Section 34

Eurocode 1
EN 1991-1-5
Section 6

34.1 Temperature changes in bridges

34.1.1 Bridge decks

Three types of bridge superstructures are distinguished in EN 1991-1-5. For the purposes of this Part, bridge decks are grouped as follow:

- Type 1. Steel deck:
    - steel box girder
    - steel truss or plate girder
- Type 2. Composite deck
- Type 3. Concrete deck:
    - concrete slab
    - concrete beam
    - concrete box girder.

THERMAL ACTIONS Representative values of thermal actions should be assessed by the uniform temperature component (see EN 1991-1-5, Sec. 6.1.3) and the temperature difference components (see EN 1991-1-5, Sec. 6.1.4).

The vertical temperature difference component should generally include the non-linear component. Either Approach 1 or Approach 2 should be used.

34.1.2 Thermal actions

UNIFORM TEMPERATURE COMPONENT The uniform temperature component depends on the minimum and maximum temperature which a bridge will achieve. This results in a range of uniform temperature changes which, in an unrestrained structure would result in a change in element length.

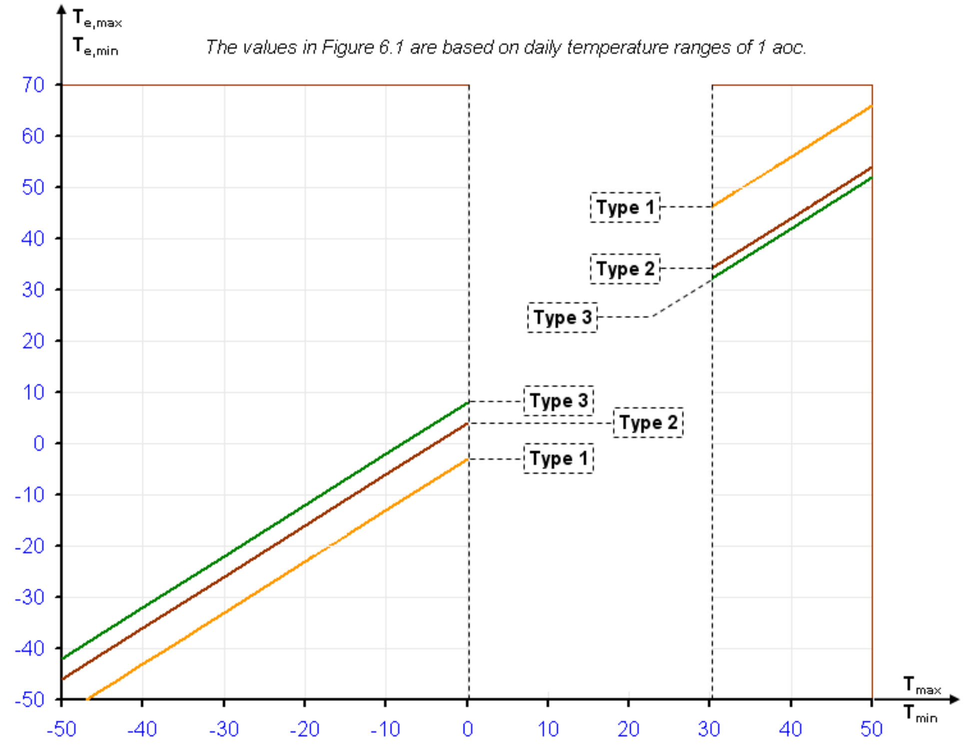


Figure 34.18 From Figure 6.1 - Correlation between minimum (maximum) shade air temperature T_{min} (T_{max}) and minimum (maximum) uniform bridge temperature component $T_{e,min}$ ($T_{e,max}$).

The minimum and maximum uniform (effective) bridge temperatures $T_{e,min}$ ($T_{e,max}$) can be determined from the relationship given in Fig. 6.1 on the basis of isotherms of shade air temperatures T_{min} (T_{max}). The characteristic values of minimum and maximum shade air temperatures for a site location may be obtained e.g. from national maps of isotherms. These characteristic values represent shade air temperatures at mean sea level in open country being exceeded by annual extremes with the probability of 0,02. The relationship given in Fig. 6.1 is based on a daily temperature range of 10°C. Such a range may be considered as appropriate for most Member States. The maximum uniform temperature component $T_{e,max}$ and the minimum uniform temperature component $T_{e,min}$ for the three types of bridge decks may be determined from the following relationships based on Figure 6.1:

$$\begin{cases} T_{e,\,max} = T_{max} + 16°C \\ T_{e,\,max} = T_{max} + 4°C \quad \text{for } 30°C \le T_{max} \le 50°C\,. \\ T_{e,\,max} = T_{max} + 2°C \end{cases} \tag{Eq. 34-30}$$

$$\begin{cases} T_{e,\,min} = T_{min} - 3°C \\ T_{e,\,min} = T_{min} + 4°C \quad \text{for } -50°C \le T_{max} \le 0°C\,. \\ T_{e,\,min} = T_{min} + 8°C \end{cases} \tag{Eq. 34-31}$$

For steel truss and plate girders the maximum values given for Type 1 may be reduced by 3°C.

For construction works located in specific climatic regions as in e.g. frost pockets, additional information should be obtained and evaluated.

Minimum shade air temperature (T_{min}) and maximum shade air temperature (T_{max}) for the site shall be derived from isotherms in accordance with 6.1.3.2. The National Annex may specify $T_{e,min}$ and $T_{e,max}$. Figure 6.1 below gives recommended values.

