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Temperature allocation in composite bridge box girder segment under the effect of summer Iraqi environmental load

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ABSTRACT

The bridge is constructed in an open environment, exposing every part of the bridge to environmental load. This paper studies the impact of the Bagdad environmental load that involves wind speed, air temperature, and solar radiation on the composite bridge box girder segment. These environmental loads are variable hourly, leading to nonlinear temperature distribution inside the segment. This nonlinear temperature distribution inside the segment led to generating thermal stress inside the segment. This paper reveals the magnitude and allocation of thermal stress inside the segment. Furthermore, this paper provides the numerical result for thermal stress inside the segment by using a unique simulation in the COMSOL program to calculate the effect of these environmental loads on the temperature allocation inside the segment..

Keywords:

Introduction

The difference in allocation and strength of temperature in the composite bridge analysis is generated by both daily (short period) and seasonal (long period) environmental behavior. Seasonal (long period) environmental behavior leads to the significant thermal movement (expansion or contraction) that will occur throughout the bridge length when the environment changes from winter to summer or vice versa. In an unrestrained bridge (free to contract and expand in a long direction), seasonal environmental thermal differences will not generate stresses. In contrast, daily environmental changes on the unrestrained bridges between day and night lead to non-linear temperature variation throughout the cross-section and generate internal stresses. Bernoulli Euler's hypothesis indicates that this internal stress will be generated whether or not the composite bridge is restrained.

Several kinds of research conducted by [1]–[4] have shown that thermal stress significantly impacts the bridge service life. This impact affected the bridge service life by generating cracks in the concrete slab or deflection and deformation in concrete elements. Additional scholars [5]–[7]suggested that when steel-concrete composite bridges are subjected to uncommon daily environmental influence, thermal stress could be generated in the order of ±5 Ksi. These daily stress changes are possibly equal to stress resulting from construction processes, such as concrete slab placement and girder erection. Therefore, the durability and structural integrity of the composite bridges can be improved if thermal stresses are computed early in the design phase.

Composite bridge box girder segment and environmental load

This section clarifies the segment that utilizes in this numerical simulation. Figure (1) shows the cross-section dimension of the segment in 2D. This segment was taken from the previously published paper [8]. This 2D segment was extruded to 1 m to transform this 2D segment into 3D, as shown in Figure (2). Moreover, Figure (3) illustrates the distribution of thermocouples inside the segment.

Furthermore, the environmental load that affects the segment during the study day in this season and 72 hours before the study day is illustrated in Figures (4) to (6).

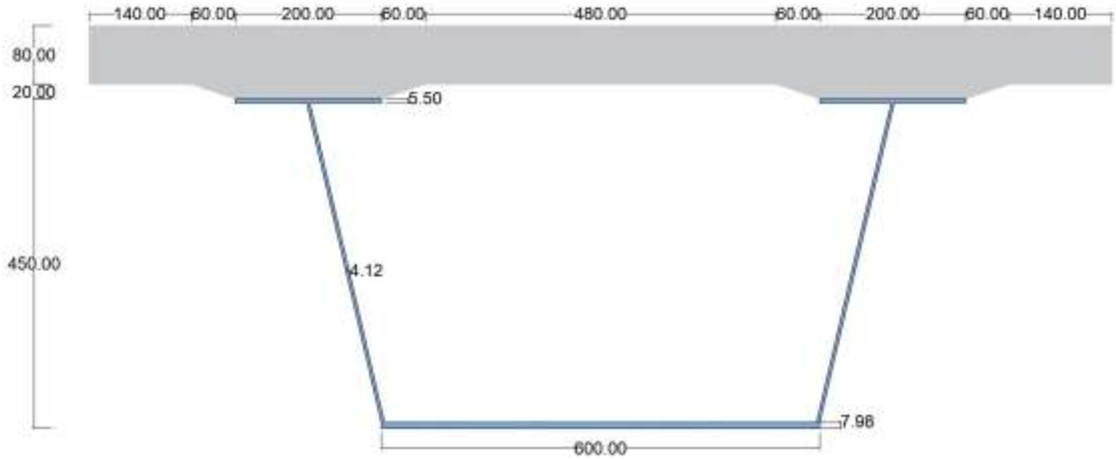

Figure (1) The dimension of the cross-section segment in this simulation.

