Measurement and analysis of inhomogeneity in asphalt pavements

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ABSTRACT: This paper describes a new measurement method using laser scanning to determine the homogeneity of asphalt pavements. The term "homogeneity of asphalt" is used to describe the even-ness of texture and surface characteristics (sub-centimeter) of the asphalt surface. In-homogeneity is the opposite; namely an irregular, un-even asphalt surface. The homogeneity of the compacted asphalt pavements is very important in order to secure a satisfactory lifetime of the pavement. This is particularly important where we use coarse asphalt materials. It is also important for the usage characteristics of the road, notably the friction level presented to normal car tires. This is both true for new-laid surfaces and for surfaces well into its life-span. As of today, contractors have no measurement method of determining the required homogeneity of the newly laid surface, but have to rely on expertise and know-how of the paving crew. In addition, the road authorities have no objective means of approving the pavements for homogeneity. The Norwegian Public Roads Administration has recently purchased 15 ViaPPS measurement vehicles, with the purpose to measure road characteristics like rutting, texture, cross-fall and other parameters related to maintenance planning. However, the laser scanner included in these instruments may, with some adjustments, be used 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. In addition to the measurement vehicle itself, advanced analysis software with focus on homogeneity must be used to extract the correct level of the parameters in question from the measurement data. Some areas of the E6 road south of Trondheim have been measured with the standard ViaPPS vehicle, with focus on detecting inhomogeneity. These preliminary measurements show a good correlation between actual inhomogeneity (visual observation) and measured values using the laser scanner.

KEY WORDS: Homogeneity, measurement, asphalt, pavement.

1 INTRODUCTION

1.1 Principal problem description

The question of homogeneity of the newly laid surface is fairly new. Few documented trials exist, and no international standardization has been done. Still, this paper will show that the issue is worth pursuing.

The macrotexture (0.5 to 50mm wavelength) of the newly laid pavement surface is an important feature, and may be subjected to different forms of analysis. Many variables in pavement surface production can be controlled by analyzing this texture. The project described in this document uses a statistical method to extract useful data from the texture measurements. The platform for the actual 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 Norwegian Road Authorities, but with software adaptations for our purpose.

The three factors of newly produced pavement this study investigate are:
1) Homogeneity of the complete newly laid surface. This is a good measurement parameter for assessing the quality of the production chain.
2) The presence of *open areas,* where the skeleton of the surface layer is too open, and this will limit the pavement lifespan, and lead to fragmentation and separation.
3) The presence of *fat areas*, where the bitumen covers the aggregate (aggregate floating), and will give important wet-friction problems.

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

Finally, the principal base of this project is Håndbok 018 (Statens Vegvesen, 2011), which describes the method of building roads in Norway.

1.2 Current state of homogeneity measurement

The use of homogeneity measurements for assessment of the newly laid pavement is not widely accepted, and is in use in but a few countries. Sweden is one of the few, and VTI, Linköping (The Swedish National Road and Transport Research Institute) has done an extensive work on this problem since 2009. Much of value has been extracted from the VTI report (Lundberg, 2012) concluding the 3 years' work. The main usage of these measurements is to give immediate feedback to the contractor.

The VTI report describes not only a measuring method, but extends the strategy the whole way into extracting parameters for pavement quality control and road maintenance. In other words, the measured data is analyzed and may produce a set of control measures, which is then used to improve quality of the pavement.

The work at VTI has some differences from our effort; most notably the Swedish use 3 separate single point lasers measuring the left track, middle of lane and right track. The presented method measures the whole width of the lane, all 4 meters wide, and calculates the homogeneity parameters of the complete area. Still, the VTI work has some important real-life experiences described in the report (Lundberg 2012):

1) The texture measurement must not be recorded too late after surface production (naturally), or too early (more difficult to understand, explanation follows below).
2) The texture measurement itself is partially flawed, and a calibrating strategy must be devised. This is due to the choice of sensor.
3) The production contractor is skeptical to this type of measurement, mostly caused by concerns about 2), and the risk of penalty.

The first point in the list above deserves some comments. The reason for this "too early" problem is simply that the texture of the newly produced surface changes over time and usage. The by far largest change (related to our problem) is from virgin pavement to about 100,000 vehicle passings. Later on, the change progresses much more slowly. So, in order to ensure the stability and credibility of the measurements, the texture recording is performed after 100.000 vehicle passings. This means about 2 to 4 weeks of usage on a main road, and may be calculated in beforehand by using traffic statistics.

1.3 The use of stock measurement vehicles

The Norwegian Road Authorities currently has 15 ViaPPS measuring vehicles, measuring rutting and even-ness, among other things.

Figure 1: ViaPPS measurement vehicle

The scanning laser attached to this type of vehicle is very much 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.

1.4 What is the goal of all this

The primary goal is to use existing measurement systems for homogeneity measurement and analysis. The homogeneity analysis (refer to 2.2) will then be used to improve the quality and lifespan of produced pavement.

