Thermal Actions on Final Lining of the Mezno Tunnel

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Abstract: Temperature measurement in the Mezno tunnel was designed to obtain data about thermal actions reached in tunnel linings. After a period of operation, the initial data has been measured and evaluated. The evaluation presented the temperature differences across the tunnel lining in various spots during the winter and spring periods, identified the maximal thermal actions reached, compared them with available prescripts for static design, and discussed the suitability of further thermal monitoring.

Keywords: Thermal actions; Thermal monitoring; Tunnel; Tunnel lining; Temperature

1 Introduction

Temperature measurement in monolithic concrete structures might be beneficial for investigating their behaviour. Thermal actions on rigid structures may induce high internal forces, potentially resulting in an oversized design if the applied thermal actions exceed those encountered in reality. Hence, a proper understanding of the actual thermal actions on tunnel linings is beneficial. The current situation involves multiple tunnel structures under construction in the Czech Republic, where a previously developed monitoring system has been installed in the secondary linings of these tunnels. The motivation for monitoring tunnel linings arises from the issue of thermal actions, which are relatively insufficiently described in standards. This motivation stems from earlier measurements conducted in the Klimkovice tunnel [1] and Valík tunnel [2], revealing a significant discrepancy with the values prescribed by the TKP ČD [3]. For a brief illustration, technical conditions prescribe only a simple temperature difference on the tunnel lining of 10 °C, whereas the measured differences were only up to 3 °C [1]. Additionally, it might be suitable to consider the division of temperature in the lining as non-linear to model realistic behaviour. However, the methodology used for these measurements cannot encompass the entire spectrum of thermal actions [2].

The monitoring system has been installed or is in the process of installation in three tunnels, with proposals for monitoring other structures in the project. These monitoring systems will continuously measure temperatures and deformations in the lining since the completion of tunnel construction. An integral part of the monitoring system's development is its optimization and adaptation for any other use in construction practice where measurements are appropriate.

The second part of monitoring thermal actions on tunnel linings involves the continuous evaluation of the measured values and the preparation of an overall assessment of the data obtained from these measurements. A method for evaluating long-term measurement data will be proposed to better describe the thermal actions on the linings. The obtained description can be further processed for adjustments to the documents used in the static design of tunnel linings.

2 Monitoring in the Mezno tunnel

The monitoring system in the tunnel has been installed based on the general conditions defined at the onset of the tunnel lining monitoring project [4]. In the Mezno tunnel, there are two measuring profiles. The first profile is located in the cut-and-covered part in block No. 1, approximately 10 meters from the eastern portal of the tunnel. The second measurement profile is situated in the bored part of the tunnel in block No. 15, approximately 180 meters from the eastern portal of the tunnel.

There are two temperature measurement points (as depicted in Fig. 1) within each profile. The first one is positioned at the top of the tunnel vault, while the second one is in the side wall of the tunnel lining. In each location, a set of thermometers is installed at specific positions to cover the entire thickness of the tunnel lining (consisting of 6 or 7 thermometers at specific depths, depicted in the result charts). Measurements are taken using resistive thermometers PT 1000 at a one-minute frequency, which can be adjusted using the remote control of the system.

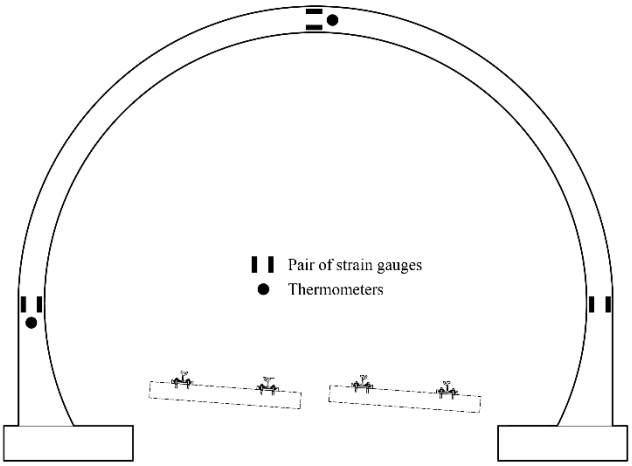

Fig. 1 Scheme of probe set positions in one measurement profile.

