Study of Temperature Effect on Different Colored Steel Bridges caused by Solar Radiation

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Most bridges are exposed to direct sunlight for a long time in the real environment, and it is considered that the surface temperature of the members rises during the daytime when the amount of solar radiation is large. This temperature rise causes thermal deformation and thermal stress of the structure. However, it is different under direct sunlight and in shadow, so the temperature change behavior may result in structural damages. The temperature effect caused by this kind of sunshine is more significant in hot summer. In this case, the temperature stress may account for a considerable proportion of the material strength. There are many factors that affect the temperature change of steel surface under solar radiation, one of which is the paint color of the steel member that causes the difference of absorption efficiency. Therefore, it is of great significance to understand the temperature distribution of steel structural components subjected to the condition of direct sunlight and the influence of other environmental factors on the temperature change. In this study, a method is proposed for estimating bridge temperature distribution by clarifying the relationship between painting color and the surface temperature of steel members under sunshine using the method of combining experiments and numerical simulation.

First, the temperature of a group of steel specimens with different coating colors under direct sunlight is measured during daytime with thermocouples. Through collecting the data of the daily temperature change of the same group of steel specimens under sunlight in different regions, such as Kyoto, Kobe, Okinawa, and Taiwan, the characteristics of the temperature change of the steel specimens under sunlight are obtained. Moreover, different parameters as ambient temperature, solar radiation intensity, wind speed, setting angle and color are also measured to study their influence on the surface temperature distribution of the steel specimens.

Secondly, based on the theory of heat transfer, a one-dimensional heat conduction model is established to simulate the output surface temperature of steel specimens by using the environmental parameters recorded in the experiment, and the numerical results are compared with the experimental results to prove its feasibility. On the basis of this model, the influence of ambient temperature, solar radiation intensity and wind speed on the temperature change of steel specimens is studied by the control variable method, and the recommended values of solar radiation absorption coefficient of steel specimens with different colors are given.

Finally, a detailed 3D model of a bridge is built based on the design documents to simulate the change of its shadow distribution during the day following the track of the sun. The experiment of measuring the temperature distribution of the whole target bridge under sunshine conditions is conducted, and the temperature of the bridge during daytime is observed by thermal camera. Then, on the basis of a one-dimensional heat conduction model, the temperature distribution of the whole bridge at the moment of the highest temperature in a day is simulated and analyzed by using the measured environmental parameter data. After analyzing the simulation result, the accuracy of the numerical simulation method is verified by the comparison of the experiment data.