TECHSUMMARY January 2020

SIO No. DOTLT1000219 / LTRC Project No. 18-3P

Best Practices for Assessing Roadway Damages Caused by Flooding

INTRODUCTION

The United States has witnessed numerous natural disasters in recent years that resulted in the inundation of thousands of roadway lane miles. Assessing damage to flooded pavements is a challenge that agencies will likely face more often as climatologists predict that the changing climate will produce more frequent extreme events. Over the years, many state and local agencies across the country have used their financial resources to assess and evaluate roadway damages caused by major flooding events with varying degrees of success. There is some guidance for engineers to follow in distinguishing between roadway damage that warrants temporary versus permanent repairs when assessing flooded roadways, but it is primarily based on visual inspection rather than tied to any pavement performance based properties.

OBJECTIVE

The major objective of the proposed research was to identify the best practices for assessing roadway damages caused by flooding and develop multiple and appropriate levels of roadway damage assessment protocols.

SCOPE

The best practices used by local, state, and federal highway agencies to evaluate flood-induced damage to roadways were collected through a questionnaire survey and a comprehensive literature review. A composite evaluation indicator, Risk Factor (a combination of hazard, vulnerabilities, and consequence factors), was proposed to take it into consideration potential of flooding, structural loading capacity, hydraulic conditions, base material properties, and damage-entailed consequence. On the basis of the Risk Factor, a hierarchical engineering evaluation framework was developed to aid decision makers to conduct an appropriate level of evaluation for a specific flooded pavement.

METHODOLOGY

The composite evaluation indicator Risk Factor (or RF) was used to rank the relative risk associated with flood of various roadways from a holistic point of view.

A ***hazard factor*** is a qualitative score used to quantify a hazard, taking into account both its probability and magnitude, which is approximated hazard the size or the recurrence interval of a flood.

A ***vulnerability factor*** is a score for quantifying the sensitivity to a specific source of risk (i.e., hazard) that can induce an event with a consequence. Two types of flooding vulnerability of a roadway section were considered in this study: (1) The vulnerability of a roadway section being flooded during a given storm, which largely depends on the location, topographic and hydrological conditions of the roadway, and the characteristics of floods (i.e., the size of a flood), which is denoted as vulnerability factor 1 (VF1); and (2) the vulnerability of a flooded roadway section in terms of the likelihood of deterioration of its structural loading capacity caused by the flooding, which is related to structural, drainage, subgrade, and surface layer conditions of the roadway; this vulnerability factor is denoted as vulnerability factor 2 (VF2).

LTRC Report 615

Read online summary or final report:
www.ltrc.lsu.edu/publications.html

PRINCIPAL INVESTIGATOR:
Mingjiang Tao

LTRC CONTACT:
Zhongjie Zhang, Ph.D., P.E.
225.767.9162

FUNDING:
SPR: TT-Fed/TT-Reg - 5

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

A ***consequence factor*** is used to quantify the economic and social impacts of the damage to the structure caused by the hazard. The consequence of flood-induced damage to a roadway depends on the class of the roadway, traffic volume, and the costs associated with repairing and service restrictions.

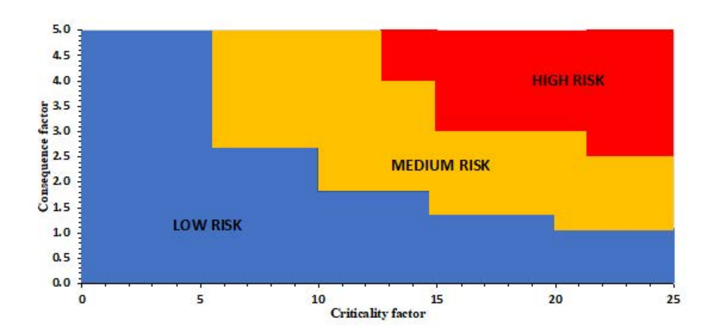

Figure 1
Risk factor map of a roadway section under a given size storm based on its risk factor in criticality factor-consequence factor space

The RF of a roadway section is plotted in a space of criticality factor-consequence factor in order to facilitate the determination of its risk to a given flooding event. The RF map can be divided into three zones (see Fig. 1): **high risk zone** with the risk factor ranging from 64 (corresponding to the case with all the parameters equal to 4) to 125 (corresponding to the case with all the parameters equal to the maximum value of 5); **medium risk zone** with the risk factor ranging from 27 (corresponding to the case with all the parameters equal to 3) to 64; and **low risk zone** where the RF is smaller than 27.

CONCLUSIONS

Based on a comprehensive literature review, researchers concluded that flexible pavements, especially those with a thin AC layer, have been identified as more prone to flood-induced damage, compared to rigid pavement and composite pavements. Therefore, local and low-volume roads are most vulnerable to flood-induced damages, even though oftentimes these roadways appear to be intact after the flood.

A holistic framework for evaluating flooding risk of roadways was proposed, which considers degree of hazard (i.e., flooding), vulnerabilities, and consequence. A quantitative composite indicator, Risk factor, as a product of hazard factor, vulnerability factor, and consequence factor, can be estimated with storm characteristics (i.e., recurrence interval); pavement characteristics (including, severity level of surface cracking, moisture sensitivity of subgrade, thickness of bound layers, and drainage condition of base/subbase layer); and functional class of pavement and traffic volume (i.e., AADT). A flooding risk map was developed based on the risk factor in a space of criticality factor-consequence factor, and a risk factor based hierarchical engineering evaluation procedure is recommended as follows:

- Level 1: Hydraulic and pavement performance analyses + Nondestructive testing + Field Reconnaissance (visual inspection-data recording-checking) (for the roadways with high risk)
- Level 2: Nondestructive testing + Field Reconnaissance (visual inspection-data recording-checking) (for the roadways with medium risk)
- Level 3: Field Reconnaissance (visual inspection-data recording-checking) or Inferring damage based upon previous engineering studies (for the roadways with low risk)

RECOMMENDATIONS

In the context of more extreme weather events, it is highly recommended that state DOTs and local municipalities regularly monitor and document structural conditions of roadways, especially those with a thin AC layer that are deemed to be more vulnerable to flooding risk, such as local and low-volume roads. Common in-situ testing tools used by various highway agencies, including FWD, DCP, and GPR, are recommended for such a purpose.

The composite risk indicator (Risk Factor) and the flood risk map developed in this study can aid pavement engineers and decision makers in identifying roadway sections with different level of risk to a given size storm, which can be readily added to GIS-based roadway network maps of existing pavement management system. The holistic evaluation framework developed in this study can enable pavement practitioners to make informed decisions in: selecting appropriate engineering methods to evaluate flood-induced damage for immediate post-flood response; deciding when a flooded roadway can be reopened to what type of vehicles; and allocating funds and resources to reduce the flood risk of roadways falling in a high risk zone in advance for long-term planning.