# A NEW MOBILE SYSTEM FOR SAFE PERFORMANCE CONTROL OF THE ROAD MARKINGS

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## ABSTRACT

A superior road marking will increase the level of road safety. Irrespective of darkness or rain, the visual guidance provided by the retroreflecting properties of the road markings is vital for the road user.

Up to now, the use of a range of portable instruments have been the only way to control all the performance parameters of a road marking, in dry and wet conditions. The use of hand held instruments is time-consuming, and at the same time, both the operator and the road user can be exposed to extensive traffic risks. The safety aspect has resulted in a lot of restrictions regarding the use of hand held instruments, especially on the heavy trafficked network of roads. The absence of performance controls is often the consequence.

Now, for the first time, it is possible to control each and all of the relevant performance parameters of the road markings in one dynamic operation. The dynamic (mobile) performance control is more efficient and much safer than any other way of controls and measurements. In the assessment, parameters like Retroreflection in dry conditions, Retroreflection during wetness, Luminance coefficient (Qd) and Skid resistance (SRT) are measured and predicted. All parameters have been validated by the Swedish National Road and Transport Research Institute. Simultaneously, geometry of the road marking as well as an estimation of wear and tear, are measured.

The method takes advantage of the latest available technology to enable the continuous measurement of each and every cm of the road markings. The survey takes place in normal traffic flow, at the same speed as the other traffic, and without any disturbance of the other road users. This paper describes the method as well as the quality of the results.

## 1. FROM MANUAL TO AUTOMATIC PERFORMANCE CONTROL SURVEYS

### 1.1. A long-awaited method

Before 2008, only one of the parameters (retroreflection in dry conditions) to control road markings could be measured with mobile surveys, i.e. using a retroreflectometer. The rest of the prescribed parameters to control road marking parameters could only be controlled using handheld portable equipment. However, using handheld control methods is time consuming and the surrounding traffic constitutes a remarkable risk for the operators performing the measurements. The consequence, when the parameters are difficult to assess, is often the absence of performance controls.

In 2008, a mobile system for safe performance control of road markings was introduced after several years of testing, model design and verification. The goal was to find an efficient, yet accurate, method to measure or predict all the parameters that describe the function and status of the road markings. The system should be able to control new road markings as well as old and do this in a safe way without closing the road.

The new system, The Road Marking Tester (RMT), is based on Laser Road surface Tester (Laser RST), PAVUE and AIES technique, combined with a retroreflectometer. This combination proved to be able to measure or predict all the necessary parameters.

### 1.2. From idea to a production system in 4 years

The RMT is the result of a 4-year research and development project by the Swedish National Road and Transport Research Institute (VTI), LG RoadTech and Ramböll.
The main idea was to find a mobile method that could control the Retroreflection in wet conditions. The predominant technique for increasing road marking performance in wet weather is to make the surface of the marking profiled. Consequently, a reasonable hypothesis is that there is a relationship between wet weather performance and the height of that profile, i.e. there should be a correlation between the wet weather reflection and the macro-texture of the surface. Furthermore, the reflection of a dry road marking is dependent on the number of glass beads on the surface. Probably, this number of active beads as well as the area of vertical walls and embedding of the glass beads also has an influence on the reflection of a wet surface
Via several field tests, and a full scale prototype, it was finally verified that such a mobile method was found, the RMT. The RMT is a combination of traditional mobile surveys on road markings and the knowledge brought from Ramböll RST concerning image analysis and laser based condition surveys with the Laser RST and PAVUE technique. The laser RST technique has been used for measuring road surface unevenness and more for more than 30 years. It is well implemented and accepted technique. The system consist of several technical components, e.g. specially developed reflectance meter, high speed camera, retroreflectometer, 3D camera, front camera, luxmeter, DGPS.

### 1.3. Each and all of the performance parameters

With the new method, it is possible to control each and all of the relevant performance parameters of the road markings in one dynamic operation. Also the geometrical dimensions of the road marking can be measured in the same operation. The new method can supply these parameters:

- Night visibility/Retroreflection in dry conditions, $R_L$(dry)
- Night visibility/Retroreflection during wetness, $R_L$ (wet) *
- Daytime visibility/Luminance coefficient, Qd *
- Friction/Skid resistance, SRT *
- Dimensions (W, L, T)
- A calculation of wear and tear
- GPS coordinates

** Predicted parameter, validated by the Swedish National Road and Transport Research Institute*

## 2. PARAMETER VERIFICATION AND QUALITY

All parameters have been verified by the Swedish National Road and Transport Research Institute (VTI) (Lundkvist and others 2008).