SHADE AIR TEMPERATURE Characteristic values of minimum and maximum shade air temperatures for the site location shall be obtained, e.g. from national maps of isotherms. Information (e.g. maps of isotherms) on minimum and maximum shade air temperatures to be used in a Country may be found in its National Annex. Where an annual probability of being exceeded of 0,02 is deemed inappropriate, the minimum shade air temperatures and the maximum shade air temperatures should be modified in accordance with annex A.

RANGE OF UNIFORM BRIDGE TEMPERATURE COMPONENT The values of minimum and maximum uniform bridge temperature components for restraining forces shall be derived from the minimum (T_{min}) and maximum (T_{max}) shade air temperatures (see 6.1.3.1 (3) and 6.1.3.1 (4)). The initial bridge temperature T_0 at the time that the structure is restrained may be taken from annex A for calculating contraction down to the minimum uniform bridge temperature component and expansion up to the maximum uniform bridge temperature component. Thus the characteristic value of the maximum contraction range of the uniform bridge temperature component, $\Delta T_{N,\,con}$ should be taken as:

$$\Delta T_{N,\,con} = T_0 - T_{e,\,min} \qquad \textbf{(Eq. 34-32)}$$

and the characteristic value of the maximum expansion range of the uniform bridge temperature component, $\Delta T_{N,\,exp}$ should be taken as:

$$\Delta T_{N,\,exp} = T_{e,\,max} - T_0\,. \qquad \textbf{(Eq. 34-33)}$$

34.2 Temperature difference components

34.2.1 Vertical linear component (Approach 1)

For the vertical temperature difference component, two alternative approaches are provided in EN 1991-1-5 which may be nationally selected: (1) linear, or (2) non linear temperature distribution.

The models applied in the linear approach are given in Table 6.1 ("*Recommended values of linear temperature difference component for different type of bridge decks for road, foot and railway bridges*") for bridges based on a depth of surfacing of 50 mm. For other surfacing thicknesses, the coefficient k_{sur} should be applied (see Table 6.2 - “*Recommended values of ksur to account for different surfacing thickness*”).

Type of Deck[a]	Top warmer then bottom $\Delta T_{M,heat}$ [°C]	Bottom warmer than top $\Delta T_{M,cool}$ [°C]
Type 1. Steel deck	18	13
Type 2. Composite deck	15	18
Type 3. Concrete deck:		
- concrete box girder	10	5
- concrete beam	15	8
- concrete slab	15	8

Table 34.9 From Table 6.1 - Recommended values of linear temperature difference component for different type of bridge decks for road, foot and railway bridges.

(a). The values given in the table represent upper bound values of the linearly varying temperature difference component for representative sample of bridge geometries. The values given in the table are based on a depth of surfacing of 50 mm for road and railway bridges. For other depths of surfacing these values should be multiplied by the factor ksur. Recommended values for the factor ksur is given in Table 6.2.

Road, foot and railway bridges						
	Type 1		Type 2		Type 3	
Surface Thickness	Top warmer then bottom	Bottom warmer then top	Top warmer then bottom	Bottom warmer then top	Top warmer then bottom	Bottom warmer then top
[mm]	k_{sur}	k_{sur}	k_{sur}	k_{sur}	k_{sur}	k_{sur}
unsurfaced	0,7	0,9	0,9	1,0	0,8	1,1
water-proofed[a]	1,6	0,6	1,1	0,9	1,5	1,0
50	1,0	1,0	1,0	1,0	1,0	1,0
100	0,7	1,2	1,0	1,0	0,7	1,0
150	0,7	1,2	1,0	1,0	0,5	1,0
ballast (750 mm)	0,6	1,4	0,8	1,2	0,6	1,0

Table 34.10 From Table 6.2 - Recommended values of k_{sur} to account for different surfacing thickness.

(a). These values represent upper bound values for dark colour.

34.2.2 Vertical temperature components with non-linear effects (Approach 2)

Values of vertical temperature differences for bridge decks to be used in a Country may be found in its National Annex.

