

EVALUATION OF ROAD MARKINGS RETOREFLECTION MEASURING METHODS

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Abstract

Modern traffic demands the safe movement of vehicles under normal conditions and especially at night and in reduced visibility (fog, rain, sleet, etc.). Quality and quantity of participants visual guidance in traffic directly depends on the visibility and the reflective properties of road markings are of crucial importance. Using the latest methods and procedures of testing road markings a high and constant quality level can be achieved, and thus the security level of individual roads can be raised.. One of the most important elements for testing the quality of road markings is testing day and night visibility of road markings. These tests can be done in two ways: method for static test of road markings reflection (daytime and night-time visibility) and dynamic method for testing retroreflection of road markings (night-time visibility). Aim of this article is to describe and evaluate mentioned methods for measuring retroreflection of road markings.

Keywords: Road markings, retroreflection, static method, dynamic method

Introduction

A typical pavement marking material consists of binders, pigments, fillers, and glass beads. Binders are responsible for the thickness of marking material and adhere to the road surface, pigments distribute color throughout the mix, and fillers impart durability to the mix.

The retroreflective effect of pavement markings is made possible with the help of small glass beads which are added by dropping them on the marking during the application of material in liquid form. The retroreflection process in a glass bead occurs in three steps. As the light ray enters a bead, it gets refracted or bent. Once inside, it gets reflected in the material in which the bead is embedded, and then gets refracted a second time while leaving the bead surface. Retroreflected luminance, R_L (referred to as retroreflectivity in this paper) is an important characteristic of pavement markings because retroreflectivity is a surrogate measure of pavement marking nighttime visibility. Pavement markings with higher retroreflectivity are assumed to provide higher levels of visibility during nighttime conditions. EN 1436 defines a standard of measure of retroreflectivity for dry pavement markings using a static and dynamic retroreflectometer. This Norm is adapted from standards originally set by the European Committee for Normalization (CEN). The standard clearly defines the requirements of a portable retroreflectometer to simulate nighttime visibility for an average driver in a passenger car. The measurement geometry of the instrument should be based on a viewing distance of 30 meters, a headlight mounting height of 0.65 meters directly above the stripe, and an eye height of 1.2 meters directly over the stripe. These measurements create an entrance angle between the headlamp beam and pavement surface of 1.24 degrees and an observation angle of 1.05 degrees. The key parameters of the standard are shown in Figure 1.

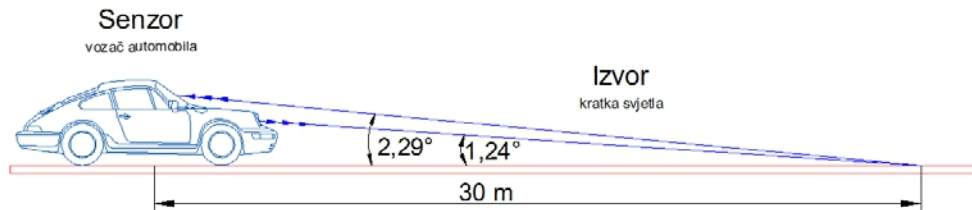


Figure 1. Standard 30-Meter Geometry Replicated by Retroreflectometers
Source: By Authors

Measuring retroreflection of road markings can give the road authorities an inside look at how road markings are performed, in which condition they are, and how well conductors do their job. With this inside look, road authorities can create a plan of restoration based on measurement results. Roads that, according to measurements results, have satisfying retroreflection will not be restored until their retroreflection decreases below minimum levels. Restoring the road markings in this way can reduce road maintenance costs.

Measuring of road markings retroreflection

The evaluation of road markings performance was introduced in the European Union through the standard EN 1436 in August 1997. In particular, EN 1436 specifies the performance for the road user of white and yellow road markings, based on luminance (colour), day-time visibility, night-time visibility and skid resistance. The standard introduces also the importance of wet-night visibility road markings and describes the methods of measuring the various performance characteristics.

The standard EN 1436 defines different classes of performance for road markings: the managing authorities of road networks can introduce a certain class of performance, in their public tenders for the installation of road markings, depending on the compromise between road users' needs and the available budget. A short description of the parameters addressed by EN 1436 is reported below. Reflection in daylight or under road lighting Q_d is the property of the marking which describes the brightness of its colour. Q_d measures, true to scale, the luminance (day visibility) of a road marking. The observation angle of 2.29° corresponds to the viewing distance of a motor car driver of 30 m under normal conditions (see Fig. 1). The illumination is diffused light. Reflection in daylight or under road lighting Q_d is measured using a retroreflectometer.

