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Summary

Bridges expand and contract due to temperature changes. Actual bridge temperatures may be quite different from idealization used in design. Recent analytical studies have shown that existing procedures are often irrational. Sometimes predicted movements are too small and this leads to damage and deterioration in the bridge. These will significantly shorten the bridge life. In other cases, the movements are too large and this leads to the selection of inappropriate expansion joints and bearings. In case of integral structures, it leads for over-dimensioning. The paper presents results of ongoing research in Poland. Preparation of new design guidelines for selection of bridge temperatures and thermal movements is the aim of this effort.

1. Introduction

Methods of determination of bridge temperatures and thermal movements have been developed for some countries and even put into standards. Extensive studies were done in Europe lately, because of preparation of Eurocodes. The values of bridge temperatures were obtained mostly through computer simulation. Unfortunately, experimental verification of these results through field measurements is rare and random. Therefore, extensive investigation of existing structures is still needed. Polish Standard devoted to thermal loading of bridges is quite conservative and did not change since many years. Growing number of damages of expansion joints, bearings and abutments due to thermal loads proves importance of these phenomena. The separate problem is taking into account thermal actions during construction of bridges. This is a reason that project sponsored by Polish government research agency is developed. New guidance for determination of bridge temperature and thermal movements will be reached through:

- statistical analysis of ambient temperature around Poland,
- determination of relation between ambient temperature and bridge temperature depending on the type of structure,
- 3-dimensional, comparative thermal-structural analysis,
- verification of computer simulation results with field measurements and observations of temperatures and movements in chosen bridges.

2. Bridge Temperature

The calculation of the bridge temperatures is based on the radiation, convection and conduction heat flow. Radiation is provided by sun. It heats the bridge during the day and transmits the heat to the environment on nights. Convection is largely driven by the wind and by air currents caused by moving traffic. Conduction describes the flow of heat within the bridge. Accurate determination of the bridge temperature requires consideration of all 3 components of heat flow including such factors like: air temperature, cloud cover, air pollution, wind speed, the angle of the sun, the time of day, the orientation of the structure with respect to the sun, topographical location, geometry of the bridge, type of cross-section and material of the structure. This is well known that 2-dimensional mathematical model of temperature distribution is usually acceptable for most type of bridges. 3-dimensional heat flow model is required in unusual circumstances only, where the temperature is expected to vary significantly along the length of the bridge.

3. Bridge Thermal Movements

Thermal movements are accommodated by bridge bearings and expansion joints. In other case the piers and abutments may be integrally constructed with the superstructure and than thermal movements are accommodated by pier deflection or movement of the abutment into the backfill. The movements are calculated by a simple uniaxial expansion equation. This model gives reasonable solution for straight bridges working in "normal" meteorological conditions.

4. The project realized in Poland

Extreme temperature weather data over the past 30 years were analyzed for 25 locations in Poland. The locations were selected to cover the variation in weather conditions and terrain within each region. The average distance between meteorological stations is from 50 km in flat area to 30 km in mountains. The data include dates and locations of extreme air temperatures and daily and yearly temperature variation. This weather data are used to calculate bridge temperatures. The measurements of temperatures and thermal movements are made on 2 straight bridges. First one is three span, continuous, plate girder with composite slab highway bridge (l =152 m). The second is simple supported plate girder with orthotropic deck railway bridge (l = 20 m). The movements are measured with photogrammetrical cameras. Photos are numerically analyzed. The comparative computer thermal-structural analysis is done. The temperature distribution within the bridge is done using FETAB program. These data is used for ANSYS system to calculate 3-dimensional thermal movements. The first results of investigations and computer simulation are encouraging. It looks that for composite and steel bridges standard requirement for maximum bridge temperature could be diminished from + 55° C to + 50° C. The temperature difference between top and bottom of structure should be increased from ± 15° C to ± 20° C.

5. Conclusion

The research will benefit Poland in new and rational recommendations for establishing bridge temperatures and thermal movements in design and construction. These recommendations will result in better long-term performance of bridges. It will reduces the initial cost of the bridge and its maintenance costs.