Measurement and analysis of homogeneity in asphalt pavements

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ABSTRACT

This paper describes a new and innovative measurement method, which uses laser scanning to determine the homogeneity of asphalt pavements.
The term "homogeneity of asphalt" is used in this paper to describe the even-ness of texture and surface characteristics (sub-centimeter) of the asphalt surface. The homogeneity of the new-laid compacted asphalt pavements is very important in order to secure a satisfactory lifetime of the pavement. This is particularly important where low temperature or coarse asphalt materials are used. It is also important for the usage characteristics of the road, notably the friction level presented to normal car tires. As of today, contractors have no measurement method of determining the required homogeneity of the new-laid surface, but have to rely on expertise and knowledge of the paving crew. In addition, the road authorities have no objective means of approving or rejecting the new-laid pavements.
The current laser scanner system operated by the Norwegian Public Road Administration is extended with the described method in order to measure homogeneity of the asphalt surface. The main advantage of this method is the possibility to measure a complete 4m width in one single run at normal driving speeds. Thus, the cost and risk of measuring the surface is optimized. This paper describes the advanced analysis software use in this method, and how innovative signal processing is used to extract the most important parameters from the measurement data.

Keywords: Bleeding, Friction, Maintenance, Performance testing, Software

1 INTRODUCTION

The question of homogeneity of the new-laid surface has come to light the last 4 to 5 years, but the problem is as old as asphalt itself. Few documented trials exist, and no international standardization has been done to date. Still, this paper will show that the issue is worth pursuing, as the Norwegian Public Road Administration (NPRA) has done in the few past years.

The macrotexture (0.5 to 50mm wavelength) of the new-laid pavement surface is an important feature because the resulting surface texture is the amalgamated result of many variables in pavement surface production. The surface texture may be subject to many different forms of analysis, most notably MPD (Mean Profile Depth), but the main obstacle with this and other simple measurement regimes is that the measurement is done in stripes or lines, and not by covering the complete road surface area.

To overcome this limitation, an NPRA research project was established to look into the possibility for surface area scanning as a method for measurement of texture, and hence homogeneity of texture.

The project described in this paper uses a statistical method to extract homogeneity data from the texture measurements. The platform for the texture measurement of the pavement is a new scanner-based area acquisition system (ViaTech, 2012). The pavement scanning system used in this project is the standard rutting and even-ness measuring vehicle owned by the NPRA, but with software adaptations for our purpose.

The principal base of this project is Handbook N200 Vegbygging (Statens Vegvesen, 2014), which is the current normal for the building of roads in Norway.

2 BACKGROUND

2.1 The Importance of Asphalt Texture

The pavement macrotexture (0.5 to 50mm) is of great importance, and reflects the quality of the pavement production. In addition, the resulting texture is important for the usability and longevity of the pavement, as we shall see.

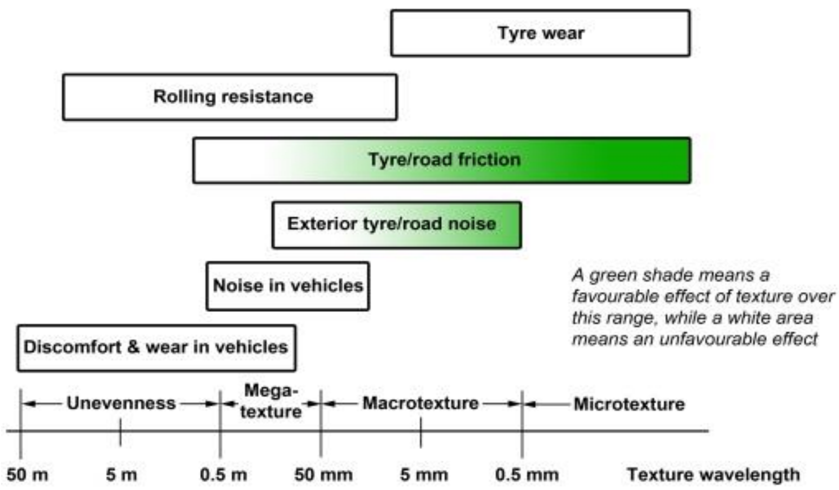

Figure 1 Texture Spectrum

The scope of this project is limited to the investigation of macrotexture, as defined in the image above. The spectrum of interest is then 0.5 to 50mm. The other parts of the texture spectrum is also of importance to the usability and longevity of the road surface, but those parts are not discussed here.

