Bridge seismic design competition

6NSC Charleston 2008

Organized by

U.S. Department of Transportation Federal Highway Administration

SCDOT South Carolina Department of Transportation

MCEER EARTHQUAKE ENGINEERING TO EXTREME EVENTS

TRB

COLLEGE OF ENGINEERING AND COMPUTING UNIVERSITY OF SOUTH CAROLINA

1. Introduction

Undergraduate Civil Engineering students are traditionally trained about the effect of static loads in structure and the design of structural members to support these loads through their curricula. The seismic analysis and design of structures is limited to advanced undergraduate classes which in most cases are not required for graduation in many schools. As a result, many students are not exposed to the effect of earthquakes loading on civil infrastructure and the difference between dynamic and static loads.

The aim of this competition is to provide an environment for Civil Engineering undergraduate students to explore the effects of earthquakes on bridges. With this competition we hope to increase awareness of the catastrophic effect of earthquakes and the importance of earthquake design. We also hope to introduce young undergraduate students who are part of the teams to the exciting world of structural engineering and encourage them to take advanced classes in dynamic of structures and earthquake engineering as part of their education.

The specific objectives of this competition are:

1. To expose undergraduate students to earthquake resistant design of bridges.
2. To increase the awareness of the catastrophic consequences of earthquakes.
3. To foster written and oral communication of undergraduate students in a professional setting.
4. To provide networking opportunities to undergraduate engineering students.

This document describes the competition and rules for the bridge seismic design competition to be held at the 6th National Seismic Conference on Bridges and Highways to be held in Charleston, South Carolina, July 2008. Testing of the structure will be performed during the conference and design teams will be invited to present a paper explaining their design in a special session at the conference. Winners will be announced at the conference's award ceremony. The prize of the competition is $500 for the first team.

1.1. Eligibility Requirements

The competition is intended for any undergraduate engineering students, including four and two year colleges and universities with graduate programs. A team will have a **maximum of five members and a minimum of two members**. **A faculty advisor is required to enter the competition.** The role of the faculty advisor is to guide students through the competition and therefore is not counted as a team member. Only one team per school will be permitted to enter the competition. Teams are required to submit a design paper by March 17, 2008. The papers will be reviewed and two members of the top five teams will be invited to the conference to test their designs. Teams are expected to register and fully participate in the entire conference. A scholarship of $1,300 will be given to each team that advances to the final competition to offset travel and registration expenses.

2. Problem Statement

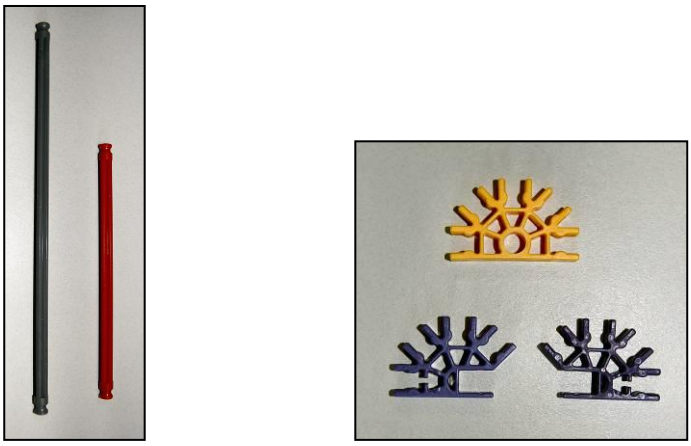
A new bridge is to be constructed across the Ashley River in Charleston, South Carolina. The structure will be part of a new highway system to enhance the transportation network in downtown Charleston. The objective is to **design the safest bridge using the least amount of material possible and constructed in the minimum time.**

The new bridge is part of the lifeline system used to assist the city in the case of an earthquake or a hurricane. For this reason, the bridge should be able to withstand a combination of static and earthquake loads with minimal damage. In addition, the bridge should be able to be constructed in the minimum time possible, providing minimum disruption to the traffic in the city. Because of the innovations of your company's design, Your team is required to submit a design report in the form or a paper to the 6th National Seismic Conference on Bridges and Highways. A scaled version of your design will be tested at the conference in an earthquake simulator.