Measurements from the Mezno tunnel are conducted by an automatic data acquisition system, which relies on the Raspberry Pi computer and operational modules for the sensors in use. The system has been operational since the beginning of December 2022, allowing for the evaluation of extreme temperature conditions during the winter and spring.

3 Evaluation of thermal actions

The measurements were evaluated with regard to the original purpose of the monitoring. The main emphasis was placed on the extreme linear and non-linear characteristics of the temperature change component (through the lining thickness) and the uniform temperature change component. These values were evaluated with respect to their location – the portal and central part of the tunnel – and the period in which they occurred. From a temporal point of view, it was appropriate to establish these characteristics in seasons and extremes for the entire period of measurement.

According to the period of system operation, data can be basically divided into the winter and spring period. The overall measured data covered the period from December 5th, 2022, to May 30th, 2023. The boundary between the winter and spring period could not be precisely

determined due to unstable weather conditions. However, this situation was not problematic, as only periods with maximal or minimal temperatures were chosen for evaluation.

These time periods were selected based on air temperatures measured in the locality of Mezno village, which were extracted from the weather archive [5]. According to the weather archive, three periods during the winter and two periods during the spring were chosen.

4 Winter seasons

During the winter, three specific periods with low temperatures and relatively high temperature changes during the day occurred. The first period was set from December 10th to December 22nd, 2022, the second one from February 3rd to February 11th, 2023, and the last one from February 24th to March 2nd, 2023. However, in contrast to previous winters, air temperatures did not reach such low values. The temperature change component has been evaluated at all four spots for these periods, and extreme situations were chosen for presentation.

4.1 Portal profile

The first evaluated spot is situated in the portal profile, down in the side wall, approximately 1.5 – 2 m from the bottom of the tunnel. Maximal differences reached values up to 5.1 °C. The non-linear component of temperature change is presented in the chart in Fig. 2.

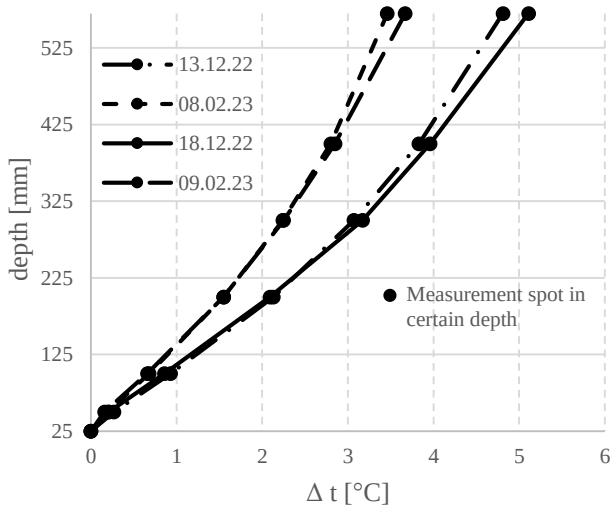

Fig. 2 Extreme temperature differences during the winter across the thickness of tunnel lining in the spot in the side wall of lining, near the portal.

The second evaluated spot is situated in the portal profile, at the top of the tunnel vault. Maximal differences reached values up to 5.2 °C, which are almost identical to those in the bottom part. The non-linear component of temperature change is presented in the chart in Fig. 3.

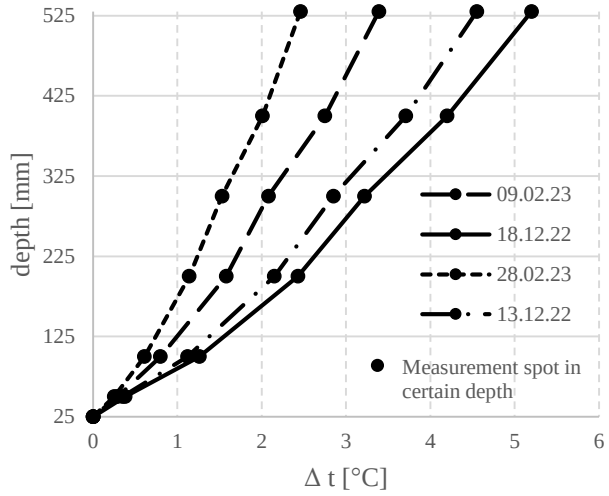

Fig. 3 Extreme temperature differences reached during the winter across the thickness of tunnel lining in the spot in the top of the tunnel lining vault, near the portal.