The three factors of new-laid pavement this study investigate are:

1) Homogeneity of the complete new-laid surface. This is a good measurement parameter for assessing the uniformity and quality of the production chain.
2) The presence of *open areas*, where the skeleton of the surface layer is too open. This will limit the pavement lifespan, and lead to fragmentation and separation.
3) The presence of *dense areas*, where the bitumen covers the aggregate (aggregate floating), and will give significant wet-friction problems.

These tree factors were currently not routinely investigated by area measurement in Norway, but some experiments with infra-red photography have addressed the homogeneity issue 1), by identifying areas with large temperature gradients after laying. The relevant measures to ensure stable laying temperature may then be taken. Unfortunately, no concluding evidence has been put forward that this method solves either of the two last problem factors reliably.

The production of pavement is checked for factor 2) by core sampling and calculation of asphalt density, and factor 3) by friction measurements. Both of these practices are in effect point sampling and not area covering methods.

2.2 Current state of homogeneity measurement

The use of homogeneity measurements for assessment of the new-laid pavement is not yet widely accepted. The current state-of-the-art is still MPD, or some similar texture measurement.

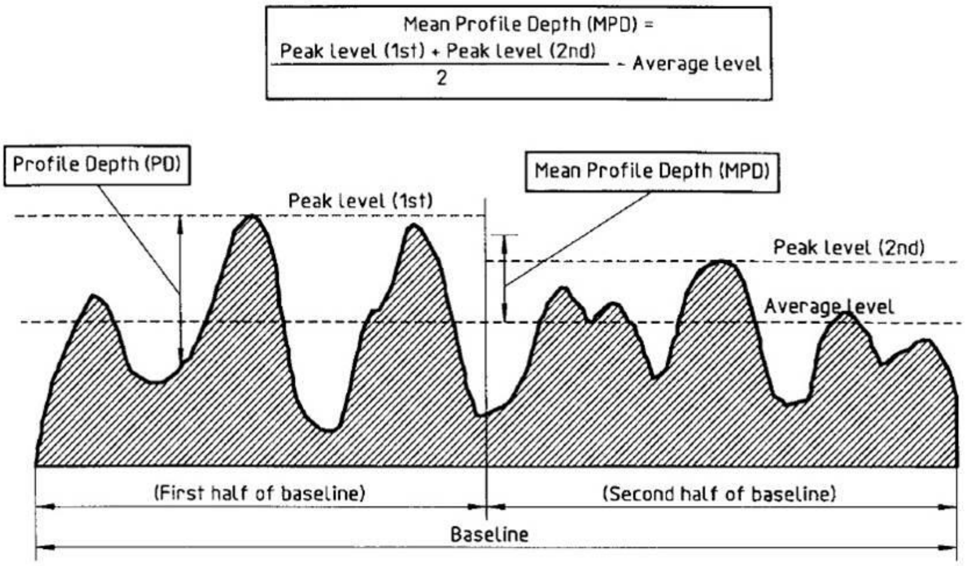

Figure 2, MPD Calculation Definition

The use of MPD is discouraged by some on the basis that it is a weak indicator on texture. It is evident that MPD filters the texture on a 50mm baseline by definition. This is at the extreme long wavelengths for macrotexture (0.5 – 50mm), and MPD is therefore unsuited to detecting the full macrotexture spectrum. Other advanced methods, such as PSD (Power Spectral Density), are more applicable. The problem with those advanced methods are primarily the inability of the measurement equipment to measure the complete area of the road surface when moving in normal vehicle speeds. The use of these methods are then incompatible with large-scale road area measurement.