3. Design constraints

The bridge design and model should follow the following constraints. Violation of any constrain will result in disqualification. For any clarifications about the design constraints see competition web page at http://www.ce.sc.edu/DeptInfo/Members/Faculty/caicedo/bridge_competition or contact the competition chairman at caicedo@engr.sc.edu. The general design constrains are:

1. Moving parts are not allowed in the design of the bridge.
2. Only traditional K'nex structural members such as those shown in Figure 1 are allowed for the design.
3. The bridge can not have any extra piers in the river for environmental reasons.
4. Glue is not allowed in the design/construction of the structure.



a. Structural Elements b. Connections

Figure 1. Sample structural elements and connections

3.2. Site Geometry

Figure 2 shows the overall geometry of the site where the bridge is to be constructed. The scaled model bridge should be 2 meters long and at least 10 centimeters wide. The maximum width of the bridge is 15 cms. Note that the maximum clearance between the river and the surface of the bridge's deck is 5 cm. No element can be underwater because of environmental concerns. **Any structure not complying with the site geometry will be disqualified.**

4. Testing

The testing of each bridge will be performed during the conference sessions allowing ample time to set up each test. Two team members will have 20 minutes to assemble their design as specified on their design paper without penalties. Both, static and dynamic tests will be performed to the structure after assembly.

4.3. Static test

A mass of 1.5 kg will be placed at the midpoint of the bridge. Any structures with a

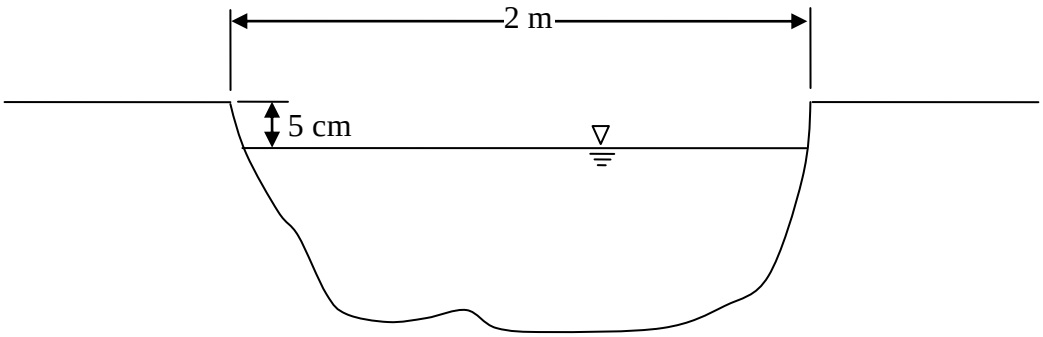


Figure 2. Bridge Geometry

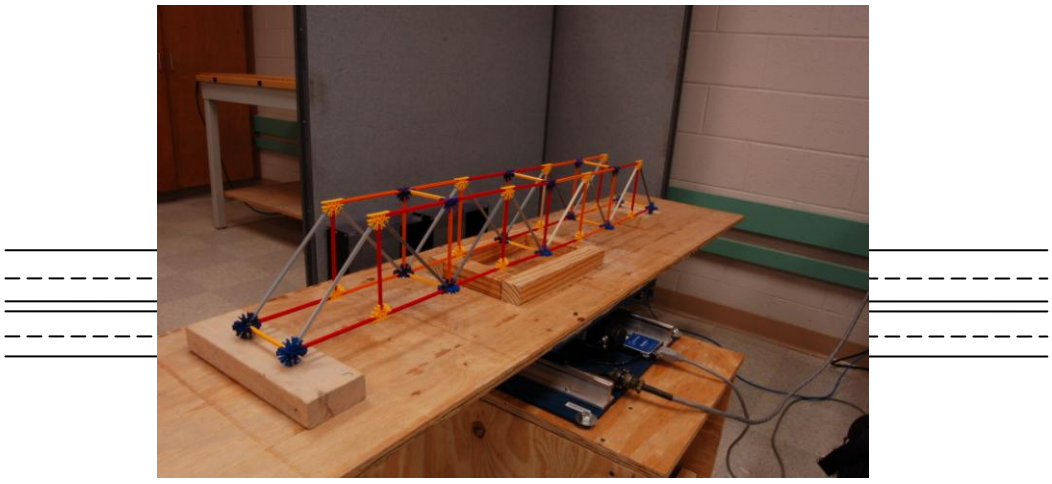


Figure 3. Sample structure

maximum displacement larger than 1.5 cm will be penalized. Failure of the structure is considered when any member of the structure has been permanently deformed or disconnects from the connection. **Any structure failing when the 1.5 Kg is applied will be disqualified.**

4.4. Dynamic test

The structure will be tested under earthquake excitation in the transverse direction of the bridge. Three earthquakes will be used to excite the structure, Kobe, Loma Prieta and the Landers earthquake. The 1995 Kobe earthquake was one of the most devastating earthquakes to ever hit Japan with a moment magnitude of 6.8. The Loma Prieta earthquake struck the San Francisco Area in 1989 with a magnitude of 6.9. The magnitude 7.3 Landers earthquake occurred on 1992 in California and a record of this earthquake was used for the design of the new Cooper River Bridge. Scaled versions of these earthquakes will be used on the earthquake simulator for dynamic testing. The scaled record can be downloaded from http://www.ce.sc.edu/DeptInfo/Members/Faculty/caicedo/bridge_competition. Any structure **failing under any of these earthquakes will be disqualified.**

An accelerometer will be installed at mid span and acceleration measurements will be recorded. The design teams will have the objective of reducing the acceleration at mid span. A number of points will be added or subtracted depending on the performance of their structure.

