Climatology of Road-Surface Temperatures for Different Site Characteristics

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Paper to be presented at the
Standing International Road Weather Conference
Lulea, Sweden, March 16-17, 1998

Abstract

Presently the Deutscher Wetterdienst (DWD) issues detailed areas forecasts of road conditions and road-surface temperatures as a part of the German road weather information system, called SWIS (Straßenzustands- und Wetterinformationssystem). In order to produce these forecasts an energy balance model is used, which is able to take into account five different site characteristics. However, up to now there exists no further distinction between the different types of bridge construction nor due to the varying topography. Based upon a climatology the behaviour of the site characteristics will be discussed. During dull or foggy weather 'bridges' exhibits road-surface temperature (TS)-values, which are about 1 K lower than 'regular traffic' and 'shaded areas'. During clear sky conditions and during the night 'bridges' shows TS-values, which are 2 K lower than in the case of 'regular traffic'. During the whole day the TS-values are 1 to 2 K lower than the air temperatures (TL) for 'shaded areas'. The site characteristics, which are defined by the topography show only a few significant differences both during dull or foggy weather and during clear sky conditions. For the different types of bridge construction during clear sky conditions and during the first half of the night some significant differences can be found. For all site characteristics similar reactions of TS to a sudden change of TL can be observed.

1. Introduction

Presently the Deutscher Wetterdienst (DWD) issues detailed areas forecasts of road conditions and of road-surface temperatures (TS) as a part of the German road weather information system, called SWIS (Straßenzustands- und Wetterinformationssystem). In order to produce these forecasts an energy balance model is used, which is able to take into account the five different site characteristics 'regular traffic', 'little traffic', 'urban influences', 'shaded areas' and 'bridges' (Jacobs and Raatz, 1996). However, up to now there exists no further distinction between different types of bridge construction nor due to the varying topography.

2. Procedure

Based upon a climatology the behaviour of the three site characteristics 'regular traffic', 'shaded areas' and 'bridges' will be discussed first. For the present study about 60 road weather monitoring stations, which are situated along German motorways, could be categorized into these three different site characteristics. In addition, a first attempt is tried, if it would be useful to distinguish additional site characteristics, which are caused by the different types of bridge construction or by the varying topography. The types of bridge construction considered are 'steel plate', 'hollow body', steel construction' and 'concrete construction'. The different types due to the topography are 'plain', 'forest', 'cutting' and 'crest'. Using the Stundent t-test it will be checked, if the behaviour of these site characteristics shows significant differences from each other.

In order to eliminate the local influences on the road-surface temperature, which are not due to the different site characteristics (e.g. the influence of the altitude), only the differences (TL-TS) between the air temperature (TL) and the road-surface temperature (TS) are considered. To obtain results, which are typical for each site characteristic (and not determined by the individual pecularities of the measuring site), averages of (TL-TS) are calculated based upon road weather monitoring sites belonging to the same category of site characteristic.

In addition, particular synoptic situations are considered, in which there are only small differences in cloudiness over a relative large areas in order to ensure that differences observed are caused by the different site characteristics only, and not by different radiation regimes. Two time periods, which meet that criterium, are chosen: 16 January to 21 January 1996 (dull or foggy) and 14 February to 18 February 1994 (clear sky conditions).

A third time period (21 December to 25 December 1995) is selected to investigate the reaction of the road-surface temperature to a sudden change of the air temperature. During that time period a strong warm air advection occurred followed by a strong cold air advection. However, in this case it does not make sense to consider averages of several road weather monitoring stations, because the change of air temperature occurred at different locations at different times.

3. Results

During dull or foggy weather conditions and during the day the following differences can be observed: In the case of 'regular traffic' TS is about 3 to 4 Kelvin higher than TL (Fig. 1 and 2). Fig. 2 shows for 'bridges' that the values of TS are about 2 to 3 Kelvin higher than the values of TL. For all site characteristics it can be observed that during the night TS is by about 1 to 2 Kelvin higher than TL. Only in the special case, when there is little traffic (e.g. on weekends), 'bridges' tends to have values of TS, which are about 0.5 to 1 Kelvin lower than TL. In the case of 'regular traffic' the minimum- and maximum-values of TS and TL can be observed at similar times. For the site characteristic 'bridges' it can be found that the extreme values of TS occure by about 1 hour earlier than the extreme values of TL.