4.2 Mid-part profile

The spot in the mid-part profile is situated analogously to the portal profile, down in the side wall. Maximal differences reached values up to 4.8 °C. The non-linear component of temperature change is presented in the chart in Fig. 4.

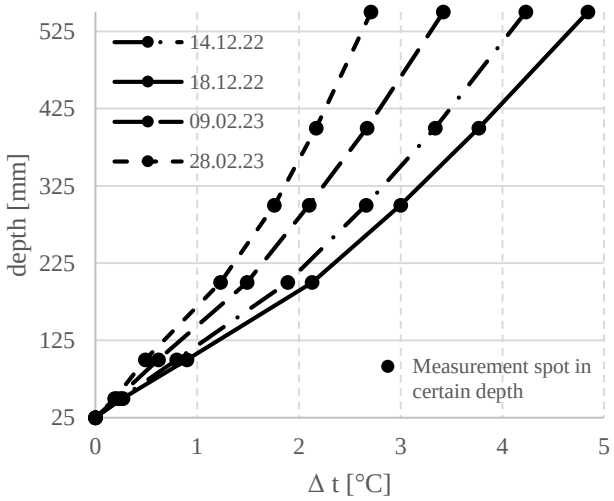

Fig. 4 Extreme temperature differences during the winter across the thickness of lining in the spot in the side wall of lining.

The maximal temperature differences in the spot at the top of the tunnel vault reached values up to 3.3 °C, which is notably less than in the bottom part. The non-linear component of temperature change is presented in the chart in Fig. 5.

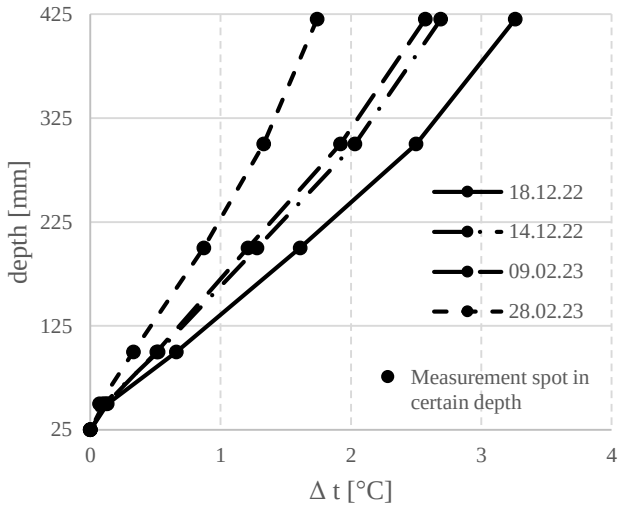

Fig. 5 Extreme temperature differences reached during the winter across the thickness of tunnel lining in the spot in the top of the tunnel lining vault.

5 Spring seasons

Spring was characterized by low air temperatures, which only rose in May, featuring two stable periods with more significant daily air temperature changes. The first one was set from May 6th to May 11th, and the second one from May 20th to May 30th, 2023. Extreme situations and maximal temperature changes are presented.

5.1 Portal profile

The spot in the mid-part profile is situated analogously to the portal profile, down in the side wall. Maximal differences reached values up to 4.9 °C. The non-linear component of temperature change is presented in the chart in Fig. 6.

