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Impact of Floods on Bridge Superstructure

Ankush Thakur[1], Hari Krishan Pandit[2] and Chandra Pal Gautam[3]

[1,2]PG Student, Jaypee University of Information & Technology Wakhnaghat
[3]Jaypee University of Information & Technology Wakhnaghat
E-mail: [1]ankush.thakur2509@gmail.com, [2]hari.pandit2050@gmail.com, [3]Cpal3012@gmail.com

Abstract—*The study deals with the bridge collapse focusing on bridge superstructure. It is based on the literature, simulations and analysis that consider in two stages: (1) initial impact and overtopping and (2) full flood up to deck level. The first stage starts from the time when the flood surface elevation reaches the low chord of the bridge superstructure, the free water surface rises and reaches the top of the bridge barrier where it overtops the bridge and starts to flow on the bridge deck, and until the bridge is totally overflowing. The second stage occurs when the bridge first becomes fully overflowing, i.e., end of the first stage, and until the most critical events, (1) the maximum storm water depth, (2) the maximum flood flux, have occurred. In this paper a short overview of the bridges is given presenting the historic context for the described incidents. It is followed by a classification of the most common reason of bridge failure, which includes structural and design inadequacy, corrosion, construction and oversight mistakes, scour, lack of maintenance or inspection, accidental overload and impact and force majeure. Some significant recent examples are described.*

1. INTRODUCTION

Floods have caused a significant damage to the human lives as well as country's Infrastructure in past few year. For example, the uttrakhand floods and Jammu Kashmir floods have destroyed many infrastructure as well as took 280+ human lives. It is seen that those bridges which survive the Bigger earthquakes sometimes washed away during heavy floods which shows that some aspects or codal provisions need to be revised or few new techniques need to be evolved so that existing structures as well as the new one's should be safe against floods.

Highway Bridge is the important part of the transportation system as they have a significant role in maintaining the access to those areas which are severely flooded. Therefore , a flood resistant design of these superstructures become important aspect

2. OBSERVED BRIDGE FAILURE MECHANISM

2.1 Bridge Superstructure-Substructure Connection Failure

This type of connection failure is mostly seen in the bridge superstructure when the free surface water level overtops the bridge deck and the velocity of water is high. As a typical failure of bridges during force majeure, standing piers along with a washed off superstructure indicates weak connection between super & sub structure. This is due to both the horizontal and uplift forces acting on the bridge superstructure

2.2 Failure of foundation, piers or Abutments

Failure due to connection of super & substructure other factors which cause a bridge to fail are failure of bridges , piers and abutments due to scouring. As, fast flowing flooded water scours away the riverbed downstream of the piers on which a bridge res. t These types of failure are related to the bridge substructure and hence these failures will not further discussed in this paper because the work focuses on the bridge superstructures.

3. OBJECTIVE

This paper presents results of a study on simulations of Water wave forces on bridge superstructures. The data is taken from the various IRC codes and Also from some reference papers which is given in Bibliography. And some elements are assumed which are further based upon the codes like, wind speed, height of bridge superstructure etc.

4. SOME RECENT EXAMPLES

4.1 4th TAWI BRIDGE in Jammu and Kashmir

This bridge is in state of Jammu and Kashmir. During the last year floods in State this bridge approach slab washed away due to the Scouring beneath the wing walls the flood water didn't overtop the bridge deck so it didn't overturned due to the uplifting force. The approach slab is constructed again after the flood and bridge is again fully functional

Fig. 1: 4th TAWI Bridge in Jammu and Kashmir

4.2 Kedaar Ghat Bridge, uttarkashi (uttrakhand)

A damaged bridge picture in kedaar ghat in uttarkashi, Uttrakhand after the flood wash in uttarkashi. The bridge girders washed away as the joints between superstructure and substructure failed due to the force caused by flooded water.

Fig. 2: Kedaar Ghat Bridge, uttarkashi (uttrakhand)

4.3 Firth of Tay Bridge, Scotland

This bridge failed due to the load of the storm and the train crossing the bridge, one of the pillars buckled and took the continuous bridge girder with it. The main causes of the collapse were found in the insufficient assumption of wind forces, the careless execution of the work and the application of low quality material, the bridge builder being responsible for all of them. The Tay Bridge disaster encourages investigations even today. The consideration of higher static wind pressure started immediately after it happened.