The results show that especially during clear sky conditions it is necessary to distinguish between the site characteristics 'regular traffic', 'bridges' and 'shaded areas'. Figure 3 and 4 show that during the day 'regular traffic' and 'bridges' show similar values of (TS-TS) of -4 to -6 Kelvin. During the night TS and TL does not differ much for the site characteristic 'regular traffic'. However, 'bridges' exhibits values of TS, which are by about 1 to 2 Kelvin lower than the values of TL. Considering 'regular traffic' the daily minimum- and maximum-values of TS occure about 1 hour earlier than the extremes of TL. In the case of 'bridges' the time lag of TL against TS is about 2 hour during the day and about 1 hour during the night. The site characteristic 'shaded areas' shows a totally different behaviour in comparison to 'regular traffic' and 'bridges'. (TL-TS) exhibits only a small diurnal cycle, but TS is usually lower than TL by about 1 to 2 Kelvin.

During the time period between 21 December and 25 December 1995 it can be observed that while TL was increasing the increase of TS was rather similar for every type of bridge construction (Fig. 5 and 6) and of varying topography. The increase of TS occures with no noticeable delay compared to the increase of TL. During the decrease of TL, however, a delay of TS can be observed, which amounts 0 to 2 hours for 'bridges' and 2 to 4 hours for 'regular traffic'. Only 'concrete construction' (Fig. 6) and 'hollow body' have a larger inertia than 'steel construction' (Fig. 5) and 'steel plate'.

The site characteristics, which are defined by the topography ('plain', 'forest', 'cutting' and 'crest') exhibit only a few significant differences (according to the Student t-test) between their mean values of (TL-TS) both during dull or foggy weather and during clear sky conditions.

However, for the different types of bridge construction significant differences can be observed during clear sky conditions and during the time period from the afternoon to midnight (Fig. 7). It can be seen that during the first half of the night the values of TS of 'steel construction' and 'steel plate' are relatively low in comparison to 'hollow body' and concrete construction'. In addition, there exists a tendency that 'hollow body' and 'concrete construction' have a larger inertia with respect to changes of the air temperature than 'steel construction' and 'steel plate'. However, the mean values of (TL-TS) of each type of bridge construction do not exceed 2 Kelvin.

4. Conclusions

From this study it may be concluded that it is useful to define in addition to the site characteristics 'regular traffic', 'little traffic', 'shaded areas', 'urban influences' and 'bridges' the site characteristics 'steel construction/steel plate' and 'concrete construction/hollow body'. However, it should be pointed out that the mean differences (TL-TS) between the "old" type 'bridges', which is currently used by the DWD, and the proposed new types 'steel construction/steel plate' and 'concrete construction/hollow body' do not exceed 1 Kelvin. It seems unlikely that this rather small difference can be worked out by the operational forecast.

The capability of forecasting road-surface temperature depends to a large extend on the capability of predicting correctly the synoptic input data for an energy balance model, e.g. cloudiness is difficult to predict. Thus, only improving the quality of the energy balance model by considering details, which improve the results by only 1 Kelvin at most, might not be relevant for routine purposes.

5. References

Jacobs, W. and Raatz, W. E. (1996). Forecasting road-surface temperature for different site characteristics. Meteorol. Appl. 3, 243-256

