RailAdapt Workshops
Beijing
19-20 June 2017
Building a resilient railway

Simulation Method Research of Temperature Distribution in Hollow Piers under Solar Radiation

Qi Wang, China Railway Design Corporation , Tianjin, China

INTRODICTION

The thermal effect caused by temperature difference will affect the safety and durability of hollow piers significantly. To study the temperature effect of a hollow pier, we must first study the temperature distribution.

Nowadays, when designing hollow piers, we use half experiential and half theoretical formulas, which simplifies the three-dimensional temperature field to be one-dimensional, to simulate the temperature distribution under solar radiation. However, due to the lack of the basis of measured temperature value among a one-dimensional theory, the precision of this method is low.

Due to the climate changing randomly, and with uncertainty, the temperature distribution of a hollow pier is a three-dimensional transient heat conduction problem with complex boundary conditions. In this case, we require a method based on developed theory and measured temperature data to simulate the temperature distribution of a hollow pier.

This paper aims to research the simulation method of temperature distribution in hollow piers through field temperature distribution monitoring and numerical simulation. The temperature variation and distribution law of the pier is analyzed and summarized based on the measured data obtained from the long-term temperature monitoring system. According to Kehlbeck's thermal analytical theory of bridge structures*(Kehlbeck, 1983)*
, combined with meteorological data, this research modifies the simplified model proposed by Elbadry and Ghali(Elbadry and Ghali, 1983, 1984).
to make it more applicable to piers. The analytical results of temperature distribution are compared with those obtained from the long-term temperature monitoring system and it shows that this method can predict the temperature distribution of hollow piers accurately.

Experimental Research

The height of the hollow pier is 39.5m, and the widths of it are 22.3m (lateral) and 4.8m (longitudinal). The radius of the round ends are 2.2m, and the thickness of the wall is 0.5m. The measured section is in the middle of the pier. The temperature of each hour was measured from June 2011 to February 2013.

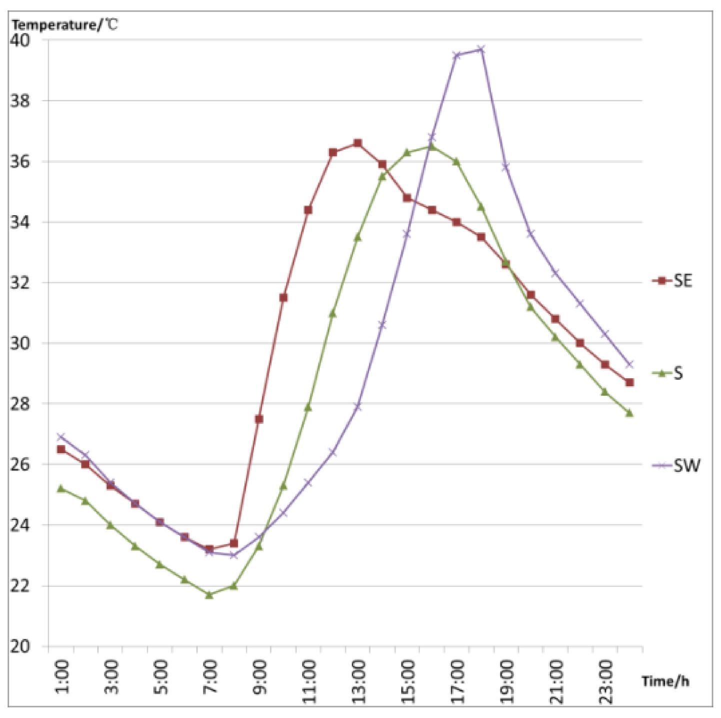

Fig.3. Temperature variation curve of typical points on Aug.29th (° C)