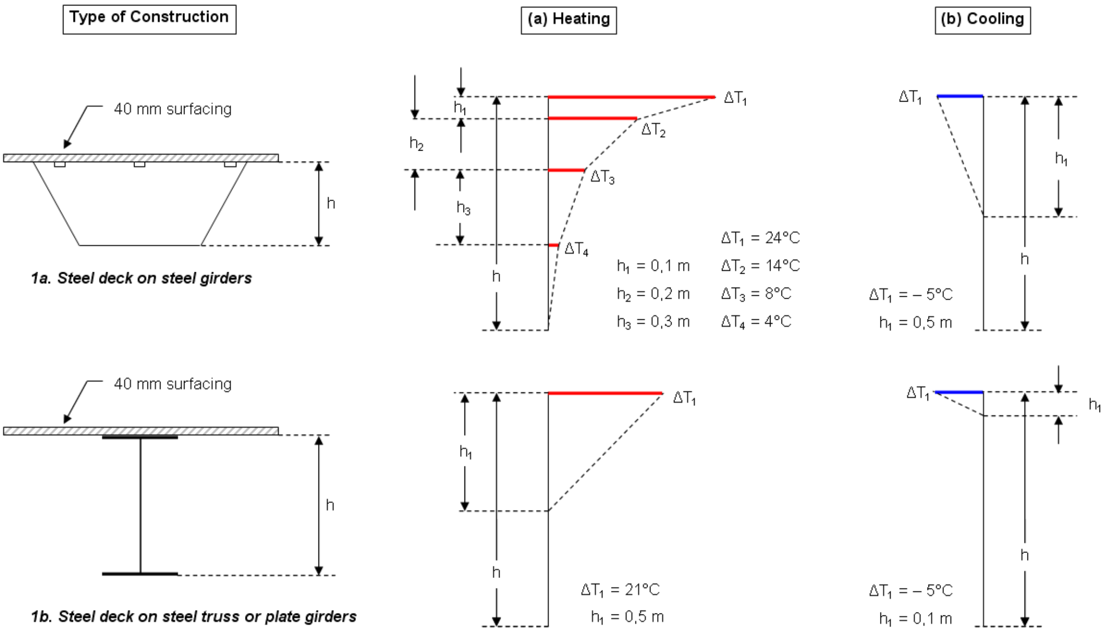


Figure 34.20 From Figure 6.2a - Temperature differences for bridge decks - Type 1: Steel Decks.

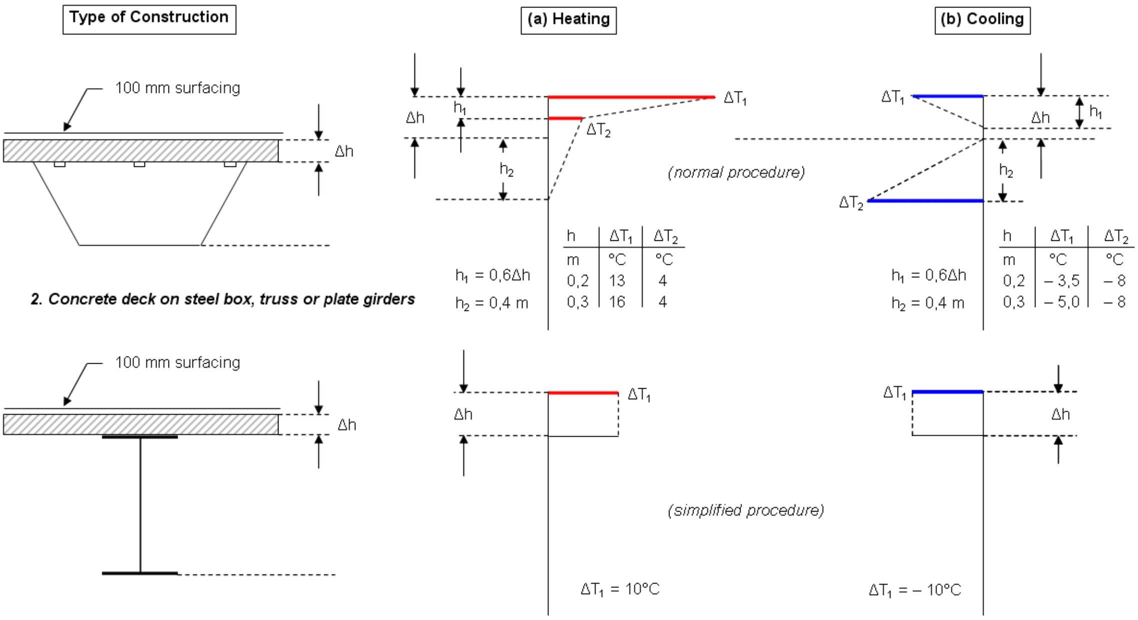
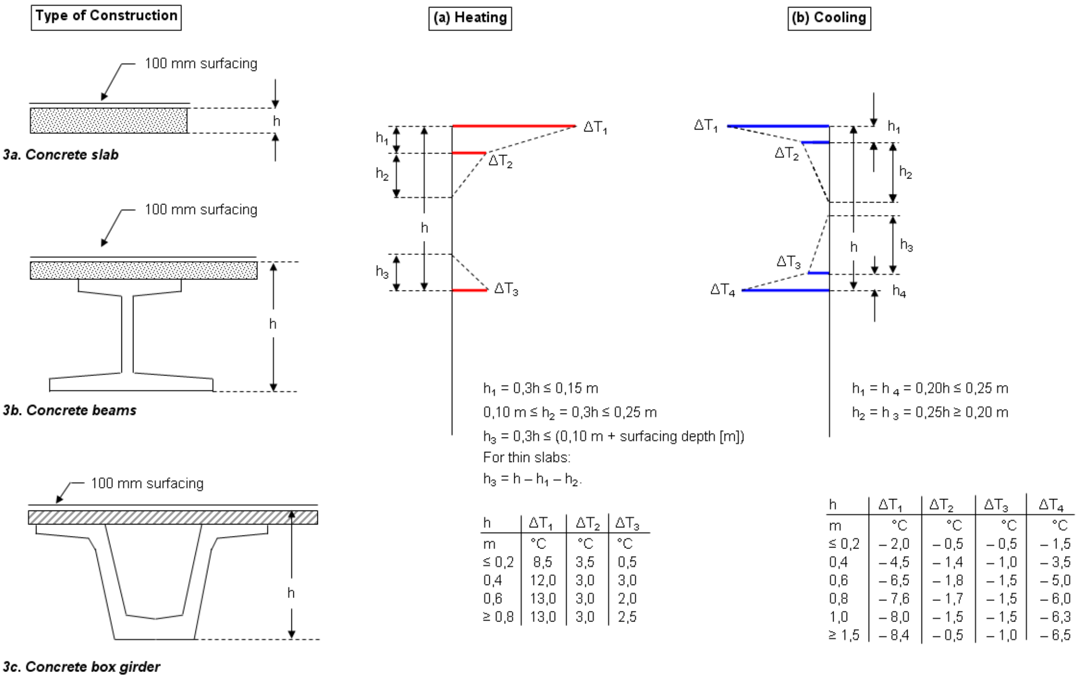


Figure 34.19 From Figure 6.2b - Temperature differences for bridge decks - Type 2: Composite Decks.



