# Temperature and moisture distribution in a highway in south Kazakhstan

Bagdat Teltayev, K. Aitbayev and E. Suppes

[1] Kazakhstan Highway Research Institute (KHRI), Almaty city, Kazakhstan

## ABSTRACT

The matters of investigation for water and thermal regime of pavement and subgrade of the highways are especially important as the moisture and temperature distribution in pavement and subgrade layers impact greatly on their deformation and strength indicators. Experimental approach has an important meaning in the investigation of the stipulated problem. Experimental results are primary ones for establishing of peculiarities and regularities for distribution and migration of heat and moisture in the mentioned structural elements of highways. Special measurement devices are required to obtain such experimental data. The paper shows the results for analysis of temperature and moisture variation in points of pavement and subgrade of “Kyzylorda-Shymkent” highway. Temperature measurement has been performed by set of special sensors. Regular temperature and moisture measurement have been performed for the period from March 31 to December 30, 2017. The obtained experimental data allowed establishing temperature and moisture variation in points of subgrade in time and their distribution in the depth. Regularities for temperature regime variation in points of pavement for 24 hours are coordinated with air temperature variations. Amplitude of variation decreases with the depth increase. The impact of daily air temperature variations in subgrade layers has been made only up to the depth of 90 cm. Daily temperature variations gradually disappear with the depth increase, and its monotonous variations have been caused by seasonal air temperature variations. The moisture content is mainly not high in subgrade layers for the period of observations. Moisture in subgrade points is gradually decreased with the reduction of daily average air temperature.

**Keywords:** highway; pavement; subgrade; sensor; temperature; moisture

## 1 INTRODUCTION

Not only mechanical forces, such as load from moving vehicles, affect the condition and service life of highways, but also natural climatic factors, among which the essential importance have temperature and moisture.

The first investigations for water and thermal regime of subgrade and pavements in Kazakhstan have been started approximately in 60-70s of the last century. These investigations, mainly, were experimental ones, moisture was measured by normal method of filling hole, selection of soil samples with further use of thermostatic and weight method.

In the beginning of 1990s the works were started for investigation of temperature regime, first for asphalt concrete pavements, then for other structural layers of pavements and subgrade with the use of specially designed sensors of transistor (Teltaev 1999; Teltaev et al. 1995) and thermal resistance (Aytaliev et al. 2003).

In 2010 Kazakhstan Highway Research Institute started a new stage for advanced study of water and thermal regime for pavements and subgrade of highways. For that purpose 3 sets of special devices have been installed in “Astana-Burabai” highway. Moreover, the sensors of each set have been installed in different depths of vertical hole, drilled in multilayer pavement and subgrade of the highway. Temperature measurement has been performed according to the principle of thermal resistance variation, and moisture measurement – according to the principle of dielectric permeability. Such combined design allows obtaining of information regarding temperature and moisture in points of pavement and subgrade simultaneously.

In 2013 the sets of sensors of temperature and moisture were laid into structures of highways, located in other climatic conditions (close to Oskemen, Atyrau, Turkestan and Almaty cities). Sensors work on automatic regime; they perform temperature and moisture measurements every hour and the obtained information is made by recording device. Measurements are performed over a long term period; outcome data are recorded into memory and further transferred by noise proof communication cable into interface. More detailed information regarding design of sensors and conditions for their installation one can take from the works (Teltaev and Suppes 2017a; Teltayev et al. 2015; Teltaev and Suppes 2017b; Teltaev and Suppes 2017c; Teltaev and Suppes 2015; Teltayev and Aitbayev 2015).

This paper represents some results of experimental study for temperature and moisture distribution in pavement and subgrade of "Kyzylorda-Shymkent" highway, relating to the period from 31st March to 30th December 2017.

## 2 EXPERIMENTAL SECTION

Temperature and moisture sensors were installed in the highway in June 2013. General view of one set for sensors and view of surface part for temperature and moisture automatic measurement system are shown in Figures 1 and 2. Experimental section is located near Turkestan city (km 2097) on "Kyzylorda-Shymkent" highway. This highway, part of Western Europe-Western China Transcontinental Transport Corridor, relates to I technical category and has 4 lanes and it is in operation after reconstruction since 2013.

