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Observation on College Steel Bridge Truss Models Thailand Eighth Contest and Thammasat University Team Bridge Model Design Concept

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ABSTRACT

This work presents the processes, scoring system, and observation of the Thailand's College Steel Bridge Truss Models 2011 Contest. For Thammasat University (TU) Bridge Design team model, we applied the load and resistance factor design (*LRFD*) of bridges [1], [2]. Prior, the *AASHTO LRFD* Bridge Code was reviewed which included investigation into the design code's background documentation [3].

For this contest, the bridge models must be the steel bridge truss structures with span lengths 5 meters. All structural members must be the rolled-steel shape members.

The scoring system for the contest is comprised of four categories: 1) Construction Speed Score, 2) Economy Score which is consisted with two parts that are the labor and material costs, 3) Structural Stiffness Score, and 4) Structural Efficiency. Types of truss failures have been observed.

1. Introduction

For the engineering education in Thailand, the college steel bridges contest has contributed to the structural engineering education and the relationship between the structural engineering schools in Thailand. This contest includes several activities such as the steel

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bridges construction, steel bridges strength testing, and steel bridge design presentations. This work observes the Eighth Thailand Steel Bridge Competition (2011 Contest), hosted by Sripatum University, Thailand.

Figure 1: Bridge Structure Members (Rolled-Steel Shape Cross Section Types).

2. Contest Rules

The contest rules are as followed.

Structural Materials and Bridge Installation

- Material

There are some limitations and specifications on the construction materials and structure installations as the follows:

1. All of bridge structure members must be steel but can use some cable as the tension member in structure.
2. All members must be the rolled-steel shape member and only Rectangular/Square box, Equal Angle, Unequal Angle, Channel, or Light Lip Channel cross sections have been allowed to use as shown in Figure 1.

Figure 2: Bridge Structure Joints

Figure 3: Bridge structures before construction.

3. All structural joints must to connect the members by bolt and nut only; the welding is prohibited as shown in Figure 2.
4. The printing is allowed but all types of the treatment covering for increasing the material strength is prohibited as shown in Figure 3.

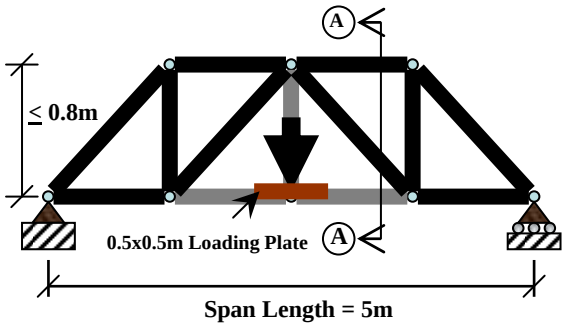

Figure 4: Typical of Bridge Structure

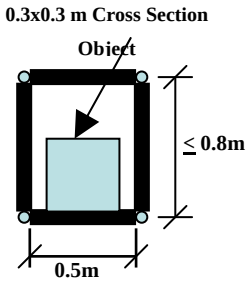

Figure 5: Section (A)-(A).

- Bridge Structure Specifications

The bridge structures must be the determinate structures and constructed under some construction specifications as the follows:

The bridge structure must be the simple span or one span structure and has the span length equal 5.0 m. that will be measured from the center to center of each support as shown in Figure 4.

1. The total height of structure is not more than 0.8 m. from the outer bottom edge to outer top edge as shown in Figure 4.
2. The total width of structure is not more than 0.5 m. from the inner edge to edge as shown in Figure 5.
3. Not allow to have any parts of the bridge structure to get below the support more than 0.1 m
4. The bridge structure must design by using the fundamental of truss structure theory.
5. Inside of the bridge structure must have space enough for a 0.3x0.3 m object can pass through as shown in Figure 5.
6. The total weight of structure is not more than 70 kg.
7. The steel structure must be installed perfectly and properly on the testing structural loading system which will be used to load on the competition structures.
8. All structural members must have their lengths not more than 1.7 m. (including the cables)

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9. Not allow to connect any parts of structure before the contest.
10. In the mid span of bridge structure, it must have a 0.5x0.5m space area for installation the loading plate as shown in Figures 4, 6, 7, and 8.