$h_1 = 0{,}3h \le 0{,}15$ m

$0{,}10 \text{ m} \le h_2 = 0{,}3h \le 0{,}25$ m

$h_3 = 0{,}3h \le (0{,}10 \text{ m} + \text{surfacing depth [m]})$

For thin slabs:

$h_3 = h - h_1 - h_2$.

h	ΔT_1	ΔT_2	ΔT_3
m	°C	°C	°C
≤ 0,2	8,5	3,5	0,5
0,4	12,0	3,0	3,0
0,6	13,0	3,0	2,0
≥ 0,8	13,0	3,0	2,5

$h_1 = h_4 = 0{,}20h \le 0{,}25$ m

$h_2 = h_3 = 0{,}25h \ge 0{,}20$ m

h	ΔT_1	ΔT_2	ΔT_3	ΔT_4
m	°C	°C	°C	°C
≤ 0,2	– 2,0	– 0,5	– 0,5	– 1,5
0,4	– 4,5	– 1,4	– 1,0	– 3,5
0,6	– 6,5	– 1,8	– 1,5	– 5,0
0,8	– 7,6	– 1,7	– 1,5	– 6,0
1,0	– 8,0	– 1,5	– 1,5	– 6,3
≥ 1,5	– 8,4	– 0,5	– 1,0	– 6,5

Figure 34.21 From Figure 6.2c - Temperature differences for bridge decks - Type 3: Concrete Decks.

Recommended values are given in Figures 6.2a/6.2b/6.2c and are valid for 40 mm surfacing depths for deck type 1 and 100 mm for deck types 2 and 3. For other depths of surfacing see Annex B. In these figures “heating” refers to conditions such that solar radiation and other effects cause a gain in heat through the top surface of the bridge deck. Conversely, “cooling” refers to conditions such that heat is lost from the top surface of the bridge deck as a result of re-radiation and other effects.

34.2.3 Simultaneity of uniform and temperature difference components

In some cases, it may be necessary to take into account both the temperature difference $\Delta T_{M,\text{heat}}$ (or $\Delta T_{M,\text{cool}}$) and the maximum range of uniform bridge temperature component $\Delta T_{N,\text{exp}}$ (or $\Delta T_{N,\text{con}}$) given as:

$$\begin{cases} \Delta T_{M,\text{heat}} + \omega_N \cdot \Delta T_{N,\text{exp}} \\ \Delta T_{M,\text{cool}} + \omega_N \cdot \Delta T_{N,\text{con}} \end{cases} \qquad \textbf{(Eq. 34-34)}$$

$$\begin{cases} \omega_M \cdot \Delta T_{M,\text{heat}} + \Delta T_{N,\text{exp}} \\ \omega_M \cdot \Delta T_{M,\text{cool}} + \Delta T_{N,\text{con}} \end{cases} \qquad \textbf{(Eq. 34-35)}$$

where the most adverse effect should be chosen. The National annex may specify numerical values of ω_N and ω_M. If no other information is available, the recommended values (reduction factors) for ω_N and ω_M are: $\omega_N = 0,35$, $\omega_M = 0,35$.

Where both linear and non-linear vertical temperature differences are used (see 6.1.4.2) ΔT_M should be replaced by ΔT which includes ΔT_M and ΔT_E (see Figures 6.2a/6.2b and 6.2c), where:

- ΔT_M linear temperature difference component
- ΔT_E non-linear part of the difference component
- ΔT sum of linear temperature difference component and non-linear part of the temperature difference component.

34.2.4 Bridge Piers: temperature differences

For concrete piers (hollow or solid), the linear temperature differences between opposite outer faces should be taken into account. The National annex may specify values for linear temperature differences. In the absence of detailed information the recommended value is 5°C.

For walls the linear temperature differences between the inner and outer faces should be taken into account. The National annex may specify values for linear temperature differences. In the absence of detailed information the recommended value is 15°C.

34.3 Verification tests

EN1991-1-5_(A)_2.XLS. 8.31 MB. Created: 20 November 2013. Last/Rel.-date: 20 November 2013. Sheets:

— Splash

— CodeSec6.

EXAMPLE 34-Q- Characteristic thermal actions in bridges - Consideration of thermal actions - **test1**

Given: Determine the maximum uniform temperature component $T_{e,\,max}$ and the minimum uniform temperature component $T_{e,\,min}$ for the three types of bridge decks determined from the relationships based on Figure 6.1. Let us assume that the characteristic values of minimum T_{min} and maximum T_{max} shade air temperatures for a site location (say the city of Birmingham) was obtained e.g. from the UK national maps of isotherms. These characteristic values represent shade air temperatures at mean sea level in open country being exceeded by annual extremes with the probability of 0,02.

[*Reference sheet:* CodeSec6]-[*Cell-Range: A1:O1-A86:O86*].