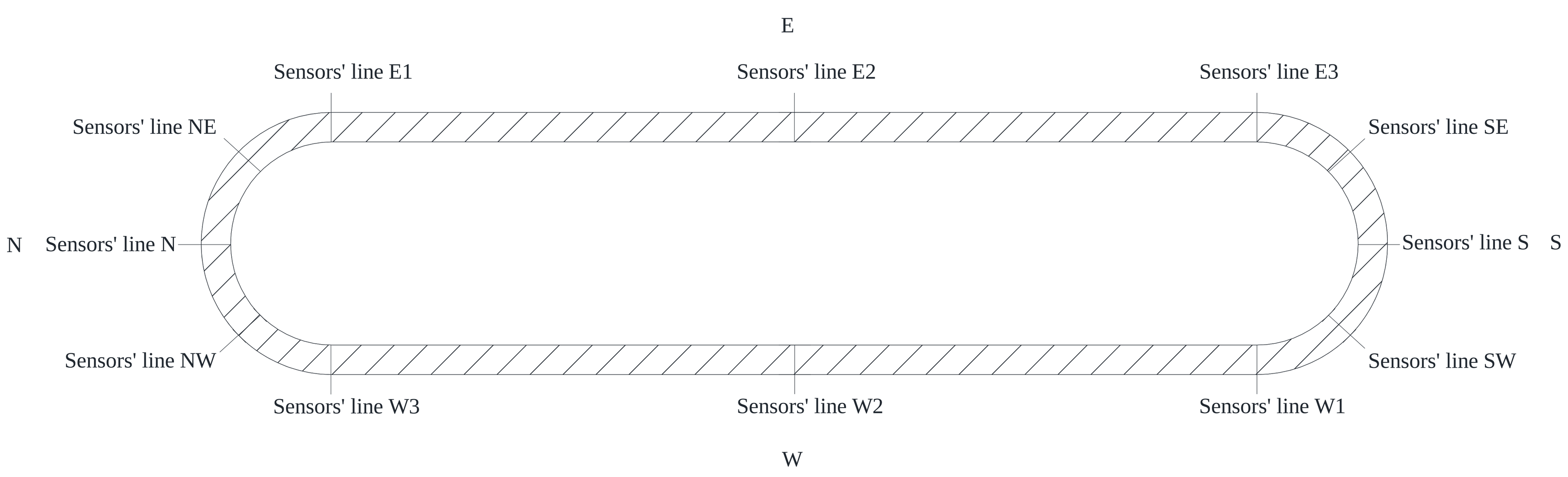

Fig.1. Pier section and sensor layout

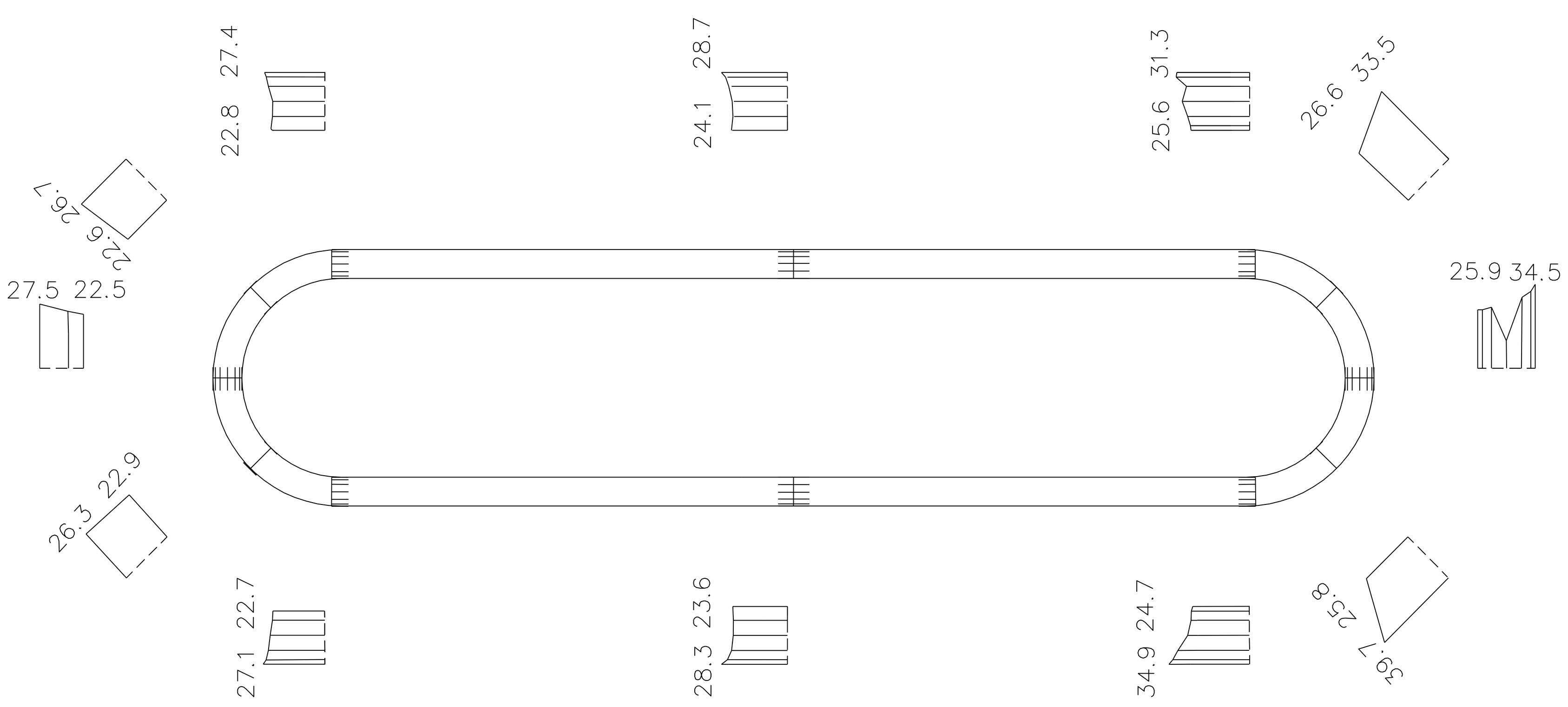

Fig.2. Temperatures of sensors' at 18:00 on Aug.29th (℃)

Simulation

Simplified Formula of Boundary Conditions

$$k\left(\frac{\partial T}{\partial x}n_x+\frac{\partial T}{\partial y}n_y\right)=q_s+q_z=A_s(q_{sdi}+q_{sdf}+q_{sr})+h_z(T_a-T)$$

In which *As* is the absorption rate of shortwave radiation, *qsdi* is the direct solar radiation, *qsdf* is the solar radiation scattered from the sky, *qsr* is the reflection of solar radiation from the ground, and *hz* is the overall heat transfer coefficient which reflects the overall effect of convective and long wave heat transfer.

hz can be calculated by the following formula:

$$h_z=\frac{q_c+q_r}{(T_a-T)}$$

in which *qc* is the convection, *qr* is the long wave heat transfer.

**The formulas above are derived from Kehlbeck's theory. (Kehlbeck, 1983)*

Parameters

The transient analysis of the temperature distribution of the round-ended hollow pier on August 29, 2011 is carried out. The value of related parameters are as the following tables:

Table 1 Meteorological parameters

Max T_a	Min T_a	Average wind velocity, v	Ground reflection coefficient, r_s
34.3°C	16.2°C	1.52m/s	0.2

Table 2 Thermal parameters of concrete

Emissivity of concrete, ε	Absorption rate, A_s	Specific heat, c	Thermal conductivity, k	Density, ρ
0.88 (Elbadry et al., 1983)	0.42 (Zhang et al., 2006)	970J/(kg ℃)	1.5 W/(m℃)) (Elbadry et al., 1983)	2400kg/m^3

Initial Condition and overall heat transfer coefficient

The initial condition of heat conduction problem of concrete structures can be the average temperature of the condition when the temperature is nearly equal. According to the measured data, at 1:00 am on August 29th, 2011, the temperature distribution of the hollow pier was nearly equal, so the average temperature 25.0℃ is set as the initial temperature.

Using the measured temperature data on August 29, 2011, the overall heat transfer coefficient *hz* can be calculated. It equals 10.82 for outer wall, and 3.26 for inner wall.

Results and Conclusion

The finite element calculation results of typical lines are compared with the measured data. The variation law of the data is consistent and the error is less than 5%, which proves the reliability of the simulation method of temperature distribution.

This paper provides a method for the simulation of temperature distribution of hollow piers in different geographic locations, different times, and under different meteorological conditions.

