

Modeling of Thermal Effects in Concrete Bridge Design

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Thermal actions have a significant effect on bridge structures and can at some sections account for more than 20% of the reinforcement. Such actions are especially important in some types of concrete bridges, e.g. portal frame bridges.

Thermal actions

Thermal actions differ from other load types considered during bridge design through being a constraining load. The different heat transfer processes causing temperature differentials in concrete structures are solar radiation, convection and long wave radiation. A temperature profile of a bridge deck is divided into two parts; a uniform part that affect the bridge with a linear expansion and a non-uniform part that will induce an arch shape of the bridge deck.

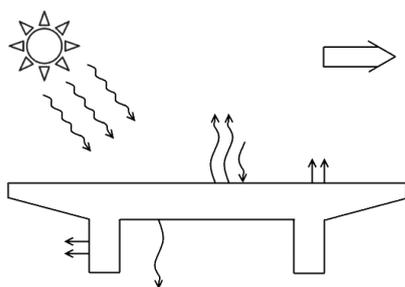


Figure 1: Illustration of thermal input factors such as solar radiation, convection and long wave heat radiation

The magnitude of the thermal loads is not only dependent on the magnitude of the temperature difference. The properties of the structures, mainly its stiffness and thermal expansion coefficient affects the magnitude of these loads. For a fully constrained structure the stresses caused by temperature difference can be calculated according to:

$$\sigma = E\alpha\Delta T \quad [Pa]$$

The traditional way to treat temperature loads is to assume an initial temperature T_0 . Any change in temperature from this level will create stresses. There is one heating load case (top warmer than bottom) and one cooling load case (top cooler than bottom).

Building code

Using the current building code, thermal actions can account for more than 20% of total demand of reinforcement at midsection making them so large that they cannot be neglected. This makes thermal actions in bridge design interesting for further investigation.

The current building code in Sweden, Eurocode, suggests two approaches for considering temperature differentials during bridge design. The first approach uses a linear temperature distribution through the bridge deck and the second approach uses a non-linear distribution. A simulation is performed using measured data presented by SMHI. The model is subjected to convection, long wave radiation and solar

radiation to evaluate the two approaches. This simulation is done for the year 1986 with data collected in Stockholm, Sweden

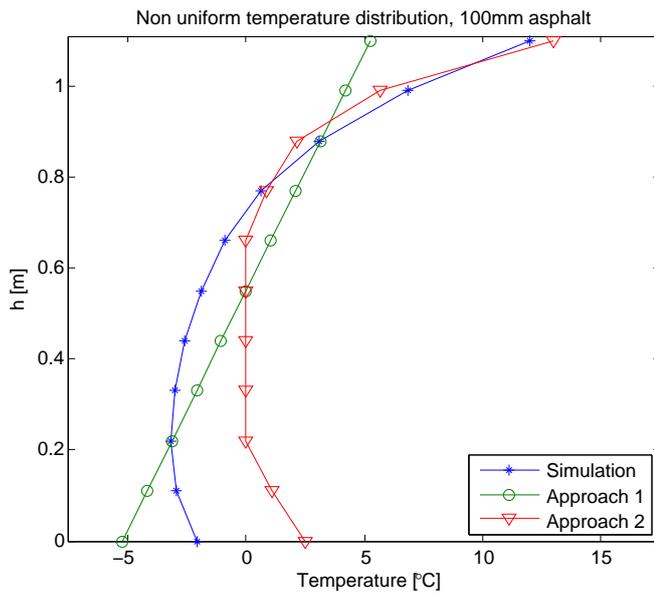


Figure 2: Comparison of temperature profiles from approach 1, approach 2 and simulation

Figure 2 shows temperature distributions from approach 1, approach 2 and simulated values from an hour in June 1986 which were identified as worst case. Results from the simulation imply that approach 2 will give a more realistic temperature distribution than approach 1.

Case Study

An analysis of a portal frame bridge built in Katrineholm, Sweden, comparing the two approaches according to Eurocode is performed. This bridge is chosen because it is a common bridge type where constraining forces can be large.

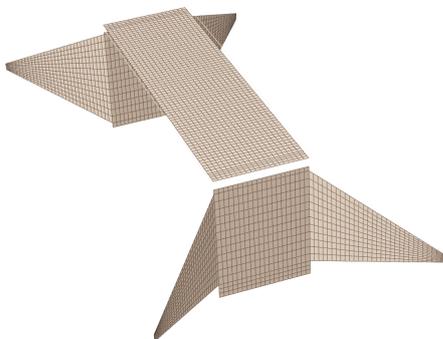


Figure 3: FE model of portal frame bridge in Katrineholm

Results indicate more favorable load effects when using approach 2 which will reduce the total demand of reinforcement. The largest difference in load effects between the two approaches is at midspan, even though there is favorable effects at the supports as well.

When using approach 2, non-linear stress peaks will arise at top and bottom of a bridge section during analysis. These stresses may cause problems with cracking in the serviceability limit state. During a load case when the bridge deck is cooled, tensile stresses close to the surface will rise above the tensile strength of concrete, implying the appearance of cracks. Based on the current building code, two methods are established to handle stress peaks in a bridge structure. Both methods show similar results, indicating that the total demand of reinforcement using these methods will increase compared with approach 2.

Concluded results

The concluded results from this thesis are shortly summarized as:

- Approach 2 in Eurocode gives a more realistic temperature profile than approach 1.
- Using approach 2 will give a lower demand of reinforcement than approach 1.
- Thermal effects from temperature difference could in portal frame bridges alone account for 20% of the reinforcement at midspan.
- The non-linear temperature distribution could cause problems with cracks close to the surface.
- If approach 2 is used, additional analysis regarding crack width limitations in serviceability limit state might be necessary, two suggestions how to do this are presented in the report.

Section moments from approach 1 (A), approach 2 (B) and without temperature difference load (C) is presented in table 1.

	A	B	C
ULS	1402 kNm	1337 kNm	1268 kNm
SLS	564 kNm	527 kNm	489 kNm

Table 1: Section moment at midspan with different temperature difference modeling