An important aspect one has to take into account is that MPD and many other measurements, including the described homogeneity measurement, calculates the *depth* of the texture. It is assumed that the depth of the texture is closely correlated to the wavelength of the texture. In fact, the depth of the texture is more spread out in a *spectrum of depths* than the longitudinal waves is spread out in a spectrum. This is so because the longitudinal spectrum is closely correlated to the aggregate size, but the texture depth is in addition correlated to the degree of compacting as well. In practice, the spectrum of depths is the most interesting variable, and has the most significant impact on usability and longevity.

2.3 Lessons learned

Early experiments on texture measurements for homogeneity purposes (Lundberg et. al.) were performed in Sweden in 2011. The experiments gathered some important knowledge about the measurements.

1) The texture measurement must not be recorded too late after surface production (worn and compacted by traffic), or too early (not hardened and not set properly).
2) The texture measurement itself is partially flawed, and a calibrating strategy must be devised. This is due to the choice of sensor, which in all cases are imperfect.
3) The production contractor is skeptical to this type of measurement, mostly caused by concerns about 2), and the risk of penalty.

These are general prerequisites that must be taken care of when scaling up the measurement regime. The item 3) in particular must be addressed with great care in order to implement homogeneity measurements in the pavement production chain. In Norway, this item is currently addressed as the main development path.

2.4 The use of stock measurement vehicles

The Norwegian Road Authorities currently has 15 ViaPPS measuring vehicles, measuring initial rutting and even-ness, among other things. The measurement regime was established in 2005. Currently, all the Norwegian roads, except county and private roads, are measured one time per year. All new-laid roads inside the regime is measured for rutting and even-ness initially after laying. All raw data from the measurements is then kept in store, and may be used for any purpose at a later time.

Figure 3: ViaPPS measurement vehicle

The scanning laser attached to this type of vehicle is very well suited to the homogeneity measurements. The laser may be used unchanged, as well as the vehicle itself. The texture analysis and report generator is implemented as an extension to the existing software. The object of the project described in this paper was to establish a prototype signal processing platform for homogeneity measurements. If successful, the signal processing could be used on any measurement raw data from the vehicles recorded since 2005.

The homogeneity measurement is an additional module in the ViaPPS signal processing suite. All 15 vehicles measure data that can be used in his module. The fact that one single pass of collected raw data may be used for a variety of purposes is an important aspect of the ViaPPS measurement vehicle. In this way the measurement of initial condition of new-laid pavement is optimized, and the cost of the measurement is spread over many different consumers and many different purposes.

2.5 The goal of the project

The primary goal is to use existing measurement systems for homogeneity measurement and analysis. The homogeneity analysis will then be used to improve the quality and lifespan of produced pavement.

3 MEASUREMENT PLATFORM AND METHOD

3.1 Measurement Platform

The platform used to acquire the necessary data is shown in the figure below:

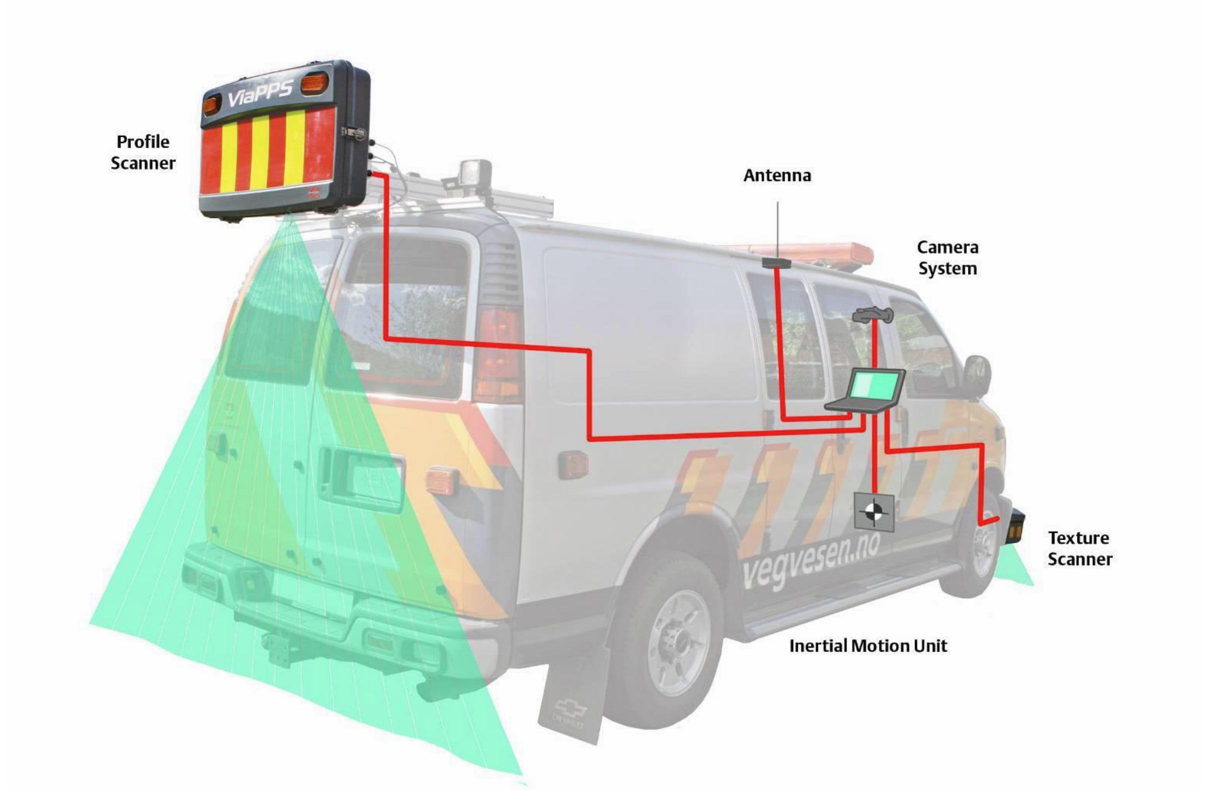

Figure 4: ViaPPS scanner position

The ViaPPS vehicle, with its scanning laser attachment, is normally used to perform rutting, transversal profile and cross fall measurements.

In our case, the raw sample-data from the laser scanner, about 600 points in a 4 meters transversal line, is used to calculate the indices for homogeneity, open and dense areas. This line is scanned once every 1/140 second. This data acquisition is done simultaneously with the normal operation of the scanner, and is completely transparent. This means as a consequence that all historically collected raw data from previous runs may be used to calculate the three new factors (homogeneity, open and dense areas).

3.2 Method of analysis

The analysis of the raw data from the scanner is based on a statistical calculation, rather than a traditional analytic approach. This is because the required three factors (homogeneity, open and dense areas) are of a statistical nature. The background for this choice is very similar to other kinds of studies where the goal is to extract (reasonably) simple parameters out of large collections of data.