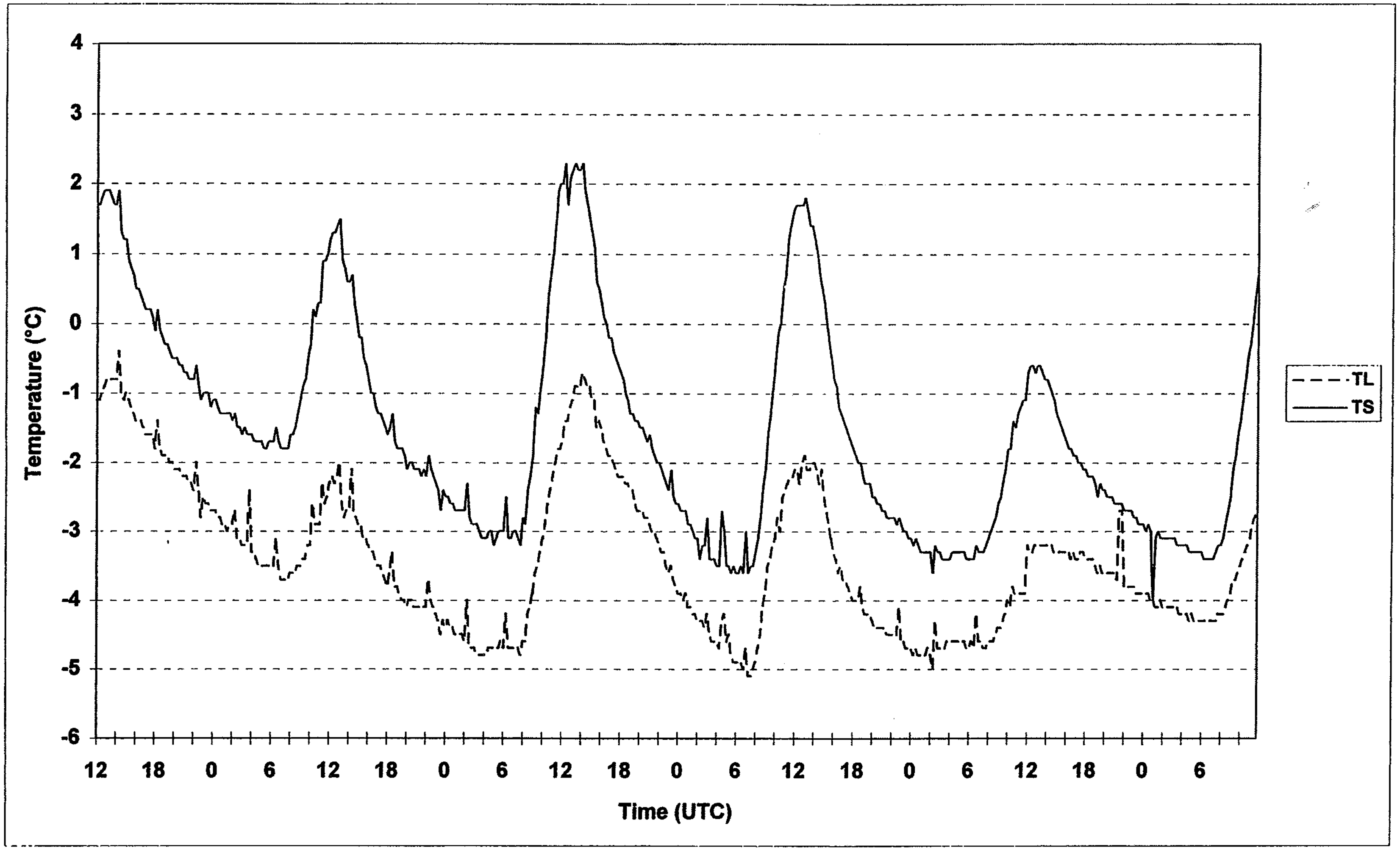

Fig. 1 Time series of mean values of the air temperature (TL) and the road-surface temperature (TS) for the site characteristic 'regular traffic' during the time period 16 January to 21 January 1996 (dull or foggy conditions)

