PUBLICATIONS

The impact of seasonal variation on the structural and functional conditions of road pavements.

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ABSTRACT

In an ongoing project the Finnish Transport Infrastructure Agency (FTIA) and ARRB Systems are monitor ing the influence of seasonal variation on pavement condition, using the comprehensive measurement equipment iPAVe.

The iPAVe measures structural and functional conditions of road pavements simultaneously. This provides a unique opportunity to evaluate the cause of seasonal effect s on pavement condition. The measurements have been conducted on two test loops located in two different climatic regions in Finland, with a total length of approximately 500 km. Measurements have been conducted during the frost/thaw period, in mid summer and end of summer in 2022, and will be repeated in 2023.

The paper will present how the road condition changes due to seasonal impact and will elaborate on how functional and structural performances interact, due to climatic changes.

The paper will also highlight how comprehensive measurements can support an overall maintenance strategy, including climatic impacts on pavement performance.

The project is part of a four year project partly funded by The Swedish Transport Administration with the aim of developing a structural condition indicator for roads, the overall project management is held by The Swedish National Road and Transport Research Institute,

1 INTRODUCTION

The study being undertaken by this project is based on a series of previous studies Herronen et al., 2022, Saarenketo et al., 2021 and Saarenketo et al., 2022).

In these studies, focus has been on the negative effect of poor drainage and too late snow removal on pavement conditions in Finland. The referenced studies recommend to further analyze the changes in the structural properties of roads in Finland due to seasonal variations and to include traffic speed deflection measurements (TSD) and ground penetrating radar GPR for recording the structural condition and the layer thicknesses. Based on the recommendations from the reference d projects FTIA initiated a project in 2022 to investigate the effect of seasonal variation on road pavements performances with a focus on the frost/thaw period. The reason is the observed change in climate with higher temperatures and rainfall is seen to have a negative impact on the structural capacity of the Finnish Road network. The aim of the project is to document if the change in weather conditions changes the lifetime of the infrastructure and ultimately requires a change of the maintenance policies in Finland.

To establish the needed data for analyzing the climatic impact, the intelligent Pavement Assessment Vehicle (iPAVe) has been used. The data collection has been performed by ARRB Systems. FTIA already collects road condition data at network level which is used for strategic and tactical planning of maintenance In some cases, more detailed data is collected for development of proactive maintenance (Saarenketo & Männistö, 2021). The hypothesis of th is project is that comprehensive and complete condition data, functional and structural will provide valuable information in a scenario where the information in a scenario where the road network seems to deteriorate faster than everroad network seems to deteriorate faster than ever, due to due to increasing increasing traffictraffic loads (forest industry, high-capacity transports) and change inchange in climate.

To provide the needed condition information, the influence of seasonal variation on pavement condition has been conducted during the frost/thaw period and during the summer period in 2022, with an additional measurement in May 2023. The paper highlights the results of the measurements and the possible change in road condition due to seasonal impact will be elaborated.

2 COMPREHENSIVE ROAD CONDITION MEASUREMENTS

The iPAVe (Figure 1) simultaneously collects pavement structural and surface data such as: Pavement strength through deflection measurement, Cracking, Longitudinal and Transverse Road profile, Pavement macro texture, Road geometry, Geospatial position, Digital imaging, Asset inventory and condition.

Figure 1. Intelligent Pavement Assessment Vehicle

Collecting comprehensive road condition data enables road engineers to carry out holistic analysis of the road infrastructure. Previous studies have shown using comprehensive/holistic measurement and analysis is the right way forward in establishing robust strategic maintenance policies (Schmidt 2022, Hoque 2018).

3 LOCATION AND CLIMATIC CONDITIONS FOR THE TEST LOOPS

The roads sections included in the project are located in two areas in southern Finland, close to the cities Turku and Tampere, as shown in Figure 2.

The criteria for the selection of the road sections were that the roads are located geographically different, but still within a reasonable distance apart for data collection. Climatically the two regions are not that different. Both the Turku and the Tampere region are classified as cold and temperate, and both regions are exposed to significant rainfall, even during the driest month.

