4.1 Overview

4.1.1 Introduction

There are thousands of culverts under the highways of Connecticut, many over 50 years old. Culverts do not receive much attention, primarily because they are generally hidden from view from the travelling public. Occasionally, however, an incident occurs that serves as a reminder that the failure of a culvert can have serious consequences.

Over the past twenty years, most of the larger highway culverts, defined as "Qualifying Structures" in Section 1.4 of the ConnDOT Bridge Inspection Manual have been inspected at least once every two years. Currently culverts that qualify are those with multiple openings measuring over 6m (20 ft.) and single culverts measuring over 3m (10 ft.) in span. These inspections, conducted on a wide variety of culvert types and materials, revealed numerous types of problems. The inspections have not only documented the problems but rated the culverts with regard to their serviceability and structural safety. Recommendations for repair of structures are normally determined following the review of the inspection reports and are kept in the Department's Bridge Safety and Evaluation Unit. However, inspection information should supplement and not take the place of the requirement of performing a condition survey should the culvert remain in use as part of a construction project.

One of the problems associated with repair, rehabilitation, and replacement of culverts is that the work frequently is approached strictly as a maintenance problem without consideration of the underlying structural or hydraulic conditions for which the deterioration originated. Moreover, there has never been enough money to maintain culverts, properly, and, over the years, the overall condition of culverts in the highway system has steadily worsened.

Although there is considerable information available on the design and construction of new culverts of many materials, there is little information in the literature on how to repair culvert problems and even less on how to rehabilitate, strengthen, or retrofit upgrade culverts. There are essentially no criteria for selecting the most cost-effective alternative for the work that should be done.

4.1.2 Overview of the Problem

There are many culverts in the ConnDOT highway system that are in various states of deterioration. Maintenance personnel are faced with the question of deciding whether to repair, rehabilitate, retrofit, or replace these culverts and how to do so with available funds. Experience has shown that it is often economically feasible to restore or upgrade culverts, and procedures have been developed for doing such work. In order to decide which repair procedures are most appropriate, it is necessary that a basic understanding of culvert design, construction, and maintenance and, more importantly, how to evaluate causes and solutions to the problems.

Culverts are primarily structures that carry surface and stream water under highway pavements. However, the same types of structures are also used to facilitate highway undercrossings by animals, people, and occasionally vehicles.

4.1.3 Construction Projects with Existing Drainage Facilities

A condition survey should be conducted for existing drainage facilities (pipes, structures, swales, ditches) that are to remain in use within the project limits, to ensure their condition is adequate and replacement is not warranted. This should be performed early in the design phase so that the proposed design includes all systems that are to be replaced. Individuals responsible for performing the inspections must possess the minimum qualifications in accordance with the National Bridge Inspection Standards. The approach and documentation with respect to verifying the condition is outlined in Appendix A (Inspection Guidelines) and Appendix B (Drainage Facility Condition Surveys Guideline). A separate report shall be prepared and submitted to the Hydraulics and Drainage Section early in the final design phase of the project.

4.1.4 Basic Characteristics

The structural and hydraulic design of culverts is substantially different from that of bridges, as are the construction, maintenance, repair, and replacement procedures. A few of the more significant characteristics of water-carrying culverts are:

• Hydraulic – Culverts are usually designed to operate at peak flows with a submerged inlet to improve hydraulic efficiency. The culvert constricts the flow of the stream and may cause ponding at the upstream or inlet end. The resulting rise in elevation of the water surface produces a head at the inlet that increases the hydraulic capacity of the culvert. The effects of ponding and flow on appurtenant structures, embankments, and abutting properties are important considerations in the design of culverts.

• Structural – Culverts are buried in soil and are designed to support the dead load of soil over the culvert as well as live loads of traffic. Either the live load or the dead load may be the most significant load element, depending on the type of culvert, type and thickness of cover, and amount of live load. However, live loads on culverts are generally not as significant as the dead load unless the cover is shallow. Box culverts with shallow cover are examples of the type of installation where live loads are important.