Solution: From the UK isotherms maps (see "*Manual for the design of building structures to Eurocode 1 and Basis of Structural Design*" - The Institution of Structural Engineers Manual for the design of building structures to Eurocode 1. April 2010), we have (near Birmingham):

$$T_{max} = 34°C \text{ (rounded value for probability } p = 0{,}02)$$

$$T_{min} = -18°C \text{ (rounded value for probability } p = 0{,}02).$$

Therefore, we get:

$$\begin{cases} T_{e,\,max} = T_{max} + 16°C = (34 + 16) = 50°C \\ T_{e,\,max} = T_{max} + 4°C = (34 + 4) = 38°C \quad \text{for } 30°C \le T_{max} \le 50°C\,. \\ T_{e,\,max} = T_{max} + 2°C = (34 + 2) = 36°C \end{cases}$$

$$\begin{cases} T_{e,\,min} = T_{min} - 3°C = (-18 - 3) = -21°C \\ T_{e,\,min} = T_{min} + 4°C = (-18 + 4) = -14°C \quad \text{for } -50°C \le T_{max} \le 0°C\,. \\ T_{e,\,min} = T_{min} + 8°C = (-18 + 8) = -10°C \end{cases}$$

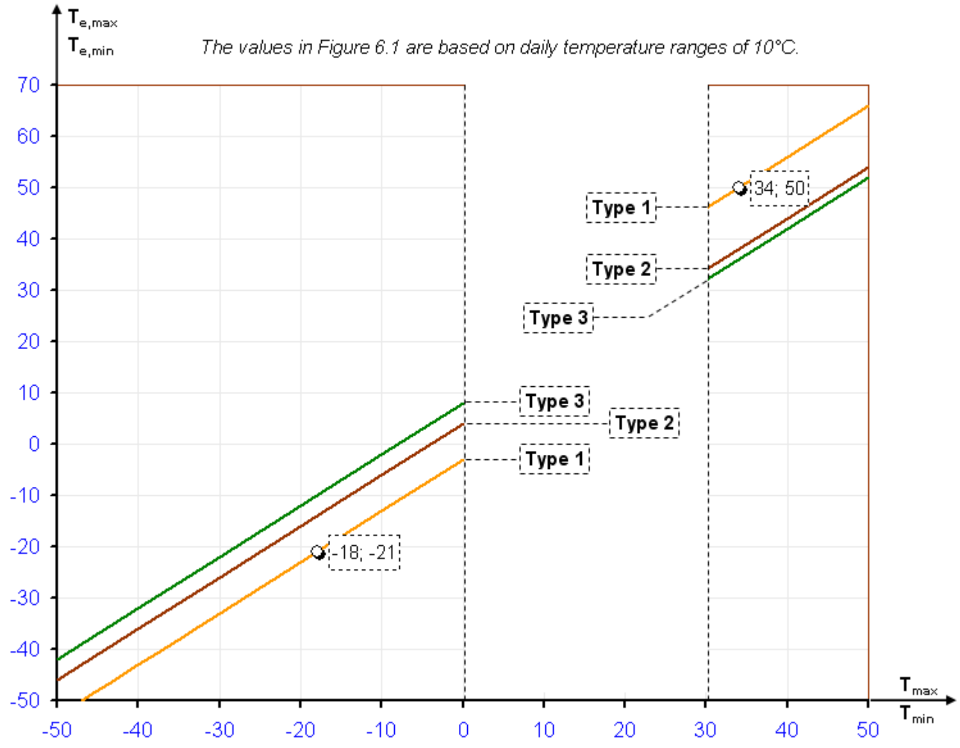


Figure 34.22 Excel® output graph (for Bridge deck Type 1).

The algorithm to draw the graph above is the same. We omit the other two cases (Type 2 and Type 3).

➡ *example-end*

EXAMPLE 34-R- Characteristic thermal actions in bridges - Uniform temperature component - **test2**

Given: Assuming the same assumptions from the previous example, find the maximum $T_{ed,\,max}$ and minimum $T_{ed,\,min}$ constant temperature component for the design of bridge bearings (linear behaviour) and expansion joints. Let us assume an initial bridge temperature $T_0 = 10°C$ at the time that the structure is restrained (see NOTE in Annex A - Sec. A.1(3)). To take into account the uncertainty of the position of the bearings at the reference temperature (see EN 1993-2, Annex A "*Technical specifications for bearings*", Table A.4 "*Numerical values for* ΔT_0") let us assume a safety term equal to $\Delta T_0 = 10°C$.

[*Reference sheet:* CodeSec6]-[*Cell-Range: A90:O90-A169:O169*].

Solution: **Note.** In the following the main contents of a future Annex E to EN 1990, that would substitute the now Annex A to EN 1993-2 is presented.

From Expressions (6.1) and (6.2) we get the characteristic value of the maximum contraction and maximum expansion value of the uniform bridge temperature component respectively (bridge deck Type 1):

$$\Delta T_{N,\,con} = T_0 - T_{e,\,min} = [10 - (-21)] = 31°C$$

$$\Delta T_{N,\,exp} = T_{e,\,max} - T_0 = [50 - 10] = 40°C .$$

Note For bearings and expansion joints the National Annex may specify the maximum expansion range of the uniform bridge temperature component, and the maximum contraction range of the uniform bridge temperature component, if no other provisions are required. The recommended values are ($\Delta T_{N,exp}$ + 20) °C and ($\Delta T_{N,con}$ + 20)C°, respectively. If the temperature at which the bearings and expansion joints, are set is specified, then the recommended values are ($\Delta T_{N,exp}$ + 10)°C and ($\Delta T_{N,con}$ + 10) °C, respectively.