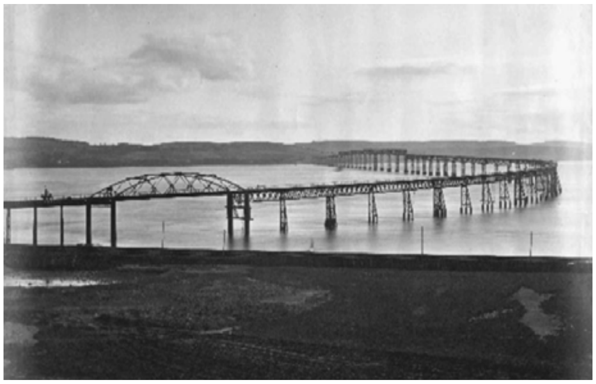


Fig. 3: Firth of Tay Bridge, Scotland

5. MODAL DESCRIPTION

A FEM modal is created using CSiBridge Software. Two different models are used because of the different flood flow fields in Stages 1 and 2. In the model developed for Stage 1], the water free-surface elevation reaches the lower chords of bridge deck & in stage 2, the goal is to achieve a constant storm water depth because the bridge is already fully inundated. For both models, the domain consists of two parts: (1) a fluid part that includes both water and air domains, and (2) a bridge superstructure. In this study, the bridge superstructure is modeled as a rigid body consisting of the bridge deck, supporting girders, and end barriers, which are continuous along the bridge's longitudinal direction. Water is modeled as compressible flow. The mass density of water is taken as 3.702E-05 and maximum sub mesh size is taken as 10mm.The loading conditions over the bridge deck is taken as Per IRC codes. The Model can be updated as SPINE(Frame) as well as Area Object(shell) as per user convenience.

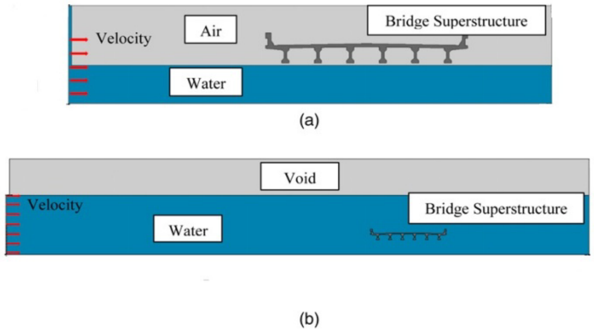


Fig. 4: Modal description at stage 1 & 2.

6. PROPERTIES OF BRIDGE

Table 1

SPAN	30.48 meters @15.24m each
Width of deck section	10.97 meters
Live load	IRC CLASS AA-T & CLASS 70R
MATERIALS	HYSD BARS Fe415 M35 &M60 GRADE CONCRETE FOR DECK AND PIERS RESPECTIVELY