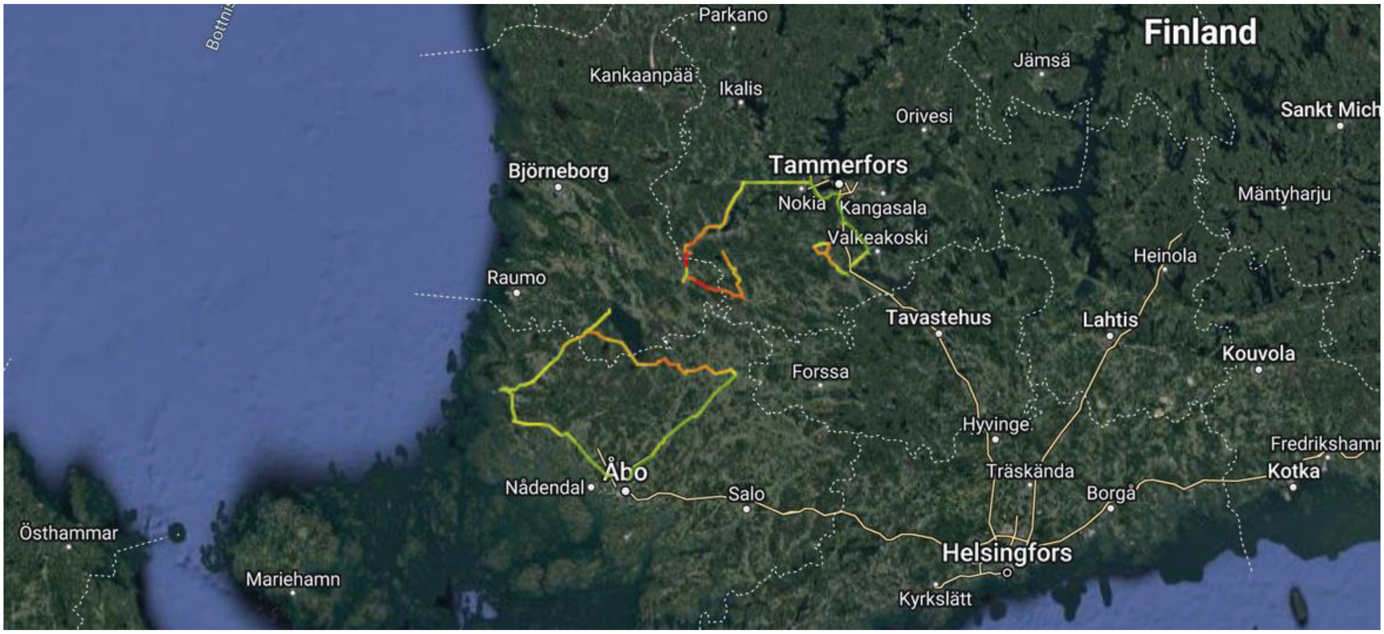

Figure 2. Location of the two test loops with a total length of 500 km

Figure 3 shows the average air temperatures for the Tampere and Turku area and Figure 4 shows the average precipitation for each of the regions.The figures show no significant differences between the two regions, and hence the climatic influence on the performances of the roads should be equal.

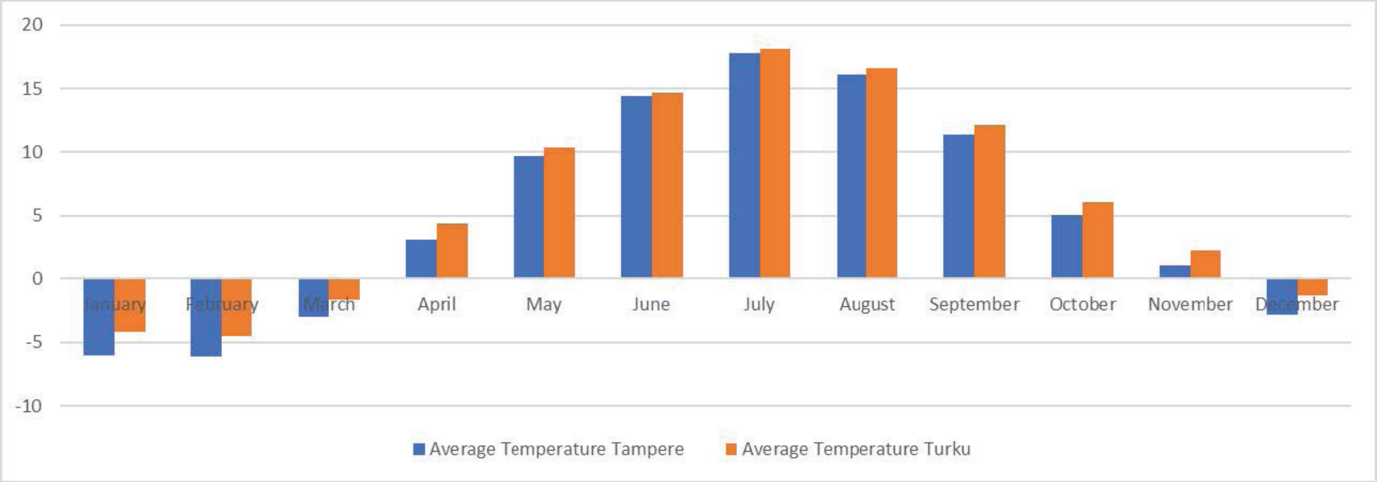

Figure 3. Monthly average temperature variation in year 2022 for Tampere and Turku region