Hence let us assume (say):

$$\Delta T_{N,\,con} = (31 + 10) = 41°C$$

$$\Delta T_{N,\,exp} = (40 + 10) = 50°C .$$

Design values of the temperature difference (see technical publication: "*Bridge Design to Eurocodes Worked examples*". Worked examples presented at the Workshop "*Bridge Design to Eurocodes*", Vienna, 4-6 October 2010. Support to the implementation, harmonization and further development of the Eurocodes. Appendix A: Design of steel bridges. Overview of key content of EN 1993 – G. Hanswille, W. Hansen, M. Feldmann, G. Sedlacek):

$$T_{ed,\,max} = T_0 + \gamma_F \cdot \Delta T_{N,\,exp} + \Delta T_0 = [10 + 1{,}35 \cdot (50) + 10] = 87{,}5°C$$

$$T_{ed,\,min} = T_0 - \gamma_F \cdot \Delta T_{N,\,con} - \Delta T_0 = [10 - 1{,}35 \cdot (51) - 10] = 55{,}4°C .$$

Bearing with linear behaviour (overall design temperature range):

$$\Delta T_d = T_{ed,\,max} - T_{ed,\,min} = [101 - (-68{,}9)] = 142{,}9°C .$$

➨ *example-end*

EXAMPLE 34-S- Characteristic thermal actions in bridges - Temperature difference components - **test3**

Given: Assuming the same assumptions form the previous examples, find the vertical linear temperature component (Approach 1) for a bridge deck Type 1 with a surface thickness equal to 100 mm.

[*Reference sheet:* CodeSec6]-[*Cell-Range: A173:O173-A238:O238*].

Solution: Entering Table 6.1 - “*Recommended values of linear temperature difference component for different types of bridge decks for road, foot and railway bridges*” with steel deck Type 1 we get (for $k_{sur} = 1$):

– linear temperature difference component (heating): $\Delta T_{M,\,heat} = 18°C$;

– linear temperature difference component (cooling): $\Delta T_{M,\,cool} = 13°C$.

The values given above represent upper bound values of the linearly varying temperature difference component for representative sample of bridge geometries. The values given in Table 6.1 are based on a depth of surfacing of 50 mm for road and railway bridges.

For other depths of surfacing these values should be multiplied by the factor k_{sur}. Recommended values for the factor k_{sur} are given in Table 6.2. For surface thickness equal to 100 mm and for bridge deck Type 1 we have:

$$k_{sur} = \begin{cases} 0,7 \ \textit{(top warmer than bottom)} \\ 1,2 \ \textit{(bottom warmer then top).} \end{cases}$$

Hence we get (for surface thickness equal to 100 mm):

$$\Delta T_{M,\,heat} = k_{sur} \cdot (18°C) = 0,7 \cdot (18) = 12,6°C$$

$$\Delta T_{M,\,cool} = k_{sur} \cdot (13°C) = 1,2 \cdot (13) = 15,6°C\,.$$

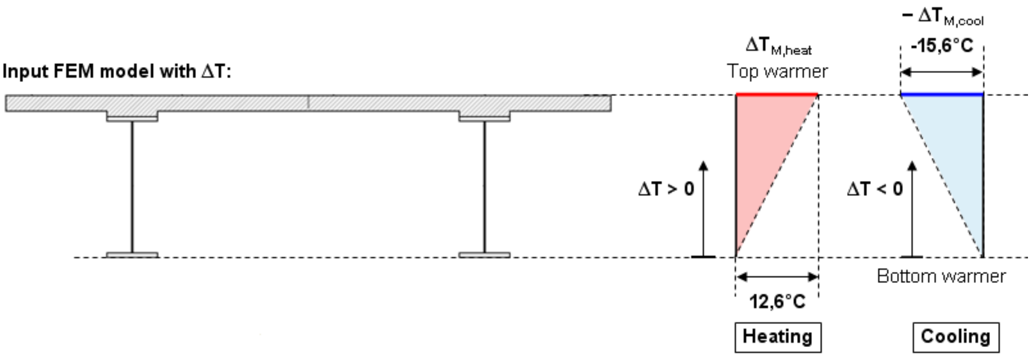


Figure 34.23 Excel® output graph (for Bridge deck Type 1): characteristic values.

EXAMPLE 34-T- Characteristic thermal actions in bridges - Vertical temperature (Approach 2) - **test3b**

Given: Let us consider a bridge deck Type 3 (prestressed precast concrete beam bridge). The height of the precast beam is 36 in = 0.91 m (rounded value). The thickness of the reinforced concrete bridge deck is 25 cm.

Assuming a surfacing depth equal to 100 mm find the temperature difference for heating and cooling (see Figure 6.2c).

[*Reference sheet:* CodeSec6]-[*Cell-Range: A242:O242-A365:O365*].

Solution: Entering Table 6.2c with $h = (0,91 + 0,25) = 1,16\ \text{m}$ we get:

(a) Heating

$$h_1 = 0,3 \cdot h = 0,3 \cdot (1,16) = 0,35\ \text{m} \le 0,15\ \text{m} \quad \to \quad h_1 = 0,15\ \text{m}$$

$$h_2 = 0,3 \cdot h = 0,3 \cdot (1,16) = 0,35\ \text{m}\ \text{with}\ 0,10\ \text{m} \le h_2 \le 0,25\ \text{m} \quad \to \quad h_2 = 0,25\ \text{m}$$

$$h_2 = 0,3 \cdot h = 0,3 \cdot (1,16) = 0,35\ \text{m} \le (0,10\ \text{m} + \textit{surfacing depth in metres}) = 0,20\ \text{m}.$$

For $h \ge 0,8\ \text{m}$ we have $\Delta T_1 = 13,0°\text{C}$; $\Delta T_2 = 3,0°\text{C}$; $\Delta T_3 = 2,5°\text{C}$.