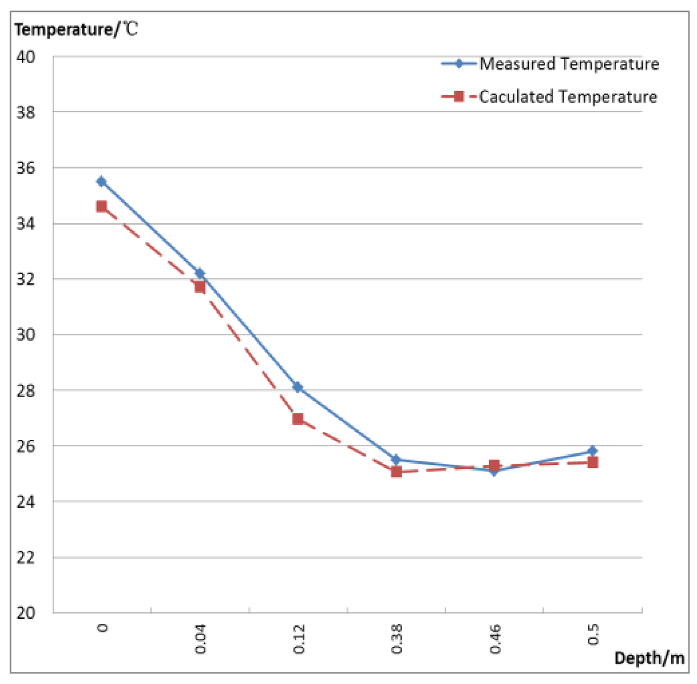

Fig.4. Curve of calculated and measured value along the normal direction of the outer surface of S point at 14:00

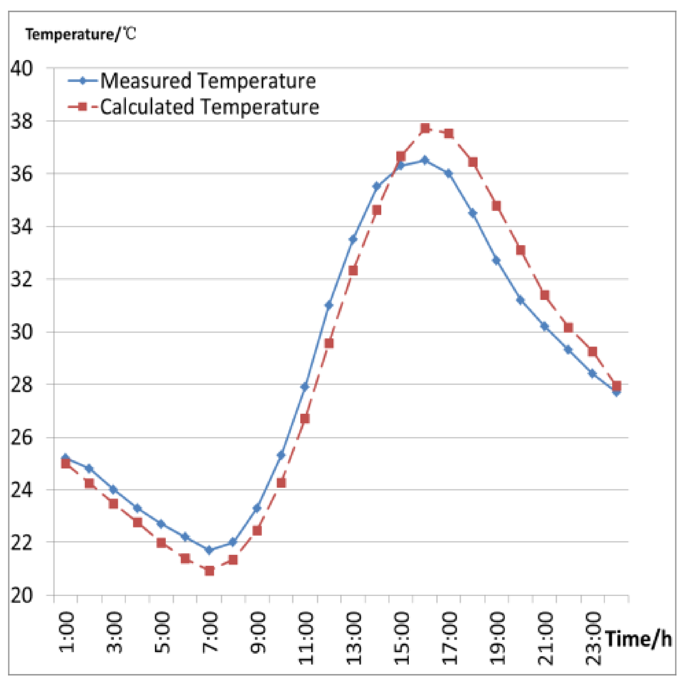

Fig.5. Curve of calculated and measured value of outer surface of S point on Aug.29th

