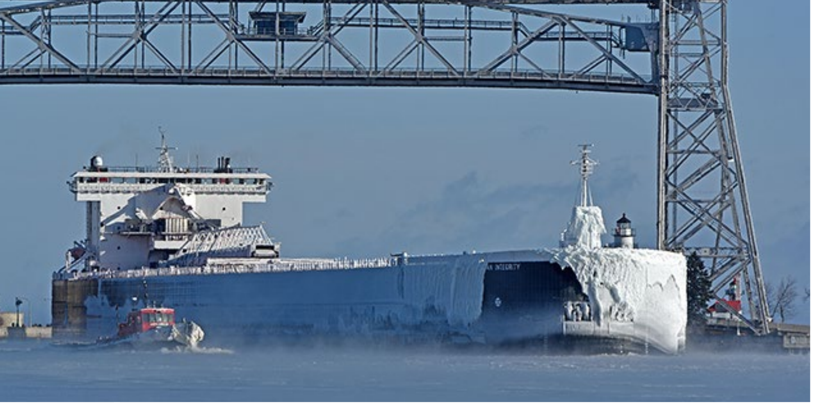
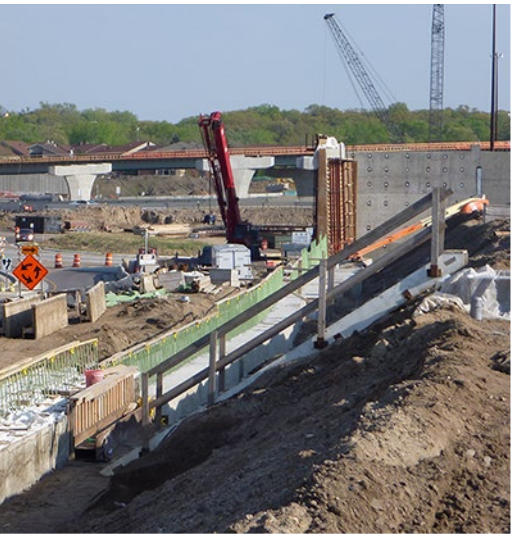
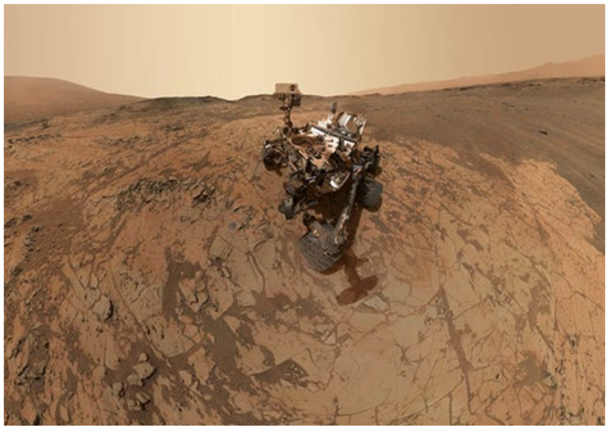
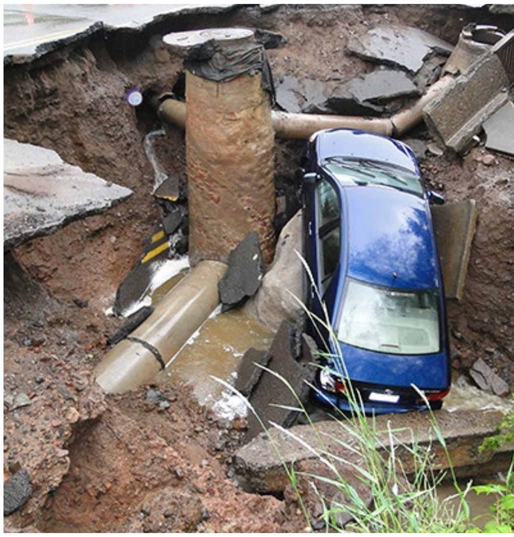



# Congress on Technical Advancement 2017

## Cold Regions Engineering

Proceedings of the Congress on Technical Advancement 2017

Duluth, Minnesota
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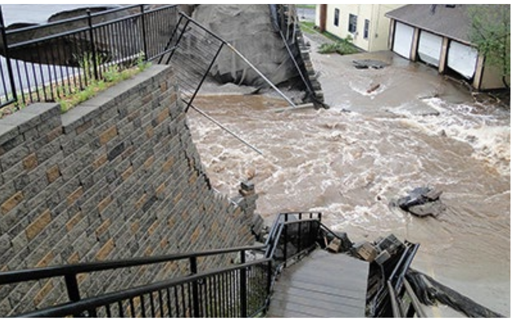
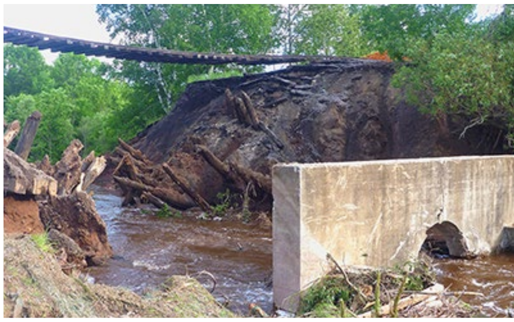