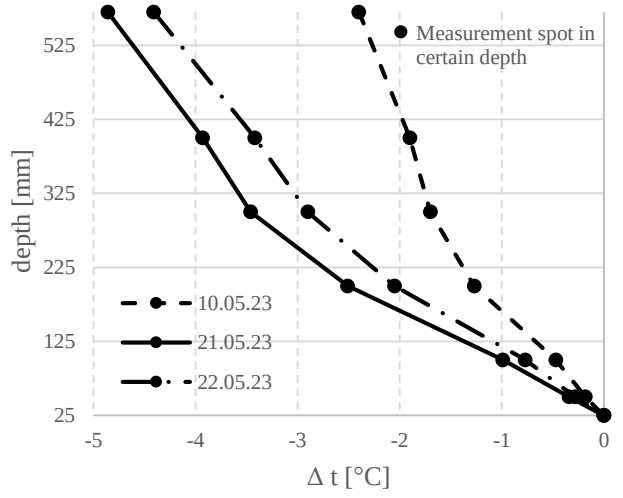

Fig. 6 Maximal temperature differences during the spring across the thickness of the lining in the spot in the side wall of lining, near the portal.

The maximal temperature differences in the spot at the top of the tunnel vault reached values up to 4.9 °C, the same as in the bottom part. The non-linear component of temperature change is presented in the chart in Fig. 7.

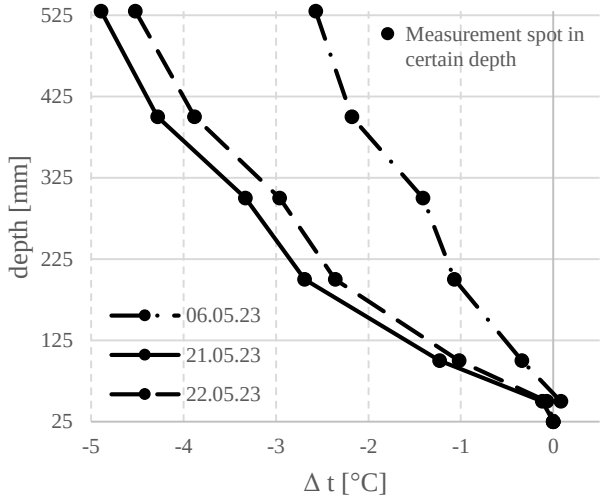

Fig. 7 Extreme temperature differences reached during the spring across the thickness of tunnel lining in the spot in the top of the tunnel lining vault, near the portal.

5.2 Mid-part profile

The spot in the mid-part profile is situated analogously to the portal profile, down in the side wall. Maximal differences reached values up to 4.1 °C. The non-linear component of temperature change is presented in the chart in Fig. 8.

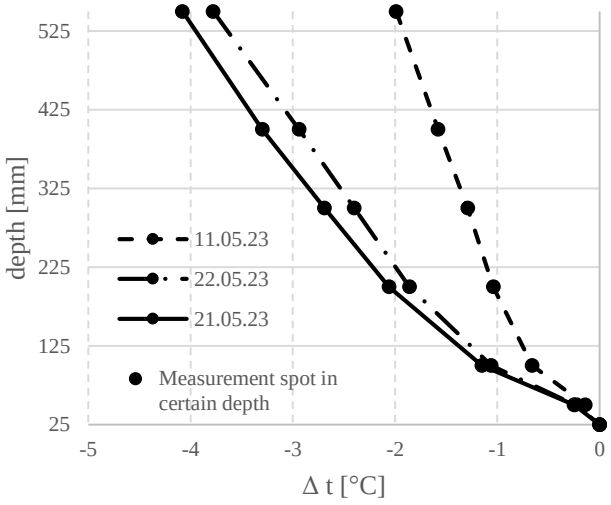

Fig. 8 Maximal temperature differences during the spring across the thickness of the lining in the spot in the side wall of lining.

The maximal temperature differences in the spot at the top of the tunnel vault reached values up to 2.9 °C, which is considerably less than in the bottom part. The non-linear component of temperature change is presented in the chart in Fig. 9.