Figure 6: Loading Plate Installation

Figure 7: Bridge Structure Loading (1)

Figure 8: Bridge Structure Loading (2)

Figure 9: Preparation and Storage Area (7.0x2.3 m)

Bridge Structure Assembly and Installation

The bridge structures must be constructed by having the following limitations:

1. Before the assembling step, all teams have only a 7.0x2.3 m area for preparation and storage all equipment and structural members as shown in Figure 9.

2. Limitation of the team members not more than 8 peoples.
3. Time limit is 120 minutes, if any team uses the construction time more than 120 minutes then it will be disqualified from the competition.

Structural Strength Conditions

The bridge must be loaded at least 1,000 kg that will be slowly applied at the mid span as shown in Figure 4 and maximum defection of the bridge structure when carrying the 1,000 kg load is not more than 5.0 cm. The loading system is consisted with Hydraulic jack, load cell, dial gages and data logger. Each team must pass the strength limitation (1,000 kg. loading and 5.0 cm defection) before considering others properties and behaviors. For the failure point, it means the rupture or failing any parts of structure or has too much deformation or deflection when compared with the normal bridge structure or bridge design code.

Scoring System

The scoring has been set as the following:

1. Construction Speed 25 points
2. Economy 25 points
3. Structural Stiffness 25 points
4. Structural Efficiency 25 points

- Construction Speed Score (25 points)

The construction speed (*CT*) score will be considered by collecting the construction time in minutes from start to finish but not more than 120 minutes. The committee will calculate the scores by considering the fastest team and slowest team construction times and then calculate the *CT* score by using Equation (1)

$$CT\_Score = 25 - (20)\left[\frac{CT_i - CT_{\min}}{CT_{\max} - CT_{\min}}\right] \quad (1)$$

when CT_i is the construction time of each team

$CT_{\max}$ is the construction time of the slowest team (min.)

$CT_{\min}$ is the construction time of the fastest team (min.)

- Economy Score (25 points)

The economy score is comprised with two parts which are the labor (*LC*) and material (*MC*) costs. The *LC* cost can calculate by Equation (2).

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$$LC = N * T \quad (2)$$

when N is the number of construction people

T is the construction time

The MC cost can consider from the weight of whole bridge structure in kg and the economy score is calculated by Equation (3).

$$Economy\_Score = \left[10 - (5)\left(\frac{LC_i - LC_{\min}}{LC_{\max} - LC_{\min}}\right)\right] + \left[15 - (10)\left(\frac{MC_i - MC_{\min}}{MC_{\max} - MC_{\min}}\right)\right] \quad (3)$$

when LC_i is the LC cost of each team

$LC_{\max}$ is the maximum LC cost

$LC_{\min}$ is the minimum LC cost

MC_i is the MC cost of each team

$MC_{\max}$ is the maximum MC cost

$MC_{\min}$ is the minimum MC cost

- Structural Stiffness Score (25 scores)

The resistant of structure is called as the structural stiffness. It is a structural property that resists the structural deformation and it can be calculated from the relationship between loads and vertical deformations at mid span in the case of bridge structure. For this contest, we assume that the bridge structure has the linear elastic behavior. The maximum stiffness (team) score (*Stiff* max) will be 25 points and the minimum stiffness score (*Stiff* min) will be 5 points. Then, the stiffness score for each team can be calculated from Equation (4).

$$Stiffness\_Score = 25 - (20)\left(\frac{Stiff\ \max - Stiffx}{Stiff\ \max - Stiff\ \min}\right) \quad (4)$$

While, the stiffness of each team (*Stiffx*) is calculated by Equation (5).