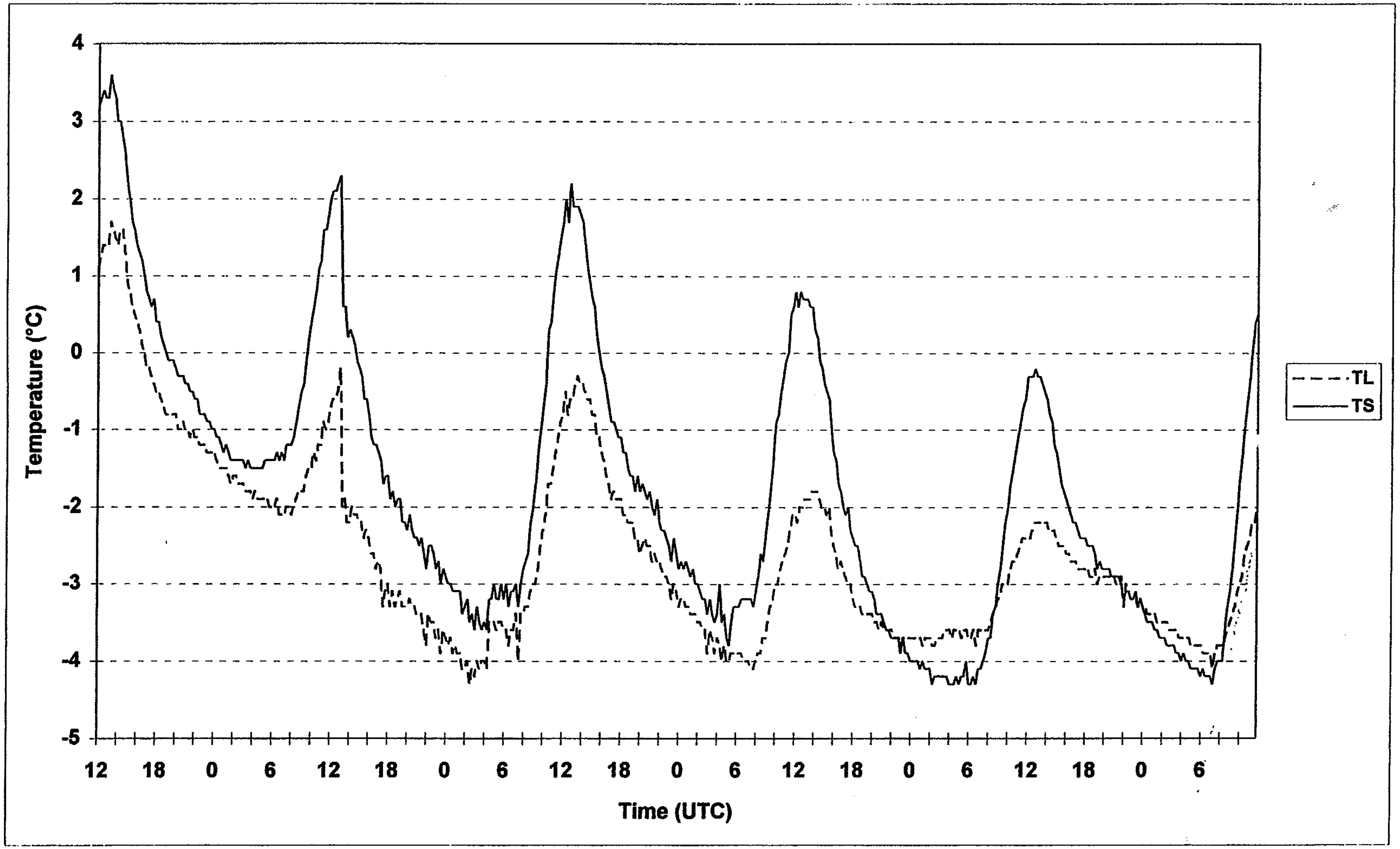

Fig. 2 Time series of mean values of the air temperature (TL) and the road-surface temperature (TS) for the site characteristic 'bridges' during the time period 16 January to 21 January 1996 (dull or foggy conditions)