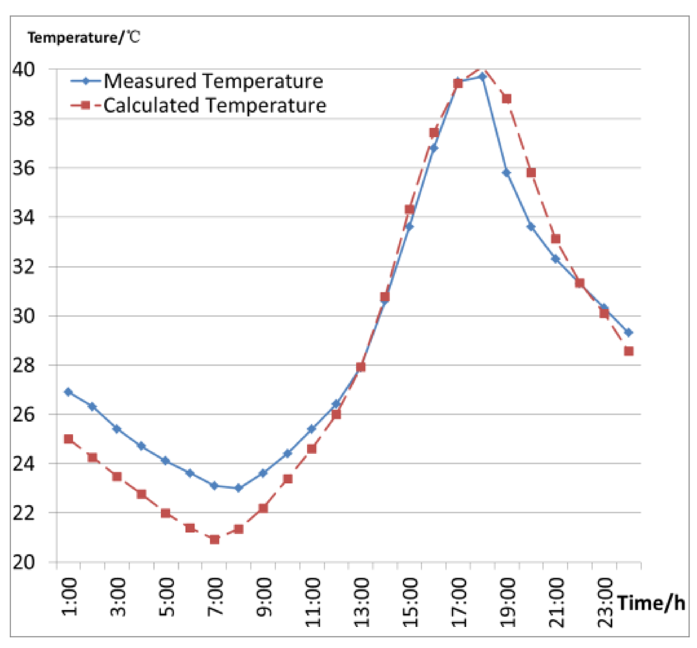

Fig.6. Curve of calculated and measured value of outer surface of SW point on Aug.29th

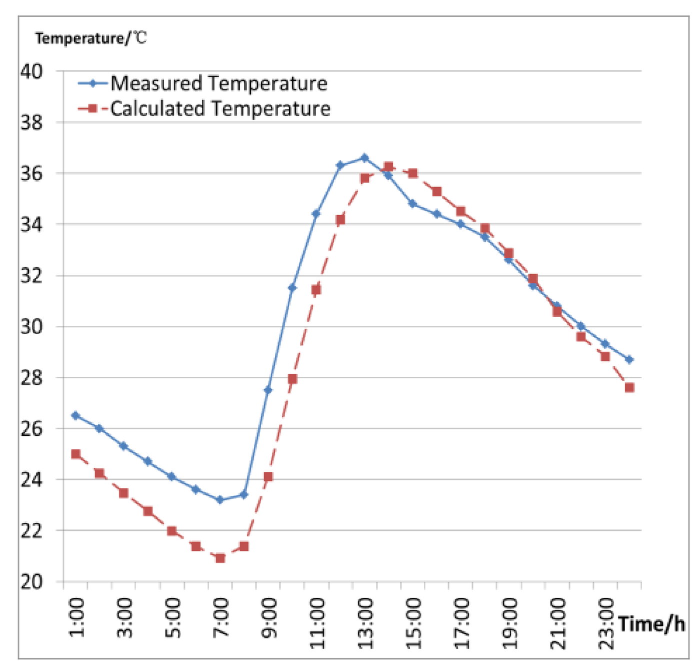

Fig.7. Curve of calculated and measured value of outer surface of SE point on Aug.29th

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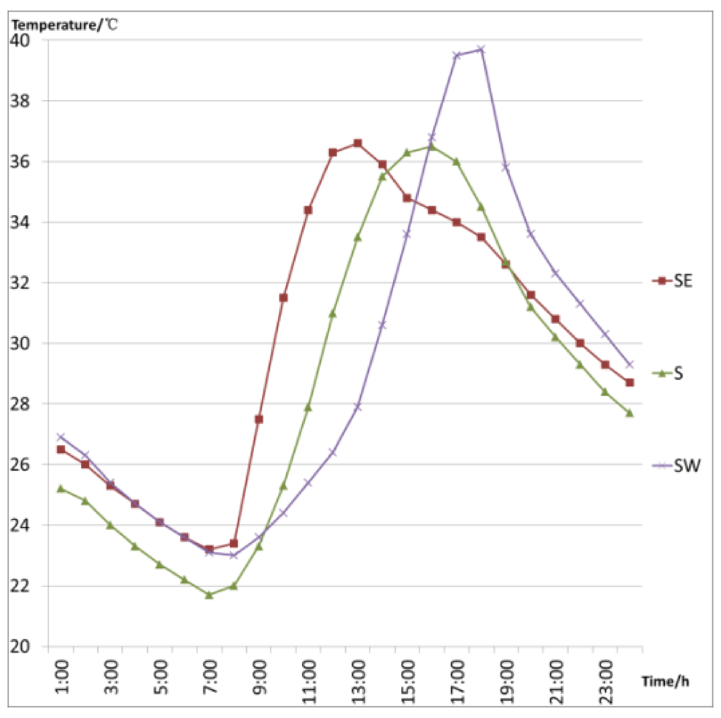