2.1. Retroreflection in dry conditions

Today there are mobile and automated methods to measure the dry retroreflection (using a retroreflectometer, e.g. the Ecodyn, Laserlux, Zehntner ZDR 6020, LTL-M etc). This is a well established method.

2.2. Retroreflection during wetness

In theory, it is possible to use a retroreflectometer to measure also the wet retroreflection. In practise however, due to splash and spray on the lenses, these instruments are not suitable for measurement on wet surfaces. Therefore, the wet weather performance must be calculated from other parameters, measured on dry surfaces.
A combination of values from the retroreflectometer and the specially developed reflectance meter (OPQ Systems RM-L1) is used to predict the Retroreflection during wetness (RL,wet). The model development was based on 133 road sections. In Figure 1, the correlation between RL,wet measured with a handheld LTL 2000 and predicted RL,wet based on measurements with the RMT is shown. With a 90 % prediction interval, the magnitude is ± 16 mcd/m2/lx and PRESS-value is 9 mcd/m2/lx. Hence, the difference between calculated and measured values will, in general, be 9 mcd/m2/lx and the difference with 90 % probability in the interval ± 16 mcd/m2/lx.

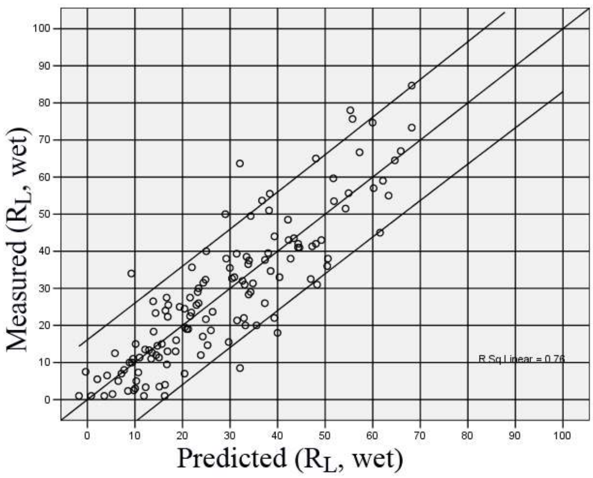


*Figure 1 Correlation between calculated and measured retroreflection for wet road markings with 90 % prediction interval (Lundkvist and others 2008).*

2.3. Luminance coefficient

The daylight visibility using the luminance coefficient (Qd) is predicted using a specially developed reflectance meter measuring a deflection value.
The reflection value from a sensor may be used for determination of luminance coefficient. The value is high on dark surfaces and low on more bright surfaces. Figure 2 shows the relation between reflection value and Qd for some few markings.

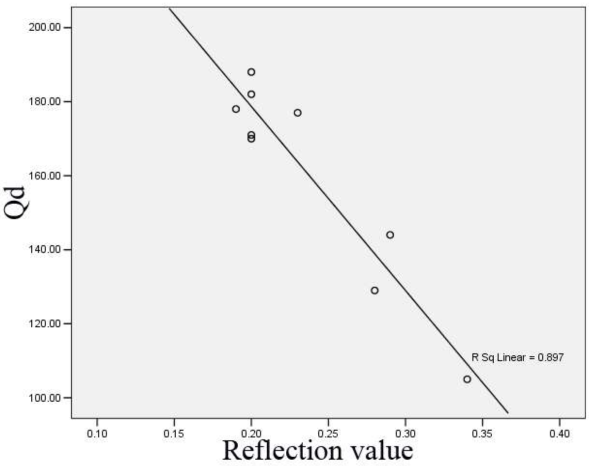


*Figure 2 Relation between reflection value and luminance coefficient, Qd [mcd/m2/lx] (Lundkvist and others 2008).*

As can be seen from the figure the number of test sections was rather small in the study (#9). Despite a high coefficient of correlation this leads to, r = 0,95. A 90 % prediction interval will be of the magnitude ± 17 mcd/m2/lx. More test sections should most likely mean an improved precision.

## 2.4. Skid resistance

The friction of the road markings are predicted using the combined information from a laser sensor and a retroreflectometer.

