# EXTENDED MONITORING AND ANALYSIS OF MOISTURE-TEMPERATURE DATA


## Abstract

The seasonal variations in the resilient modulus of asphalt concrete (AC) pavements and the corresponding resilient modulus variations of the subgrade soil are major factors in determining the performance of new AC pavements and overlays. Unfortunately, current design procedures do not directly consider these factors. It is expected however, that with the implementation of mechanistic pavement design procedures these variations will be included, leading to a more realistic design

Moisture-temperature-rainfall data was collected for a period of three years from monitoring stations previously installed during the ODOT-funded project "Characterization of Ohio Subgrade Types" and monitored for an additional period of 2-1/2 years during the project "Monitoring and Analysis of Data Obtained from Moisture-Temperature Recording Stations." These stations record hourly, daily and seasonal variations in air temperature, rainfall, temperature within the asphalt concrete layer and moisture content (or degree of saturation) and temperature within the subgrade soil. Typically, temperature variations within the subgrade soil are minimal on a daily basis. Only the uppermost subgrade soil thermistor shows daily temperature variations although within a narrower range, following those of the bottom asphalt concrete thermistor.

The thermistors within the asphalt concrete layer exhibit large daily temperature fluctuations. Typically the AC layer exhibits a uniform temperature (no temperature gradient) twice a day, normally occurring between 8:00 and 10:00 AM and around 8:00 PM. Similarly, the maximum daytime temperature gradient within the pavement is observed between 2:00 and 4:00 PM at all seasons and the maximum overnight temperature gradient occurs around 6:00 AM. It is

to be noted that the temperature gradient is greater in the afternoon than in the early morning and that AC layer temperature variations closely follow air temperature changes.

The average AC pavement temperature was calculated in the middle of the layer at each location, and then monthly and seasonal averages were tabulated. The average pavement temperature difference between summer and winter is of the order of 30 to 35 deg. C at all sites. This range also indicates the wide variation in the elastic properties of the AC. As expected the northern sites exhibit slightly lower averages than the southern sites. Observations in temperature changes within the pavement and subgrade profiles indicate that the daytime and the nighttime averages for any sensors located at depths in excess of 30.48 cm. (1.0 ft.) from the surface (i.e. the subgrade soil sensors) are very similar. In addition, the asphalt concrete sensors show warmer temperatures than the soil sensors (on the average) during the spring and summer. However, this trend reverses during the fall and winter.

Polynomial equations were derived relating the average asphalt concrete pavement temperature to the air temperature for eight (excluding the Columbiana Co.) of the nine monitored stations. The coefficients included in these equations indicate that asphalt concrete temperature is higher in the southern part than in the northern part of the state. The regression coefficients also point to the fact that the state of Ohio may be subdivided into three general temperature zones: North, (from the North Shore to Mansfield – Mount Vernon) Central (from Mansfield – Mount Vernon to Lancaster) and South (from Lancaster to the southern state line).

As a result of temperature differences during the four seasons the resilient modulus of the asphalt concrete also changes in an inverse form to the temperature variation. It was determined that for a typical mid-season day the resilient modulus averages:

3791.7 MPa (550 ksi) in the spring (+/- 1034.1 MPa or +/- 150 ksi)

1723.5 MPa (250 ksi) in the summer (+/- 1034.1 MPa or +/- 150 ksi)

8272.8 MPa (1200 ksi) in the fall (+/- 1378.8 MPa or +/- 200 ksi)

15511.5 MPa (2250 ksi) in the winter (+/- 1551.1 MPa or +/- 225 ksi)

Recorded depths of frost penetration show, as expected, that they are greater in the northern than in the southern stations. On a normal season the average depth of frost penetration is about 45.7 to 61.0 cm. (1.5 to 2.0 ft) at the southern stations and from 70.1 to 82.3 cm. (2.3 to 2.7 ft) at the northern locations. It was also observed that when the frost penetration is high at the northern sites the number of freeze-thaw cycles is lower. This normally occurs during severe winters. The number of cycles appears to increase during milder winters. Normally, the northern sites experience an average 7 to 12 cycles as compared to between 4 and 5 in the southern sites.

A calibration equation previously developed was used to obtain monthly and seasonal averages of the degree of saturation from moisture and temperature sensor readings at each of four moisture sensor locations. The degree of saturation typically varied between about 90% and 100% throughout the monitoring period. The late spring to early summer period seems to consistently lead to slightly higher (nearing 100%) degree of saturation at all depths.

Finally a method to back calculate the resilient modulus of subgrade soils at the break point from measured FWD deflections was developed. Overall seasonal averages of the modulus were obtained at each of six station locations where FWD testing was conducted. Seasons were ranked in terms of expected higher resilient modulus. The designated "fall" testing period (early fall) showed the highest followed by "summer", "winter" and "spring" in decreasing order. This ranking is expected since the fall testing period follows the generally drier summer season and the spring testing period happens at the spring thaw and normally wetter early spring. Generally, for the most part a higher back calculated resilient modulus followed lower amounts of rainfall. Similarly lower resilient modulus back calculations were generally preceded by higher rainfall. Attempts to correlate the amount of rainfall accumulated over either one month, two or three months preceding the date of FWD testing with the back calculated resilient modulus were unsuccessful.