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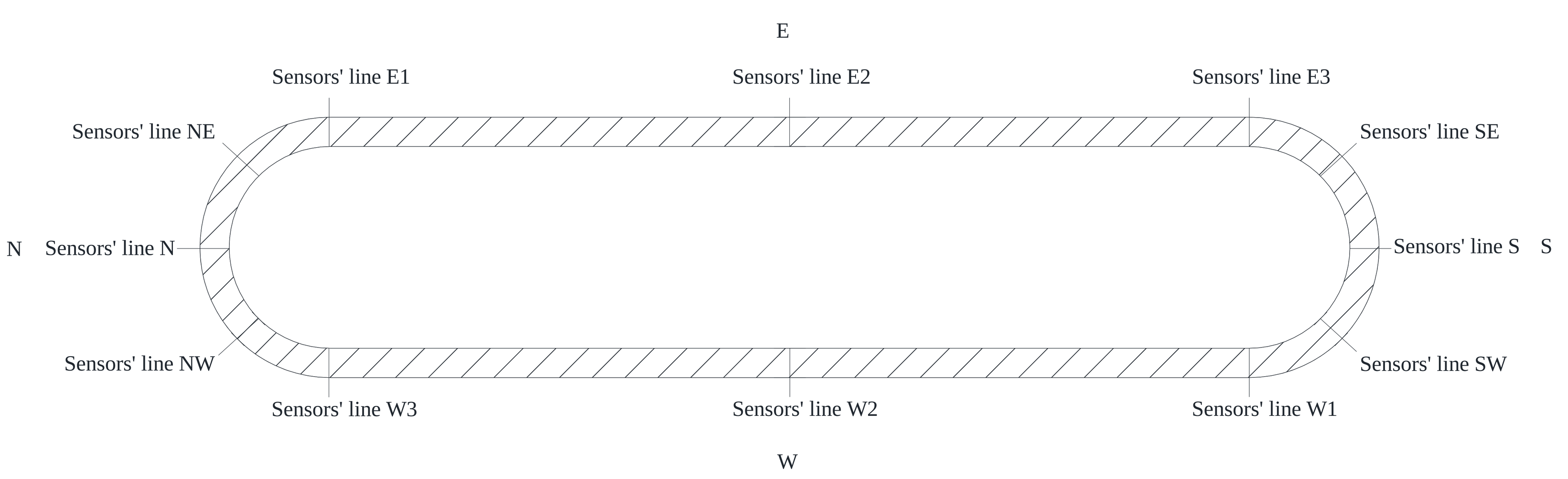