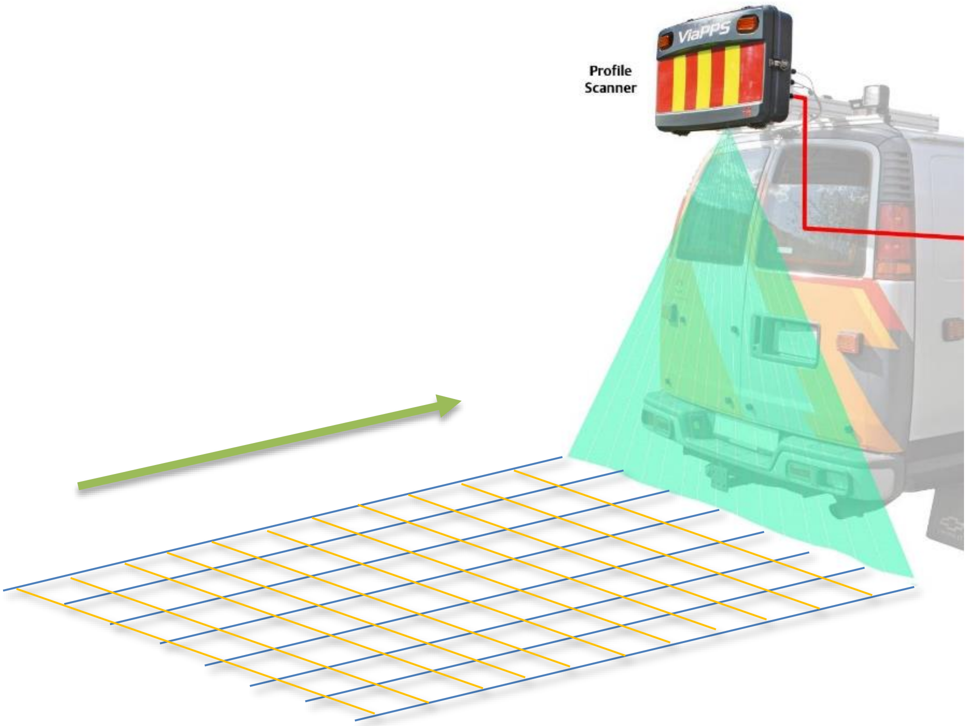

Figure 5, Cell Definition

The scanned area (which may contain the whole length of the new pavement) is divided into cells, which are the entity used for statistical calculation. The cell size is still subject to empiric trial, but the initial tests have used cell size of 1 meter lengths of the lane (4 meters wide) divided into 25 sub-lanes. One cell is then 0.16m wide and 1m in length.
To put this into proportion, one cell is a set of 201 discrete measuring points at 60 km/h (16.7m/s) measuring speed.

$$Npoints = (1.0 * \frac{140}{16.7}) * \frac{600}{25} = 201$$

Each point is measured by a relative accuracy of about 1mm. This implies that he texture depth spectrum that can be analyzed is limited to 1.0 to 50mm. This is close enough to the macrotexture spectrum of 0.5 to 50mm, and this is sufficient to calculate statistical parameters for the cell, such as Standard Deviation, sigma (σ), which later is used to form the basis for the three indices.

In 2015 and 2016 the old 2005 issue ViaPPS laserscanner will successively be replaced, and the new unit will cover the complete 0.5 to 50mm spectrum.

3.3 Statistical tools

The cell raw data is the basis for the calculation of cell sigma. This number is experimentally shown to have a closely correlated relationship to the surface texture, as calculated by MPD (Mean Profile Depth) calculations and others.

In other words, it is the surface texture which makes the basis for the homogeneity analysis.

4 RESULTS

4.1 Investigating the correlation

The output of the statistical calculations are presented in a map describing the texture along the recorded surface:

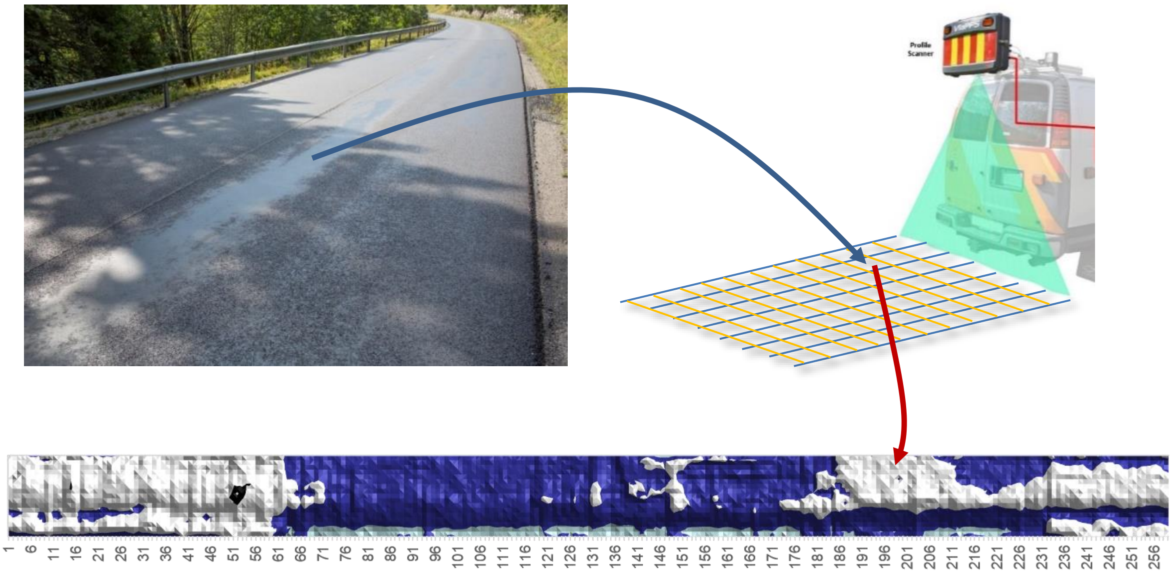

Figure 6 Texture Map

The system is not yet finalized and in production, but the initial test period has been performed. The results from those tests show good correlation between indicated problem areas by the homogeneity analysis and genuine problem areas on the road surface.

The actual representation of the texture map is shown in the following figures.

The following images show an example of the correlation between an indicated dense area, and the photographic evidence of the same area.