Reflection under vehicle headlamp illumination R_L (commonly named retroreflection) is the ability of a road marking to reflect light from vehicle headlights back to the driving position of a vehicle. Retroreflected light is reflected back toward the source (headlight) but it must spread out slightly in a very narrow cone or the driver would not be included within it and the sign or marking would not be seen by the driver. R_L measures, true to scale, the retroreflection (night visibility) of a road marking. Also in this case, the observation angle of 2.29° corresponds to the viewing distance of a motor car driver of 30 m under normal conditions. The illumination angle is 1.24° (see Fig. 1). Reflection under vehicle headlamp illumination R_L should be measured in dry wet and rain conditions with a retroreflectometer.

Retroreflectivity of road marking have a significant effect on safety. Therefore, the presence road markings must be recognized and marking retroreflectivity performance should also be recorded. A sizeable body of literature describes activity in this area (Austin, 2004; Fletcher et al., 2007; Maerz and Niu, 2003a,b; Mandli, 2005; Pardillo-Mayora and Hatzi, 1996; Rasdorf et al., 2005, 2007, 2006; Sitzabee, 2008). This literature is describing measuring of road markings retroreflection, from different approaches and standards. But main common thing is that they recognize two main methods of measuring road markings

retroreflection, static (with handheld device) and dynamic (with device mounted on moving vehicle).

Department for Traffic Signalization on Faculty of Traffic and Transport Sciences, University of Zagreb has been performing dynamic testing of road markings retroreflectivity on the Croatian state roads since 2010. In collaboration with Croatian Roads Ltd., intervals of retroreflection values (R_L) are made so that the quality of road markings can be evaluated.

These intervals are related to the state of line (restored or existing) and line type (type I and type II). Minimum values that certain types of lines in certain states must satisfy are defined in technical terms Croatian Roads Ltd.

Table 1. Minimum values of retroreflection for restored lines type I

Visibility and state of pavement	Minimum value	Interval ($\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$)
Nighttime visibility, dry pavement	$RL \geq 200$	$180 \leq RL \leq 220$
Daytime visibility, dry pavement	$Qd \geq 130$	$110 \leq Qd \leq 150$

Source: Guidelines and technical requirements for the works on renewing road markings, Croatian Roads Ltd.

Table 2. Minimum values of retroreflection for restored lines type II

Visibility and state of pavement	Minimum value	Interval ($\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$)
Night time visibility, dry pavement	$RL \geq 300$	$270 \leq RL \leq 330$
Daytime visibility, dry pavement	$Qd \geq 160$	$140 \leq Qd \leq 180$

Source: Guidelines and technical requirements for the works on renewing road markings, Croatian Roads Ltd.

Table 3. Minimum values of retroreflection for existing lines type I

Visibility and state of pavement	Minimum value	Interval ($\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$)
Night time visibility, dry pavement	$RL \geq 100$	$90 \leq RL \leq 110$
Daytime visibility, dry pavement	$Qd \geq 100$	$90 \leq Qd \leq 110$

Source: Guidelines and technical requirements for the works on renewing road markings, Croatian Roads Ltd.

Table 4. Minimum values of retroreflection for existing lines type II

Visibility and state of pavement	Minimum value	Interval ($\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$)
Night time visibility, dry pavement	$RL \geq 150$	$130 \leq RL \leq 170$
Daytime visibility, dry pavement	$Qd \geq 130$	$110 \leq Qd \leq 150$

Source: Guidelines and technical requirements for the works on renewing road markings, Croatian Roads Ltd.

According to the Technical terms, if restored road markings after the dynamic measurements do not satisfy minimum values additional static measurements must be performed. If at first static measurement, road marking continues to fail it is necessary to

perform additional measurements and if even then road marking does not satisfy the Contractor must perform application of new road marking at their own expense. Problem with the current way of analyzing retroreflection quality of road markings is the term “state of road marking” and intervals for each state (restored and existing). Making differences between the restored and the existing lines prevents comparison of two measurements carried out in the same year on the same road. For example, Figure 2. shows the results of measurements performed on national road on 27th of April in 2012, when the line state of was “existing”, while Figure 3. shows measurements results of the same road carried out on 22nd June in 2012, when the state of line was "restored".

