Applied Thermal Engineering 37 (2012) 329–335

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Theoretical and experimental study on the temperature distribution of H-shaped steel members under solar radiation

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ARTICLE INFO

Article history:
Received 2 March 2011
Accepted 23 November 2011
Available online 3 December 2011

Keywords:
Temperature
Solar radiation
H-shaped steel
Numerical analysis
Simplified calculation method

ABSTRACT

Thermal effects on steel structures exposed to solar radiation are significant and complicated. Furthermore, the temperature variation within a year may result in damage in steel structures considering the solar radiation. In this paper, the temperature distribution of H-shaped steel members was investigated through a systematic experimental and theoretical study in the case of solar radiation. First, an H-shaped steel specimen was designed and its temperature distribution under solar radiation was obtained by a test. After that, a numerical method was proposed to obtain the temperature distribution under solar radiation. This method was based on transient thermal analysis and the analytical result was verified by the above experimental result. Furthermore, a parametric study was conducted to investigate the influence of various solar radiation parameters and orientation of H-shaped steel members on the temperature distribution under solar radiation. Finally, a simplified approach was developed to predict the temperature distribution under solar radiation. Both experimental and numerical results showed that the solar radiation had a significant effect on the temperature distribution of H-shaped steels. Considering the solar radiation, the temperature of the specimen is about 20.6 °C higher than the surrounding ambient air temperature. The temperature distribution under solar radiation was observed to be sensitive to the steel solar radiation absorption and orientation, but insensitive to the solar radiation reflectance.

1. Introduction

Steel structures are usually exposed to solar radiation, such as steel bridges and spatial steel structures. Furthermore, the solar radiation can irradiate the surface of steel members if the roof material above the steel structures is either glass or ETFE membrane. Due to the effect of solar radiation, the temperature of these steel structures is significantly higher than the surrounding ambient air temperature in summer, and the temperature difference between steel surface and ambient air may exceed a value of 20 °C. In addition, the temperature of steel structures is non-uniform under solar radiation. Therefore, the thermal stress and thermal deformation in these structures are larger and more complicated than those which the solar radiation cannot irradiate. If a steel structure is constructed in summer, its temperature change may exceed a value of 80 °C in winter. For this temperature change, the thermal stress for a pinned steel member may reach 196 MPa. Therefore, the steel member will fail or fracture considering the temperature change in addition to other loads, such as gravity and wind load.

Recent researches on solar radiation focused on the building energy [1,2]. Some researches also had a concern on the temperature distribution of bridges [3–6], dams [7,8] and pavements [9,10] under solar radiation. For the structures, the main published paper referred to the temperature distribution of concrete structures and masonry structures under solar radiation [11,12]. However, only a few researches were conducted on the temperature distribution of steel structures under solar radiation. Fan investigated the temperature distribution of National Stadium under solar radiation based on a steady thermal finite element (FE) analysis [13,14]. A research on the temperature distribution of steel plates under solar radiation has been conducted through a theoretical and experimental study [15]. However, an algorithm for the shadow of solar radiation is firstly required for the temperature analysis of H-shaped steel members. Furthermore, there is a large difference in the temperature distribution between steel plates and H-shaped steel members under solar radiation.

Consequently, an extensive study was conducted on the temperature distribution of H-shaped steel members under solar

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doi:10.1016/j.applthermaleng.2011.11.045