5. Design Reports

Participating teams will be asked to submit a paper to the conference explaining the design and construction of their structures. The report should include a detail drawing of their design. This drawing will be used to judge if the team has deviated from their original design during construction. Papers should also include a table of structural elements and connectors, and the calculated total weight of the scaled model..

6. Scoring

The goal of this competition is to design the most efficient design. Efficiency is defined here as the less expensive design that is able to withstand the design loads. Therefore, the score of each team will depend on the amount of material used (number of structural elements and number of connections) as well as their performance under static and dynamic loads. **The team with the least number of points at the end of the competition will be the winner.**

6.5. Material cost

Structural members: Structural members will have a cost of 1 point for each linear centimeter. Figure 1 shows typical allowed structural members.

Connections: Each connecting unit will have a cost of 5 points. Connections using multiple connecting units will cost 5 points per connecting unit. For example, the cost of the connection shown in Figure 4.a is 5 points because it only has one connecting unit.

The cost of the connection shown in Figure 4.b is 10 points because it has two connecting units (blue and purple in the picture).

6.6. Construction time

Two team members will have 20 minutes to build their bridges based on their original design. Team builders will start with only the number of pieces indicated in their design and all the pieces will be separated in groups of the same type. Teams taking more than 20 minutes will be penalized with 10 points for each additional minute. After the bridge is constructed a judge will compare the original design drawings with the constructed bridge. A penalty of 10 points for each structural member of connection assembled in the wrong location will be added.

6.7. Static load

The design firm will be charged 100 points for each additional centimeter above the 1.5 allowable mid-span deflection on the static test. If the bridge has a static deformation higher than 1.5 cm, the number of points to be added to the design will be calculated using the equation

$$P_s = 100(D - 1.5)$$

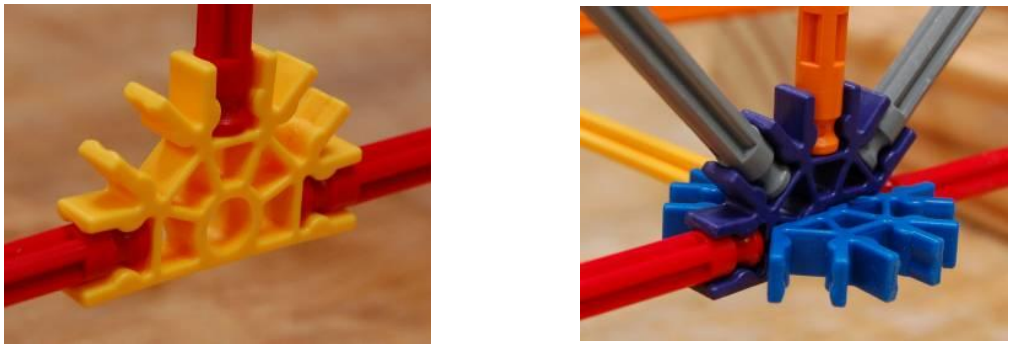
Where *Ps* is the number of points and *D* is the number midspan deflection in cm.

6.8. Dynamic load

Each structure will be judged dynamically based on the ration between the ground peak acceleration and the structures acceleration. Each team can add or deduct points based on the equation

$$P_D = 100 * \frac{(A_s - A_g)}{A_g}$$

Where P_D are the number of points to add/substract. A_g is the peak ground acceleration and A_s is the structure ground peak acceleration. Each structure will be



a. Single unit connection b. Two unit connection

Figure 4. Connections

tested with and without the additional 1.5 Kg mass and the highest number will be added to their points.

7. Registration

Teams can register by downloading the registration package on the conference website (http://www.ce.sc.edu/DeptInfo/Members/Faculty/caicedo/bridge_competition/). Teams are required to have a faculty advisor for registration. The first 10 teams to register will receive a startup kit containing information about the conference and a set of k'nex. The team can buy and use additional k'nex to design and build their structure.

Scoring sheet

Team:_____

Construction time:_____ Additional points due to construction time delays: _____

Deviation from original design? Yes / No. Additional points for deviation from original design: _____

Item	Description	Number	Points/Unit	Points
Materials	**Beams**		1 / cm	
	Single connections		5 / Unit	
	Double connections		10 / Unit	
Testing				
Static test		**Midspan deflection (cm)**	**Equation**	**Points**
Dynamic test	**A_g**	**A_s**	**Equation**	
Kobe				
Loma Prieta				
Landers				