<u>Quarterly Progress Report</u>:

Project Number and Title: : 3.7 Development of general guidelines related to the effects of factors such as the bridge span range, range of pile length, roadway profile grade, and skew angle range on integral abutment bridges (IABs)

Research Area: Trust 3: New systems for longevity and constructability

PI: Susan Faraji, University of Massachusetts Lowell

Reporting Period: 4/1/2020 - 6/30/2020

Submission Date: 6/30/2020

<u>Overview:</u>

The overall objective of this research is to improve the guidelines for the modeling, design, and construction of integral abutment bridges (IABs) by completing the following tasks:

Task 1: Literature review and gathering of information

Task 2: Improve the guidelines for the modeling, design, and construction of IABs

Based on the input from a number of state DOTs (Mass, Vermont, and Maine), the following tasks have been undertaken:

(a) A study of the effect of the roadway profile grade on substructure;

(b) A study of the constructability of pile-supported IABs at a site with shallow bedrock;

(c) A study of the effect of skew angle along with other factors such as bridge span to width ratio, relative stiffness of substructure with respect to superstructure on the distribution of forces between superstructure and substructure;

(d) Improve the finite–element modeling and analysis of IABs.

Task 3: Provide general guidelines in a final report regarding the topics studied.

Summary of the activities performed during the reporting period:

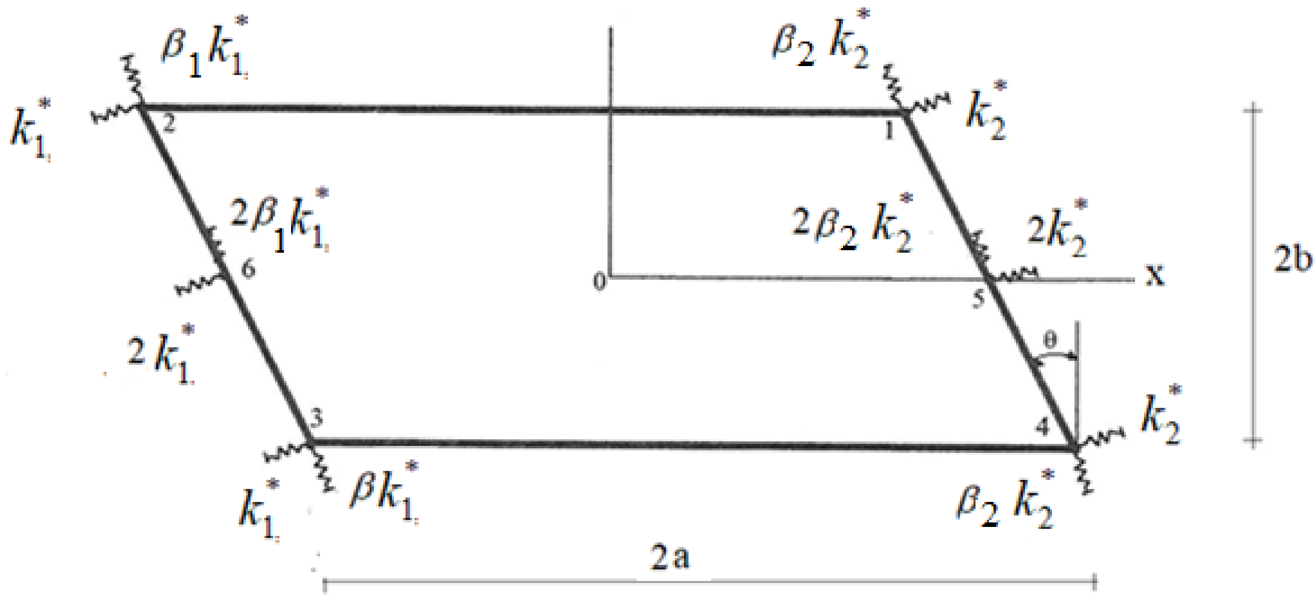
Task 2(c):

The analytical and parametric studies of a symmetrical skewed rigid plate with restraining symmetrical springs acting on two sides of the plate subjected to a uniform thermal loading were extended to an asymmetrical skewed rigid plate with restraining non-symmetrical springs.