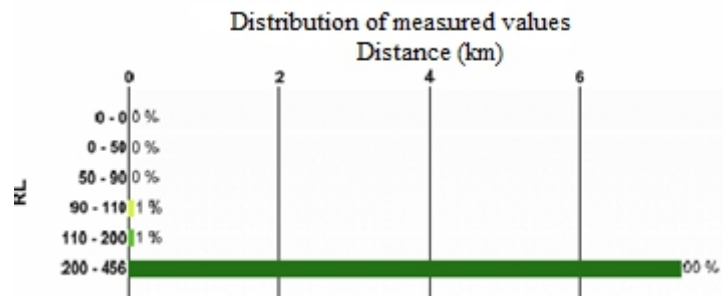


Figure 2. Results of measurement of road markings retroreflectivity on the national road, line state: existing

Source: Department for Traffic Signalization, Faculty of Traffic and Transport Sciences

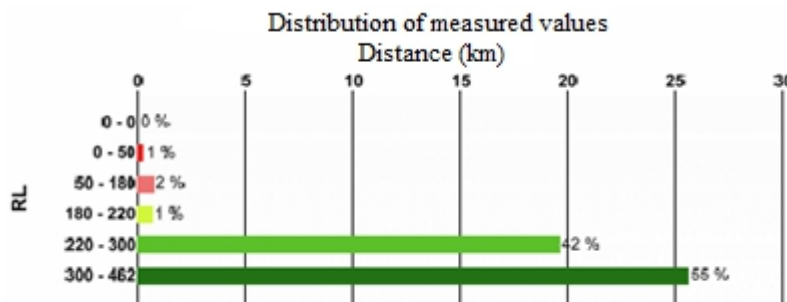


Figure 3. Results of measurement of road markings retroreflectivity on the national road, line state: restored

Source: Department for Traffic Signalization, Faculty of Traffic and Transport Sciences

From this example, it can be concluded that the comparison of measurement results before and after the restoration is almost impossible (Babic et al., 2012). Also, minimum levels of retroreflectivity after restoration should be increased to prolong the lifetime of road marking, to increase visibility at night and in wet conditions and with that to increase traffic safety overall.

Static methods for measuring retroreflectivity of road markings

Handheld retroreflectometers are used for static measuring of pavement markings retroreflectivity by illuminating the pavement marking surface and then measuring the retroreflected luminance. Static testing of road markings can be done by using the static retroreflectometer (Fig. 4.). Weighing of device is 52x218 mm. The device simulates the visual distance markings on the pavement 30 meters from the eyes of drivers, with an eye height of 1.2 m and 0.65 m height of the lights from the road surface. Daily visibility module

Q_d is expressed and measured in $\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$ observed at an angle of 2.29° at a distance of 30 m and represents the value of the diffuse scattered light received by the observer. Night-time visibility or value expressed by the coefficient of retroreflection R_L and measured in $\text{mcd}\cdot\text{m}^{-2}\cdot\text{lx}^{-1}$. For measurement night visibility device measures retroreflection luminous rays from the study area at an angle of 2.29° , the input light angle of 1.24° and at a distance of 30 m with a low beam. Measurements are performed according to European standards EN 1436, Materials for Road markings- Characteristics required for road users. Static testing of day and night visibility can be done by two methods: According to "Kentucky" method (old one), and according to new guidelines and technical requirements of the test procedure, ie. measurement and valuation of derivative road markings shall be carried out in accordance with the German regulation ZTV M 02.

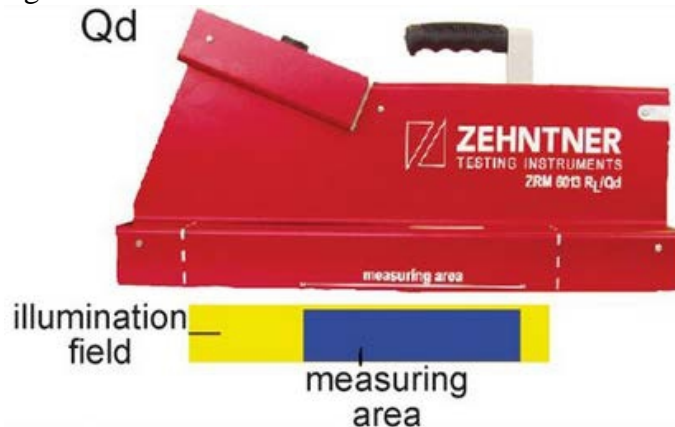


Figure 4. Device (static) for measuring retroreflection of road markings
Source: <http://www.zehntner.com/products/product-list/obsolete-products/zrm-6013-retroreflectometer#pictures>