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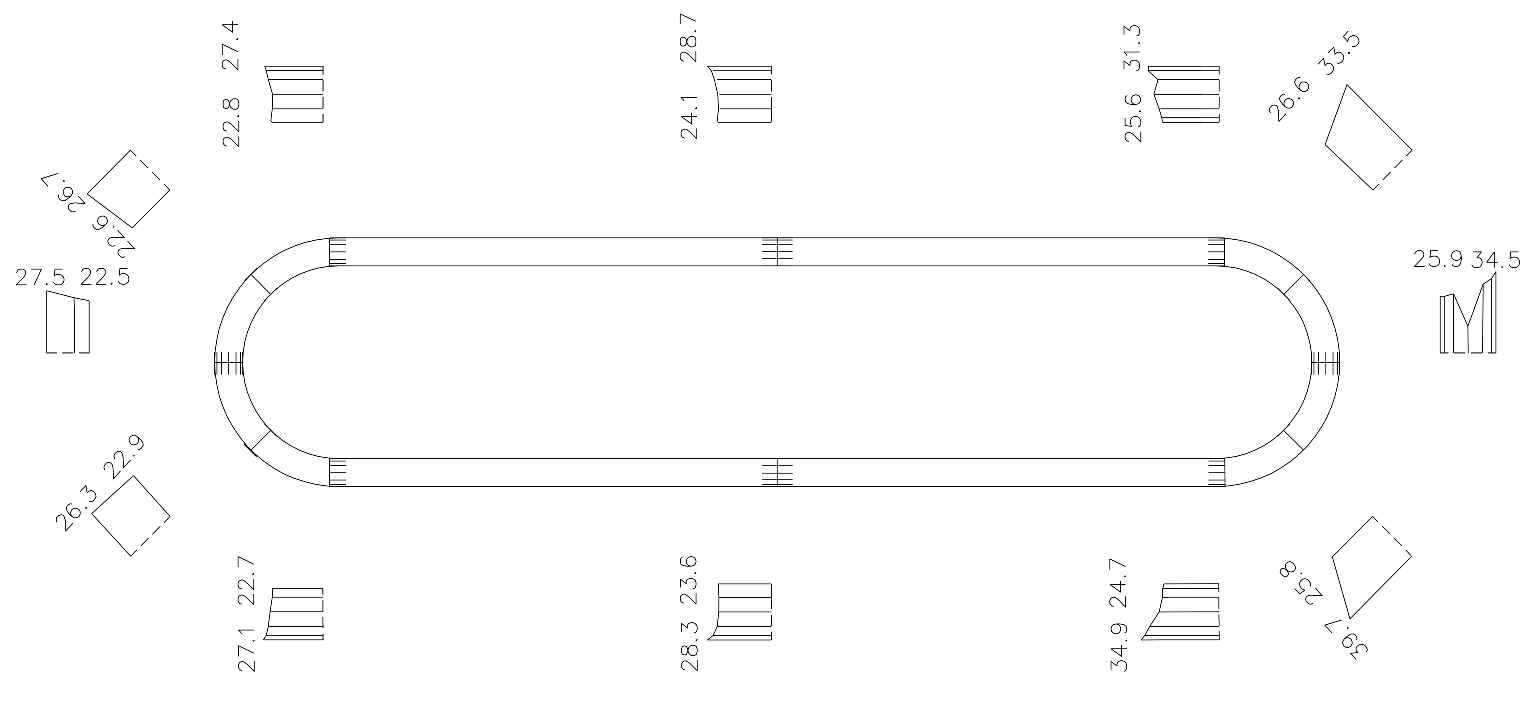

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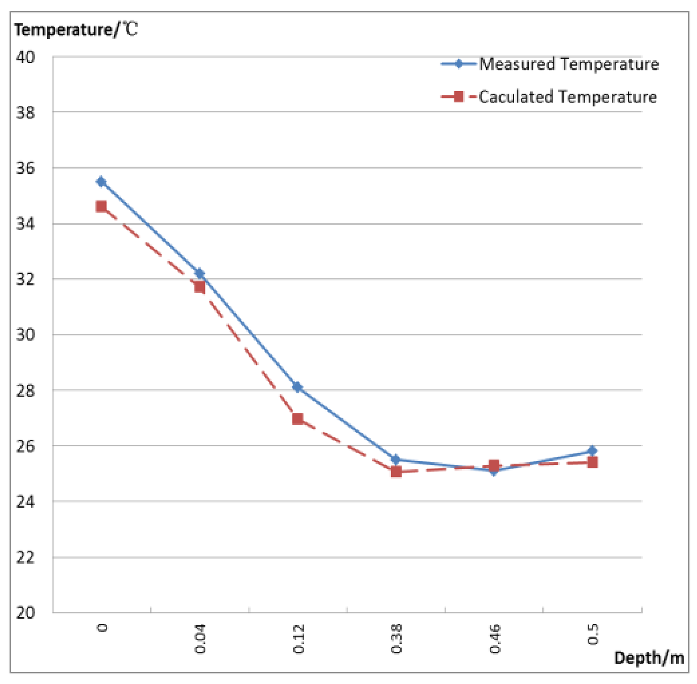