The relation between friction/RL(dry) and MPD for road markings is complex. For older markings friction is mainly dependent on retro reflection. For new markings texture has more influence. In practise, this means that different models have to be used for older and newer road markings respectively. A special model is also needed for profiled road markings. VTI has modelled the correlation between predicted friction from measurements with the RMT compared to wet friction measurements with PFT combining the three models. Figure 4 shows the correlation between predicted and measured friction from both newer and older road markings as well as flat and profiled road markings using three combined models. As can be seen, the prediction model shows very good correlation (R2=0.891).

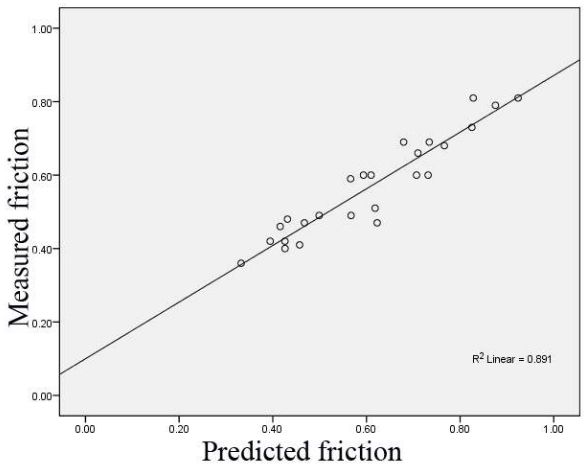


*Figure 3 Correlation between calculated and measured wet friction (using PFT) for new, old, profiled and flat markings.*

### 2.5. Thickness

The thickness is measured using a lasers sensor. Two instruments have been used as reference, one from VTI (Sweden) and one from VTT (Finland). The correlation between these was r = 0.98. The thickness measured, mobile, with a laser had the correlation r = 0,92 with booth reference instruments (Figure 5).

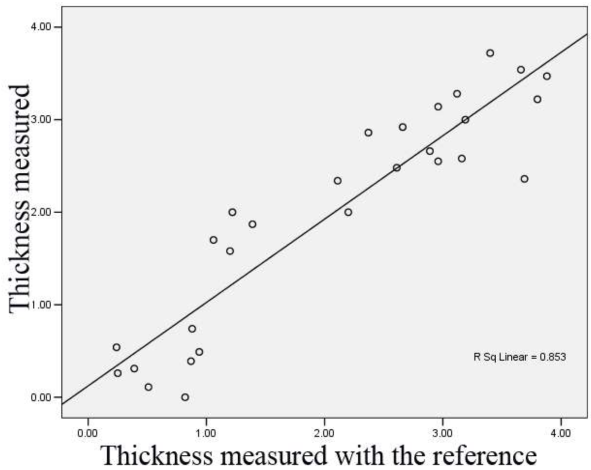


*Figure 4 Thickness (mm) of road marking measured mobile with laser and with reference instruments (Lundkvist and others 2008).*

### 2.6. Geometry

The geometry of the road markings, i.e. width, length, gap and design, is measured using a vertical camera and PAVUE/ AIES technique. For determination of geometric properties of road marking continuous photographs were taken from the RMT (mobile). Figure 6 shows examples on three marking types.

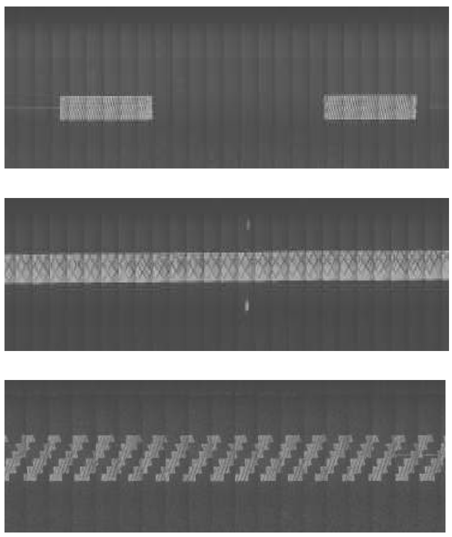

*Figure 5 Digital images of three marking types taken during mobile surveys in 70 km/h (Lundkvist and others 2008).*

From the images the marking type and geometric features can be determined (e.g. length, width and gap size). The position of markings is GPS tagged. Furthermore, the wear and tear can be interpreted from these images.