Kentucky method

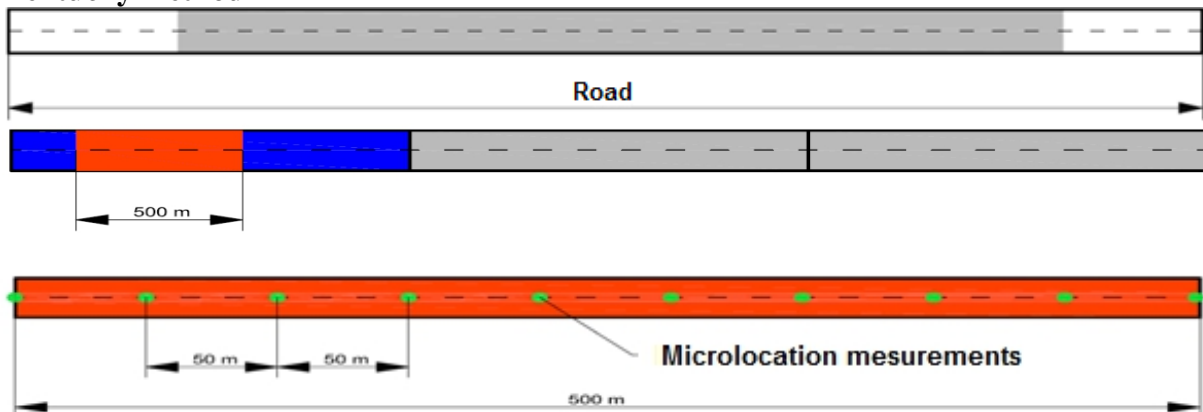


Figure 5. Measurement principle according to Kentucky method
Source: Prepared and adapted by the authors

In Kentucky method, measurements are performed on a single zone of 500 m on each section, where the section is part of the label performed from one team in one day. Start measuring zone is in the first third of the length of the section. In each zone shall be 10 measurements at distances of 50 m. For all 10 microlocation's is carried out by three measurements and obtained an average value of these measurements is taken as authoritative.

The main disadvantage of this method is that the test is performed only in the first

third of the test section, where you cannot get the value of retroreflection of complete testing section.

Method in accordance with the German regulation ZTV M 02

ZTV M 02 includes measuring the thickness of dry paint film, the assessment day and night visibility derived labels in dry conditions, night-time visibility in wet conditions and the slip resistance expressed in units of the SRT and the measurements are carried not earlier than 30 and no later than 60 days after execution road markings. The scope of measurements of longitudinal labels is determined by the daily execution of the working group that performed on pavement according. In the diary, for section of road that is necessary to assess, must be specified data when the works are executed and with what daily effect (especially for the central and especially for the edge line), and the number of measurement sequences is determined by the following table (Table 5.).

Table 5. Number of measurement sequences

The length of longitudinal markings done in one day (km)	The length of the other markings done in one day (m2)	Number of measuring sections
< 1	< 120	1
1 – 5	120 - 600	2
>5 – 10	> 600 - 1200	3
> 10	> 1200	4

Source: Prepared and adapted by the authors

Measurement sequences are selected according to the principle of randomness. Within each segment measuring selects five (5) measuring points (Fig. 6.). For full labels longitudinal measurement points are distributed at 100 m in length at equal intervals (beginning, 25 m, 50 m and 75 m in the end). For discontinuous measurement of longitudinal labels are allocated to the middle point of each other full lines. In relation to the Kentucky method, it is possible to take sequence in the end of testing section, and can get a more realistic view of retroreflection on the entire section.

