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A method for observing weights of trucks running on a bridge

Eiki Yamaguchi*, Kazushi Matsuo

Department of Civil Engineering
Kyushu Institute of Technology, Kitakyushu, Fukuoka 804-8550, Japan

Abstract

The development of the weigh-in-motion techniques that give the weights of running trucks without disturbing traffic flow has attracted many researchers. We employ herein a technique based on the deformation of a steel girder. For the accuracy of this technique, the usage of a short simply-supported straight steel bridge is preferred. However, that kind of bridge is not always available. Actually, the highway of our interest does not have steel bridges except a continuous skew steel-plate-girder bridge. Because of this, we conduct running tests with three trucks of known weights very carefully. The present technique then proves to be satisfactory, yielding the weights of running trucks with about 11% error at most. Thus, we may conclude that a continuous skew steel-plate-girder bridge can be used for the weigh-in-motion.

1. Introduction

For carrying out a good maintenance work of an existing bridge, it is important to know actual traffic loads acting on the bridge. To this end, a technique to measure the weight of a running truck without disturbing traffic flow is needed. Such a technique is known as the weigh-in-motion and various efforts have been made. One of the weigh-in-motion techniques is based on the deformation of a bridge and is called the bridge-weigh-in-motion. The technique was developed by Moses (1979) and is relatively inexpensive so that it has been explored much in Japan (Matsui & El-Hakim 1989, Ojio et al. 2001, Miki et al. 2001, Ikeda et al. 2002, Ishio et al. 2002).

For a good accuracy in the bridge-weigh-in motion, it is essential to use a bridge whose deformation is not so small and not complicated either, and on which multiple trucks do not run at the same time. Thus, a short, simply-supported steel bridge is idealistic. However, this type of bridge is not always available in the highway of interest.

* E-mail: yamaguch@civil.kyutech.ac.jp

We have encountered such a situation actually when we initiated a project to figure out actual truck loads in a national highway near Fukuoka City, Japan. There is only one steel bridge in the area and it is a continuous skew steel-plate-girder bridge, far from an ideal structure. To the best knowledge of authors, the accuracy of the weigh-in-motion using such a type of bridge has not been known well. Therefore, we first study the accuracy that we can achieve by this bridge. In this paper, we present the result of this study.

2. Bridge-weigh-in-motion

The truck weight is evaluated from the deformation of a bridge due to a truck running upon it. The technique used herein follows specifically the one employed by Miki et al. (2001). The outline of their method is described in what follows.

When the location of an axle of a truck at time t is denoted by x_n, strain at Point i at this time is given by

$$\varepsilon_i(t) = \sum_{n=1}^{N_A} A_n \, I_i\left(x_n(t)\right) \tag{1}$$

where $\mathrm{N_A}$ is the number of axles, A_n is the weight of the axle at x_n, and I_i is the influence line corresponding to $\varepsilon_i(t)$ that is the normal strain in the direction of the bridge axis at the bottom flange at Point i at time t.

Letting $\varepsilon_i^*(t)$ denote the measured strain, the following equation can be set up:

$$E = \sum_{i=1}^{N_M} \sum_{j=1}^{N_S} \left[\varepsilon_i(j\Delta t) - \varepsilon_i^*(j\Delta t)\right]^2 \tag{2}$$