The use of restraining symmetrical springs is representative of identical substructure conditions at both abutments. On the other hand, the use of restraining non-symmetrical springs is representative of different conditions at the abutments, such as variations in the soil pressure behind the abutment walls, the HP piles inertia, the length of the HP piles, and wing wall type.

Where β_1 and β_2 are tangential relative stiffness parameters representing the effect of friction force and the effect of wing wall and soil the behind it,

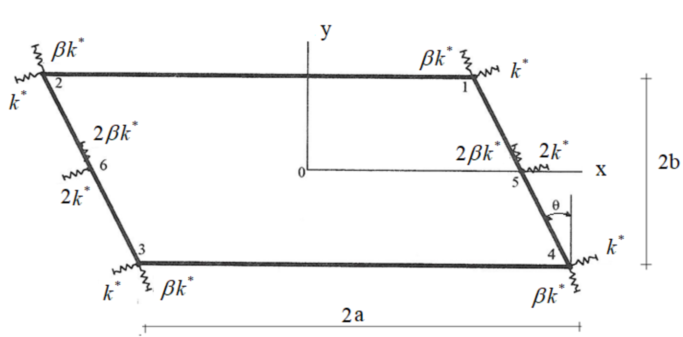
k_1^* and k_2^* are the reference normal stiffnesses.



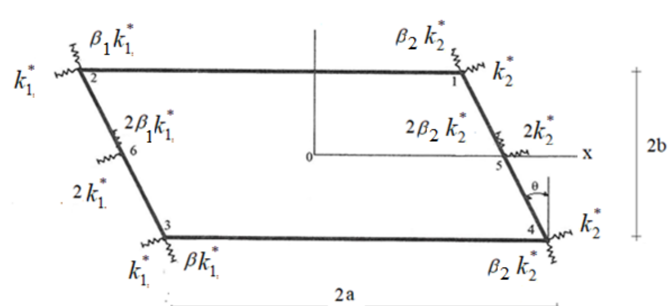
Geometry of a skew rigid plate and location of non-symmetrical springs

For thermal loading the rotation of the plate, the normal displacements and spring forces at the sides of the plate were derived by varying different factors such as skew(θ), span/width ratio (a/b), tangential relative stiffness parameters (β_1, β_2) and normal reference stiffnesses (k_1^*, k_2^*).

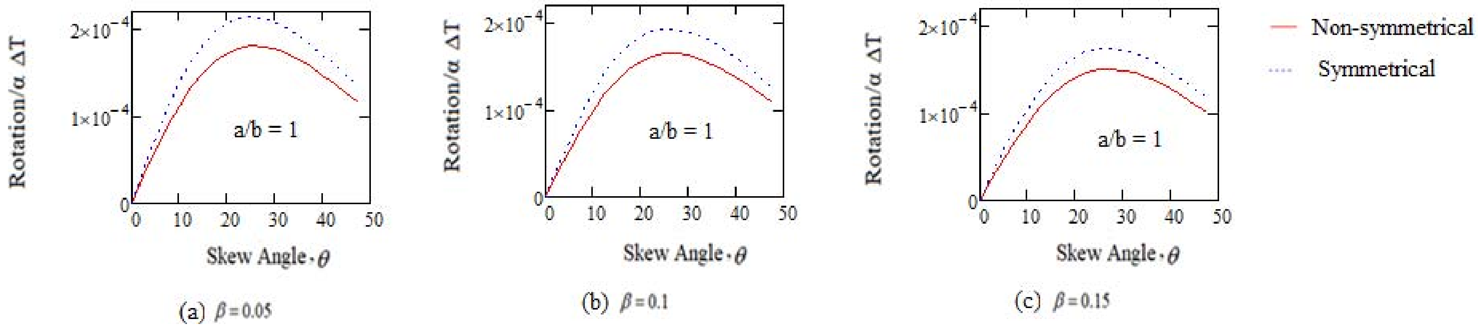
Some of the analytical solutions results for symmetrical springs versus non-symmetrical springs are shown in the following plots:



Symmetrical springs

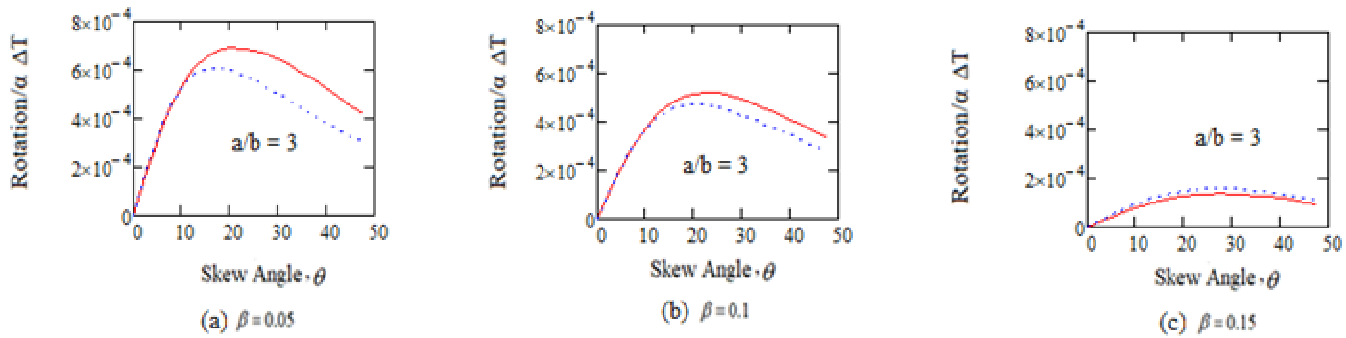


Non-symmetrical springs



$\beta_1 = \beta_2 = \beta \; , \; k^*_2 = 1.05 \; k^*_1$

Variation of horizontal in-plane rotation of rigid plate for a range of skew angles under thermal loading for symmetrical vs. non-symmetrical springs



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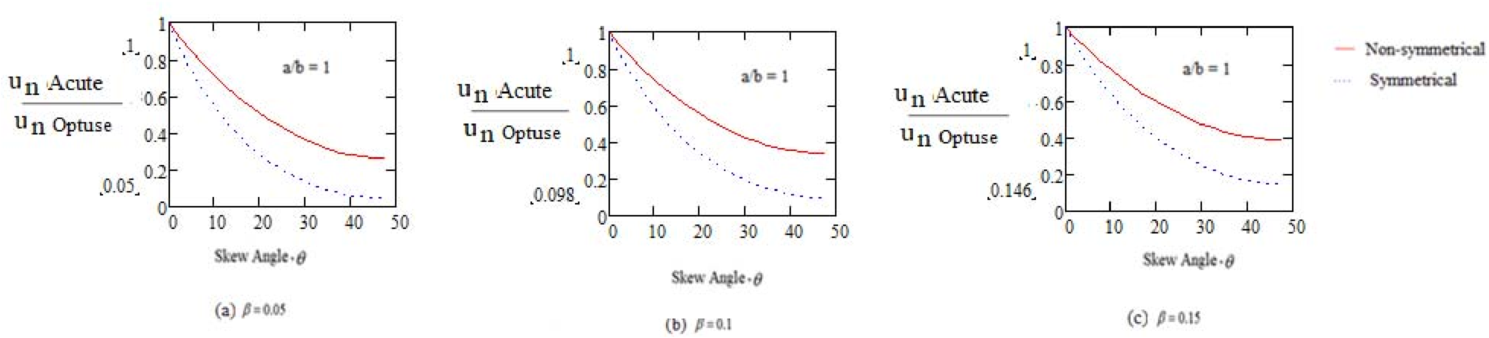
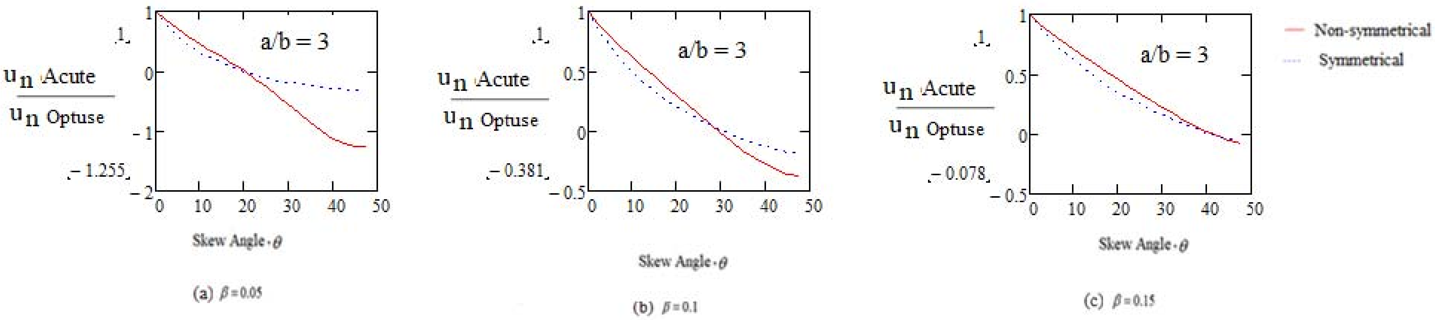
Variation of horizontal in-plane rotation of rigid plate for a range of skew angles under thermal loading for symmetrical vs. non-symmetrical springs