Edited by **Jon E. Zufelt, Ph.D., P.E., D.WRE**

ASCE

# CONGRESS ON TECHNICAL ADVANCEMENT 2017

## *COLD REGIONS ENGINEERING*

PROCEEDINGS OF THE 17TH INTERNATIONAL CONFERENCE ON COLD REGIONS ENGINEERING PRESENTED AT THE FIRST CONGRESS ON TECHNICAL ADVANCEMENT

September 10–13, 2017
Duluth, Minnesota

SPONSORED BY

Committee on Technical Advancement
Aerospace Engineering Division
Cold Regions Engineering Division
Committee on Adaptation to a Changing Climate
Energy Division
Forensic Engineering Division
Infrastructure Resilience Division
Construction Institute
Duluth Section of ASCE
Utility Engineering and Surveying Institute of the
American Society of Civil Engineers

EDITED BY
Jon E. Zufelt, Ph.D., P.E., D.WRE

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org



*Errata:* Errata, if any, can be found at https://doi.org/10.1061/9780784481011


ISBN 978-0-7844-8101-1 (PDF)
Manufactured in the United States of America.

# Preface

The Congress on Technical Advancement was established to bring together several of the Divisions under the ASCE Board-level Committee on Technical Advancement (CTA) at a single venue. While some of the CTA Divisions hold regular small conferences, others do not have an established forum to present technical information to their constituents or the engineering community. One of the goals of the Congress is to provide greater opportunities for interaction and synergy among the activities of the Divisions and ASCE's Institutes. This 1st Congress on Technical Advancement was held at the Duluth Entertainment and Convention Center in Duluth, Minnesota on September 10-13, 2017.

This 1st Congress included the participation of and presentations by the Aerospace Engineering Division, Cold Regions Engineering Division, Committee on Adaptation to a Changing Climate, Energy Division, Forensic Engineering Division, Infrastructure Resilience Division, the Construction Institute (CI), and the Utilities Engineering and Surveying Institute (UESI), representing the combination of existing conference series as well as opportunities for new periodic technical symposia. The Congress was hosted by the Duluth Section of ASCE as they celebrated their 100th Anniversary with a special session and evening social event.

The 2017 Congress on Technical Advancement included 3 days of presentations with daily plenary sessions followed by 6 parallel tracks of technical sessions providing a venue for over 160 presentations. The conference also included an Awards Luncheon highlighted by the presentation of the Harold R. Peyton Award for Cold Regions Engineering, the CAN-AM Civil Engineering Amity Award, the Charles Martin Duke Lifeline Earthquake Engineering Award and the Alfredo Ang Award on Risk Analysis and Management of Civil Infrastructure. Other recognitions during the Congress include the Eb Rice Lecture Award, the Best Journal of Cold Regions Engineering Paper Award, and the Best Cold Regions Conference Paper Award. An Opening Congress Reception, Duluth Section 100th Anniversary Session and Social Event, and Technical Tours provided additional opportunities for attendees to share ideas.

This collection of 60 papers brings together the current state of knowledge on a variety of topic areas presented at the 2017 Congress on Technical Advancement and is separated into three EBooks. The first represents selected papers from the Proceedings of the 17th International Conference on Cold Regions Engineering. The second includes the papers on Infrastructure Resilience, Aerospace and Energy. The third EBook presents papers addressing Construction and Forensic Engineering.

I would like to thank all of the volunteers and ASCE Staff who have made this 1st Congress on Technical Advancement and Proceedings possible. It could not have been done without all of the authors, reviewers, attendees, and Congress Committee members.