(b) Cooling

$$h_1 = h_4 = 0,20 \cdot h = 0,20 \cdot (1,16) = 0,23\ \text{m} \le 0,25\ \text{m} \quad \to \quad h_1 = h_4 = 0,23\ \text{m}$$

$$h_2 = h_3 = 0,20 \cdot h = 0,25 \cdot (1,16) = 0,29\ \text{m} \le 0,20\ \text{m} \quad \to \quad h_2 = h_3 = 0,29\ \text{m}.$$

Linear interpolation for ΔT_j within the range $1,0\ \text{m} < h < 1,5\ \text{m}$ with $h = 1,16\ \text{m}$:

h [m]	ΔT_1 [°C]	ΔT_2 [°C]	ΔT_3 [°C]	ΔT_4 [°C]
1,0	– 8,0	– 1,5	– 1,5	– 6,3
1,16	ΔT_1	ΔT_2	ΔT_3	ΔT_4
1,5	– 8,4	– 0,5	– 1,0	– 6,5

Table 34.11 Values from Figure 6.2c - Temperature differences for bridge decks - Type 3: Concrete decks.

$$\frac{(-8,4)-(-8,0)}{1,5-1,0} = \frac{\Delta T_1 - (-8,0)}{1,16-1,0} \quad \to \quad \Delta T_1 = -8,13°\text{C}$$

$$\frac{(-0,5)-(-1,5)}{1,5-1,0} = \frac{\Delta T_2 - (-1,5)}{1,16-1,0} \quad \to \quad \Delta T_2 = -1,18°\text{C}$$

$$\frac{(-1,0)-(-1,5)}{1,5-1,0} = \frac{\Delta T_3 - (-1,5)}{1,16-1,0} \quad \to \quad \Delta T_3 = -1,34°\text{C}$$

$$\frac{(-6,5)-(-6,3)}{1,5-1,0} = \frac{\Delta T_4 - (-6,3)}{1,16-1,0} \quad \to \quad \Delta T_4 = -6,36°\text{C}.$$

Rounded to the first decimal place we get:

$\Delta T_1 = -8,1°\text{C}$; $\Delta T_2 = -1,2°\text{C}$; $\Delta T_3 = -1,3°\text{C}$; $\Delta T_4 = -6,4°\text{C}$.

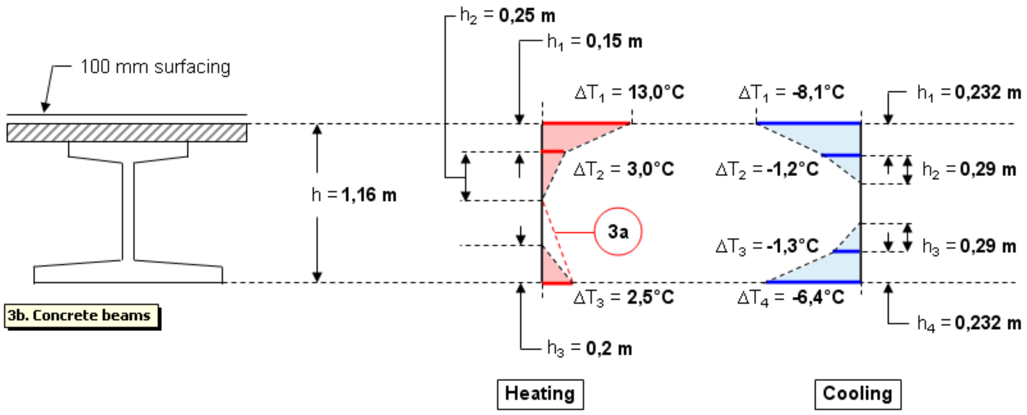


Figure 34.24 Excel® output graph (for Bridge deck Type 3c): characteristic values.

EXAMPLE 34-U- Characteristic thermal actions in bridges - Simultaneity of uniform and temperature difference components - **test4**

Given: Taking into account both the temperature difference $\Delta T_{M,\,heat}$ (or $\Delta T_{M,\,cool}$) and the maximum range of uniform bridge temperature component $\Delta T_{N,\,exp}$ (or $\Delta T_{N,\,con}$) assuming simultaneity, find the most adverse effect to be chosen as input in the FEM analysis. Refer to the data in Example 34-S (bridge deck Type 1 with $T_{e,\,min} = -21°C$, $T_{e,\,max} = 50°C$).

[*Reference sheet:* CodeSec6]-[*Cell-Range: A415:O415-A509:O509*].