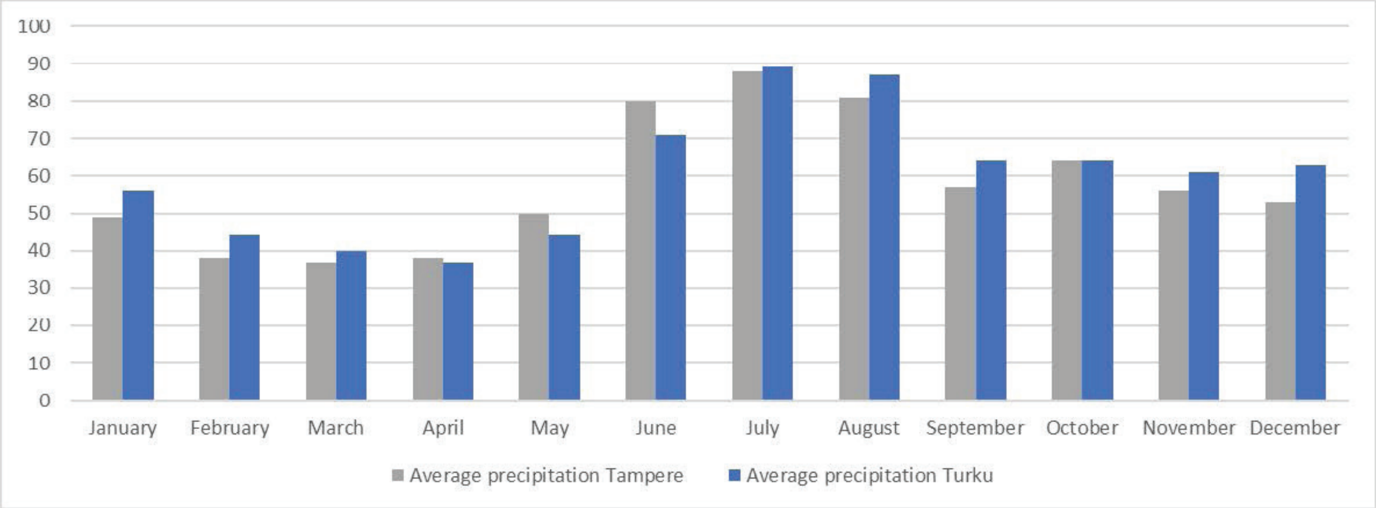

Figure 4. Monthly average precipitation variation in year 2022 for Tampere and Turku region

4 AIR AND PAVEMENT SURFACE TEMPERATURE DURING MEASUREMENTS.

The iPAVe measures both air and pavement surface temperature during measurements. The temperature readings of the air and asphalt surface is important parameters, when analyzing the bearing capacity of roads, because the asphalt temperature has an influence on pavement stiffness and hence the measured deflections. As the aim of the project is to study the effect of seasonal variation on pavement performance, no temperature corrections of the deflections were done.

Figure 5 and 6, shows that the air and asphalt temperatures did not change significantly during the time where measurements were performed. However, the difference in seasonal temperatures is significant, and in general terms comply with the monthly average temperatures shown in Figure 3. Table 1 shows the average temperatures recorded during testing, and the table shows that the temperatures in the Tampere region was higher than in the Turku area during measurements, which differs from the general average temperatures shown in Figure 3.

	Average Air temperature			Average Pavement temperature		
	May 2022	August 2022	May 2023	May 2022	August 2022	May 2023
Turku Region	13.14	26.22	9.96	14.31	29.64	12.53
Tampere Region	15.15	27.86	13.21	18.68	31.32	15.96

Table 1. Average air and pavement temperature measured by the iPAVe during measurements.