Jon E. Zufelt, Ph.D., PE, D.WRE, F.ASCE Congress Chair and Proceedings Editor

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# Contents

# Effect of the Presence of Pre-Service Construction Cracks in Concrete Decks on the Thermal Profile of Composite Steel-Concrete Bridges in Cold Regions

Omar Y. El Masri[1] and Caesar Abi Shdid[2]

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**Abstract**

Thermally induced stresses in composite steel-concrete bridges are higher than those experienced by their concrete and steel cousins, leading to significant damage in the concrete deck and corrosion of the steel reinforcement. Bridge design engineers use thermal profiles prescribed by codes such as AASHTO to predict future service stresses. A 3D finite element model is presented that investigates the temperature distribution in a case study bridge with pre-existing construction deck cracks. The non-linear transient simulation is performed using actual environmental loads for a geographic region with severe climate (North Dakota), and the resulting profile is compared to that of AASHTO. The results show the thermal gradient proposed by AASHTO to be overly conservative in cold regions. Existing models seem to ignore the nonlinearity of the thermal gradient, which can be critical for thermal stress calculations. The pre-service deck cracks appear to have a considerable effect on both the vertical and the longitudinal temperature distributions, and it is recommended that they be given careful consideration by design codes.

## 1. Introduction and Justification

Bridges are subjected to continuously changing diurnal environmental conditions that lead to continuous heat gain and loss with their surroundings. The thermal gradient that develops within a bridge cross section is affected by four basic heat transfer phenomena: a- convection at the surfaces, b- irradiation, c- solar radiation, and d- conduction within the bridge. While the solar radiation intensity has the highest effect on changing the bridge temperature, the thermal gradient is largely affected by the thermal diffusivity of the constituent materials. It is the difference in this thermal diffusivity of concrete and steel that makes the thermal gradient in composite steel-concrete bridges rather high. The non-uniform temperature distribution within a bridge cross section when combined with different coefficients of thermal expansion and shear connectors that prevent slip between the concrete deck and steel girders, will lead to considerable thermal stresses. These stresses are known to be relatively high when compared to service load stresses, leading to considerable damage in the concrete deck. The major damage attributed to thermal stresses is developing deck cracks. However, and despite its importance, limited studies have been dedicated to investigating the temperature distribution in composite bridges [1,2,3].

Design codes, such as the American Association for State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications, assert the importance of accounting for thermal stresses in bridge design by providing designers with proposed thermal gradients that describe the vertical temperature distribution in bridges located in various geographic regions [4]. However, previous studies, on which the proposed AASHTO gradient is based, mostly consider two- or one-dimensional models with, in some cases, even steady state analysis. They have thus failed to consider the effect of construction cracks, which are pre-existing in the bridge deck, on the temperature distribution within the deck in both the transverse and longitudinal directions. These cracks are found to develop directly after the concrete deck casting and before the opening of the bridge for traffic [5]. The work presented here uses a three-dimensional computational model to examine the accuracy of presently used thermal profile models in cold regions.

## 2. Related Work

Analytical, numerical, and experimental investigations have led to the development of various thermal profiles that have been adopted by different codes around the world. Zuk [1] developed equations to calculate the longitudinal and transverse stresses in composite bridges under different conditions of temperature and shrinkage. These equations were developed for four (4) different and critical cases of temperature distribution; however, a uniform temperature for the steel beam is adopted in all cases due to its high thermal conductivity and its ability to adjust its temperature quickly to that of the surrounding environment [1]. In a later study, Berwanger [6] developed a numerical procedure that uses two-dimensional thermo-elastic finite element analysis (FEA) to predict the transient temperature in the cross sections of composite bridges. Results showed a slower response for the concrete slab with a very rapid increase in thermal moments. The study concluded that a linear temperature profile could be used satisfactorily to represent the temperature in the transverse cross section. The study also stresses that possible existing cracks in the concrete deck were ignored.

Thermal gradients used in composite bridges differ from one code to another. Imbsen et al. [2] evaluated the thermal effects on bridge superstructures based on different codes. Many of the findings and recommendations of this study were included in the following revision of the AASHTO code: Thermal Effects in Concrete Bridge Superstructures [7]. Kennedy and Soliman [8] synthesized the various theoretical and experimental studies that had been conducted on composite concrete slab on steel beam bridges, and proposed a simple one dimensional vertical temperature distribution within the section. The distribution they proposed is uniform through the depth of the steel beam and is linear through the concrete deck. A study by Fu et al. [3] concluded that a steady-state thermal condition never exists within a bridge structure, and that the time dependency of the ambient air temperature and solar radiation would dictate a transient analysis. A more recent thermal profile was proposed by Chen [9] based on numerical analysis using two-dimensional finite element (FE) analysis. Emanuel and Taylor [10] conducted a computer-based study on composite bridges to investigate the relationship between uniform, linear, and non-linear components of thermally-induced stresses on the one hand and varying span lengths, number of spans, and support conditions on the other hand. The study concluded that the three components of thermally induced stresses are independent of the span length.

Bridge decks with overhangs present a problem for predicting the daily temperature in a cross section due to the shading effect that they will have on the steel girders—an effect that will vary between geographical locations and throughout the time of the day. An analytical parametric study was conducted by Fu et al. [3] on composite bridges to determine the effects of shading.