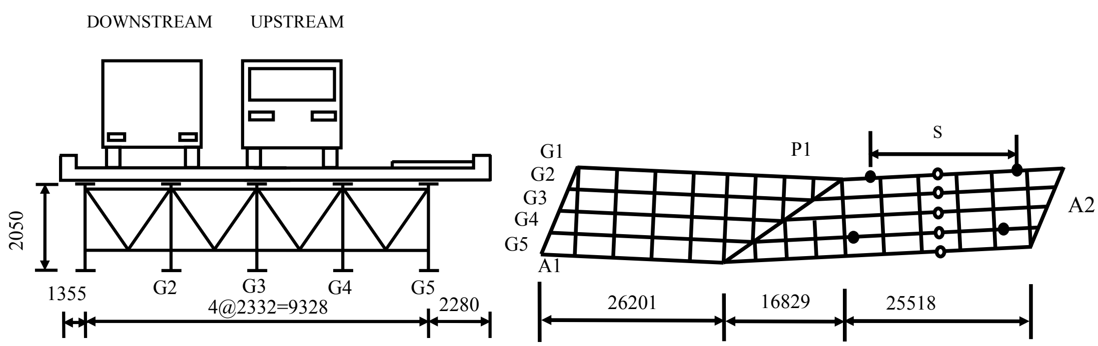
where N_S is the number of strain measurements for each of which the location of the axle is different; N_M is the number of strain-measuring points; Δt is the time difference between two consecutive strain measurements. The values of A_n that minimize E would give the axle weight we look for. To be specific, the stationary condition of $\partial E / \partial A_n = 0$ yields the values of A_n. It may be understood from Equations (1) and (2) that the final equations to be solved would be a set of simultaneous equations for A_n. Once the axle weights are obtained, we can compute the gross weight of the truck by simply summing up the axle weights.

For this method to be effective, the influence lines and the positions of the axles must be known. The influence line is determined by running a truck of known axle weight on the bridge. For the determination of the positions of the axles, we measure the strains at several vertical stiffeners in addition to the strains at the bottom flanges. The strain at the vertical stiffener is sensitive to the axle load, so that without much difficulty we can identify when the truck passes right above the vertical stiffener. Knowing the distance between stiffeners, then we can evaluate the speed of the truck and the distance between the axles. Thus the position of the truck at any time can be estimated.

3. Outline of bridge and strain measurement

The bridge used in this study is presented schematically in Figure 1. The bridge is a two-span continuous steel bridge, having 5 main plate girders. The bridge axis is not straight but skewed. Therefore, the deformation of the bridge may be quite complicated. The bridge carries two traffic lanes, one for each direction. A sidewalk exists above the G5 girder.

Figure 1(b) shows the positions of the strain measurements: the circles indicate the positions in the bottom flange while the solid circles correspond to the positions in the vertical stiffeners.



(a) Cross section (b) Top view

Fig.1. Schematic of bridge

4. Running tests

We conduct running tests with three trucks of known weights: Truck A-C are 20.35 tf, 20.00 tf and 16.39 tf in weight, respectively. The following five running patterns are employed:

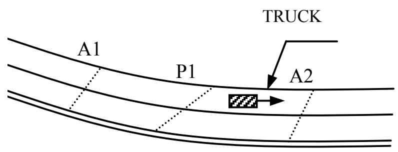
- Pattern 1: Only one truck runs
- Pattern 2: One truck runs right after the other
- Pattern 3: Two trucks run in different directions
- Pattern 4: One truck runs right after another while the other runs in the opposite direction
- Pattern 5: A truck runs in an ordinary traffic flow

Patterns 1 to 4 are illustrated in Figure 2. For Pattern 1 to 4, the traffic is controlled so that no traffic except our trucks runs on the bridge during the test.

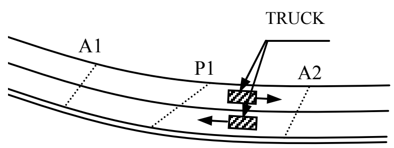
The influence of the speed is also investigated. Multiple tests are conducted under the same condition, since the scatter of the measured data is expected in this kind of test. Altogether the number of the running tests amounts to 76.

5. Evaluation of truck weights

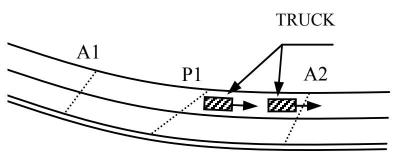
Based on the strain measurement of Pattern 1, the influence lines are constructed. There are several sets of measurements even for Pattern 1, but they yield the influence lines very similar to each other. The strain measured in the G5 girder is much smaller than those in the other girders. Hence, the strain in the G5 girder is ignored.



