Learning Bridge Design and Evaluation

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Abstract

A considerable number of bridges in the United States are reaching a stage in need of repair, rehabilitation, or replacement due to aging, increasing load spectra, and lack of regular maintenance. These bridges are subjected to a higher risk of distress, damage, and even catastrophic failure. Evaluation, repair, and rehabilitation are necessary for the preservation of their load capacity and service performance. To minimize cost of replacement or repair, the evaluation needs to accurately reveal the current load carrying capacity of the bridge and to cover future loads and further changes in the capacity. Teaching civil engineering students a course on bridge design and evaluation can greatly help them understand the fundamental concepts of bridge safety. In this course they will learn how to design and evaluate bridges. As a result, they will have the technical know-how to help maintain bridge infrastructures as they graduate from college and they could use such skills in their future careers.

Introduction

Highway bridges are usually designed to possess reserved strength to accommodate occasional overloads although they were designed for standard load. This additional amount may be substantial depending on a number of factors. However, some states allow overloads on their highway systems. Vehicles that exceed the national truck weight limit are allowed to cross the bridges. This issue becomes critical when actual truck loads are noticeably higher than the design load.

At 6:05 pm on Wednesday, August 1, 2007, during the evening rush hour, the main spans of the I-35W Mississippi River Bridge collapsed, falling into the river and onto its banks. Thirteen people died and approximately one hundred more were injured[1]. A disaster like this can be prevented from happening if there is a reliable assessment method to identify the risk of failure of the bridge.

It is unlikely that funds will ever be available to repair and strengthen all inadequate bridges. Therefore the challenge for policymakers at the state, local, and federal level is to determine which bridges are the highest priority for repairs given limited funding[2]. The American Society of Civil Engineers (ASCE) estimates that repairing every deficient bridge across the nation would cost $9.4 billion per year for 20 years[3]. Hence, there is a need to evaluate the bridges to be able to identify those that needed the funding the most.

Course Description and Objective

The course will be a three credit-hour elective course in a semester system. This will be intended for senior level civil engineering students. This course will cover the structural design and evaluation of modern typical highway bridges. Its objective is to introduce the students to the concept, requirements, and fundamental skills for highway bridge design and evaluation. Upon completion of the course, the student is expected to be able to design and evaluate typical highway bridges according to the current and future U.S. specifications.

The course is primarily a lecture course. In addition to traditional homework assignments and exams, a term project will be required from the students. The term project will enhance students' learning through analysis and evaluation of existing highway bridges to prepare them for the types of problems they will encounter in the real world. This will offer them hands-on experience on the design and evaluation of highway bridges. As a part of the project, they may have to visit the bridges used in their study. The class may be divided into groups (e.g. 4 students per group). Each group may evaluate two to three existing highway bridges. Towards the end of the semester, each group is expected to complete and present their project results to the class and submit a written report of the project. This will also help students develop their oral and written communication skills.

The following sections will be among the important topics of the course that can be used for the term project and the course as a whole.

Design and Evaluation Codes

Throughout the semester the students will learn how to use the following standard codes and specifications for bridge design and evaluation.

a) AASHTO Standard Specifications for Highway Bridges
b) AASHTO LRFD Bridge Design Specifications
c) AASHTO Manual for Condition Evaluation of Bridges

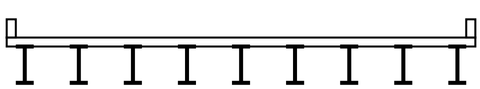
These will provide students the understanding and familiarity with the different design codes and specifications.

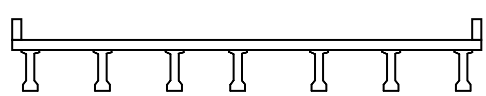
Data Procurement

The procurement of data for bridge design and evaluation is presented in this section. The following four major types of bridges may be used in this course.

1. Steel composite beam bridges
2. Prestressed concrete I-beam bridges
3. Prestressed concrete adjacent box beam bridges
4. Prestressed concrete spread box beam bridges

Typical bridge cross sections of each of these bridges are shown in Figure 1. These types represent a majority of new bridges.





(a) steel composite beam (b) prestressed concrete I-beam

(c) prestressed concrete adjacent box beam (d) prestressed concrete spread box beam

Figure 1 Typical cross section of new bridges

Dead Load Calculations

Although the dead load of a bridge system is not considered to vary significantly with time, the actual value of the load is uncertain. In addition, the analysis of the dead load effect on the bridge structure also involves a degree of uncertainty, for example, due to the assumptions about the structural members' boundary conditions, etc. For many bridges, for example, the primary dead load is due to the weight of the primary beams, the deck, and the deck's surface. The uncertainties in predicting the magnitude of the dead load are due to variations in the density of the materials used to form the deck and other members as well as the variations in the dimensions of these members. The dead load effect's nominal values can be calculated using the available bridge plans. The dead load is assumed to act as a uniformly distributed load to the focused bridge member.

