribed response associated with each condition state. The four condition states are ranked in terms of increasing deterioration and the responses range from “do nothing” to “re-lining or replacement”.


A Markov deterioration model was used to predict the future condition state of new CSCP in urban and rural settings. The transition probabilities were based upon inspection data and corrosion studies. The model was extended to predict the future condition of new CSCP in both settings over a 30-year design service life. The inspection guidelines and deterioration model provided the basis for developing a comprehensive plan for inspection, cleaning, condition assessment, and prediction of the remaining service of CSCP's, which would lead to the development of a culvert information management system (CIMS). The CIMS would be capable of analyzing decisions to inspect, rehabilitate/replace, or do nothing at both project and network levels. At the project level this is achieved by comparing inspection and/or rehabilitation/replacement costs with risks and costs associated with failure. At the network level, the associated costs are optimized to meet annual maintenance budget allocations by prioritizing CSCP's needing inspection and rehabilitation/replacement. The proposed CIMS can also be used to estimate the required annual budgetary allocation for a stipulated planning horizon to maintain or improve the aggregate condition state of the CSCP network, or to maintain or improve the total highway CSCP network asset value, thereby meeting the GASB-34 requirements.

Culvert Data Form

Location: R.T 1 NORTH, EDISON,N.J		Milepost: 28	MH_Start: AMH 28.3C	MH_End: CB 28.308I
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Record ID: U-504-1051-171-174	Project Name: U-504-1051	DP Number:
Street: R.T 1 NORTH	Section Number: 0	MH1_id: AMH 28.3080N
City: EDISON,N.J	Condition:	MH2_id: CB 28.3080NE
Location_code: A Main Highway - Urban	Condition Number: 0	
Route_and_Control_Section:		

Material Type: RCP Reinforced Concrete Pipe	Inv_date:	Clean Date:
Segment Length: 3.76	Pipe Length: 12.33	Pre_Cleaned: H Heavy Cleaning
Pipe Diameter: C Circular 18" / 18"	Flow_direction: 2	Drain Area:
Pipe Thickness: 0	Flow Control:	Lining Type:
Use_of_Sewer: SW Stormwater	Weather: 1 Dry	PSR:
Survey Customer:	System Owner:	

Inspector Name: D.SALAZAR	
Inspection Date: 10/03/2005	
Inspection Reason: F Routine Assessment	
Video ID: DVD04	
Video Direction: D	
Video Operator:	
Report File:	
Remarks:	

Update

Inlet/Outlet Structure Form

Report Preview

Close Me

Record: 2 of 662

Phase I of the CIMS was developed and implemented. This first part is capable of storing and retrieving the locations and condition states of all the culverts that belong to NJDOT. The figure above shows the information displayed for an inspected culvert.

In this research, CSCP deterioration is defined based on the condition state, and the assumption that life added through rehabilitation results in an upgrade of the condition state. Rehabilitation options can be grouped as (a) cleaning/painting, (b) invert paving, (c) slip-lining, (d) in-situ cured liners, and (e) pipe replacement.

Proposed rehabilitation methods are based on culvert length and diameter. CSCP's with small to medium size diameters (i.e., 6-12 inches and 1-3 feet) may require the use of robots for inspection and rehabilitation. In addition, small to medium sized culverts in Condition State 3 (section loss 10-30% of thickness) are differentiated based on pipe length (i.e., whether $L < 25\text{ft}$ or $L > 25\text{ft}$).

RECOMMENDATIONS

All culverts should be inspected either annually, or every three or ten years based on susceptibility for corrosion & erosion. Based on the inspection data, the current condition state of each culvert should be determined. Each year, based on the current condition state, the decision process should determine whether the culverts should be inspected, rehabilitated, or replaced, or whether no action should be taken.

A comprehensive CIMS that is capable of determining culvert inspection or rehabilitation/replacement needs at both the project and network levels, while adhering to budgetary allocations and minimizing risks and costs associated with failure, should be developed.

Instrumented Cathodic Protection should be considered when installing new CSCPs to prevent corrosion.

FOR MORE INFORMATION CONTACT:	
NJDOT PROJECT MANAGER:	Robert Sasor
PHONE NO.	1-609-530-5965
e-mail	Robert.Sasor@dot.state.nj.us
UNIVERSITY PRINCIPAL INVESTIGATOR	Dr. Jay N. Meegoda [Dr. Thomas Juliano]
UNIVERSITY:	New Jersey Institute of Technology
PHONE NO.	(973)-596-2464 [(973)-596-5694]
e-mail	Meegoda@njit.edu Juliano@njit.edu

A final report is available online at:
<http://www.state.nj.us/transportation/refdata/research/ReportsDB.shtm>

If you would like a copy of the full report, please FAX the NJDOT, Bureau of Research, Technology Transfer Group at (609) 530-3722, or send an e-mail to Research.Bureau@dot.state.nj.us and ask for:

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