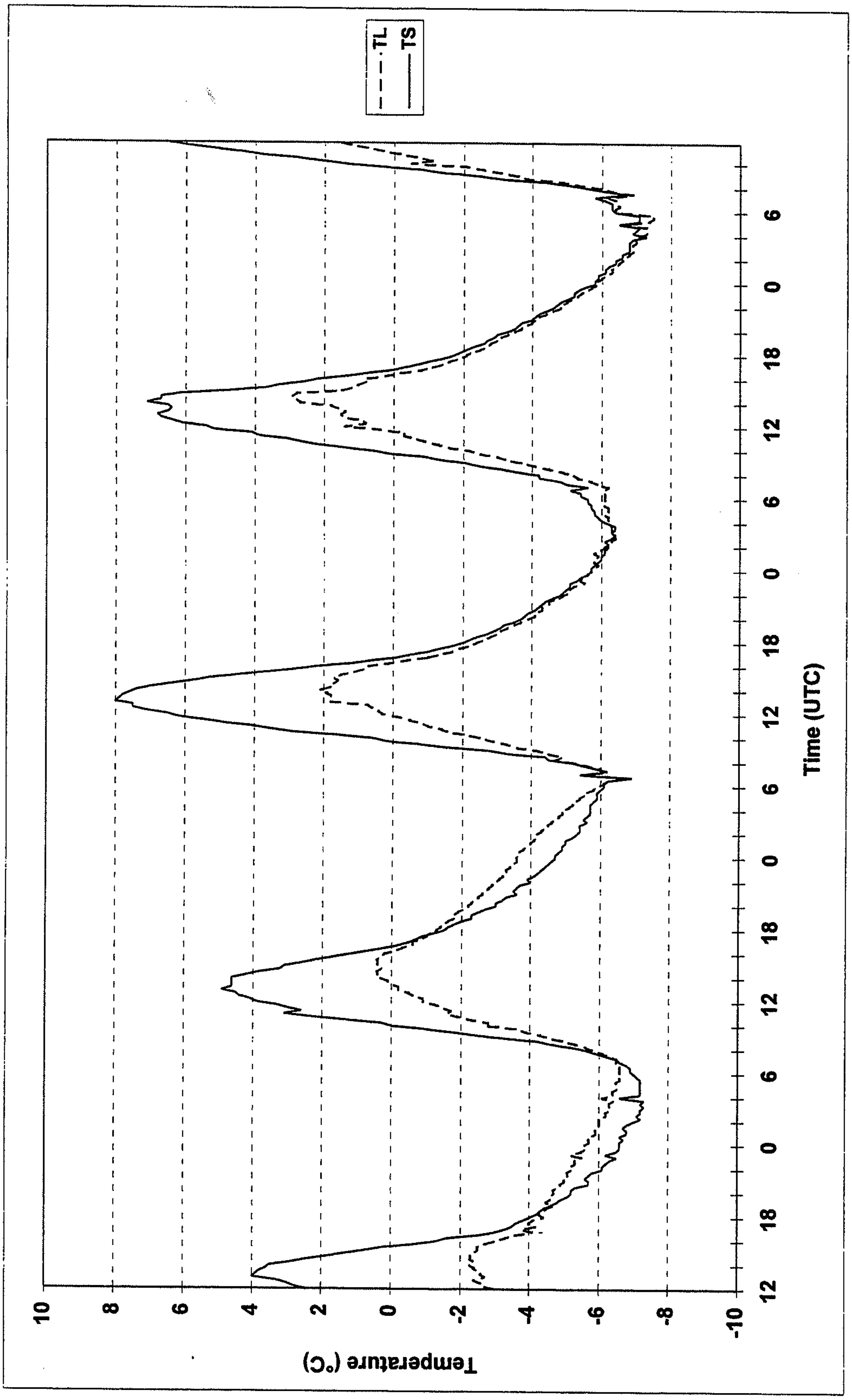

Fig. 3 Time series of mean values of the air temperature (TL) and the road-surface temperature (TS) for the site characteristic 'regular traffic' during the time period 14 February to 18 February 1994 (clear sky conditions)