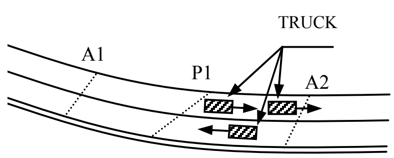
(a) Pattern 1



(b) Pattern 2



(c) Pattern 3



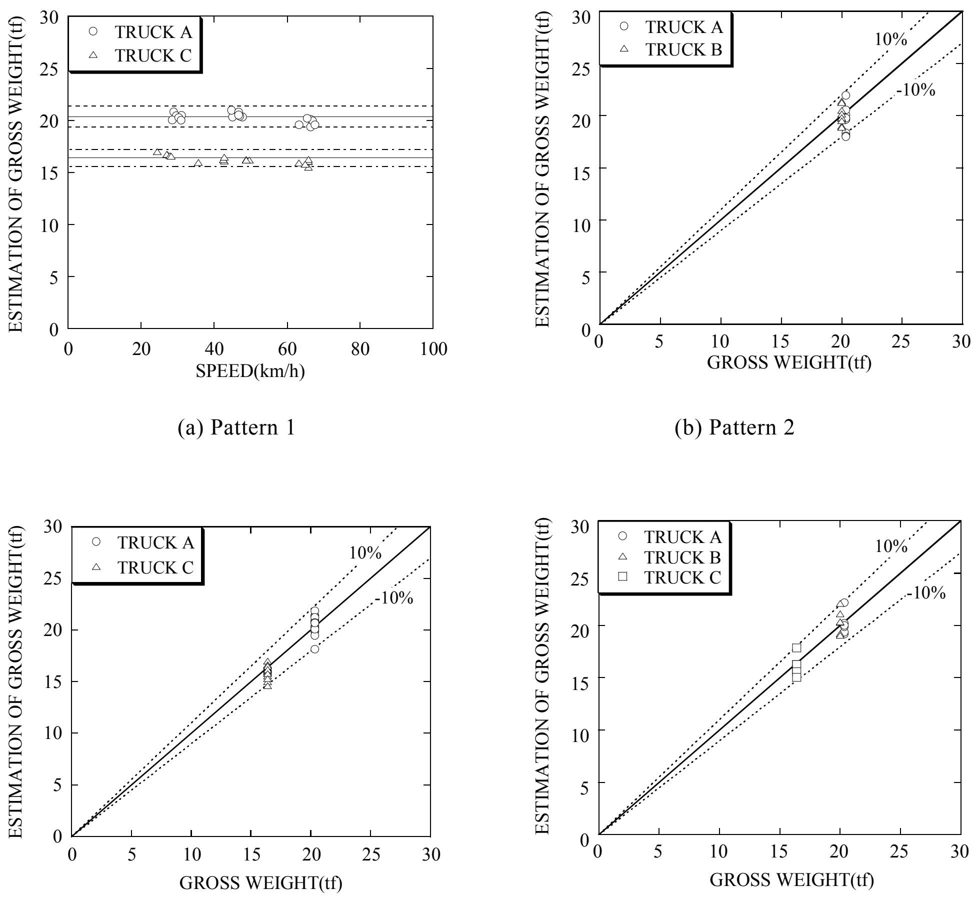
(d) Pattern 4

Fig. 2. Running test patterns

Figure 3 (a) presents the result of the bridge-weigh-in-motion for Pattern 1. The accuracy varies, but the error is no more than 5.4%. It can be also observed that the influence of speed is insignificant. Figures 3 (b) to (d) give the result of the bridge-weigh-in-motion for Patterns 2 to 4. In most cases, the error is less than 10%. In 2 tests of Pattern 2 and one test of Pattern 3 the error exceeds 10%: the maximum error is found to be11.6%. In all the tests of Pattern 5, the error is less than 10%. Therefore, we may conclude that the accuracy of the bridge-weigh-in-motion by the present bridge is satisfactory in all the practical situations.

6. Concluding remarks

The bridge-weigh-in-motion technique is applied to a continuous skew steel-plate-girder bridge. Through quite a few running tests, we have made sure that the technique works satisfactorily for all practical purposes. Hence, we may conclude that the bridge-weigh-in-motion can be applied even when we have no other choice but to use a complicated bridge such as this continuous skew steel-plate-girder bridge.



(a) Pattern 1

(b) Pattern 2

(c) Pattern 3

(d) Pattern 4

Fig. 3. Evaluation of truck weight

Acknowledgements

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