Fig. 1. General view of one set for temperature and moisture sensors

Fig. 2. View of surface part for temperature and moisture automatic measurement system

Pavement structure of "Kyzylorda-Shymkent" highway consists of the following layers: crushed stone mastic asphalt concrete (5 cm), coarse-grained dense asphalt concrete (10 cm), coarse-grained high porous asphalt concrete (13 cm), sand and gravel mix (40 cm). Subgrade soil is dusty sand.

## 3 TEMPERATURE REGIME

Graphs for air temperature variation and temperature on the surface of asphalt concrete pavement are shown in Figure 3, and the graphs for temperature distribution in points of pavement and subgrade of the highway section are in Figures 4 and 5.

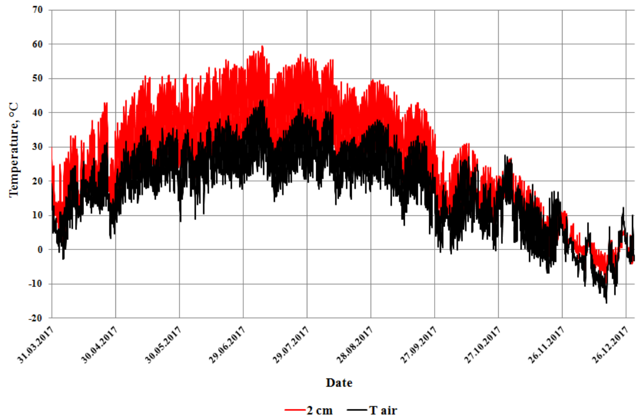


Fig. 3. Air temperature variation and variation of asphalt concrete pavement surface temperature on "Kyzylorda-Shymkent" highway

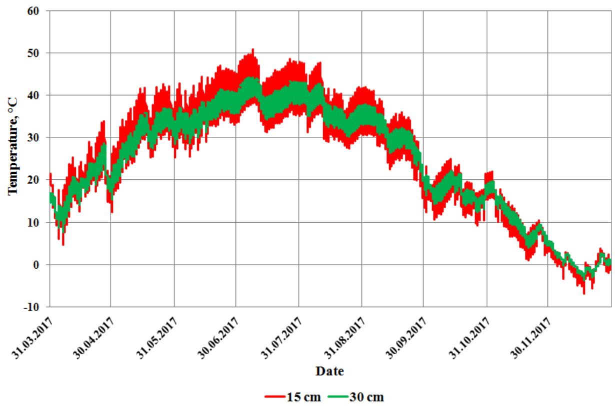


Fig. 4. Temperature variation in pavement points of "Kyzylorda-Shymkent" highway

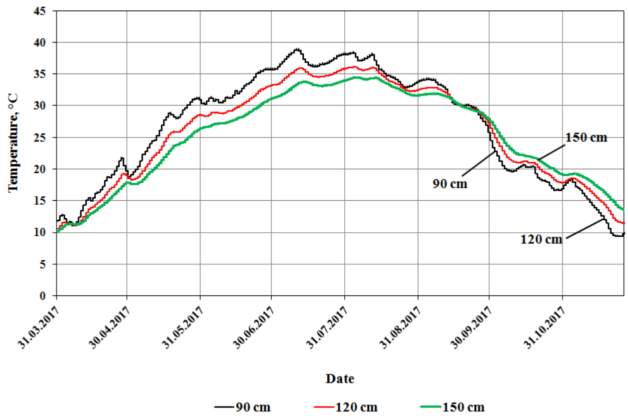


Fig. 5. Temperature variation in subgrade points of "Kyzylorda-Shymkent" highway

Air temperature in spring season is characterized by non-stability, for example, during the month of April air temperature varies within the range of 30°C (from 0°C to +30.1°C). Maximum air temperature at noon is alternated with minimum air temperature at midnight. The graphs for temperature variation in points of pavement fully imitate the configuration of graphs for air temperature. The difference of the above graphs between them is only in the reduction of values for daily amplitudes, which decreases with the depth increase, and phase shifts of extremums of each graph in relation to extremums of the graph for air temperature variation. Meanwhile, phase shift value in time increases with the depth increase, which is explained by property of material thermal resistance for constructive layers of pavement and subgrade.