$$Stiffx = \frac{\Delta_{load}}{y_{1000} - y_{500}} \text{ , unit: (kg/mm)} \quad (5)$$

when Δ_{load} is the different between 1000 kg and 500 kg which is 500 kg

y_{1000} is the vertical defection in mm. at the load equals 1000 kg

y_{500} is the vertical defection in mm. at the load equals 500 kg

Stiff max is the maximum stiffness value

Stiff min is the minimum stiffness value

- Structural Efficiency (*SE*) Score (25 points)

The efficiency of bridge structure can be calculated from the multiplication between the material volume and the mid span vertical defection at 1000 kg loading as Equation (6).

$$SE_i = MC * y_{1000} \tag{6}$$

When, the small value of *SE* means the rather good efficiency, from this meaning, the minimum *SE* team will get the maximum score that is 25 points and the maximum *SE* team will get the minimum score that is 5 points as well. The each team *SE* score can be calculated from Equation (7).

$$SE\_Score = 25 - (20)\left(\frac{SE_i - SE_{\min}}{SE_{\min} - SE_{\min}}\right) \tag{7}$$

when SE_i is the structural efficiency of each team

y_{1000} is the vertical defection in mm. at the load equals 1000 kg

$SE_{\max}$ is the maximum *SE* value

$SE_{\min}$ is the minimum *SE* value

Total Score

For the total score, it can be calculated by accumulating all parts of score as shown in Equation (8)

$$Total\_Score = CT\_Score + Economy\_Score + Stiffness\_Score + SE\_Score \tag{8}$$

3. Thammasat University (TU) Bridge Design: Design Concepts and Teamwork

For "TU Bridge Design" team, the steel bridge model has been designed by Load and Resistant Factors Design (*LRFD*) [1], [2] that based on the reliability based design [3], [4]. For this design method, it has followed the *AASHTO LRFD* Design specifications.

In the design process, the two limit state functions have been created that are the tension limit state function and compression limit state function. And then the reliability index has been selected that is 3.5 [4] for both the tension and compression members. In this process, the load combination and load and resistance factors have been properly selected [3], [4]. By

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this design method, the TU Bridge Design team model is the Pratt Arch truss and all members are the 2.5x2.5 mm angle cross-section. The 2 mm thickness steel plates (gusset plate) are used in the truss joints and only one bolt is used to connect between the joint (plate) and truss member in order to control the total weight and construction time of the model as shown in Figures 10 and 11.

Figure 10: Bridge Structure Joints: TU Bridge Design Team

Figure 11: TU Bridge Design Team and Model

There are eight students in TU Bridge Design. The group is separated into two subgroups, the build & installation and preparation groups. The build & installation subgroup consisted of five students, with mission both preparation the bridge model and building the model during competition time. The preparation subgroup included three students.

4. Results and Discussions

From the steel bridge model contest, there are many types of bridge failure. Figures 12 and 13 show the bridge joint, member, and support failure, respectively. Figures 14, 15, 16,

and 17 show the various bridge structure failures such as side sway, side-sway combined with vertical buckling, structural (vertical) buckling, and lateral buckling respectively.

Figure 12: Joint Failure

Figure 13: Support Failure.

Figure 14: Side-sway of Bridge Structure

Figure 15: Side-sway with Vertical Buckling

Figure 16: Vertical Buckling

Figure 17: Lateral Buckling

For TU Bridge Design, its model is failed by the joint failure because a support is set at the member (near the end of member) not at the joint as shown in Figure 12 and the maximum defection of the model is about 4 cm. For this kind of failure, it can be eliminated and controlled by setting the supports exactly at the joints not at the members.

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5. Conclusion

From the steel bridge model contest, there are many kinds of bridge collapse such as the joint failure, member failure, whole structural failure, structural buckling, lateral buckling, support failure, etc.

From the competition and testing, the students could study, observe, and recognize the bridge behavior in real time. It creates the recognized knowledge, perfect learning, and useful experience as well.

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