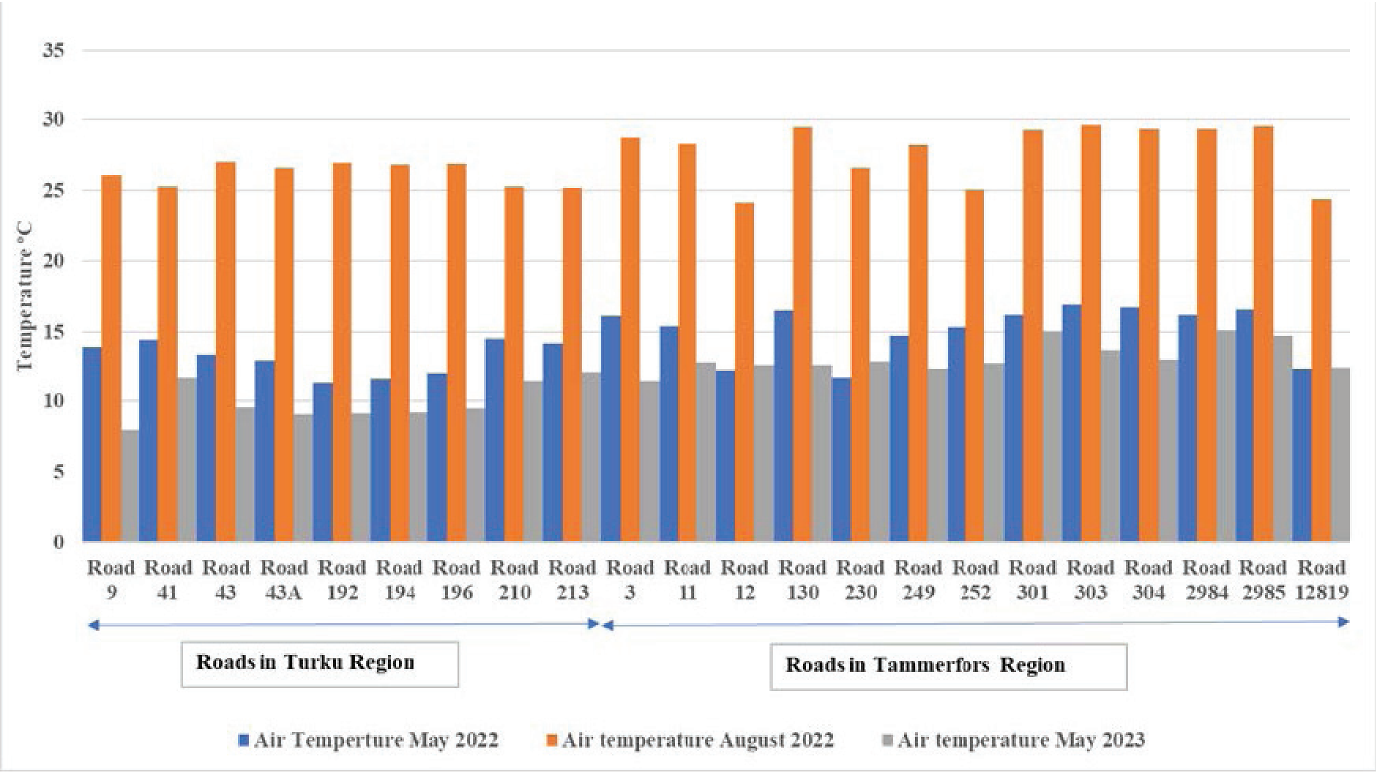

Figure 5. Average air temperature on each road measured by the iPAVe during condition measurements.

