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Modeling of temperature variations and response in a mining road bridge in Kiruna

The climate affects all structures in several ways, depending on for example the material, the geometry and the location. For a structure located at a place as Kiruna in the north of Sweden, the temperature variation can be extreme. A model to describe the temperature variation in concrete structures can aid when describing short term deformations. Also, an approximate method has been tested during the validation of the temperature model.

The climate can increase and decrease the temperature of concrete structures. This kind of temperature variation can lead to deformations, it is therefore of interest to be able to simulate the temperature variation within concrete structures.

A concrete bridge located in the north of Sweden, in the small municipality of Kiruna, has been used for transporting iron mine between the year of 1959 and 2014, when it was demolished. Before the demolition of the bridge, temperature- and strain measurements were made with temperature and strain gauges.

The exchange of thermal energy between the bridge and the surroundings occurs in several forms. During the day the solar radiation from the sun hits the bridge surfaces that face the sun. During the night, when the temperature decreases, longwave radiation is transferred from the bridge. Also, heat is transferred from the bridge due to convection caused by the wind.

The magnitude of the solar radiation was calculated with data from the STRÅNG database, created by the Swedish Radiation Protection Authority and the Swedish Environmental Agency.

To calculate the effects from wind and outgoing heat radiation, data from the Swedish Meteorological and Hydrological Institute was obtained.

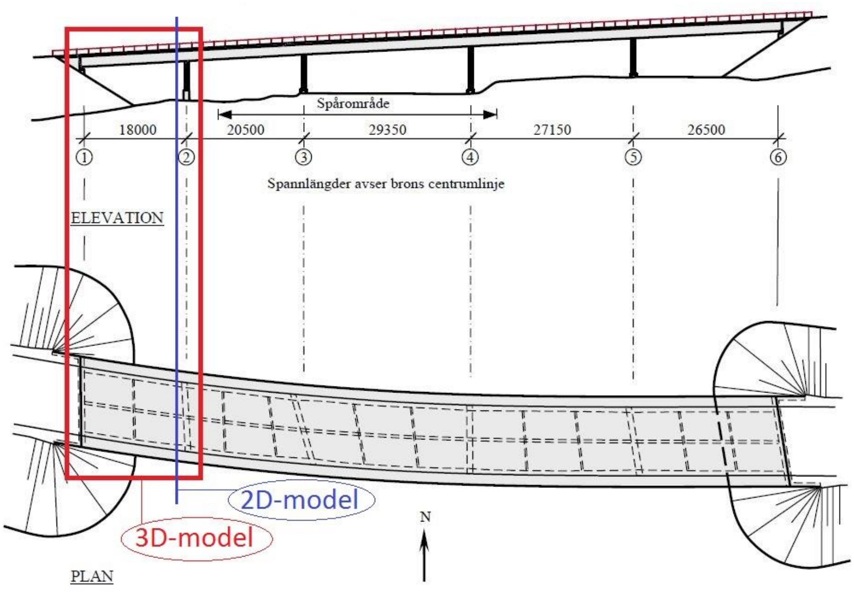

Figure 1. The cross section of the bridge which was modelled in Abaqus is located at the blue line titled "2D-model". The box titled "3D-model" is the area of the bridge which was modelled to calculate strain variations., but is not discussed further in this article.

Calculation of the long wave heat radiation was made using an approximate method. The air was considered a surface with a temperature given by subtracting six degrees from the air temperature. Interestingly it appears that good results can be achieved with this simple method.

To simulate how the climate affects the temperature variation within the bridge, the computer software Abaqus was used.

The temperature variation from a two-dimensional model was compared to measured data from the temperature gauges. The same way, the strain variation from a three-dimensional model was compared to measured data from strain gauges for validation.

The results, seen in figure 2, show that the temperature model works well along with the use of the approximate long wave radiation method.

In figure 2, the x-axis shows time in days and the y-axis shows the corresponding temperature. The measured temperature is named "measured" in the graph. The calculated temperature from the simulation in Abaqus is named "calculated".

The results from the temperature model can be used as input to estimate short term deformations. The strain results show that the calculated- and measured strain vary about the same way. However the daily variation is much larger for most of the measured values compared to the calculated values. Furthermore it seems that the strain model overestimates the strain, but underestimates the daily strain variation.

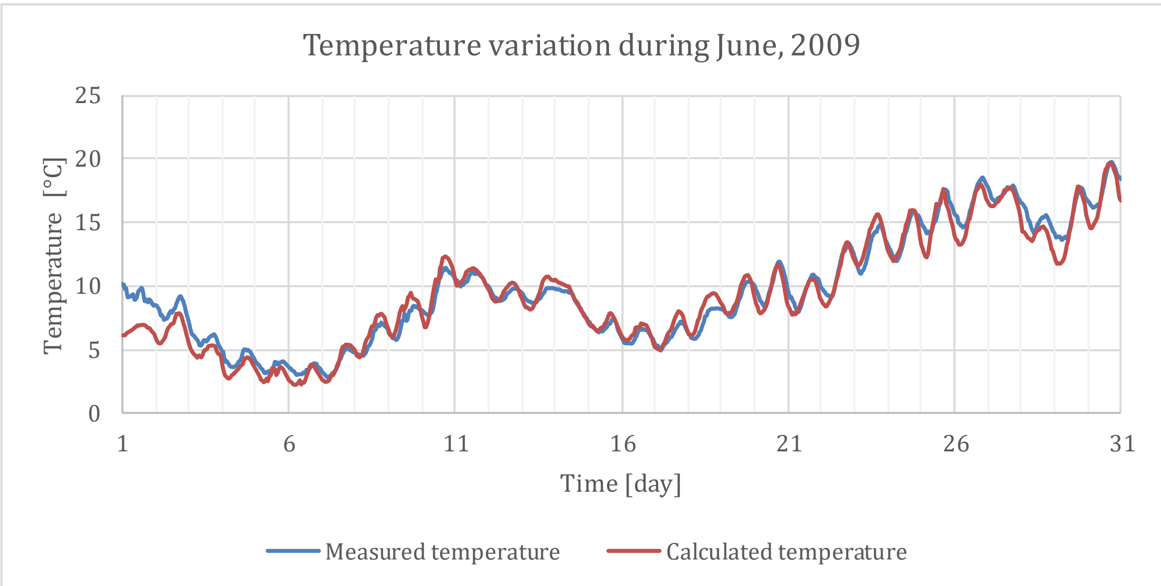

Figure 1. An overview of the temperature variation during the month of June in the middle of the bridge cross section. The peaks correspond to the daily maximum values which occur during day time when the sun warms up the bridge. The bottoms correspond to the daily minimum values which occur during the night when the temperature decreases and the coldest time of the day occur. As seen in the graph, the calculated temperature from Abaqus exhibits a good closeness and similarity to the measured temperature from the temperature gauge.