Summer season of 2017 was relatively hot, air temperature reached +40...+43°C, and average daily temperature was about +30°C. Peculiarity for temperature regime variation in pavement in hot season is the essential temperature excess of pavement points over air temperature. For example at air temperature of +42ºC…+43ºC maximum temperature in asphalt concrete pavement layer, located in the depth of 2 cm, was equal to +60ºC. The difference was 17-18°C. Meanwhile, such kept up to the depth of 30 cm, where maximum temperature reached +43…+49ºC.

In the subgrade layers the impact of daily air temperature variations are revealed only up to the depth of 90 cm. Daily temperature variations gradually disappear with the depth increase, and its monotonous variations are caused by seasonal air temperature variations.

Beginning from the middle of the month November a stable air temperature reduction is observed. Frosting of asphalt concrete layers for pavement started in the beginning of December 2017. Peculiarities for temperature regime variations in pavement points during the day strictly comply with air temperature variations. Temperature in pavement layers and subgrade gradually decreases with the air temperature reduction. For the end of observation period (30th December 2017) air temperature reached -13°C, but temperature on the surface of subgrade remains still positive (+2.3°C).

## 4 MOISTURE DISTRIBUTION

Moisture distribution in subgrade soil impacts greatly on its strain and strength indicators. As an example let us give the graphs for moisture variation in upper subgrade layers (Figure 6). As it is seen from the graphs, moisture regime on this highway section during the observation period (from 31.03.17 to 30.12.17) is stable on the whole, there is a tendency for slow seasonal moisture decrease.

Daily moisture variations in subgrade points are not available. Moisture of subgrade in the depth of 90 cm during this observation period varies within the range of 2% (from 10.8% to 12.8%), in the depth of 120 cm it varies from 10.7% to 9.1% and in the depth of 150 cm – from 9.7% to 11.7%.

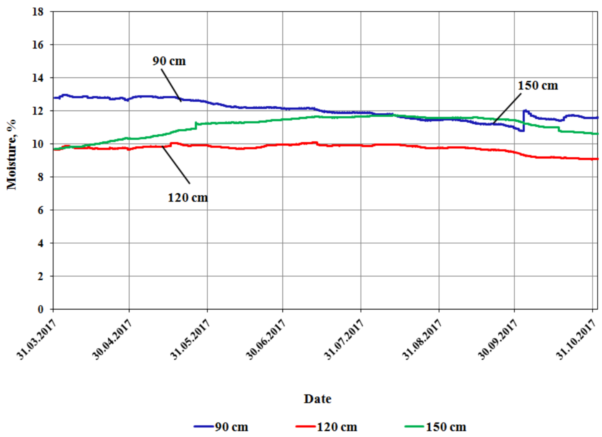


Fig. 5. Moisture variation in subgrade points of “Kyzylorda-Shymkent” highway

## 5 CONCLUSION

1) Temperature field in highway pavement and subgrade in southern region has been formed under the considerable impact of solar radiation;

2) Regularities for temperature regime variation in points of pavement during the day strictly comply with air temperature variations. Amplitude of temperature variation has been decreased with the depth increase, and when it reaches the depth of 120 cm it approaches zero;

3) Moisture content, mainly, is not high in subgrade layers during observation period (from 31st March to 30th December 2017). Maximum moisture value has been recorded in the depth of 90 cm, where moisture content is within the limits of 11-13%;

4) Moisture in points of subgrade has been gradually decreased with average daily air temperature decrease;

5) Maximum temperature of pavement reaches +60ºC at the air temperature of +43ºC (month of July 2017).

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