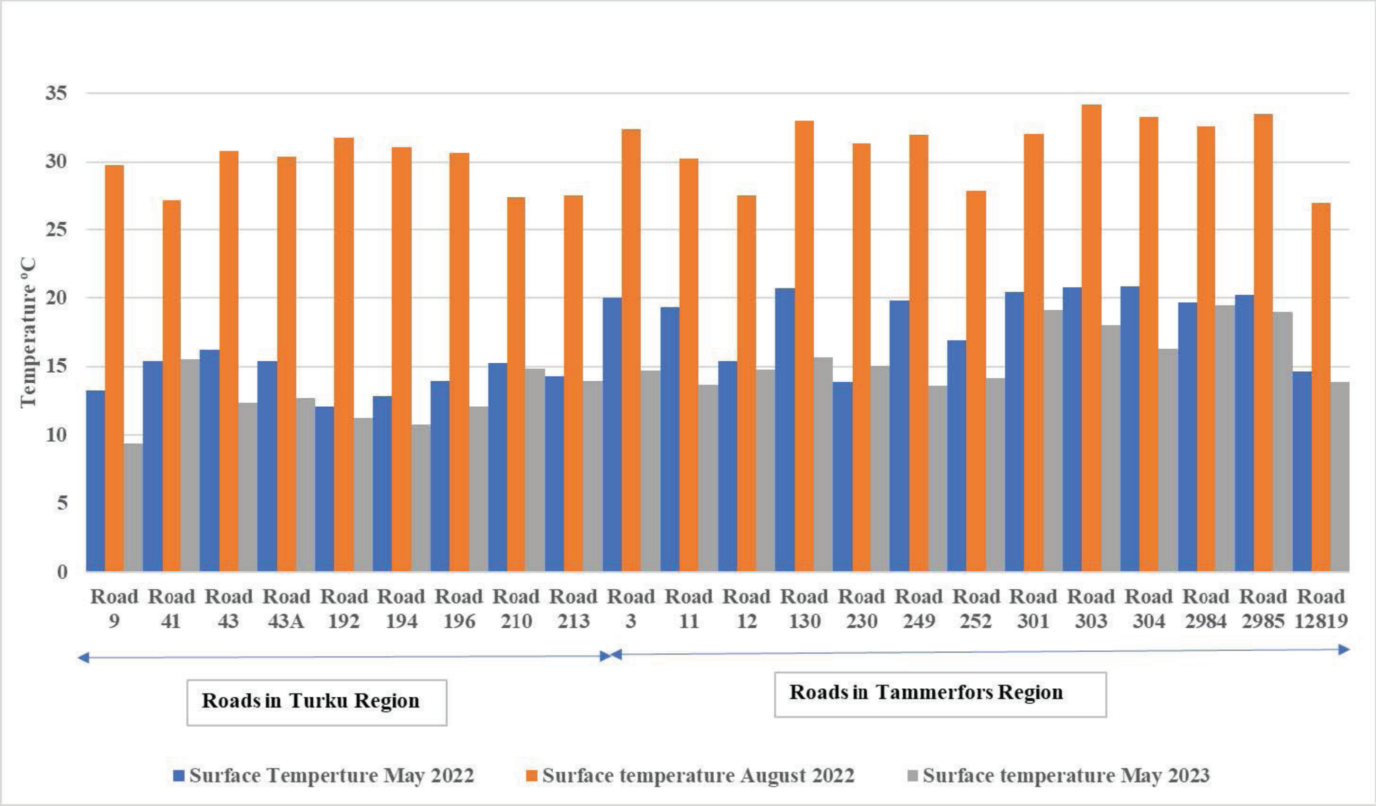

Figure 6. Average pavement surface temperature on each road measured by the iPAVe during condition measurements.

5 RESULTS OF MEASUREMENTS.

Several indices can be used to analyze the stiffness of the pavement layers. To study the bearing capacity of the pavement, the Center deflection D0, the Surface Curvature Index (SCI) 300 and the Surface Curvature Index (SCISUB) are used. The SCI300 is the difference in measured deflection under the center of the loading plate and 300 mm away and represents the stiffness of the upper part of the pavement structure. SCISUB is the difference of the measured deflection in position 900 mm and 1500 mm and represents the stiffness of the lower layers in the pavement and thereof also the subgrade.

Figure 7 indicates there is a difference in the seasonal effects, when comparing the two regions. In the Turku region, three out of the nine road sections show that deflections measured in August are lower than in May, whereas in Tampere, all the road sections show lower deflections in August. This shows an interesting difference in the recovery of the pavement strength, when comparing the two regions. Although the climate is similar for both regions, the higher precipitation in the summer month, seems to have a higher impact on the bearing capacity in the Turku region than in the Tampere region. A lower bearing capacity in the frost/thaw period might not be surprising, as the pavements normally accumulate more moisture in the unbound layers, due to melting snow and ice.

The interesting part is, however, if the influence of this possible excess water in the pavement can be detected by changes in the bearing capacity.