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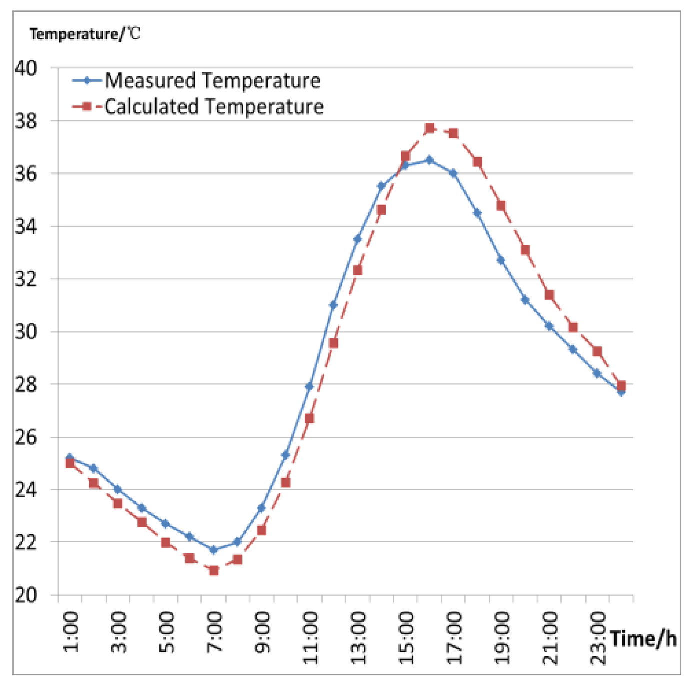

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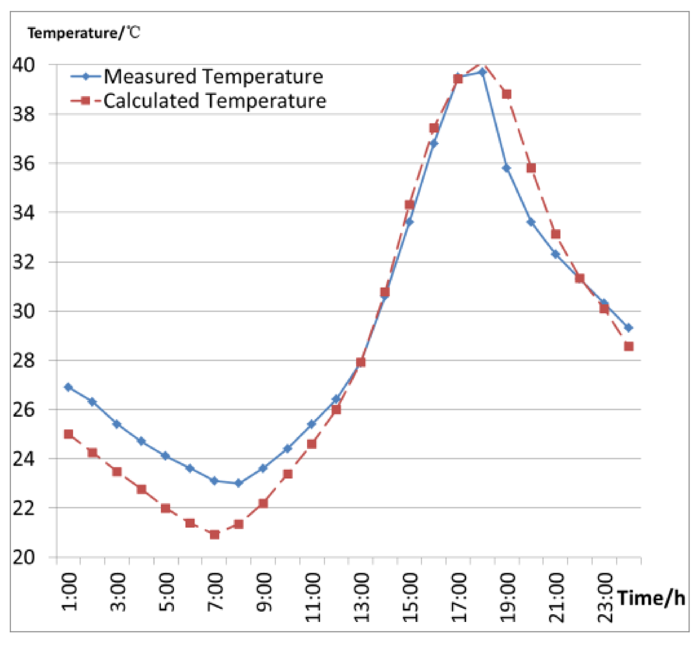

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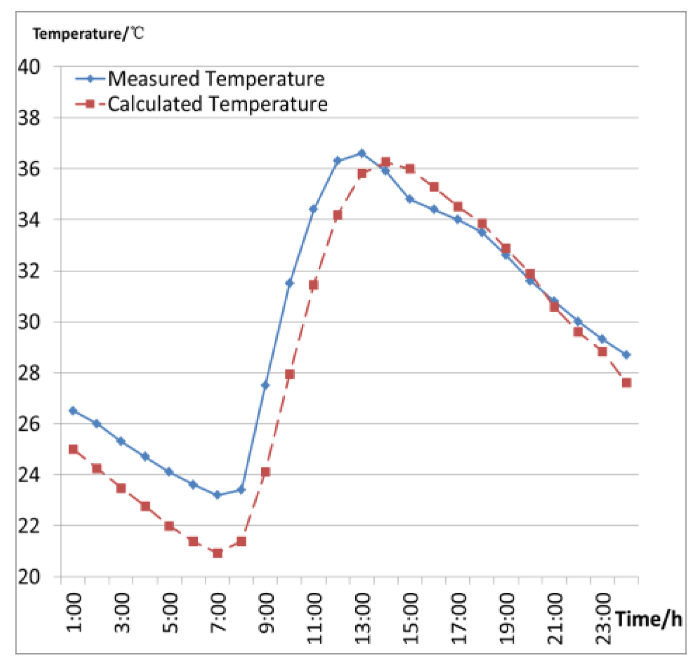

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