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WIM+RESPONSE SYSTEM OVERVIEW

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Introduction

This report summarizes the results of a research investigation conducted at Lehigh University during which a FHWA Weigh In Motion (WIM) system was redesigned to obtain simultaneous load and response data from in-service bridges. The prototype system is designated as the WIM+RESPONSE system. This system has both hardware and software necessary to acquire and store strain data from steel and concrete bridges as well as to process that data to obtain simultaneous load and response information. This integrated system allows these data to be stored simultaneously on a mass storage device (floppy disk) since it is important when interpreting both types of data that there are no questions as to their relationship in time. By coupling the WIM system with a system for measuring strains in bridge components, data on bridge response can be achieved at the same time that loading data is being obtained from all the vehicles crossing the bridge, within an arbitrary period of time. For an evaluation of bridge response the primary information required is the magnitude and variation of stress in bridge components during passage of vehicles over the bridge. The prototype WIM+RESPONSE system is designed to obtain simultaneous load and response data for both steel and concrete highway bridges. The correlation of gross vehicle weight (GVW), axle weights and frequency with induced maximum stress and stress range is the foundation of simple bridge design procedures and specifications based on strength and serviceability (such as fatigue) requirements.

Background

Highway bridges sustain vehicular traffic which varies in weight, overall length, number of axles, axle spacing, speed and dynamic characteristics. The volume and conditions of traffic such as headway and multiple presence, as well as the correlation of traffic with bridge type, geometry, configuration and other factors, such as maintenance, determines the integrity and life expectancy of highway bridges and their components.

For any particular bridge the static and dynamic response to a vehicle can be accurately monitored and evaluated if the geometrical and loading characteristics of the vehicle are known. Until recently, it has not been possible to determine, to a reasonable degree of accuracy, the characteristics of vehicles crossing a bridge under actual highway conditions. Consequently, expected damages, if any, by vehicular traffic could not be accurately estimated.

In recent years significant advances have been made in the development of weigh-in-motion (WIM) systems. The WIM system developed for the FHWA by Case Western Reserve University is portable and utilizes an existing bridge to serve as an equivalent static weigh scale to obtain not only gross vehicle weights (GVW) but also axle weights and spacings, as well as speeds of vehicles crossing the bridge at normal highway speeds. Under FHWA sponsorship

three WIM systems were built and used to weigh more than 27,000 trucks in seven states. Since the weighing operation cannot easily be detected by truck drivers the results are not subject to the usual bias associated with traditional truck weighing methods. Both loadometer surveys and weight data from weigh stations are subject to bias because illegal trucks can easily avoid an operating weigh station with the aid of CB radios. The WIM system data has begun to reveal the true spectrum of truck loads, especially the extent of the high loads which are causing significant bridge damage.

Current analysis and design of highway bridges in the U.S. is based on the AASHTO H and HS trucks and lane loads. These "standard" AASHTO loads have remained basically unchanged for over 40 years and do not represent the majority of modern trucks using the highway system. Since that time the volume and weight of trucks has increased significantly. Many states have responded by raising their design loads, say from HS 20 to HS 25. Some states also check their designs by comparing with the heaviest permit vehicles authorized in their state. With the development of the FHWA WIM system it is possible to obtain relatively unbiased statistical data on truck configuration and loading and to update that data. This data can be used to develop more rational "standard" design trucks for use in bridge design and rating procedures.

The prototype WIM+RESPONSE system, designed and built by Lehigh University, was developed to acquire and process the truck weight plus bridge response data needed for the continuing improvement of bridge design and rating specifications and procedures. The prototype WIM+RESPONSE system was used to acquire and process a large amount of data from over 19,000 trucks crossing four in-service steel and concrete bridges in Pennsylvania. The final report of this investigation presents the results of these field studies and comparisons of the results of an analytical study of each bridge superstructure, employing the finite element method. In addition, it presents an evaluation of the Bridge Formula based on the results of these field studies. This information is contained in "WIM+RESPONSE STUDY OF FOUR IN-SERVICE BRIDGES", FINAL REPORT, FHWA/RD - 86/045.

Capabilities

The capabilities of the prototype WIM+RESPONSE system are briefly summarized as follows:

1. The WIM+RESPONSE system was designed for use with multiple, steel, concrete or prestressed concrete girder bridges. The system can be used with right or skew bridges. Simple or continuous span, composite or non-composite bridges. Accurate WIM data acquisition requires relatively long, level approaches, so that truck speeds over the weigh span are constant, and a relatively smooth deck.