In most culvert designs, the soil or embankment material surrounding the culvert plays an important structural role. Lateral soil pressures enhance the culvert's ability to support vertical loads. The stability of the surrounding soil is important to the structural performance of most culverts.

• Maintenance – Because culverts usually constrict flow, there is an increased potential for waterway blockage by debris and sediment, especially for culverts subject to seasonal flow. Multiple barrel culverts are particularly susceptible to debris accumulation. Scour caused by high outlet velocity or turbulence at the inlet end is of concern. As a result of these factors, routine maintenance for culverts primarily involves the removal of obstructions and the repair of erosion and scour. Other defects from weathering, loads, and age will occur and require routine maintenance.

• Traffic Safety – A significant safety feature of many culverts, as compared to bridges, is the elimination of a constriction in the roadway. Culverts can economically be extended so that the standard roadway cross section can be carried over the culvert. However, when the ends are located near traffic lanes or adjacent to a shoulder, guiderail may be required to protect the traffic.

• Construction – One of the most significant factors is that culverts are constructed in and through the roadway embankment, and vehicle loads are carried by the combined strengths of the culvert and the surrounding embankment. The trench width, bedding, compaction, and amount of fill over the culvert are important factors that influence the ability of the culvert to carry the design loads. Thus, the construction techniques and quality control of workmanship are critical to the ultimate serviceability and life expectancy of culverts.

• Durabilty – Durability of materials is a significant problem in culverts and other drainage structures. In hostile environments, corrosion and abrasion can cause deterioration of all commonly available culvert materials. Many types of serviceability problems may occur because of scour of streambeds and erosion of embankments adjacent to the culverts.

• Inspection – Highway bridges and culverts designated as "Qualifying Structures" in Section 1.4 of the ConnDOT Bridge Inspection Manual must be inspected at least once every two years. There is no mandated criteria for the length of time between inspections for culverts that are less than 6.1 m (20 ft.) in roadway span. However, ConnDOT inspects all culverts over 1.8m (6 ft.) on State highways. It is recognized that all other culverts may not be routinely inspected and that problems are reported on an as-noticed basis.

4.1.5 Types of Culverts

Although there is a very wide range of styles and designs of culverts in service, all culverts may be classified into two basic types: rigid and flexible. This classification is based on the primary difference in the manner in which structural loads are carried by the culvert and the interrelationship between the culvert structure and the surrounding soil. Rigid culverts are designed to resist bending moment; flexible culverts are not.

Culverts are also often described by their shape, which may be circular, arch, elliptical, or box. The box shape may be made more torsionally rigid by adding internal web walls between the top and bottom surfaces. Culverts may also be made with multiple barrels for additional flow capacity. Most modern culverts are made from either corrugated metal, plastic, or reinforced concrete. Concrete culverts may be of either precast or cast-in-place construction, which may be post-tensioned in the field. These materials may be used to construct most of the mentioned structural shapes.

4.1.6 General Problems with Culverts

There is a wide variety of types of problems that occur with culverts. The problems may be classified by serviceability and strength-related criteria. Listed below are general types of culvert problems:

Serviceability-related problems

- Scour and erosion of streambed and embankments
- Inadequate flow capacity
- Corrosion and abrasion of metal culverts
- Abrasion and deterioration of concrete and masonry culverts
- Sedimentation and blockage by debris
- Separation and/or dropoff of sections of modular culverts

- Inadequate length

Strength-related problems

- Cracking of rigid culverts
- Undermining and loss of structural support
- Loss of the invert of culverts due to corrosion or abrasion
- Over-deflection and shape deformation of flexible culverts
- Stress cracking of plastic culverts

4.1.7 Need for Economical Methods of Repair and Replacement

Many culverts are reaching the end of their design life. In many cases, these culverts have been constructed under high fill or are under roadways that carry high volumes of traffic. Replacement of these culverts can be very costly as well as cause severe disruption to traffic. These circumstances require that viable methods of repair and rehabilitation be investigated.

The information provided in this chapter was obtained from FHWA-RD-94-096, Culvert Repair Practices Manual, Volume 1, May 1995. This publication should be used as a guide in the repair of culverts and appurtenances on ConnDOT facilities.