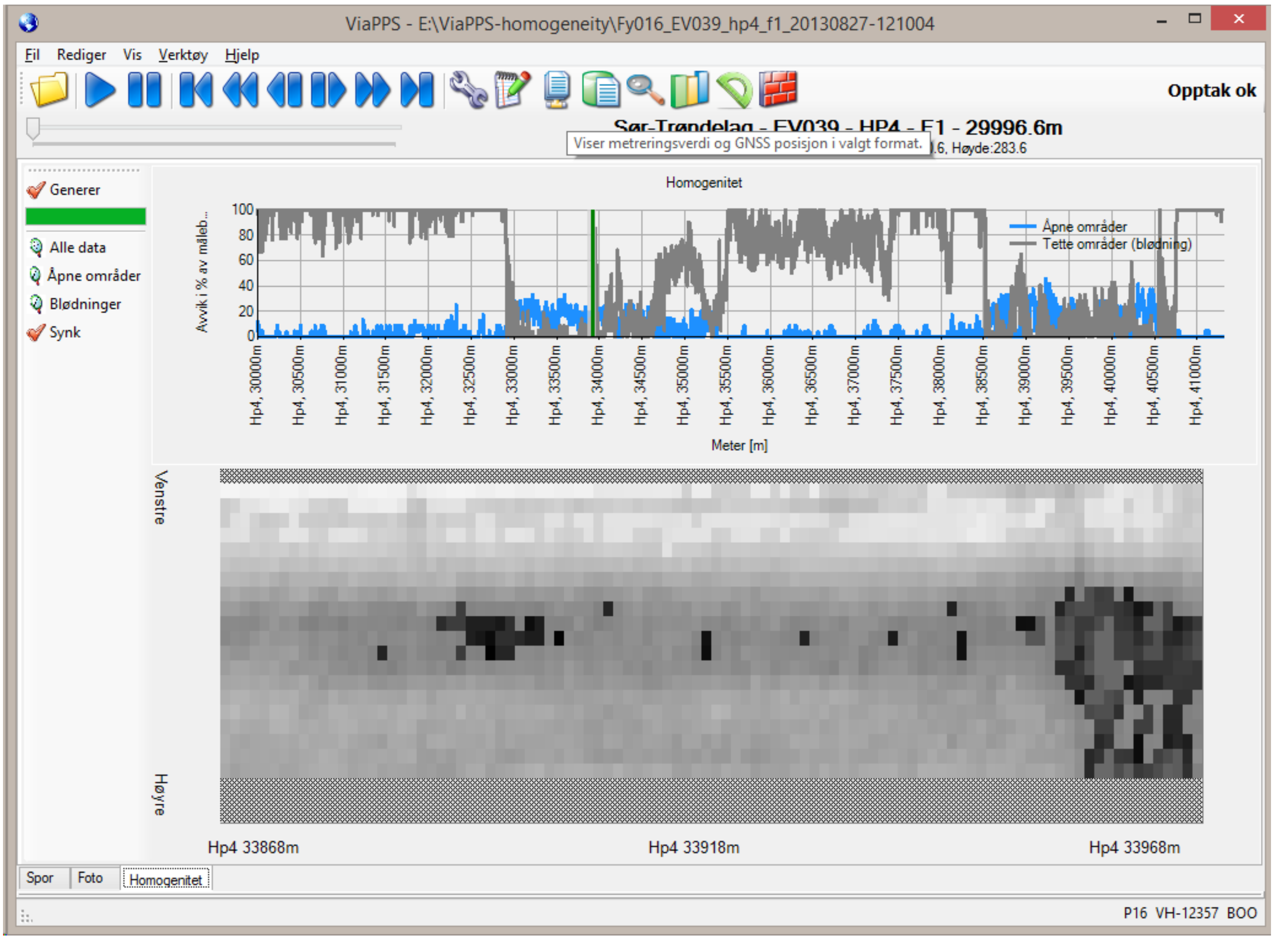

Figure 7 Display of Problem Area

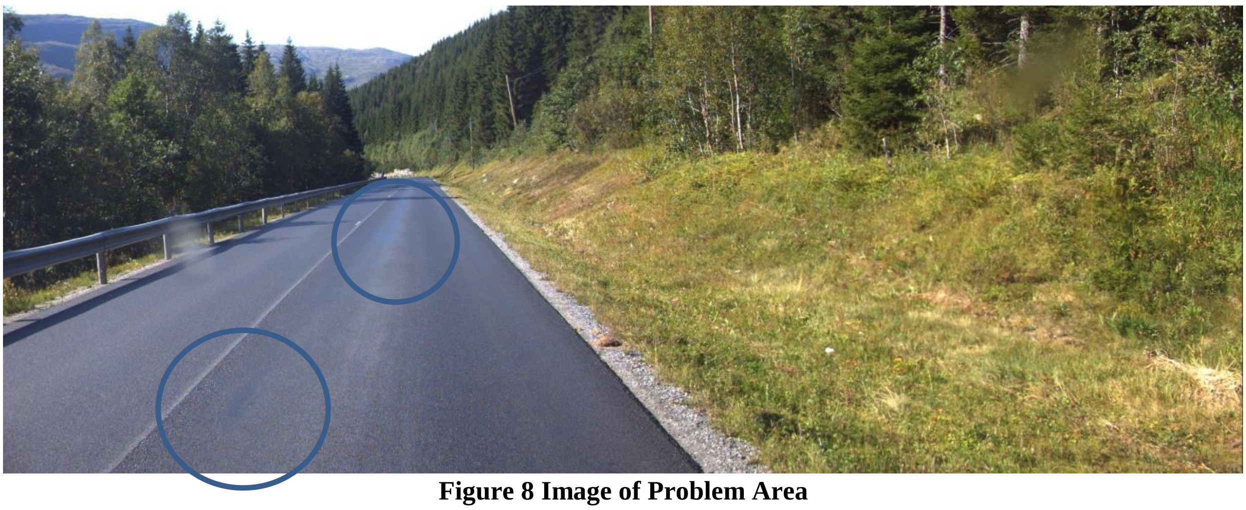

Figure 8 Image of Problem Area

In order to simplify the interpretation of the homogeneity analysis, the system provides the user with a graphic representation of the percentage of problem areas along the road surface.