## 3. EXPERIENCES FROM PERFORMANCE CONTROL IN PRODUCTION

The RMT is run by one person. It performs measurements in normal traffic speed. Data is sent to office for post processing of the various parameters. Results can be gathered in a data base for easy access through a customised data viewer.

Extensive performance control measurements of more than 30 000 kilometres has been made using the RMT in 2008-2010 for the Swedish Transport Administration. That has provided a large volume experience from field measurements.

Data from these large scale road marking measurements with the complete set of road marking control parameters have provided an enhanced base for determining the status of road markings on the entire Swedish road network.

From 2011, yearly national measurements of approximately 6 600 km with the RMT will be performed in Sweden based on a Method description for mobile measurements (The Swedish Transport Administration 2009).


*Figure 6 The measurement equipment is easily moved from one side of the vehicle to the other for measurements of the side road markings and the centre road marking, respectively. Measuring the centreline, the equipment is positioned just above the centre road marking, never extending to the other road lane.*

### 3.1. Use of measurements

It is important that the road markings are kept in good condition with high quality for:

- Visual guidance – a quality road marking supports the road user by outlining the direction and design of the road, enabling the car driver to plan a comfortable and safe ride.
- Preview time – optical performance and geometry of roadmarkings are providing a safe reaction time during driving
- Traffic safety – road markings help the road user to stay in the intended line.

- Law enforcement – road markings are a part of, and act as, a reinforcement of the traffic regulations
- New technology – quality roadmarkings constitute an essential support for new technology.

The measurements can be used to ensure the quality of the road makings through:

- Control of old markings
- Maintenance inventory
- Coordinate file to use by the Contractor to steer the marking equipment to optimise the production
- National measurements on network level

A superior road marking will increase the level of road safety. Irrespective of darkness or rain, the visual guidance provided by the retroreflecting properties of the road markings is vital for the road user. Therefore it is important to control the quality of old markings. This control can be used both as a base for maintenance inventory and as a coordinate file that you supply directly into the  marking equipment to steer the amount of markings that needs to be applied on the road and where.

The material cost of markings is very high and therefore it is important to control that the volume paid for (W x D x T) is actually the one prescribed. It is easy to use the RMT for quality control of new markings.

The data from national measurements can be used to get an overview of the overall condition of the road markings as well as for allocating money.

## 4. SUMMARY

In the RMT advantage of the latest available technology is taken to enable the measurement of each and every cm of road marking in a continuous flow. The survey takes place in the normal traffic flow, at the same speed as the other traffic, and without any disturbance of the other road users.

The most important advantage of the complete mobile technology is the immense improvement of safety during the survey and that a large volume of road markings can be measured time and cost efficient as well as with high accuracy. Generally, the contracts tend to prescribe mobile controls, more and more often. The high level of traffic safety, and the minimal disturbance of the surrounding traffic, is well in accordance with the policies of the roads administrations. However, there are more advantages.

The mobile technology will enable, contrary to the traditional random spot test, a continuous and total flow of measurements. This will contribute to a fair and rightful assessment of the works of the contractors, and even illustrate whether he has succeeded in applying a consistent quality throughout the full distance of the road marking. The latter is of great importance for the road users when driving in darkness and difficult weather conditions.

There will never be any doubts about the positions of the collected measurement data, as all the intervals of measurements are connected to continuously recorded GPS coordinates. All markings of a controlled roads network can easily be identified by position, type of marking, and level of quality.

A RMT survey will even comprise a documentation of the road itself, by help of the 2 advanced cameras. The front camera will give an overall continuous view of the road with its markings and traffic furniture in the direction of driving. The second camera is mounted in a vertical position, just above the road marking, and provides a very sharp and detailed image of the marking.
This system can prove to be a valuable support to both contractors and roads administrations in discussions about the quality of works.
The study has shown that (Ekdahl 2009):

- Retroreflection for wet markings can be calculated from survey on dry markings and by using the macro texture.
- Friction on flat markings can be calculated from retroreflection on dry markings and macro texture. Friction, for profiled markings, is almost always sufficient. However, friction on new markings (both flat and profiled) would benefit from additional studies.
- The luminance coefficient on dry markings can be calculated from specially developed reflectance meter readings.
- Thickness of road markings may be measured by using laser technology. Geometry is achieved by using photo technology.
- All performance parameters in the Swedish standards are judged to be possible to measure using mobile surveys.

## REFERENCES


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