2. The WIM+RESPONSE system was designed to achieve a balance between storing as much truck weight and bridge response data on a floppy disk as possible and maximizing the total length of bridge that can be accomodated. The prototype system can be used to acquire data from a series of continuous or simple spans, or a combination of simple and continuous spans with a total bridge

length up to 170 ft. Simultaneous load and response data from as many as 110 trucks can be stored per data disk.

3. The WIM+RESPONSE system is capable of acquiring and storing up to 16 channels of simultaneous truck weight plus bridge response data. Up to 6 of these channels may be dedicated to WIM data from gages located on the weigh span. Any or all of the remaining channels are available for response data from gages anywhere on the bridge. The total number of gages on the bridge may exceed the number of channels available. While WIM data is being acquired the remaining channels may be dedicated to different groups of gages, thus making it possible to increase significantly the amount of simultaneous truck weight plus bridge response data that can be acquired.

4. The WIM+RESPONSE software permits data reduction and load-response evaluations to be made. Individual truck plus response data can be acquired and evaluated. Statistical load-response information can be acquired and processed in the form of GVW histograms, stress range histograms and other displays of interest to the bridge engineer, researcher, or planner.

Operational Description

The WIM+RESPONSE prototype is a stand-alone system used for obtaining undetected truck weight and bridge response data at a bridge site. It is intended to be used with the cooperation of State Departments of Transportation. Practical considerations, especially in heavily trafficed areas, necessitate their assistance in the form of personnel and peripheral equipment for activities such as placement and mounting of tapeswitches, transducers, and strain gages.

The major activities associated with the WIM+RESPONSE operation may be conveniently grouped into the following categories.

1. Set Up. These initial activities which enable the acquisition of data involve: tasks beneath the bridge deck such as placing of transducers and strain gages; tasks on the bridge deck such as placing and securing of tapeswitches; and tasks inside the instruments van such as connecting cables to the system and to a power supply.

2. Data Acquisition. These activities permit the actual collection and storage of truck weight and bridge response data on floppy disks. This phase involves: booting or starting up the system hardware and software; generating, through self- contained software, an influence line for the bridge; and answering questions on the parameters of the bridge being studied to begin the process of data collection and storage.

3. Field Data Processing. These activities permit a preliminary examination of the data which have been collected. This phase is carried out by first running a computer program which inspects and reviews the raw data. Then if desired, a plot of the strain data can be displayed on a graphics screen located at the field site.

4. Take-Down. These activities take place when the field study of a particular bridge is completed. The tasks are centered around an orderly disconnection of the WIM+RESPONSE equipment and a removal of all temporary instrumentation from the bridge site.

5. Data Reduction. These activities, generally undertaken in an office or laboratory environment, permit more detailed and thorough investigations of the acquired data. The tasks involve running a series of self-contained programs to produce the following information: stress range histograms, strain rate histograms; GVW versus maximum stress; and histograms for either stress range, GVW distribution or strain rate. These studies can be output in either tabular or graphical form.

Details of the installation and operation of the system can be found in the following documents developed at Lehigh University:

"WIM+RESPONSE Training Guide" FHWA/RD - 86/047
"WIM+RESPONSE System Users Guide" FHWA/RD - 86/048
"WIM+RESPONSE Hardware" FHWA/RD - 86/049
"WIM+RESPONSE Software Reference Manual" FHWA/RD - 86/050
"WIM+RESPONSE Appendices" FHWA/RD - 86/051

These documents are supplementary to the final report, "WIM+RESPONSE STUDY OF FOUR IN-SERVICE BRIDGES", FINAL REPORT FHWA/RD - 86/045.

Impact Of The WIM+RESPONSE System

The WIM+RESPONSE system is a new tool offering promise to extend knowledge bases in areas of research, design specifications and ratings for bridges.

Current bridge research includes studies of redundancy, fatigue and fracture control, overload behavior and load distribution to name a few. For the first time a tool is available to enable results of research to incorporate data based on simultaneous measurements of truck weight and bridge response.

AASHTO Specification provisions are frequently amended as research results become available. Design procedures are based on the specification provisions as well as on modern analytical tools. Specification provisions and design procedures both are heavily dependent on assumptions regarding bridge behavior. This new tool will help establish the validity or falcity of many of these assumptions.

As the nation's bridges age, more frequent inspections become necessary. Rehabilitation and replacement priorities become tied to rating procedures, which in turn derive from specification provisions and design procedures. The new tool therefore will lead to improved rating procedures and more realistic decisions on the planning of bridge rehabilitation and replacement.