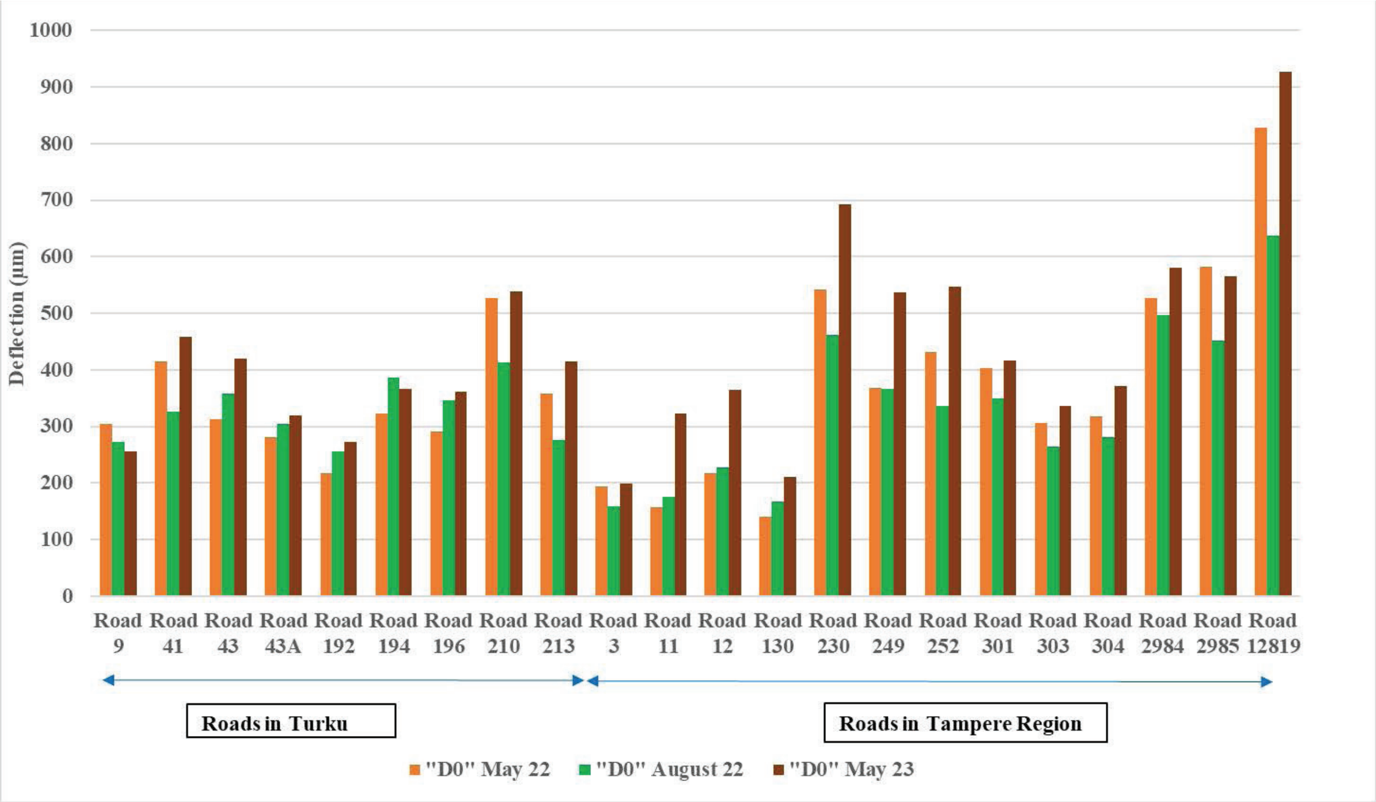

Figure 7. Center deflection measured by the iPAVe

Figure 8 shows it is not possible to make a clear conclusion on the effect of seasonal variation on the upper layers in the pavements. The frost/ thaw influence of the upper layers in the pavement seems to be on the same level, when comparing the May 22 and May 23 measurements. As asphalt temperature influence asphalt stiffness, the higher asphalt temperature in May 22 compared to May 23, table 1, should cause an expected higher deflection in May 22. However, Figure 8 does not show a significant difference between the deflections that can be justified by the differences in asphalt surface temperature. The reason might be, that the stiffness of an asphalt layer depends more on the temperature gradient than the surface temperature alone.

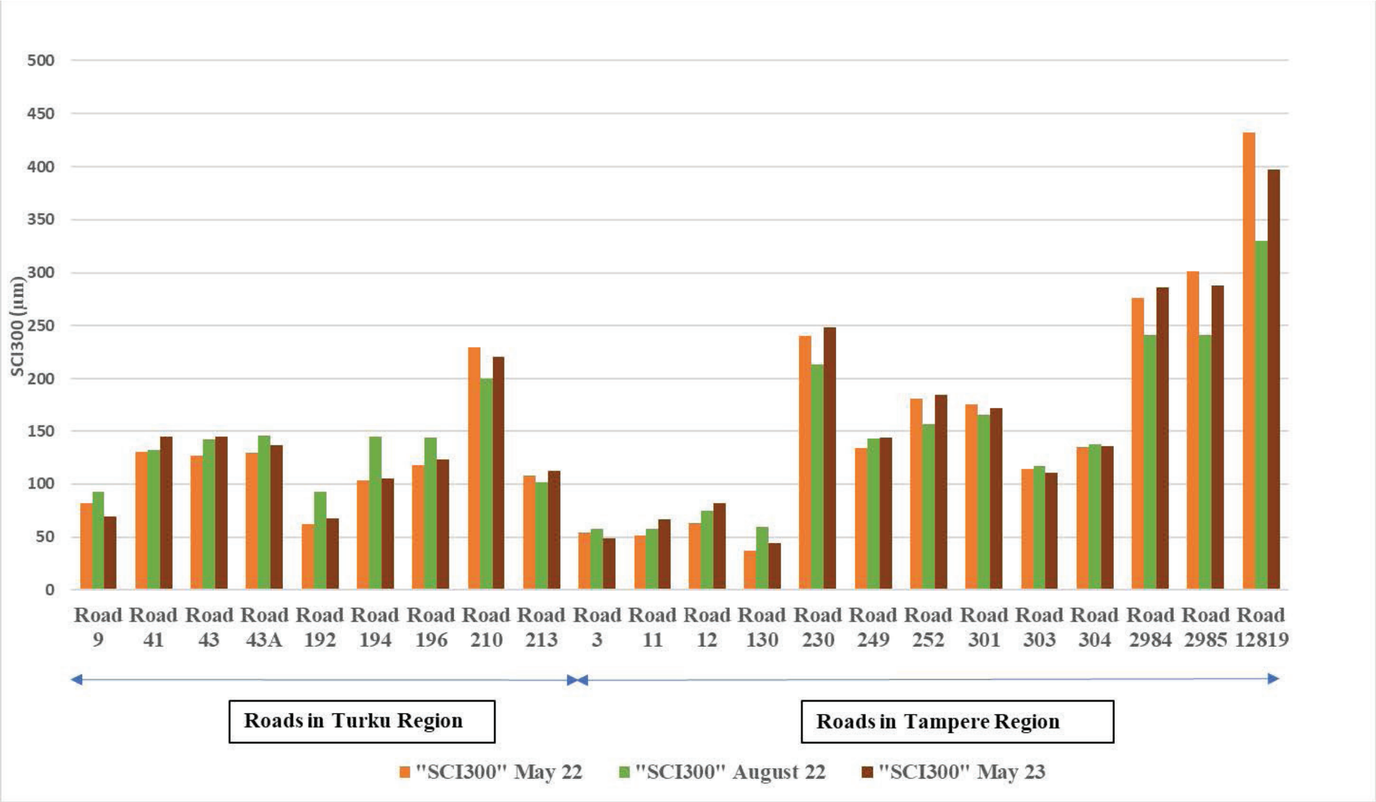

Figure 8. SCI300 calculated from measured deflections.