$\beta_1 = \beta_2 = \beta \; , \; k^*_2 = 1.05 \; k^*_1$

Horizontal variation of ratio of normal displacement at the acute corner to normal displacement at the obtuse corner of a skewed rigid plate for a representative range of β and θ under thermal loading for symmetrical vs. non-symmetrical springs



$\beta_1 = \beta_2 = \beta \ , \ k^*_2 = 1.05 \ k^*_1$

Horizontal variation of ratio of normal displacement at the acute corner to normal displacement at the obtuse corner of a skewed rigid plate for a representative range of β and θ under thermal loading for symmetrical vs. non-symmetrical springs

Task 2(d):

A full three dimensional finite element model of a sample three span skew integral abutment bridge (F-4-20) incorporating the nonlinear soil response behind the abutment walls and adjacent to the HP piles has been started. This sample skew bridge will be included in the final report.

All the research done to date falls within the parameters of the tasks listed.

Table 1: Task Progress			
Task Number	**Start Date**	**End Date**	**% Complete**
Task 1:	7/1/2018	10/31/2019	90%
Task 2:	11/1/2019	9/30/2020	50%
Task 3:	11/1/2019	9/30/2020	30%
Overall Project:	1/1/2019	9/30/2020	60%

Table 2: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date***
$200,943	**$98,432**	60%

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
Behavior of skewed integral abutment bridges under thermal loading	A presentation to the Vermont Agency of Transportation	Seminar	Virtual	June 8, 2020

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Non*				

* The submission of papers to refereed journals has been delayed because of a lack of student help.

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Dr. Susan Faraji, Professor	Susan_Faraji@uml.edu	Civil and Environmental Engineering	Project Principal Investigator

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Non*				

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**
Non*			

* Expecting to hire one or two graduate students by the fall of 2020.

Table 8: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
Vermont Agency of Transportation	Vermont		x			x

Technical Champion for this project:

Mr. James Lacroix PE

State Bridge Design Engineer

Vermont Agency of Transportation

James.Lacroix@vermont.gov

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Changes:

Because of the departure of the graduate student and other factors there will be a delay in planned publications.

Planned Activities:

- Analytical and parametric studies will continue within the parameters of Task 2 of the project.

- Virtual seminar presentation to Maine DOT on the behavior of skewed integral abutment bridges under thermal loading on August 3, 2020