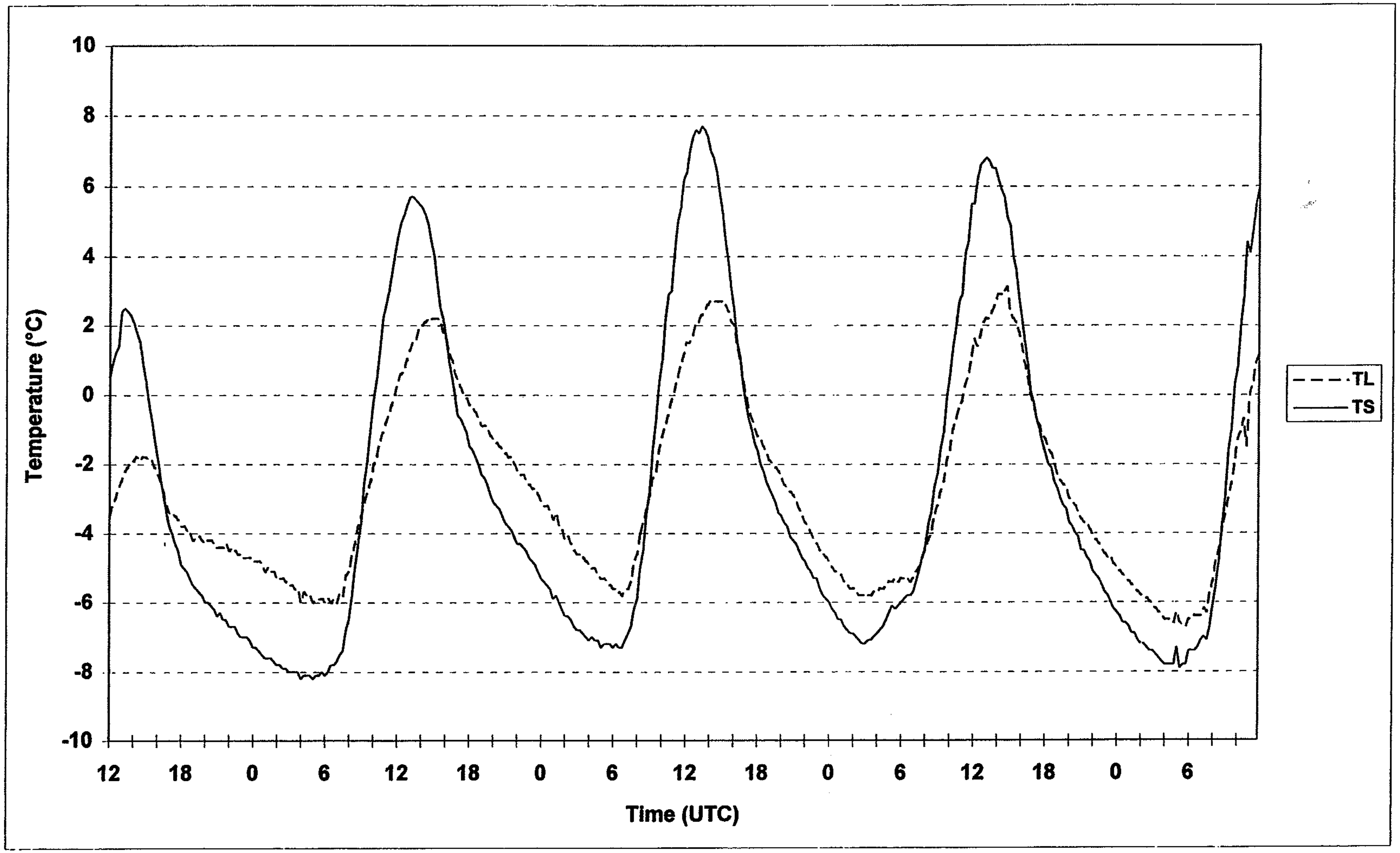

Fig. 4 Time series of mean values of the air temperature (TL) and the road-surface temperature (TS) for the site characteristic 'bridges' during the time period 14 February to 18 February 1994 (clear sky conditions)