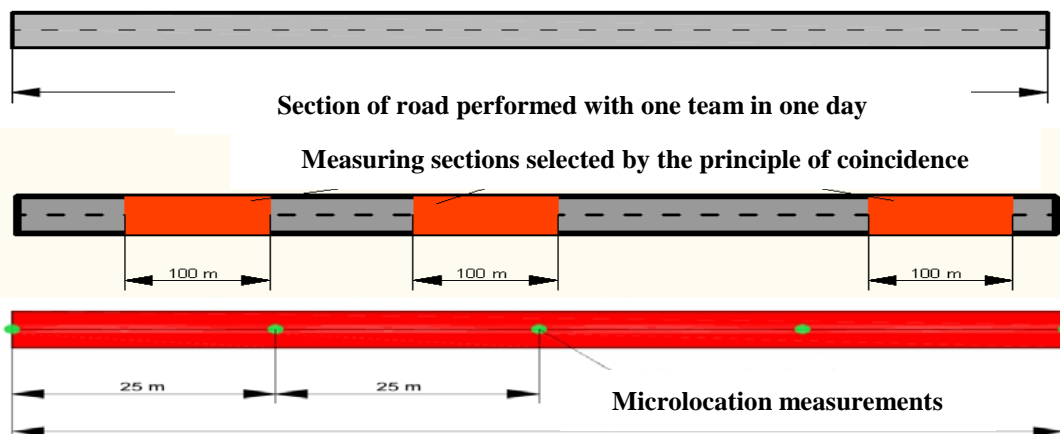


Figure 6. Measurement principle according to ZTV M 02

Source: Prepared and adapted by the authors

Dynamic method for measuring retroreflectivity of road markings

Dynamic method for testing retroreflection of road markings involves the measurement of night visibility with dynamic measuring device throughout its length. It can be performed with dynamic retroreflectometer which is installed on a vehicle measuring and thus allows continuous measurement of the night visibility (R_L) road markings while driving vehicles. Principle of measuring visibility at night with dynamic retroreflectometer is the same as in static measuring device, ie at measuring the night visibility of the device measures retroreflection of light rays from the study area at an angle of 2.29° , the angle of input light of 1.24° and at a distance of 30 m at short lights.



Figure 7. Measurement vehicle with dynamic retroreflectometer
Source: Prepared by the authors

The dynamic retroreflectometer has following features:

- Measurement of road markings night visibility R_L in the day and night conditions
- It is suitable for measuring all kinds of night visibility of road markings, and profiled benchmark to 9 mm
- It is suitable for measuring night visibility in dry and wet conditions
- Has an integrated surveillance cameras, takes pictures automatically every 25 m, and also has the ability of shooting photos manually
- It has a built-in GPS system that captures the movement of vehicles and has sensors for measuring temperature and humidity
- Has the possibility of sending and processing data in a RetroGrabber software package and the ability to switch data into .xls format that allows statistical analysis of measured values.

Measurements are done in a way that the measuring vehicle moves along the road surface and reads the coefficient of road markings retroreflection along which it moves.

Before the measurements it is necessary to select the length of the measurement interval at which the device will measure the average value of each measurement section (ie the length of the measurement interval of 100 is set, this means that the device while measuring the shares for every 100 m will give an average value of visibility in this night measurement interval). Our experience shows that the optimal length of measurement interval is 50 or 100 m.

On the, Department for traffic signalization , Faculty of Transport and Traffic Sciences, University of Zagreb we have developed the new software (Fig. 8.) that will significantly enhance and accelerate the course of preparing reports and interactive viewing the results of measurements.

Main advantages of the newly developed software:

- On-line review of the results on an interactive map, complete with a report made
- data entry and data delivery to end user
- eliminating the use of CDs or DVDs that have been used as a medium for the delivery of results
- ability to analyse data from previous years with more recent data
- enter the amount of reconstructed line on a particular road in a given county by the contractor marks on the road
- currently easier business end users with better insight into the current state
- Automatic itinerary (software itinerary creation) in a given county, according to the amount of reconstructed line on a particular road