Looking deeper into the pavement, Figure 9 shows a noticeable lower structural capacity in May 23, than in the May 22 measurements, and clearly there is a visible higher SCISUB, and hence lower bearing capacity for the lower layers, when comparing the May 22 data with the May 23 data. The August 22 data shows that the lower layers of the pavements seem to have gained strength during the summer period. This can be a result of that the lower layer in the pavement dries out during the summer period.

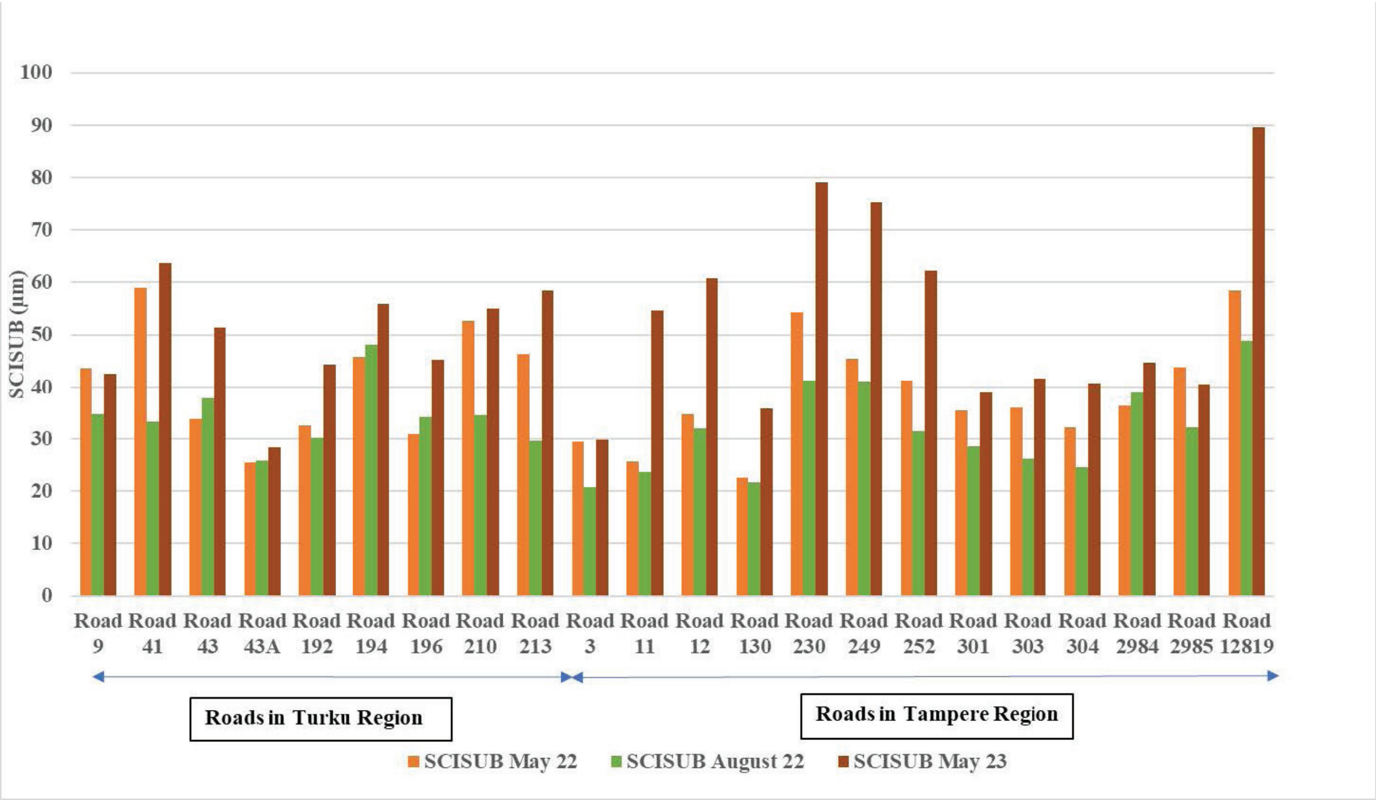

Figure 9. SCISUB calculated from measured deflections.

One interesting factor that can be used to explain the influence of seasonal variations on bearing capacity is the amount of pavement cracking. If the pavement is severely cracked, there is a high risk the rainwater penetrates through the pavement surface, keeping the unbound bearing layers and subgrade moist throughout the year.

The ability of the iPAVe to collect pavement crack data, simultaneously with bearing capacity, provides a unique opportunity to be able to directly compare changes in surface cracking with deflections. Figure 10 shows the measured total crack % for each of the roads, and the table shows there is no clear change in the amount of cracking that can explain why some of the sections shows a lower bearing capacity in May 23 compared to the May 22.