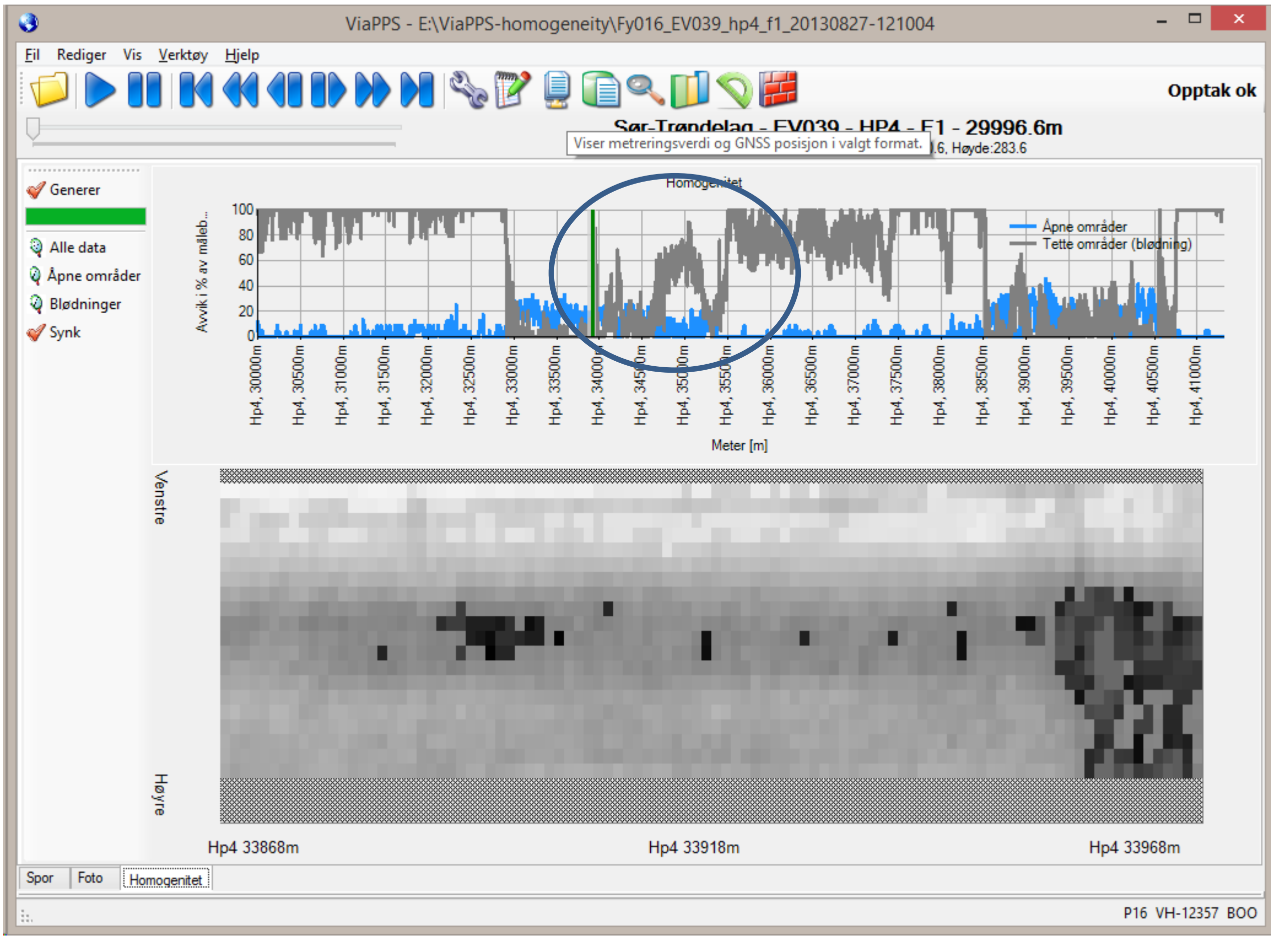

Figure 9 Percentage of problem area graph

Dense and open areas have each one such graph, and this is used to get a quick overview over the complete measured part of the road. Parts with significant problems may then be inspected by eye and by camera.

4.2 Further plans

The next step for the ViaPPS Homogeneity module is to implement the homogeneity measurement as a screening for open and dense areas in new-laid pavement. In this way, the ViaPPS is used as a fast and effective method to indicate areas of interest, and then use traditional methods such as photos and core samples to secure evidence of surfaces that must be re-done or improved.

Further on, the ViaPPS Homogeneity system may be used directly as evidence of problematic surfaces. This requires the cooperation of the contractor, and a high level of trust in the system. This trust must be established over a period of some years where the ViaPPS gradually is accepted as a standard for measuring homogeneity.

REFERENCES

Lundberg, Thomas, 2012. "*Kontrollmetod för nya vägbeläggningar – Makrotextur*", VTI publication, Linköping, Sweden.

Statens Vegvesen, 2014. "*Håndbok N200, Vegbygging*".

ViaTech, 2012. *Product Sheet ViaPPS*, www.viatech.no/ezpublish-4.2.0/local/datasheets_en/ViaPPS_ENG.pdf