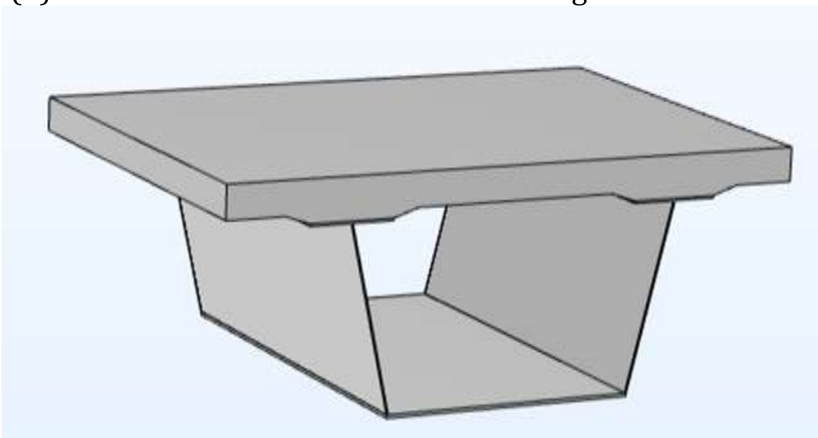
Figure (2) The 3D segment in the COMSOL program.

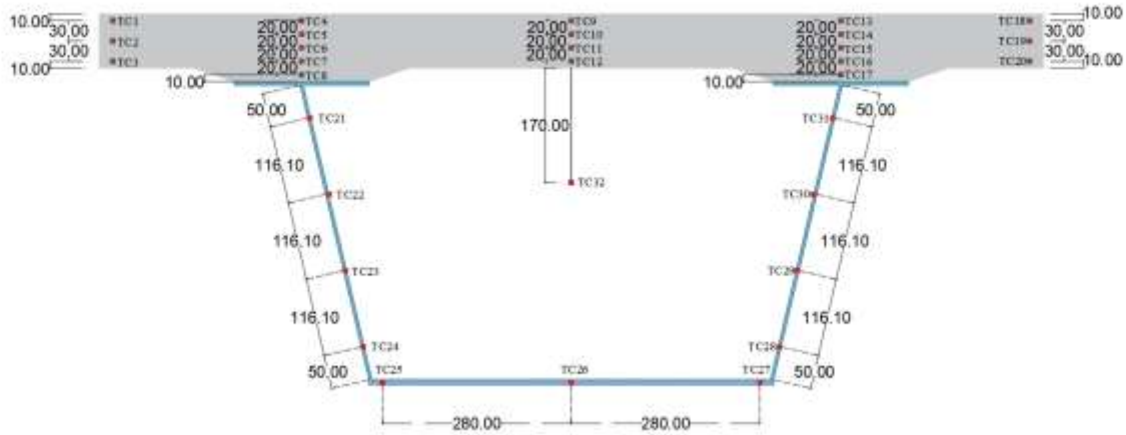

Figure (3) Thermocouples location inside the segment.

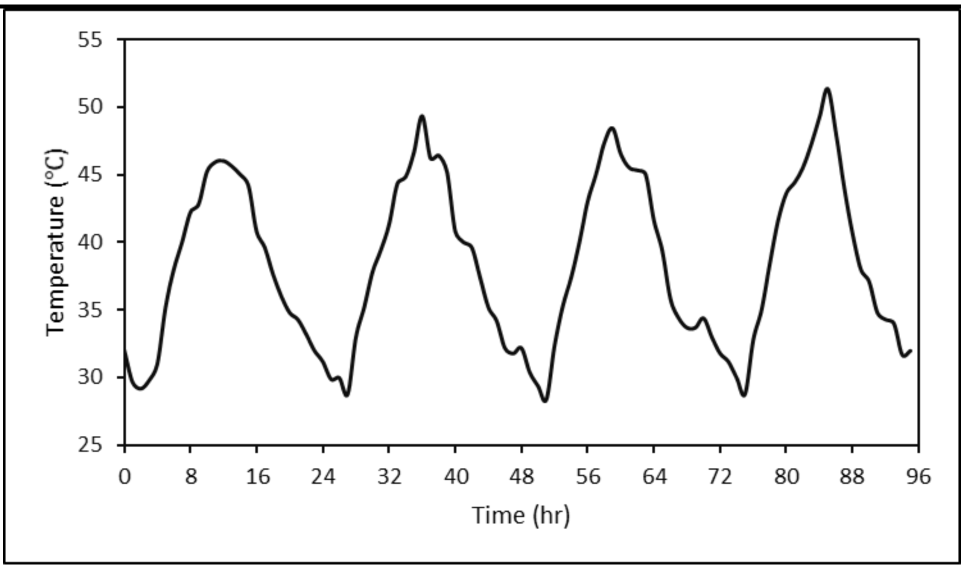

Figure (4) Air temperature that affects the segment for 96 hours.