		IRI m/km			Rutting mm		
		May 2022	August 2022	May 2023	May 2022	August 2022	May 2023
Turku Region	Average IRI	1.39	1.39	1.51	8.99	8.67	9.39
	Average standard deviation	0.38	0.41	0.49	1.62	1.76	1.86
Tampere Region	Average IRI	1.85	1.84	1.92	9.45	8.92	9.74
	Average standard deviation	0.92	0.92	0.94	2.31	2.31	2.44

Table 2. Average IRI, m/km and rutting, mm measured by the iPAVe during measurements.

The changes in evenness and rutting have also been studied. The results presented in Table 2 shows that no significant change in evenness (IRI) and rutting is observed from May 22 to May 23, within the two regions. This can be explained by the fact that the changes of these two parameters often takes years. To study the seasonal effect on these parameters, requires additional measurements.

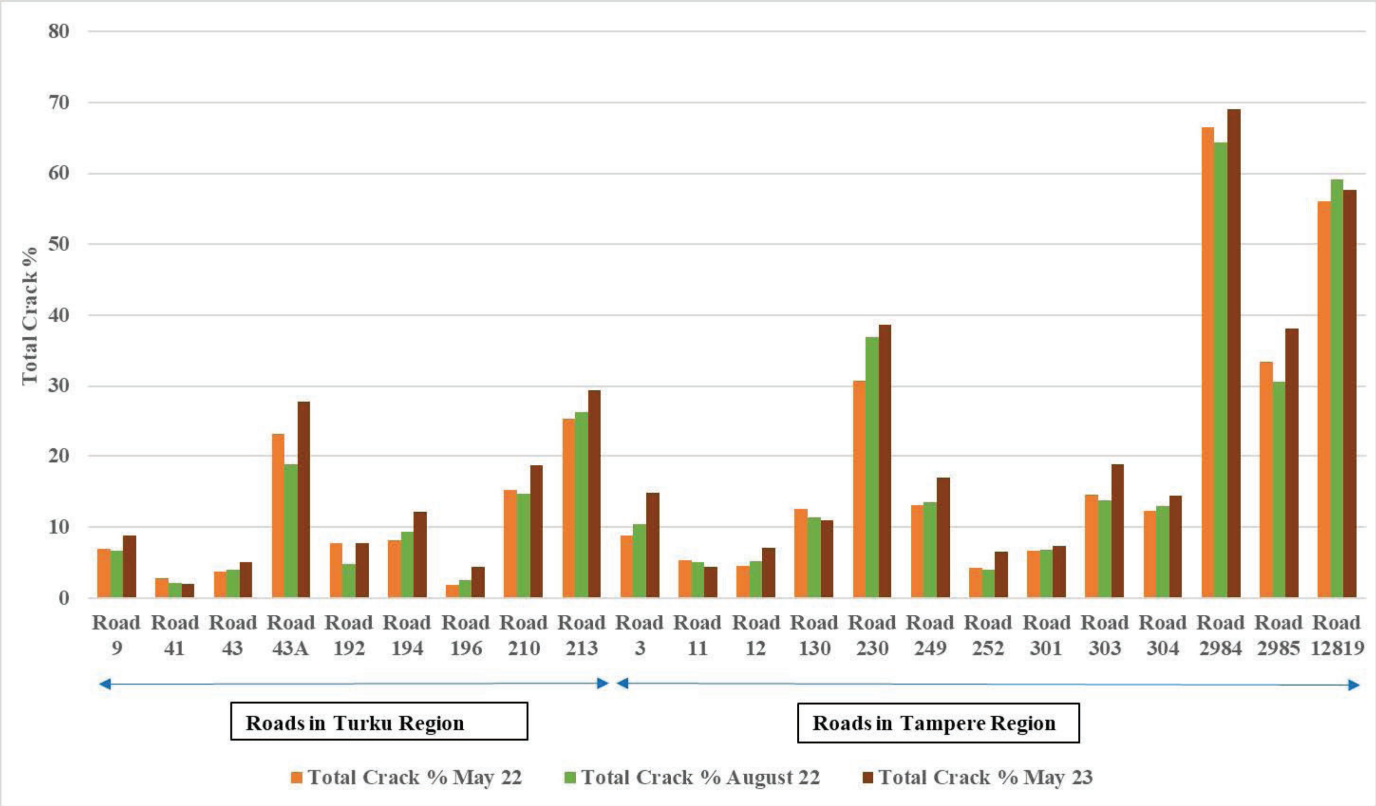

Figure 10. Total crack % of the pavements.

6 CONCLUSIONS

The paper shows there is a clear influence of seasonal variation on the structural capacity of the roads tested, but also that some of the road sections regain their bearing capacity during the summer period. This positive effect is considered to be caused by a reduction in the moisture in the unbound sublayers, during the summer period. Further analysis will be conducted to investigate the influence of moisture content. The paper also shows that no significant changes in surface characteristics of the pavements are observed from 2022 to 2023, therefore a study of the long-term impact of seasonal variation on these parameters is needed.

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Climate data