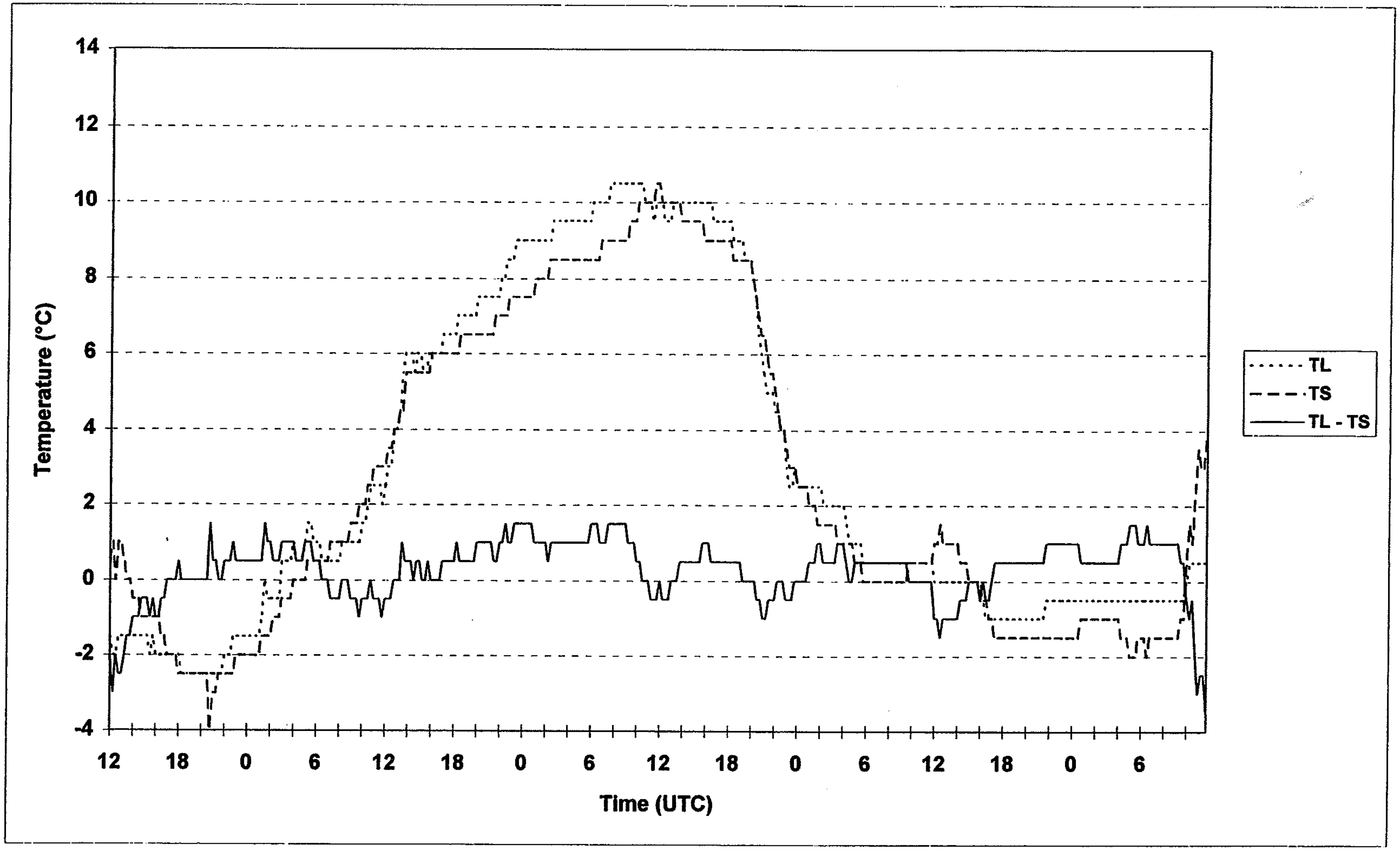

Fig. 5 Time series of the air temperature (TL), the road-surface temperature (TS) and (TL - TS) for the road weather monitoring station "Berghäuser Brücke" ('steel construction') during the time period 21 December to 25 December 1995 (strong temperature advection)

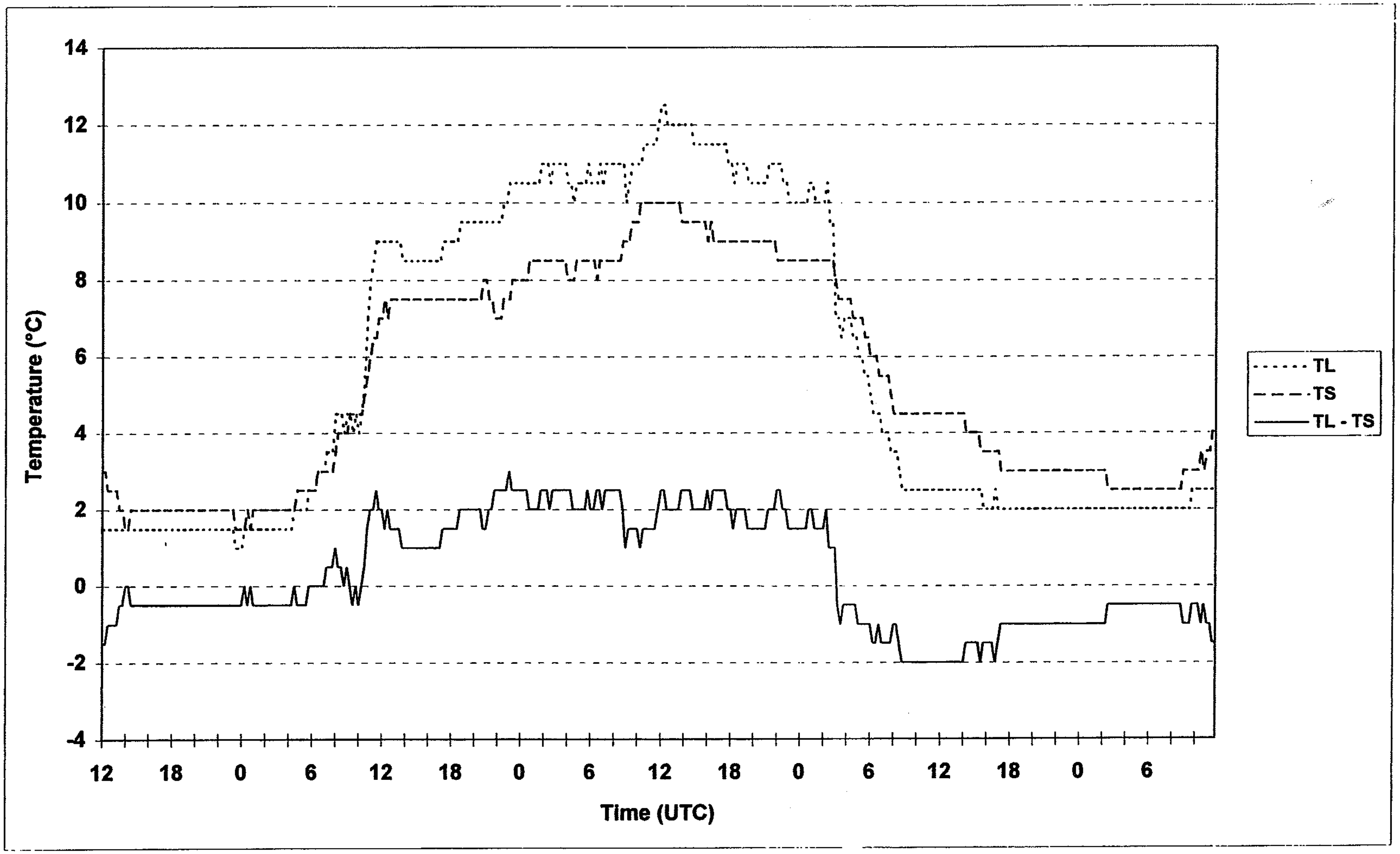

Fig. 6 Time series of the air temperature (TL), the road-surface temperature (TS) and (TL - TS) for the road weather monitoring station "Darmstädter Kreuz" ('concrete construction') during the time period 21 December to 25 December 1995 (strong temperature advection)