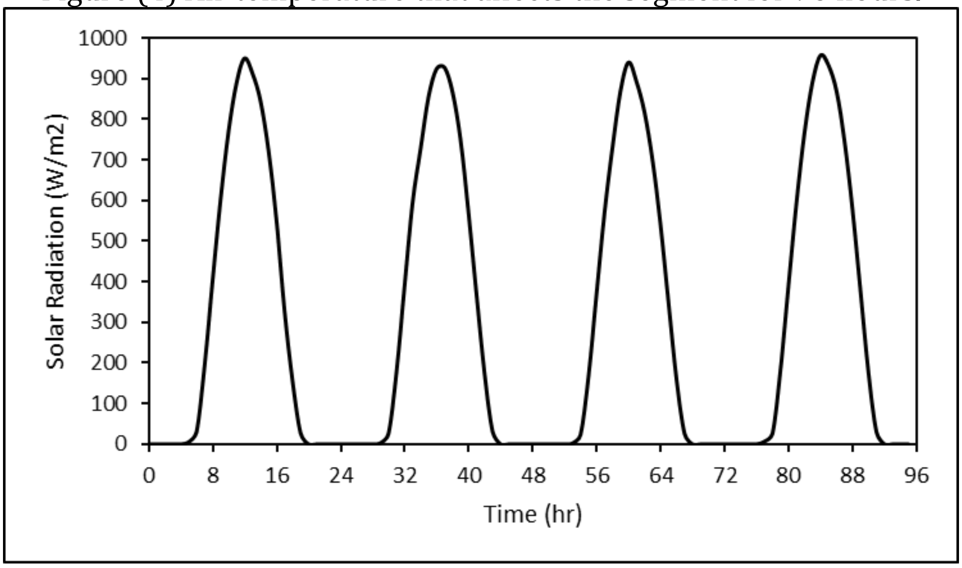

Figure (5) Solar radiation that affects the segment for 96 hours.

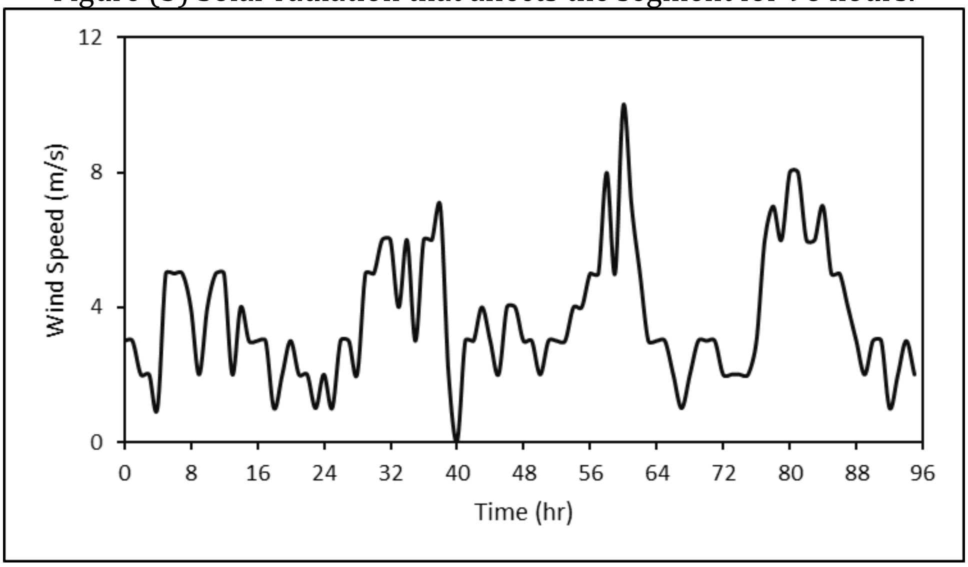

Figure (6) Wind speed that affects the segment for 96 hours.