In the dead load effects calculations, the students will learn how to interpret bridge architectural and detail drawings. This will give them the training that they may be able to apply into any other infrastructure drawings.

Live Load Calculations

There are a large number of transient loads that are normally applied on highway bridges. These include all moving loads as well as temperature effects, wind and earthquake loads. For typical short to medium span bridges, the most important loads are those due to moving vehicular traffic including their static and dynamic effects. Although these two effects occur simultaneously as one or more vehicles move across the bridge structure, it has been traditional in bridge engineering practice to treat the static effect separately from the dynamic effect. With this approach, bridge members are analyzed for the static effect of the vehicles and then a dynamic amplification factor is used to account for the effect of bridge vibrations due to moving vehicles.

There are two existing methods for measuring weights of trucks. One is static weighing and the other is dynamic weighing. Static weighing involves stopping a vehicle and measuring its weight statically, the weight of which is termed as *static weight*. Dynamic weighing allows a vehicle to be weighed while in motion, or dynamically, the weight of which is termed as *weigh-in-motion* (WIM) *weight*. WIM scales are dynamic weighing systems that determine weights while vehicles are in motion. They enable vehicles to be weighed with little or no interruption of their travel. WIM scales have been designed to sense the weights of the axles passing over the instrument through the use of piezo sensors, strain gauges, or hydraulic or pneumatic pressure transducers. The readings are transmitted to a receiving unit, where they are converted to actual weights[4]. Dynamic truck weighing is more advantageous than static weighing. For this reason, only WIM data are reported to the Federal Highway Administration (FHWA) Truck Weight Study. Hence, WIM data become readily available from state Department of Transportation (DOT). Dynamic weighing through high-speed WIM systems provides continuous unbiased weighing of practically all vehicles passing the system. They are also hardly noticeable that the drivers are not aware of the weighing operation and do not try to avoid it. WIM data will be used as live load of the bridge structures to be studied in this course. Since WIM data are usually readily available from state DOT's, this is a good way of training students how to obtain data from the DOT offices. They may also be able to observe how the data are being collected by visiting WIM stations.

Beam Resistance Calculations

The resistance here refers to the capacity of the bridge component being investigated. Two different cases can be considered. The first case is the *as-built* capacity, for which basic principles of engineering structural analysis/structural mechanics are applied using the construction bridge plans to estimate the nominal strength. The second case is the *as-designed* capacity, which is calculated based on both the AASHTO Standard Specifications for Highway Bridges (referred to as *Standard Specifications*)[5] and the AASHTO LRFD Bridge Design Specifications (*LRFD Specifications*)[6].

To calculate the *as-built* capacity of the bridge, basic principles of engineering structural analysis/structural mechanics will be used. The *as-designed* capacity calculation, which is based on *AASHTO Standard Specifications*, follows the following requirements: The HS25 design load consists of a truck load with the axle weights and spacing shown in Figure 2, or a lane load of 0.8 kip/ft plus one or more point loads of 22.5 kips (for moment) or 32.5 kips (for shear). Whichever gives a larger result will be used as the nominal live load moment or shear for computing the required nominal strength.

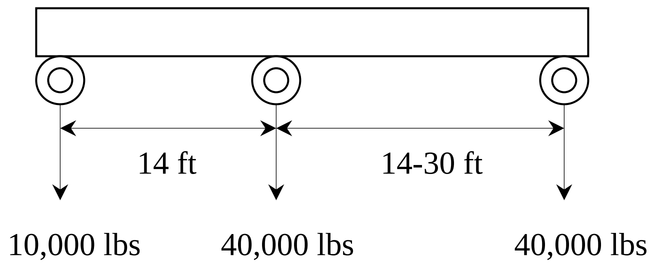


Figure 2 Axle weights and spacing for HS25 bridge design load

The design requirement according to *AASHTO Standard Specifications* is expressed as a combined dead and live load effects as follows.

$$\phi R = 1.3(D) + 2.17(L + I)$$

where D and $(L + I)$ are the nominal load effects due to dead load and live load plus dynamic impact factor, respectively, R is the nominal strength, and ϕ is the resistance factor.

The sections discussed above will equip civil engineering students who take the course with additional technical knowledge they need in their engineering career.

Conclusions

A number of bridge networks are currently experiencing deterioration. Some of them may need immediate attention. Hence, being able to identify the deficient bridges is necessary so that the policymakers can determine those that deserve immediate attention for repair, rehabilitation, or even replacement. Incorporating a course in bridge design and evaluation into the civil engineering curriculum will produce civil engineering graduates with the capability of bridge design and assessment. This will also draw more students to be interested in specializing in bridge structures and eventually produce more bridge experts in the nation. In this way, structurally deficient bridges can be identified early and be repaired to make them safer. This will help in maintaining current bridge infrastructures to avoid catastrophic failures. As a result, not only bridges are saved but most importantly, human lives.

Bibliography

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Biography

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