2 METHODS

2.1 Measurement Platform

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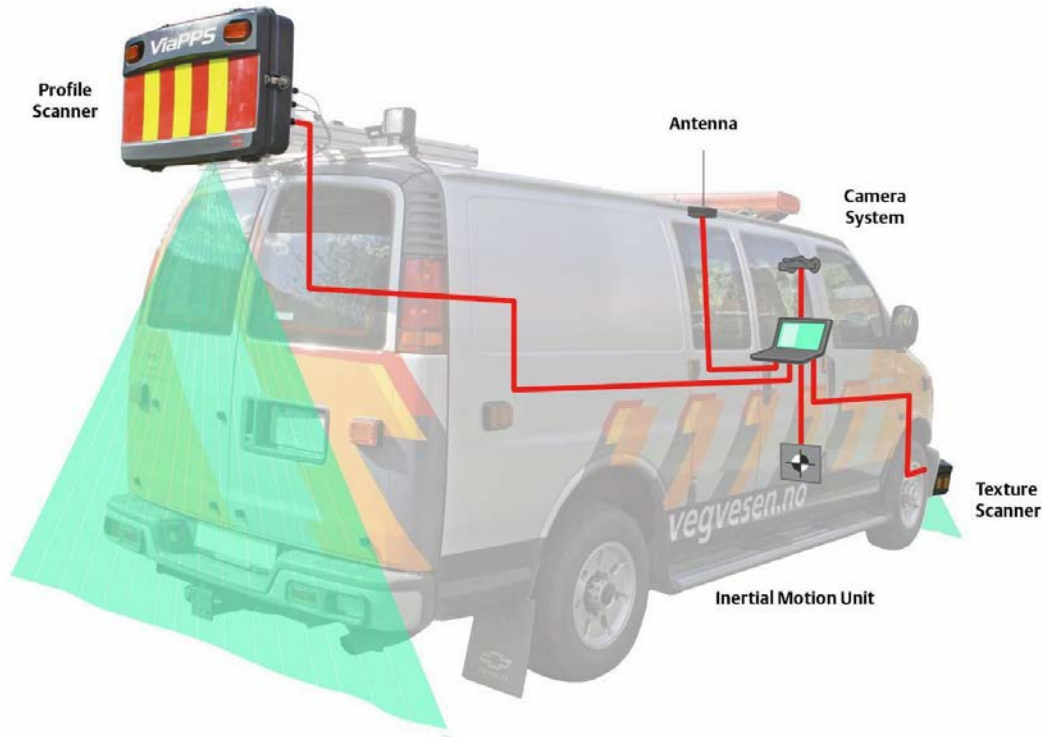

Figure 2: ViaPPS scanner position

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

In our case, the raw sample-data from the laser scanner, about 600 points in a 4 metres transversal line, is used to calculate the indices for homogeneity, open and fat 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 fat areas).

2.2 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 fat 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.

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 subject to empiric trial, but the preliminary tests have used cell size of 1 meter lengths of the lane (4 meters wide) divided into 5 sub-lanes. One cell is then 0.8m wide and 1m in length.

To put this into proportion, one cell is a set of 1006 discrete measuring points at 60 km/h (16.7m/s) measuring speed.

$$Npoints = (1.0 * \frac{140}{16.7}) * \frac{600}{5} = 1006$$

This is sufficient to calculate statistical parameters, such as Standard Deviation, sigma, σ, which later is used to form the basis for the three indices.

2.3 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.

3 RESULTS

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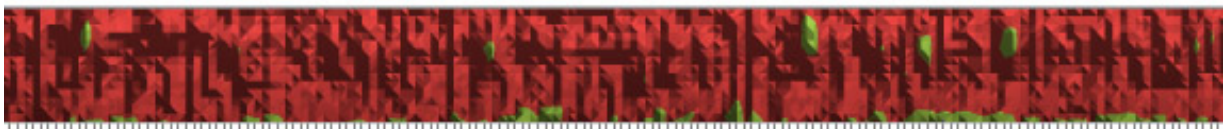

Figure 3: Pavement section homogeneity map

In the above image, the statistical distribution (homogeneity) of the cells (0.8m x 1m) is coded in color, and the light green spots are areas (or cells) with *open structure*, which is factor 2) in the list of homogeneity, open and fat areas. The red/black areas indicate different levels of macrotexture, the lighter color, the higher macrotexture value.

Similar maps may be produces for *fat areas*, and the complete map gives a visual impression of the overall homogeneity of the measured pavement.

In addition to maps of this kind (which is visually simple, and gives the reader a quick overview), textual reports are produced. These reports contain position and size of the problematic area, and will be the background for bonus and penalty discussions with the contractor.

Figure 4: Pavement section open areas

Figure 5: Pavement section fat areas

4 DISCUSSION

4.1 ViaPPS data compared to VTI procedure

The VTI procedure described in Lundberg, 2012 is a very good strategy, on many levels. From the low level data acquisition to the top level method of analysis, it gives a good framework for improvement of pavement quality. The VTI method is by far the most advanced complete analytic strategy in the Nordic countries. The VTI method is therefore the measuring stick of our own enterprise.

It is therefore necessary for us to compare the two methods, and to point out the differences and similarities.

Table 1: Comparison of VTI and ViaPPS

Item	VTI method	ViaPPS method
Measurement principle	3 single point lasers	4m scanning laser
Measuring coverage	3 lines along the lane	Complete pavement area
Raw data analysis	MPD calculation	Statistical analysis
Measurement strategy	New pavement after 100k vehicles	New pavement after 100k vehicles
Measures extracted	Reward and/or penalty to contractor	Reward and/or penalty to contractor

The above shows that the methods are most similar, except of the measurement method, which is area-covering in the described system (ViaPPS).

Tests comparing the ViaPPS and VTI method will be executed. These tests will be performed at the same location and time.

To sum up a conclusion of this paper:

1) The ViaPPS solution is area-covering; i.e. the whole pavement area is measured.
2) The ViaPPS solution is an add-on to existing measurement vehicles and existing hardware.
3) Statistical analysis is used to extract homogeneity parameters.
4) The homogeneity measurement may provide an important input to the laying quality control.

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