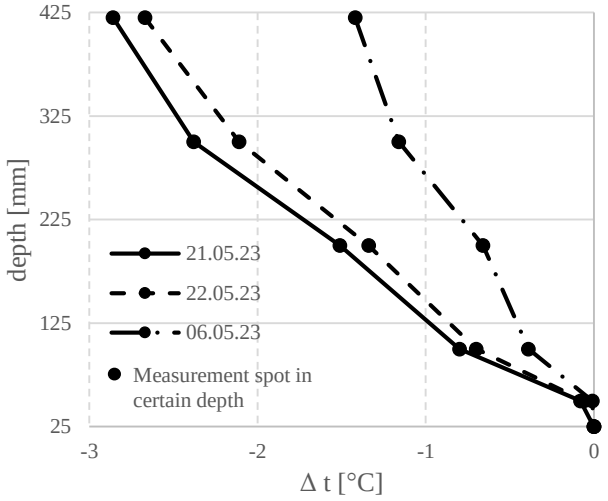

Fig. 9 Extreme temperature differences reached during the spring across the thickness of tunnel lining in the spot in the top of the tunnel lining vault.

Conclusion

The evaluation of thermal actions on the tunnel lining in the Mezno tunnel after half a year of monitoring operations brought specific new information. Firstly, temperature differences across the thickness of the lining are within the expected values. Therefore, the presumption of overestimation of thermal actions by the TKP ČD prescript may be considered confirmed. However, for setting the thermal actions, further measurement and evaluation are necessary.

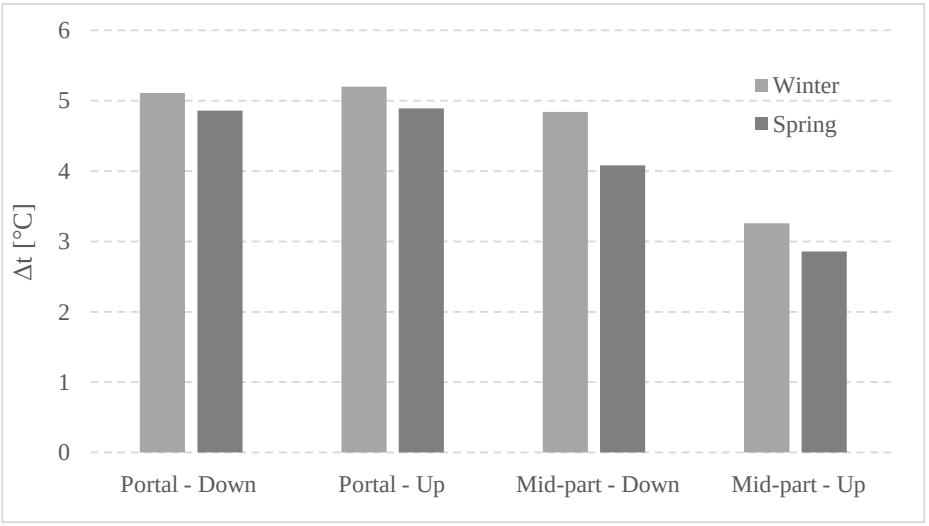

Fig. 10 Comparation of temperature changes reached in the measured spots in winter and spring season.

According to the comparison depicted in the chart in Fig. 10, there are a few differences that deserve discussion. Firstly, the temperature differences reached in the spring season were

slightly lower than those reached in the winter. This should be considered as a specificity of the period during which the measurement was taken. These differences could be evaluated only statistically after more years of monitoring operation.

Secondly, a slight difference is observed between the portal part and the middle part of the tunnel. These differences should be confirmed by statistical evaluation; the assumption cannot be made at this point. However, in the case of a significant difference between the upper measurement spot in the mid-part and the other spots, the reason could be sought in the different thickness of the lining in this spot. The lowest point in the measurement is 425 mm deep, which is about 100-140 mm shallower than the deepest points in other spots. Therefore, the thermal behaviour at this point is more variable than in more deep-seated points in other spots of monitoring.

The maximal temperature difference reached 5.2 °C. As mentioned earlier, this value falls within the expected range. Continuous measurement of thermal actions in tunnel linings should provide a sufficient basis of data, creating the first step for a proper description of thermal actions and the efficient and safe design of tunnel linings in the end. Therefore, further measurements and system control will follow.

Acknowledgements

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