Results

This part of the temperature result displays the result of calculating temperature in the specific horizontal and vertical lines in the segment at particular times. This study used two horizontal lines inside the segment to determine the temperature variance in these lines; The first horizontal temperature variance line includes the result of the calculated temperature in these TC (TC1, TC4, TC9, TC13, and TC18) refers to the temperature variance across the upper concrete surface. In contrast, the second horizontal temperature variance line includes the result of the calculated temperature in these TC (TC25, TC26, and TC27) refers to the horizontal temperature variance across the underside of the segment. Also, this investigation presents the temperature variance in two vertical lines inside the segment; the first one is used to display the temperature variance that occurred in the south face of the segment depending on the result of temperature in these TC (TC25, TC24, TC23, TC22, TC21, TC3, TC2, TC1). In contrast, the second one refers to temperature differences in the north segment face relying on the calculated temperature in these TC (TC27, TC28, TC 29, TC30, TC31, TC20, TC19, and TC 18).

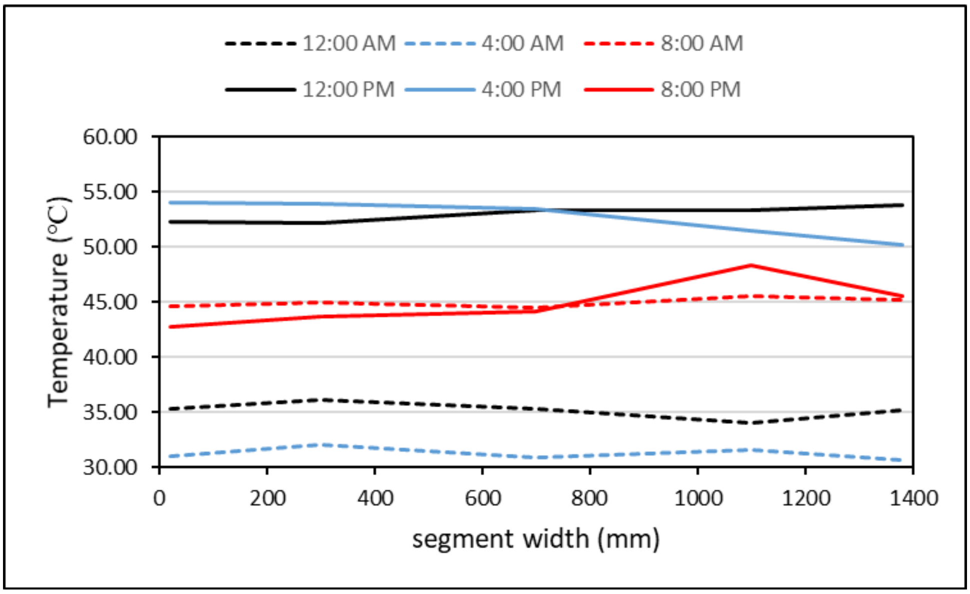

Figure (7) Horizontal temperature allocation in the upper concrete surface during summer investigation day.

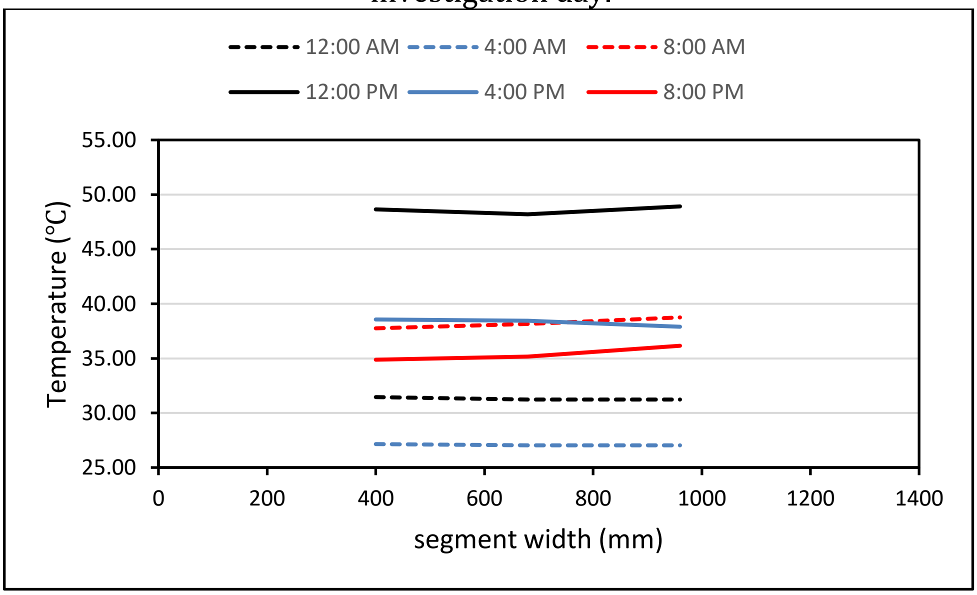

Figure (8) Horizontal temperature allocation in the underside of the segment during summer investigation day.

