Measurement of Temperature Distribution on Yamashiro Bridge

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1. Introduction

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 complicated structural responses. The temperature effect caused by this kind of sunshine is more significant in hot summer. Existing research[1)] shows that under the condition of direct sunlight, the maximum temperature rise of the steel bridge can reach 55 degrees, and the temperature difference between the components can reach 25 degrees, which exceeds the design value of the specification. 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.

2. Experiment method

The experiment objective is Yamashiro Bridge, which is located in Kyotanabe City, Kyoto Prefecture as shown Fig.1. It is a steel arch bridge with single arch rib, and the overall trend is East-West direction. The length of the bridge is 541m and the width is 22.3m. The painting color of the bridge is red. In this observation, measured are the surface temperature of each component of the bridge. The surface temperature of bridge body was measured by handheld infrared thermal camera at different measuring points on the bridge. The solar radiation intensity, ambient temperature and wind speed are taken into consideration as environment parameters. Ambient temperature and wind speed were measured using a portable weather meter. The intensity of solar radiation was measured by illumination-solar-UV Meter. The measurement was conducted from 6AM to 7PM, August 16th of 2020 and the interval is about one hour. At the same time, a 70mm×150mm red steel plate specimen is set horizontally as a reference.

(a) Location of Yamashiro Bridge

(b) View at 1PM

Fig.1 Outline of Field Observation

3. Experiment result

A group of examples of the results measured by thermal camera is shown in Fig.2. Fig.3 records the temperature change of the main arch at different positions from 8AM to 7PM every hour, as well as the solar radiation intensity and ambient temperature. At 1PM, the sun was directly above the bridge and the ambient temperature was at its peak for the day.

Keyword Solar radiation, steel bridge, temperature, paint color

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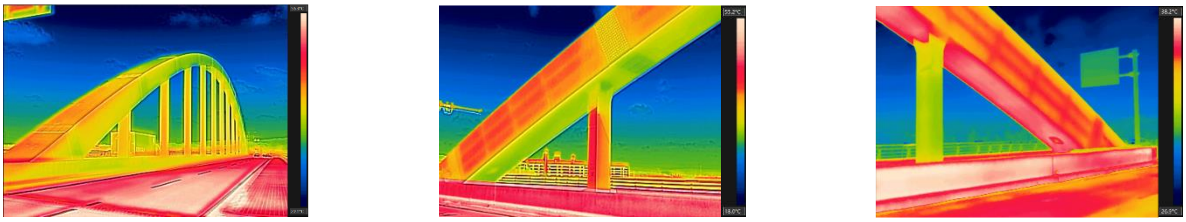
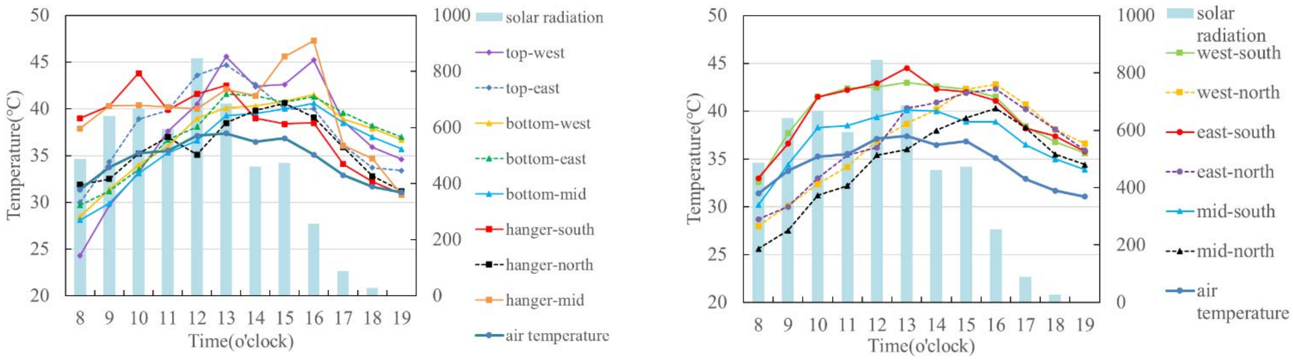


(a)northeast (b)southwest (c)southeast

Fig.2 Thermal images at different angles



(a) arch top and bottom flange, hanger (b)arch webs

Fig.3 Temperature distribution of different parts of bridge

At this time, the east and west sides of the top flange were both exposed to the sun, and the data collected in thermal images shows that temperature of the west side is higher than the east side for the first time. The temperature of components on the east and south sides also reached the maximum of the day, and then began to fall down gradually, while the temperature of the components on the north and west sides continued to rise slowly. The temperature difference between the north and south webs is about 7 degrees, and there exists a transverse temperature decrease of 3 degrees from south to north on the lower flange. At 4PM, the sun was on the northwest side of the bridge. The ambient temperature dropped and the solar radiation intensity also decreased. At this point, the temperature of the arch web on the north and west sides reaches the maximum, as well as the west part of the top flange. Since the sun was at a lower altitude, the vertical bars were subjected to direct sunlight more. Therefore, the temperature of webs of hangers increased, reaching up to 47.3 degrees, which was also the maximum temperature of the bridge over the course of the day.

It can be seen from Fig. 3 that the temperature variation range of hanger is much larger than that of the arch, and the maximum surface temperature of the whole arch structure also appears in hanger. The reason may be that the plate area of the arch is larger, so the temperature change will be smaller under the same intensity of solar radiation because of the difference of heat capacity. What's more, according to the data of the small steel specimen as a reference, the maximum average hourly temperature can reach 57.8 degrees, which occurs at 12PM when both the solar radiation intensity and the temperature are the highest. The smaller the size of the specimen, the higher the temperature rise under the same environmental condition, which might be due to the different heat capacities caused by different sizes, and more heat is needed to raise the same temperature.

4. Conclusion

1) The surface temperature distribution of Yamashiro Bridge in one day was measured. At 4PM, the maximum temperature of 47.3 degrees appeared in the whole bridge, located at the web of hanger.
2) There exists the size effect in temperature distribution of the real size of bridge because of heat input under solar radiation only in one side facing to the sun, but other sides in shade as well as internal of hollow members not heated.

Reference：1)Hashimoto, K., Okumura, S., Sugiura, K., Taniguchi, N., Fujiwara, Y.: Thermal change behavior of composite trussed rohze bridge with SRC structure, J. of St. Eng., JSCE, Vol.61A, pp.816-828, 2015 (in Japanese).