7. FEM SPINE MODAL OF BRIDGE

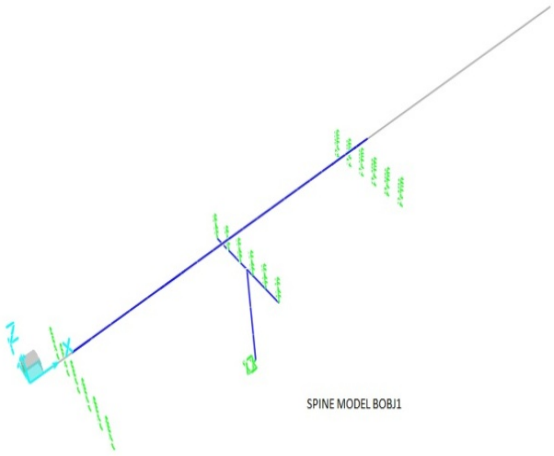


Fig. 5: spine modal of bridge

8. EXTRUDED VIEW OF SPINE MODAL

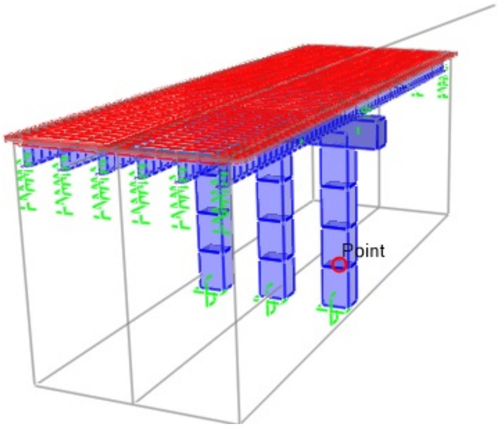
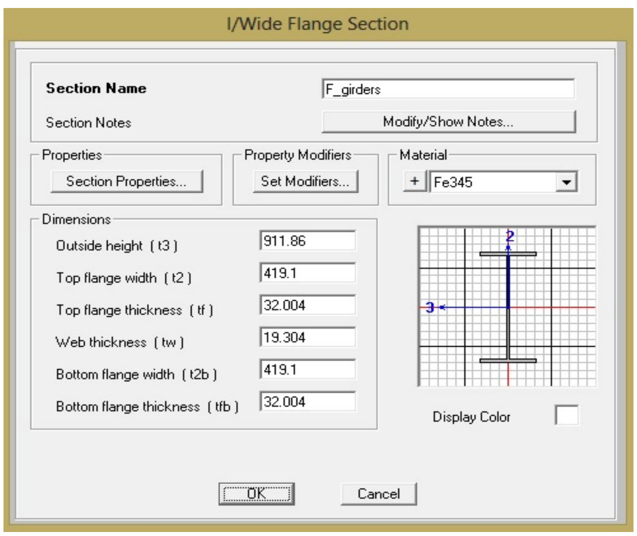
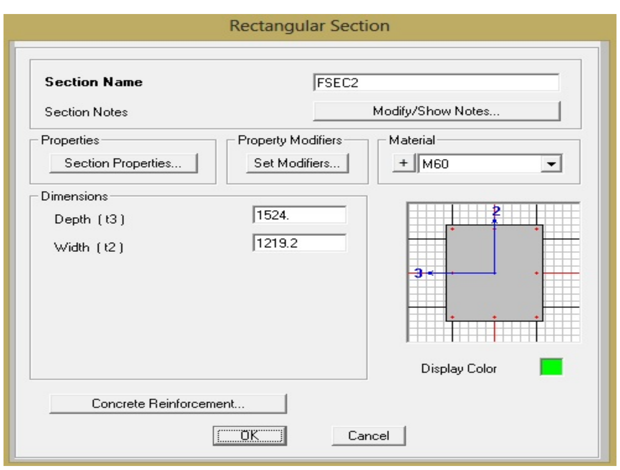


Fig. 6: Extrude View of Model

9. STEEL GIRDER SECTION PROPERTIES



10. PIER SIZE



11. ANALYSIS RESULTS

Various loads are applied to the bridge superstructure and analysed further.The Results are displayed in the tabular form.

Table 2

TYPE OF LOAD	SHEAR FORCE	
	MAXIMUM	MINIMUM
DEAD LOAD	755.40KN	-755.40KN
LIVE LOAD(moving)	40650.81KN	-40650.81KN
LIVE LOAD(Multi-step Static)	385.97 KN	-732.22 KN
WAVE(STAGE 1)	0.965 KN	-2.21KN
WAVE (STAGE 2)	175.24KN	-173.33KN

Table 3

TYPE OF LOAD	BENDING MOMENT	
	MAXIMUM	MINIMUM
DEAD LOAD	975.80KN-m	-1875.54KN-m
LIVE LOAD(moving)	8116.4KN-m	-10806.5KN-m
LIVE LOAD(Multi-step Static)	704.47KN-m	-1373.61KN-m
WAVE(STAGE1)	12.31KN-m	-12.41KN-M
WAVE(STAGE2)	443.72KN-m	-212.815KN-m

12. CONCLUSION

Modeling, simulation, analysis, and approximate flooded water wavelength which is itself program calculated is summarized here. A finite element model was developed for the simulation. Simulation is performed for both the stages and horizontal & vertical forces and overturning moment are calculated. it is found that as the free water surface rises the moment also keep on increasing and when the water overtops the bridge deck the moment become so high that it may fail the bridge in negative moment i;e uplift force is generated.

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