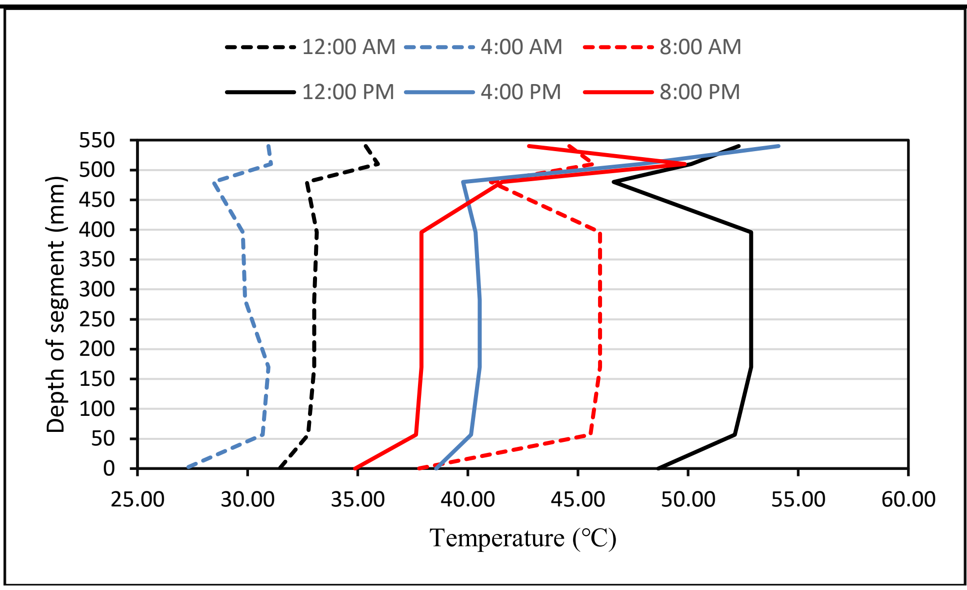

Figure (9) Vertical temperature allocation in the south flank of the segment during the summer study day.

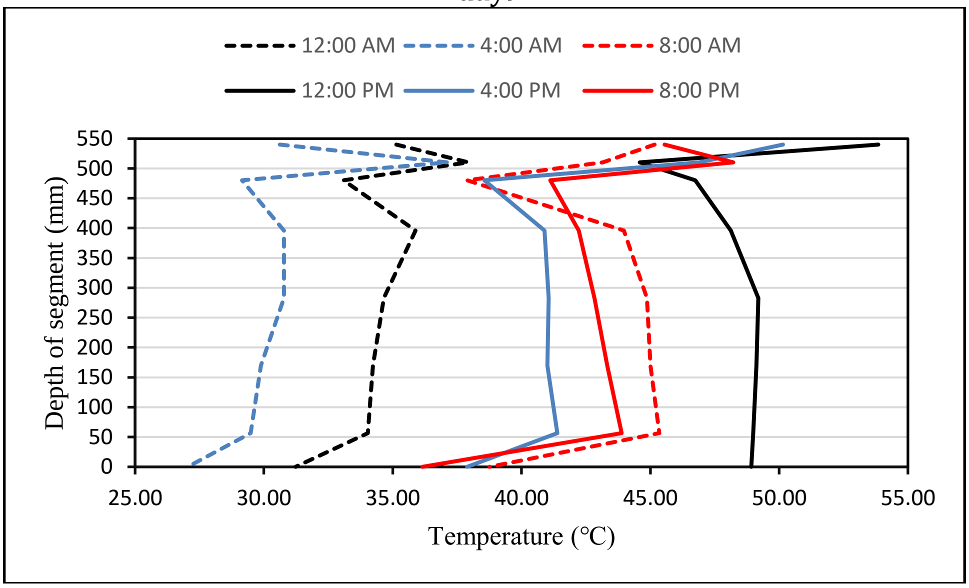

Figure (10) Vertical temperature allocation in the north flank of the segment during the summer study day.

Conclusion

- The highest temperature in the upper horizontal line occurred at 4 pm in TC1, equal to 54.10 ℃.
- The highest temperature in the lower horizontal line occurred at noon in TC 27, equal to 48.92 ℃.
- The highest temperature in the vertical south side occurred at 4 pm, equal to 54.10 ℃ in TC1.
- The highest temperature in the vertical north side occurred at noon in TC18, equal to 53.85 ℃.

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