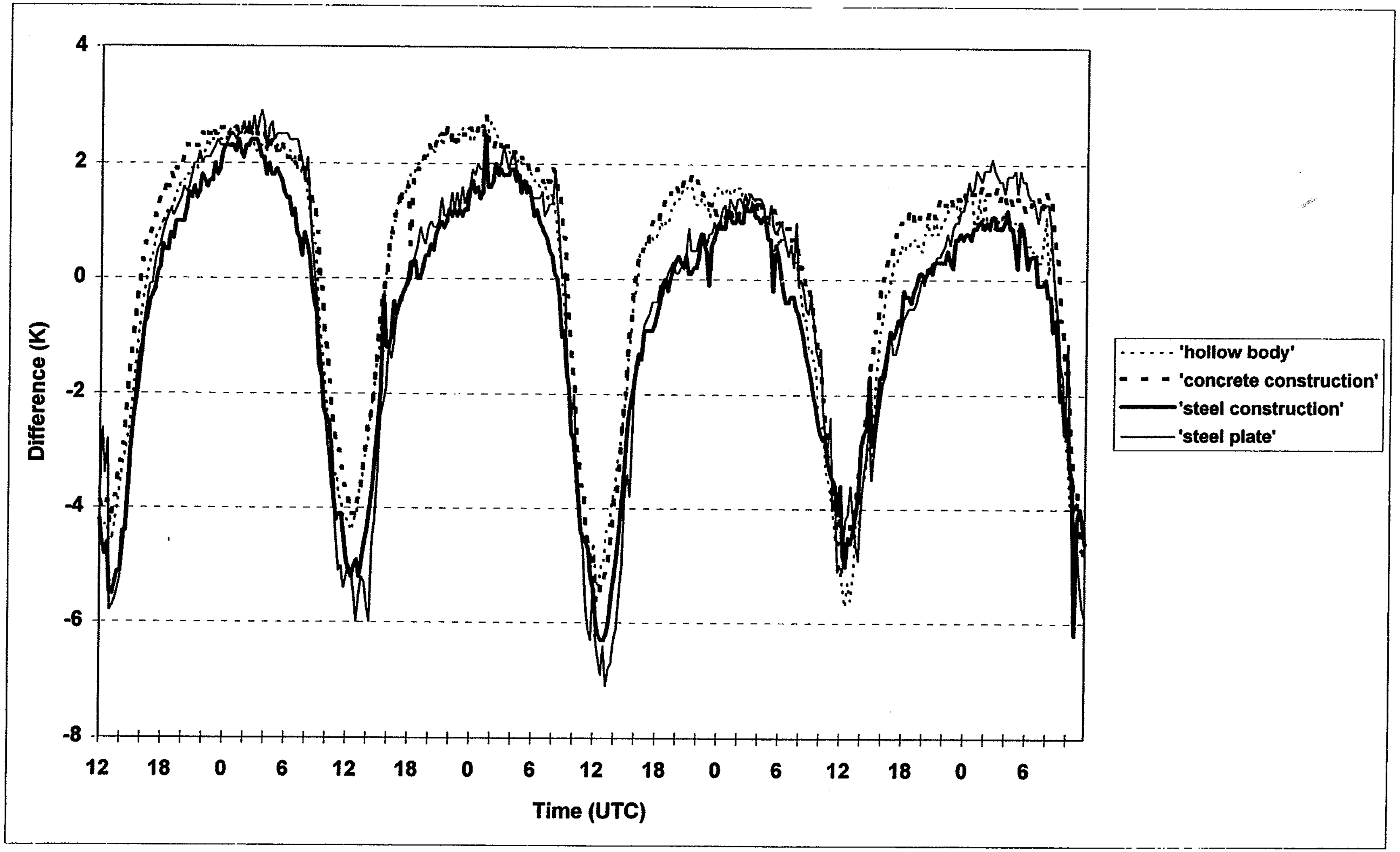

Fig. 7 Time series of mean differences (TL - TS) for different types of bridge construction during the time period 14 February to 18 February 1994 (clear sky conditions)