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FOOTBRIDGES LOAD TESTS IN POLAND: HISTORY, REGULATIONS, EXAMPLES, RESULTS.

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Summary

The paper presents some chosen results of footbridges tests on site that have been done by the authors, recently. Dynamic amplification factor, natural frequency, mode shapes and damping have been analyzed by dynamic footbridges testing. The paper describes also the dynamic method of the suspension control system forces. As the result of registration and analysis of free vibration of a suspender, the authors present quick, non-destructive and reliably test as the contemporary method to improve safety of arch and suspended footbridge superstructures.

1. Introduction

The habit of load tests of bridges is very old. A long time ago, under the bridge, which was the maximum load, was its builder. This type of tests did not provide information about the safety of the bridge. In later years started to perform measurements of displacement and support settlement. Only such measurements allow to determine the actual characteristics of the materials used. Analysis of results also allows us to evaluate the behaviour of the structure and verify the calculation model. Today's measurements allow for advanced analyses of footbridges constructions work.

Bridge loading tests are required for new structure, for refited construction and in some cases for existing bridges to ascertain their load capacity.

2. Dynamic analysis of pedestrian bridges

Modern footbridges are sensitive to vibration. Dynamic issues are very important for large spans and slender objects. People moving on the footbridge affect the platform with little force, but in combination with the low frequency of these impacts they can cause strong vibrations that reduce comfort. The most annoying for pedestrians are horizontal oscillations that affect maintain balance.

Footbridges whose natural frequencies fall within this range may be susceptible to pedestrians movement. In most cases footbridges are used by walking people, so the most unfavorable is range between 1,5 – 2,2 Hz.

2.1 Acceleration comfort criterion

Vibration of the footbridge makes its use less comfortable. Commonly used comfort criterion is acceleration. In Polish standards for bridge design do not provide any guidelines. Comfort criteria can be found in foreign standards and literature. The values are considered separately for vertical and horizontal acceleration.

Maximum value of vertical acceleration should be less than 0,7 m/s^2, according to annex A2 to EC 1990.

A verification of the comfort criteria should be performed if normal frequency of the construcion is less than 5 Hz for vertical vibrations and less than 2,5 Hz of horizontal or torsional vibrations.

Setra in their technical guide gives more stringent criteria. To provide comfort for pedestrian, it is recommended that maximum value of vertical acceleration should be less than 0,50 m/s^2.

3. Dynamic method of the suspension control system forces

The Aspekt Laboratory uses during a load tests innovatory method of measurement values of forces in lines and cables. To compare with other method, this one is cheaper and easier to apply. To measure this method, is no need to break the protective coating of the element which is the main advantage. The method also does not require complicated equipment. To determine the strength of the cable, the element vibrates and values of the acceleration of oscillations are recorded, in two orthogonal directions. Based on the results of the measurement, a spectral analysis is performed. To estimate the strenghts, this method uses lowest natural frequencys of the element. Using numerical models and mathematic formulas, values of forces are determined. Accuracy of method depends on many factors like cable geometrical parameters, material and complexity of the element. Usually it is about 5-10%, which is confirmed by previous tests. This simply method can also be used to monitor existing structures.

4. Results of footbridges tests

4.1 Footbridge over DK1 (National) Route

Located in Czestochowa (Poland), over the National Route DK1, footbridge is a cable-stayed structure. The length of the bridge is 46.90 m. Two spans are 21.10 m and 25.80 m long. The 13.20 m high steel pylon is connected to the deck by a cable. The 3.50 m width deck of the footbridge is made of a steel-concrete composite. The main girders are made of HEB 400 I-sections and crossbars are made of HEA 300 I-sections. The thickness of concrete slab is between 17.0 and 20.0 cm.

According to load test project, was carried out one static load setting. For the load was used twelve concrete plates. The mass of each of them was 1800 kg. During the static test measured vertical displacement of the main girders (2 points), settlement of supports (4 points), tilting of the pylon and changes of forces in cables. The maximum elastic vertical displacement was 9.29 mm. The force measurement in cables showed an increase of about 30 kN, which was consistent with the theoretical model.

Measurement of dynamic parameters were performed using a group of nine people. Eighteen tests were performed during which vertical displacement and acceleration were measured. The test group simulated several possible ways of moving people, such as walking, jogging, running and sprinting. In addition, the tests consisted of squats, jumps and jerks of the barrier was made.

The first of the identified normal frequencies was 2.78 Hz, which is higher than the frequency corresponding with walking, but is still within the unfavorable range.

Maximum acceleration values for normal use (walking, jogging) are lower than comfort criteria 0.7 m/s^2. In the case of a synchronous run of a group of people with a frequency of about 2.8 Hz may cause acceleration slightly above the comfort criteria, but this type of interaction is unlikely.

4.2 Arch footbridge over S8 Expressway in Warsaw

Located in Warsaw (Poland), over the Expressway S8, footbridge is a two spans arch structure. The length of the bridge is 39.80 m. Two spans are 21.95 m and 17.85 m long. The 6.36 m width deck of the footbridge is made of a steel-concrete composite and connected to the arch with stiff hangers with square cross section. The main girders are two pairs of arches in a 6.0 m spacing. The shape of the arches is adapted to the shape of the soundproof screens.

According to load test project , was carried out two static load settings. For the load was used water containers, total mass of them was 7000 kg. During the static test measured vertical displacement of the main girders (4 points), settlement of supports (6 points) and changes of forces in hangers. The maximum elastic vertical displacement was 3.00 mm which confirms the high stiffness of the structure. The force measurement in hangers showed an insignificant changes of forces. The analysis proves very high stiff of the hangers used and confirms the theoretical analysis of the small increase of the force from the test load.

Measurement of dynamic parameters were performed using a group of ten people. Forty tests were performed during which vertical displacement and acceleration were measured. The test group simulated several possible ways of moving people, such as walking, running and sprinting. In addition, the tests consisted of jumps and jerks of the barrier was made.

The identified natural frequencies are similar to those calculated theoretically. All of them are higher than the unfavorable range for footbridges. In all test of normal usage, maximum vertical acceleration of bridge are lower than comfort criteria.

5. Conclusions

Dynamic load tests are important in assessing comfort and safety in pedestrian bridges. They are especially important for less stiff construction that may be highly susceptible to dynamic influences. Dynamic tests results may also be helpful for designers, who could more precisely assume the dynamic parameters of bridge at the design stage.