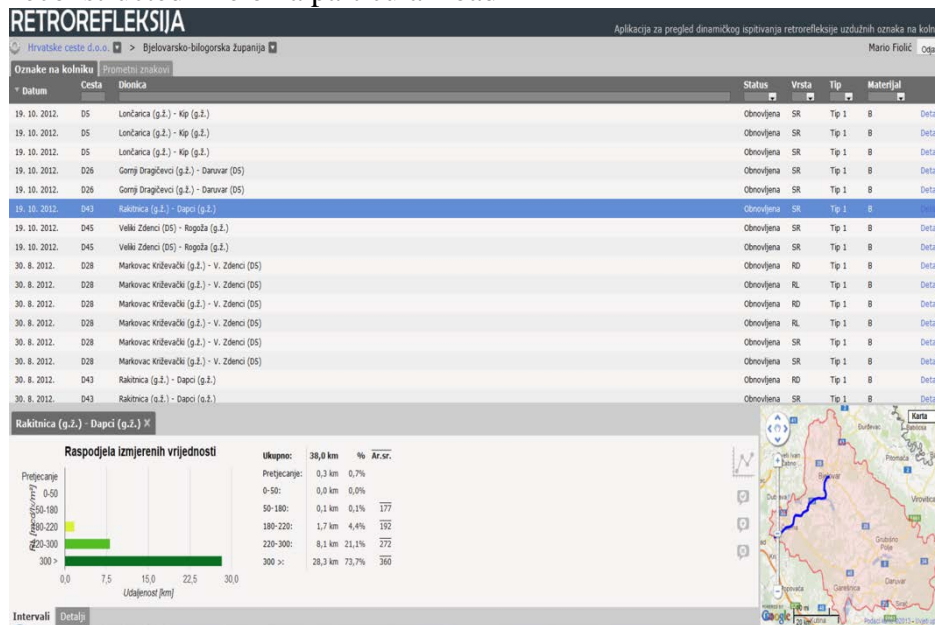


Figure 8. The appearance of the interface after the selected region

Source: Prepared by the authors

Comparison of methods for testing the quality of road markings

As already stated, the reflective properties of road markings are of crucial significance, and represent one of the main factors increasing the safety of participants in road traffic. In order to achieve a better quality of road markings, measurements should be done in compliance with internationally recognized methods (Fiofic at al., 2012). Also, methods for testing the quality of road markings must be recognized by the road authorities and in accordance with the technical requirements in each country.

Each of these methods has its advantages and disadvantages and it is on the employer to conduct the measurements by a particular method in accordance with their own needs.

However, for the detailed control of road markings quality the best method is of dynamic method. Table 6. shows the main advantages and disadvantages of each method.

Table 6. Advantages and disadvantages of each method for measuring the quality of road markings

Method	Advantages	Disadvantages
Kentucky	- measuring day and night visibility	- only the first third of length of the section is being measured which cannot represent whole section

Ztv m02	<ul style="list-style-type: none"> - measuring day and night visibility - gives a more realistic picture of the quality of road markings on the entire length of the section in relation to the Kentucky method 	<ul style="list-style-type: none"> - measurement sequences are selected according to the principle of randomness
Dynamic	<ul style="list-style-type: none"> - measures of night visibility throughout the whole length of the section or road - provides an overview of results in computer application displaying GPS coordinates and pictures from the field - in combination with software it represents live data base of all measurements suitable for analysing and preparing maintenance plans 	<ul style="list-style-type: none"> - does not measure day visibility - little higher level of error in measurement (but in overall doesn't influence the results)

Source: Prepared by the authors

While mobile reflectometer's typically have more error in their measurements of pavement markings, portable handheld units require maintenance of traffic and can be quite tedious for examining large segments of roadway. Mobile devices have the benefits of reduced safety risks to road workers, faster data acquisition, as well as a reduction in traffic congestion as compared with handheld devices.

In some cases, it has been determined that small changes in the positioning of a handheld unit on a marking can produce significantly different readings. This may allow operator to influence the measurement of the marking retroreflectivity if only one measurement is to be recorded. This is not the case with mobile device because it takes many more samples than typically obtained with a handheld unit, and averages the scans, which reduces operator bias, and gives a more reliable reading for a stretch of roadway. Thus mobile reflectometer's are considered a supplement to conventional handheld technology and full replacement with further study on reducing their error.

Conclusion

Testing road markings with a measurement vehicle (dynamic method) equipped with dynamic retroreflectometer offers the possibility of obtaining a continuous measurement results for the whole section intended to be measured, in a short time. At the static method

Measurement sequences are selected according to the principle of randomness. In the dynamic method selected road section is examined in its entirety while static method tested only selected sequences of selected road.

At the same time, the process of testing, measuring vehicle with dynamic retroreflectometer performs accurately, and disruption of traffic is reduced to a minimum (the operating speed of testing the quality of road markings is 60 km/h). All the above suggests the possibility of systematic testing the quality of road markings on the Croatian roads and getting quality results for individual sections which represents a solid basis for the optimal maintenance plan, and savings in the maintenance of road markings.

The results obtained in tests enable you to efficient maintenance of certain roads, review of critical places and prioritization of maintenance and optimize the order of applying the markings on the roadway. Using this measurement method it is possible to organize a system of road maintenance, which provides a constant high level of visibility markings on the roadway, which affects the safety of drivers, especially when driving in adverse weather conditions.

From the above it can be concluded that the static methods for measuring the quality of road markings are appropriate for certain quality checks, but for a systematic and detailed analysis and monitoring of the quality of road markings dynamic method should be performed.

Acknowledgement

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