Solution: From Expressions (6.1) and (6.2) we get the characteristic value of the maximum contraction and maximum expansion value of the uniform bridge temperature component respectively (bridge deck Type 1):

$$\Delta T_{N,\,con} = T_0 - T_{e,\,min} = [10-(-21)] = 31°C$$

$$\Delta T_{N,\,exp} = T_{e,\,max} - T_0 = [50-10] = 40°C\,.$$

From data in Example 34-S we have:

$$\Delta T_{M,\,heat} = 12,6°C \text{ (expansion);}$$

$$\Delta T_{M,\,cool} = 15,6°C \text{ (contraction).}$$

From Expressions (6.3) and (6.4), using the given numerical data, we get respectively:

$$\begin{array}{ll}\text{Load} - \textit{Case 6.3-a:} & \left\{\begin{array}{l}\Delta T_{M,\,heat} + \omega_N \cdot \Delta T_{N,\,exp} = 12,6 + 0,35 \cdot (40) = (12,6+14)°C \\ \Delta T_{M,\,cool} + \omega_N \cdot \Delta T_{N,\,con} = -15,6 + 0,35 \cdot (-31) = -(15,6+10,9)°C\end{array}\right. \\ \text{Load} - \textit{Case 6.3-b:} & \end{array}$$

$$\begin{array}{ll}\text{Load} - \textit{Case 6.4-a:} & \left\{\begin{array}{l}\omega_M \cdot \Delta T_{M,\,heat} + \Delta T_{N,\,exp} = 0,75 \cdot (12,6) + 40 = (9,45+40)°C \\ \omega_M \cdot \Delta T_{M,\,cool} + \Delta T_{N,\,con} = 0,75 \cdot (-15,6) + (-31) = (-11,7-31)°C\end{array}\right. \\ \text{Load} - \textit{Case 6.4-b:} & \end{array}$$

having assumed $\omega_N = 0,35$, $\omega_M = 0,75$ for the reduction factors.

Having thus considered four different combinations of load (Case 6.3-a; Case 6.3-b; Case 6.4-a; Case 6.4-b), we have (see Figure above):

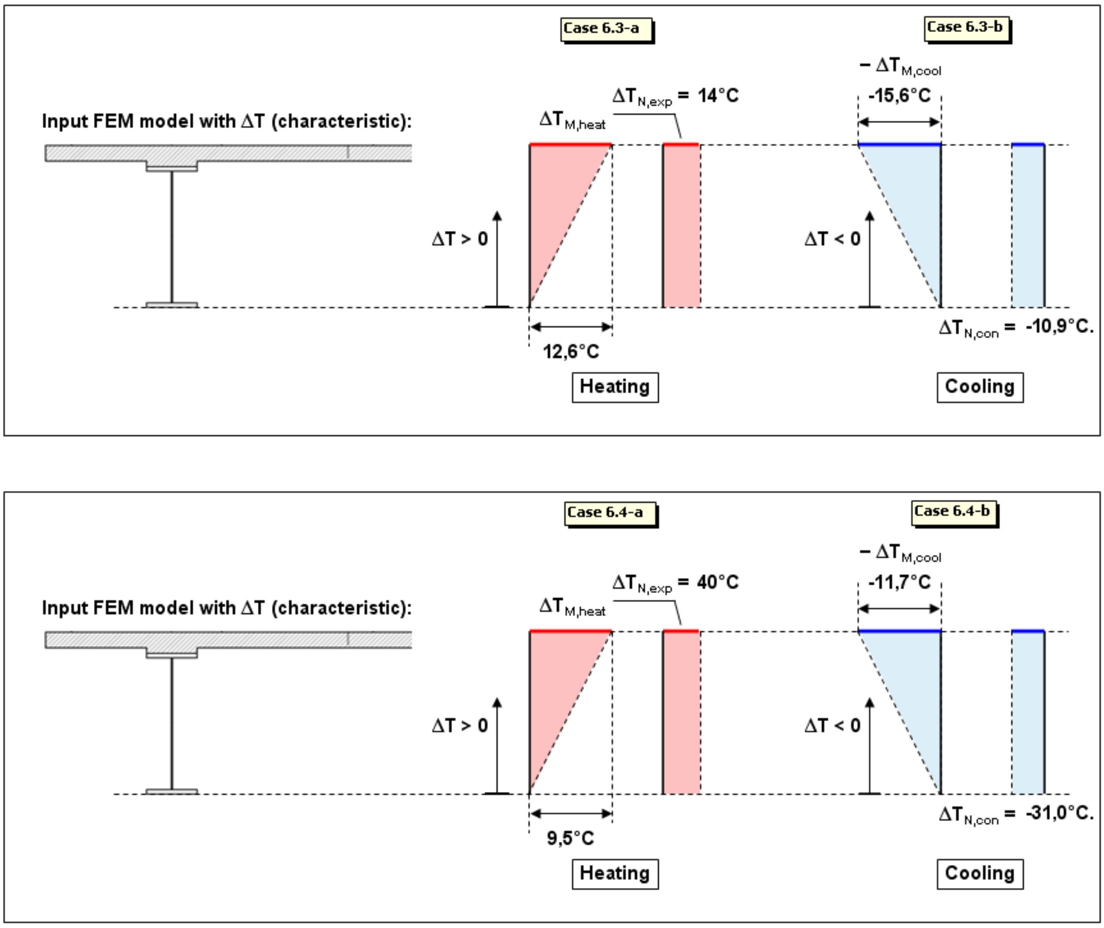


Figure 34.25 Excel® output graph (for Bridge deck Type 1): characteristic values.

34.4 References [Section 34]

EN 1991-1-5:2003. Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions. Brussels: CEN/TC 250 - Structural Eurocodes, November 2003 (DAV)

EN 1991-1-5:2003/AC:2009. Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions. Brussels: CEN/TC 250 - Structural Eurocodes, March 2009

Manual for the design of building structures to Eurocode 1 and Basis of Structural Design April 2010. © 2010 The Institution of Structural Engineers

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